Distillery feed by-products briefing

An AA211 Special Economic Study for the Scottish Government

Prepared by: Julian Bell, Colin Morgan, Gavin Dick, Gillian Reid

Contact: Julian.bell@sac.co.uk

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EXECUTIVE SUMMARY

(i) This report was commissioned by Scottish Government in response to concerns by livestock farmers about the availability of distillery by-products in Scotland. It aims at investigating the parameters influencing the supply of co-products to farmers. It also estimates the carbon implications on farm of using draff.

(ii) **Distillery by-products provide animal feed to the beef and sheep sectors** in Scotland, the UK and elsewhere in a variety of forms including wet and dried product. It is estimated by trade sources that around 346,000t (on a dried product basis[1]) of distillery by-products from the whisky industry in Scotland will be used in animal feed in 2012. Of this around 60% will be consumed in Scotland and 40% England.

(iii) **Price spreads indicate that distillery by-products are currently close to competitive**[2]with alternative feeds of equivalent nutritional value and draff is significantly cheaper than the alternatives. Losses due to spoilage, seepage etc. explain some of the price advantage of draff and correct management in storage & use is required to benefit from this price advantage. The dry-matter content of draff also varies widely and draff of lower dry-matter content also has a lower feed value.The main alternative feeds considered in this study were rapeseed meal, barley and grass silage.

(iv) **Distillery by-products on farm are generally cheaper in Scotland than in the rest of the UK** due to proximity to the distilling industriesreducing transport costs.

(v) **On farm, the use of draff in feed compared to other feeds is expected to result in about 8-10% lower carbon emissions associated with beef finishing based on the PAS2050 Life Cycle Analysis methodology.**Feeds represent between 27% and 37% of total emissions arising from the production of beef in finishing units. The majority of emissions arise from methane and nitrous dioxide from animal digestion and manures.

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[1]*At 10% moisture content and equivalent to Distillers Dark Grains with Solubles (DDGS)*

[2]*In the absence of distillery by-products, a ruminant feed ration could be prepared using barley and rapemeal. The price differential shown provides an indication of the equivalent monetary value that the producer should be prepared to pay for these alternative feeds to deliver feed of a comparable nutritional status to distillery by-products) At current market values the competitiveness of different distillery by-products relative to other comparable feeds varies as follows; draff is 34% cheaper while wheat distillers is 2% more expensive and barley distillers is 12% more expensive*

(vi) **In the distillery, the emissions associated with producing draff are only around 20% of those associated with producing Distillers Dark Grains (DDGS) on a Dry Matter basis.** This is due to the large amount of energy required to dry and pelletise the draff to produce DDGS.

(vii) **Estimating the supply and demand of distillery by-products in animal feed is hampered by the lack of official usage data.** SAC has estimated the potential output of distillery feeds in Scotland in 2012 was 466,000t of distillery by-product residue on a dry matter basis. Usage in animal feed was estimated by SAC and feed trade sources at around 346,000t in 2012 on a dry matter basis. The difference is due to draff being delivered or collected straight from distilleries, losses, disposal of wastes and utilisation for energy.

(viii) **Feed trade sources reported that availability of distillery co-**products in feeds was at a historical high level in 2012, with usage in animal feed having risen 51% since 2007. Both estimates are subject to uncertainty.

(ix) **Distillers in Scotland have announced since April 2012 further plans to increase malt distillation capacity**. These involve the construction of at least three new malt distilleries, the reopening of a 'silent' distillery, and expansion at existing distilleries. In total these investments will increase distillation capacity by around 33 million lpa which in-turn could generate around 27,000 tonnes (dry) of additional by product (draff and pot ale syrup) per annum by 2014.

(x) **In future bio-ethanol plants in England could have a major impact on by-product availability in Scotland. The estimated <u>potential</u> output of 750000t of feed by-products greatly exceeds the total output of the Scottish distilling sector.**

Contents

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION TO DISTILLERY BY-PRODUCTS 5

2.0 NUTRITIONAL VALUE OF DISTILLERY FEED BY-PRODUCTS 8

3.0 ESTIMATING CARBON EMISSIONS FROM THE PRODUCTION OF DISTILLERY BY-PRODUCTS 13

4.0 DISTILLERY BY-PRODUCTS AND POTENTIAL FARM CARBON IMPACTS 15

5.0 SUPPLY AND DEMAND OF DISTILLERY BY-PRODUCTS 19

APPENDIX 1 - NUTRITIVE VALUES OF FEEDSTUFFS 25

APPENDIX 2 – HISTORICAL FEED PRICES 29

APPENDIX 3– ESTIMATED EMISSIONS FOR THE PRODUCTION OF DISTILLERY 28

FEED BY-PRODUCTS

APPENDIX 4 – CARBON EMISSIONS OF ALTERNATIVE FEED RATIONS 29

APPENDIX 5 – ESTIMATED DISTILLERY FEED BY-PRODUCT OUTPUT 30

1.0 INTRODUCTION TO DISTILLERY BY-PRODUCTS

1.1 A range of feed by-products are produced from the malt and grain distilling processes as outlined in the following table. Unprocessed feeds (draff, moist grain feeds) have a high water content (70-80%) which raises transport costs per unit of dry matter and makes storage more difficult.

1.2 Draff can be stored by en-siling in clamps alongside silage during the summer months. In practice the quantity of surplus draff which can be preserved in this way is restricted by the availability of clamp space and the limited duration of the grass silage harvest. Effective storage requires experience and losses can be high if not undertaken with care.

1.3 Dried and pelletised feeds (barley, wheat and maize dark grains) have a low moisture content (<10%) and can be readily stored and transported economically.

1.4 Demand for draff from farms in the vicinity of each distillery can at times be insufficient resulting in a surplus at distilleries. Draff might be hauled by road from the North of Scotland to the Central Belt and into the North of England to meet demand.. This raises the cost of draff to the farmer in these more distant regions. This cost can at times be reduced by utilising return loads on otherwise empty trucks returning from the delivering grain from England to local maltings and distilleries.It is estimated that around 60% of distillery by-products used in feed are consumed in Scotland and 40% are exported mainly to the north of England.

1.5 Any feeds which have originated in a copper malt still (pot ale syrup, Barley DDGS) can not be used for sheep feed due to the high levels of copper whichsheep are particularly sensitive to.

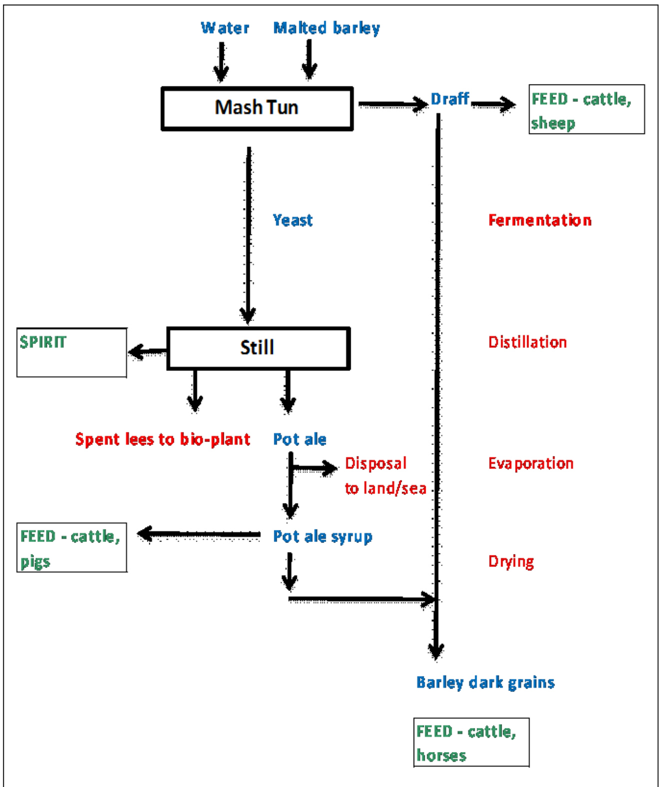
Table 1: Summary of distillery feed by-products

Spirit	Product	Type	Livestock
Malt	Draff	Wet	Cattle, sheep
Malt	Pot ale syrup	Liquid	Cattle, pigs
Malt	Malt DDGS	Pellet	Cattle, horses
Grain	Grain moist feeds ("Supergrains", "Vitagold")	Wet	Cattle
Grain	Spent wash syrup	Liquid	Cattle, sheep, horses
Grain	Wheat/Maize DDGS	Pellet	Cattle, sheep, horses

Note - * Distillers Dark Grains with Solubles (DDGS)

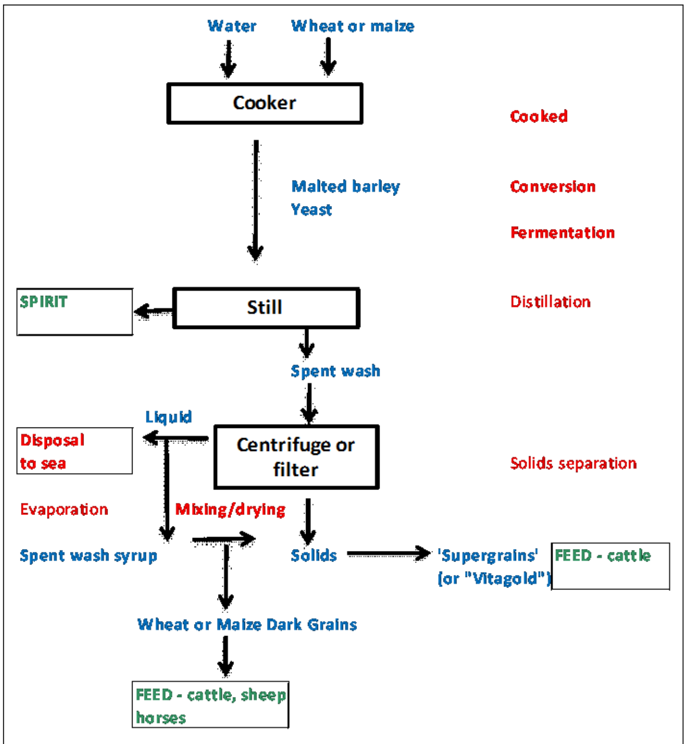
1.6 The following figures (1 & 2) outline the inputs, process flows and product outputs involved in malt and grain spirit production.

Figure 1: Malt distilling by-products - typical process



(Adapted from: Pass, B, and Lambart, (2003) Whisky: Technology, Production and Marketing, Elsevier)

Figure 2: Grain distilling by-products - typical process



(Adapted from: Pass, B, and Lambart, (2003) Whisky: Technology, Production and Marketing, Elsevier)

2.0 NUTRITIONAL VALUE OF DISTILLERY FEED BY-PRODUCTS

2.1 The feed value of distillery feed by-products are well documented[3]. The SAC Farm Management Handbook 2011/12 contains a list of the relative feed values of the main by distillery feed by-products. The nutritional value of feeds varies by animal species. In Scotland ruminant livestock (cattle and sheep) are the main consumers of distillery feed by products. A summary of the key nutritional values of these feeds for ruminants is given in Table 1 below (full details in Appendix1).

Table 2 – Nutritive value of feeding stuffs - ruminants

Feed	Dry Matter (DM) (g/kg)	Metabolisable Energy (ME) (MJ/kg DM)	Crude Protein (CP) (g/kg DM)
Brewers grains or draff(23% DM)	230	11.1	200
Wheat Distillers Dark Grains	900	13.5	340
Malt Distillers Dark Grains	900	12.2	265

Source: SAC Farm Management Handbook

2.2 Distillery by-products are best suited for use in ruminant diets (beef, dairy and sheep) where they provide good quality protein and digestible fibre. These feeds are highly palatable with few limiting factors to feeding in ruminants though high levels of copper may limit use in some sheep diets. In contrast these feeds are of limited use in pig and poultry rations due to the high level of fibre and low energy density. Table three overleaf details recommended maximum inclusion rates in different species.

[3]Ewing, W.N. (1997), The Feeds Directory – commodity products, CONTEXT

Table 3 – maximum inclusion rates by species (%)

	Brewers Grains (draff)	Distillers Dark Grains (Barley)	Distillers Dark Grains (wheat)
Dairy	30	30	40
Beef	40	30	40
Ewe	5	10	0
Sow	0	0	5
Broiler	0	0	5

Source: The Feeds Directory, Dr W.N. Ewing (1997)

2.3 Given nutritional information it is possible to determine the financial value of different feeds relative to one another. For ruminants the dominant feeds used by SAC to set the base line are barley as an energy source and rapeseed meal as a protein source. The SAC Farm Management Handbook 2011-12 (prepared in June 2011) contains relative feed values for different feeds at set prices for the base feeds (barley and rapeseed meal). These are summarised in Table 4 which also contains more up to date feed valuations (January 2012). This table details relative feed values for distillery by-products (a full list of feeds is given in Appendix 1). These are also compared to market prices for the different feeds.

Table 4 - Nutritional versus market values for distillery feed by-products

Feed	Relative Feed Value1 (£/t)	Relative Feed Value2 (£/t)	Average market values* for feeds (£/t),	Difference with RFV2 (£/t)	Difference with RFV2 (%)
Brewers grains or draff(23% DM)	35	41	27	-14.00	-34.14
Wheat Distillers Dark Grains	191	202	205.5	3.50	1.73
Malt Distillers Dark Grains	161	167	187.5	20.50	12.28
Base(i) – barley	150	153	153	0	0
Base(ii) - rapemeal	175	187.5	187.5	0	0

Notes	**Source**
Relative Feed Value1 (RFV1)	SAC Farm Management Handbook (FMH) 2011/12 prepared June 2011
Relative Feed Value2 (RFV2)	SAC Feed Byte January 2012
Average Market values for Feeds	Farm Brief, Scotland delivered values January 2012, except barley HGCA delivered E Anglia 13 January 2012

Explanation – a ruminant feed ration could be prepared using barley and rapemeal. Alternatively the nutritional requirements of the animal could be met with other feeds. The Relative Feed Value is an indication of the maximum equivalent monetary value that the producer should be prepared to pay for these alternative feeds to deliver feed of a comparable nutritional status and costs to using barley and rapemeal.

2.4 Table 4 illustrates that at recent market values the competitiveness of distillery by-products relative to other comparable feeds varies as follows; draff is 34% cheaper while wheat distillers dark grains is 2% more expensive and barley distillers dark grains is 12% more expensive. Price spreads indicate that distillersdark grains are currently close to competitive with alternative feeds of equivalent nutritional value and draff is significantly cheaper than the alternatives.

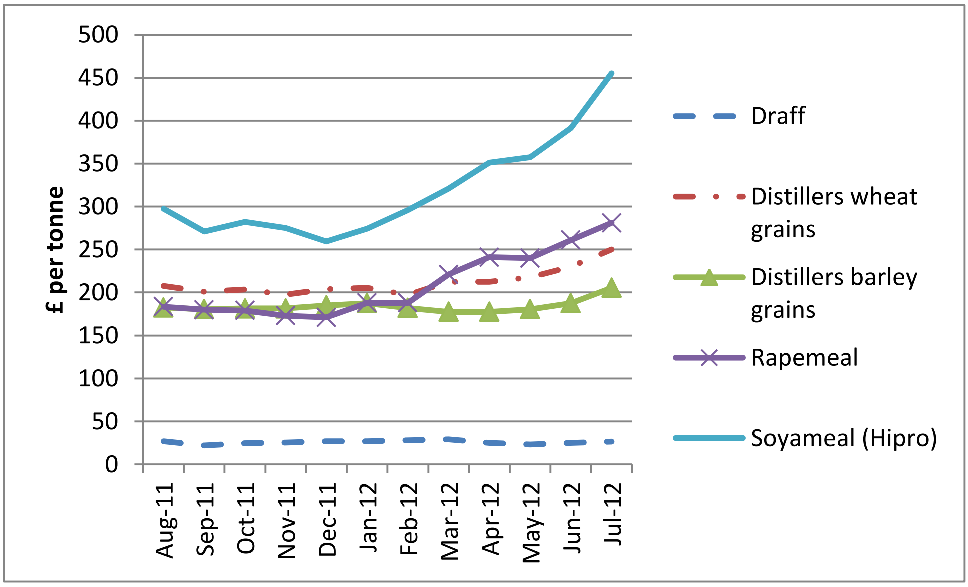
2.5 The apparently low value of draff reflects the difficulties end users face in transporting, handling and storage due to its high water content. Losses can readily reach 30% by volume between delivery and feeding due to spoilage, seepage etc.

Historical values

2.6 The price of distillery by-products varies significantly across the season in response to local supply and demand issues (see Chart 1 and Appendix 2). The most pronounced price swings are seen in draff due to the high cost of transport, difficulties in storage and the seasonal nature of production and demand. Feed demand is higher in the winter and early spring and then declines as grass growth resumes in late spring. This can lead to an oversupply of distillery by-products in early summer and lower prices. During summer most distilleries shut for a period of maintenance leading to localised shortfalls in supply.

2.7 Dried by-product prices are more stable reflecting their ease of storage and greater portability enabling supply to a wider area. Price swings are also influenced by the price of competing feed and grain crops on the European and global markets particularly rapemeal.

Chart 1 – monthly feed prices delivered Scotland



Source: Farm Brief

UK price differentials

2.8 The price of distillery by-products is significantly lower in Scotland than England due to the transport cost advantage which is most pronounced in draff. The price of alternative protein sources such as rapemealis generally lower in England due to the proximity to oilseed crushing plants and major ports.

Table 5 – feed price differentials Scotland vs. England

	Draff	Distillers wheat grains	Distillers barley grains	Rapemeal	Soyameal (Hipro)
£ per tonne	-15	-12	-12	15	8
%	-58%	-6%	-7%	8%	3%

Source: Farm Brief, year to February 2012

2.9 This pricing structure is likely to be altered by the development of bio-ethanol and associated feed by-product production in the north of England. (see section **5.13)**

3.0 ESTIMATING CARBON EMISSIONS FROM THE PRODUCTION OF DISTILLERY BY-PRODUCTS

Methodology

3.1 SAC prepared estimates of the carbon emissions resulting from the production of the main distillery feed by-products. The following main sources of emissions were considered:

- Crop production – the emissions resulting from the cultivation of grain on farm (fuel, fertiliser, soil)
- Energy consumption at the distillery (electricity and gas)
- Transport

3.2 The calculations were undertaken with SAC's Agri-CARB© carbon calculator using an approach consistent with PAS2050:2008 methodology.

3.3 Once total carbon emissions had been calculated these were then allocated to the two principle outputs of the process; spirit and feed by-product. Feed by-products comprised draff and the more heavily processed Distillers Dark Grains. Where possible emissions were allocated directly otherwise they were allocated on the basis of economic value as set out in PAS2050.

Results

3.4 Results are summarised in the table overleaf including carbon emissions and economic value for each stage of the production process for wet and dry distillery feeds. Full details are given in Appendix 3. These estimates are provisional only and are based on available generic input/output data from ethanol distillery manufacturers and may not compare directly with typical values for whisky distilleries for which data was not available.

Table 6 – Summary of input/outputs in distillery feed production

Process	Activity	Unit	A) Draff from malt	B) DDGS from malt	C) DDGS from grain
Malting & Distilling	Production	kg CO2e	3297.35	3297.35	2,267.23
	Draff value share	% value	4.9%	8.9%	19%
	Draff emissions	kg CO2e	161.43	292.79	429.00
Feed Processing	Drying - heat	kg CO2e		620.77	620.77
	Pelletise - electricity	kg CO2e		76.68	76.68
	Transport	kg CO2e	22.66	6.30	6.29
	Total emissions	kg CO2e	184.09	996.54	1132.74
	DDGS weight	t	5.43	1.51	1.51
Fresh weight	**CO2/unit**	**kg CO2e/t WET**	**33.90**	**661.27**	**751.65**
Dry Matter Basis	**CO2/unit**	**kg CO2e/t DM**	**147.40**	**734.75**	**835.17**

Source: SAC, see Appendix 5

3.5 Producing Distillers Dark Grains (DDGS) requires significantly more energy than producing draff as it has to be dried from 75% water content to below 10%. The material also has to be pelletised, again another energy intensive process. As a result emissions from the production of DDGS are much higher than for draff.

3.6 It is also important to note that using economic allocation results in a greater proportion of emissions against the feed element in grain distilling compared to malt distilling. This is because feed forms a greater share of the total value of output from grain distilling.

4.0 DISTILLERY BY-PRODUCTS AND POTENTIAL FARM CARBON IMPACTS

Carbon impact

4.1 Distillery by-products in Scotland are used in a range of feeds predominantly for ruminants such as beef and dairy cattle. The availability and use of co-products as livestock feed is determined by a range of factors. A reduction in the availability of by-products could result in farmers switching into other feed ingredients as a replacement. Farmers choose feeds taking into account various factors including;

- Nutritional value
- Livestock type and system
- Price and availability
- Ease of handling and feeding

4.2 In order to estimate the carbon footprint associated with different feeds an example case study is presented below. Selection of a different system and livestock type would produce a different result but this example is intended to provide some initial guidance.

Methodology – beef steer finishing example

4.3 Using the SAC Feedbyte programme[4], a typical beef finishing system was selected and a variety of diets were assessed with and without distillery by-products. This is based on a 500kg steer gaining 1kg of live weight per day. The full details of the feeds used are contained in Appendix 4.

4.4 Product emissions for beef production were calculated using the SAC Agri-CARB © life cycle carbon calculator. This has been certified to the PAS2050:2008 supply chain standard[5]. Feed emissions factors were obtained from two sources;

(i) Carbon Trust PAS2050:2008 compliant database Footprint Expert 3.2 [6] - barley, rapemeal, draff (brewer's grains).

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[4] SAC Feedbyte - http://www.sac.ac.uk/consulting/services/i-r/livestock/dairyselect/dairyfeatures/
[5] PAS2050 - http://www.bsigroup.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050/PAS-2050/
[6] Carbon Trust Footprint Expert - http://www.carbontrust.com

(ii) SAC calculated values[7] – grass silage, barley straw. In addition SAC calculated emissions for DDGS though these feeds were not used in this comparison.

The Carbon Trust database and SAC calculations provide carbon 'footprints' of the different feedstocks - their life cycle GHG emissions.

Table 7 – emissions estimates by feed

Feed	Emissions kg CO2e/tonne fresh weight feed	Emissions kg CO2e/ tonne Dry Matter feed[8]	Source
Barley	360	423	Carbon Trust – Footprint Expert 3.1
Rapemeal	400	449	" "
Draff - barley	34	136	SAC
DDGS - barley	661	734	" "
DDGS - wheat	752	835	" "
Straw	242	303	" "
Grass silage	116	464	" "

4.5 Using this approach emissions for wet distillery by-products (draff) were estimated to be 70% lower than for the main alternative high protein feeds: rapemeal.This is due to the PAS2050 principle that emissions are apportioned on the basis of economic value[9]&[10]. Given the low economic value[11] of by-

[7]SAC Agri-CARB© carbon calculator received certification in February 2012 to PAS 2050:2008, CICS Verification Ltd -www.cicsglobal.com

[8] Fresh feeds dry matter content assumed as follows: barley 85%, rapemeal 89%, draff 25%, DDGS 90%, straw 80%, silage 25%.

[9] PAS2050:2008 (2008), Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, BSI (page 22, Section 8.1.1)

[10] Guide to PAS 2050, How to assess the carbon footprint of goods and services, (pages 32 & 33, Table 3).

[11] SAC calculations based on whisky industry data (Gray, AS, (2011) The Scotch Whisky Industry Review 2011, Sutherlands Edinburgh) indicate that the relative value of distillery feed by-products in 2011 was around 1.3% of total economic output in malt distilling and 5.7% in grain distilling.

products used in feed (e.g. draff) compared to the primary product (malt or grain spirit) then most of the emissions associated with production are attributed to the primary product (e.g. spirit).

4.6 This assessment has considered the farm impact on Green House Gas (GHG)emission of using different feeds (barley, rapeseed meal, draff, grass silage and straw), to finish beef cattle.

4.7 Apart from a small share of emissions from production the main emissions attributable to draff as a feed are those associated with transporting it from the distillery to the farm gate. Given this system of allocation, replacing draff with alternative feeds will result in an increase in emissions associated with animal feed use on farm. This is because most other feeds will carry a much larger share of the emissions resulting from their production.

Table 8 -Feed modelling results

Emissions	**1) Straw**	**2) Straw + draff**	**3) Silage**	**4) Silage + draff**
kg CO2e per kg deadweight (or % as stated)				
Total	21.74	19.61	22.57	20.65
'of which feed	7.46	5.33	8.29	6.36
Feed as % of emissions	34%	27%	37%	31%

4.8 Employing the above methodology when comparing different feedstocks in beef production, the use of draff results in a lower computed carbon footprints compared to other feeds (see table 8):

- in a straw based finishing diet the use of draff has a carbon footprint which is lower by 9.8% compared to alternative feeds (19.61kg and 21.74kg CO2e per kg of deadweight gain). The use of draff also results in a lower contribution of feeds to total emissions (27 % and 34% respectively)

- in a silage based finishing diet the use of draff has a carbon footprint which is lower by 8.5% compared to alternative feeds (20.65kg and 22.57kg CO2e per kg deadweight gain). The use of draff also results in a lower contribution of feeds to total emission (31% and 37% respectively).

4.9 Using the PAS2050:2008 carbon footprint methodology in this case study highlights the potentially beneficial impact of wet distillery by-products such as draff compared to other feeds in a beef enterprise. This benefit stems partly from the use of economic allocation placing most of the emissions burden from the production process on the higher value spirit rather than the lower priced feed by-product. In addition by utilising a wet feed on farm this leads to a reduction in the energy required by the distillery to process the feed as it does not need to be dried and pelletised.

Impact of use of feeds for energy

4.10 These above estimates compare the carbon footprint of different feeds, including co-products on the farm. The use of co-products for renewables generation by distilleries has carbon implications which are not subject of this study. The carbon benefits of renewables generation arise from.

- substituting fossil fuel at distillers – this could also reduce road haulage of fuel oil at certain sites
- Reducing energy demand by not processing distillers by-products into feed
- Exporting energy (such as electricity) off site – this can displace more carbon intensive centralised generation with renewable localised generation.

5.0 SUPPLY AND DEMAND of DISTILLERY BY-PRODUCTS

Introduction

5.1 Distillery by-products have traditionally been used as livestock feed. More recently there have been concerns about the availability of co-products to Scottish farmers, due to increase in prices, export to England and use of co-products for renewables generation by distilleries. In order to determine the availability as livestock feed a range of information and data would be required including;

(i) The amount of distillery by-product produced

(ii) The amount of by-product used in bio-energy production

(iii) The amount of by-product disposed as waste

(iv) Supply and demand for use in animal feeds

(v) The relative price and availability of competing feeds

Data availability

5.2 Further details on data availability are given as follows;

(i) <u>The level of distillery by-product produced</u>

Data on grain use and spirit production are collated by a number of organisations (SWA) and government bodies (DEFRA, HMRC). From this data it is possible (with some assumptions) to estimates the level of distillery by-products produced. The key parameters are as follows:

- For every Litre of Pure Alcohol (LPA) produced a known quantity of malt or grain (wheat or maize) can be assumed to be consumed.
- For every tonne of grain processed into spirit a specific quantity of by-products can be assumed to be produced which differs by spirit type (malt or grain).
- From these input values annual estimates of total by-product output can be estimated.

(ii) The amount of distilling by-product used in bio-energy production

and

(iii) The amount of by-product disposed as waste

There is no centrally held data on the number, capacity and utilisation of bio-energy plants using distilling by-productin Scotland nor on the quantities disposed of as waste by other means. It is therefore not possible to derive an accurate estimate of current or future distillery by-product used in energy production or disposed of as waste.

(iv) Local use of distillery by-products in animal feeds

There are no official records of total feed use or distillery by-product use by the livestock sector or by region in Scotland. DEFRA however, survey the use of dried distillery products used in animal feed across Great Britain as a whole. It can be assumed that the majority of this material is produced in Scotland. The feed industry also collates unofficial estimates of feed usage by sector.

(v) The price and availability of competing feeds

Feed prices are widely quoted and have been included earlier in this report.

Estimated production of Scottish distillery by-products

5.3 Estimates of total *potential* output of distillery by-products were calculated for the period 1990 to 2010 based on available industry data. Projections were also made from 2011 to 2015.

5.4 These estimates were calculated using the following data;

- Spirit production (in million of Litres of Pure Alcohol (m LPA) and spirit yields (LPA per tonne of malt and grain) published by Sutherlands[12] and based on the Scotch Whisky Association Databank.
- Conversion factors in distilling from malt/grain to feed by-product obtained from industry experts Pass et al (2003)[13].
- Full details of the calculations are given in Appendix 5 and results displayed in Chart 2 overleaf.

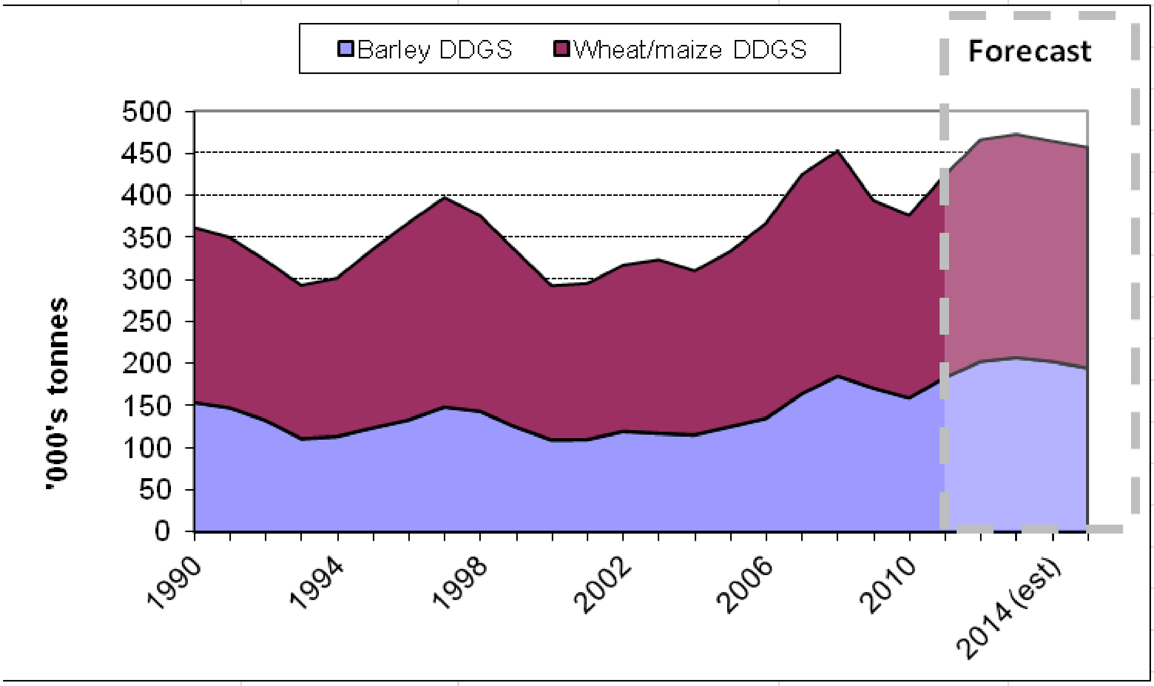
Results

5.5 Based on these methods the production of distillery by products in Scotland in 2012is estimated at 466,000t of dry matter equivalent. This comprises the total output (on a zero % dry matter basis) of distilling by-products for both malt and grain distilling. In practice as well as dried and pelletised product (at around 10% dry matter) much of this feed was produced in a wet form with dry matter in the 20% to 30% range for draff and substantially lower for other waste streams such as pot ale. Therefore on a wet basis a greater overall tonnage was produced.

5.6 Given the uncertainties outlined above these estimates should only be taken as a starting point for the potential availability of feed by-products from the distilling sector. Further detailed analysis on a plant by plant basis would be required to refine these estimates, work which is outside the scope of this study.

[12] Gray, AS, (2011) The Scotch Whisky Industry Review 2011, Sutherlands Edinburgh
[13] Pass, B and Lambart, I, (2003) Whisky: Technology, Production and Marketing, Elsevier

Chart 2: Potential total by-product feed output from distilling in Scotland



Source: SAC

Since May 2012, distillers have announced further plans to increase malt distillation capacity. These involve the construction of at least three new malt distilleries, the reopening of a 'silent' distillery, and expansion at existing distilleries. In total these investments will increase distillation capacity by around 33 million lpa which in-turn could generate around 27,000 tonnes (dry) of additional by product (draff and pot ale syrup) per annum by 2014.

Estimated quantities of Scottish distillery by-products used in feed

5.7 Given estimates for the total potential output of distillery by-products (chart 2 above) further work is then required to determine the quantity that was actually used for feed. The lack of comprehensive official usage data for distillery products in feed meant it was not possible to determine usage quantities though official data sources. Instead SAC has prepared estimates based on discussions with the feed industry. These indicate that total usage of Scottish produced distillery by-products for animal feed in 2012 is likely to be around 339,000t of dry feed equivalent[14]or 790,000t on a fresh weight basis. These figures encompass a wide range of feed types and moisture contents as detailed in the table 9.

[14]On a dry matter basis at 0% moisture

Table 9 – estimated feed use of Scottish distillery by-products2012)

	Fresh weight (t)	Dry matter (%)	Dry equivalent (0% MC) (t)
MALT DISTILLING			
Draff	300,000	25%	75,000
Pot Ale Syrup	40,000	45%	18,000
Malt DDGS	75,000	90%	67,500
	415,000		**160,500**
GRAIN DISTILLING			
Grain moist feeds	240,000	33%	79,200
Spent wash syrup	25,000	30%	7,500
Grain DDGS	110,000	90%	99,000
	375,000		**185,700**
	790,000		**346,200**

Source: trade and SAC

5.8 Trade estimates (feed compounders and brokers) of actual usage in feed are lower than estimates of total distillery by-product output prepared by SAC (based on spirit production and grain use – Appendix 5). For malt by-products trade usage in feed of 160,500t dry matter compares to SAC estimated total output of 202,270t dry matter equating to 80% utilisation in feed. For grain by-products trade usage in feed of 185,700t dry matter compares to SAC estimated total output of 264,340t dry matter equating to 70% utilisation in feed. The average across all distillery by-products is 74% utilisation in feeds.

5.9 The difference between the potential output of distillery by-products and the actual use in feed is due to a range of factors;

- Collection of draff by farmers straight from distilleries
- Diversion to non-feed uses (such as bio-energy)
- Spread on land as soil improver and disposalto sea
- Losses in processing

5.10 Trade sources reported that the availability of distillery by-products in feeds was at a historically high level in 2012 despite the utilisation of some by-product for other uses. The estimated 346,000t of dry matter of distillery by-products used for feed in

2012 represents a 51% increase on estimates prepared in 2007 of 228,000t[15]of dry matter (or around 500,000t on a fresh basis).

5.11 Looking ahead to 2013 and beyond it is expected that the use of distillery by-products for energy will increase, which will have an impact on the supply of grain distilling moist feeds. At the same time overall whisky production is expected to rise leading to higher by-product output

5.12 The destination countries for distillery by-products varies by feed but the overall split is currently around 60% used in Scotland and 40% used in the north of England.

Table 10 – estimated feed use of Scottish distillery by-products

	Sales in Scotland (%)	Sales in England (%)
MALT DISTILLING		
Draff	60%	40%
Pot Ale Syrup	40%	60%
Malt DDGS	50%	50%
GRAIN DISTILLING		
Grain moist feeds	60%	40%
Spent wash syrup	100%	0%
Grain DDGS	70%	30%
Weighted total	61%	39%

Source: trade and SAC

Patterns of use of distillery by-products in feed in Scotland

5.13 **The experience of SAC advisers is that many beef and dairy farms in Scotland will utilise distillery by-products when ever they are priced competitively. SAC estimate that the quantities of distillery by-products used on farm represent around 5-6% of the total feed intake of cattle across Scotland on an energy basis. As a source of protein however distillery by-products are a more important feed source due to their typically high protein content. The pattern of use varies widely by farm type and geographical area;**

[15] Pass, B, (2007), The burning question – Feed or Fuel? Distillers feeds in a period of change, The Brewer and Distiller International, Issue 4, April 2007, ww.ibd.org

- Draff and grain moist feeds –are widely used in the feeding of suckler cows and store cattle are often mixed with silage and stored in clamps for winter feeding. Many dairy units across Scotland including the South West use draff and grain moist feeds on a regular basis. Usage of draff is more common in the north and north east of Scotland due to greater availability, lower pricing and generally closer proximity to distilleries. Despite higher prices usage of draff remains important across the south of Scotland with use restricted more by shortage of supply than the level of demand for these feeds.

- Pot ale syrup – is a particularly good value feed at present but its usage is less widespread on farm due to difficulties in handling and storage. Farmers are currently taking greater interest in the feeding of pot ale syrup as a good value feed.

- Distillers Dark Grains – these are widely used in the finishing of beef cattle as a protein source added to barley. They are also regularly used in a range of compound and straight feeds for all types of cattle.

Estimated feed use of distillery by-products from bio-ethanol plants in England

5.14 The local supply of distillery by-products within Scotland has also traditionally been determined by the level of product exported to England and overseas. In the future there is also the likelihood of a growth in supply of very similar by-products from the bio-ethanol industry in England and elsewhere in the EU. The pricing and availability of this feed source is however highly uncertain at present due to timing and scale of production from the two plants.

5.15 The Ensus[16]bio-ethanol plant at Teesside has the capacity to process over 1.0mt of wheat per year and produce around 300,000t on a dry basis of distillery by-product for feed. After opening in 2010 the plant then closed for 15 months. In August 2012 the company announced the plant would re-open and build up to full production within 2 months. In September 2012 the plant was estimated to be using 2,000t of wheat per day and producing around 800t of by-product feed (on a dry matter basis).

[16] http://www.ensusgroup.com

5.16 The Vivergo[17] bio-ethanol plant near Hull is under construction and will have the capacity to process 1.1mt of wheat per year and produce around 350,000t on a dry basis of distillery by-product for feed. The plant is expected to open in early 2013.

5.17 **Taken together these two plants have the <u>potential</u> to produce around 750,000t of feed by-products on a dry matter basis greatly exceeding output of the Scottish distilling sector.** Actual output from these ethanol plants is hard to estimate and has been excluded from this study as it will be driven by a wide range of factors including;

- the market price and government support for bio-ethanol in the UK and the EU
- the level of ethanol imports into the EU and the level of import controls and tariffs
- the price and availability of wheat and feed by-products
- the technical performance of the plant

5.18 **The implications for Scotland of a rise in distillery by-product availability in England are expected to include**;

- a sharp reduction (or cessation) of distillery by-product exports to England
- a greater availability of by-products within Scotland
- more competitive pricing of by-product feeds within Scotland to maximise utilisation
- pricing levels for dry distillery products within Scotland are likely to be determined by the export price to other European markets
- pricing levels for wet products will be determined by price levels within Scotland and the north of England in competition with bio-ethanol by-products

[17] www.vivergofuels.com

Appendix 1 - Nutritive values of feedstuffs

Source: SAC Farm Management Handbook 2011/12

NUTRITIVE VALUES OF FEEDINGSTUFFS-RUMINANTS

Food	Dry matter (g/kg)	ME (MJ/kg DM)	CP (g/kg DM)
Rapeseed meal	900	12.0	400
Barley	860	13.2	115
Hay (average)	850	8.6	85
Hay (good)	860	9.2	100
Silage (average)	240	10.6	130
Silage (good)	240	11.2	140
Barley straw	860	6.3	35
Oats	870	12.0	100
Wheat	860	13.6	115
Maize	860	13.8	95
Brewers grains (draff)	230	11.1	200
Wheat dark grains	900	13.5	340
Malt dark grains	900	12.2	265
Maize gluten (20%)	880	12.9	220
Soya bean meal (47%)	890	13.3	530
Potatoes	210	13.3	90
Swedes	105	14.0	90
Molassed sugar beet feed	890	12.5	100

RELATIVE VALUES (£) OF FEEDINGSTUFFS-RUMINANTS

Food			£/t			
RAPESEED MEAL		175			225	
BARLEY	100	150	200	100	150	200
Hay (average)	59	81	104	63	86	108
Hay (good)	67	92	116	72	97	121
Silage (average)	24	32	40	26	34	42
Silage (good)	26	35	43	28	37	46
Barley straw	32	48	65	31	48	64
Oats	88	132	176	88	132	176
Wheat	103	156	209	102	155	208
Maize	99	157	214	95	152	210
Brewers grains (draff)	29	35	41	33	39	46
Wheat dark grains	170	191	212	207	228	248
Malt dark grains	139	161	183	166	188	210
Maize gluten (20%)	129	162	195	146	180	213
Soya bean meal (47%)	219	210	200	287	278	268
Potatoes	23	36	50	22	35	49
Swedes	12	20	27	12	19	26
Molassed sugar beet feed	94	142	191	93	141	190

NUTRITIVE VALUES OF FEEDINGSTUFFS-PIGS

Food	NE (MJ/kg as fed)	Dig Lys(g/kg as fed)
Hipro soya bean meal	8.4	26.6
Barley	9.6	2.8
Oats	8.0	3.0
Wheat	10.5	2.5
Wheat feed	7.7	4.6
Wheat bran	6.2	4.0
Maize	11.1	1.8
Wheat dark grains	9.3	5.6
Maize gluten (20%)	7.0	4.0
Peas	9.7	12.5
Beans	8.6	12.8
Molassed sugar beet feed	6.6	2.9
Molasses	7.0	0.1
Biscuit waste	11.7	2.5
Rapeseed meal	6.5	14.0

RELATIVE VALUES (£) OF FEEDINGSTUFFS-PIGS

Food			£/t			
HIPRO SOYA BEAN MEAL		275			350	
BARLEY	100	150	200	100	150	200
Oats	89	129	169	91	131	171
Wheat	105	161	216	103	159	215
Wheat feed	98	134	170	106	142	177
Wheat bran	82	110	138	88	117	145
Maize	104	165	225	100	160	221
Wheat dark grains	119	163	206	128	171	215
Maize gluten (20%)	88	121	154	94	127	160
Peas	176	209	242	206	239	272
Beans	169	196	222	201	228	254
Molassed sugar beet feed	76	109	142	79	112	145
Molasses	58	98	138	52	92	132
Biscuit waste	115	177	240	112	175	237
Rapeseed meal	162	174	186	199	211	223

The tables are provided as a general guide and should be used with care. Each foodstuff has been attributed a specific nutritive value and often this will vary, e.g. draff (see previous page). The relative values of the feeding stuffs are also affected by the rationing situation. The relative values for ruminants are calculated on an ME and CP basis using barley and rapeseed meal as standard reference foods. The relative values above for pigs are calculated on a NE and Dig Lys (digestible lysine) basis, using barley and hipro soya as standard reference foods

Appendix 2 – Historical feed prices

Monthly feed prices - delivered Scotland

	Draff	Distillers wheat grains	Distillers barley grains	Rapemeal	Soyameal (Hipro)
					£ per tonne
Aug-11	27.00	207.50	182.50	183.50	297.50
Sep-11	22.00	201.00	180.50	180.00	271.00
Oct-11	24.50	203.50	181.50	179.00	282.00
Nov-11	25.50	197.50	181.50	173.00	275.00
Dec-11	27.00	204.00	185.00	171.00	259.50
Jan-12	27.00	205.50	187.50	188.00	274.50
Feb-12	28.00	197.00	182.00	188.00	296.00
Mar-12	29.00	212.50	177.50	221.00	321.00
Apr-12	25.00	212.50	177.50	241.00	351.00
May-12	23.00	217.50	180.50	240.00	357.50
Jun-12	25.00	230.00	187.50	261.00	391.50
Jul-12	26.50	250.00	205.50	281.00	455.00
Average	25.79	211.54	184.08	208.88	319.29

Source: Farm Brief

Monthly feed prices - delivered England

	Draff	Distillers wheat grains	Distillers barley grains	Rapemeal	Soyameal (Hipro)
					£ per tonne
Aug-11	42.00	220.00	192.50	165.50	284.50
Sep-11	42.00	218.00	195.00	161.50	266.00
Oct-11	41.50	223.00	196.00	169.00	279.50
Nov-11	42.50	210.00	196.00	158.00	257.00
Dec-11	42.50	216.00	196.00	158.00	249.00
Jan-12	42.50	216.00	195.00	179.50	270.50
Feb-12	44.00	197.50	195.00	185.50	290.00
Mar-12	48.00	215.00	187.50	206.00	317.50
Apr-12	46.00	217.00	187.50	221.50	347.50
May-12	42.00	227.50	190.00	221.50	349.50
Jun-12	44.50	231.00	191.00	255.00	381.50
Jul-12	47.50	255.00	213.00	261.50	448.00
Average	43.75	220.50	194.54	195.21	311.71

Source: Farm Brief

Difference - Scotland vs England

	Draff	Distillers wheat grains	Distillers barley grains	Rapemeal	Soyameal (Hipro)
£ per tonne	-18	-9	-10	14	8
%	-70%	-4%	-6%	7%	2%

Appendix 3– Estimated emissions for the production of distillery feed by-products

A) **Estimated CO2e emissions for malt distilling + DRAFF**

	Factor	Unit	Quantity (a)	*REF*	kgCO2e/unit (b)	*REF*	kgCO2e TOTAL (c)
Malting	**INPUT**						
	Barley production	t	4.2	*1*	350.00	*4*	1457.40
	Transport - farm-maltings	t km	416	*2*	0.04	*5*	17.38
	Mains gas	kWh	3123	*1*	0.23	*5*	708.11
	Electrical power	kWh	541	*1*	0.59	*5*	319.28
	OUTPUT						
	Malt	t	3.33	*2*			
Distilling	**INPUT**						
	Wheat production						
	Transport malt - maltings-distillery	t km	333	*2*	0.04	*5*	13.90
	Transport wheat - farm-distillery						0.00
	Mains gas - ferment & distill	kWh	2548	*3*	0.23	*5*	577.79
	Electrical power - distilling	kWh	345	*3*	0.59	*5*	203.49
							3297.35
Feed processing							
	Mains gas (inferred) - dry DDGS	kWh		*3*	0.23	*5*	0.00
	Electrical power - feed processing	kWh			0.59		0.00
	Transport - DDGS distillery - farm	t km	543	*2*	0.04	*5*	22.66
							22.66

OUTPUT	Unit	Quantity (d)	*REF*	Unit value (£) (e)	*REF*	*Total value (£) (f)*	Value % (g)
Alcohol	litres	1266	*3*	2.25	*6*	2,848.10	95.1%
Draff	t	5.43	*3*	27.00	*7*	146.61	4.9%
						2,994.71	

FEED Emissions	Emissions	Share (%)	Total	kg CO2e/t
Malting & Distilling	3297.35	4.9%	161.43	29.73
Feed processing	22.66	100.0%	22.66	4.17
Total			**184.09**	**33.90**

REFS & NOTES

1	Source: SAC + FAO Agribusiness Handbook, Barley, Malt, Beer (2009)
2	Source: SAC
3	Source: SAC + Chematur Engineering AB, Economic Evaluation of Bioethanol Production, prepared for ITI Life Sciences, (2005)
4	Source: Carbon Trust Footeprint Expert 3.1
5	Source: SAC + 2012 Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting
6	Source: Sutherlands Scotch Whisky Review 2011
7	Source: Farm Brief
c	= (a) * (b)
f	= (d) * (e)
g	=(f) as % of total
i	= (h)/(d)

B) Estimated CO2e emissions for malt distilling + DDGS

	Factor	Unit	Quantity (a)	*REF*	kgCO2e/unit (b)	*REF*	kgCO2e TOTAL (c)
Malting	**INPUT**						
	Barley production	t	4.2	*1*	350.00	*4*	1457.40
	Transport - farm-maltings	t km	416	*2*	0.04	*5*	17.38
	Mains gas	kWh	3123	*1*	0.23	*5*	708.11
	Electrical power	kWh	541	*1*	0.59	*5*	319.28
	OUTPUT						
	Malt	t	3.33	*2*			
Distilling	**INPUT**						
	Wheat production						
	Transport malt - maltings-distillery	t km	333	*2*	0.04	*5*	13.90
	Transport wheat - farm-distillery						0.00
	Mains gas - ferment & distill	kWh	2548	*3*	0.23	*5*	577.79
	Electrical power - distilling	kWh	345	*3*	0.59	*5*	203.49
							3297.35
Feed processing							
	Mains gas (inferred) - dry DDGS	kWh	2738	*3*	0.23	*5*	620.77
	Electrical power - feed processing	kWh	130		0.59	*5*	76.68
	Transport - DDGS distillery - farm	t km	151	*2*	0.04	*5*	6.30
							703.75

OUTPUT	Unit	Quantity (d)	*REF*	Unit value (£) (e)	*REF*	*Total value (£) (f)*	Value % (g)
Alcohol	litres	1266	*3*	2.25	*6*	2,848.10	91.1%
Draff	t	1.507	*3*	184.17	*7*	277.54	8.9%
						3,125.65	

FEED Emissions		Emissions	Share (%)	Total	kg CO2e/t
	Malting & Distilling	3297.35	8.9%	292.79	194.29
	Feed processing	703.75	100.0%	703.75	466.99
	Total			**996.54**	**661.27**

REFS & NOTES

1 Source: SAC + FAO Agribusiness Handbook, Barley, Malt, Beer (2009)
2 Source: SAC
3 Source: SAC + Chematur Engineering AB, Economic Evaluation of Bioethanol Production, prepared for ITI Life Sciences, (2005)
4 Source: Carbon Trust Footeprint Expert 3.1
5 Source: SAC + 2012 Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting
6 Source: Sutherlands Scotch Whisky Review 2011
7 Source: Farm Brief
c = (a) * (b)
f = (d) * (e)
g =(f) as % of total
i = (h)/(d)

C) Estimated CO2e emissions for grain distilling + DDGS

	Factor	Unit	Quantity (a)	REF	kgCO2e/unit (b)	REF	kgCO2e TOTAL (c)
Malting	**INPUT**						
	Barley production	t	0.56	*1*	350.00	*4*	194.60
	Transport - farm-maltings	t km	55.6	*2*	0.04	*5*	2.32
	Mains gas	kWh	417	*1*	0.23	*5*	94.55
	Electrical power	kWh	72	*1*	0.59	*5*	42.63
	OUTPUT						
	Malt	t	0.45	*2*			
Distilling	**INPUT**						
	Wheat production		3.37	*3*	340.00	***4***	1,145.80
	Transport malt - maltings-distillery	t km	45	*2*	0.04	*5*	1.87
	Transport wheat - farm-distillery	t km	100	*2*	0.04	*5*	4.17
	Mains gas - ferment & distill	kWh	2548	*3*	0.23	*5*	577.79
	Electrical power - distilling	kWh	345	*3*	0.59	*5*	203.49
							2,267.23
Feed processing							
	Mains gas (inferred) - dry DDGS	kWh	2738	*3*	0.23	*5*	620.77
	Electrical power - feed processing	kWh	130	*3*	0.59	*5*	76.68
	Transport - DDGS distillery - farm	t km	151	*2*	0.04	*5*	6.29
							703.73

OUTPUT	Unit	Quantity (d)	REF	Unit value (£) (e)	REF	Total value (£) (f)	Value % (g)
Alcohol	litres	1266	*3*	1.05	*6*	1,329.11	81.1%
Draff	t	1.51	*3*	205.83	*7*	310.19	18.9%
						1,639.30	

FEED Emissions		Emissions	Share (%)	Total	kg CO2e/t
	Malting & Distilling	2267.23	18.9%	429.00	284.67
	Feed processing	703.73	100.0%	703.73	466.98
	Total			**1132.74**	**751.65**

REFS & NOTES

1 Source: SAC + FAO Agribusiness Handbook, Barley, Malt, Beer (2009)
2 Source: SAC
3 Source: SAC + Chematur Engineering AB, Economic Evaluation of Bioethanol Production, prepared for ITI Life Sciences, (2005)
4 Source: Carbon Trust Footeprint Expert 3.1
5 Source: SAC + 2012 Guidelines to Defra/DECC's Greenhouse Gas Conversion Factors for Company Reporting
6 Source: Sutherlands Scotch Whisky Review 2011
7 Source: Farm Brief
c = (a) * (b)
f = (d) * (e)
g =(f) as % of total
i = (h)/(d)

Appendix 4 – carbon emissions of alternative feed rations

Table 1 Comparison of beef finishing diets

Beef - 500kg steer/1kg daily liveweight gain

Ingredient		**STRAW**		**SILAGE DIETS**	
		Feed make up - kg of materials per day			
DIET NOS	Source	**1**	**2**	**3**	**4**
barley	SAC	5.6	2.6	3.8	2
rapeseed meal	SAC	1.3	0.38	0	0
draff - barley	SAC	0	20	0	15
straw	SAC	5.3	4.3	0	0
silage	SAC	0	0	24.8	18

Source SAC and Carbon Trust Footprint Expert

Table 2Beef finishing carbon emissions

Beef steer finishing emissions kg CO2e

100 beef finishers, 1kg liveweight gain per day

			1) Straw	**2) Straw + draff**	**3) Silage**	**4) Silage + draff**
INDIRECT	Carbon dioxide equivalent	Feeds	68,753	49,115	76,406	58,644
DIRECT	Methane	Digestion	94,792	94,792	94,792	94,792
		Manure	26,569	26,569	26,569	26,569
	Nitrous oxide	Grazing	10,353	10,353	10,353	10,353
		Crops				
TOTAL			**200,467**	**180,829**	**208,120**	**190,358**
OUTPUT		kg LWT	17,400	17,400	17,400	17,400
Emissions per kg LIVEWEIGHT			11.52	10.39	11.96	10.94
of which feeds			3.95	2.82	4.39	3.37
Emissions per kg DEADWEIGHT			21.74	19.61	22.57	20.65
of which feeds			7.46	5.33	8.29	6.36
FEEDS as % of total emissions			34%	27%	37%	31%

Source: SAC Farm Management Handbook and SAC PAS 2050 Agri Carb© Carbon Calculator

Appendix 5 – Estimated distillery feed by-product output

	SPIRIT PRODUCTION			SPIRIT YIELD		GRAIN/MALT USE		CONVERSION		BY PRODUCTS		
	million LPA			LPA per tonne grain		tonnes		t by-product / t of grain/malt				
	MALT	GRAIN	TOTAL	Malt	Grain	Malt	Grain	Malt	Grain	Barley DDGS	Wheat/maize DDGS	TOTAL
REFS	**a**	**b**	**(a+b)**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**(i+j)**
1990	193.1	235.9	429	391	371	494	636	0.3114	0.3272	153.80	208.05	361.85
1991	187.8	230.5	418.3	397	372	473	620	0.3114	0.3272	147.32	202.74	350.06
1992	167.9	217	384.9	395	373	425	582	0.3114	0.3272	132.37	190.35	322.73
1993	142.8	210.2	353	402	377	355	558	0.3114	0.3272	110.62	182.43	293.06
1994	148	215.5	363.5	407	374	364	576	0.3114	0.3272	113.24	188.53	301.78
1995	159.7	243.1	402.8	403	374	396	650	0.3114	0.3272	123.41	212.68	336.09
1996	173.8	269.1	442.9	407	375	427	718	0.3114	0.3272	132.98	234.80	367.78
1997	195.2	287.2	482.4	410	377	476	762	0.3114	0.3272	148.27	249.26	397.53
1998	187.1	267.6	454.7	407	376	460	712	0.3114	0.3272	143.16	232.87	376.03
1999	162.1	245.2	407.3	406	383	399	640	0.3114	0.3272	124.34	209.48	333.81
2000	144.7	215.3	360	413	384	350	561	0.3114	0.3272	109.11	183.45	292.56
2001	145.8	216.7	362.5	414	382	352	567	0.3114	0.3272	109.67	185.61	295.29
2002	157.7	228.5	386.2	412	378	383	604	0.3114	0.3272	119.20	197.79	316.99
2003	153.2	238.7	391.9	408	378	375	631	0.3114	0.3272	116.94	206.62	323.56
2004	152	224.2	376.2	411	376	370	596	0.3114	0.3272	115.17	195.10	310.27
2005	165.3	243.5	408.8	412	382	401	637	0.3114	0.3272	124.95	208.57	333.51
2006	178.4	273.6	452	412	385	433	711	0.3114	0.3272	134.85	232.52	367.37
2007	213.5	306.2	519.7	405	384	527	797	0.3114	0.3272	164.17	260.91	425.08
2008	240.7	310.8	551.5	405	379	594	820	0.3114	0.3272	185.08	268.32	453.40
2009	223.2	261.3	484.5	407	383	548	682	0.3114	0.3272	170.78	223.23	394.01
2010	208.3	252.7	461	408	380	511	665	0.3114	0.3272	158.99	217.59	376.58
2011 (est)	240	280	520	408	380	588	737	0.3114	0.3272	183.19	241.09	424.28
2012 (est)	265	307	572	408	380	650	808	0.3114	0.3272	202.27	264.34	466.61
2013 (est)	271	309	580	408	380	664	813	0.3114	0.3272	206.85	266.07	472.92
2014 (est)	265	305	570	408	380	650	803	0.3114	0.3272	202.27	262.62	464.89
2015 (est)	255	305	560	408	380	625	803	0.3114	0.3272	194.64	262.62	457.26

REFS	
a	Source: Sutherlands Scotch Whisky Review 2011 including projections to 2015
b	Source: Sutherlands Scotch Whisky Review 2011 including projections to 2015
c	Source: Sutherlands Scotch Whisky Review 2011 up to 2011, SAC assumed 2011 spirit yields remained static to 2015
d	Source: Sutherlands Scotch Whisky Review 2011 up to 2011, SAC assumed 2011 spirit yields remained static to 2015
e	SAC calculation - (a / c) * 1000
f	SAC calculation - (b / d) * 1000
g	Source: Pass, B and Lambart, I, Whisky: Technology, Production and Marketing, (2003) Elsevier, Chapter 8, Figure 8.2
	2002 estimate - 145mLPA / 414 litre PA/t grain = 350,000t grain / 109,000t residues (dry matter) = 0.3114 t feed by-product/t of grain
h	Source: Pass, B and Lambart, I, Whisky: Technology, Production and Marketing, (2003) Elsevier, Chapter 8, Figure 8.1
	2002 estimate - 229mLPA / 382 litre PA/t grain = 599,000t grain / 196,000t residues (dry matter) = 0.3272 t feed by-product/t of grain
i	SAC calculation - e *g
j	SAC calculation - f *h