Guidelines for the Carbon Footprinting of Dairy Products in the UK

SEPTEMBER 2010

CARBON TRUST

Dairy UK DairyCo

Dairy UK is the 'Voice of the Dairy Industry'.

Dairy UK represents the interests of dairy farmers, producer co-operatives, manufacturers of dairy products and the processors and distributors of liquid milk throughout the United Kingdom. This supply chain approach is unique within the global dairy industry.

Between them Dairy UK's members collect and process about 85% of UK milk production.

Mission Statement: "To provide dynamic leadership to the entire UK dairy sector and to seek to create an environment which allows the sector successfully to compete and realise a sustainable future."

For more information, please contact Simon Bates at info@dairyuk.org or on 020 7486 7244.

DairyCo's aim is to promote world class knowledge to British dairy farmers so they can profit from a sustainable future.

To achieve this DairyCo aims to:

- Ensure farmers have access to world class information needed to improve competitiveness, GHG reduction and productivity
- Ensure farmers have access to direct and indirect support to help them improve their profitability through better business management
- Ensure that dairy farming is reducing its impact on the environment
- Ensure farmers understand the benefits of breeding and use the related tools

DairyCo is funded entirely by milk producers, via a statutory levy on all milk sold off-farm, at the rate of 0.06p per litre. This provides an annual income of around £6.5m.

DairyCo is a division of the statutory levy board, the Agriculture and Horticulture Development Board (AHDB).

For more information, please contact Jennie Tanner, DairyCo R&D on 02476 478 685 or jennie.tanner@dairyco.org.uk or please refer to our website www.dairyco.org.uk

The Carbon Trust is a not-for-profit company with the mission to accelerate the move to a low carbon economy. We provide specialist support to business and the public sector to help cut carbon emissions, save energy and commercialise low carbon technologies. By stimulating low carbon action we contribute to key UK goals of lower carbon emissions, the development of low carbon businesses, increased energy security and associated jobs.

We help to cut carbon emissions now by:

- Providing specialist advice and finance to help organisations cut carbon
- Setting standards for carbon reduction

We reduce potential future carbon emissions by:

- Opening markets for low carbon technologies
- Leading industry collaborations to commercialise technologies
- Investing in early stage low carbon companies

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The above organisations have contributed to the development of these guidelines

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Acknowledgements

This document was produced with the sponsorship of DairyUK and of DairyCo. Acknowledgement is given to the staff of both organisations, who helped with the development and review of these guidelines. The document was reviewed by the DairyUK Sustainability & Environment Committee, and by the DairyCo GHG Industry Working Group.

Review of document

It is intended that this document will be reviewed at intervals of two years, to reflect changes in the science and practice of product carbon footprinting.

August 2010

1 Introduction

1.1 Scope of document

This document provides guidance on the calculation of product carbon footprints for dairy products.

The product carbon footprint is the measurement of all the greenhouse gasses emitted during the life cycle of the product. The greenhouse gases included within the scope of the measurement are those listed in Annex A of the PAS 2050[1]. The Greenhouse Gas emissions are expressed as Carbon Emissions in terms of CO2e (Carbon Dioxide equivalent) by using the latest IPCC 100-year global warming potential (GWP) coefficients as specified within the PAS 2050.

This document applies the methodology of the PAS 2050 specifically to the dairy sector, and relies heavily upon documentation within the Footprint Expert™ Guide, which itself provides generic guidance for the application of PAS 2050.

This document defines the method for calculating the greenhouse gas emissions for each phase in the life cycle of the dairy product.

Products covered in scope of this document are (see section 5.3 for more details):

- Milk
- Cream
- Milk Products
- Cheese
- Butter
- Yogurt

1.2 How to use this document

This document is intended to provide guidance in the measurement and calculation of the carbon footprint of dairy products. It is complementary to the PAS 2050, by providing sector specific guidance for the dairy industry. This document also references Footprint Expert™[2] which provides generic product carbon footprinting guidance and some specific data factors for use in footprinting. PAS 2050 and Footprint Expert™ are described further in sections 1.6 and 1.7.

The document is intended to be used both by practitioners who are carrying out a carbon footprint assessment, and also as background information, so that those people involved in the process (e.g. farms providing data) have a better understanding of the process.

The document is structured as follows:

Section 1 - Introduction (this section) describes at a high level what carbon footprinting is, and describes some of the key concepts used in product carbon footprinting.

Section 2 - Typical footprinting project takes the reader through the stages of a typical footprinting project, discusses the reasons for measuring a carbon footprint and explains what you should expect from the process of footprinting a set of dairy products.

Sections 3 to 9 provide the technical guidelines to be followed through the different life cycle stages of the product.

Section 3 provides the technical guidance for measuring the carbon footprint for the on farm milk production.

Section 4 provides the technical guidance related to data sampling requirements, thus specifically addressing the question of how many farms need to be sampled when collecting data.

Section 5 provides the technical guidance for measuring the carbon footprint due to the dairy processing stage of the life cycle.

Section 6 provides the technical guidance for measuring the carbon footprint due to transportation.

Section 7 provides the technical guidance for measuring the carbon footprint due to the distribution and retail stage of the life cycle.

Section 8 provides the technical guidance for measuring the carbon footprint due to the use phase of the life cycle.

Section 9 provides the technical guidance for measuring the carbon footprint due to the End-of-Life stage of the life cycle.

The Appendices cover default data items that may be used in the footprinting process, further detail on some technical aspects of the process, a glossary of terms, and a list of references.

1.3 Life Cycle Assessment and Phases

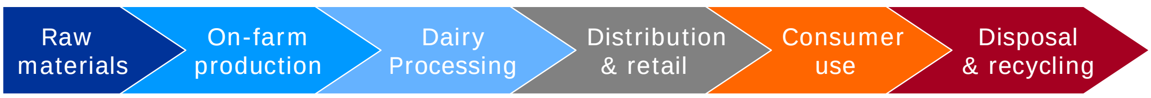
Life cycle assessment (LCA) refers to an evaluation of the actual impacts a product, service or process may have on the environment. Calculating a product carbon footprint involves applying the technique of LCA specifically looking at the impact of greenhouse gas emissions.

When carrying out a carbon footprint assessment for dairy products, the key phases of the life cycle are as follows:

- On-farm milk production (including supply of raw materials such as feeds and fertilisers to the farm)
- Dairy processing
- Distribution and retail
- Use by consumer
- End-of-Life phase (covering disposal and recycling).

A carbon footprint covering the full life cycle is known as business-to-consumer (B2C) and is also referred to as 'cradle to grave'. Figure 1 illustrates the key stages for a B2C life cycle assessment.

Figure 1: The key stages of a dairy B2C life cycle assessment



For a business-to-business (B2B) carbon footprint, the life cycle includes the raw material and production phases, finishing with a product that is then available to a downstream business. Within the dairy sector a B2B footprint would typically be either to "farm gate" (including all emissions upstream of the farm and on farm), or to “factory gate” (including emissions to the farm, on the farm and at the dairy processing stage).

1.4 Functional units

The functional unit is the basic amount of the product, in terms of which the carbon footprint is expressed.

For example, in the case of liquid milk the functional unit could be a litre, and the carbon footprint would then be expressed as “kg CO2e per litre of milk”.

When selecting the functional unit, it is important that it is a meaningful and recognised unit. It may be an industry standard measure, or a measure used widely in the industry. Typical examples for the dairy situation would be litre, pint, and kilogram. For food products it is common to use the same functional unit as used for nutritional information (i.e. per specified serving quantity).

1.5 Data quality

A key issue for managing uncertainty in product carbon footprints is data quality. The aim is to balance confidence in the result with requirements in terms of cost of data collection and data availability.

PAS 2050 section 7.2 discusses data quality rules in terms of how appropriate the data is related to the measurement being undertaken.

The Footprint Expert™ Guide extends these rules to provide specific guidance on applying relevant data quality rules to the most significant parts of the footprint. The approach is summarised as follows:

> Classify the different activities based on their contribution to the overall footprint into three groups (this is known as ABC Analysis). The activities that contribute the top 70% of emissions are in the A group, those that contribute the next 25% are in the B group and the final 5% make up the C group.
>
> The data quality requirements for these three groups are then set as:
>
> ‘Good quality data’ required for group A
> ‘Acceptable quality data’ required for group B
> Data quality assessment not necessary for group C

For dairy products a significant proportion of the total life cycle emissions are from the on-farm production (e.g. for liquid milk this is typically 70% to 80% of the total emissions). Therefore it is especially important to have a rigorous approach to data collection from the farm. Because of this it is also important to follow specific guidelines concerning the number of farms to be sampled in the data collection process for the carbon footprinting. It is for this reason that in this guidance document there is a complete section related to data sampling requirements (section 4).

Where reliable primary data is available it should be used in preference to secondary data, however where the contribution due to a specific item is small or where the primary data is not available then secondary data may be used, provided that data quality rules are met.

1.6 PAS 2050

PAS 2050 is a 'publicly available specification' and is the first standard method for assessing the greenhouse gas (GHG) emissions associated with a product or service. This independent standard was developed by the British Standards Institute (BSI), and co-sponsored by the Carbon Trust and the UK Department for Environment, Food and Rural Affairs (DEFRA) and published in October of 2008. PAS 2050 provides a systematic framework for organisations and aims to aid the quantification of GHG emissions associated with a particular product or service across a supply chain.

Alongside this, PAS 2050 provides a common basis for comparison and claims of conformity of the results through offering practical guidance on the monitoring and measuring of the life cycle GHG emissions. In addition, the Code of Good Practice[3] provides guidance and structure for reporting the life cycle GHG emissions of products.

1.7 Footprint Expert™

Footprint Expert™ is a product developed by the Carbon Trust Footprinting Company to support organisations in product carbon footprinting. It is referenced here as it supports the footprinting process and provides generic guidance in more detail than is appropriate in this document. The use of common data (such as emissions factors) and calculation methods from Footprint Expert™ helps to ensure consistency and comparability of results. If you intend to have your footprint calculation certified by the Carbon Trust Footprinting Certification Company, then there are certain elements of Footprint Expert™, which are mandatory to follow for comparability reasons.

This document provides a comprehensive overview of the carbon footprinting of dairy products; however it focuses on those requirements that are unique to the dairy industry. Thus more common requirements (e.g. calculation of emissions due to transportation) are only covered in summary here, and the reader is referred to the Footprint Expert™ Guide for more detail. In addition, there are a number of calculators in Footprint Expert™ that are useful in determining the carbon footprint – again an example is the transportation calculator, while another example is the crop calculator which calculates the emissions from crop growing and would be used where crops are grown as feedstuffs for the cows. Also the Footprint Expert™ Reference Database will provide a number of common and default data values for use in carbon footprinting (as Footprint Expert™ is updated and new releases are issued these data values will be also kept up to date).

The Footprint Expert™ toolkit comprises four key components:

1. **Footprint Expert™ Guide**: A comprehensive guidance document to product carbon footprinting;
2. **Footprint Expert™ Reference Database:** The reference data includes emissions factors for common processes and commodities;
3. **Footprint Expert™ Calculators:** These calculators model emissions for common events; and
4. **Footprint Expert™ Model Framework:** This framework provides Excel templates that aid the development of product carbon footprint models.

2 Typical footprinting project

This section describes a typical Carbon Footprinting project for dairy products. It describes the typical stages of a project, what is involved, why you would do this, and what the benefits are.

2.1 Why measure the carbon footprint of a dairy product?

The concerns over the future effects of climate change are well known, and are being taken seriously by both governments and commercial organisations. The focus on climate change and the mitigation of greenhouse gas emissions is being felt in all industries and sectors. In agriculture in general, and for dairy farming particularly, there is an increasing awareness of the issues. Dairy farming produces the potent greenhouse gases, methane and nitrous oxide, due to enteric fermentation from the cattle's digestive system, from manure storage and usage, and from the use of synthetic fertilisers.

There is, therefore, a strong incentive to understand better the greenhouse gas emissions in order to manage and reduce these emissions. The first step to doing this is to measure the current emissions and identify where the opportunities for reduction are.

The technique of measuring the carbon footprint of a product (e.g. for a litre of milk) uses 'Life Cycle Assessment' principles which looks at the emissions throughout the whole life cycle of the product ("from cradle to grave"). This document provides guidelines for applying this technique specifically for dairy products.

The benefits related to measuring the product carbon footprint include:

- Identify opportunities for cost saving
- Responding to retailers requesting information
- Identify opportunities to reduce greenhouse gas emissions
- Demonstrate 'green credentials' to consumers

2.2 Defining scope and objectives

The first step involves defining the scope and objectives for the measurement project. The project may be instigated by the farmer, by the dairy company or by the retailer; in all cases it is important to understand the reason for the project and what the expected objectives are.

Example 1: for example, the retailer may have initiated the project and the objective may be to measure the carbon footprint from a representative sample of farms. In this case, the dairy processing company will also be involved, and usually a third party consultancy will be involved to collect data and calculate the carbon footprint.

Example 2: for example, the retailer may have initiated the project and the objective may be to measure the carbon footprint from all farms within a milk pool. The results from the project may be fed back to the individual farms with advice on how to reduce emissions. Again, a third party consultancy will usually be involved to collect data and calculate the carbon footprint. The dairy processing company may also be involved.

Example 3: for example, an individual farm (or a group or cooperative of farms) decide to initiate a project. In this case the farm(s) may use a third party consultancy to help with the data collection and calculation. It is important in this case for the farm(s) to be clear what the objectives for the work are, and whether and how the results are to be communicated and to whom.

A further decision to be taken is whether to have the results independently certified; this provides greater confidence in the results and is recommended if the results are to be publicly communicated. The Carbon Trust provides a service for certification of product carbon footprints against PAS 2050 and Footprint Expert™ through its subsidiary the Carbon Trust Footprinting Certification Company.

2.3 Choosing products

The choice of which product to footprint will in some cases be obvious, but in others it may be not. In the case of a farm the product is likely to be a litre of milk leaving the farm gate – this then is known as a B2B (Business to Business) footprint (or “cradle to gate”) and only covers part of the full life cycle. (See section 1.3 for further clarification of B2B andB2C footprints.)

In the case of a dairy processing company that produces many different dairy products (e.g. different types of cheese, butter and other milk products) then a decision is needed on whether to include all products within the scope of the project or to prioritise a sub-group of products to start. This decision will be influenced by the similarity of the products, and the physical nature and geography of the supply chain (e.g. are there multiple dairy processing plants? Are the same products produced in more than one plant? Which milk pools supply which plants?)

There is also the level of sku (stock keeping unit) to decide, for example:

- 1 pint, 2 pint, 4 pint or 6 pint milk packages (or litres)
- Single pack or multi pack
- Different packaging materials for the same product

2.4 Engaging suppliers

Any footprinting project will involve working with suppliers to collect data. The first step is to identify the key suppliers, what information is needed, and what the existing relationship is with each supplier. Depending on the level of information needed from each supplier and the overall objective of the project it may be important to plan clearly the engagement with the suppliers to explain:

- the objective of the project
- what the process will be
- what information will be needed
- what will be done with the results
- what feedback will be provided to the suppliers

Again to illustrate with some examples:

- Where the project is initiated by a retailer, then they will want to engage with the dairy processing company, the farmers and, potentially, upstream suppliers. Where a dairy processing company is footprinting their products then they will want to engage with the farmers in their milk pool.
- Where the project is run by a farm (or group of farms) they will want to understand the key inputs to the farm(s) – for example, understanding the supply of feeds and fertilisers.

2.5 Understanding the process

Once the project is started it is necessary to define in detail the full process at different stages of the life cycle. Building a process map helps to visualise the different process steps, how they interact and clearly identify all the materials and processes.

At the farm level it is necessary to define the boundaries – for example, for a mixed farm identifying the boundaries between the arable, dairy and beef “enterprises” (see section 3.3 on the Farm system for more details of this).

At the dairy processing stage the following need to be clarified:
- Clear definition of the farms in the milk pool (or pools) which supply the dairy
- Process map of the dairy processing, showing what products are produced, where co-products are created, where energy is used, where the energy is sub-metered

For the distribution and retail stage the following needs to be understood:
- Distribution network (including use of RDCs), typical or average distances
- Type and length of storage (chilled or ambient, and number of days)

2.6 Collecting data

Data collection is a major part of the project, and is often carried out (or supported by) a third party consultant who has experience in the dairy industry and expertise in product carbon footprinting. Typically the consultant will prepare a questionnaire for the specific data required. This will be followed by either a site visit or a telephone conference to go through the data requirements. For farm data the majority of the data required will already exist in the normal farm records (e.g. annual accounts, annual milk return). Section 3 “On-farm milk production” explains the different sources of greenhouse gas emissions and thus gives a background as to what data is needed and why it is needed to calculate the carbon footprint.

2.7 Calculating the footprint

The calculation of the footprint requires a model to account for and calculate the on-farm emissions. As this is a specialised area it is normal to use an existing model that has been specifically developed for calculating on-farm GHG emissions. (See section 3.9 for a further discussion of this and of ‘accredited’ models). This calculation will give the B2B footprint to the farm gate. The emissions for the subsequent downstream processes (dairy processing, distribution and retail, use and end-of-life) need to be also calculated. The Footprint Expert™ Model Framework provides templates that help to build up the full life cycle footprint. The Footprint Expert™ Reference Database also includes a number of standard emissions factors that will be used in calculating the footprint (e.g. EF for electricity, EF for various common packaging materials, national average domestic wastage rates).

3 On-farm milk production

3.1 Introduction

The purpose of this section is to provide an overview of the key requirements for measuring the carbon footprint due to on-farm GHG emissions. More detail is provided in the Footprint Expert™ Guide.

On-farm emissions represent a high proportion of the overall carbon footprint for dairy products (for liquid milk this is typically 70% – 80%). There are a number of sources for these emissions, the following being some of the major sources:
- Methane from cows’ enteric fermentation
- Nitrous Oxide and Methane related to manure
- Nitrous Oxide and Carbon Dioxide related to manufacture and use of fertilisers (where crops are grown as feed for the cows)
- Carbon Dioxide related to farm fuel and electricity use

Both Methane (CH_4) and Nitrous Oxide (N_2O) are potent greenhouse gases.

The Global Warming Potential (GWP) of a greenhouse gas (GHG) is a measure of the impact of a given greenhouse gas relative to an equivalent mass of CO_2 over a given time period. The PAS 2050 specifies using the latest IPCC 100-year global warming potential (GWP) coefficients. These current values are 25 for CH_4 and 298 for N_2O.

Note that CH_4 produced from a non-fossil biogenic carbon source (e.g. digested plant matter) has a lower effective GWP of 22.25. See Appendix 2 for further explanation of this.

Regarding the calculation of non-CO_2 emissions from livestock and soils the PAS 2050 (clause 7.8) requires that one of the following two approaches shall be used:

- *"The highest tier approach set out in the IPCC Guidelines for National Greenhouse Gas Inventories, or*
- *The highest tier approach employed by the country in which the emissions were produced"*

The IPCC Guidelines provide a tiered approach to calculation of emissions from agriculture:

Tier 1

- o Simplistic, use of generic default values for emission factors and key variables
- o Typically, this approach is only acceptable where the emissions from the product (e.g. milk, beef, lamb, chicken, etc) contribute only a small proportion of the overall emissions from a product

Tier 2

- o More rigorous assessment of emissions, utilising country-specific emission factors and key variables and, potentially, more advanced equations
- o This approach is acceptable for the assessment of emissions from the product (e.g. milk, beef, lamb, chicken, etc) production

Tier 3

- o Primary measurement of emissions to establish country- or regional-specific emission factors; and/or development of more detailed models that more accurately measure GHG emissions
- o This approach, whilst ultimately desired, is generally not practical. It requires scientific experimentation and research, and requires an extensive international peer review process

Therefore, when calculating the carbon footprint for dairy products, the IPCC Tier 2 methodology shall be followed unless a Tier 3 methodology is available and can be justified.

3.2 Milk pool considerations

The scope of any milk footprinting exercise needs to consider which farms are included within the scope. Typically this will cover all the farms supplying milk to a single 'Dairy Processing Plant' (for the purposes of this document the term "milk pool" is defined to mean all these farms).

When footprinting a milk pool, a representative sample of the farms within the milk pool will be measured (the process for deciding the number of farms to sample is covered in detail in section 4 Data sampling).

The cases to consider in terms of defining the farms within scope:

- Measuring the footprint of milk from a single farm
- Measuring a milk pool (considering all the farms supplying a dairy processing plant)
- Case where a farm supplies milk to more than one dairy
    - o In this case, the farm would need to be included when measuring the footprint of any milk pools that it belongs to

- Case where all or part of the milk supply is from the 'spot market' and, therefore, not from a defined set of farms
  - Where it is not possible to trace the milk supply to a specific set of farms, then a default value will be used. A default UK value will be provided within the Footprint Expert™ Reference Database.

3.3 Farm system

When calculating the carbon footprint of milk from a farm it is necessary not only to identify the sources of greenhouse gas emissions from the farm activities, but also to allocate those that relate specifically to the milk production.

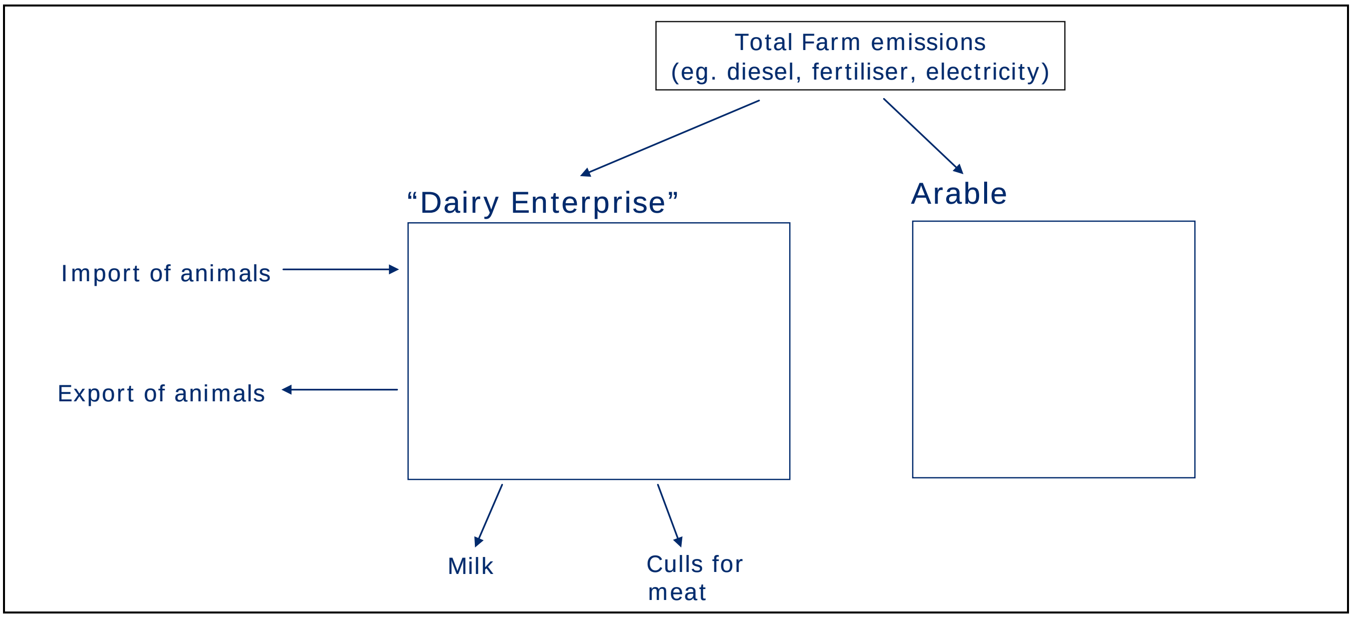
Thus for a mixed dairy and arable farm, there will be some emissions, such as diesel and electricity usage which may only be able to be measured at the farm level, and will need to be split between the arable and dairy production. When it is not possible to sub-divide the emissions based on the process then the PAS 2050 recommends allocation based on the economic value of the co-products.

Thus it is important to understand the farm system, defining the boundaries for the "Dairy Enterprise" and understanding where allocation decisions need to be made.

For mixed dairy and beef herds the allocation between dairy and beef is again done on an economic basis.

Also to be considered is the import and export of live animals, and recognition of diseased and dead animals.

The following diagram illustrates the typical allocation decisions required for a farm.



3.4 Emissions due to enteric fermentation

This needs to be calculated according to a Tier 2 or Tier 3 model and shall consider the following:

- Mix of feed
- Type of feed
- Quantity of feed
- Age of cattle

To reflect the different methane emission rates due to age of cattle the herd should, as a minimum, be divided into the following subgroups:

- Cattle under 1 year old
- Cattle 1-2 years old
- Cattle over 2 years old

Digestible Energy Percentage (DE%) factors are used to calculate the conversion of feed to energy by the cattle and therefore directly affect the methane emissions. The Footprint Expert™ Reference Database contains a list of DE% factors. Where comparability of results is required then it is recommended to use the consistent factors in Footprint Expert™.

3.5 Emissions due to fertiliser usage

The emissions due to synthetic fertiliser production, transport and usage need to be calculated.

The Footprint Expert™ Transport calculator and Crop calculator provide support with these calculations.

3.6 Emissions due to manure

Methane and Nitrous Oxide are emitted due to manure storage and application. The calculation of emissions needs to consider the amount of manure produced, the storage method, the application of manure to crops as a fertiliser (where those crops are being grown as feed for the dairy animals), and the manure deposited by the cattle while grazing.

3.7 Emissions due to feeds

Emissions due to feed need to be considered for both feeds imported and feeds grown on the farm.

3.7.1 Feed grown on the farm

All crops grown on the farm for feed shall be considered (including grazing). The Footprint Expert™ Crop calculator provides support with these calculations.

3.7.2 Imported feeds

For feed that is imported onto the farm, the emissions from land use change, growing, harvesting, and transporting the feed shall be assessed.

Footprint Expert™ Reference Database has a set of emissions factors for feedstuffs. It is important when using secondary data emissions factors that they are representative of the actual feed used, and reflect the distance transported.

3.8 Emissions due to farm fuel and electricity use

Farm fuel and electricity usage related to milk production needs to be calculated.

3.9 Accredited models

The calculation of on-farm emissions related to milk is a complex process, and requires the development of a model to correctly perform all the calculations. A number of proprietary models have been certified by the Carbon Trust as accredited models. (The list of accredited models will be published on the Footprint Expert™ website www.footprintexpert.com).

Thus, in order to calculate a certified footprint it is necessary to either use an accredited model or to build your own model following the guidelines and have it certified. In both cases it is necessary to have the results certified to ensure that valid data and other assumptions have been used in conjunction with the model.

4 Data sampling

4.1 Sampling – general issues

4.1.1 Introduction

Situations can occur during a product carbon footprint assessment where there are a large number of known supply locations for the same product. Ideally data would be collected from each of these locations to generate the most accurate possible model of the supply chain. Clearly though the cost of collecting accurate data from a large number of locations can quickly become prohibitive.

This can potentially occur in the product footprint of any product, but is most prevalent in agriculture, where data is required from each farm known to supply a producer.

This section therefore gives guidance on when it may be appropriate to collect data from a reduced number of locations, how this may be done, and sets a minimum acceptable level for such sampling.

4.1.2 Sampling requirements and footprinting objective

As discussed in section 2.2 "Defining scope and objectives", it is important to be clear on the objective of the footprint assessment. To some extent the objective will influence the level of sampling required.

These sampling guidelines give alternative methods for sampling, and specify the minimum level for sampling. It is always acceptable to sample more than the minimum number of sites. Indeed, there will be many cases where exceeding this minimum level is desirable for the company undertaking this footprinting assessment, even though this increases the cost.

At its extreme this means deciding to collect data from every site (100% sampling), but a decision may equally be made to exceed the minimum without collecting from all sites to improve data quality or to meet objectives of the footprint assessment which the minimum sample may not achieve.

Thus different objectives will have different sampling requirements:

1. To calculate the footprint of each farm
    - Data must be collected from each farm (100% sampling)

2. To help individual farms reduce their footprint
    - Data must be collected from each farm (100% sampling)

3. To calculate the average footprint across all farms
    - Sampling from the recommended minimum number of farms

4. To prove reduction of the average footprint across all farms
    - Sampling from the recommended minimum number of farms, to meet the defined error margin

- If a company wishes to reduce the error margin that they find acceptable then they should sample from a greater number of farms

5. To provide generic reduction advice across all farms
   - The minimum sample will be of some use, but a larger sample would be highly recommended

6. To provide reduction advice for a particular type of farm
   - Sampling will need to be taken from farms of the particular type. The minimum sample will be of some use, but a larger sample would be highly recommended

7. To compare farming practice impacts on footprint
   - The minimum sample will be of some use, but a larger sample would be highly recommended

4.1.3 Frequency of sampling and rolling averages

PAS 2050 and the Code of Good Practice require that footprints are recalculated every two years. However, for agriculture there is significant variability from year to year and thus it is useful to collect data and re-measure the footprint on an annual basis.

Thus the minimum requirement is for data sampling every two years, and the recommendation is for annual data sampling.

Because of the variability from year to year, it is recommended to communicate both an annual footprint figure and a five year rolling average figure.

Obviously, if data has not yet been collected for five years, then the rolling average can only be based on the number of years for which data does exist. (i.e. building up from one to two to three years until five years of data has been collected).

4.2 Sampling of dairy farms

Typically there will be a large number of farms within a milk pool supplying to a specific dairy. Depending on the objective (see “4.1.2 Sampling requirements and footprinting objective”), it is often not cost-effective to collect data from all of the farms within the milk pool, in which case a number of the farms may be sampled and the data from these farms used to represent all of the farms in the milk pool.

There are three basic choices available for the sampling approach:

1. **100% sampling**
   (Full sampling of all farms)
2. **Random sampling without grouping**
   (Sample a percentage of the farms on a random basis)
3. **Sampling with grouping**
   (Sample a lower percentage of the farms, by using a “grouping” system to categorise the farms into a number of groups, and then sample from each of the groups)

The following provides further details of how and when each of these options should be used.

The data and cost requirements of each method of sampling are quite different, and are intended to provide robust statistical results at optimum cost.

The following sections give guidance on minimum sampling levels required, but the objective of the footprint exercise must be always borne in mind to decide if exceeding these gives 'value for money'.

4.3 100% sampling

This option requires collecting data from every farm within the milk pool, and calculating a footprint for each farm.

This option would be appropriate where an objective of the study is to provide individual feedback to each farm. Also when the number of farms in the milk pool is small then it may be appropriate to sample each farm.

4.4 Random sampling without grouping

This option requires collecting data from a random sample of the farms.

The minimum number of farms to be sampled under this option follows a statistical approach:

- The statistical details of this approach are discussed in Appendix 3
- The equation (Equation 1) to determine how many farms must be sampled depending on the total number of farms in the milk pool can be found in Appendix 3 (section "A.5 Random sampling theory")
- The table below provides an extract of the full table for quick reference

Table 1 - Extract of table for random sampling of farms – without grouping

Total number of farms	Random sample size	Percentage sampling rate
5	5	100%
10	9	90%
20	17	85%
30	23	77%
40	28	70%
50	33	66%
70	41	59%
100	49	49%
150	59	39%
200	65	33%
300	73	24%
400	78	20%
500	81	16%
1000	88	9%
5000	94	2%

As with any statistical approach it can be seen that at small population sizes a very large percentage of farms must be sampled, and this declines as the population rises.

4.5 Grouping and then sampling

This option follows a two-stage approach. Firstly, to group all the farms in the milk pool into groups of similar farms. Secondly, to collect data from a random sample of farms in each group.

This is a more refined approach than just taking a random sample from the total population and has the effect of reducing the number of farms from which detailed data is required to be collected. It does, however, have the overhead of the initial grouping process, which requires knowing some high level information about **all** of the farms (this is data that typically the dairy processor will be able to easily collate).

This sampling process is known statistically as "stratified sampling" and more details of the statistical background are in Appendix 3. The objective of the grouping is to divide the total set of farms into groups of farms that are expected to have similar carbon footprints. This process thus has the effect of reducing the standard deviation within each group, and thus reducing the total number of farms which must be sampled to achieve an acceptable margin of error.

4.5.1 The data collection process

The process for grouping then sampling involves two stages of data collection:

1. First, data is collected to allow for grouping to be conducted.
    - This data is needed for all the farms in the milk pool, however it is generally quite simple data and easily accessible
    - The exact data requirements are discussed in the next section (4.5.2) and more fully in Appendix 3
    - A portion, or in some cases all data, may already be known without directly contacting these farms
    - The remaining data should be sought from all farms in the population, and can easily be obtained remotely, e.g. via telephone, or questionnaire

2. Second, detailed data is collected from each of the farms to be sampled following the grouping process. This data is used to calculate the carbon footprint for each farm sampled.

4.5.2 The grouping process - overview

In the case of dairy farms, the following 8 pieces of data are required for each farm:

1. Average milk yield per cow
2. Ratio of forage to concentrates used
3. Proportion of the year animals are grass fed (out to pasture)
4. Amount of fertiliser used on-farm for dairy feed
5. Herd replacement rate
6. Manure management system
7. Irrigation used
8. Total annual milk production (in litres)

Note**: these data items are described in much more detail in Appendix 3 (section "A.1 Data for grouping criteria***")**.*

Items 1 to 7 may be expressed as "either or" (binary) values – for example "high yield" or "low yield", or as discrete continuous values. The 8th item of data (the total annual milk production, expressed in litres) is needed to calculate the weighting that will be applied to each group.

Once the above data has been assembled for all farms three steps are required:

1. The farms need to be placed into groups of similar farms (the process for doing this is described in Appendix 3, section “A.2 Creating groups”).
2. Once these groups have been determined, the table in “4.5.3 The number of farms that need to be sampled”, shall be used to determine the minimum number of farms which need to be sampled (this will permit the valid use of a lower sampling rate than a purely random sample without grouping).
3. Once this is done, the individual farms from which to collect data must be randomly selected from within each group and then the detailed farm data collection and product carbon footprint calculations can be carried out for each of these selected farms.

4.5.3 The number of farms that need to be sampled

The minimum number of farms to be sampled from each group is defined below:

- The statistical details of this approach are discussed in Appendix 3
- The equation (Equation 7) to determine how many farms must be sampled can be found in Appendix 3, section “A.6.4 Sample sizes”
- The number of farms to be sampled is allocated between the groups considering the milk volume contribution from each group
- For 10 farms and below it is not appropriate to apply the grouping method, so the random sampling without grouping should be followed
- Above 10 farms a minimum of 10 farms should be sampled
- The table below provides an extract of the full table for quick reference

Table 2 - Extract of table for sampling of farms following grouping

Total number of farms	Number of farms to be sampled	Percentage sampling rate
5	5	100%
10	9	90%
20	10	50%
30	10	33%
40	10	25%
50	10	20%
70	10	14%
100	10	10%
150	12	8%
200	14	7%
300	17	6%
400	20	5%
500	22	4%
1000	32	3%
5000	71	1%

4.6 Examples of how many farms need to be sampled

The following examples compare the different options for sampling and demonstrate the minimum level of sampling required by each method in these examples:

Example A: 22 farms

Sampling method	Number of farms to be sampled	Number of farms to be sampled (as a percentage)
100% sampling	22	100%
Random sampling without grouping	18	82%
Sampling with grouping	10	45%

Example B: 88 farms

Sampling method	Number of farms to be sampled	Number of farms to be sampled (as a percentage)
100% sampling	88	100%
Random sampling without grouping	46	52%
Sampling with grouping	10	11%

Example C: 350 farms

Sampling method	Number of farms to be sampled	Number of farms to be sampled (as a percentage)
100% sampling	350	100%
Random sampling without grouping	76	22%
Sampling with grouping	19	5%

Example D: 4400 farms

Sampling method	Number of farms to be sampled	Number of farms to be sampled (as a percentage)
100% sampling	4400	100%
Random sampling without grouping	94	2.1%
Sampling with grouping	66	1.5%

4.7 Calculation of carbon footprint for milk pool

Following calculation of the carbon footprint for each of the farms that have been sampled, this needs to be reflected into the carbon footprint for the milk pool that these farms represent. This process is one of calculating the weighted average, and depends on the type of sampling that has been used. The weighting used in all cases is based on the annual volume of milk production (in litres) for each farm.

Where 100% sampling (i.e. all farms sampled) was used then the carbon footprint for the milk pool is the weighted average of the carbon footprints for each of the farms.

Where random sampling without grouping was used then the carbon footprint for the milk pool is the weighted average of the carbon footprints for each of the sampled farms.

Where sampling with grouping was used then the carbon footprint for each group is first calculated as the weighted average of the carbon footprints for each of the sampled farms in the group. Then the carbon footprint for the milk pool is the weighted average of the averages of the carbon footprints for each of the groups.

See Appendix 3 section A.3 for the weighted average calculation.

4.8 Sampling in subsequent years

In subsequent years, the farms sampled should correlate closely with the original sample. If any farms drop out of the sample group (for example, because they have been retired or changed contract) then they shall be replaced by a farm which is close in size and production system.

If the milk pool from which the original sample is selected changes in size, the number of farms sampled shall be changed in line with the sampling methodology. Therefore the process for selecting the farms to be sampled should be reviewed each time a new assessment is carried out. If the milk pool changes then the sampling process shall be applied again.

Also, when doing sampling in subsequent years, data collected from prior assessments may be used to modify sample rates, i.e. having collected data on prior occasions the standard deviation for each sample, grouped and/or all sampled farms will now be known, this may be fed back into the sampling calculator to adjust the size of sample required to meet the acceptable margin of error.

5 Dairy processing

5.1 Overview

This section covers the assessment of emissions due to the processing of milk into different dairy products.

The emissions are due to energy usage, and a key issue is how to allocate these emissions appropriately. In some cases there will be sub-metering in the dairy processing plant, which allows the energy relating to each process to be measured. In other cases there will only be a total energy measurement and the energy then needs to be allocated between the processes.

Additionally, where a process produces co-products then the emissions for the process need to be allocated between the co-products.

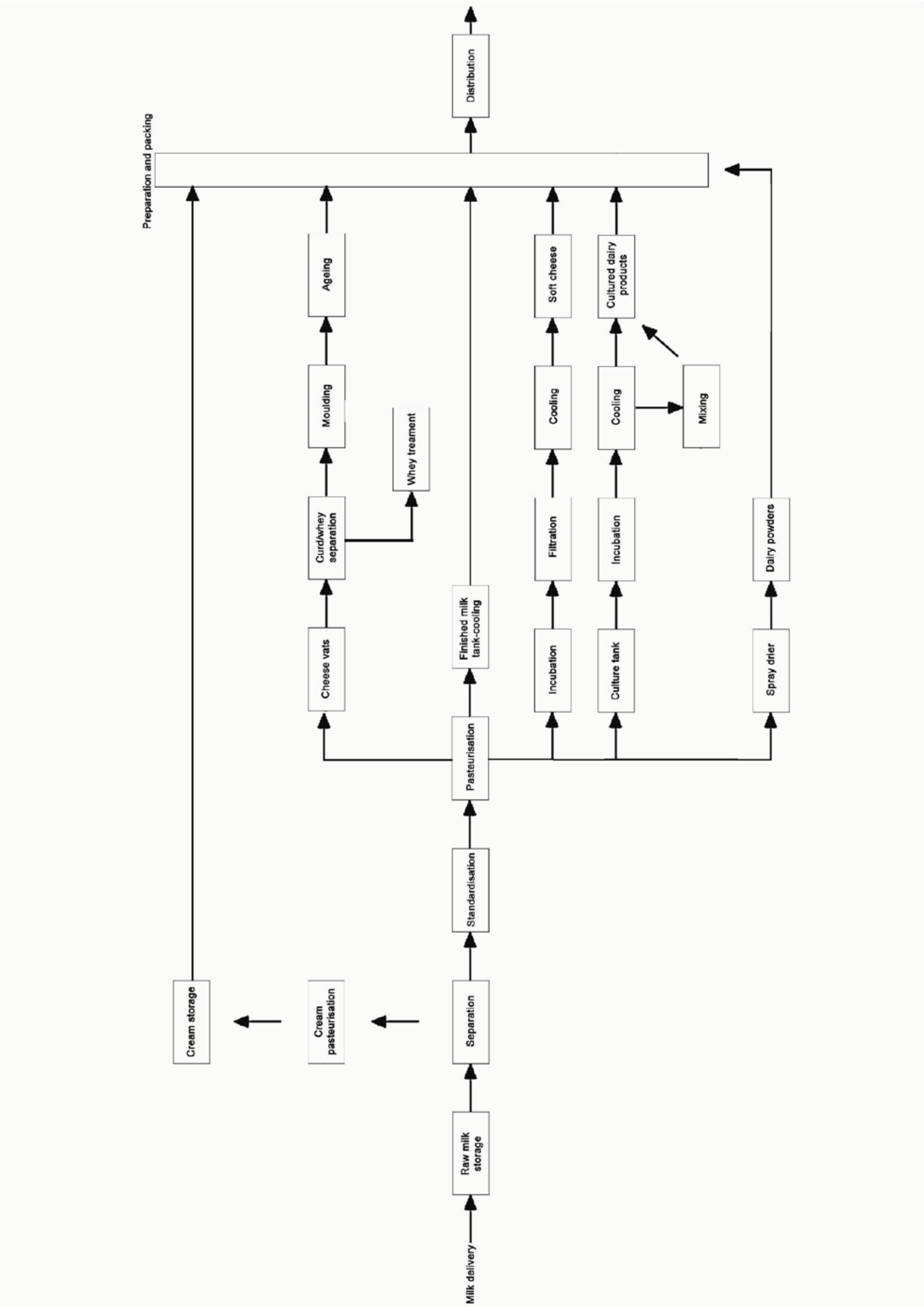
The question of allocation is covered in section 5.2.

Section 5.3 discusses the different dairy products within the scope of this document and any specific issues to be considered for each product.

Section 5.4 covers different packaging types typically used for dairy products and any specific issues to be considered for each type.

To help in understanding the emissions due to the dairy processing it is useful to develop a process diagram, showing the flow of product and identifying where co-products are created, and where energy is consumed.

Some example process flow diagrams are shown below.


Milk delivery
Raw milk storage
Separation
Cream pasteurisation
Cream storage
Standardisation
Pasteurisation
Cheese vats
Curd/whey separation
Whey treament
Moulding
Ageing
Finished milk tank-cooling
Incubation
Filtration
Cooling
Soft cheese
Culture tank
Incubation
Cooling
Mixing
Cultured dairy products
Spray drier
Dairy powders
Preparation and packing
Distribution

5.2 Allocation

5.2.1 Allocation principles

Allocation in Product Carbon Footprinting occurs when GHG emissions need to be allocated between two or more products or product systems.

There are two separate cases of allocation to be considered:

1. Co-product allocation: Where a single process gives rise to more than one product. These co-products cannot be created separately, but both occur inherently as outputs of a single process. In this case the embodied upstream emissions must be allocated to two or more co-products. For example, where milk from the farm is processed into milk and cream the embodied emissions of the incoming milk (relating to the on-farm emissions) are allocated partially to the outgoing milk product and partially to the cream product.

2. General allocation (typically of emissions due to energy used in processing): where multiple processes occur within a single entity (such as a plant or factory), and the measurement of the energy usage does not exist at sufficiently granular level for it to be attributable to one product only. For example a dairy processing plant produces both milk and cream. It is not possible to measure the energy usage separately to produce each product. In this case the total energy usage is measured and allocated between the two products.

These two cases of allocation are discussed in detail further below.

Allocation of embodied emissions from the milk and processing energy emissions is done in order to calculate the emissions for each saleable product and usable waste.

A saleable product is one with an economic value to the dairy. A usable waste can be defined as a zero or negative revenue product of milk processing that is used in one of the processes listed under the Environment Agency's definition of biowaste with recoverable value[4] or animal feed.

5.2.2 Process mapping

Before attempting to allocate emissions for a dairy processing plant it is important to define the boundaries of the plant by drawing a process map, showing clearly the input materials, the output products and waste, and the separate processes within the plant. The list of output products will define where the emissions are to be allocated to. Where sub metering exists the process map should show the energy used by each process or group of processes.

5.2.3 Normalisation of milk carbon footprint

In order to ensure comparability and ease of calculation, the carbon footprint of incoming milk should be normalised according to its fat content. This means that the footprint per litre provided to the dairy will fall for milk with higher than average fat content and rise otherwise. The standard value is:

- Fat content = 4%

5.2.4 Co-product allocation

The allocation of the on-farm emissions from the incoming milk to dairy product shall be done using dry mass. (While PAS 2050 requires economic allocation for co-products, this approach is using dry mass as a suitable proxy for economic value, as it is a stable value and has a correlation to economic value).

The calculation used to allocate the milk production emissions per unit mass of co-product is as follows:

$$\frac{\text{Total Emissions Milk Production}}{\text{Mass of Co-Product}} \times \frac{\text{Co-Product Dry Mass Percentage}}{\text{Whole Milk Dry Mass Percentage}}$$

Note that the mass value used in this calculation is the wet mass value of the co-product (and not the dry mass).

Note that this equation uses the fact that the total dry mass of co-products is equal to the dry mass of the incoming raw milk.

In addition to each of the saleable products, it is also necessary to perform this calculation on the usable waste (e.g. animal feed), using the default value for useable waste in the table below as the “Co-Product Dry Mass Percentage” (unless this value is known).

Typical dry mass percentage values for dairy products are as follows. These should be used if specific data is not available.

Table 3 - Dry Mass percentage values

	Dry Mass (%)
Whole Milk	13
Semi-Skimmed Milk	11
Skimmed Milk	9
Cheese	64
Whey powder	96
WMP	97
SMP	96
Butter	85
Yogurt	14
Single Cream	23
Whipping Cream	45
Double Cream	53
Clotted Cream	68
Useable Waste	53

5.2.5 Energy allocation

This section describes the method for allocating emissions due to the processing of different products. These emissions are from the energy use or the water use in the processing plant. The energy use will be from electricity or from combustion fuels (eg. use of gas or other fuels). The water used has emissions associated with it due to the pumping of borehole water or the supply of mains water, and the processing of waste water. Emission factors for electricity, fuel and water are all provided within the Footprint Expert™.

Where specific site data (e.g. through sub-metering) is available for the separate production lines of each product, and there are no processes common between products, then no allocation of the energy emissions is required (as the energy emissions will be specific and discrete for each process).

In most cases, however, the complexity of dairy processing makes the use of specific data impractical. Where this is the case, then specific allocation factors shall be used for the allocation of emissions due to electricity use, combustion fuel use and water use as defined below.

The allocation factors are those published by Feitz *et al*[5] and are summarised in the following table. If any of the products to be footprinted are not covered by this data, an equivalent value should be derived, reflecting the relative energy and water used in comparison to SMP.

Table 4 - Allocation Factors (AF) for each product

	Electricity Use AF	Combustion Fuel Use AF	Water Use AF
Whole Milk	0.14	0.03	0.15
Semi-Skimmed Milk	0.14	0.03	0.15
Skimmed Milk	0.14	0.03	0.15
Cheese	0.57	0.1	1.4
Whey powder	1.5	1.3	1.2
WMP	1	1	1
SMP	1	1	1
Butter	0.36	0.17	0.4
Yogurt	0.86	0.11	0.28
Cream	0.14	0.03	0.15
Useable Waste	0.59	0.38	0.59

The following equation is used to calculate the allocated emissions per unit mass of product for each energy source or water use.

$$\frac{\text{Mass of Co-Product} \times \text{Co-Product Allocation Factor}}{\sum\left(\text{Each Co-Product Mass} \times \text{Each Co-Product Allocation Factor}\right)} \times \frac{\text{Total Emissions for type of Energy or Water use}}{\text{Mass of Co-Product}}$$

Note that the mass values used in this calculation are the wet mass values of the product as sold (and not the dry mass).

Note that the "Energy Emissions" should be calculated by multiplying the amount of electricity, water etc. used on-site by the appropriate emission factor. (These emissions factors are provided in the Footprint Expert™ Reference Database).

The water AF should be applied to both incoming mains water and outgoing water to the sewage system. Additional emissions according to IPCC 2006 Guidelines, volume 5 chapter 6 equation 6.5[6] may need to be calculated for specific processing (on- or off-site) of biological wastes, such as settling lagoons.

5.2.6 Totalling the allocated emissions

To calculate the total allocated emissions for each product, sum the results of the following:

- Emissions calculated from co-product allocation using dry mass.

- Emissions from electricity calculated using the Electricity Use AF from "Table 4 - Allocation Factors"
- Emissions from combustion fuels calculated using the Combustion Fuel Use AF from "Table 4 - Allocation Factors"
- Emissions from water use calculated using the Water AF from "Table 4 - Allocation Factors"

5.3 Products

This section lists the dairy products included in the scope of this guidance document, and discusses any specifics to be considered for the product which may not be covered elsewhere in the document.

5.3.1 Milk

Fresh milk (pasteurised) with different fat content:
- skimmed
- semi-skimmed
- whole

Filtered Milk
- note that filtered milk has a longer shelf life, which should be reflected in the use phase.

UHT milk
- processing of UHT milk is different from pasteurised milk (using a different heat treatment process)
- typically UHT milk is produced in a different processing plant from pasteurised milk, and will have its own milk pool. As UHT milk has longer storage times, its direct milk pool is often supplemented by milk from the "spot market" to balance the overall supply and demand of fresh milk.

5.3.2 Cream

Single cream
Double cream
Whipping cream
Pouring cream
Clotted Cream

5.3.3 Milk products

SMP (Skim Milk Powder)
WMP (Whole Milk Powder)

5.3.4 Cheese

Cheese sub-products
- hard cheese
- soft cheese
- cream cheese
- cottage cheese

Rennet
Curds
Whey

5.3.5 Butter

Butter

Spreads

As spreads are a mixture of butter and vegetable oils, the footprint of the oils need to be calculated in addition to the butter. The footprint of the oil will consider the supply chain for the growing, production and transport of the oil.

5.3.6 Yogurt

The footprint for the yogurt needs to include the footprint of the fruit and other ingredients in the end product.

5.4 Packaging

5.4.1 Overview

Packaging is used for all dairy products, and while the contribution of the emissions due to packaging to the total footprint is typically small, it must be included. As packaging is a small contribution it is acceptable to use secondary emission factors for the packaging materials.

Where the packaging is formed on site (e.g. “blowing” of HDPE bottles for milk) then the energy used to form the packaging (e.g. energy used by injection moulding machines) must be included in the calculation of the carbon footprint. Where this energy is measured separately (e.g. through sub-metering) then the calculation is straightforward. If the energy is not measured separately, then an appropriate allocation of the energy needs to be estimated for the packaging forming process.

Where the packaging is manufactured completely off-site and imported in, then the emissions factor used for the packaging needs to include the forming of the packaging and not just the raw material.

The following lists typical packaging materials used in the dairy industry, and any specific considerations required for each material.

5.4.2 Glass Bottles

The emissions of the glass bottle shall include the energy required to form the bottle. The calculation of the emissions due to the glass bottle shall also consider the number of times that the bottle is re-used during its life (this is also known as the “trippage rate” and is included in the data factors in Appendix 1).

5.4.3 HDPE Bottles

The emissions of the HDPE bottle shall include the energy required to form the bottle – see general discussion of considering this in section 5.4.1.

5.4.4 Pouches

Liquid milk can be supplied in polyethylene pouches.

5.4.5 Cardboard laminate packaging

Cardboard laminate packaging (Liquid Packaging Board, LPB) can be used for liquid milk (both fresh and UHT). The emissions for this packaging need to consider all the materials used in the laminate, and the energy used to create and form the laminate.

5.4.6 Plastic containers

Plastic containers are used for a variety of dairy products, typically yogurt.

5.4.7 Foil and films

Metallic foils and plastic films are used (e.g. foil for butter, films as closures on milk bottles and yogurt cartons).

5.4.8 Recycled content in packaging

When considering recycled content in packaging there are two impacts that come into play:

- Raw material end: Using recycled material reduces or avoids the need for as much virgin material in this specific product
- End-of-life end: Ensuring materials from this product are recycled into future products reduces or avoids the need for as much virgin material in the system of all products

These approaches are known as '100:0' and '0:100', the guidance in the Footprint Expert™ Guide is to calculate the footprint due to both approaches and use the minimum of the two.

The key data required for this is:

- The % use of recylcate at input, or
- The % of product recycled at end-of-life

In practice the higher of these two factors will determine which approach is used.

The national recycling rate should be used unless more specific values are available.

Footprint Expert™ provides a list of recycling rates and default emissions factors for common raw materials used in packaging.

For a more detailed explanation regarding the consideration of recycled materials refer to the Footprint Expert™ Guide.

5.4.9 Secondary packaging

Emissions due to secondary packaging shall be included. For example the cardboard boxes or plastic crates used for transporting the products, or the packaging used for supplying raw materials.

6 Transportation

6.1 Introduction

The emissions due to transportation are to be included in the carbon footprint calculation, where 'Transportation' refers to the movement of goods by any mechanism, including car, truck, plane, ship or train. This shall include both the transportation of the product being footprinted, and also the transportation of any other materials required for the life cycle of the product (e.g. transportation of feed or fertiliser to the farm, transportation of packaging materials to the dairy).

Where fuel usage data is available then the emissions can be calculated directly by multiplying the fuel usage by the relevant fuel emission factor.

Where fuel usage data is not available then the emissions can be calculated based on the distance travelled (together with information on the type of vehicle, whether refrigerated or not, loading and backhaul).

In all cases the transport calculation needs to consider

- Emissions due to Empty Backhaul – i.e. where the vehicle returns empty
- Apportionment between products, where several different products are being transported at the same time. Apportionment should be done either based on mass or on volume, depending on which is the constraining factor.
- Refrigeration during transport. If products are refrigerated during transport this should be included in the calculations. When calculating based on fuel usage, the fuel to power the refrigeration unit will be included. Where calculation is based on distance travelled, the Footprint Expert™ Transport Calculator includes an uplift factor for refrigerated transport.

Support on calculating transport emissions is provided in Footprint Expert™ (see below).

In accordance with PAS 2050, the GHG emissions associated with constructing the transport method itself (such as trucks) and any infrastructure it uses (such as airport runways) are not included. In addition, consumer travel to and from the point of retail purchase and employee travel to and from their place of work are excluded from the assessment.

6.2 Support on modelling transport emissions from Footprint Expert™

Further guidance on modelling transport emissions can be found in the Footprint Expert™ Guide.

The Footprint Expert™ also includes transport calculators, which should be used where fuel usage is not known or measured.

The Footprint Expert™ transport calculators comprises four templates, one for each of the key transportation modes: road, sea, air, and rail.

6.2.1 Modelling transport emissions based on fuel usage data

Where primary fuel usage data is available, transport emissions can be calculated directly provided that the data is sufficiently robust.

Footprint Expert™ provides emission factors for common fuel types. The Footprint Expert™ Transport Calculator can be used for this calculation.

Note that consideration must be made for proportion of empty backhaul, and also for allocation between products where multiple products are transported in the same load.

6.2.2 Modelling transport emissions based on distance travelled

When calculating the transport emissions based on the distance travelled, the Footprint Expert™ Transport Calculator can be used for this calculation. Additional information will be required, for example for transport by road the following information is input into the calculator:

- Mass of load (kg)
- Distance of outbound journey (km)
- Empty Backhaul distance (km)
- Type of vehicle
- Load utilisation (i.e. percentage full)
- Volume or Mass Constrained
- Refrigerated or not

7 Distribution and retail

7.1 Introduction

In accordance with PAS 2050, the GHG emissions associated with the storage of a product shall be included in the footprinting life cycle assessment. At the Retail Distribution Centre (RDC) and store stages of the supply chain, this should include the storage of any inputs into the product and any environmental controls related to the product (e.g. refrigeration).

The distribution chain modelled should reflect the actual distribution of the products, for example fresh milk is typically (for large stores) distributed direct to store from the dairy (i.e. not through an RDC). If some of the milk is distributed as doorstep delivery, then this should be reflected in the calculation. The storage times should reflect those for the different products (and typically be related to the shelf life for those products).

For factors on the average shelf life for dairy products and for milk doorstep delivery, please see Appendix 1.

7.2 Support on modelling RDC and store emissions from Footprint Expert™

The Footprint Expert™ Guide provides direction on how to calculate the emissions generated at the RDC and store.

The Footprint Expert™ Model Framework can be used to calculate the emissions associated with a product during its residence in a typical RDC or a retail store. The Footprint Expert™ Model Framework offers:

- Footprint Expert™ RDC and Store Calculators for calculating the emissions associated with a product during its residence in a typical RDC or a retail store
- Templates to model RDC and store emissions

Note: To reflect emissions from a specific distribution chain, then actual data from the retailer should be used rather than using the generic values in Footprint Expert™.

8 Use Phase

8.1 Introduction

According to PAS 2050, the Use Phase of a product's life cycle occurs between the release of the product from the store to the consumer and the end of life stage. The Use Phase must take account of the direct energy associated with the preparation and consumption of the dairy product being footprinted and exclude additional emissions generated from indirect activities following its use.

A large majority of the emissions generated during the Use Phase for many dairy products (e.g. fresh milk, yogurt, butter, cheese, cream, and ice cream) will be attributed to domestic refrigeration/freezing storage methods.

For data factors on the average duration dairy products are stored in domestic refrigerators and the industry standard used-by dates for dairy products, please see Appendix 1.

8.2 Support on modelling Use Phase emissions from Footprint Expert™

The Footprint Expert™ Guide provides direction on how to calculate the emissions generated during the Use Phase of the life cycle.

The Footprint Expert™ Model Framework provides a template for modelling the emissions generated during a product's Use Phase. The Footprint Expert™ Model Framework also includes a Domestic Refrigeration Calculator for calculating the emissions generated from home refrigeration and freezing.

9 End-of-Life

9.1 Introduction

End of Life emissions shall be calculated including the emissions of waste disposed of through landfill, incineration etc. This should account for transportation of waste, and any direct emissions from degradation of the product and packaging.

For data factors on default average domestic wastage rates for dairy products please see Appendix 1. Wastage rates should include both the percentage of the product not used (e.g. for the proportion of product disposed after expiry of use-by dates) and an allowance for product left in the bottom of the container.

9.2 Support on modelling End-of-Life emissions from Footprint Expert™

The Footprint Expert™ Guide provides direction on how to calculate the emissions generated during the End of Life Phase of the life cycle.

The Footprint Expert™ Model Framework provides a template for modelling the emissions generated during a product's End-of-Life. Footprint Expert™ also includes a Carbon Storage & End of Life Calculator for calculating the emissions associated with carbon storage and due to different end of life scenarios such as landfilling and incineration.

Appendix 1 Default Data values

This Appendix lists typical default data items and secondary data items that may be used as default UK values in carbon footprinting of dairy products.

Where reliable primary data is available it should be used in preference to secondary data, however where the contribution due to a specific item is small, or where the primary data is not available, then secondary data may be used, provided that data quality rules are met.

Note: the following table only provides a list of the typical data items. The full list with actual data values to be used is held in the Footprint Expert™ Reference Database. This is because many of the data items will change over time and as the Footprint Expert™ data is updated at regular intervals, it is more practicable to refer to Footprint Expert™ for the latest values.

Data Item	**Material or Category**
Default weight for milk container	Glass
Default weight for milk container	HDPE
Default weight for milk container	LDPE
Default weight for milk container	PET
Default weight for milk container	Liquid Packaging Board (LPB)
Default weight for milk container cap / top	Aluminium
Default weight for milk container cap / top	HDPE
Default weight for milk container cap / top	LDPE
Default weight for pallet	Steel
Default weight for pallet	HDPE
Number of times pallet is reused	Pallet re-use
Default weight for crate	HDPE
Number of times crate is reused	Crate re-use
Average percentage of milk using this packaging	Packaged in plastic (PET or HDPE)
Average percentage of milk using this packaging	Glass
Average percentage of milk using this packaging	Cartons (includes pockets)
Default recycling rate	HDPE milk bottle
Default transport distance for milk	Transport of raw materials, assume 32 tonne+ truck
Default transport distance for milk	Transport of bottles to dairies, assume 32 tonne+ truck

Data Item	Material or Category
Default transport distance for milk	Sale to supermarkets does not involve RDCs, assume 16 tonne refrigerated truck
Default transport distance for milk	Diesel van doorstep delivery distance
Default transport distance for milk	Electric van doorstep delivery distance
Default transport distance for milk	Landfill waste transport distance
Default transport distance for milk	Recycling transport distance
Default transport assumptions for milk	Number of pallets per truck
Default transport assumptions for milk	Fuel uplift due to refrigeration transport of milk
Default transport assumptions for milk	Split between diesel and electric doorstep delivery vehicles
Default food wastage rate (%)	Milk
Default food wastage rate (%)	Yogurt / yogurt drink
Default food wastage rate (%)	Cheese
Default food wastage rate (%)	All other dairy and eggs
Default food wastage rate (%)	Dairy Average
Average times glass milk bottles are reused	Trippage Rate
Average retail shelf life	Retail Shelf Life by product
Average ambient storage time	Domestic Ambient Storage time by product
Average refrigeration time	Domestic Refrigeration times by product
Default emission factor	Emission Factors for common packaging materials
Emission Factor for use for spot market milk, or where milk is a minor component of the overall product footprint	UK default milk footprint to farm gate (fat corrected for 4%)
Default Emission Factor	Default Emission Factors for different animal feeds
DE% (Digestible Energy %) factor	DE% factors for different animal feeds

Appendix 2 Background to GWP for CH_4

Emissions from biogenic carbon escaping to the atmosphere as CH_4 are factored down to account for the sequestration of CO_2 that gave rise to the biogenic carbon source in accordance with PAS 2050 Clause 5.3.2. The GWP of methane will be factored down from 25 to 22.25 based on the fact that 2.75kg of CO_2 (GWP = 1) are removed from the atmosphere to produce one 1kg of CH_4 and considering the differences in GWP of the two gases.

The global warming potential (GWP) of methane (CH_4) can be effectively reduced because the ultimate source of the carbon (C) in the CH_4 was originally CO_2 from the atmosphere. As part of the life-cycle of C, CO_2 is absorbed by plants, eaten by animals and then re-emitted as CH_4 by the animal. The figure of 22.25 for CH_4 produced for biogenic C sources ensures that these processes are taken into account.

The net effect is that the GWP of methane from enteric fermentation and manure can be reduced from 25 to 22.25

The calculations of the GWP figure of 22.25 for CH_4 produced from biogenic carbon sources are shown below:

$CO_2 + 2H_20 > CH_4 + 2O_2$

Molecular Weight of CH_4 (MW_{CH4}) is 16.
Molecular Weight of CO_2 (MW_{CO2}) is 44.

Global Warming Potential of CH_4 (GWP_{CH4}) is 25.
Global Warming Potential of CO_2 (GWP_{CO2}) is 1.

$$\text{Adjusted } GWP_{CH4} = \frac{GWP_{CH4} \times MW_{CH4} - GWP_{CO2} \times MW_{CO2}}{MW_{CH4}}$$

$$= \frac{(25 \times 16) - (1 \times 44)}{16} = 22.25$$

Appendix 3 Details on Sampling Approach

This appendix provides some further details on the grouping process for the "Sampling with Grouping" method, and also provides some background on the statistics behind the sampling approaches.

A.1 Data for grouping criteria

In order to create the groups for the "Sampling with Grouping" method the data in the table below is required for each farm.

This data can be collected in two forms, and it is important to decide which to use up front, either is valid, but has different advantages:

1. A 'binary' value (e.g. High/Low)
   - The binary approach is simpler to collect the data
2. A 'continuous value' (e.g. 8000 litres per year)
   - The continuous value approach is more rigorous in determining the groupings

It is important to remember that data shall be for the specific year being assessed.

Table 5 - Data Required to create Farm Groups

Parameter	***Binary Measurement***	***Continuous Value***	***Notes***
Average milk yield per cow	Actual average yield per milking cow expressed as either "High Yield" or as "Low Yield"	Actual average yield per milking cow expressed in litres per year.	
Feed used	The majority of feed type used expressed as either "Forage" or as "Concentrates"	Ratio of Forage to Concentrates used expressed as a percentage by dry mass.	Data should indicate the ratio of forage to concentrates fed to the dairy herd. If non-dairy animals are present on the farm, their feed should be discounted. Forage should be accounted for in terms of dry mass.
Feeding system	Proportion of year animals are grass fed expressed as "High grass fed" or "Low grass fed"	Proportion of year animals are grass fed expressed in months.	Data will be an average for the herd and should indicate the proportion of the year that milking cows spend grazing grass (out to pasture) versus kept in-doors. Youngstock grazing ratios are not significant in this instance.

Parameter	***Binary Measurement***	***Continuous Value***	***Notes***
Fertiliser use	Amount of fertiliser used expressed as either "High Fertiliser use" or "Low Fertiliser use"	Amount of Nitrogen (not fertiliser) measured in kg applied per hectare.	Data should be in terms of fertiliser or Nitrogen applied per hectare used to feed the dairy herd (i.e. fodder, straights and grazing land). Total N used / hectares is suitable.
Herd replacement rate	Number of milking cows (as a proportion of the total herd) replaced during the year expressed as either "High replacement rate" or "Low replacement rate".	Number of milking cows replaced during the year expressed as a percentage of the total herd.	Data should be expressed as the number of milk producing cows directly replaced during the accounting year. This does not include animals imported or raised to expand the herd.
Manure management system	Majority of manure managed as slurry expressed as "Slurry" or "Not Slurry".	Proportion of manure managed as slurry expressed as a percentage.	The manure storage method is expressed as slurry as opposed to solid (FYM), direct to pasture or biodigestate.
Irrigation	Whether irrigation water is used for the dairy enterprise or not, expressed as "Yes" or "No".	Amount of irrigation water used per year for the dairy enterprise expressed in litres.	For the vast majority of UK dairy farms irrigation is not used, however this question is included here for completeness.

When collecting data as binary values, it is important to remember that the purpose is to divide the farms within the milk pool into separate groups. Therefore, the ranges which define each category (such as high or low) need to represent the farms within the milk pool, and are not necessarily related to any external definitions. Thus farms in the "high" category would be expected to have more similar footprints to one another than with those in the "low" category.

The following rule shall be adhered to:

- Ideally the above data should be collected for all farms.However it is acceptable to have data missing from some farms, so long as these farms represent no more than 3% of the total production volume

A.2 Creating groups

Having collected data for the grouping questions above, it is then necessary to split the farms into groups based on the answers to the questions. The aim would be to have 5 groups, with a minimum of 3 groups. The grouping can be done in two ways, either by manual grouping or automated clustering:

Manual Grouping Process

- This process involves a person manually examining the data to convert it into groups of similar farms
- For 'binary' systems this is possible to do manually, but not advised, other than in very simple situations
- For 'continuous' systems this is not possible, and the automated clustering method below will be required

Automated Clustering Process

- To perform clustering with a complex set of data, a calculator will be needed which uses a clustering algorithm to create groups of farms similar to each other, based on the answers provided to the grouping criteria. The clustering process and the algorithm to be used are explained further later in this appendix (section “A.6 Stratification theory”).
- A clustering calculator to provide this function will be provided as part of Footprint Expert™. The calculator will output the grouping to be used based on inputting the responses to the grouping criteria for each farm.

If a group is produced that represents less than 3% by volume of the total milk supply, then it is not necessary to sample from that group. It is recommended that a minimum of 2 farms is sampled from each group. If the minimum of 3 groups is not achieved then it is recommended to either adjust the separation factor in the clustering algorithm or to re-define the ranges for the “high” and “low” categories for the grouping criteria.

A.3 Weighted average calculation

The weighted average for a set of farms is calculated as follows:

$$\frac{\Sigma V_f \times F_f}{\Sigma V_f}$$

Where V_f = annual Volume of Milk for Farm (f)
And F_f = footprint for Farm (f)

The weighted average for a set of groups is calculated as follows:

$$\frac{\Sigma V_g \times F_g}{\Sigma V_g}$$

Where V_g = annual Volume of Milk for Farm (g)
And F_g = footprint for Farm (g)

A.4 Background to sampling approach

In the case of dairies, the milk production phase clearly requires good quality data as it typically forms at least 70% of B2C milk footprints. Currently available secondary data does not comply with the data quality rules of PAS 2050 in terms of one or more of the following: age, geography (especially when applied to regional milk pools) and life-cycle boundaries.

Collecting primary farm data enables these non-compliances to be dealt with.
Sampling therefore completes the quality picture that is missing in available secondary data. Sampling is the key to providing primary data that satisfies the quality rules, without having to collect detailed data from every farm.

The UNFCCC has defined a number of statistical techniques[7] that may be used for managing large and complex data gathering exercises within a carbon credit project. The one that is most applicable in this case is described by EcoSecurities as follows:

"Plots [of trees] should be distributed so as to incorporate the range of variability that exists within the site, and to be representative of the larger area to which the estimates will be applied. A stratified random design is recommended, where the strata are defined by topographical positions, site conditions…"[8].

The following sections describe how we suggest this methodology be used within product carbon footprinting specifically geared towards the dairy industry.

A.5 Random sampling theory

The sample size required to estimate a population mean can be calculated using the following formula when the population size is known:

$$\frac{z^2 \bullet s^2 \bullet \left(N / (N-1) \right)}{\left(ME^2 + \left(z^2 \bullet s^2 / (N-1) \right) \right)}$$

Equation 1

Where:
Z = 1.96 for a 95% confidence interval
S = standard deviation
N = population size
ME = margin of error

This is the equation that is to be used to determine the number of farms to be sampled, and has been used to generate "Table 1 - Extract of table for random sampling of farms – without grouping" using the following parameters:

Z = 1.96 for a 95% confidence interval
S = 0.25
ME = 5%

The figure for the standard deviation is based on, but is more conservative than, the figure calculated by Gerber et al[9] using a monte-carlo uncertainty analysis.

Where the population size is not known and where the population size is large (in this case greater than 1000 farms) then the sample size can be calculated using the following formula:

$$\frac{z^2 \text{ x } s^2}{ME^2}$$

Equation 2

A.6 Stratification theory

A.6.1 Overview

Stratification is the process of separating a population into different groups or strata. Then sampling can be applied to each group, rather than to the overall population. As the entities (in our case farms) within a group are chosen to be similar to each other, there will be a smaller standard deviation within each group as opposed to within the whole population and therefore it is appropriate to use a smaller sample size within the group than if sampling the whole population without grouping.

A.6.2 Clustering

Clustering is the process of creating groups of similar entities based on a set of criteria for each entity (in our case farms). It is the same process as grouping farms together based on their physical distances from each other and so creating groups of farms that are physically close to each other geographically, except that rather than considering distance we are considering a number of factors that will influence the carbon footprint and the difference between these factors.

The graph below shows, on the vertical axis, the differences between the estimated carbon footprints for the products of a set of farms. The graph shows that the distances between, for example, farms 3 and 4 are much less than between these farms and the others.

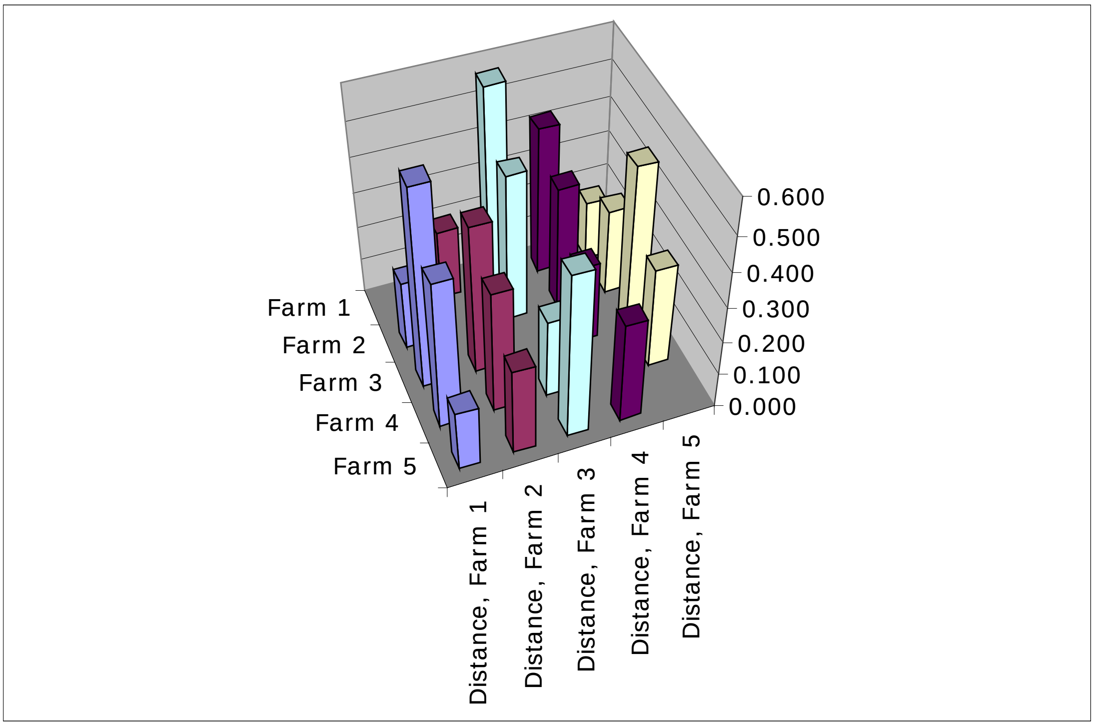


Figure 2- Illustration of a cluster analysis matrix, based on answers to pre-grouping questions

The cluster analysis formula for calculating the difference ("distance") for each farm pair is:

$$\sqrt{\sum_{x=1}^{X}\left(Farm_n Data_x - Farm_m Data_x\right)^2}$$

Equation 3

Where:
n and m = A pair of farms
x = Number of data points (e.g. fertiliser use and yield per cow)
Each data point x has been normalised to a range between 0 and 1
A 2x2 matrix of calculations is performed for each farm pair *n:m* and data point *x* (see. for example. Figure 2)

Subsequent analysis of the matrix enables separation of the farms into groups based on the magnitude of the distances (as shown in Figure 2). For +/- 10% clustering within data normalised between 0 and 1, this indicates a cut-off distance of 0.1.

A.6.3 Statistical methodology details

The equations used for initial exploration of the statistics are as follows:

$$\frac{n_h}{n} = \frac{W_h \bullet V_h}{\sum_h W_h \bullet V_h}$$

Equation 4

Where:
n_h = stratum sample size
n = stratum population size
W_h = stratum weighting
V_h = stratum standard deviation
h is the individual stratum

Equation 4 shows the key equation which calculates the percentage of a stratum to be sampled.

Where:

$$W_h = \frac{n}{N}$$

Equation 5

Where:
N = total population size

$$V_h = y_g \bullet s_g^2$$

Equation 6

Where:
y_g = stratum mean
s_g^2 = stratum variance

Note that stratum variance should be estimated, based upon the clustering distance used to form the stratum.
Stratum weighting should be based upon the proportion of milk production supplied by each group.

A.6.4 Sample sizes

For sampling within a group following stratification, the "root N" sampling method shall be used with the following equation:

$$\text{Sample Size} = \sqrt{N}$$

Equation 7

This is the equation that is to be used to determine the number of farms to be sampled in the "Sampling with Grouping" method, and has been used to generate "Table 2 - Extract of table for sampling of farms following grouping".

Note 1: For 10 farms and below it is not appropriate to apply the grouping method, so the random sampling without grouping should be followed.

Note 2: Above 10 farms a minimum of 10 farms should be sampled

The root N method is an empirical approach often used as a "rule of thumb" for statistical sampling and, while it is not based directly on mathematical theory, there is evidence to support its use. Based on a simulation study, Saranadasa[10] showed that if the underline distribution is normal and the population size is greater than 30, then the sample size obtained from the square root of N plus one rule guarantees that at least 90% of the time the 95% confidence interval would cover the population mean. Thus, given the improvement due to the stratification, it is felt that the root N method provides a simple and appropriate way of calculating the sample size.

Appendix 4 Glossary

List of terminology used, abbreviations etc.

AF	Allocation Factor
B2B	Business to Business
B2C	Business to Consumer
Carbon footprint	The measurement of the greenhouse gases emitted, measured in terms of CO2e. In this document, “footprint” or “carbon footprint” is used specifically to refer to the “product carbon footprint”, which is a measurement of the greenhouse gases emitted over the full life cycle of a product.
CH4	Methane (a potent greenhouse gas)
CO2e	Carbon Dioxide equivalent
DM	Dry Mass
EF	Emissions Factor
Emissions	Generally this refers to environmental emissions of gases and particulates emitted into the atmosphere. In this document the term “emissions” refers specifically to emissions of greenhouse gases.
Enteric fermentation	Enteric fermentation is the digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream of an animal. Enteric fermentation produces methane (CH_4) in the rumen of the animal as microbial fermentation takes place.
Functional Unit	The basic amount of the product, in terms of which the carbon footprint is expressed. For example, in the case of liquid milk, the functional unit could be a litre and the carbon footprint would then be expressed as “kg CO2e per litre of milk”.
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LPB	Liquid Packaging Board
Milk Pool	An aggregate term to describe all farms that supply milk to one dairy processing plant.
N20	Nitrous Oxide (a potent greenhouse gas)
RDC	Regional Distribution Centre
Sku	Stock Keeping Unit
SMP	Skim Milk Powder
Spot Market Milk or Open Market Milk	Milk that is bought on the open market (i.e. not on a contract basis) and therefore by definition does not come from a dedicated milk pool.
WMP	Whole Milk Powder

Appendix 5 References

1 PAS 2050:2008 Specification for the assessment of the life cycle greenhouse gas emissions of goods and services

2 Footprint Expert™, 2010; published by the Carbon Trust; www.footprintexpert.com

3 Code of Good Practice for Product Greenhouse Gas Emissions and Reduction Claims, Carbon Trust 2008

4 http://www.environment-agency.gov.uk/business/topics/waste/105375.aspx

5 Feitz *et al* 2007; Generation of an Industry-Specific Physico-Chemical Allocation Matrix: Int. J. LCA 12 (2) p109-117: DOI: http://dx.doi.org/10.1065/lca2005.10.228

6 http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

7 UNFCCC sampling methodology, Annex 27; https://cdm.unfccc.int/EB/archives/meetings_09.html#047

8 Issues related to monitoring, verification and certification of forestry-based carbon offset projects; Pedro Moura-Costa and Marc Stuart, EcoSecurities (page 10); www.ecosecurities.com/GetAsset.ashx?AssetId=3167

9 Gerber et al 2010; Greenhouse Gas Emissions from the Dairy Sector - A Life Cycle Assessment; published by FAO

10 Hewa Saranadasa; The Square Root of *N* Plus One Sampling Rule How Much Confidence Do We Have?; published in ***Pharmaceutical Technology;*** MAY 2003