



Greenhouse gas emissions on British dairy farms

DairyCo carbon footprinting study: Year one

February 2012



DairyCo

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Foreword

D. Under the umbrella of the Dairy Roadmap, the British dairy industry is seen as a world leader in its efforts to tackle the environmental impact of dairy farming.

Speaking at the launch of the Dairy Roadmap report in May 2011 at the House of Commons, The Right Honourable James Paice MP, Minister of State for Agriculture and Food, said: "It's not easy being in this industry but the people who produce, process and sell dairy products are continuing to lead the charge to becoming more sustainable. The Roadmap shows real achievements right across the board, from entering land into environmental stewardship to more efficient use of energy and water. There's more that can be done but the industry has shown that it's up to the challenge and is providing a great example of the fact that collective action for change is every bit as effective as the heavy hand of regulation."

To meet legislative and policy requirements and to optimise the use of natural resources, nationally and at the level of the individual farming system, we require robust information, based on sound science and the use of appropriate tools and methodologies. This will enable us to make informed decisions.

With this in mind, in September 2010, the E-CO₂ Project (E-CO₂) was contracted by DairyCo to establish a national annual average carbon footprint figure for GB milk production based on actual farm data. This three-year research project is part-funded by levy payers and match-funded by participating milk processors to ensure a sufficiently large sample of over 400 participating farms, reflecting the diversity of British dairy farming.

The first year of this study provides the dairy industry with a point of reference for the carbon footprint of milk production from British dairy farms, based on current industry performance. This will allow us to benchmark any year-on-year improvements. This point of reference will also supply factual information to cross reference with other sources of carbon footprinting data, including the Government national inventory on green house gas emissions.

These first year results, available to all British dairy farmers, highlight areas where resource use efficiency and economic performance can be improved. Over time, the project will increase understanding of what can be practically implemented on farm to reduce carbon footprint, while aiming to improve farm profitability and long-term sustainability. They will also provide better understanding of how weather, disease outbreak or changes in management practice can impact positively or negatively on farm carbon footprint.

Sustainable food production and dealing with climate change are global issues that need a global solution and dairy farmers are part of that solution. Our climate, geography and knowledge mean that British dairy farmers are ideally suited to produce dairy products in an efficient and environmentally sustainable way. This project demonstrates our continued commitment to improving environmental performance by actively addressing the challenges and opportunities which lie ahead.

Acknowledgements

DairyCo and the E-CO₂ Project would like to thank all of the organisations that have taken part in this study including those listed below:

- All participating dairy farmers
- Robert Wiseman Dairies
- First Milk
- OMSCo
- Arla Foods UK
- Milk Link
- Belton Cheese
- Cropwell Bishop
- A number of independent farms – these include suppliers of Dairy Crest, Glanbia, Barbers Maryland Cheese, Wyke Farms, Windmill Foods Limited, Lactalis, AshleyChase, R Grahams and Marks & Spencer.

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Executive summary

D. Under the Climate Change Act 2008, the UK Government is legally required to reduce greenhouse gas (GHG) emissions across the UK economy by 80% of 1990 levels, by 2050. The agriculture sector is committed to playing its part in meeting this national goal and will need to demonstrate an 11% reduction on 2008 levels, by 2020. While GHG emissions from dairy farms account for less than 2%¹ of the UK's total annual GHG emissions, further reduction commitments have been made through initiatives such as the Dairy Roadmap. To support the industry's position and efforts, better data are required on the carbon footprint of milk production from British dairy farms. Focusing on more efficient use of inputs will also help reduce costs of production, as well as enhance the environmental credentials of the dairy industry.

In September 2010, the E-CO₂ Project (E-CO₂) was contracted by DairyCo to establish a national annual average carbon footprint figure for GB dairy farms. This three-year research project is part-funded by levy payers and match-funded by participating dairy processors, to ensure a sufficiently large sample of participating farms.

The specific objectives during Year 1 were to:

- Provide a Carbon Trust verified average carbon footprint figure for GB milk production based on actual farm data
- Benchmark current industry performance, in order to measure year-on-year improvement
- Provide each participating farmer with a carbon footprint figure, identifying 'hot spots' of carbon emissions and how these may be reduced
- Record any mitigation or abatement practices which reduce carbon footprint
- Calculate separately, carbon footprint according to International Dairy Federation (IDF) methodology
- Present information from six participating farms as specific case studies.

A total of 415 GB dairy farms, varying in size, system and geographical location, participated in the study. Information was collected from farm records and financial accounts. Thorough data validation and verification processes were carried out on all assessments made. The results were anonymised, compiled and analysed to produce a report for every farm, which was returned to each participant.

In this first year of the study, the average carbon footprint figure² for GB milk production was 1,309g of carbon dioxide equivalents per litre (g CO₂e/l) of fat-corrected milk. Across the sample of farms, carbon footprint ranged from 832 to 2808 (g CO₂e/l). The majority of the data lay within + or - 276 g CO₂e/l of the mean. The average figure calculated using IDF methodology (1327 g CO₂e/l) was very comparable to these results.

The results show that regardless of farming system there are opportunities for reducing carbon footprint. The largest contributors to carbon footprint were enteric emissions from rumen fermentation (40%) and

¹ Misselbrook T, Cardenas L, Gilhespy S, (2010), DairyCo Report Greenhouse Gas Emissions from UK Agriculture: Reporting by Agricultural Sector for 1990 and 2008

² For interpretation or comparison of this figure please refer to the results section: average carbon footprint figure

concentrate feed inputs (26%). Furthermore, the data suggest that there is likely to be more variation between farms, than between production systems. When correlated with carbon footprint per litre of milk across the sample of 415 farms, no single variable (eg milk yield, fertiliser use or energy consumption) accounted for most of the variation between farms. Some relationships were stronger than others, although all were in the direction anticipated. The carbon footprint of six case studies, reflecting a range of circumstances and production systems, ranged from 886 to 1,246 g CO₂e/l.

Data collection for Year 2 began in October 2011. As the data set expands, the robustness of the figures produced will continue to increase and deeper analyses of factors contributing to carbon footprint, as well as the impact of specific mitigation measures, will be undertaken.

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Agriculture and the environment

D. The report 'Livestock's Long Shadow'³, published in 2006 by the Food and Agriculture Organisation of the United Nations (FAO), cast a considerable cloud over global livestock production. A figure of 18% was reported for GHG emissions associated with livestock. Although this figure covered all livestock agriculture around the world (including, for example, ducks in China and buffaloes in India), it became associated almost exclusively with beef and dairy in the developed world. This headline message was picked up in the media and in popular culture, precipitating a debate on reducing the consumption of livestock products, in pursuit of environmental benefit. These messages also prompted consideration of whether reduced consumption should be advocated as Government Policy.

Further reports provided more detailed information on emissions including differences between regions and between different agricultural sectors. A report by the Dutch Research Institute CE Delft⁴, commissioned by the European Dairy Association specifically for the dairy sector, reported pre-farm gate GHG emissions of around 3% globally. These orders of magnitude were confirmed by a further FAO report⁵ which indicated that GHG emissions from the entire dairy sector, including its beef output, was 4%. Dairy on its own was reported to account for 2.7%, of which between 85% and 90% is attributable up to the farm gate. This report highlighted enormous variation in GHG emissions associated with various dairy industries around the world.

Why measure carbon emissions?

Under the Climate Change Act 2008, the UK Government is legally required to achieve an 80% overall reduction in GHG emissions from 1990 levels across the UK economy, by 2050. The agriculture sector is committed to playing its part in contributing to meeting the national goal and will need to demonstrate an 11% reduction on 2008 levels by 2020. This underlines the need for robust evidence, based on sound science and consistent methodology, when making important policy decisions relating to GHG emissions.

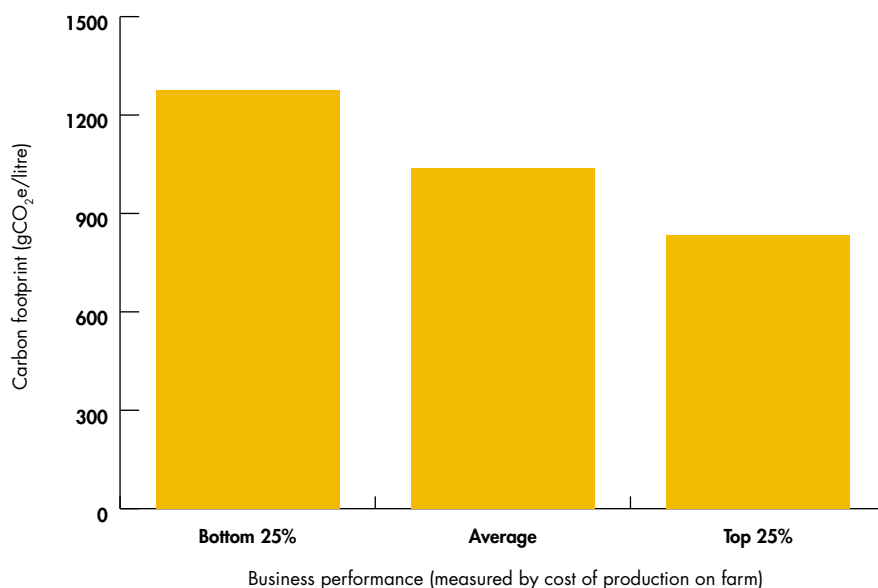
Interest in carbon footprinting in the GB dairy industry has grown considerably in recent years. At farm level, GHG emissions account for approximately three quarters of the overall carbon footprint for liquid milk, underlining the value in targeting emissions pre-farm gate. Although environmental drivers are not universally well received by farmers, evidence is available (Figure 1) to illustrate that lower carbon footprint is associated with reduced production costs. This reinforces the message that improving production efficiency and reducing the carbon cost of milk production, can be highly complementary.

³ Livestock's long shadow. Environmental issues and options. FAO, Rome. 2006.

⁴ CE Delft (2008). A sustainable dairy sector. Global, regional and life cycle facts and figures on greenhouse gas emissions. Author(s): Sevenster, M. and de Jong, F. October 2008.

⁵ Gerber P, Vellinga T, Dietze K, Falcucci A, Gianni G, Mounsey J, Maiorano L, Opio C, Sironi D, Thieme O, Weiler V, (2010), Food and Agriculture Organisation (FAO) Report Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment.

Figure 1 The relationship between dairy farm business performance and carbon footprint from a small sample of dairy farms (figure kindly supplied by the Asda/Arla milk pool).



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How do we measure carbon emissions?

Carbon footprint refers to the emission of three major greenhouse gases produced in agriculture. These are carbon dioxide (CO₂), methane (CH₄) produced from enteric fermentation in the rumen and from stored manures, and nitrous oxide (N₂O) produced as a result of soil management and the application of fertiliser and manures. Methane and nitrous oxide, respectively, are around 23 and 297 times more potent as a greenhouse gas, than carbon dioxide.

National reporting of GHG emissions

As part of its international commitments under the Kyoto Agreement, the UK is required to report annually on GHG emissions. Greenhouse gas emissions reported under agriculture, include methane (CH₄) and nitrous oxide (N₂O). Other emissions from agriculture are reported elsewhere. For example, fuel use within the agricultural sector is captured within the national inventory for energy.

Based on the National Inventory, GHG emissions from dairy farms account for less than 2% of the UK's total annual GHG emissions (43.8 Mt CO₂ equivalent for 2008).

The current level of assessing GHG emissions from agriculture is relatively simplistic (described as a 'Tier 1' approach). Calculations are based on multiplying the number of cattle present by an emission factor, which is a generic internationally-applied default value. Emissions are estimated at the national level, with high levels of uncertainty associated with the emission factors applied. This means that no allowances are made for differences in production system or in the management applied by individual farms. Until now, no baseline GB data were available based on actual farm emissions.

If a 'Tier 1' approach continues to be relied upon, the impact of different mitigation strategies to reduce GHG emissions, will not be adequately captured. As part of international efforts to improve the accuracy of measuring and calculating GHG emissions, the UK has committed £12.6 million in funding to new research⁶. With better data, reporting could combine UK — specific emission factors across the most important land use or livestock categories relevant to UK conditions (a 'Tier 2' approach). Eventually, more comprehensive calculations may be possible, based on more detailed industry information, better technical data and the

⁶ <http://www.ghgplatform.org.uk/>

use of more sophisticated modelling approaches ('Tier 3').

New Government-funded research on GHG emissions is not set to deliver until 2015/2016, so even 'Tier 2' calculations for the national inventory are some years away. However, agriculture is still required to demonstrate progress in the intervening period – one of the main drivers for the current DairyCo carbon footprinting study.

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On-farm carbon footprinting

Carbon footprinting is defined as the total set of GHG emissions caused directly or indirectly by an individual, organisation, event or product⁷.

In this study, carbon footprint is based on calculations made for all major inputs, outputs and GHG emissions relating to milk production, up to the farm gate.

Emissions include:

- Methane (CH₄) – mainly from enteric fermentation in the rumen and from stored manures
- Nitrous oxide (N₂O) – from soil management, and as a result of the use of fertilisers and manures
- Carbon dioxide (CO₂) related to the manufacture and use of fertilisers (where fertiliser is used for crops grown as feed for dairy cows)
- Embedded emissions from purchased feed.

In this report, carbon footprint is expressed in terms of carbon dioxide equivalent (CO₂e) per litre of milk produced, adjusted to a standard 4% butterfat.

Carbon footprinting tools, standards and methodologies

There are a number of carbon footprinting tools available on the market. Some have undergone certification by the Carbon Trust. The Carbon Trust certification scheme is based on PAS 2050 methodology. PAS 2050⁸ is an independent Publicly Available Specification, developed by the British Standards Institute (BSI) and Defra, to provide a consistent method for assessing the life cycle GHG emissions of goods and services. The specification has widespread application but, inevitably, cannot cater for every characteristic of particular products or industries such as dairy farming. Therefore, DairyCo, Dairy UK and the Carbon Trust have developed a set of guidelines addressing the measurement and calculation of the carbon footprint of dairy products⁹. They are complementary to PAS 2050, providing sector-specific guidance for the dairy industry.

The E-CO₂ model uses guidance from Carbon Trust Certification, Intergovernmental Panel on Climate Change (IPCC) 2006 and PAS 2050 methodology to carry out a Life Cycle Analysis (LCA), which calculates the carbon footprint or global warming potential (GWP) of milk production up to the farm gate.

Under the International Dairy Federation (IDF), the dairy industry has also been working towards developing a methodology for carbon footprinting within the dairy sector, which could be applied internationally. There are a number of differences between the methodology used in GB and IDF methodology – notably in terms of how inputs are apportioned between different enterprises or types of output. Assigning all of the GHG emissions from a dairy farm to milk, would result in an overestimation of the product footprint ie for milk.

⁷ UK Carbon Trust, 2008 (www.carbontrust.co.uk)

⁸ <http://www.bsigroup.com/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050>

⁹ Guidelines for the carbon footprinting of dairy products in the UK. A Dairy UK, DairyCo and Carbon Trust publication, September 2010. http://www.dairyuk.org/component/docman/cat_view/110-publications

Some of the farm emissions have to be borne by co-products, eg calves for beef. GB methodology uses an allocation based on economic parameters, while IDF methodology uses an alternative 'system expansion approach' (see Glossary), to deal with systems which produce both products and co-products. In addition, both methodologies differ in the value taken for the global warming potential (GWP) of methane – 25 in the IDF model¹⁰ and 22.5 in the current E-CO₂ model. E-CO₂ developed an IDF compliant calculator, which has also been applied to data collected within the current project.

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¹⁰ IDF sampling guidelines document 'A Common Carbon Footprint Approach for Dairy: The IDF Guide to Standard Lifecycle Assessment Methodology for the Dairy Sector.'

DairyCo carbon footprinting study

D. Reducing the environmental impact of dairy farming is one of the priorities set out within the DairyCo Business Plan. The overall aim of this study is to collect comprehensive data from a sample population of dairy farms across GB, to provide a better understanding of GHG emissions from milk production and to highlight the potential reduction opportunities available.

Objectives

The specific objectives of the study are to:

- Provide a Carbon Trust verified average carbon footprint figure for GB milk production, based on actual farm data
- Monitor progress against the targets set out by Government and industry, highlighting positive efforts being made on farm
- Provide each participating farmer with a carbon footprint figure, identifying 'hot spots' of carbon emissions and how these may be reduced
- Record any mitigation or abatement practices and their associated effect on reducing carbon footprint
- Calculate separately, carbon footprint according to IDF methodology
- Provide British dairy farmers with the practical information and knowledge of the key target areas to improve business efficiency and reduce environmental impact
- Cross reference a Carbon Trust verified average carbon footprint figure for GB milk production based on actual farm data, with a GB figure derived from the UK National Inventory.

Study design

The involvement of sufficient GB dairy farms, fully reflecting a range of systems, farm types and geographical distribution, was essential to deliver the objectives of the study.

Sample selection

The decision to target a sample size of 415 participating farms was based on consultation with a statistician.

A sampling protocol was developed to ensure that the national average carbon footprint figure for GB milk production at farm gate level was statistically robust, and reflective of the industry. This was determined by geographic location, with a proportional allocation based on the total number of dairy farmers in each country (Table 1), where possible, further broken down into production systems within each country. The farm sampling process was then independently appraised by a Carbon Trust Certification Manager to provide external verification. While this dataset would result in statistically robust data for the GB population, it was not intended to provide statistically robust information by dairy farming system.

Table 1 Sampling numbers per country¹¹

	England	Wales	Scotland	Total
Number of holdings	9639	2104	1628	13371
% of GB total	72%	16%	12%	100%
Country split based on % of 415	299	66	50	415

In the event of a farmer exiting the study at the end of year one (eg due to ceasing milk production) every effort would be made to recruit another farm within the same region with a similar production system as the exiting farm.

Recruitment

Although carbon footprint data already existed for a proportion of GB dairy farmers, it was felt that these producers tended to do so because it was a requirement of their milk contract or they were genuinely interested in reducing their farm carbon footprint. Therefore, to use these farms might lead to a skew in the data and produce results which were not reflective of the wider industry.

E-CO₂ worked with DairyCo and other extensive contacts in the dairy industry, liaising with milk processors and first purchasers across GB, to identify farmers that were willing to participate in the study.

Data collection

For each farm assessment, an E-CO₂ trained assessor collected data using independent evidence, such as livestock records, farm accounts and software recording packages, where available.

The data have been collected and analysed according to the following criteria:

- **Average milk yield per cow**
Total milk produced, divided by the number of cows within the herd.
- **Concentrate feed use**
Amount of concentrate feed used relating to the dairy enterprise, including all replacement heifers, youngstock and dry cows. The feed allocated to the milking cows is then used to report a figure of kg of feed per litre of milk produced.
- **Proportion of the year animals are grass fed (out to pasture)**
Information was recorded to capture the extent of the grazing season for the milking herd, youngstock and replacement heifers. This information was used for data analysis and nitrous oxide calculations.
- **Quantity of fertiliser used**
The total amount of fertiliser used on the dairy enterprise, this does not include any fertiliser used to produce home-grown cereals. The fertiliser is allocated to individual enterprise.
- **Herd replacement rate**
Number of cows that leave the herd as cull cows, sales or deaths divided by the total number of cows in the herd.
- **Manure management system**
Imports, exports and application of manure, including details of application methods and timings.

¹¹ DairyCo Datum statistics (www.dairyco.org.uk/datum.aspx)

- **Total annual milk production (in litres)**

The total amount of milk produced on the farm, including estimates of discarded milk, milk used domestically and for feeding calves.

Allocation between enterprises

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When calculating the carbon footprint of a mixed enterprise it is important to identify all of the GHG emissions for the farm and to allocate the emissions specifically related to milk production. For example, for a dairy farm that also has an arable enterprise, the fertiliser, fuel and electricity are split between the arable enterprise and the dairy enterprise by the economic value of each enterprise.

Carbon credits to the dairy system

Carbon credits may also be given to the dairy enterprise, for cull cows, heifers sold for breeding and calves that are transferred into a beef production system. This is calculated by comparing the total financial value of the milk that a cow produces over her lifetime, with the financial value of her carcass at the end of her life, along with the number and value of the calves that she will produce for the beef supply chain. Similarly, farmyard manure leaving the enterprise has a carbon credit, which in turn may be offset if additional fertiliser has to be imported as an alternative source of soil nutrients.

Data handling and analysis

E-CO₂ ensured that all of the participating farmers agreed for their data to be pooled anonymously, analysed and reported within this study. For the purposes of this report, descriptive statistics (see Glossary) were used to describe the main features of the data – mean, mode and median (where applicable), and standard deviation (how much variation there is from the mean). With the addition of data from years 2 and 3, it will become increasingly possible to use more sophisticated statistical techniques to interrogate and characterise patterns within the data.

All results were expressed in terms of grams of carbon dioxide equivalents per litre (g CO₂e) of milk sold, adjusted to 4% butterfat (BF). For example, a 1,000,000 litre producer at 4.5% BF is adjusted to a 4% figure, giving an imputed volume of 1,125,000 based on the extra BF value.

Data quality assurance

Every on-farm assessment was graded to assess the quality and credibility of the data provided by the farmer to input into the carbon footprinting model. This grading ranged between 1 and 5, with Grade 1 being assigned to a farm with accurate, objective and high quality data and Grade 5 being assigned to a farm with very little independent and reliable data available. Verification of each dataset was completed by a member of staff independent of the farm and the assessment. This protocol follows a set procedure to identify any potential errors that may have been made at the inputting stage, therefore eliminating the possibility of any anomalies grossly affecting the carbon footprint numbers. This, combined with results of the descriptive statistical analysis of the entire dataset, gives confidence that the carbon numbers generated and the dataset are statistically robust.

Carbon Trust verification

Carbon Trust Certification reviewed all of the E-CO₂ procedures (the assessor training, data entry and validation system) used by the assessors. Approximately 40 farms were selected at random by the Trust, ensuring a representative sample of farms from each region. Each of the randomly selected farms was then analysed to check key variables. Some of the outliers in the dataset were also selected and further investigated, to confirm whether the information collected was accurate.

Carbon Trust Certification has therefore verified the carbon footprint of GB national milk produced for this project and has agreed a standard communication to be used when reporting on the results. This states that Carbon Trust Certification has assessed the claim within the DairyCo carbon footprinting study with a reasonable level of assurance. The carbon footprinting study is consistent with the PAS 2050:2008 approach, with particular regard to the application of IPCC methodology. However, the carbon footprint produced from this study cannot be considered to be in full conformity with PAS 2050:2008, as it does not meet clause 4.3 on product differentiation and the footprint covers a milk pool spread across a number of supply chains, which are not under the direct control of DairyCo.

Results

Farm selection and recruitment

The target of 415 participating farms was achieved. Of these, 90% were graded 1-3 for quality of data obtained. Farmer recruitment proved slightly more challenging than anticipated, predominantly due to the difficult weather conditions experienced in the winter of 2010/2011. Farmer wariness of carbon footprinting and reluctance by some to engage with the DairyCo project were additional factors.

Figure 1 Geographic distribution of farms participating in the carbon footprinting project



Farm type and performance

Across the dataset, the mean average milk sold was 1,360,233 litres, representing an average herd size of 180 cows and an average yield of 7,490 litres/cow/year. This is slightly above the national average of 119 cows and 7,315 litres/cow/year (Source Datum 2010 data¹²).

¹² DairyCo Datum Statistics <http://www.dairyco.org.uk/library/market-information/on-farm-data/average-milk-yield.aspx>

Table 2 Milk production details from the 415 dairy farms - descriptive statistics

	Herd size	Av.yield per cow (l)	Total milk sold (l)
Mean	180	7,490	1,360,233
Standard Error	6	70	46,575
Median	150	7,566	1,092,985
Mode	100	N/A	N/A
Standard Deviation	119	1,420	948,814
Skewness	3	-0.3	2.6
Range	1012	8,307	8,173,250
Minimum	25	2,659	79,048
Maximum	1037	10,966	8,252,298

A small number of large farms tended to bias mean herd size, as both the median (150) and the mode (100) are below the average herd size of 180. This trend is further illustrated by the positive skew of 3.

For average herd yield, both standard deviation and standard error are relatively high, indicating the wide range of milk outputs represented in the sample population.

The presence of some large producers tended to skew the average total volume of milk produced. However, a wide range in the total volumes of milk sold off farm reinforces the view that the 415 farms assessed were representative of a diversity of dairy farming systems.

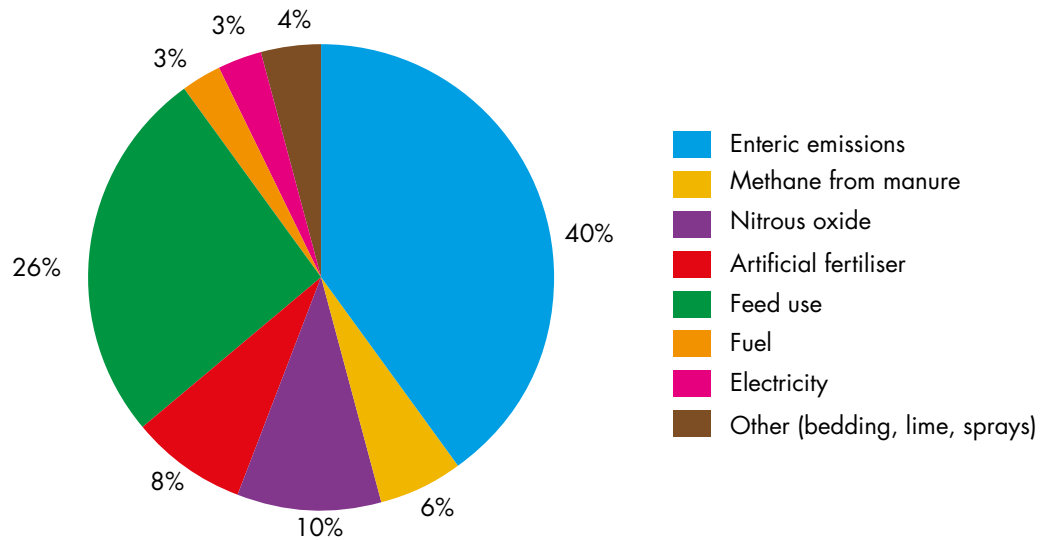
Distribution of GHG emissions by source

The three major sources of GHG emissions were:

- Carbon dioxide emissions – derived from inputs of fertiliser, lime, herbicides, pesticides, fuel, electricity, straw/bedding and animal feed
- Nitrous oxide – derived from fertiliser application, animal and organic manure management, sewage sludge (if applied), other crop residues and atmospheric deposition
- Methane – arising from enteric fermentation in the rumen and, to a lesser extent, emissions from manure management.

Figure 2 shows the average distribution of farm emissions calculated within this study. Enteric emissions account for the majority of emissions on most farms suggesting improvements in feed conversion efficiency and increased output, as routes to reduce carbon footprint.

Figure 2 Breakdown of the average farm emissions by source



Average carbon footprint

The average carbon footprint of the farms sampled during the first year (2010/2011), calculated using the Carbon Trust certified E-CO₂ milk model, is 1,309g CO₂e/litre of fat-corrected milk produced².

The figure is calculated as the weighted mean of the dataset, which enables a more representative value to be achieved, ie the larger producers have a slightly greater effect on the overall mean.

The average figure quoted is deemed to be accurate only within the scope of this project – the work is not intended to make any formal comparisons with other milk product carbon footprints. In addition, the reporting convention of Carbon Trust Certification is that footprint figures above 1,000g CO₂e/litre of milk, are rounded to the nearest 100g CO₂e/litre of fat-corrected milk. Therefore, any comparisons made with other footprints should use the rounded carbon footprint numbers – in keeping with the Carbon Trust Code of Good Practice.

Table 3 Average carbon footprint figure on 415 GB dairy farms

Average	1,309g CO ₂ e/l ²
Standard Error	13
Median	1,248
Mode	1,129
Standard Deviation	273
Skewness	1.7
Range	1,976
Minimum	832
Maximum	2,808

Table 3 indicates a large range (1,976g CO₂e) in carbon footprint across the 415 dairy farms. However, the standard deviation shows that the majority of data lies within 276g CO₂e/l of the average, indicating a relatively tight distribution. Standard error is also low, indicating a relatively low spread in the sampling distribution. The positive skew (1.7) illustrates that the majority of the data lies slightly below the average – a value of zero indicating perfect alignment about the mean.

Carbon footprint and herd profile

The range of farm carbon footprint recorded, set against herd profile for size, average yield per cow and total herd yield, is given in Table 4.

Table 4 Average carbon footprint figure on 415 GB dairy farms

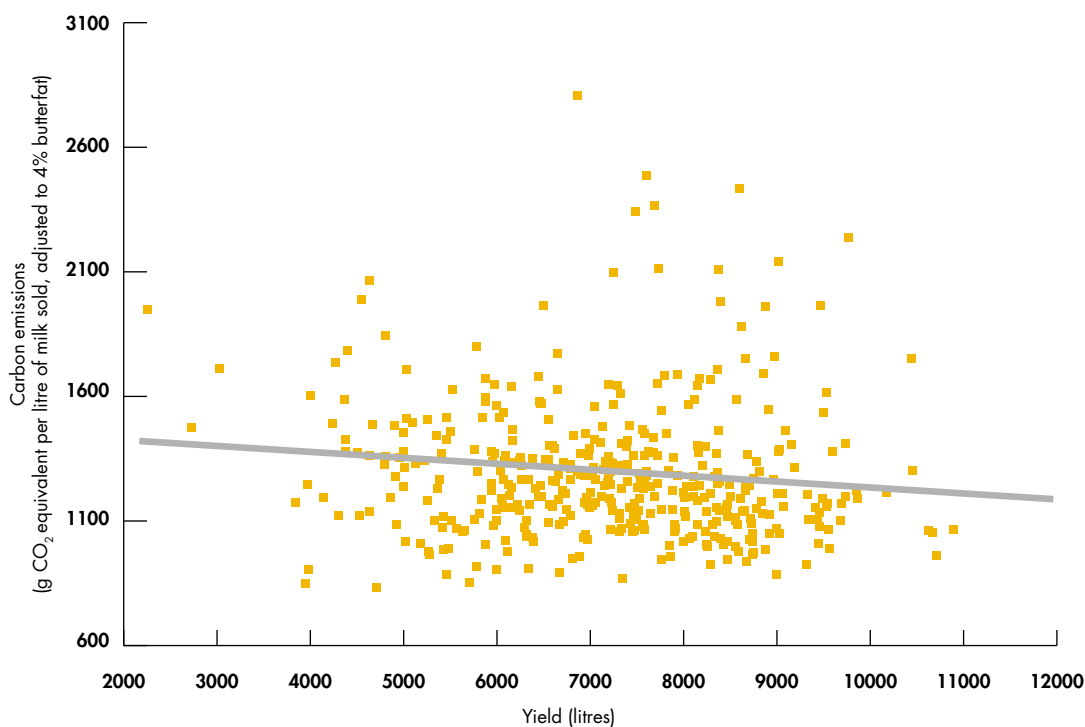
Full data set analysis	Herd size	Average yield (l)	Total milk sold (l)
Mean	180	7,490	1,360,233
Median	150	7,566	1,092,985
Mode	150	7,207	1,689,305
Farm with lowest carbon score	124	5,615	696,254
Farm with highest carbon score	586	7,360	4,312,674
Lowest 10% (carbon)	201	7,818	1,626,292
Highest 10% (carbon)	203	7,242	1,510,355

Carbon footprint and average yield per cow

Milk yield is usually identified as a key variable in determining carbon footprint per litre of milk. Methane emissions per litre will be lower in higher yielding animal, as the emissions attributed to the herd will be spread over a larger volume of milk.

Figure 3 shows carbon footprint plotted against average yield. For the dataset as a whole, there is a slight, but positive, trend indicating that as the yield per cow increases, carbon footprint decreases. Given the range of yield and carbon footprint within the sample, this underlines the fact that carbon footprint is also being affected by other factors, in addition to yield.

Figure 3 Milk yield carbon footprint



Carbon footprint and concentrate feed rate

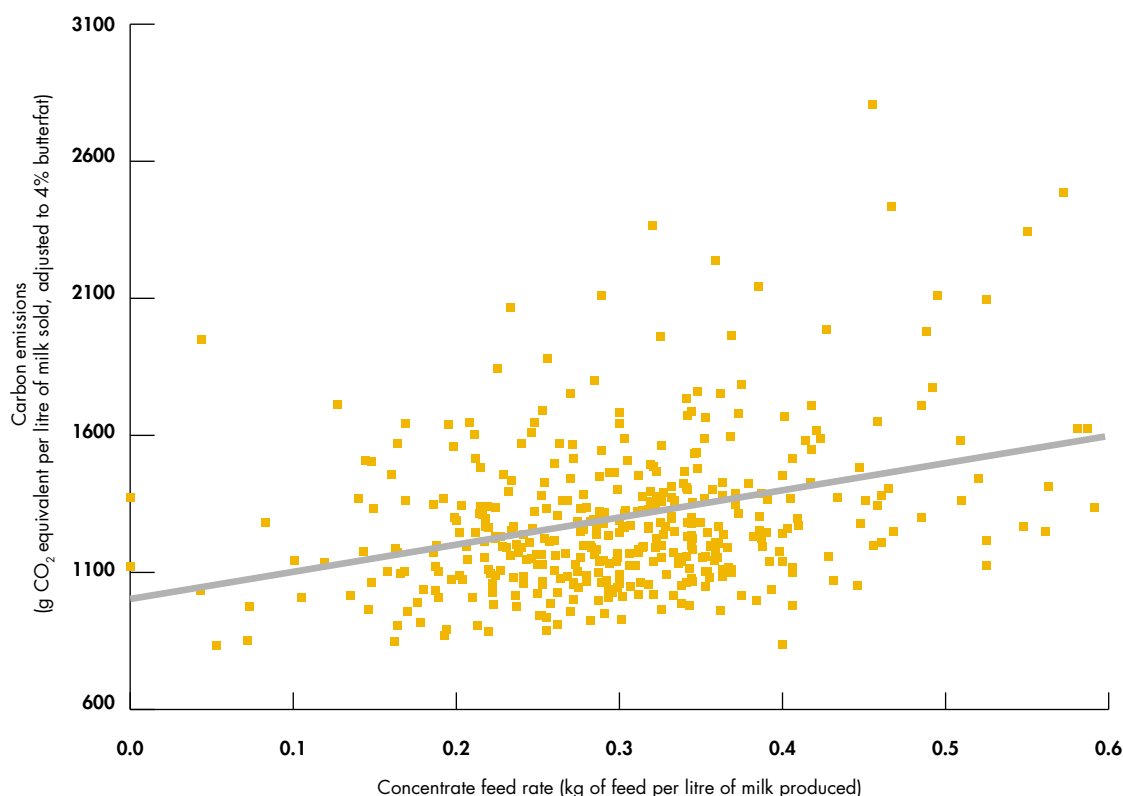
Concentrate feed rate in the carbon footprinting model is calculated by the addition of all feeds (concentrates, bought in feeds, home-grown feeds and by-products), ie total dry feed divided by the litres

of milk produced. This provides a concentrate feed rate in kg per litre of milk produced. Forage fed is not accounted for in this calculation.

Soya has a high carbon emission factor due to the imputed land use change associated with its production. On the other hand, feeding certain by-products can reduce the carbon cost of the ration. This is because the bulk of the carbon cost is attributed to the human food chain. Brewers grains, for example, bring onto the farm approximately 10% of the carbon attributed to grow and process the product; the other 90% being apportioned to the brewing industry as the primary user of the grain.

The mean average feed rate across the dataset was 0.30 kg/l with a high of 0.69 kg/l and a minimum of 0.0kg/l (ie a grazing system that fed no concentrates). Figure 4 indicates that, as feed rate (kg of feed per litre of milk produced) increases, carbon footprint per litre of milk also tends to increase.

Figure 4 Feed rate versus carbon footprint



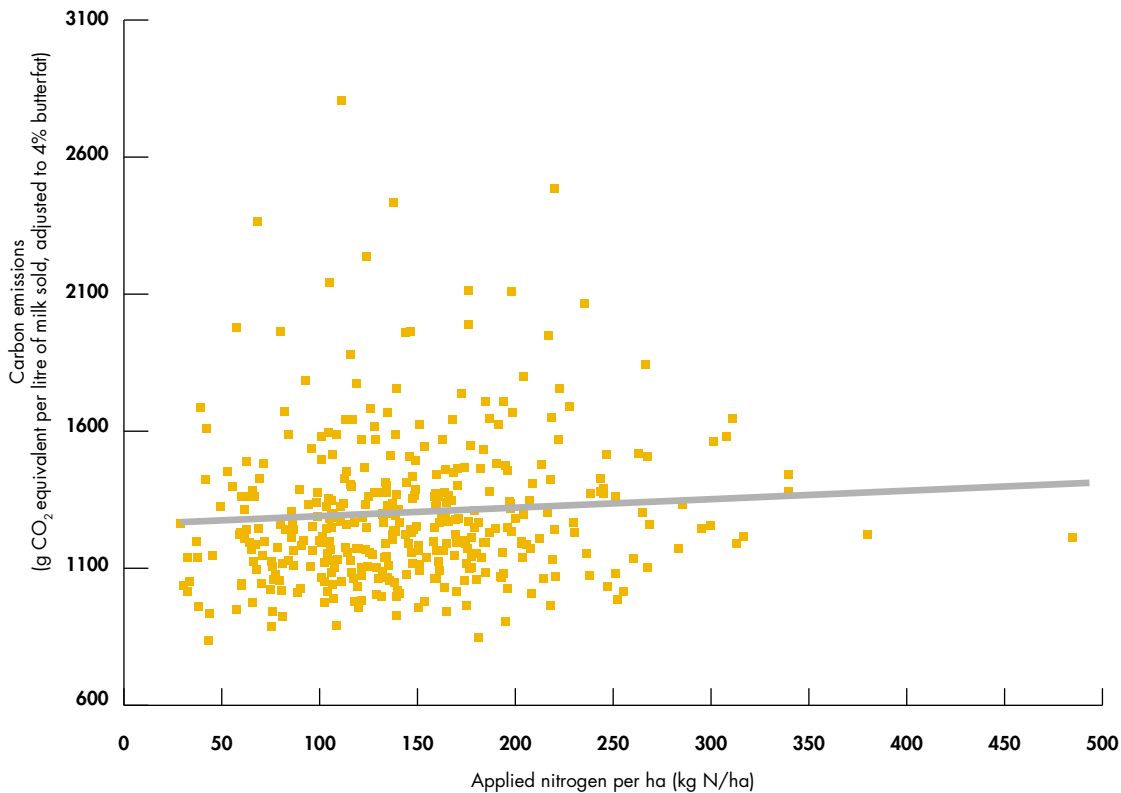
Optimising feed conversion efficiency and providing cows with high quality, highly digestible forages help to ensure efficient utilisation of the diet and reduced methane production. Increasing dietary starch at the expense of more fibrous carbohydrates can reduce the amount of methane produced per unit of feed dry matter consumed but implications for rumen health and animal welfare must be carefully considered. Utilising more home-grown forages will help reduce the amount of purchased feeds required, thereby reducing feed costs and carbon footprint.

Carbon footprint and fertiliser use

Across the sample, the application of artificial fertiliser accounted for around 8% of average farm emissions (Figure 2 above). Figure 5 demonstrates a considerable range in nitrogen applications per hectare. Plotting nitrogen fertiliser use against carbon footprint per litre of milk, indicated a slight tendency towards increased total emissions.

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Figure 5 Artificial fertiliser and carbon footprint



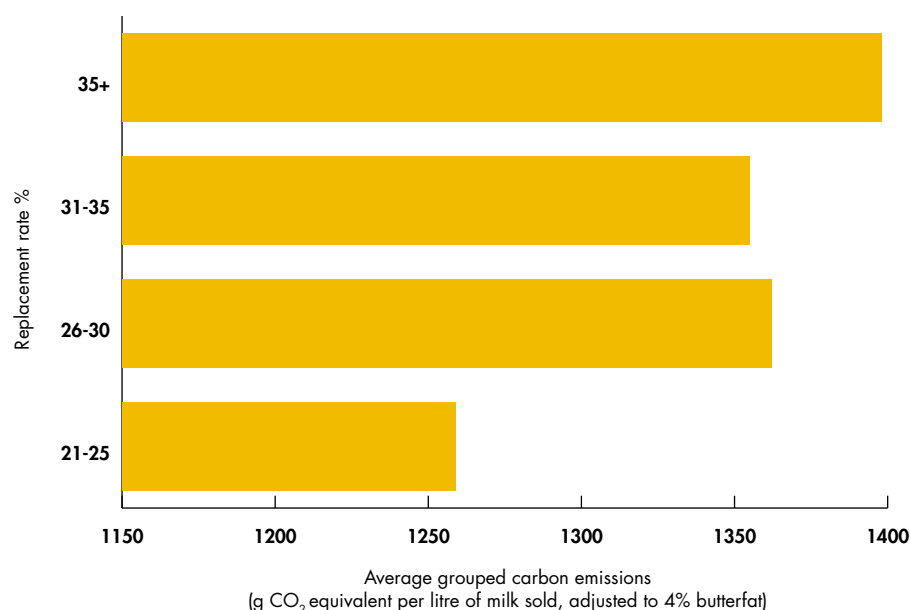
Reliance on artificial fertiliser can be reduced by better nutrient planning and management and more efficient use of home-produced manure and slurry.

Carbon footprint and herd replacement rate

Reducing herd replacement rate has a direct effect on carbon footprint per litre of milk, as emissions are offset over a longer productive life (Figure 6). Replacement rate can be improved by a focused approach to herd health and welfare, targeting issues such as lameness, mastitis and fertility. These factors are also linked with improving yield, further helping to reduce carbon footprint per litre of milk.

Calving heifers between 22-24 months of age means fewer youngstock are required and carbon emissions associated with the rearing period are reduced. The benefits of calving heifers down earlier are not just environmental, there are also proven economic advantages to the farm business.

Figure 6 Replacement rate and carbon footprint



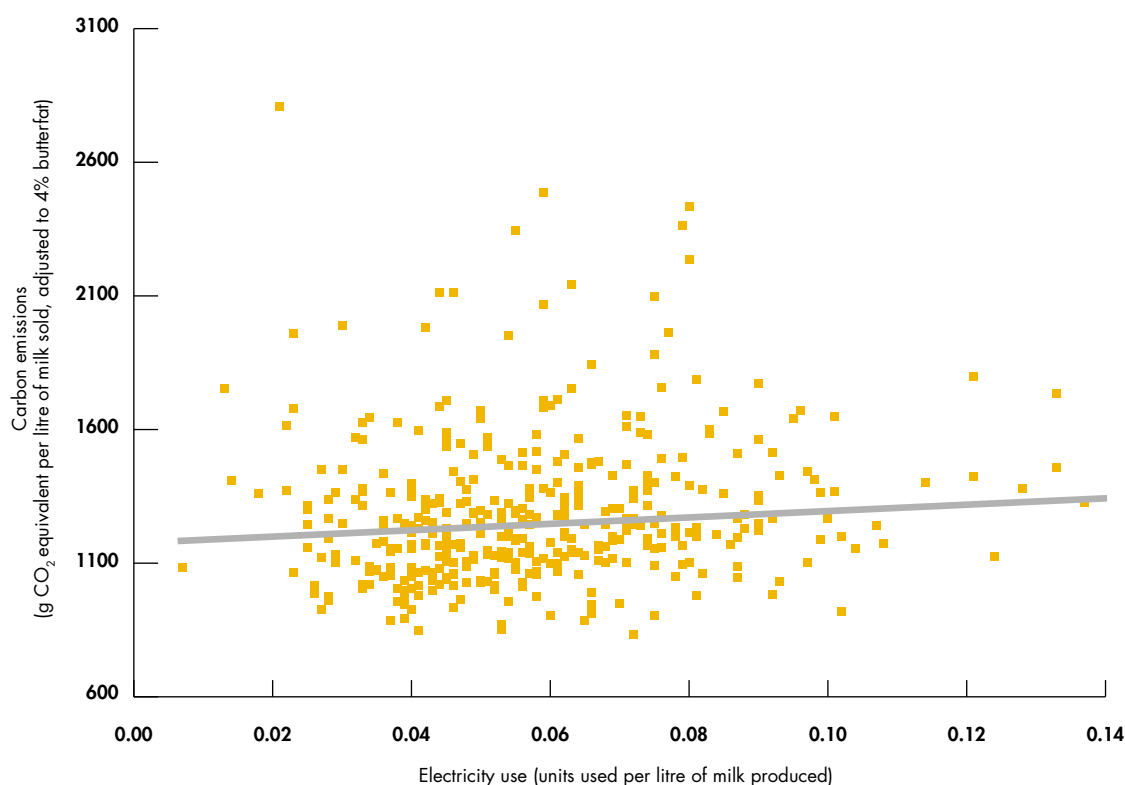
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Carbon footprint and electricity use

Figure 7 illustrates the relationship between units of electricity used per litre of milk and carbon footprint. Energy efficiency is a very small component of a farm carbon footprint but there are many cost-saving opportunities available to farmers that don't always need considerable capital investment.

The average consumption of electricity per unit of milk sold was 0.06KWH/litre, with a huge range in the data recorded. Within the sample of farms assessed, milking, milk cooling and plant washing were the areas that provided the greatest potential reductions.

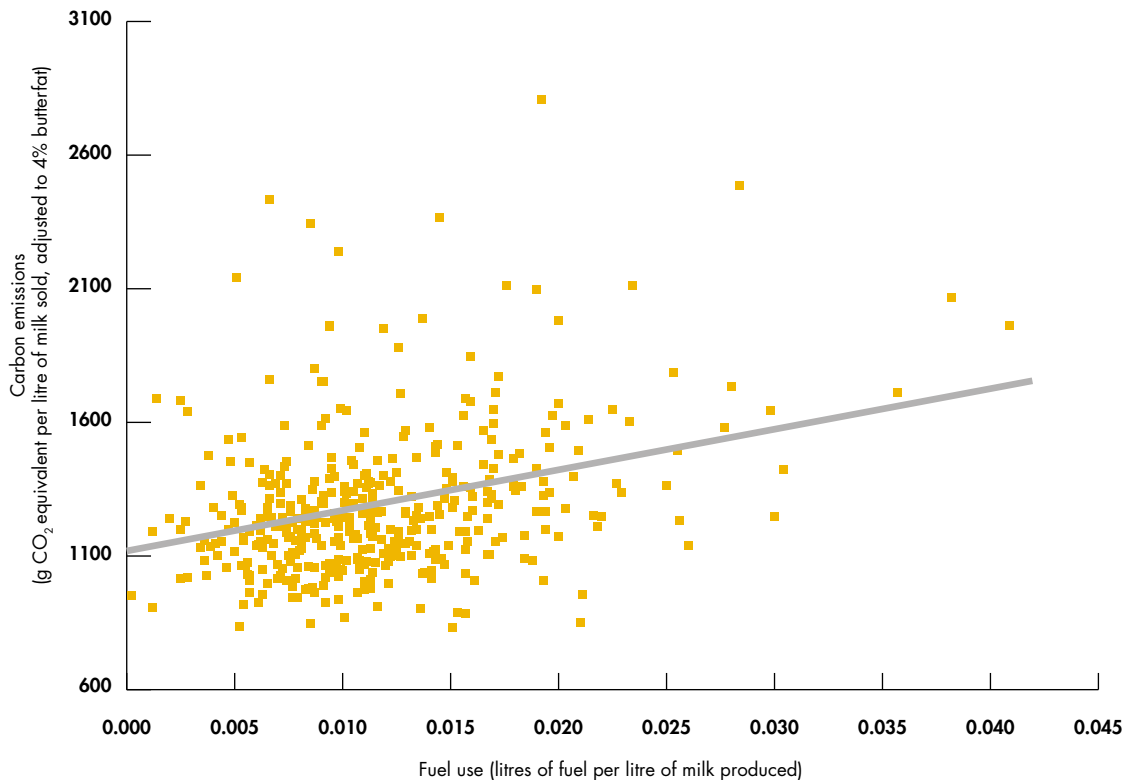
Figure 7 Electricity use and carbon footprint



Carbon footprint and fuel use

The data collected indicate that there are potential opportunities for carbon reductions by reducing fuel use by dairy farmers and contractors (Figure 8). Although on-farm fuel use comprises only 3% overall GHG emissions (Figure 2), reducing fuel use can provide worthwhile savings, particularly as prices continue to increase. Carbon emissions from fuel inputs for transport are much smaller than might be expected. Fuel used for transporting stock or purchased feed will affect the final carbon number by less than 1%, so this element of fuel use can be ignored under PAS 2050 methodology.

Figure 8 Fuel use and carbon footprint



International Dairy Federation compliant carbon footprint

The calculated IDF figure for the DairyCo data set is 1,327g CO₂e/l of fat and protein-corrected milk. This is also a weighted average figure.

Farmer reports

Participating farmers received a carbon footprint report, along with a simple NVZ (Nitrate Vulnerable Zones) report and summary of potential cost savings (in electricity and water usage) based on recommendations made during the on-farm assessment.

Discussion

The carbon footprint model applied by E-CO₂, took into account all inputs and variables used for the dairy enterprise.

All of the data were collected during on-farm visits by trained and approved assessors, providing confidence in the reliability and accuracy of the data collected. Statistical analyses of the data collected also lend weight to the robustness of the dataset produced.

The overall carbon footprint figure for GB milk production up to the farm gate, generated from first year data (1,309g CO₂e/l of fat corrected milk), is consistent with the results of a recent French study¹³. The latter reported a carbon footprint of 1200 to 1300g CO₂e/l, when carbon sequestration was excluded from the calculation. Net carbon footprint was reported to be 800 to 1200g CO₂e/l when estimated carbon sequestration was included. The figure produced from the E-CO₂ standard model was also comparable to that calculated using IDF methodology (1327 g CO₂e/l).

Although robust data have been collected in year 1, the addition of second and third year data will further strengthen confidence in this baseline. The intention, ultimately, is to produce a three-year rolling average carbon footprint which would allow for year-to-year variation due to seasonal effects, for example, on herd performance, levels of external inputs required and potential changes in disease status.

The largest contributors to carbon footprint were enteric emissions from rumen fermentation (40%) and concentrate feed use (26%). When correlated with farm carbon footprint as single variables, no one parameter (eg milk yield, fertiliser use, feed rate, or energy consumption) accounted for most of the variation between farms. The case studies included in Appendix 1 illustrate how elements of management can be brought together in different combinations to reduce the carbon cost of milk production.

Each participating farm received an individual report which contained the carbon footprint performance and identified key 'hot spots' which should be the focus of attention to bring about improvement. A sample farm report is given in Appendix 2.

Methane production is inherent to ruminant animals. However, the quantity of methane produced per litre of milk can be reduced by altering the type of diet fed, increasing feed conversion efficiency, reducing the proportion of followers and replacement animals required to sustain the milking herd and optimising milk or milk solids output within the production system chosen.

Technical or biological efficiencies can also be correlated with economic performance.

Energy use represents a relatively small proportion of overall carbon footprint. However, energy consumption is highly transparent, and any potential cost savings immediately apparent in reduced bills. For example, a 2,500,000 litre farm with 300 cows will use approximately 140,000 KWH of energy/year, at a financial cost of around £15,000 and emissions of 83,476kg of CO₂e from electricity (3.2% of the farm's footprint). If this electricity use was reduced to 125,000 KWH/year this would reduce the cost to £11,625 and lower the associated emissions to 74,961kg of CO₂e (2.8% of the farm's footprint).

Similarly, if the dairy unit above used 110 tonnes of Ammonium Nitrate (AN), this would contribute emissions of 314,310 CO₂e per annum, accounting for approximately 13% of the farm's carbon footprint, equivalent to a carbon score of 1,202gCO₂e/litre of milk produced. At £203/tonne, this would have resulted in a fertiliser cost of approximately £22,330. If, through better grassland management and more efficient use of home-produced manures and slurry, fertiliser input could be reduced to 95 tonnes, this would result in emissions of 271450 CO₂e, accounting for 11% of farm carbon footprint and a cost saving of over £3,000.

Carbon footprinting for agriculture is in its relative infancy and the science will continue to evolve. Currently, protein source is the subject of debate, particularly in the pig and poultry sectors. The UK dairy industry consumes very little soya (less than 1% of global supply). E-CO₂ is currently using the emission factor for soya as provided by the Carbon Trust's Footprint Expert™ in June 2011. PAS 2050 requires that the previous 20 years be taken into account when considering the impact of land use change. This typically involved varying levels of deforestation to clear land for agriculture. The standard also requires that when the

13 Dollé, S. B. and Baptiste, J. (2011) The carbon footprint at farm gate: main results on 400 dairy farms, identification of hotspots and technical solutions. Paper to the International Dairy Federation, World Dairy Summit, Parma, Italy, 13-19 October 2011.

location and land use status of agricultural land over those 20 years is not known, the worst-case scenario should be used. The emission factor for soya provided by Footprint Expert™ takes into account the worst-case assumption, based on the split in country of origin of general soya beans imported to the UK (eg 40% from Brazil). As better information becomes available on the total carbon burden of actual imports to the UK, it may be possible to move away from using these default factors.

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The scientific evidence provided to accurately quantify the carbon absorption potential of the soils or growing crops lacks the accuracy to be reliably incorporated into current models. If a consensus is formed from the scientific evidence and IPCC decides to support sequestration calculations in carbon footprint assessments, the E-CO₂ carbon footprint model does have the capacity to incorporate carbon sequestration.

Conclusions

The first year's results, from a robust sample of 415 dairy farms, show a considerable range in carbon footprint. This suggests that significant opportunities exist for most to reduce environmental impact and improve business efficiency. Some of the opportunities highlighted can be implemented on farm at little or no cost to dairy farmers.

The largest contributors to carbon footprint were enteric emissions from rumen fermentation (40%) and concentrate feed use (26%). When correlated with carbon footprint as single variables, no one parameter accounted for most of the variation between farms. Some relationships were stronger than others, although all were in the direction anticipated.

A key message from the data collected is that there is no single production system that appears to be more carbon efficient than any other. The data show that each farm should aim to run as efficiently as possible, within its chosen system of production and with the resources available.

This suggests that there are opportunities for most dairy farmers to improve, by targeting particular hotspots related to their farm. Depending on the circumstances, these could include some or most of the following:

- Increasing output (within the parameters of the production system)
- Optimising the utilisation of manure and slurry, particularly if reductions can also be achieved in the use of artificial fertilisers
- Improving feed conversion efficiency
- Reducing heifer wastage and herd replacement rate
- Calving well grown heifers between 22-24 months of age
- Reducing electricity and fuel consumption.

Some of the practices already occurring on British dairy farms are highlighted in the Case Studies in Appendix 1. Sources of further technical information, freely available from DairyCo to help levy payers improve production efficiency and reduce carbon footprint, are given in Appendix 3.

These first year data provide a useful baseline. As further data accumulate in years 2 and 3, the value of the data set will increase. This will enable more detailed statistical analyses to be conducted on the data set as a whole, in particular, to investigate more fully interrelationships between the different parameters contributing to carbon footprint. A case study approach will enable the impact of specific mitigation strategies to be calculated, using field data.

Carbon footprinting is still in its relative infancy. Further work is required to continue to develop the methodology and reduce the assumptions used to calculate farm carbon footprint. In particular, uncertainties over carbon sequestration and accounting for imported feeds need to be resolved, to increase credibility with farmers.

The dairy industry is at the forefront of GB agriculture in terms of tackling environmental impact. This is likely to continue as high quality, high welfare foods that reduce impact on the environment will remain high on consumer and Government agendas. The ultimate aim of the study is to develop a three-year rolling average carbon footprint figure, which will be produced at the end of the third year of the study. Each annual report will be beneficial in monitoring the dairy industry's progress towards achieving targets set by Government, Agricultural Industry's Greenhouse Gas Action Plan and the Dairy Roadmap.

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Appendix 1 – Case studies

D.

Case study 1: Kirkland Farm – Stewart Jamieson

Location

Thornhill, Dumfriesshire

Farm size

Total of 206 Ha (just over 500 Acres) consisting of annual forage crops and permanent and temporary grassland. The latter taking the form of five-year silage leys which are then followed with spring-sown peas and then winter triticale, in rotation.



Farm business

Kirkland Farm milks 200 organic Holstein cows supplying First Milk. These cows average 8,500 litres annual sales and are housed for approximately six months of the year in cubicles. All replacements are home-reared and sexed semen is used to maximise the number of heifers born on the farm. The farm is within an NVZ area.

The farm has two sets of farm buildings 0.5 mile apart. One site has accommodation for milkers and silage clamps, the other houses dry cows and replacement heifers. The farm business converted to organic in 2001 and is managed by two dairymen and one tractor man.

Current carbon footprint

1,006 grams of carbon dioxide equivalents per litre of milk.

Key areas of carbon and business efficiency – strengths

- **Managing grass for productivity without artificial nitrogen**

As an organic producer, Dr Jamieson uses no artificial fertiliser within the farming system. In a typical conventional system, this might contribute around 10-15% to the total farm carbon footprint. Lime is applied every 3 or 4 years. Grassland for silage is maintained and kept productive by incorporating a high proportion of Red Clover and reseeding a significant area of the farm (around 16ha/40acres) each year. Pasture with white clover is block grazed, so as to effectively use the available forage.



- **Yield above average**

The cows are producing yields above that of the national average for both conventional and organic dairy farms. Higher yields per animal will tend to lower the average carbon footprint per litre because the methane produced by the animal as part of its maintenance is 'diluted' over a greater number of litres produced. Further to this, where a set total volume is required, higher yielding cattle mean less stock need to be carried in the milking herd.

- **Feeding**

Wholecrop triticale makes up an integral part of the winter ration and buffer feed. Wholecrop is a lower fibre feedstuff than grass silage; this means less methane will be produced compared with grass silage. Wholecrop peas produce home-grown protein for the winter diet and leave N in the soil to benefit winter triticale. Organic concentrate and wheat are fed at around 0.28 kg/litre. These purchased organic feeds are expensive, so the use of home-grown forage, produced at lower cost, is maximised in the diet.

- **Cattle management**

As dry cows and heifers are managed on a separate farm site, care can be taken to ensure that these stock have the correct level of nutrition at key times. Heifers are managed to ensure calving at 24-27 months of age. Calving cows and heifers are moved to the milking site two weeks before calving. Good cow mobility is a key contributor to the high levels of performance achieved on this farm. Mobility scoring is carried out monthly. Foot bathing is completed twice a week in a copper sulphate solution and foot trimming is carried out by the dairymen. By having a proactive approach to foot care, replacement rates are kept down and production efficiency maintained. All cows are foot trimmed at drying off and heifers feet are examined 60-90 days post-calving.

- **Soil analysis and manure management**

Soil analysis is carried out routinely, with a third of the farm tested each year for N,P & K levels, pH and percentage soil organic matter content, to drive more effective soil management. Over winter, the majority of cows and youngstock are kept in cubicles, meaning slurry is the main nutrient available to be applied to land. This is spread either using contractors with an umbilical and dribble bar attachment, or a tanker with a splash plate. The dribble bar is a more effective way to spread slurry in terms of carbon efficiency as fewer nutrients are lost to the air than with a splash plate equivalent. This should mean the grass can take advantage of a greater proportion of nitrogen applied, and productivity can be maximised. Where possible, spreading is undertaken straight after silage is cut. Slurry is stored in a large tower and a lagoon. Together, these are capable of holding manure for the whole of the closed period, this, along with the nutrient planning requirement, helps to ensure the farm is NVZ compliant. When full, the stores have a potential value in terms of nutrient of over £15,000 at current prices.

- **Energy efficiency**

Though the carbon footprint of the electricity used by a dairy farm is quite small relative to other sources, the financial cost is often more significant. Kirkland Farm uses a Westfalia 20:20 herringbone parlour and, two years ago, the decision was made to install a variable speed vacuum motor. Dr Jamieson is feeling the benefits, with costs already recouped "within two years".



- **Planned changes**

Dr Jamieson thinks that his herd is beginning to become too extreme in Holstein characteristics and is looking to introduce genetics to produce a less angular, more robust cow. The main driver behind this is that he feels this type of cow would be better suited to the housing available at the farm and they would also have better locomotion. This should add greater weight and value to the calves produced that will not serve as herd replacements. Should the dairy bull calves be more appealing to beef finishers this would mean more of the farm's annual greenhouse gas emissions could be attributed to the beef calves produced than is currently the case. Cow longevity might also be improved from the current level of 25% replacement rate, meaning fewer replacements would need to be reared. Replacements are a necessity to maintain production but each heifer consumes feed and emits methane for at least two years prior to producing any milk. As such, an increase in the average number of lactations the cows achieve is more carbon efficient, when set against an increase in the number of heifers reared each year.

Case study 2: Kingston Hill Farm – David Christensen

Location

Kingston Bagpuize, Oxfordshire

Farm size

436 Ha (1,075 acres) comprising grassland and maize.

Farm business

Kingston Hill Farm milks 600 Holstein Friesian cattle supplying Milk Link. The cows are milked through a 60-point rotary milking parlour constructed in 2001. The cows average 8,700 litres of milk produced/cow/year. Cattle are grazed as one group from early March to early October. All replacements are home-reared on a dedicated site where they are overwintered in cubicles. The farm is wholly within an NVZ area on fairly light land with limited rainfall.

Current carbon footprint

886g CO₂e/l of milk produced. The carbon footprint of this farm is among the lowest within this study this year.

Key areas of efficiency – strengths

- **Nutrient management**

During the year assessed, only 40 tonnes of Urea and 50 tonnes of compound fertiliser were applied to the dairy production area (maize and grass), approximately half that of the average farm participating in the carbon footprint study. Considering almost 1,500 tonnes of farmyard manure (FYM) is exported off farm (in muck, under straw agreements), the reduced artificial fertiliser use is even more striking. Mr Christensen said, "Having a large herd of cattle, we will always have an equally large store of manure with which to fertilise the land. We also manage



the grassland quite extensively due to the climate being quite dry and also the autumn calving pattern. We cannot and do not look to produce high volumes of late-season grass. The nutrient requirement of the large area of maize we grow is largely met with slurry and home-produced manure. We also have an area of low input grasses in environmental stewardship agreements.” Where possible, best practice is observed with regard to slurry spreading whether this be by quick incorporation of manures and slurry (ideally within 6 hours of spreading but certainly within 24 hours) prior to maize establishment or spreading using a trailing shoe application method onto grassland. Grass reseeds are always accompanied by clover in the mix to optimise nitrogen use efficiency.

- **Feeding**

Winter feed is provided as a TMR comprising concentrate, rapeseed meal, feed wheat, wheatfeed, Trafford Gold and citrus pulp along with minerals and supplements. Using co-products as moist feeds from another industry, the carbon footprint is reduced because the feedstuff has already been used to produce human food and the primary product must accept the major proportion of the carbon cost involved in its production and processing.

- **Heifer rearing**

Historically, the herd produced replacements all year round but with the move to Autumn block calving, the farm is now managed so that cattle calve consistently at 24 months. This will have reduced the farm’s carbon footprint because, although this means using about 1,200kg of dried feed per calved heifer, the carbon cost of this feed is more than offset by earlier entry of the heifer into the milking herd. Kingston Hill Farm has recently been affected by TB breakdown so higher numbers of heifers are being reared to ensure enough replacements are available. This may increase the carbon footprint of the farm next year.

- **Yield above average**

The cattle are producing yields above that of the national average. Higher yields per animal will often mean less greenhouse gas emissions produced per litre. Methane emissions represent approximately 40% of the average farm carbon footprint across this study. Improving feed conversion efficiency reduces the production of methane so there is an environmental as well as economic benefit to improving the diets provided to dairy cows.



- **Recent changes**

Mr Christensen is very interested to see how the switch to autumn calving may affect the carbon footprint of the herd, going forward. He is keen to see whether the carbon footprint can be further improved, as he starts to master the challenges of managing an autumn calving herd.

- **Carbon weaknesses**

Although entirely out of the control of the farmer, the TB breakdown will increase carbon footprint, because of the higher requirement to replace the slaughtered animals. Each of the replacements carries an additional carbon cost to rear and the carbon credit attributed to cow beef produced from the dairy enterprise does not fully offset the effect of the reduced number of lactations. The other area of the audit where the farm may be able to improve would be to reduce fuel consumption. One reason for the high fuel use could be attributed to the large proportion of the farm dedicated to establishing and harvesting maize.

- **Why complete a carbon footprint?**

Mr Christensen felt that carbon footprinting could be regarded as a measure of efficiency, regardless of the environmental connotations. "Farmers should be made aware of the outputs they are generating and they should be proactively looking to reduce the inputs that are used in producing milk. Our benchmarking groups take an active interest in the carbon footprinting results and the differences observed between farms of a similar system. We also have a responsibility to act sensibly and prove that we are good custodians of the land and the environment. Carbon footprinting is one such measure of this."

Case study 3: Plas Uchaf – Einion Owen

Location

Llanfaethlu, Anglesey

Farm size

116 Ha (285 Acres). Made up of grass and maize within the time period assessed. The maize has since been replaced with wholecrop wheat. The farm comprises land owned (150 acres), tenanted (80 acres) and rented land. Soil type is predominantly clay loam.



Farm business

Mr Owen is assisted on the farm by his father and two full-time staff. Plas Uchaf currently milks 200 Holstein Friesians supplying Arla UK. The cows are milked through a 16:32 swing-over herringbone parlour. The cows produce an average of 9,000 litres/cow/year. Replacements are reared on a tenanted farm site and calving is all year round. Dairy is the primary business, although neighbouring sheep graze the pasture during winter on short-term agreements.

In recent years, the business has altered its operations in response to market forces and challenges to the business. Until three years ago, the farm operated a flying herd system but Mr Owen, in partnership with his father, decided to rear their own replacements in response to the high prices for replacement stock and the risk to biosecurity from bought-in disease.

Carbon footprint

1,091g CO₂e/l of milk produced.

Key areas of efficiency – strengths

- **Yield above average**

The cattle are producing yields above that of the national average. Higher yields per animal will tend to lower the average carbon footprint per litre because the methane produced by the cow as part of maintenance does not greatly increase as the yield per cow increases and so it is 'diluted' over a greater number of litres. Operating a high input, high output system has a significant impact on input costs. Buoyant grain and protein prices may mean that a more moderate system based upon home-grown forage may be pursued in the coming years.

- **Use of by-products from other sectors**

Poultry manure is locally available and has been imported for use on maize and wholecrop. By taking advantage of this waste stream from another sector, the farm is using a lower carbon nutrient option than purchased granular fertiliser.

- **Good feed conversion**

An average feed rate of around 0.33kg/litre indicates that the ration is being managed well in return for over 9,000 litres per cow. Also, heifers are calved at close to two years of age, using around 700kg of concentrate per head.

Weaknesses and planned changes

- **Forage crops**

Wholecrop has been a recent addition to the forage platform. The benefits of using such a crop are that stubble can be ploughed and grass reseeds established much earlier than would be the case if following forage maize. This is also important as maize aftermath can be vulnerable to soil erosion during wetter periods later in the year. Due to the high costs of inputs associated with the current system, Plas Uchaf is likely to move to a more home-produced forage-based diet



with a high proportion of milk generated from crops grown on the farm. This should insulate the farm a little from the high costs of purchased feed but there may be an associated reduction in milk yield. Mr Owen would like to aim for an autumn/winter calving herd, getting the cows back in calf and then maximising grass utilisation during the spring/summer. The soil type along with the open aspect of the farm does not lend itself well to the spring block calving system.

Mr Owen also highlights the need for improvements in slurry storage. Currently, the over ground tower store does not sufficiently cover the farm storage requirements over the winter period. The farm is not in an NVZ, but Mr Owen identifies that this area would be of environmental benefit to the farm in a number of ways. Currently contractors are employed to spread over winter using an umbilical system, causing a lot of damage to the soil structure. It also makes the tracks vulnerable to further erosion and has a detrimental effect on the quality of the pastures at turn-out in the spring. "If we had more storage we could time our slurry applications and use it in response to crop growth demand. It would make better use of the nutrients that we have in store and reduce our purchased fertiliser demand," Mr Owen said. The electricity use on farm appears a little higher than that of the average farm participating in this study. By investigating options for energy generation and opportunities for reductions in energy use, economic and carbon savings may be made.

Case study 4: Avon Farm – Hugh and Sally Rogers

Location

Chippenham, Wiltshire

Farm size

D. 90 Ha (around 220 Acres) Grass and Maize. Maize makes up about 40% of this area.

Farm business

Avon Farm occupies low lying, loamy soil over gravel adjacent to the River Avon and carries 100 Holstein cows plus replacements. The milk is supplied to Kraft via the Selkley Vale Milk Group. Avon farm also runs a small suckler cow herd, and 180 breeding ewes managed by Mrs Rogers. The farm relies largely on family labour, although there is a relief herdsman who milks five times a week.

Carbon footprint

1,199g CO₂e/l of milk produced.

Key areas of efficiency – strengths

- **Low emissions from feed**

At Avon Farm, great emphasis is placed on home-grown maize. Mr Rogers aims to make conserved maize the base for dairy cow rations throughout the year and at times this will make up two thirds of the mix in the tub feeder. This is then supplemented with beet pulp, soya, rape and distillers grains. Concentrate is also offered in the milking parlour. A high proportion of milk from home grown forage is a positive on a number of levels, not least as this helps to reduce the financial cost of purchased feed. The carbon cost of producing milk from a maize crop is less than concentrate. The consistency of quality within the maize clamp coupled with the high energy content is something that Mr Rogers feels is of benefit to the cows. Around 2.4 tonnes of purchased dried feed is used per cow per year, equivalent to 0.28kg/litre, fuelling yields of 8,600 litres/cow/year.



- **Good fertility**

Fertility is an area that has seen a great deal of time and investment in recent years. Aside from offering the high energy maize-based ration at key times of the year, a reproductive management system is used to provide an insight into cow fertility. The culling rate at Avon Farm is lower than average, in part because of good fertility, though as the herd size is being expanded some older cows are being kept on in the herd that historically may not have been retained.

Carbon weaknesses, future plans and changes

There are a number of ongoing and planned changes at Avon Farm.

The area which should improve the carbon footprint the most will be improved use of manure and slurry and an associated reduction in purchased fertiliser use. A processed poultry waste product 'Fibrophos' makes up a large proportion of the fertiliser applied. Fibrophos can be considered a lower carbon fertiliser, as it is a by-product of poultry production, reused as a fuel for power stations. NVZ regulations will mean the current weeping wall system, with the liquid fraction being applied by rain gun and the solid with a Shelbourne spreader, is no longer adequate. Mr Rogers plans to install a slurry separator to remove solids, which can be spread throughout the year and build a new slurry lagoon for the liquids to be sited on the farm. Contractors will then be employed to spread onto land using an umbilical system. These improvements should reduce the farm demand for bagged fertiliser and it is estimated that the farm carbon footprint may fall by approximately 5% through more efficient use of home-produced nitrogen and less nitrogen lost to the air, due to rain gun spreading.



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Though the farm boasts a three-year-old 168-place clear span cubicle shed with feed barriers to the sides, there are still some old buildings not ideally suited to modern milk production. These are mostly calf or heifer buildings that will double up as sheep housing at appropriate times of the year. The plan is to replace these older buildings with a purpose-built versatile shed. This should improve ventilation and allow for better management of youngstock.

Based on the costs of the dairy rations, a decision was taken to reduce the soya content within the mix; this was based solely on economic terms. As a result, the carbon footprint will also be reduced further, given that soya is a high carbon feedstuff.

A heat recovery unit has been investigated under a regional development agency scheme and installation should reduce the total electricity consumed by the farm at a time when energy costs are increasing sharply.



Finally, a school leaver apprentice is due to start work at the farm, and will take some responsibility for the dairy cattle. Staffing is always a key challenge to any farming business and the hope is that in the long term the apprentice will add to the strong family unit already in place.

Why did you have a carbon footprint on your farm?

Mr Rogers said, "We supply our milk to Kraft to produce chocolate under the Cadbury's brand. They are a very environmentally-minded company and the thought was that some of the milk supply group would take the plunge and see how much work was involved with regard to producing the figures and going through the process. We found that the member of staff who came to complete the assessment was both knowledgeable and efficient. We were happy that they were able to process the information accurately and

after the assessment was finished, there was the majority of the day left to carry on with the jobs at hand. Our experience was that farmers shouldn't be discouraged at the thought of the extra time and paperwork involved with carbon footprints as some of the information can help to inform decisions to make changes moving forward. It will also be interesting to see how the changes we will make to our farm to comply with NVZ regulations and general farm management will impact on future years' carbon footprints and the profitability of our farm business."

D. Case study 5: Glyn Crest Farm – Mike and Claire Colwell

Location

Redruth, Cornwall

Farm size

97 Ha (240 Acres) of grass

Farm business

Glyn Crest Farm is a tenanted farm with 10 years left to run of a 15-year tenancy. Mr Colwell milks 200 Pedigree Jersey cattle supplying close to a million litres (butterfat corrected) to Milk Link with the majority of the milk then sold on to Roddas Clotted Cream. The farm is running a spring block calving system with any late calvers being sold out of the system. The farm operates a simple grazing system supplemented with in-parlour feed-keeping machinery use down in favour of grazing the cattle. The soils are generally light and the topography flat or gently sloping southwards.

Carbon footprint

1,194g CO₂e/l of milk produced.

Key areas of efficiency – strengths

- **Grassland management and grazing**

Cows are typically at grass for eight months of the year. Having such a long grazing period means that there are positive effects in terms of carbon footprint reflected in elements of the footprint such as fuel use. This is about a third lower than the average farm of a similar size. Lucerne is another component of the shorter-term grass leys. As a legume, it is a nitrogen fixer and the deep root network means lucerne will remain productive in dry spells. The forage containing the lucerne/clover/grass mix is high in dietary protein and fibre. Mr Colwell says each element is an essential part of the sward and performs well in the changeable, sometimes droughty, conditions. The dry periods in summer often mean fertiliser application offers less than it might do in less dry regions; this is reflected in below-average fertiliser use.



Yearling heifers are outside for longer periods of the year and only receive purchased concentrate in their first year. The low use of concentrate at around 200kg per calved heifer will mean the heifers carry lower emission levels than in the average herd participating in this study. Heifers must calve down at two-years of age in order to maintain the tight calving pattern so the number of days of greenhouse gas emission prior to calving is reduced. The only dried feeds offered are concentrates in the 20:40 herringbone parlour at around 0.22kg/litre.

- **Health status**

A conscious effort is made to keep on top of herd health. The herd has been managed as a predominantly closed system and the key areas of mastitis and foot health have been tackled to the benefit of longevity and milk production. When cattle are bought, they are typically yearling heifers to allow them time to adapt to the conditions and disease challenges specific to the farm, prior to bulling and calving. The farm has been affected by TB breakdowns over the last few years and this has implications for the replacement rates, the pool of replacements available and the ability to sell out late calvers.

- **Manure storage**

Storage is more than adequate to cover the whole of the winter period. This allows the farm to apply slurries at the most effective times of year reducing fertiliser demand. Slurry is applied by a contractor with splash plate. It may be worth considering the use of a different application method such as trailing shoe, so that the nutrients are delivered to the base of the plant.

- **Energy efficiency**

The figures provided for the period covered by this carbon assessment indicated that the farm is using above the average levels of electricity per litre. Within the year, measures have been put in place to increase efficiency and save money. Vacuum on demand is one such installation which is saving “up to £1,500 per annum” according to Mr Colwell. A heat recovery unit has also been installed. Together, they will make a reduction in carbon footprint. Mr Colwell explained, “Our milk is sold for manufacture and perhaps the measure of carbon footprint on a per litre basis is not the most useful for our purposes. It may be better to measure kg carbon produced per kg of milk solids. It would be interesting to understand this, especially as about 50% of our county’s milk goes for manufacturing these days.”

- **Weaknesses**

The electricity use on Glyn Crest Farm is above average and it will be interesting to see if this is reduced by the energy saving measures being implemented in future. The herd is looking to expand by around 50 cows to closer to 250. The requirement to rear surplus replacements due to the risk of TB reactors being removed from the herd, will mean a greater number of followers being carried than the final culling rate might dictate. This may increase the size of the carbon footprint until a maintenance level of youngstock is reached. Any cattle that are sold to produce milk on other farms offer a carbon credit to the business, as do cows culled for beef, although the carbon credit is not as great.



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- **Future changes**

The farm is considering a medium scale wind turbine installation of around 11KW in size. This should go some way to meeting the needs of the dairy while also providing a guaranteed income stream for the life of the installation by supplying electricity to the National Grid. The farm will reduce its reliance on power from the National Grid, and will also reduce its carbon footprint.

D. Case study 6: S J Walker (Farmer) and Evolution Farming (Oliver Hall and Tom Rawson, Management Consultants)

Location

Dronfield, Sheffield

Farm size

225 Ha (555 Acres) of grassland

Farm business

Bowshaw Farm milks 300 Holstein Friesian cattle supplying milk to Arla on an Asda contract with replacements part home-reared and part-purchased.



The farm is located on the South Sheffield/ Derbyshire border on heavy soils, with high rainfall ideally suited to grass growth. The absolute minimum amount of machinery is owned, with contractors being used for the slurry, foraging and reseeding operations. The farm is within an NVZ area.

Current carbon footprint

1,246g CO₂e/l of milk produced.

Key areas of efficiency – strengths

- **Grassland management**

Evolution Farming consultant, Oliver Hall, identifies grassland management as a key area. The aim is always to produce quality over quantity and the M.E. average across all cuts should exceed 11.5MJ/kg. High energy forage will result in smaller volumes of methane being emitted by each cow. Also, by producing quality grass silage, a greater proportion of the milk can be generated from this grass, reducing the need for high volumes of purchased feeds to push yields up.

- **Electrical efficiency**

Comparing the electricity use of this farm to that of the average shows that the power used per litre is among the very lowest. Around 0.03 Kilowatt Hours (KWH) are used per litre of milk sold. The average is closer to 0.05KWH per litre produced, meaning a carbon saving of around 30 tonnes per year compared to the average farm. In business management terms, the other positive of the electricity management on the farm is that nearly 60% of the total use is recorded on the night rate meaning the costs are reduced to a minimum. This can be attributed to good attention to detail in managing time clocks, heating water and timing of milkings.

- **Reduction in machinery capital costs**

The business model at Bowshaw aims to minimise the amount of machinery owned and maintained by the farm. This means an almost total reliance on contractors. The thought behind this is that

larger, faster, more fuel efficient and, ultimately, expensive machinery would only be considered by contractors, therefore offsetting the economic and carbon costs. It also means that there is not machinery lying idle for proportions of the year.

- **Heifers managed to calve at two years of age**

Those heifers that are reared on the farm are managed to calve as close to two-years of age as possible. This reduces the number of days to calving and, with it, the emissions produced prior to the first lactation for each heifer reared.



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- **Using feed by products**

Bowshaw Farm uses Brewers Grains and, as these have already been used once in the brewing industry, up to 90% of the carbon cost to produce the grain can be attributed to the beer produced, leaving much less to be allocated to the farm.

- **Carbon weaknesses**

One area which appears to stand out is the replacement rate at around 30%. This is, in part, down to the fact that the majority of the cattle purchased are third or fourth lactation cows and, as such, raise the average age of the herd. This is an element of the business which may well change in future years, with a contract rearing system being considered to supply the farm with herd replacements.

- **Fertiliser use is above average**

Ammonium Nitrate is the only product used on the dairy supporting area. The tonnage used indicates an average of 160kg of N per Ha (64kg per acre) is supplied from artificial fertiliser across the total land allocated to the dairy. Fertiliser is both an economic and carbon costly product and so can have a big effect on the carbon footprint of a business,



therefore reinforcing the importance of using manures and slurry as efficiently as possible. The slurry lagoon is allowed to crust which reduces the greenhouse gas emissions to air. The slurry is spread by contractors using a splash plate. It may be worth considering other methods of slurry application so that the slurry is applied at the base of the plant. If the slurry is applied according to crop demand, it may be possible to reduce the amount of bagged fertiliser required. "Next year we are planning to use a contractor with access to a trailing shoe and we are interested to see how this may reduce our fertiliser costs and effect our grazing management following the spreading of slurry," said Mr Hall.

- **Why complete a carbon footprint?**

Mr Hall felt that, in completing and compiling information for the assessment, it provided a good opportunity to review the inputs used on farm. It also provided an excellent opportunity to spend some time away from the normal day-to-day challenges to look at the bigger picture and analyse the factors which may generally have less attention. For example, whether heaters and coolers are set up in the most efficient manner or time clocks are set to the correct time.



Appendix 2 – Example carbon footprint report

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The E-CO₂ Project

Example Carbon Footprint Report

**“increasing your profit and protecting the
environment”**

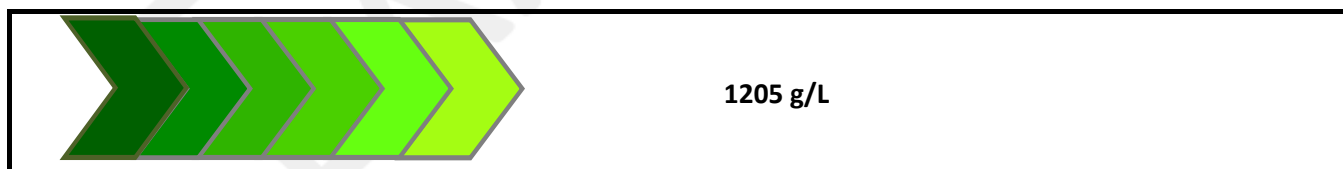
Carbon footprinting for the dairy sector

A carbon footprint refers to the emission of three major greenhouse gases (GHG) produced in agriculture. These are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). As these gases have different potencies they are all factored down into a carbon dioxide equivalent (CO₂e) figure to give a simple total. This total of the carbon equivalent emissions is divided by the litres of milk produced during the year analysed to give the dairy enterprise's footprint. The carbon emissions are the greenhouse gases released by farming operations relative to the dairy enterprise during the year analysed.

The UK obligation to reduce the carbon footprint of agriculture is set at a reduction of emissions by 11% compared to the 2008 level by 2020. As an industry, agriculture is also part of the UK Low Carbon Transition Plan which is a key driver in the overall UK emission reduction.

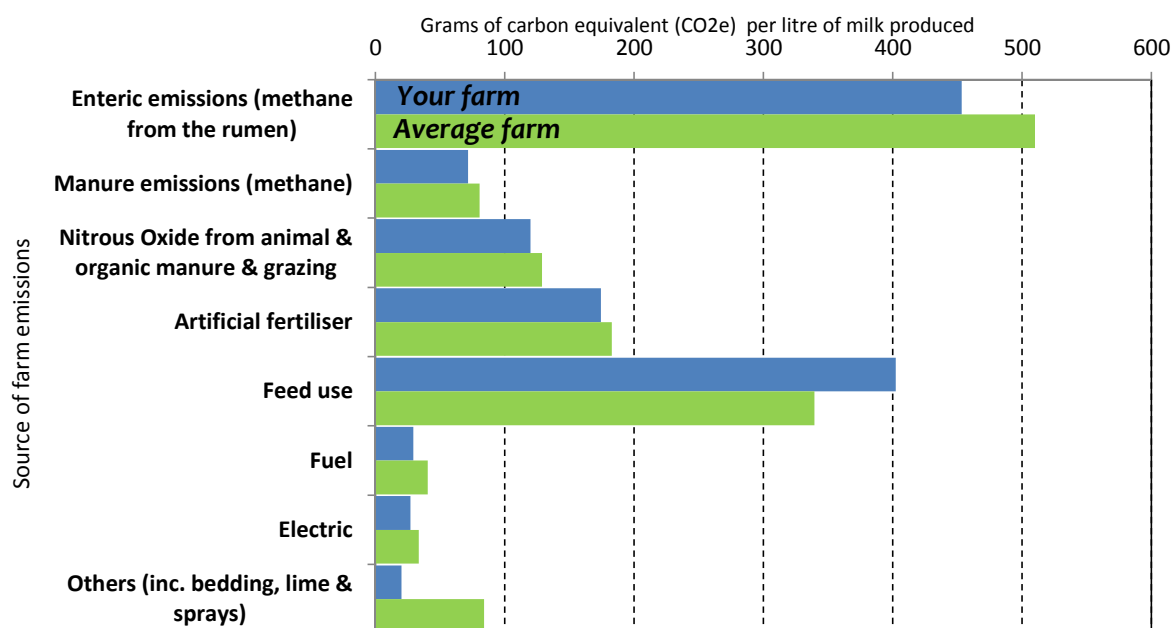
Your Farm's Carbon Performance

All results refer back to 'grams of carbon' per litre of milk produced on the farm during the year analysed.



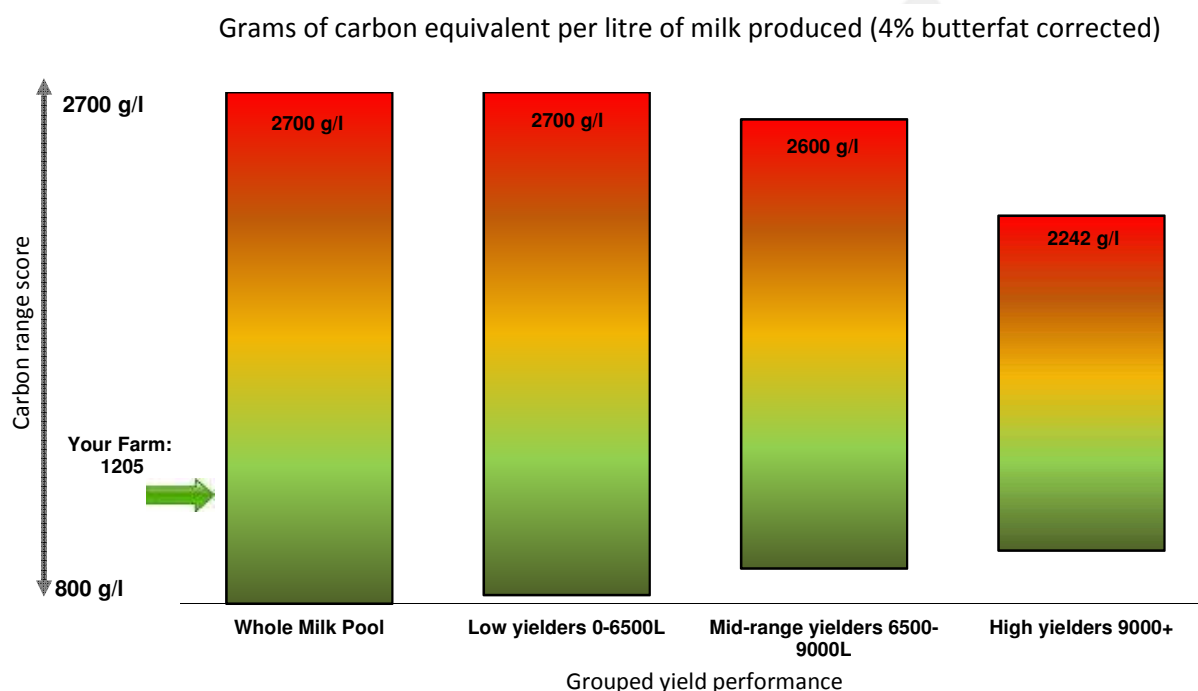
Your farm's carbon footprint result is presented above on a colour coded scale. The sliding scale represents the milk pools range, green colours for the lowest carbon results and red for the highest carbon results. Your farm's result is represented by the coloured arrow and the figure presented.

Your Farm Emissions by Source



This graph displays all of the farm emissions and the sources they come from. This is divided then by the number of litres produced to present a measure which can be compared from farm to farm regardless of farm size.

Farm Carbon Details



Carbon Comments

The carbon footprint of the dairy business is below the rolling average. Since our last visit, your milk yield per cow has increased, which has helped your carbon number as higher yielding cows produce less methane per litre than lower yielding cows. Your feed conversion has improved and is very efficient showing you are getting good milk returns for the amount of feed used. Feeding soya to the dairy cows is pushing up your carbon number as the emissions associated with soya are very carbon intensive and is having a negative impact on your footprint. The heifers number have decreased which has helped your methane emissions, but to reduce the emissions further consider calving your heifers closer to 24 months, which would be a real positive as they would be producing milk sooner and therefore less methane is produced during rearing when they are consuming just inputs. Your cull rate for the year has increased and this maybe due to mastitis. Fuel, electric and fertiliser used on farm are all being used efficiently, which has helped your footprint.

Carbon Strengths of Your System

- > High milk yield per cow.
- > Good feed conversion.
- > Efficient electric and fuel usage.
- > Fertiliser consumption below the average.

Reduction Opportunities Within Your System

- > Heifers calving later than 24 months.
- > Feeding soya to dairy cows.
- > High cull rate (maybe due to mastitis).

Previous Carbon Assessment Results

Period viewed

31/03/2009 - 30/03/2010

Resources	Total used	Total cost (£)	Cost per litre (£)	Cost per cow (£)
Electric used (KWH)	21,441	2,037	0.0024	19.40
Red diesel used (Litres)	4,052	1,945	0.0023	18.52
Mains water used (m ₃)	3,278	3,442	0.0040	32.78

Livestock

	Total used	
Total number of cows	105	head
Total heifers on farm	92	head
Milk sold	857,509	litres
Yield per cow	8,167	litres
Calving rate	83	%
Culling rate	29	%
Average feed rate *	0.39	kg/ L

*(Concentrates and straights fed)

Cropping

		Total	Total per Ha	Total per cow
Dairy area	Ha	130	N/A	1.23
Total tonnes of fertiliser	tonnes	51	0.39	0.48
Kg of N applied	Kg	13,430		
Kg of P applied	Kg	1,406		
Kg of K applied	Kg	2,480		

Carbon footprint

Total emissions from farm	1,099	tonnes of carbon equivalent
Emissions per cow	10	tonnes per cow
Emissions per hectare	8	tonnes per hectare
	1,244	grams of carbon emissions per litre of milk

Previous carbon footprint assessment results

1,244

Grams of carbon per litre of milk

Carbon footprinting is a field which is still in its infancy. Subsequent to your previous visit by the E-CO₂ project the carbon model calculator has been subject to many changes, mainly concerning improved emission factors being employed where the science has been developed or research has taken place. As a result it is no surprise to see changes between the reported carbon number subsequent to our last visit and the number re-delivered on the latest model. As a responsible industry we should look to always improve our tools to give accurate data, both for starting numbers and current figures.

After now having multiple visits, it is possible to compare the differing sets of results. Rolling averages are often preferable to single year analyses because they start to take out some of the financial and climatic influences which can have a great impact upon single year carbon numbers, these being factors outside of the farmer's control. Ensuring we try to isolate these other pressures will mean targets for emissions reduction will be accurate and attainable whilst demonstrating that we are taking our obligations for environmental improvement seriously.

Recent Carbon Assessment Results

Period viewed

01/04/2010 - 31/03/2011

Resources	Total used	Total cost (£)	Cost per litre (£)	Cost per cow (£)
Electric used (KWH)	42,306	4,273	0.0045	42.73
Red diesel used (Litres)	7,800	4,680	0.0050	46.80
Mains water used (m ₃)	3,356	4,564	0.0048	45.64

Livestock

	Total used	
Total number of cows	100	head
Total heifers on farm	75	head
Milk sold	941,874	litres
Yield per cow	9,419	litres
Calving rate	88	%
Culling rate	35	%
Average feed rate *	0.27	kg/ L

*(Concentrates and straights fed)

Cropping

		Total	Total per Ha	Total per cow
Dairy area	Ha	96	N/A	0.96
Total tonnes of fertiliser	tonnes	37	0.38	0.37
Kg of N applied	Kg	11,769		
Kg of P applied	Kg	828		
Kg of K applied	Kg	1,200		

Carbon footprint

Total emissions from farm		1,138	tonnes of carbon equivalent
Emissions per cow		11	tonnes per cow
Emissions per hectare		12	tonnes per hectare
		1,205	Grams of carbon emissions per litre of milk

Previous assessment data on latest model	1,244	Grams of carbon emissions per litre of milk
Recent carbon footprint assessment results	1,205	Grams of carbon emissions per litre of milk

E-CO₂ Project Best Practice Guidelines

A series of best practice guidelines have been developed that are linked to reducing the carbon footprint of a dairy farm. These are simple measures which should also increase the efficiency of your farm, these can be applied across all farming types and are irrelevant to herd size.

Key sources of greenhouse gas emissions on farm:

Methane (CH ₄)	Carbon dioxide (CO ₂)	Nitrous oxide (N ₂ O)
>Enteric emissions	> Machinery usage	>Muck and slurry storage
>Emissions from manure	>Dairy equipment use	>Inorganic fertilisers
	>Feed use	>Ploughed/disturbed soils

The text below explains the opportunities that can be taken to reduce the three major greenhouse gasses.

Reduce methane by

1) Herd health planning

By improving the health and welfare of cows more milk will be produced, which reduces production of methane per litre. Further to this; healthy cows will tend to live longer, reducing culling rates and helping keep replacement rates low. Productivity can be maximised by:

Improving fertility:

- Concentrating on heat detection to avoid lengthening calving interval
- Prevention of milk fever and calving problems
- Feeding cows to minimise weight loss after calving and maintain body condition during lactation

Reducing lameness:

- Improved accommodation
- The best foot trimming and foot bathing
- Avoidance of acidosis

Reducing mastitis

- Hygiene
- Identification and treatment
- Fly control
- Record keeping of incidence
- Milking machine maintenance
- Isolation where necessary

2) Optimising milk yields

The main source of methane in agriculture is from intestinal fermentation in ruminants. On average, dairy cows each produce around 100 kg methane/year and this figure is not greatly affected by yield. So more milk per cow = less methane per litre. Furthermore, if stable production is required, higher yields per cow mean that fewer cows are needed.

- Get heifers to calving condition by 24-26 months
- Provide quality palatable forage
- Maximize dry matter intake

3) Feed low carbon by-products which have a low carbon cost as the primary consumer must bear most of the carbon cost of producing and processing these products. E.g. brewers grains, bread waste or super grains.

4) Lowering the pH of the slurry can reduce methane emissions. This can be carried out by using slurry bugs which can also help reduce losses of nitrogen on application. Slurry and manure stored outdoors will have produced less greenhouse gas emissions than slurry stored indoors due to lower temperatures.

5) Reduce heifer rearing period to 24-26 months.

Rearing a heifer to thirty months old on a conventional silage and cake system creates a carbon footprint greater than when they are calved earlier as the process takes longer and so more days of methane emitted. The carbon footprint associated with the rearing period will therefore be significantly reduced if this were to become the norm. Calving younger can also make economic sense.

Reduce nitrous oxide by

1) Prudent use of artificial nitrogen and making better use of slurry and manure. Matching supply to crop demand is a key aspect of this.

2) Make more use of legume crops

Legumes such as clover reduce the need for additional nitrogen application and consequently provide an effective way of reducing nitrous oxide emissions.

3) Management of dietary protein levels can influence nitrous oxide emissions. If excess protein is fed then this is excreted as urea and adds to the greenhouse gas burden of dairy production.

Reduce carbon dioxide by

1) Make sure dairy equipment is running as it should, that time clocks are used where appropriate and that equipment is switched off at the socket when not in use.

2) Regularly servicing engines will reduce your fuel consumption by up to 15%, ensuring that suitable machinery is selected for each relevant job which will also reduce fuel consumption.

3) Use alternative energy sources where possible such as:

- solar power
- heat pumps
- straw-burning boilers
- biogas from manure digestion
- wind power
- hydro-electric power

➤ Your Farm Energy Savings Report



Potential Savings

Section	Details	Saving	
Lighting	Switch off lights in unoccupied areas	£	-
	Switch to energy efficient lighting throughout the site	£	-
	Switch off lighting during daylight hours	£	-
	A time clock would pay for itself in 0 years		
	Fitting Motion Detectors to control lights	£	-
Heating	Fitting a time clock on the heating system	£	-
Milking, Cooling & Washing	Insulate hot water cylinders	£	-
	Fitting a time clock	£	-
	Correctly fitting a time clock	£	47.27
	A time clock would pay for itself in 0 years		
	Recovering water from the plate heat exchanger	£	-
	Changing to an automated switch	£	-
	Improving Milk Cooling	£	405.00
	Fitting a plate heat exchanger	£	-
Vacuum Pumps & Compressed Air	Reducing the running time of the compressor	£	-
	Reducing the pressure of the compressor	£	-
Rainwater	Collecting/reusing rainwater could save up to	£	-
Utilities	Reviewing your suppliers could generate significant savings, particularly if you're on a single rate supply.		

General Comments

Conventional lighting in cow sheds and feed area, consider energy saving options. Correct the time clock to the hot water cylinder so hot water is produced at the correct time of day.

➤ Your Farm Nutrients Report



Our basic NVZ package gives an 'at a glance' picture of the main challenges the farm faces with regards to the new regulations. This is intended as a guideline only and does not fulfil the required accuracy of the legislation

Estimated slurry store volume

1,722 m³

The approximate potential value of nutrients stored in the farms slurry store assuming 6% dry matter is:

£8,438

(not all of this will be crop available, applying this at the correct time of year maximises its utilisation)

'Home produced' N

13527 Kg / Year

Imported N

0 Kg / Year

Exported N

0 Kg / Year

FARM SIZE

128 Ha

N Loading in Last Year

106 Kg/ N per Hectare

N capacity*

21760 Kg N

*without grassland derogation (where appropriate)

Comments

Maintenance and calibration of spreaders is essential to achieve the desired spread pattern and therefore use fertilizer efficiently. A well maintained spreader will lead to more even and productive crops.

Control the use of Phosphate & Potash fertilizers as well as the use of slurries and manures, so that the levels of nutrient do not build excessively. Excess soil nutrient can lead to animal health problems, by locking up others essential to an animals well being.

It is essential that records are kept of all applications that are made to fields, not doing so could mean compliance is not being met. This could have an effect on your single farm payment. Ensure an accurate field recording system is being used.

Numerous factors, beyond the scope of this report influence individual results, E-CO2 cannot accept any responsibility for the information supplied. E-CO2 have taken every care to formulate this report to be accurate and does not accept any liability for any loss arising from any defect in the report.

Appendix 3 – Sources of additional information

D. DairyCo offers a wide variety of services and tools to British dairy farmers. A series of + programmes provide technical information on specific areas of milk production and can be downloaded from the Farming Information Centre or Library section of the DairyCo website (www.dairyco.org.uk/farming-info-centre). Alternatively, you can contact your local DairyCo extension officer, who is your first point of contact on technical dairying topics.

A selection of currently available of DairyCo publications and tools, relevant to improving production efficiency and reducing carbon footprint, is listed below:

- Grass+
- Feeding+
- Strategies to reduce culling and culling calculator
- Heifer rearing options factsheet and rearing cost calculator
- Energy efficiency on farm – a practical guide
- Energy use calculators – web-based
- Effective use of water on dairy farms
- Muck and slurry on clover swards
- Cost-effective slurry storage strategies on dairy farms
- Breeding briefs
- DairyCo Mastitis Control Plan
- DairyCo Healthy Feet Programme
- Factsheet series on efficient milk production and climate change.

Appendix 4 - Glossary

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- **Atmospheric deposition**

Transfer of substances from the air to the surface of the earth, either in a dry form through gases and particles or a wet form in rain, snow and fog. Within agriculture, it should be considered from all sources of additional N-load on soils and from manure storage.

- **Carbon footprint**

The total set of GHG emissions caused directly and indirectly by an individual, organisation, event or product.

- **Carbon Dioxide Equivalents (CO₂e)**

CO₂e is a standard unit for measuring carbon footprint and describes for a particular greenhouse gas the quantity of carbon dioxide that would have the same global warming potential, calculations are based on the global warming potential of each greenhouse gas.

- **Correlation**

A statistical measurement of the relationship between two variables. Possible correlations range from +1 to -1. A zero correlation indicates that there is no relationship between the variables. A correlation of -1 indicates a perfect negative correlation, meaning that as one variable goes up, the other goes down. A correlation of +1 indicates a perfect positive correlation, meaning that both variables move in the same direction together.

- **Distribution**

An order or pattern formed by the tendency of a sufficiently large number of observations to group around a central value. The familiar bell-shaped curve is an example of normal distribution in which the largest number of observations is distributed in the centre, with progressively fewer observations falling evenly on either side of the centre (average) line. See also frequency distribution, normal distribution and standard deviation.

- **Economic allocation**

Once the total carbon footprint of the dairy operation has been calculated, it is divided between products and co-products based on their relative value at the farm gate. For example, if 80% of annual farm revenue comes from milk then milk takes on 80% of the farm footprint.

- **Enteric fermentation**

The process in which microbes resident in the ruminant digestive system ferment the feed consumed. A by-product of this process is methane which is emitted from the animal and results in lost energy.

- **Feed conversion efficiency (FCE)**

Calculated by dividing daily milk yield by daily dry matter intake. The FCE demonstrates how well the animal is utilising one kilogramme of feed so that farmers can see where improvements can be made.

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- **Greenhouse Gases (GHG)**

Gaseous constituents of the atmosphere that occur from natural processes and human activities. These gases emit and absorb heat and are said to be contributing to the warming of annual global temperatures. The principal greenhouse gases that enter the atmosphere as a result of human activity are carbon dioxide, methane and nitrous oxide.

- **Global Warming Potential (GWP)**

A measure of how much a given mass of GHG is estimated to contribute to global warming. It is a relative scale which compares the gas in question to that of the same mass of CO₂ (whose GWP is by convention equal to 1 when considered over a 100-year period).

- **Life Cycle GHG Emissions**

Sum of greenhouse gas emissions resulting from all stages of the life cycle of a product and within the specified system boundaries of the product.

- **Mean**

The most commonly used form of statistical average. It is calculated by finding the total sum of the data set and dividing this by the amount of data. This gives an indication of the average number of the dataset. The advantage of using the mean is that it minimises the error within the given average. The mean, however, is not always the best form of average to use, as it can be easily affected by anomalies within the data set. Weighted mean – is an average in which each quantity to be averaged is assigned a weight. These weightings determine the relative importance of each quantity on the average.

- **Median**

The middle number (in a sorted list of numbers). To obtain the median, place a dataset in value order and find the middle number.

- **Mode**

The value that occurs most often. If no number is repeated, there is no mode.

- **Range**

The difference between the largest and smaller number in a dataset.

- **Skewness**

The degree to which a statistical distribution is not in balance around the mean (is asymmetrical or lopsided). A perfectly symmetrical distribution has a value of 0. Distributions with extreme values (outliers) above the mean have positive skew and the distributions with outliers below the mean have negative skew.

- **Standard deviation**

A measure of the dispersion of a set of data from its mean. The more diverse the spread of data, the higher the deviation from the mean. Standard deviation is calculated as the square root of variance.

- **Standard error**

The estimated standard deviation or measure of variability in the sampling distribution of a statistic. A low standard error means there is relatively less spread in the sampling distribution. The standard error indicates the likely accuracy of the sample mean as compared with the population mean. The standard error decreases as the sample size increases and approaches the size of the population.

- **System expansion**

System expansion involves the consideration of other product systems as well as milk production. For example, the production of one dairy calf may result in a beef calf not being grown for the beef production. If this relationship holds true then we can say that a beef calf has been offset by the production of a dairy calf. As a result, the burdens associated with the production of a beef calf can be subtracted from the carbon footprint of the dairy farm.

- **Variable**

A characteristic, number, or quantity that increases or decreases over time or takes different values in different situations. There are two basic types, which are (1) Independent variable: that can take different values and can cause corresponding changes in other variables, (2) Dependent variable: that can take different values only in response to an independent variable.

D.

Disclaimer

D. While the Agriculture and Horticulture Development Board, operating through its DairyCo division, seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law, the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

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February 2012

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