Greenhouse gas emissions on British dairy farms

DairyCo carbon footprinting study: Year Two (2011-2012)

May 2013

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Foreword

Agriculture will play a key role in combatting three of the greatest challenges of the 21st century – achieving food security, adapting to climate change, and mitigating climate change. As we face these challenges there is greater competition for land and resources. Sustainable agriculture simultaneously increases production and income, adapts to climate change and reduces Greenhouse Gas (GHG) emissions, while balancing crop, livestock, fisheries and agroforestry systems within a thriving rural community.

Published in 2006, The Food and Agriculture Organization report 'Livestock's Long Shadow' demonstrated the first ever global estimate of the livestock sector's contribution to GHG emissions. The study estimated that the agricultural sector accounts for around 18% of total anthropogenic emissions. This figure of 18% was inclusive of the entire livestock food chain which includes all farming sectors. Inevitably most of the emissions became associated with the ruminant sector and in particular the dairy and beef industry within the developed world. UK research at National Inventory level suggests that agriculture accounts for 9% of the UK economy's emissions.

Agriculture is currently under great pressure to increase productivity sustainably whilst reducing greenhouse gas emissions. A triple win solution is needed which will see agriculture achieve food security, increase productivity sustainably and reduce GHG emissions.

Acknowledgements

DairyCo and the E-CO_2 Project would like to thank all of the organisations and individuals who have participated in this study including those listed below:

- All participating dairy farmers
- Arla Foods UK
- Belton Cheese
- Cropwell Bishop Creamery
- First Milk
- Milk Link
- Müller Wiseman Dairies
- OMSCo
- A number of independent farms – these include suppliers of Ashley Chase, Barbers Maryland Cheese, Dairy Crest, Freshways, Glanbia, Kraft Foods, Lactalis, R Grahams, The Fresh Milk Company, and Marks & Spencer.

Executive summary

Work completed in the first DairyCo Project ‘Greenhouse gas emissions on British dairy farms’ published in February 2012 showed a considerable range in carbon footprint. The range demonstrates that a significant number of opportunities exist to reduce emissions and increase business efficiency.

A key message from the data collected in year one was that no particular production system was more carbon efficient than any other.

This was again supported by the analysis of milk production, feed conversion, manure utilisation, synthetic nitrogen applications, stock replacement rate, and electricity and fuel consumption (i.e. the ‘key’ efficiency measures) compared to the carbon footprints of 415 farms in year two. Carbon efficiency was found to be driven by using resources available as efficiently as possible within a given system. Three hundred and forty eight (348) of the original farms from year one participated in year two of this study and 67 ‘replacement farms’ joined to maintain a total group of 415. The average carbon footprint of the 415 farms assessed in year two using the Carbon Trust certified E-CO_2 model is 1,227 g CO_2e/litre (as calculated on a weighted mean basis); this represents a 5.4% decrease from year one.

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Agriculture, the environment and climate change

Carbon foot printing on British dairy farms

The UK government's targets as set under the Climate Change Act 2008 are to cut GHG emissions by 80% of 1990 levels across the UK economy by 2050. The UK economy also has a short term aim of reducing its emissions by at least 30% by 2020.

Defra has set the agriculture sector an interim target to reduce its contribution to GHGs by 11% by 2020 based on 2008 figures, the scale of the challenge for the dairy industry should not be underestimated. The targets set by the UK government cannot be effectively met without addressing the emissions from the agricultural sectors.

Around the world there is increasing demand from governments and consumers for information about the environmental impact of certain products, in particular the greenhouse gas emissions (GHG).

Agriculture will need to demonstrate a reduction in GHG emissions based on robust evidence collected. Collecting on farm data to form a benchmark will be the first phase of demonstrating the reduction of associated emissions.

The dairy industry must continue to reduce the quantity of inputs needed to maintain the same level or an increased level of output at the same time as maintaining or enhancing quality of outputs. The dairy sector is working towards meeting the challenge with many farmers actively engaging in this, and similar projects.

At a farm level, this project has been able to disseminate the findings to farmers clearly, about how they can help to meet these tough environmental targets. This report and the previous report drives home the message that improving production efficiency and reducing carbon emissions do go hand in hand.

The calculation of a farm's carbon footprint focuses on one environmental indicator. Future studies may focus on other indicators such as water use and biodiversity to quantify wider environmental impacts of production.

How is a carbon footprint calculated?

A carbon footprint is the total amount of greenhouse gas emissions caused directly or indirectly by an individual, organisation event or product.

A carbon footprint quantifies the total of GHG emissions associated with a product, along its supply-chain and sometimes includes emissions from consumption, end-of-life recovery and disposal. It is usually expressed in grams or kilograms of carbon dioxide equivalent (CO_2e).

The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O); the product carbon footprint (in this case milk) is calculated as the sum of emissions from production up to the farm gate.

The carbon footprint model takes into account all significant inputs and variables used for the dairy enterprise only. Carbon footprint models use Intergovernmental Panel on Climate Change (IPCC) 2006 and PAS 2050 methodology to measure the greenhouse gases emitted during the life cycle of the product. The GHG emissions are expressed in terms of carbon dioxide equivalents by using the latest IPCC 100 year global warming potential (GWP) coefficients as specified within PAS 2050.

The calculation of a dairy enterprise's carbon footprint allows the identification of GHG emissions from cradle to the farm gate and does not include any transport from the farm gate onwards, retailer or consumer impacts, this is the approach used in this study.

National Inventory/National reporting of figures
Currently the UK has to report its GHG emissions annually as part of its commitments to the international Kyoto Agreement. These figures reported for agriculture include nitrous oxide (N_2O) and methane (CH_4) and carbon dioxide (CO_2) largely generated from national inventory figures.

These figures are estimations and do not include any methods for comparing differing systems, bought in feed products or for any form of seasonality. Collecting data at a farm level to calculate a robust national average will develop these national inventory figures and also allow for seasonal fluctuations which affect farming conditions.

Why do we collect information on farms?
The emissions at farm level account for around 70 – 80% of the carbon footprint of a litre of milk (sold to the consumer), meaning this area provides the greatest scope for a reduction to the carbon footprint of milk and dairy produce.

There are a number of sources for these emissions, the following being the major sources:

- Methane (CH_4) from the dairy cows (and followers) - enteric fermentation and manure emissions
- Nitrous oxide (N_2O) - soil management and methane related to manure
- Carbon dioxide (CO_2) - related to manufacture of fertilisers (where forage crops are grown for the dairy cows) and embedded emissions from purchased feed

Standards and specification/Calculators:
Carbon footprint figures are calculated for a dairy enterprise using set guidelines to ensure a level playing field between farms, systems and products. The E-CO_2 model used to calculate the GB national average within this study has undergone certification by the Carbon Trust based upon PAS 2050 methodology. PAS 2050 methodology 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. This Specification has widespread application to all products and industries. DairyCo, Dairy UK and The Carbon Trust have subsequently developed a set of specific guidelines addressing the sampling, measurement and calculation of the carbon footprint of milk and dairy produce.

The International Dairy Federation (IDF) has now also developed a methodology for carbon foot printing within the dairy sector. The IDF standards align all methodologies produced to date across the globe. The IDF accounts for around 83% of the world's milk supply so this harmonisation of methodologies is a far reaching and should provide a basis for meaningful international comparisons.

Sequestration
Neither the PAS 2050 carbon foot printing guidelines nor the IDF guidelines allow for a calculation of sequestration to be included in the final footprint value for milk. This is because sequestration (carbon capture) in grassland is a very slow process and only takes up carbon from the soil in very small amounts over a 12 month period. It occurs by the addition of manure and the slow natural cycle of decaying plant residues. However, as soon as

grassland is opened up by sub soiling, ploughing, or any other form of cultivation, the carbon in the soil is released.

The Intergovernmental Panel on Climate Change (IPCC) do not include carbon capture in their modelling for grassland. At current, 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 such a model.

There is potential for a sequestration element to be added to future foot printing calculations given the appropriate development of scientific evidence supporting this.

DairyCo carbon foot printing study

Objectives
The second year of the DairyCo carbon foot printing study retains the same objectives as year one. Perhaps the most important of these are; to provide a Carbon Trust verified average carbon footprint figure using actual farm data for British milk production; provide each participating farmer with an individual carbon footprint figure whilst identifying opportunities for improved efficiencies on-farm; and provide British dairy farmers with the practical information and knowledge needed to reach key targets in improved business efficiency, environmental stewardship, and carbon reduction.

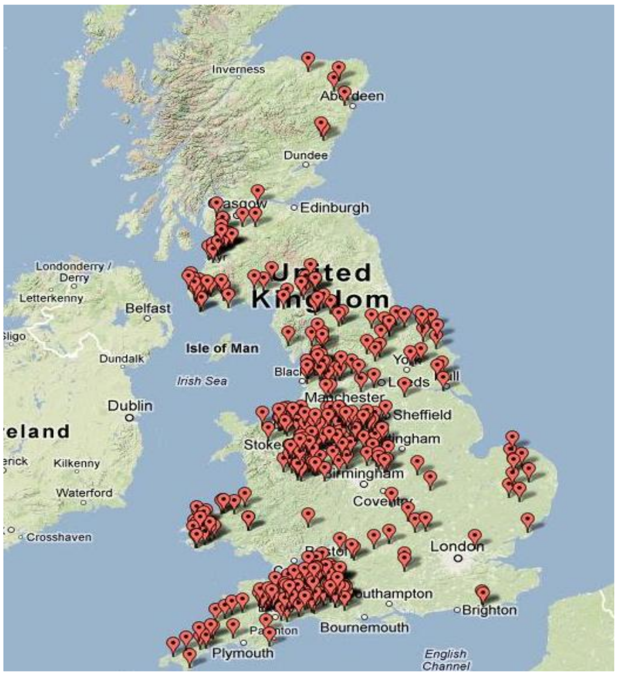
In addition for year two, the study seeks to identify and analyse differences in emissions and key efficiency measures as compared to year one.

Study Design

Sample selection and recruitment: maintaining the sample set into year two
Four hundred and fifteen farms participated in year one of the study. These were geographically selected to reflect the overall distribution of British dairy farms (2009); providing a geographically representative sample. Of the farms participating, 72% were from England, 16% were from Wales, and 12% were from Scotland.

Inevitably some of the participating farmers in year one of the study ceased milk production or for various reasons were unable to participate in year two; 67 farms fitted this category. A replacement strategy was implemented recruiting farms to maintain the sample set at 415, with the same geographical distribution. This necessitated finding 67 replacement farms which were preferentially selected based on system and scale to match the farms leaving the study.

Figure 1. Geographical distribution of 415 year 2 farms: 358 continuing from year 1 and 67 replacements



The replacement farms are compared with those they replaced in Tables 1a and 1b below.

Table 1a. Descriptive statistics for 67 ‘replacement farms’ for year 2 of study

	Herd size	Average yield	Total milk sold
Mean	183	7,893	1,438,660
Median	161	7,986	1,211,199
Mode	180	N/A	1,500,000
Farm with lowest carbon score	180	5,765	995,099
Farm with highest carbon score	180	6,851	1,211,199

Table 1b. Descriptive statistics for 67 ‘year 1 only farms’ (no longer participating)

	Herd size	Average yield	Total milk sold
Mean	196	7,549	1,444,153
Median	165	7,425	1,155,200
Mode	75	N/A	N/A
Farm with lowest carbon score	268	8,903	2,323,420
Farm with highest carbon score	97	7,791	725,726

Data collection and quality assurance
As with year one of this study, each assessment for year two was completed on-farm by an E-CO_2 trained assessor. Data was collected using objective evidence where possible including livestock records, farm accounts, and reports from software recording packages. Data collected can be broadly categorized into the following groups: livestock management, milk yield and characteristics, feed use, fertiliser use, and manure management.

Carbon allocation and credits
The methodology for carbon allocation and credits remained unchanged for year two. Dairy farms were assessed individually in order to calculate their carbon footprint on a gram CO_2 equivalent (CO_2e) per litre of milk produced corrected to 4% butter fat. Where farms were found to be a component of a mixed enterprise, the dairy component was effectively ‘split out’ by identifying greenhouse gas emissions associated with milk production only.

Carbon credits may also have been given to the dairy farm; for instance a portion of the emissions generated from a cull cow, heifers sold, and calves sold can be ‘credited’ back to the farm as these animals will either enter the beef production system or be sold to another farm to produce milk.

Data confidentiality
Participating farms granted the E-CO_2 Project permission to collect, aggregate, and analyse their data anonymously.

Carbon Trust verification
Following Carbon Trust Certification review of E-CO_2 procedures, data collection, and analysis in December 2012, this year’s study can again be considered consistent with the PAS 2050:2008 approach with particular regard to the 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, as the carbon footprint for this study covers a milk pool spread across a number of supply chains which are not under the direct control of DairyCo.

Year 1 Results – Updated

Model update and impacts on year 1 results

Following the successful completion of the first year of this study, a review of the E-CO_2 Project's carbon foot printing model for dairy was completed. Based on farmer feedback, and newly published data, an expanded feeds list was added to the model, and emission factors of existing feeds updated.

The carbon footprints of year 1 farms were recalculated to facilitate a direct comparison with year 2 results (Table 2).

Table 2. Recalculated carbon footprint figure on 415 GB dairy farms used in year 1 (2011)

	2011 - published	2011 – updated model	% change
Mean	1,309gCO_2e/l	1,293gCO_2e/l	-1.26
Standard Error	13	13	-1.18
Median	1,248	1,245	-0.24
Mode	1,129	1,008	-12.02
Standard Deviation	273	262	-4.30
Skewness	1.7	1.7	-2.14
Range	1,976	1,929	-2.46
Minimum	835	828	-0.81
Maximum	2,808	2,757	-1.86

When the year one figures were recalculated using the E-CO_2 model's updated feeds database, the mean carbon footprint decreased by 1.26% from 1,309g CO_2e/l to 1,293g CO_2e/l, or an average absolute decrease of 16g CO_2e/l. While the range is still large (1,929g CO_2e/l), it also showed a decrease from the original dataset. Similarly, standard deviation decreased slightly.

Year 2 Results

Farm participation, type and performance

The target of 415 farms participating in the study was achieved again in year two: 348 continued with the study from year one into the second year, while 67 farms were added to replace farms dropping out of the analysis. The same quality grading scheme, with a scale of 1 to 5 with a low score indicating high data reliability, was applied to each set of farm data, and 91% of the data collected in year two scored 1-3, up from 90% in the previous year.

Across the dataset, the average farm sold 1,371,036 litres of milk. This is an increase over the year one average of 1,360,233 litres and is significant because the average herd size remained similar at 182 milking cows. Average yield increased from 7,490 litres/cow/year to 7,616 litres/cow/year in year two.

Table 3. Milk production details from 415 dairy farms – descriptive statistics year 2

	Herd size	Average yield	Total milk sold
Mean	182	7,616	1,371,036
Standard Error	6	73	48,010
Median	150	7,742	1,113,015
Mode	150	9,500	1,300,000
Standard Deviation	118	1,491	978,041
Skewness	2.5	-0.4	2.6
Range	967	8,802	7,862,315
Minimum	28	2,337	92,204
Maximum	995	11,139	7,954,519

The replacement process was effective, in that adding 67 replacement farms to the dataset, the median remained unchanged from year one to year two. However, standard deviation and standard error for average yield both increased, suggesting that the range in milk outputs widened in the sample represented.

Distribution of greenhouse gas emissions by source

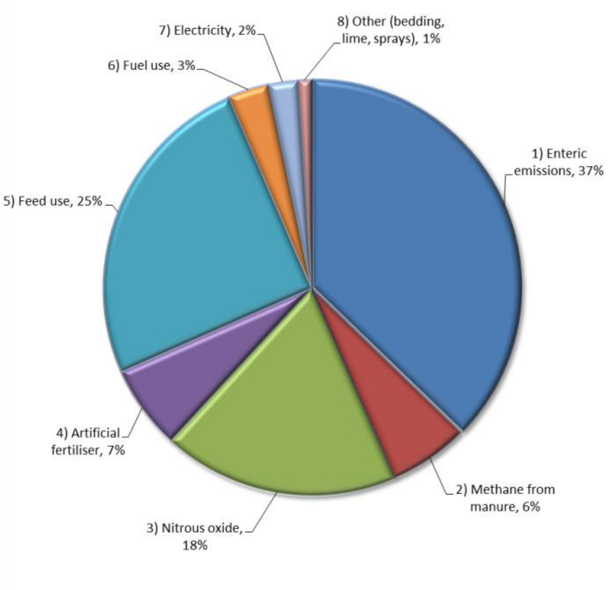
The three major sources of agriculturally-related Greenhouse Gas (GHG) emissions are:

- Carbon dioxide – derived from fuel use, electricity consumption, and the production and transportation of fertilisers, herbicides, lime, straw/bedding, and animal feed
- Nitrous oxide – derived from the conversion of fertiliser, animal manures, sewage sludge (if applied), and other crop residues
- Methane – arising from enteric fermentation in the rumen and, to a lesser extent, emissions from manure management.

On each farm, (1) enteric emissions, (2) methane from manure, (3) nitrous oxide, (4) artificial fertiliser, (5) feed use, (6) fuel use, (7) electricity, and (8) bedding, lime, sprays, etc. are assessed as a proportion of the farm's overall emissions (numbers corresponding to the figure below).

The average distribution of farm emissions remained relatively unchanged. While still the single largest component, enteric emissions decreased from 40% in year one to 37% in year two. Conversely, nitrous oxide emissions increased from 10% to 18% as a proportion of overall farm emissions.

Figure 2. Breakdown of the average farm emissions by source*



**Total does not equal 100% due to rounding.*

Average carbon footprint

The average carbon footprint of the farms sampled during year two of the study (2011/2012), calculated using the E-CO_2 Project's Carbon Trust certified dairy model, is 1,227 g CO_2e/litre of 4% fat-corrected milk. As with year one, the figure was calculated as a weighted mean from the dataset. Emissions per litre were multiplied by milk produced for each farm; this value was summed for the 415 farms, and then was divided by total milk produced (4% butterfat corrected).

As the average carbon footprint for year two is 5.4% less than that of year one (1,227 g CO_2e/litre vs. 1,293 g CO_2e/litre recalculated), this necessitated further investigation. The basic question was whether this reduction was because 67 replacements had significantly lower emissions, or whether there was a genuine reduction amongst those 348 farms participating in both years of the study. The average carbon footprint of the 67 replacement farms was then calculated (Table 4a) and found to be 1,204 g CO_2e/litre.

Table 4a. Average carbon footprint figures – year 2 all farms vs. replacements

	Year 2 – All 415 Farms	67 Replacement Farms
Mean	**1,227gCO_2e/l**	1,204gCO_2e/l
Standard Error	**10**	23
Median	**1,191**	1,191
Mode	**1,114**	N/A
Standard Deviation	**211**	185
Skewness	**1.4**	1.4
Range	**1,336**	900
Minimum	**820**	936
Maximum	**2,157**	1,836

A year-on-year comparison of the 348 farms participating in both years was also undertaken (Table 4b).

Table 4b. Average carbon footprint figures – 348 farm subset continuing in the study

	Year 1 – 348 Farms	Year 2 – 348 Farms
Mean	1,309gCO_2e/l	1,231gCO_2e/l
Standard Error	14	12
Median	1,250	1,189
Mode	1,008	N/A
Standard Deviation	264	216
Skewness	1.7	1.4
Range	1,929	1,336
Minimum	828	820
Maximum	2,757	2,157

The average carbon footprint of the 348 farm-subset (i.e. those participating in both years of the study) was 1,309g CO_2e/litre for year one, recalculated using the E-CO_2 Project's Carbon Trust certified and updated dairy model emissions. It is entirely coincidental that this is the same value as the original published year-one mean carbon footprint. When compared to the year two average of 1,231 g CO_2e/litre, this is a 6.3% reduction.

The 5.4% reduction between year one to year two across the whole 415 farm sample is therefore genuine, and not a result of the 67 replacement farms having a significantly lower carbon footprint.

Average carbon footprint
Year two herd characteristics for all 415 farms, including size, average yield, and total milk sold is given in Table 5a. The median and modal averages of the dataset remained unchanged from year one at 150 cows, whereas the mean herd size increased slightly from 180 to 182.

The farm with the lowest carbon footprint in year 2 had a herd size of 87, and an average yield of 5,487 litres/cow. Generally speaking, this farm had a smaller than average herd size and lower than average yield. In year one, the farm with the lowest carbon footprint was broadly similar, with a herd of 124 cows and an average yield per animal of 5,615 litres.

The 42 farms that represent the 'lowest 10%' group (i.e. those farms with the lowest carbon footprints) had an average herd size of 191. The 'highest 10%' group had an average herd size of 210.

Table 5a. Herd characteristics – year 2 all farms

Full data set analysis	Herd size	Average yield	Total milk sold
Mean	182	7,616	1,371,036
Median	150	7,742	1,113,015
Mode	150	9,500	1,300,000
Farm with lowest carbon score	87	5,487	463,437
Farm with highest carbon score	105	5,749	600,000
Lowest 10% (carbon)	191	8,169	1,545,696
Highest 10% (carbon)	210	7,047	1,508,250

Herd characteristics for the 348 farms contributing data over both years 1 and 2 are given in Table 5b.

Table 5b. Herd characteristics – year 2 (348 farm subset)

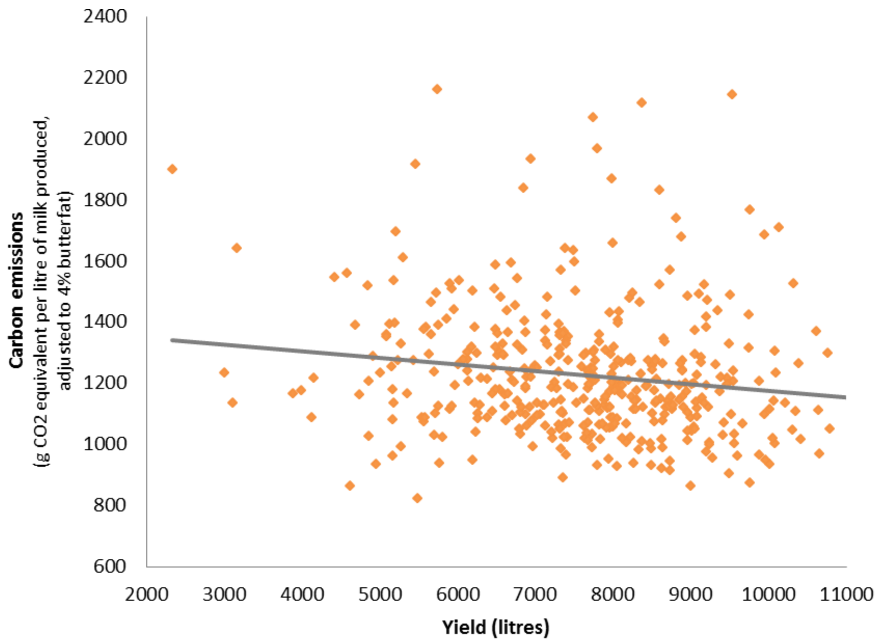
	Herd size	Average yield	Total milk sold
Mean	181	7,563	1,358,017
Median	150	7,696	1,103,092
Mode	150	8,644	1,300,000
Farm with lowest carbon score	87	5,487	463,437
Farm with highest carbon score	105	5,749	600,000

The herd characteristics for the 348 repeating-farm subset are remarkably consistent with those of the entire year two 415 farm dataset.

Carbon footprint and average yield per cow

Milk yield is usually identified as a key variable in determining carbon footprint per litre of milk; a higher yielding cow spreading her methane output across greater litres of milk. Year one of the study showed a slight, but positive trend indicating that as the yield per cow increases, carbon footprint decreases. While this trend occurs again, the year two dataset had a large range of yields and carbon footprints. In addition, the farm with the lowest carbon score had a lower than average milk yield (non-fat corrected). This underlines the fact that there are many factors affecting carbon footprint beyond yield *per se*, and that seeking maximum efficiency for a given system or management approach is key to obtaining a lower carbon footprint.

Figure 3. Milk yield vs. carbon footprint – year 2 all farms

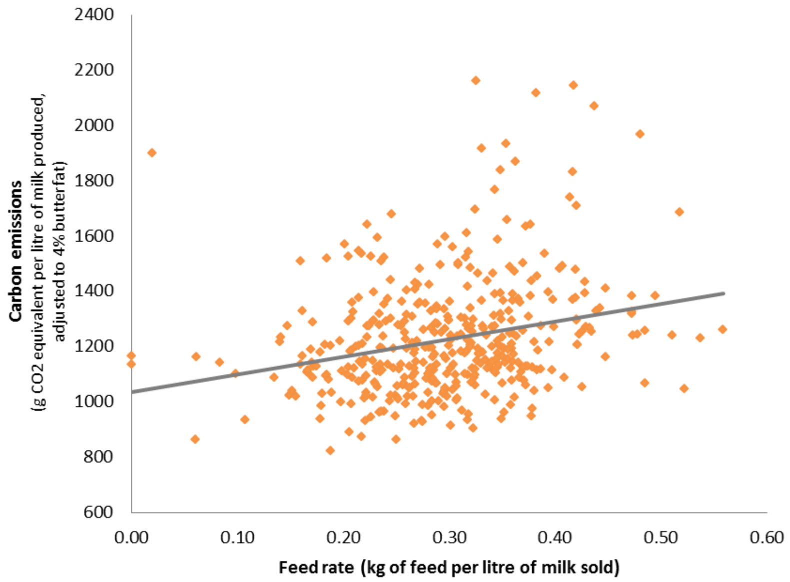


Carbon footprint and feed rate

Feed rate has been calculated as the sum of concentrates, straights, and non-forage home-grown feeds fed to cows and dry cows divided by litres of milk sold. Feed rate in this context does not include forage (home-grown or purchased). This measure is presented as being ‘per litre of milk sold’ whereas the majority of other measures are in terms of ‘milk produced’.

The average feed rate across the dataset was unchanged year one to year two at 0.30 kg/l. Two farms were forage and moist feed-based grazing systems that fed no additional concentrates or straights and subsequently had a ‘feed rate’ of 0 kg/l for purposes of comparison. As with year one, while there may be a general trend (r^2=.0649) between lower feed rates and lower carbon scores, considerable variation can be seen in the scatter diagram below (Figure 4).

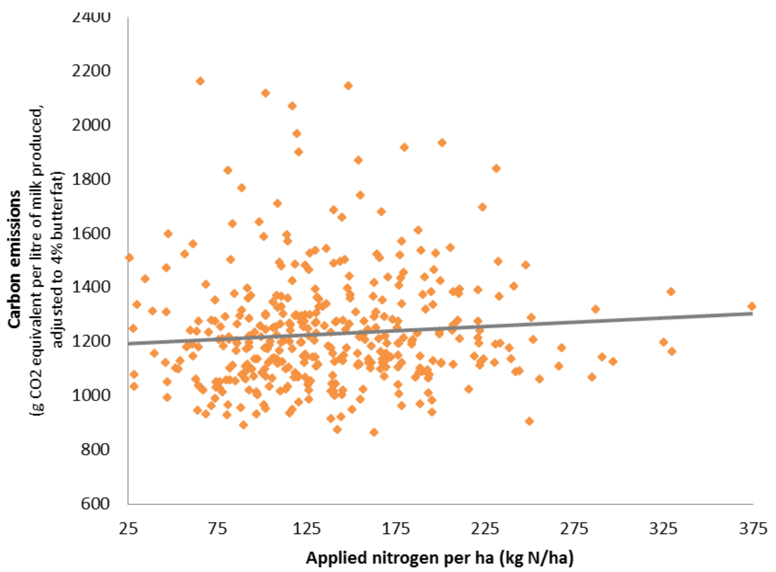
Figure 4. Feed rate vs. carbon footprint – year 2 all farms



Carbon footprint and fertiliser use

A wide range in synthetic nitrogen fertiliser application was again observed in year two. While there may be a slight trend linking higher nitrogen applications with a larger total footprint, the relationship is poor for the dataset as a whole (r^2=.0097). One partial explanation might be that efficient use of nitrogen to grow higher quality forage, which in turn could reduce the need for purchased concentrates and straights.

Figure 5. Synthetic nitrogen fertiliser application vs. carbon footprint – year 2 all farms

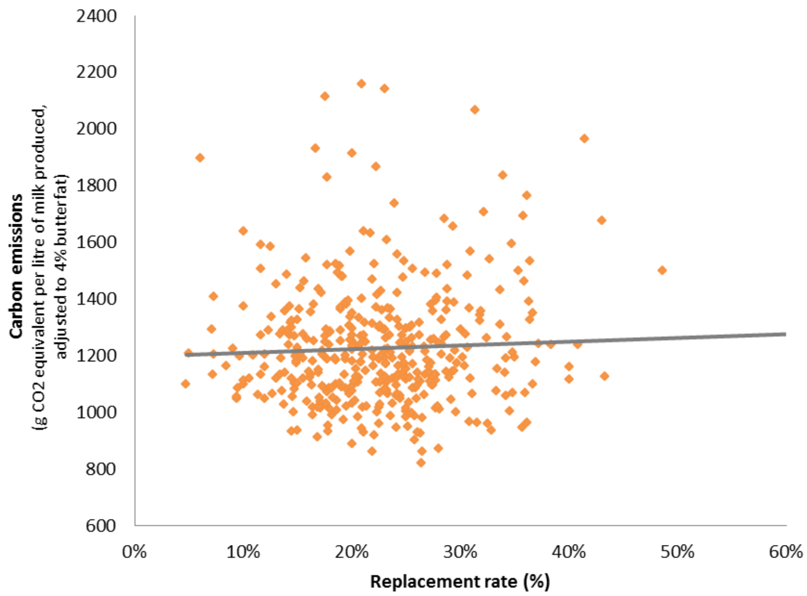


Carbon footprint and herd replacement rate

Lower herd replacement rate would be expected to have a direct effect on carbon footprint, as emissions are offset over a longer productive life, and therefore a greater volume of milk per cow.

While the replacement rate distribution in year two, shows a slight trend indicating those farms with a higher replacement rate have a higher carbon footprint, there is huge variation within the dataset (Figure 6). Likewise, the mean herd replacement rate of the 'highest 10%' farms (i.e. those 42 out of 415 with the highest carbon footprint) is 25%, whereas the mean for 'lowest 10%' group is 24%.

Figure 6. Replacement rate vs. carbon footprint – year 2 all farms

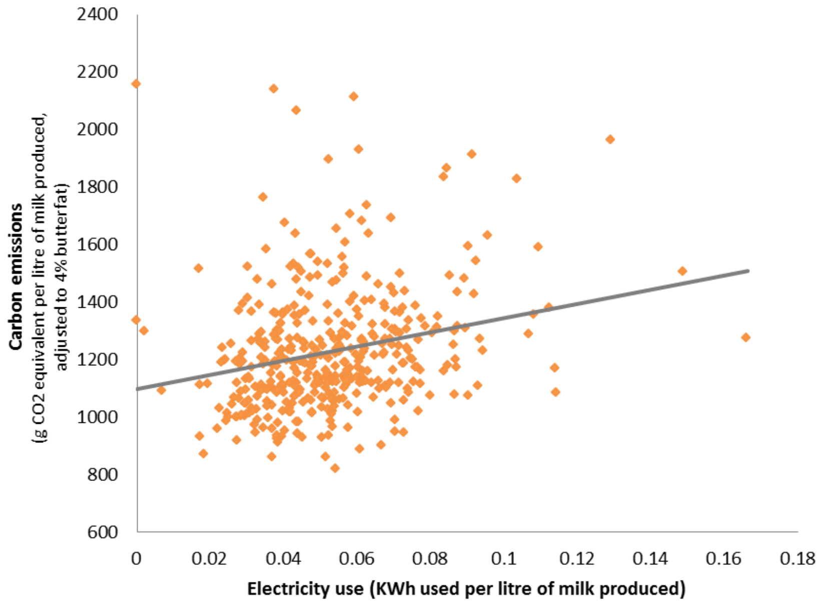


Carbon footprint and electricity use

Electricity use was shown to be a relatively small proportion of overall emission in year one of this study at an average of 3% of total emissions. Year two maintained this pattern with the total proportion of electricity use shrinking to an average of 2% of overall emissions.

As the E-CO_2 Project provides all participating farms with a summary of potential cost savings from improved electrical efficiency, it could be assumed that this had an influence on farmer behaviour, as the average consumption of electricity fell from 0.060KWh/litre to 0.052KWh/litre; a 15.4% reduction. Efficiencies in milking and milk cooling continue to provide the greatest potential for further reductions in energy use per cow or per litre produced.

Figure 7. Electricity use vs. carbon footprint – year 2 all farms



While electricity consumption fell, average milk production rose from 1,361,180 to 1,420,213 litres per farm. At an average price of 9 pence per KWh, a typical farm would have seen their electricity bill stay relatively unchanged at approximately £6,400 per year. This is assuming no change in electrical tariff. See Table 6 below.

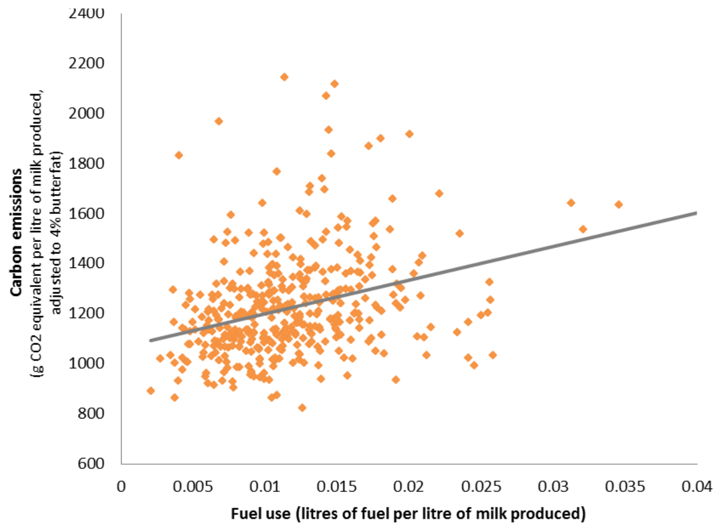
Using the year 1 example of a 300 cow dairy, producing 2,500,000 litres of milk per year, a 15.4% reduction in electrical use from 125,000 KWh/year to 105,750 KWh/year would save the farm £2,108 p/a.

Table 6. Electricity Use – Year 1 vs. Year 2

	Ave milk production	Ave KWh/L milk produced	Ave KWh/Year	Cost/Year (@9p/KWH)
Year 1 electric use	1,361,180	0.06	71,731	£6,456
Year 2 electric use	1,420,213	0.05	71,440	£6,430
Percent difference	4.2%	-15.4%	-0.4%	-0.4%

Carbon footprint and fuel use
Emissions from fuel use remained unchanged at an average of 3% of total farm emissions, and present some practical opportunities for carbon reduction. Though this is a small portion of overall emissions, the potential for financial savings from improved fuel efficiency continues to increase as fuel prices rise.

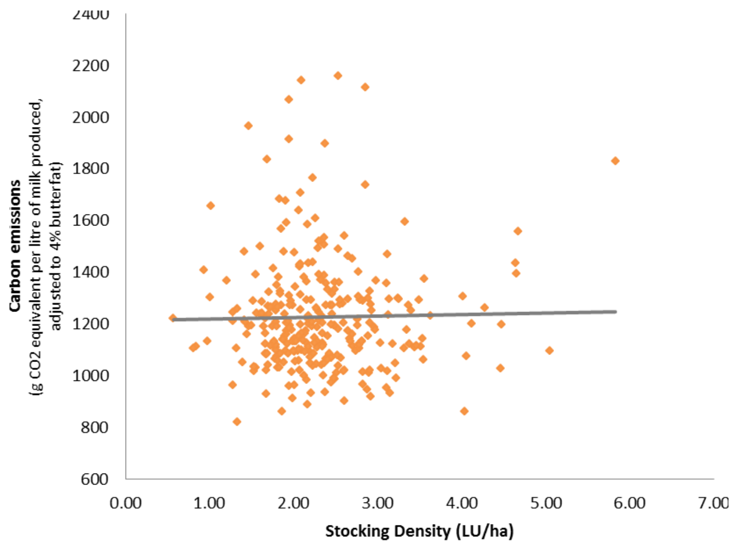
Figure 9. Fuel use vs. carbon footprint – year 2 all farms



Stocking Density

The number of heifers and cows on each farm, expressed in terms of livestock units (LU), were compared to the size of the cropping area (ha) in an effort to determine if stocking density was correlated to carbon footprint. Cows were converted to LUs at 1 cow/LU and heifers were converted at 0.8 heifers/LU. This value was then divided by the total cropping area to determine stocking density. 'Flying herds' were removed from this analysis. On most farms stocking rate varied from 2 to 3 LU/ha, but there was virtually no relationship between stocking density and carbon footprint (Figure 10).

Figure 10. Stocking density vs. carbon footprint – year 2 all farms



International Dairy Federation (IDF) compliant carbon footprint

An IDF carbon emission was calculated for the year two DairyCo data set. It is 1,269g CO_2e/l of fat and protein-corrected milk; year one it was 1,327g CO_2e/l. Both of these values are on a weighted average basis.

Discussion and conclusions

The carbon footprint model applied to the dataset by E-CO_2 took into account all significant inputs and variables used by each of the 415 dairy enterprises assessed during the second year of this study. The data were collected on-farm by trained assessors, providing confidence in the reliability of the data collected.

The carbon footprint figure for year one was recalculated following updates to the E-CO_2 model. As a result, farm emissions for year one decreased by 1.26%, from 1,309g CO_2e/l to 1,293g CO_2e/l 4% fat corrected milk. In year two, 348 of the original 415 farms participated in the study; requiring the 'replacement' of 67 farms. The overall carbon footprint figure for year two for all 415 farms, and using the updated model, is 1,227g CO_2e/litre - 5.4% less than year one. The subset of 348 farms repeating the survey in year 2, had an average carbon footprint of 1,231 g CO_2e/l compared with 1,309 g CO_2e/l in year one - a 6.3% reduction year on year.

Enteric emission from rumen fermentation remained the largest contributor to carbon footprints at an average of 37% of total emissions. Feed use was the second largest contributor, at 25%. As with year one, no single parameter accounted for most of the variation between farms, reinforcing last year's message that there is no single production system that appears to be more carbon efficient than any other.

Given the wide range in performance, significant opportunities exist for most farms to reduce their carbon footprint, environmental impact, and improve farm efficiency. To investigate whether there were particular farm types or characteristics which were more or less conducive to lower carbon foot print, the combined data set from years 1 and 2 was subjected to a Principal Component Analysis. The analysis found that there were no particular farm types which stood out as leading to lower overall emissions.

Analyses were also undertaken to establish the strength of relationships between selected input and output parametres on carbon footprint. The results indicate weak relationships for the sample as a whole, although they are generally in the direction expected (Table 7).

Table 7. Correlation coefficients summarising the linear relationships between total carbon emissions and specified covariates

	Year 1	Year 2
Average yield (l/cow)	-0.14	-0.15
Concentrate fed rate (kg/l)	+0.24	+0.25
Replacement rate (%)	+0.12	+0.05
N applied (kg/ha)	+0.15	+0.10
Months housed	+0.16	+0.20
Electricity used (KWh/l milk)	+0.13	+0.24
Fuel used (l/l milk)	+0.36	+0.34

There was a strong positive relationship (correlation coefficient = 0.62) between carbon foot print in year 1 and year 2, further reinforcing the view that individual farm circumstances and level of management applied that are the main drivers of carbon foot print. The case study examples which follow indicate how different combinations of husbandry and management can result in low carbon emissions.

DairyCo

DairyCo case studies
John Barrowman, North Knockglass (Stanraer, Wigtownshire)

Farm business
John Barrowman and father John own 61ha (150 acres) at North Knockglass and rent a further (20ha) 50 acres, all on heavy clay soils. Of this 77ha (190 acres) is suitable for cropping and this is all grass, but the growing season is relatively short with grazing only usually possible five months of the year. Annual rainfall is 1200mm (48in).

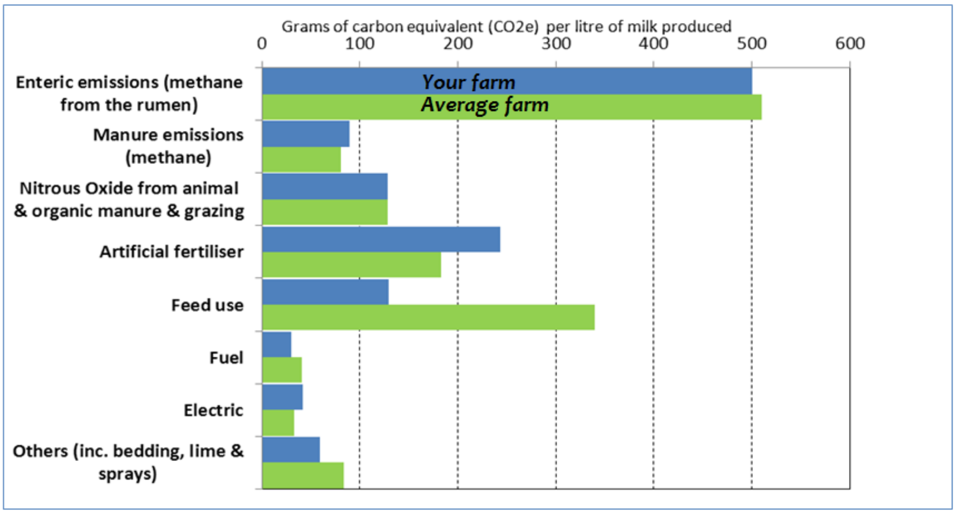
Dairy system
The closed herd averages 95 cows, with facilities suitable for 100 at any time with the current set up. The main calving period is July to October, with a few then calving each month until May.

Cows are milked in a 10:10 herringbone parlour, but with John senior reducing his hours on the farm, a new 16:32 herringbone parlour is being built to reduce milking times, allowing John to manage the herd with minimal assistance. No labour is currently employed. To keep labour requirements low, automatic scrapers are fitted in cow cubicles.

Replacements are home-reared. “We’re not looking for an extreme Holstein or a cow that’s too Friesian, we want cows of about 650kg with good feet.” Milk is sold to Nestlé via First Milk.

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



The chart above represents all emissions generated by the dairy over the 12 month period assessed. Carbon subsequently allocated to cull beef or calves is included within the scope of the graph hence the total will not equal the CO_2e figure quoted below which does not include the carbon allocated to other beef produced.

Farm’s carbon footprint – 1,007g of CO_2e/l of milk (previous year 1,349)

DairyCo

Ration improvements increase efficiency

Between the first and second year carbon footprint assessment, feed efficiency had increased, helping reduce the footprint by 17%. This was achieved by producing an extra 1,000 l a cow, with yields up to 7,500 l from a similar amount of purchased feed, with the average feed rate reducing from 0.32 to 0.26kg a litre, including an allowance for Vitagold fed in both years.

“We managed to make a high quality, dry silage,” explains John. “The earliest we can take a first cut is in late May or early June and second cut is about 7-8 weeks later.” He uses an inoculant additive with the aim of improving the silage feeding value.

Silage analysis in the year efficiency improved was 28% dry matter, 67.5 D-value, 10.8 MJ/g of ME and 13% crude protein. This is included in a mixed ration with 5kg a cow of the by-product Vitagold. “With the Vitagold in the mix, we can achieve high feed intakes,” says John.

Some of the ration ingredients also changed between years, with protected fat and yeast added. This is balanced with a 23% blend, which includes wheat, rapemeal and soya, fed at 4kg a cow. Wheat or oat straw also started to be added at 0.5kg a day.

In the parlour a 20% compound is fed to yield at between 1kg and a maximum of 5kg a day, so considering the Vitagold and blend already identified, the maximum intake of feed can be up to 14kg per day at peak times. “We feed in the parlour to yield and to settle the cows for milking but yet we also feed a semi complete ration to reduce acid loading of the cows’ rumen,” says John.

The climate and clay soils mean an early turnout is difficult, so typically cows start grazing in May and with a tight stocking rate for the situation, buffer is often fed, except in June. But efficient use of the grazing that is available is key. “We provide a fresh strip of grazing every day. Twice a day would be our ideal and I hope to move to this once the parlour is in and milking times are shortened.” Cows are usually fully housed during October.

Heifers moving to 24 month calving

John has previously calved heifers at up to 30 months old, with them reared on land 20 miles away making it historically difficult to push up growth rates and get heifers served. “But we don’t want to keep extra animals on the farm, so we are reducing this to 24 months,” he says.

“It will still take the same amount of purchased feed and we don’t want to push them too hard at the start. It is a challenge to avoid moving them too much, which costs us in fuel and time.”

“We rear them on whole milk for a week to ensure they are feeding well. Then they go on ad-lib milk replacer through an automatic feeder, to save labour, and are weaned at eight weeks. We’re keeping them on a coarse blend for three months because it’s a higher quality, more palatable feed, before putting them on an 18% protein blend, at 2.5kg a head and straw until turnout.”

Heifers then go to away ground for the summer, but will now come back to the farm for serving before their second grazing season.

Energy use

The farm’s fuel use remains low, despite having stock on away ground. However, electricity use is slightly above average, with automatic scraping, longer milking times and a traditional vacuum pump contributing to use.

John will be addressing milking times with the new parlour, hopefully saving two hours a day, and is considering running costs in his decisions, to try and reduce his bills.

The power to run automatic scrapers is justified with the savings in labour they make possible.

Planning to improve nitrogen efficiency

Current fertiliser use is significantly above average in relation to contribution to the carbon footprint. But John has plans to tackle this with a program of reseeding and a new slurry storage tank.
“Our silage swards are not responding to nitrogen as well as they might and we’ve been using N to push up grass yields, so we are going to reseed a proportion of the silage area over the next few years. We planned to reseed 17 acres this autumn but the wet weather has stopped us. We will also be liming where needed.”

Soil tests have not been frequently done in the past but a new fertiliser plan including a testing routine is scheduled for the New Year. This undertaking should better manage artificial nutrients applied to balance nutrients removed through silaging which should boost productivity and reduce the carbon footprint of the milk produced in the coming years.

“We needed to adopt greater levels of soil testing to apply for a grant for the new slurry tank. This will stop us having to spread onto a neighbours’ stubble ground when we need to empty the tank and allow us to save enough to put on after first cut and second cut.”

Why have a carbon footprint completed on your farm?

“Our contract with Nestle requires us to have a carbon footprint. I can see it becoming a condition of more contracts in future and we are not in an area where there is much choice of buyer. But it is useful to look at efficiency and if our carbon footprint is low, it means we are not wasting much which is reassuring.”

DairyCo

Alan Cooper, Millers Farm (Upton Noble, Somerset)

Farm business

Alan Cooper has been running his family's 87ha (215 acre) farm with the help of his brother for the last five years, with his father Brian gradually reducing day-to-day input. Earlier this year a farm worker was employed and he is now trained to milk the cows.

"All the land is close to the buildings, saving time and fuel," says Alan. "Fields around the farm are relatively dry loams to stone brashes, but the rest of the farm has clay soils making it less suitable for grazing."
Maize is currently grown on 16ha (40 acres). "But the acreage may be reduced, as yields are not reliable."

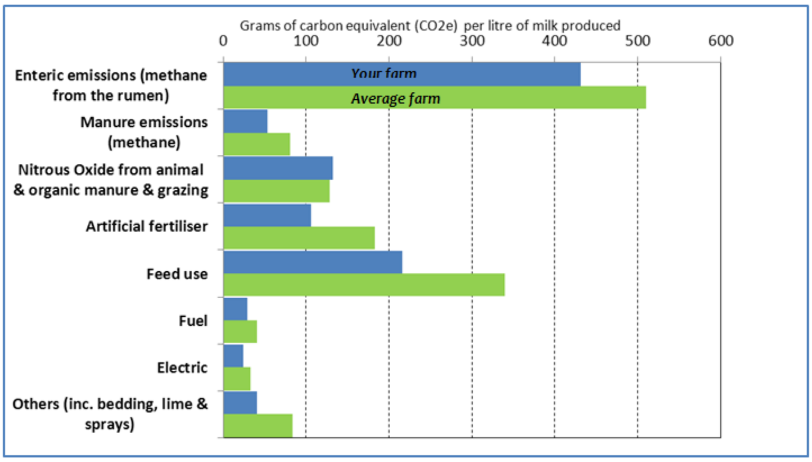
There are 20 dairy beef animals on the farm, which were kept when the farm was under TB restrictions; the farm is now TB free.

Dairy system

Alan's objectives on returning to the farm were to move from a flying herd to rearing replacements, increasing the stocking rate, but with similar cow numbers and he has increased yields to average 8000 litres. "We're aiming to be producing as much milk as possible from forage, with some concentrate to keep yields up."
"Cows were all Holsteins, but we are now crossing with British Friesian to increase longevity and improve fertility." His aim is to keep 110-115 milking cows, plus replacements. Calving is more concentrated around spring, but stretches all year round. "We'd like to move towards a break in calving in December and January."

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



The chart above represents all emissions generated by the dairy over the 12 month period assessed. Carbon subsequently allocated to cull beef or calves is included within the scope of the graph hence the total will not equal the CO2e figure quoted below which does not include the carbon allocated to other beef produced.

Farm's carbon footprint 926g of CO_2e/l of milk (previous year 932g)

Feed efficiency

Alan's feeding policy is focussed on keeping forage intakes up. In spring and summer this means a fresh area of grass each day and night. With grazing cheaper than silage making, Alan aims to have the cows out as early as possible in the year, although the actual date varies due to ground conditions. "If possible, we may have cows out in February, but if we do we accept they will be likely to spend wet days back in," says Alan.

"In winter, we feed a partial total mixed ration, 50:50 grass and maize silage, with up to 3kg of a 30% crude protein blend and in some years we add by-products, such as pressed pulp, if we need to."

Concentrate is then step rate fed in the parlour. Typically, this is an 18% crude protein blend with rapemeal as the main protein source. The 30% blend also includes more rapemeal and maize distillers than soya.

"The maximum we feed in the parlour is 6kg a day for the best cows in early lactation," says Alan. Therefore, the most fed is 9kg of concentrate a cow a day, equating to 2.1t a cow annually and a feed rate of 0.27kg a litre.

Dry cows are out-wintered until a few weeks before calving, reducing their requirement for conserved forage.

Home produced forage provides the keystone to the dairy ration on the farm, quality grass and maize silage are often the lowest carbon feedstuffs available to farmers due to the minimal inputs and processing required. By maximising dry matter intake from these sources the smaller the amount of carbon attributed to feed becomes, as less purchased concentrate or blends are required.

The ration is carefully balanced to ensure no additional dietary protein is fed. Excess protein is excreted as urea which adds to the greenhouse gas burden of the farm.

Soya is defined as a high carbon feed due largely to land use changes in some of the regions where it is grown. By reducing the percentage of the diet derived from soya, the emissions from feed will be lowered.

Fertiliser

The farm's policy has been to keep fertiliser use low. "We use little on the grazing fields," says Alan. "We rely on clover and pastures grow well. Many paddocks have been reseeded in the last five years too, after using the fields for out-wintering dry cows, to increase grass yields."

Historically, the slurry from the weeping wall slurry pit has gone on maize ground, but more of the pit slurry is now going onto silage fields. "We did some soil tests a couple of years ago and found our potash levels on grassland were very low, so to increase production, as we increase the stocking rate, we are aiming to build the indexes."

Purchased nitrogen use on silage ground is also modest at 100kg of N/ha a year.

Re-seeding is a key tool available to farmers to maintain sward productivity and maintain desirable species within it. Higher grass yields should reduce the need for artificial fertiliser which comes at a high carbon cost and high protein levels in silage should reduce the protein requirement for purchased feed which comes onto farm with a greater carbon cost.

Youngstock rearing
The farm's current batch of 15 home-bred in-calf heifers will all calve between 24 and 26 months. Alan aims to keep this as close as possible to 24 months of age to minimise unproductive stock on the farm. "We've served them with sexed semen to achieve a number of high quality home-bred replacements."

Although relatively new to heifer rearing, they are managing to achieve good growth rates with no pneumonia and very low mortality. "We've got to get calves off to a good start. We keep them on fresh milk and wean at eight weeks. We also feel that to get them big enough to serve for two year old calving they need a little concentrate, even when we turn them out to grass and we keep a close eye on their body condition."

The practice of purchasing replacements as opposed to rearing one's own shouldn't make a difference to the carbon footprint of the milk on the farm. There is an assumed carbon cost attached to a purchased heifer which represents the carbon released over its life up until that point which should be equivalent to the carbon released when rearing on the holding. Where the farmer is managing replacements and calving heifers at close to two years is achievable the footprint is reduced compared to a 30 month first calving system as there are fewer days' methane production prior to the first lactation.

Culling rate
The herd culling rate is below average at 20%. "The reasons for culling are equally split between mastitis, lameness and infertility," says Alan. "We make an effort to keep on top of cow health, looking after their feet is important, as is picking up clinical mastitis cases quickly and keeping cell counts low. Having enough labour around allows us to keep on top of any health issues.

"But we feel we are losing too many first and second lactation animals due to infertility, hopefully more British Friesian genetics will help reduce this."

Electricity
Electric use on the farm at 0.04KWh/l of milk produced, is below the average of 0.052KWh/l. "We are careful to only heat the water we need," says Alan. "There's a timer on the water heater and we only hot wash the parlour once a day and the bulk tank washer has a 48 hour timer, as we're on alternate day collection."

The farm uses a plate cooler to cool milk before it enters the bulk tank. The project's Energy Savings report shows a second stage plate cooler could save a further £480 a year and Alan is considering this and a variable rate milk pump to lower electricity costs further.

Why have a carbon footprint completed on your farm?
"It's an opportunity to look at what you are doing in a different way and compare ourselves with other farms," says Alan, who worked as an accountant before coming back to run the farm. "It's made us think about where we could change things to save money. We also thought our milk buyer would look favourably on our taking part and by getting involved now we would be ahead of the game if a premium became available based on carbon in the future."

David and Marian Harding, Court Lodge Farm (Hailsham, East Sussex)

Farm business

The Hardings have been at Court Lodge for 23 years, converting to organic farming in 1998. Of the 220ha (540 acres) farmed, 90ha (220 acres) of sandy loams are suitable for productive grass and cropping. The remainder is on the Pevensey Levels under Higher Level Stewardship mostly with no inputs and restrictions on grazing. They are keen to encourage wildlife and have also established a 6.5ha (16 acre) reed-bed for rare birds, taking drainage water from surrounding fields, where rare beetle species can now be found.

On the productive land they grow 16ha (40 acres) of winter wheat for whole-crop or occasionally crimping, 16ha (40 acres) of spring oats and peas for whole-crop and 16ha (40 acres) of red clover swards for silage. The rest is permanent pasture, much of which cannot be ploughed.

Average rainfall is about 825mm (33in) a year. "But the silty clay of the Levels dries out slower than other pasture giving better summer grazing than might be expected," explains David.

Dairy system

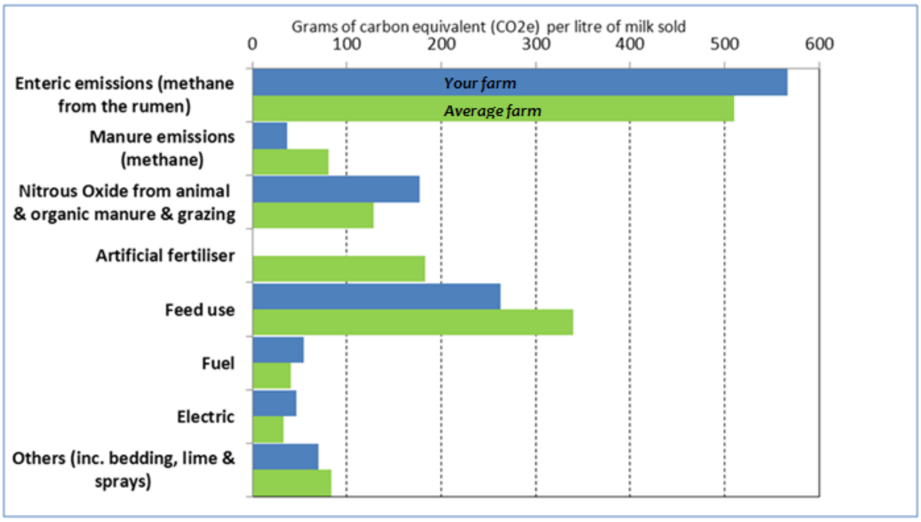
"Cows are managed on an extensive system at 1 cow/ha because of the nature of the Levels," says David. Numbers are gradually increasing from 135 to a target of 160, with home-bred replacements. "That's about our limit for the current 16:16 herringbone parlour."

"Most of the herd is pedigree Holstein Friesian, with a few Ayrshires, but we're moving the Holsteins back towards a Friesian type for extra longevity, better herd health, fertility and to hopefully lower mastitis incidence," says David. Foot problems are less of an issue because winter housing is in straw yards. Cows calve from July to March.

Yields of 7000 litres are seen as optimum for the system, with variations between years depending on forage quality. Most milk is sold to OMSCo, with a small amount processed on farm into drinking yoghurt for sale locally and in Waitrose supermarkets.

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



The chart above represents all emissions generated by the dairy over the 12 month period assessed. Carbon subsequently allocated to cull beef or calves is included within the scope of the graph hence the total will not equal the CO_2e figure quoted below which does not include the carbon allocated to other beef produced.

Farm's carbon footprint – 1,047g of CO_2e/l of milk (previous year 1,047g)

Fertiliser
Being organic, the farm doesn't buy in any inorganic nitrogen, phosphate and potash, which is a major contributor to its low carbon footprint. "We are running an extensive system with a low stocking rate, but we do test for lime, P and K levels," says David. "Lime is spread every five years if it's needed to keep pH at optimum levels. The last time we spread any phosphate was 12 years ago and to get an organic derogation from the Soil Association to put that on, the index has to be below 0."

To keep crop yields up on the farm's more productive land, David relies on clover, the crop rotation and careful management of farm yard manure and dirty water. "On grazing ground, we're aiming for 30% clover. Much of the pasture can't be ploughed and reseeded, so clover seed was stitched in many years ago to improve them."

The rotation is one year of winter wheat, two of spring oats and peas for whole-crop and then a 3-year red clover ley with modern, high water soluble carbohydrate, ryegrasses. "The next wheat crop then benefits from the nitrogen fixed by the clover," explains David.

"Dirty water is spread in spring and autumn on the highest land at the lowest possible rate, to cover as many acres as possible. It goes on with a low trajectory umbilical system. We'd like to inject it to keep even more of its nutrient value, but there isn't an injector available locally.

"Farm yard manure is mixed with some more liquid material and spread on when cultivating land at a moderate rate of 10t/ac." Incorporation of these manures by ploughing is completed promptly to avoid nutrient loss to the atmosphere to conserve nitrogen value and reduce gaseous emissions to the atmosphere.

Electric use and solar panels
The farm's electricity use is above average. The CFP assessment has recommended changing remaining conventional bulbs to low energy ones, which would pay for themselves in one year and David is planning to change them as a result.

He's also recently installed 50kw of solar panels on the roofs of the farm buildings, which should reduce the footprint in the third year assessment and save a third of the farm's electricity bill. "We put them up partly because of our interest in harnessing natural resources," says David. "We considered a wind turbine, but could see planning would be an issue. The solar panels only required a little strengthening of existing roofs and the visual impact is minimal."

"We are using the electricity directly in daylight hours and get the government's Feed In Tariff for every kilowatt generated. Any excess goes into the National Grid, but we are not selling it because we would have to pay for an export meter and we're not currently convinced it's worth the cost."

Feed use efficiency
Wet ground conditions and slower spring grass growth than on conventional farms which apply nitrogen, typically see turnout around March 20th. "Initially, only the top ground can be grazed and this is rotationally, paddock grazed," says David. "But from early May they can graze the Levels. There the fields are larger but as grass is more extensive, they still usually provide one day of grazing."

"Once cows are out day and night, no forage is fed. Cows usually stay out until November 10th, with good tracks helping us keep cows out later."

Typically in winter, the forage fed is 40% red clover and grass silage, 30% pea and oat whole-crop and 30% wheat whole-crop, with these mixed in a wagon before being put into troughs, both helping achieve high forage intakes.

"We have the forages analysed to check the crude protein of concentrate is adequate," adds David. "Usually, we buy in 18% crude protein concentrate in winter and 16% in summer. Concentrates are fed to yield in the parlour to a maximum of 7kg a cow a day and as low as 2kg a day for staler cows in summer. There have been issues over GM contamination of imported organic soya so our ration includes sunflower, peas and rapemeal rather than soya"

Feed efficiency was improved between years 1 and 2 of the DairyCo project because yields increased from 6517 l/cow to 7321 l/cow with the same feed volume used. "Forage quality has a large impact on yields achieved on the farm year-to-year," says David.

The carbon attributed to the feed purchased on this farm is much lower than the average farm as demonstrated by the emissions bar chart. The difference in yield performance between the two years assessed shows a stark contrast, in having a higher energy, more digestible forage available, the rumen will operate more efficiently releasing less methane. As methane is a potent greenhouse gas this will mean a reduction in total carbon from the rumen.

Heifer rearing and cull rates
Generally, it's accepted that rearing heifers to calve at 24-26 months is more economic and that should achieve a low carbon footprint in terms of emissions from unproductive stock. David agrees this may well be the case, but is keen to test an alternative theory for his farm, increasing age of first calving to three years, from close to two, for the last two years. "This is currently increasing our carbon footprint, but could reduce it in the long run, as I'm hoping cows will live longer so we end up with fewer unproductive animals," he says.

"We weren't happy with the size of heifers calving at 24 months. Under our organic system we can't push them as calves and on the HLS ground we are prevented from feeding any concentrate at grass. This limits potential growth rates."

"We find those calving now at three years are better grown, calve more easily and produce a very good first lactation yield. We are hoping to get an extra lactation or two from them and reduce the culling rate to 10-15% a year." The current culling rate is 15% a year, already below the UK average.

Why have a carbon footprint completed on your farm?
"I went to a DairyCo presentation about the carbon footprint of dairy farming and decided to sign up for this project because it would challenge us to look at the efficiency of our farm and where we could improve it. We are always on a learning curve."

![DairyCo]

Richard Jones and family, Hackett Farm (Kilgetty, Pembrokeshire)

Farm Business
This family farm is run by Richard and William Jones, with parents Edward and Margaret working part-time on the farm and recently Richard's son Tom has returned from university to join the business. Allocated to dairy production is 109ha (270 acres) of mainly owned land, including some away land. About a third of the farm is heavy clay with the rest clay loams. Annual rainfall is about 1200mm (50in).

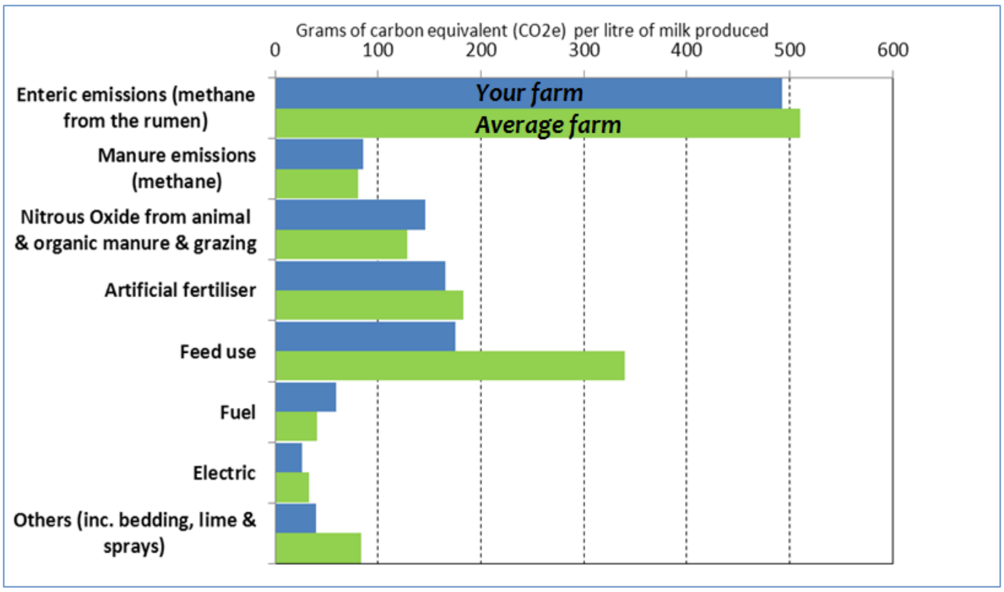
Typically 28ha (70 acres) of spring barley is grown, allowing for reseeding of grass. In most years 16ha (40 acres) of this is whole-cropped and 12ha (30 acres) combined and rolled for stock. The main enterprise is dairy cows, with replacements home-reared. Dairy beef animals are also finished, but this enterprise will be reduced as cow numbers are increased from home-reared replacements now Tom has returned home.

Dairy System
The 170-cow Pedigree Holstein herd has autumn and spring calving groups, each calving over 3-4 months. Average yields increased from 6000 litres to 7200 litres from spring 2011 to spring 2012 from 1.5-1.6t of concentrate/cow a year. Milk is sold to First Milk. The herd is free from BVD, IBR and Johne's, but has lost cows to bovine TB in recent years.

Cows are milked in a 10:20 herringbone parlour, which is currently deemed adequate but it is likely to be replaced in the next few years as cow numbers increase. There are 200 cubicles, which are bedded with sawdust.

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



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Farm's carbon footprint – 1,019g of CO_2e/l of milk (previous year 1,334g)

Feed use efficiency
The Jones's feeding system is based on a 'keep things simple' approach. "In winter we feed a forage mix of 25% fermented whole crop barley and 75% grass silage plus 2kg of a 20%

crude protein concentrate blend in the trough," says Richard. "Then in the parlour we feed an 18% crude protein blend to yield, at up to 8kg a head a day."

The grazing season is extended in spring, but not in autumn. "Good tracks to pasture mean an early turnout in late February is usually possible with the herd strip grazing on a rotation," says Richard. "The farm is in a wet area and with freshly calved cows coming into the herd in autumn, they are often fully housed by late October."

Once cows are fully out the only supplementation is a concentrate blend fed to yield in the parlour, with use kept at a moderate level. The blend required to balance the ration has a moderate protein level of 18-20%, so it includes some by-products and little or no soya.

To spring 2012, average concentrate use was 0.22kg/l of milk down from 0.25 the previous year. Overall the concentrate use per cow was similar in both years (less than 100kg higher) but milk yield a cow increased from 5941l to 7201l, increasing total herd output by 200,000 litres. "Milk yields increased because we made the best silage we have ever made on the farm," says Richard. "Improving cow genetics probably also helped."

This increase in milk yields with reduced concentrate input is the main driver behind the carbon footprint per litre falling year on year. Higher yielding cattle produce less methane per litre and methane is a potent greenhouse gas. High energy silage is more efficiently digested in the rumen with less methane as a by-product of the digestion process.

Herd replacements
As the family have introduced calving blocks over the last 2-3 years, there has been a tendency to serve heifers older to get them into sync with the herd, seeing some reach 30 months old by calving.

"Most have been allowed to grow too big by the time they are served," admits Richard. But the vet and his son Tom have taken a fresh look at their management, they conclude that they are well grown enough to get them served to calve at 22-25 months old. "This is now the policy and it's reducing rearing costs and the number of unproductive stock on the farm, as well as increasing the herd size as quickly as possible." Reducing this calving age should see a decrease in carbon footprint by up to 5%. They are also serving heifers with sexed semen to increase the number of high quality replacements.

TB means they can easily lose more cows than they have planned, despite generally having a very low replacement rate which is attributed to high herd health, below average mastitis incidence and using a foot trimmer regularly to successfully reduce lameness in older cows. Without TB culls the replacement rate is 16%, allowing fewer herd replacements to be reared.

TB and TB restrictions can have a marked effect on the carbon footprint of a farm. If more replacements have to be reared each year to cover the risk of losing cattle then this means more heifers will be on the farm at any one time, heifers that consume inputs and emit methane but produce no milk and also it reduces the potential for the farm to generate dairy X beef for sale into the meat sector which would take with them a proportion of the carbon generated on the farm for that year.

Energy use
The farms electric use is 0.043KWh/l of milk produced, well below the average 0.052KWh/l, with the farm using 52700KWh in the year to spring 2012 down from 57000KWh in the previous year. The difference between years is accounted for with moving from rolling their own feed barley to using a contractor with a diesel powered machine. General efficiency in electric is attributed to cooling milk with a pipe cooler installed many years ago, which

reduces milk to 8°c in summer and 6°c in winter before it enters the bulk tank. They also try to keep milking times down to about 2.5 hours. “We usually have a second person coming into the parlour at key times to speed up milking – possibly for up to half the milking in all,” says Richard.

A heat recovery unit has not been installed to warm wash water, but it is deemed to be worth the investment. “We will install one when we put in a new parlour, which we are likely to do in the next few years.”

The brothers are keen to invest in renewable energy and are seeking planning permission for a 50kw wind turbine on the farm. “It’s a big investment, but we’re looking at it as part of our pension plan,” explains Richard. “We could invest in more cows, but once the wind turbine is up it won’t take as much looking after and the return should be better. We’re hoping it will cancel out the farm’s electricity bill.” They’d prefer to invest in wind power rather than solar panels, because they believe the return will be better. “But if planning permission isn’t granted, we’ll likely put solar panels on the roof of the new parlour.”

Diesel use is slightly above average, which is believed to relate to keeping stock on away land.

Fertiliser use

Part of the drop in carbon footprint between years is accounted for by a reduction in purchased fertiliser from 75kg N/ha to 52kg N/ha. This is partly explained by a better grass growing season in 2011, with a good quantity of first cut made allowing fertiliser savings. But the fertiliser plan set out in spring had also been revised to reduce costs by targeting use of slurry nutrients, with slurry mainly applied with an umbilical system after first and second cut silage. However, fertiliser use will not be quite so low in future years as Richard is keen to keep grass yields up.

“A local contractor has now purchased a trailing shoe which we will likely use at least some of the time in future to improve efficiency further and because it scores points towards the new Glastir environmental scheme in Wales, which we’re considering applying for when our current Tir Gofal agreement ends.”

Rotating cereals around the grassland area and new more nitrogen responsive swards also contribute to fertiliser use efficiency. They would like to be able to rely on clover more but docks are a problem and clover-safe sprays are expensive.

Why have a Carbon footprint completed on your farm?

“It’s allowed us to look at figures we don’t usually look at, but which have an impact on our efficiency,” says Richard. “We’ve been able to benchmark our fuel and electricity use year to year and against other farms and the assessor has given us some useful tips on securing a cheaper electricity contract for the farm. The reports we’ve received have been useful and interesting. They’ve made us aware of the environmental impact of efficient feed use.”

Neil Morgan, Trederwen Hall (Llanymynech, Powys)

Farm business

Neil and his mother Vidah farm 70ha (173 acre) at Trederwen with land from heavy clay through loams to deep self-draining soils. Average annual rainfall is about 1000mm (50in).

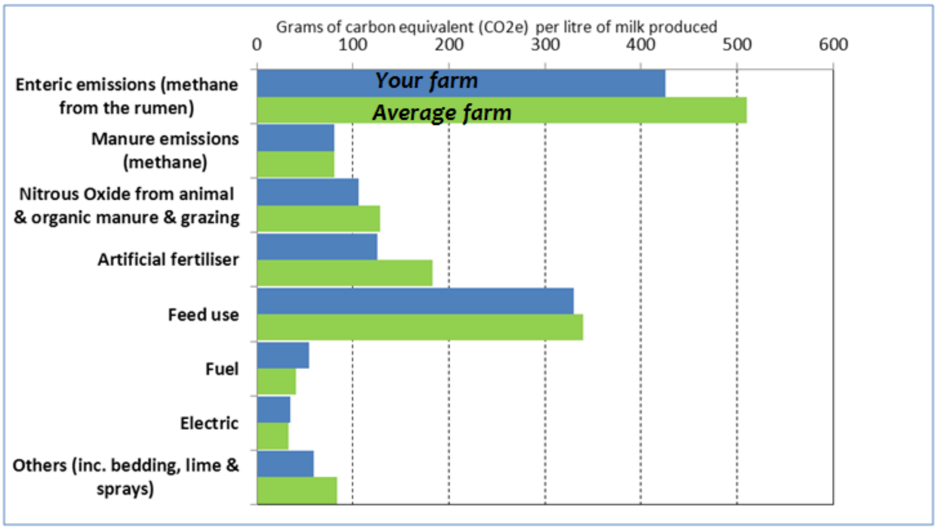
The cropping includes 9ha (23 acres) of maize, 6ha (14 acres) of wheat, some of which is whole-cropped, with most of the rest in four to seven year grass leys. The aim is to grow as much feed as possible for the dairy herd on the farm.

Dairy system

The facilities are suitable for 120 Holstein Friesian cows and the aim is to feed cows well to increase yields to above 9000 litres, with that being achieved prior to a TB breakdown which saw all remaining milking cows culled in spring 2011. Restocking began at the beginning of 2012 with imported heifers and home-bred replacements, which were thankfully saved from the compulsory order to cull.
This wet farm makes it better suited to high yields from all year round calving cows, than extended grazing, says Neil.

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



The chart above represents all emissions generated by the dairy over the 12 month period assessed. Carbon subsequently allocated to cull beef or calves is included within the scope of the graph hence the total will not equal the CO_2e figure quoted below which does not include the carbon allocated to other beef produced.

Farm's carbon footprint – 1,101g of CO_2e/l of milk (previous year 1,250)

Injecting slurry and productive swards save fertiliser

Neil's purchased fertiliser use is about 30% less per l of milk produced than the average farm which has been carbon foot printed. "We're growing a mixture of forages and so our grass is 4-7 year leys, so they are high yielding and respond well to nitrogen," he says. "We recognise new grasses don't last forever and their yields will fall. But we don't rely on clover, because it makes it more expensive to control docks."

"We soil test each field before ploughing and apply lime when it's needed." Most of the land is ploughable and so crops can be rotated around the farm, with solid muck going on before ploughing for maize.

To maximise use of the nutrients including the nitrogen in slurry it's generally injected, using an umbilical system, or otherwise applied with a dribble bar. "We can get to the whole farm with slurry," adds Neil.

This allows him to apply at moderate rates across a large area. "We also find we can graze cows soon after injecting, unlike using a splash-plate." Injecting slurry will also help make the farm eligible for the Glastir environmental scheme.

Very little phosphate and potash has to be purchased, although a little is often put on with purchased nitrogen as Neil buys a 25.5.5 blend as well as ammonium nitrate for grassland and some potash is applied to maize.

Artificial fertiliser is manufactured in a high energy process meaning it has a high associated carbon cost per kg to apply. When the fertiliser is broken down there are also atmospheric losses of nitrogen as greenhouse gasses so both elements considered, the artificial fertilisers used by a farm must be applied efficiently to complement the use of home produced manures and yield the optimum in dry matter production possible.

Feeding mixture of high quality forages key to efficiency

Knowing the quality of forage is seen as paramount to efficient feeding. "We analyse silage routinely as we go through the pit so we can balance the concentrate blend, particularly for protein," says Neil. To ensure high quality silage is made, it's typically cut on May 12th as soon as there is sufficient bulk and an inoculant additive is used. In early 2011 the silage was 71 D-value, 12 MJ/kg DM of ME and 15% crude protein.

"We always make some hay for the cows too, as we prefer it to putting straw in the ration to slow digestion." This is mixed with maize, fermented whole-crop and grass silage in a tub feeder with 4kg of blend, with the crude protein content adjusted as necessary depending on the protein levels from forage analysis.

"Concentrate is also fed to yield in out of parlour feeders and a small amount of concentrate flat rate in the parlour." This is a 17% crude protein compound is fed at up to 9kg a cow in total in the parlour and out of parlour feeders.

"Cows only go out to graze in the day time from May," says Neil. "We tend to strip graze to make the best use of the available grass." Brewers grains are fed when available and these can be considered a low carbon option due to them having already been used in the human food chain, much of the carbon from the crop and processing is therefore allocated to the beer.

Heifers reared for 24 month calving

"There is a high cost in getting heifers well grown enough to calve at 24 months," says Neil. But he does think the extra effort and feed worthwhile to minimise the unproductive stock the farm has to carry and to get improved genetics into the milking herd faster.

Vidah rears the calves and is keen to ensure they are well grown and healthy for weaning, adjusting the age of weaning when necessary. The hutches which accommodate five calves are labour intensive. "But when we reared calves in old buildings, pneumonia was often a problem. In the hutches, we only see the odd one or two a year."

Calves are reared on milk replacer, to minimise the chances of calves contracting TB. Once weaned, they are fed on an 18% crude protein rearing nut and straw. "We always weigh them before worming so we can check they are growing well," adds Neil.

They tend to stay inside on their straw and concentrate diet, to keep growth rates up, until after serving, then go out to grass.

The effect of TB on the herd in the previous year is likely to impact on the carbon footprint of the milk produced over the next few years. With a high number of milking heifers in the herd at current, average yields are likely to be down coupled with this, there is a high number of replacements on farm not producing milk; both likely to increase the footprint per litre in the short term.

Electricity savings

The farm's electric use was found to be 0.07KWh/l of milk produced, higher than the average of 0.052KWh/l. "We now know there is scope to improve," says Neil.
"We've also been made aware that our night usage means we could save money with an off-peak rate, which we haven't had before. When our current contract ends we will be looking into that."

"We also recently had to replace one of our water heaters, so we chose a well lagged tank, which will cost less to run." A heat exchanger for the DX bulk tank is currently being considered and it may be eligible for a Glastir grant.

Milk cooling is already quite efficient with a plate cooler installed. However, Neil is considering the economics of changing from two vacuum pumps, the second one installed when the parlour was expanded, for one. But is not yet sure the economics will stack up.

He has already invested in buying and installing a 4kw solar panel and is selling the power to the National Grid, with the rate paid higher than he pays to buy electricity because it was installed when the Feed In Tariff was about its highest in p/KWh. "Within 6 years, it should have paid for itself," he adds.

Why have a carbon footprint completed on your farm?

"We feel it's a good thing to have done and we've identified we can save quite a bit of money on our electricity bills," said Mr Morgan.

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Philip, Kath and Matthew Smith, Lower Castle Hayes Farm (Burton-on-Trent, Staffs)

Farm business

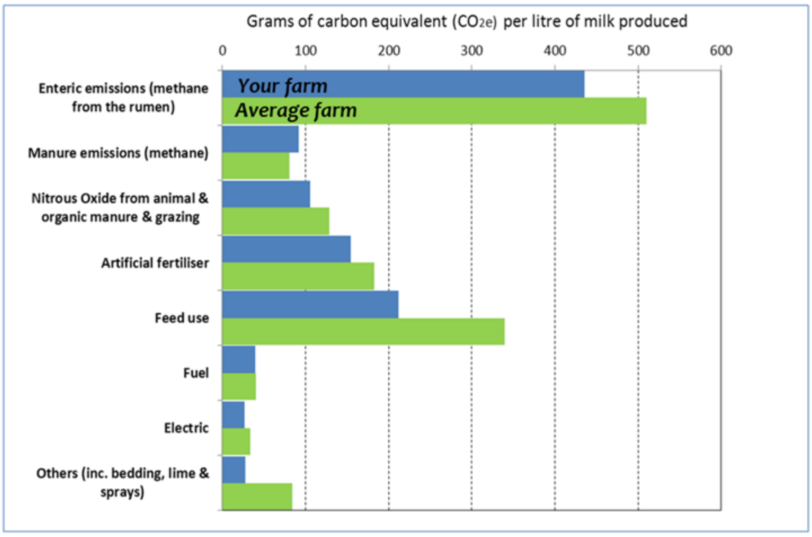
This family partnership has held the tenancy at Lower Castle Hayes Farm for 12 years. The farm extends to 160ha (400 acres) of medium to heavy loams, of which 144ha (355 acres) is allocated to the dairy enterprises. It's cropped with 30ha (76 acres) of maize, 8ha (20 acres) of winter wheat for crimping, 75ha (173 acres) of grass leys and 30ha (74 acres) of permanent pasture. Annual rainfall is 650mm (26in).

Dairy system

Currently, the 250-cow herd includes some pedigree Holsteins, with numbers increasing in recent years through home-bred replacements, up towards a maximum of 270 cows. However, the herd is now being crossbred with carefully selected Montbeliarde sires, using sexed semen. The Smiths expect to continue to achieve an average yield of about 9000 litres a cow, but for crossbred cows to live longer, even though the farm's culling rate is already below average at 26% a year.
Cows calve from June to January with a short calving interval, helped by the use of heat detection pedometers and computer monitoring. The farm has a 14:28 herringbone parlour. Milk is sold to Arla.

Key factors contributing to carbon footprint

A graph to demonstrate the contributions of different sources of greenhouse gases on the farm towards the total emissions generated per litre produced.



The chart above represents all emissions generated by the dairy over the 12 month period assessed. Carbon subsequently allocated to cull beef or calves is included within the scope of the graph hence the total will not equal the CO_2e figure quoted below which does not include the carbon allocated to other beef produced.

Farm's carbon footprint – 1,033g of CO_2e/l of milk (previous year 997)

Quality forage boosts feed efficiency

Quality of forage and a consistent total mixed ration are key to the good feed conversion efficiency on the farm, which is seen as a more important target than yield itself. "We're trying to eliminate things that restrict yield by feeding a good diet," says Philip. "But we're not pushing yield, we want to promote long term performance."

"The quality of forage is key to our business. Grass silage is cut in early May, when the weather is right, in preference to waiting for bulk. Then we cut every five weeks, so our first and second cuts are the same quality."

The first cut analysis for the year of this footprint shows it was 37% dry matter (DM), 74 D-value with a metabolisable energy (ME) content of 11.9MJ/kg of DM and 17% crude protein. Maize silage was 40% DM, 8% crude protein, 73 D-value, 11.3 MJ/kg of ME and 33% starch. “We grow early maturing maize varieties, so we achieve high starch levels”, says Philip. These high quality forages saw a 200 l increase in yield to 9,373 l that year.” Higher forage quality and improved feed conversion will both lead to a lower carbon footprint.

“We’re producing 1.7 litres of milk for each 1kg of feed,” says Matthew. “We ensure an identical mix is fed every time.” That’s whether cows are out grazing by day or fully housed, with the only adjustment made to the quantity put out. The mixer wagon controls allow him to input the number of cows to be fed for each load and it calculates the amount of each ingredient needed. Then when the mixer churns it, it shuts off automatically after the right number of turns, ensuring a consistent mix. “If the trough isn’t empty we cut the amount back by a few cows or if it’s all gone we might add a few,” says Matthew.

When cows are grazing in summer, Matthew ensures there is some fresh grass in front of them each day and adjusts the quantity of supplementary feed that is put out for them accordingly. Paddocks are typically cleared in three to four days and then left to regrow, he explains.

Home-grown crimped cereals make up a good proportion of the ration. “When the premium for malting wheat fell, we realised that rather than sell it and buy back feed wheat, it was more economical to crimp our own wheat,” says Philip. “The chaff adds another 20% to the bulk, we have no drying costs and it’s a better quality feed with slower release starch.”

The Smiths are keen to feed by-products in the mix. The 39% crude protein blend includes distillers’ grains, as well as rapemeal and soya. Protected minerals and salt are also fed. The mix includes 1kg a cow of straw to slow down the cow’s digestion. No concentrate is fed in the parlour.

Heifer rearing & heat detection
With a tight stocking rate, keeping the heifer calving age to 24 months is minimising the number of unproductive stock on the farm, “but they need to be healthy and feed well to get them to the correct size for serving,” explains Matthew.

“We make sure they get plenty of colostrum. Then rear them on milk replacer to keep feeding consistent.”

“Post weaning, we feed 2kg of concentrate in troughs every day up to serving. This gives us the opportunity to have a close look at them every day and pick up any problems. Heifers are regularly wormed, as well as being vaccinated for leptospirosis, BVD and IBR.”

The heat detection system allows for the reduction of calving interval and improved management of milk production profiles. This will keep the footprint down by ensuring a greater number of calves are born each year, some of which will go for beef production and take a proportion of the farm emissions with them into this other sector also the yield per cow should be maximised.

Slurry separation saving P and K inputs
All the farm’s phosphate and potash requirements are being met by home produced manures and slurry, with the liquid portion of separated slurry being spread on grassland through the summer for optimum efficiency.

“Cow housing has automatic scrapers,” says Philip. “This scrapes into channels which lead to a central pit, then it goes through the separator.” The liquid is stored in slurry towers and the solid material heaped up.

“Liquid is applied to silage ground after each cut and before first cut when ground conditions allow,” says Philip. “The separator allows us to spread through the summer without contaminating the next crop. We’re eliminating pollution risks and saving 25% on our fertiliser costs.”

Slurry is spread with an umbilical system with a low trajectory splash-plate. “We’ve considered injecting it, but because we go on three or four times a year it would damage the grass root structure,” says Philip. Nitrogen is also accounted for in these applications, with a further 180kg of purchased N/ha going on to achieve high crop yields.

The solid manure is spread in autumn on wheat ground and in spring on maize ground. “But some is exported to a neighbouring farm to comply with Nitrate Vulnerable Zone (NVZ) regulations.”

Heat exchanger contributes to low electric use
A heat exchange unit installed on the DX bulk milk tank contributes to the farm’s low electric use at 0.045KWh/l of milk produced, compared with a 0.052KWh/l average, even though slurry is separated using electric motors.

Philip reckons it saves more than 50% of the farm’s water heating costs. “The heat exchanger captures heat from the refrigeration unit to heat the wash water, so its 55°C when it enters the hot water tank, so we only have to heat it to 85°C. The water tank is heavily insulated, so it only loses 1°C in 24 hours.”

“The heat exchanger is also cooling the bulk tank coolant, so it doesn’t take as much energy to cool milk. When we bought the tank, we chose one with its own cooling system, so it was easier to install and keeping the fans outside and dust free makes the fans more efficient,” he says. They also use a variable speed milk pump which means milk can go more slowly through the plate cooler, so it’s down to 17°C before it goes in the bulk tank.

To keep electric bills as low as possible, they make best use of an off-peak rate. “More than 40% of power used is off peak, including most of the morning milking and all the slurry separating. We’ve been able to negotiate a good tariff for our off-peak electric, producing good financial savings.”

Why have a carbon footprint completed on your farm?
“We are keen to minimise waste on the farm and maximise use of the farm’s resources,” says Philip. This includes the farm’s water use, with a borehole drilled and recycling of water where possible.

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Glossary

Atmospheric deposition
The 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 Dioxide Equivalents (CO_2e)
CO_2e 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

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

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 the either side of the centre (average) line. See also frequency distribution, normal distribution, and standard distribution.

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

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 CO_2 (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.

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, then there is no mode.

r^2 (r-squared)
Is the coefficient of determination and is defined as the percent of variation in the values of the dependent variable (y) that can be explained by variations in the value of the independent variable (x).

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
Is 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
Is 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.

Sustainable agriculture
Sustainable agriculture simultaneously increases production and income, adapts to climate change and reduces GHG emissions, while balancing crop, livestock, fisheries and agroforestry systems.

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, and (2) Dependent variable: that can take different values only in response to an independent variable.

Weighted mean
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. Weightings are the equivalent of having that many like items with the same value involved in the average.

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