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A common carbon footprint approach for dairy
The IDF guide to standard lifecycle assessment methodology for the dairy sector

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Send any comments or inquiries to:

International Dairy Federation (I.N.P.A.)
Diamant Building
Boulevard Auguste Reyers 80
1030 Brussels
Belgium
Phone: + 32 2 733 98 88
Fax: + 32 2 733 04 13
E-mail: info@fil-idf.org
Web: www.fil-idf.org

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A common carbon footprint approach for dairy

The IDF guide to standard lifecycle assessment methodology for the dairy sector

Foreword

'Go green' developments around the world in recent years have resulted in increasing interest from civil society, respective governments and individual consumers in how food is produced and the environmental impact of its production.

In response to this, the dairy value chain has been actively working towards reducing greenhouse gas emissions associated with the production, collection and processing of milk and delivery of dairy products, while satisfying the needs of the marketplace in the most sustainable manner.

In recent years, IDF has been particularly active in putting environmental concerns at the top of its priorities, through scientific research and a close dialogue with various key stakeholders worldwide.

This IDF Guide will play a major contribution in supporting the evolution of efficient and sustainable businesses that strive to continually reduce their GHG emissions, and in helping the dairy industry to demonstrate a conscientious and accountable focus on environmental issues to all stakeholders.

The IDF expresses its gratitude to the experts from the Action Team on Life Cycle Analysis / Life Cycle Management and Carbon Foot printing in the Dairy Sector for their outstanding commitment and hard work in developing and publishing this crucial document. Members of the Action Team include: Jim Barnett , Sophie Bertrand , Peter Roger Darlington , Robin Dickinson , Jean-Baptiste Dolle , Onur Durmus , Anna Flysjö , Thais H Passos Fonseca , Chris Foster , Pierre Gerber , Jan Dalsgaard Johannesen , Park Kyuhyun , Brian Lindsay , Sven Lundie , Daniel Massé , Anna-Karin Modin Edman , Rick Naczi , Tim Nicolaï , Sarah Paterson , Nico Peiren , Cyrus Poupoulis , Marcin Preidl , Jean-Pierre Rennaud , Maartje Sevenster , Olaf Thieme , Greg Thoma , Janusz Turowski , Neil Van Buuren , Theun Vellinga , Harald Volden , Erika Wallén , Ying Wang and Mr. Peter Erik Ywema.

The IDF also wishes to particularly thank its two partner organizations the Food and Agriculture Organization of the United Nations (FAO) and the Sustainable Agricultural Initiative (SAI) Platform for their valuable contribution.

A special word of thanks is due to Sophie Bertrand for her outstanding leadership in producing this essential Guide to help the global dairy sector to calculate and subsequently estimate the reduction of its carbon foot print.

Christian Robert
Director General

November 2010

1. Introduction

1.1 Background

Most industries are now being challenged to quantify and reduce their carbon footprints, or emissions of greenhouse gases (GHGs) to the atmosphere; businesses in agriculture and food production are no exception. Both food processors and farming organizations within the international dairy industry have recognised the need to calculate their impact on the environment in terms of GHGs, and this has led many to proactively engage professional bodies or specialist organizations to review and calculate the carbon footprints of their products.

Others have developed their own systems and some governments have even devised high level evaluation tools to support policy development.

This guide has been developed at the request of the 56 IDF member countries representing 86 per cent of the world's milk, since it has become evident that the wide range of figures resulting from the differing methodologies and data is leading to inconsistencies. This poses a very real danger of confusion and contradiction, which in turn could create a false impression that the industry is failing to actively engage with the issue of climate change.

This guide was developed by the IDF Standing Committee on Environment (SCENV) with active participation of the Food and Agriculture Organization of the United Nations (FAO) and the Sustainable Agriculture Initiative Platform (SAI Platform). Creating consistency and a clear message is important for the reputation of the industry as a global whole, to highlight the high level of engagement that is already taking place in relation to this issue, and to identify practices that will further reduce greenhouse gas emissions.

1.2 About this guide

This guide was developed through a consultation and review process to address the issues of credibility and consistency in how the carbon footprint of milk production or a dairy product is developed. The solution was to develop clear guidance on functional unit, boundaries, change of land use, co-products and other well-debated aspects within the methodology.

An IDF workshop involving leading experts was initially held in Brussels in June 2009 to capture the latest knowledge about Life Cycle Assessments (LCAs) in general and carbon footprinting in particular in the dairy sector. Following this, and to resolve the issues that emerged, small working groups were formed to debate the most robust and appropriate route forward in each case based on current scientific knowledge and report back to the wider group.

This resulting guide:

- Identifies an approach, based on current best knowledge, to address the common LCA challenges of co-products and land use change
- Identifies the key areas in which there is currently ambiguity or differing views on approach
- Recommends a practical yet scientific approach that can also be inserted into existing or developing methodologies
- Adopts an approach that can be applied equally in developing and developed dairy industries across the world.

It **does not**:

- Re-create knowledge: where the science is available, references have been provided to support the approach; where a suitable model is already in existence, this has been used.

The importance of incorporating existing knowledge and collaborating with organizations that were already involved in improving the standardization of LCA methodology was recognised from the start. The organizations include:

- **International Organization for Standardization (ISO)**, responsible for ISO 14040, 14044 and 14067, which were the original standards for producing carbon footprints for products; almost all existing methodology is in line with these protocols.

- **British Standards Institution (BSI)** in collaboration with Britain's **Department for Environment, Food and Rural Affairs (Defra)** and the **Carbon Trust**, which developed Publicly Available Specification 2050 (PAS2050), the specification for the assessment of the lifecycle greenhouse gas emissions of goods and services.
- **The World Business Council for Sustainable Development (WBCSD)** and the **World Resources Institute (WRI)**, which are developing the Greenhouse Gas Protocol Product Life Cycle Standard and the Scope 3 (Supply Chain) Standard.
- **Intergovernmental Panel on Climate Change (IPCC)** is the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO)
- **Food and Agriculture Organization of the United Nations (FAO)**, whose methodology for calculating the greenhouse gas emissions from the dairy sector (FAO, 2009) was developed at the same time as this guide.

Figure 1. The IDF common methodology embraces a comprehensive range of international knowledge and aspects of existing standards.

While the dairy-specific approach adopted by the IDF means its views differ from these organizations in some areas, it has worked collaboratively with all of them in developing the methodology in this guide.

Finally, this guide focuses on GHG emissions but there are other important issues such as water and ecosystem quality, that need to be taken into account to the enable assessment of the impact of the dairy sector globally. Any new and relevant outcomes from research into these areas can be incorporated into future versions of this guide.

1.3 Who should use this guide?

This guide has been developed by the IDF for use by the dairy cattle farming and dairy manufacturing sector, for those interested in defining a carbon footprint of their production systems and products using an LCA approach. By incorporating this approach, fair comparison can then be made across different production systems, regions and products as the result of applying a standard approach.

At the moment, this guide only covers milk production from cattle, although work into milk production from other species is pending.

The methodology developed in the guide aims to allow:

- comparison of GHG emissions between dairy products, for example 'cheese' or 'liquid milk'
- identification of GHG emissions from cradle to the manufacturing gate out (not including transport from manufacturing gate and retailer or consumer impacts)
- identification of particular areas where there is potential for reducing emissions if they are particularly large or the reductions are easy to realise

1.4 Attributional and consequential methods

The purpose of these guidelines is to provide an **attributional** approach to calculating the carbon footprint of both dairy farming and manufacturing.

Attributional LCAs focus on describing the environmentally relevant physical flows to and from the product or process; this is in contrast to **consequential** assessments which describe how relevant environmental flows will change in response to, for example, changes in demand.

Attributional LCAs use average data, for example for electricity or other commodities traded on markets with no specific link to the supplier. For the purposes of establishing this common methodology for footprinting for the dairy industry, this is calculated to be both sufficient and practical.

1.5 What you need before starting

- IPCC – Task Force on National Greenhouse Gas Inventories, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land Use (available at www.ipcc-nggip.iges.or.jp/ under NGGIP Publication on the website menu bar) TWO CHAPTERS 10&11
- ISO 14040 and 14044 (available from searching in www.iso.org)
- PAS 2050 (available from searching in www.bsigroup.com)
- WBCSD (www.ghgprotocol.org/)

1.6 Future reviews and enhancements

The IDF is committed to continually reviewing new science, incorporating relevant outcomes into existing guidelines and informing members of advances in specific topics. The area of LCAs and the environmental impact of food production systems is one area of rapidly evolving science and knowledge.

Therefore, the IDF, conscious that the recommended methodology in this guide focuses purely on GHG emissions, will continue to monitor developments and will seek to incorporate any relevant outcomes, for examples in the areas of water and biodiversity. It will also continue to liaise closely with other organizations working in a similar field with the aim of sharing information, increasing consistency in approaches and remaining at the cutting edge of developments.

1.7 Summary

By developing internationally harmonized standards and guidelines for the methodology for calculating the carbon footprint of milk and dairy products, the IDF is aiming to:

- support the production of consistent and comparable carbon footprint figures internationally, and
- enable the evaluation of dairy products on a consistent basis.

These in turn will:

- support the evolution of efficient and sustainable businesses that are continually reducing their GHG emissions, and
- allow the dairy industry to demonstrate a credible focus on environmental issues to retailers, customers and potential critics.

2. LCAs and carbon footprints: the basics

2.1 Definition of a product carbon footprint

Greenhouse gases are all gaseous substances for which the Intergovernmental Panel on Climate Change (IPCC) has defined a global warming potential coefficient. They are expressed in mass-based **CO_2 equivalents (CO_2e)**. The main agricultural greenhouse gases are **carbon dioxide (CO_2)**, **nitrous oxide (N_2O)** and **methane (CH_4)**.

The product carbon footprint is the sum of the greenhouse gases emitted throughout the life cycle of a product within a set of system boundaries, in a specific application and in relation to a defined amount of a specified product.

A product carbon footprint is usually based on an **LCA methodology**. LCAs were originally used to analyse industrial process chains, but have been adapted over the past 15 years to assess the environmental impacts of agriculture, although has mainly been in arable and less in livestock farming. The LCA method analyses production systems systemically to account for all inputs and outputs for a specific product and production system across a specified **system boundary**. The system boundary is largely dependent on the goal of the study. The reference unit that denotes the useful output is known as the **functional unit** and has a defined quantity and quality, for example a litre of milk of a defined fat and protein content.

The application of LCA to agricultural systems is often complex because, in addition to the main product, there are usually **co-products** created, such as meat, energy etc. This requires appropriate partitioning of environmental impacts to each product from the system based on an **allocation** rule which can be based on different criteria such as value, product properties or system expansion.

Calculation of the carbon footprint of a product using LCA methodology should be based on the ISO 14000 series, specifically ISO 14040, ISO 14044, and in future ISO 14067; the recommendations of PAS 2050 should also be taken into account where advised in this document.

A decision to calculate a carbon footprint of a product is a conscious decision to focus on one indicator at a time. Other environmental impacts such as water quality and biodiversity are likely to be included in the future in order to address environmental impacts of the global dairy industry in a holistic manner.

2.2 The challenges of carbon footprinting

There are many challenges in calculating a carbon footprint, and calculating one for milk or a dairy product is no exception. To date, there have been several LCA studies investigating and evaluating GHG emissions from milk production[1]. However, comparison between these different studies is difficult and it is hard to identify where meaningful reductions in GHG emissions can be made when it is not clear whether a benefit really exists or only appears to exist because of a different method of calculation[2].

The carbon footprint for milk and dairy products is dominated by the agricultural stage, where three quarters or more of the GHG emissions occur[3]. This is why it is crucial to consider the variables in primary milk production that can affect the carbon footprint outcome, and to have a common approach for allocating the environmental burden from raw milk production between products such as milk, cream, cheese and butter, irrespective of the farm, system, country or even region.

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[1] eg Haas et al., 2000, Hospido 2005, Williams et al., 2006, Casey & Holden 2004, Thomasen et al., 2008, Basset-Mens et al., 2008, Cederberg & Flysjö 2004, Cederberg et al., 2007, Cederberg & Mattison 2000, Flysjö et al., 2008.

[2] Basset-Mens 2008, Flysjö et al., 2009.

[3] FAO 2009.

2.3 Existing international standardization processes

From the outset, the IDF was committed to reviewing existing standardization work and collaborating with organizations that were already involved in improving the standardization of LCA methodology. As emphasized in the introduction, where a suitable model is already in existence, this has been used.

2.3.1 ISO 14000 series, encompassing ISO 14040, 14044 and future 14067

ISO 14040 'Life cycle assessments' provides an important basis for framework and principles, and ISO 14044 (2006) 'Environmental management – life cycle assessment' provides requirements and guidelines. ISO took up the task of preparing a standard for 'carbon footprints of products' (ISO/NP 14067) in 2009. The standard will consist of two parts: one for assessment and quantification, and one for communication. The aim is to finalize ISO 14067 by 2012 and the IDF is engaged with these processes where practicable.

2.3.2 PAS 2050 (2008)

The British Standards Institution, in collaboration with the UK's Department for Environment, Food and Rural Affairs (DEFRA) and the Carbon Trust, has produced a Publicly Available Specification 2050 'Specification for the assessment of the life cycle greenhouse gas emissions of goods and services'.

This British pre-standard sets out an initial comprehensive proposal for the methodology of the product carbon footprint. The final version of the PAS, published in October 2008, is largely based on the LCA standard ISO 14040. It refers to this standard on a number of points but also deviates significantly from it in some areas. PAS thus represents the first attempt to create a standardized basis for the assessment of greenhouse gas emissions arising throughout the product carbon footprint.

2.3.3 Greenhouse Gas protocol Product/Supply Chain initiative of the WBCSD

The Greenhouse Gas Protocol (GHG Protocol) is the most widely used international accounting tool that allows businesses to understand, quantify, and manage GHG emissions. It is a decade-long partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), and brings together stakeholders from business, government, NGOs and academic institutes, to develop internationally accepted GHG accounting and reporting standards.

The GHG Protocol provides the methodology for nearly every GHG standard and programme in the world – from the International Organization for Standardization, ISO, to The Climate Registry – as well as hundreds of GHG inventories prepared by individual companies.

Since 2008, the WRI and the WBCSD have convened over 1,600 stakeholders from around the world to develop new accounting and reporting standards. The GHG Protocol Product Life Cycle Standard and the Scope 3 (Supply Chain) Standard are expected to be finalized in late 2010, after undergoing road testing in over 70 companies and through a series of stakeholder consultations.

2.3.4 Summary

The IDF guidelines contained in this document consitute a sector specific guideline and at a more precise level than the current GHG Protocol developments. Having said that, the IDF has liaised closely with the WBCSD throughout its respective programmes and will continue to do so in the future as developments in this field unfold.

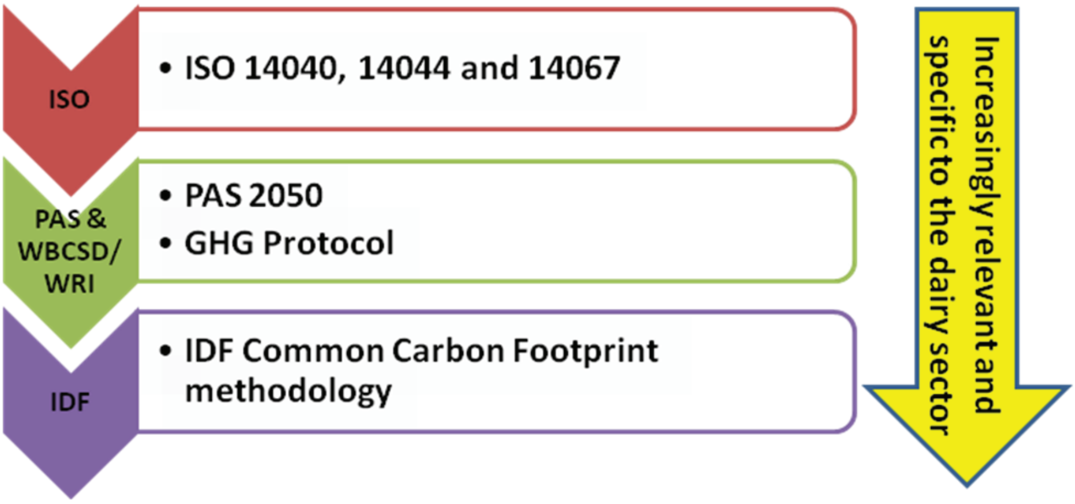

Figure 2. ISO, PAS and WBCSD/WRI protocols feed into the IDF methodology.

3. The steps in an LCA

3.1 A summary of the steps

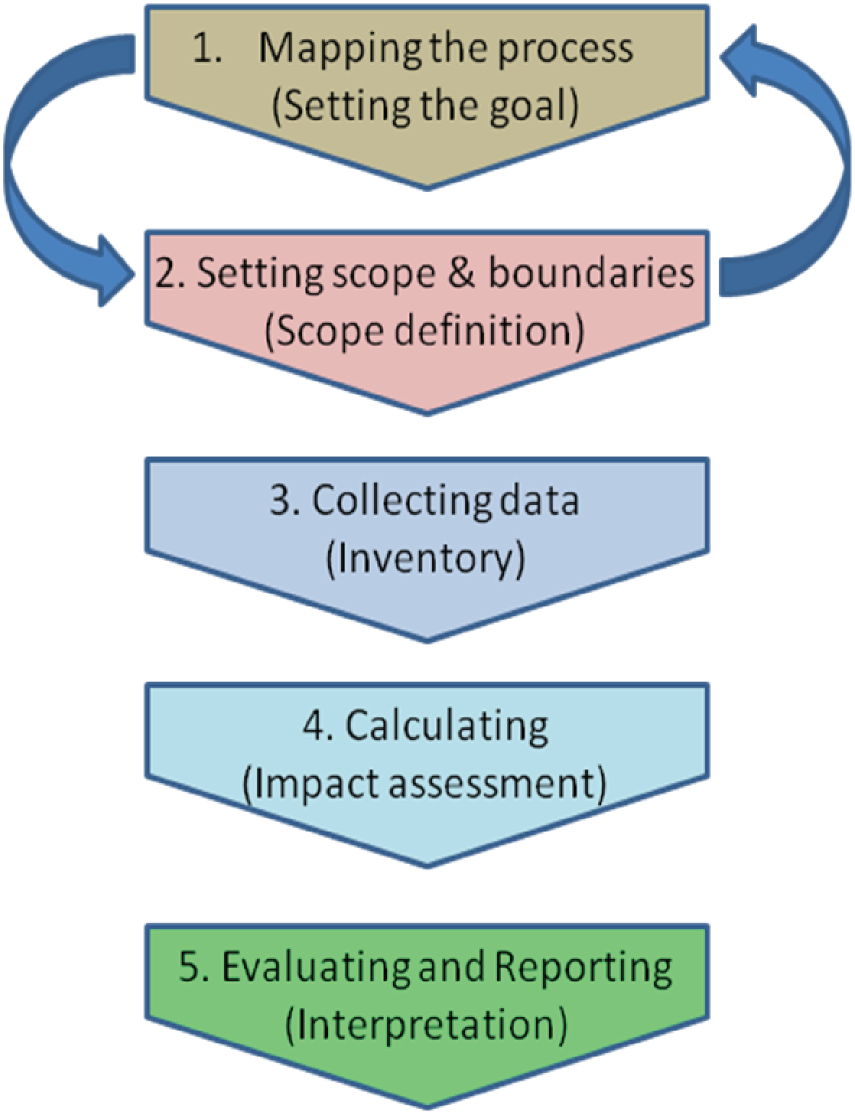

Figure 3. The steps for conducting an LCA are similar, whether based upon ISO 14000 or PAS2050.

3.2 Mapping the process

This first step is about identifying the **goal** of the project, then the **functional unit** that will be the subject of the analysis, and all materials, activities and processes that contribute to the chosen product's life cycle. It is also important to make a decision about which of two possible approaches will be adopted for modelling: **attributional** or **consequential** (as mentioned in introduction, in this guide it is recommended that the attributional approach is used). Establishing all these at the outset is important in ensuring that the aim is clear, that all parts of the process are included, but also that the project does not get bigger or start to expand into areas that are irrelevant.

3.3 Setting the scope and boundaries

In the second step, the scope of the analysis is defined. The scope should address the overall approach used to establish the **system boundary** which determines which unit processes are included in the LCA and must reflect the goal of the study.

3.4 Collecting the data

This phase involves **data collection** and **modelling** of the product (eg milk, cheese) system, as well as description and verification of data. This encompasses all data related to processes within the study boundaries. The data must be related to the functional unit. The list of the minimum technical data required to calculate to the emission is proposed in Appendix C.

3.5 Calculating the carbon footprint

The fourth step is calculation of the **carbon footprint** using all the information gathered in the previous steps. All the GHG emissions are converted into CO_2e figures and added together to give the carbon footprint, expressed as CO_2e.

3.6 Evaluating and reporting

It is important the information is presented correctly and accurately.

4. Mapping the process

4.1 Creating a process

From the outset of an LCA exercise, it is important to be clear about the goal. Knowing the goal – as in what is being measured (the functional unit) and why, the intended audience, and whether the results are intended to be used in public comparisons – helps identify what is needed to conduct the analysis.

Figure 4. The process for milk production and dairy processing starts at the creation of farm inputs and stops at the factory gate out.

This is a typical Business-to-Business or 'cradle to gate' model, as described in ISO 14040[4]. If just part of the process is being studied, for example only milk production to the farm gate, then this process would be shortened accordingly.

4.2 Defining the process

PAS 2050 explains that to build a process map, the following stages should take place:

- Define where the process being studied starts and finishes
- Define the functional unit
- List all the activities involved in the process
- Reflect on what might have been missed
- Identify any co-products or by-products
- List all inputs and their inputs from their origins (eg fertiliser used to grow feed for cow nutrition).

This provides a framework which then feeds the next stage – setting goals, scope and boundaries.

[4] Environmental management – Life cycle assessment – Principles and framework.

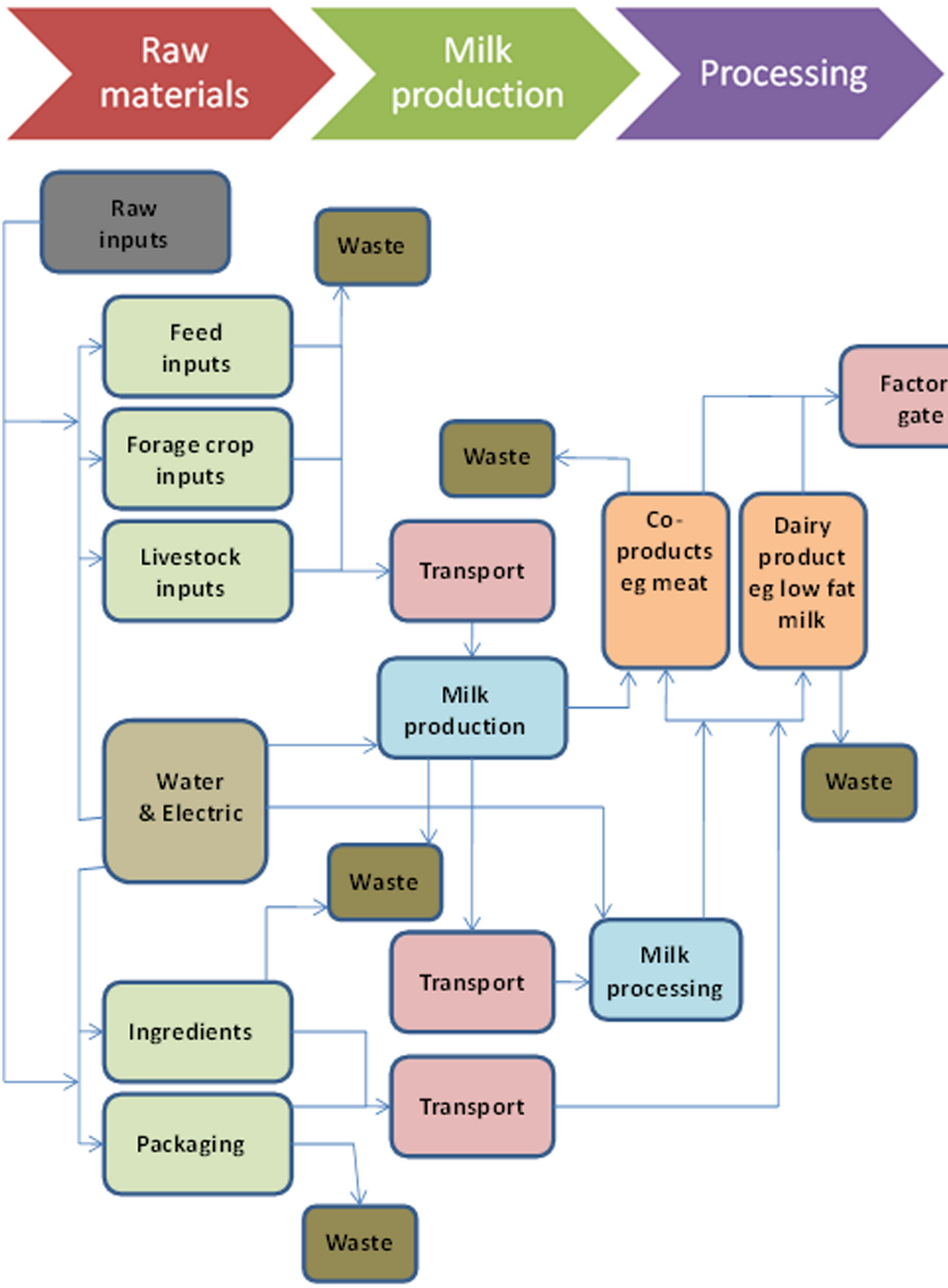

Figure 5. A process map.

4.3 The Functional Unit

4.3.1 Farming

If a study is conducted on-farm, the functional unit is one kilogram of **fat and protein corrected milk** (FPCM) at the farm gate in the country in which the analysis is taking place.

Using FPCM as the basis for farm comparisons assures a fair comparison between farms with different breeds or feed regimes. FPCM is calculated by multiplying milk production by the ratio of the energy content of a specific farm's (or region's) milk, to the energy content of standard milk with 4 per cent fat and 3.3 per cent true protein content.

$$\textbf{FPCM (kg/yr) = Production (kg/yr)} \times [0.1226 \times \textbf{Fat\%} + 0.0776 \times \textbf{True Protein\%} + 0.2534]$$

Figure 6. Formula for calculating the Functional Unit for farming.

If a different milk composition is needed for the standard milk, the energy equation (Appendix A) can be used to calculate the new standard milk energy and then used to recalculate the coefficients for the FPCM equation.

4.3.2 Processing

At the processing gate, the recommended functional unit is one kilogram of product, with x per cent fat and y per cent protein, packaged at dairy factory gate ready to be distributed in the country in which the analysis is taking place.

5. Setting the Scope and Boundaries

5.1 Farming

The system boundaries are from feed production (and its inputs) to farm-gate and include, but are not limited to:

- Production of milk on-farm (methane from productive and replacement animals/enteric fermentation) including:
  - on-farm feed production (diesel, and direct and indirect emissions of nitrous oxide from soil)
  - farm dairy effluent management (methane and direct and indirect emissions of nitrous oxide)
  - cow management (diesel, petrol)
  - milk extraction (electricity, refrigerants)
  - water supply (electricity)
- Production and supply of supplementary feed
- Production of synthetic fertiliser and its delivery
- Production and delivery of any other crop and pasture inputs, eg pesticides
- Any activities which take place on other farms eg feed production for the dairy cow replacements and any cows grazed away over the winter
- Releases resulting from processes, including chemical and ingredients production on farm
- Refrigerant manufacturing and losses and other emissions sources on-farm
- Usage of energy that has greenhouse gas emissions associated with it
- Consumption of energy carriers that were themselves created using processes that have GHG emissions associated with them (eg electricity)
- Wastes that produce greenhouse gas emissions.

This accounts for at least 95 per cent of the likely life cycle emissions from feed production to farm-gate thereby meeting one of the key requirements of the PAS2050 standard. A threshold of one per cent has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources (PAS2050). So it is accepted that, for practicality, if any material or energy flow contributes less than one per cent of the total emissions, then these can be excluded – provided the threshold of accounting for 95 per cent of emissions is met[5].

5.2 Processing

The system boundary encompasses relevant processes within the system and includes, but is not limited to:

- The transport of the raw milk to the processing sites from the farm gate and inter-factory product transport
- Production, delivery and consumption of operating materials, eg chemicals, packaging materials and ingredients
- Freshwater usage on-site and wastewater treatment

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[5] Frischknecht et al., 2007.

- Releases resulting from processes, including chemical and ingredients production, refrigerant manufacturing and losses and other emissions sources
- Usage of energy that has greenhouse gas emissions associated with it
- Consumption of energy carriers that were themselves created using processes that have GHG emissions associated with them (eg electricity)
- Wastes that produce greenhouse gas emissions.

It is possible to apply and refer to these guidelines also when calculating the carbon footprint of different parts within the system boundaries defined above. For example, when a dairy is planned to be enlarged or re-built, carbon footprint calculations can be performed on part of the processing system.

Because the LCA may be undertaken in a series of phases each part of the dairy manufacturing system (farm and processing) is considered separately.

The post-manufacturing transportation of milk and milk products also contributes to GHG emissions, but this guide does not include this as it is not specific to the milk production and milk processing.

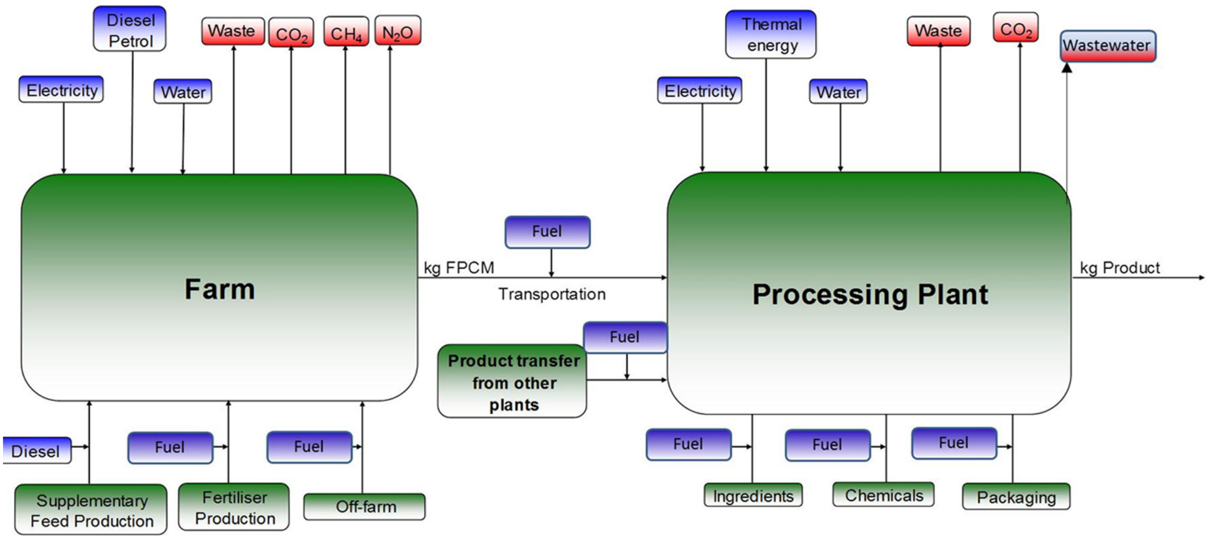

Figure 7. A summary of the flow of resources and input in dairy farming and processing.

5.3 Emissions to be included

Main sources of emissions that should be included are:

- fossil carbon dioxide (energy use, eg combustion of diesel and electricity production)
- biogenic carbon dioxide from direct land use change (carbon released from deforestation and conversion of pasture and shrub lands to agricultural land, emissions both from above and below biomass, as well as carbon from soil)
- biogenic carbon stored in packaging material (carbon stored in biogenic material should be accounted for to be able to make a more 'fair' comparison to material originated from fossil materials, eg plastic produced from fossil oil); biogenic carbon retained in packaging (paper, card etc) may be retained for a while if recycled, or if incinerated with energy recovery then the feedstock is essentially carbon neutral; carbon from fossil sources can be retained (eg in plastics which breakdown slowly or are recycled), otherwise it is generally a direct emission

- fossil methane emissions (leakage from eg natural gas)
- biogenic methane emissions (enteric fermentation and manure management, storage and spreading/on field)
- nitrous oxide emissions (N_2O emissions from production of N-fertiliser, direct N_2O emissions from field and manure management/storing, indirect N_2O emissions from field (NO_3 => N_2O and NH_3 => N_2O) and manure management/storing (NH_3 => N_2O))

Emissions that should not be included are those that are accounted for in the short (biogenic) carbon cycle.

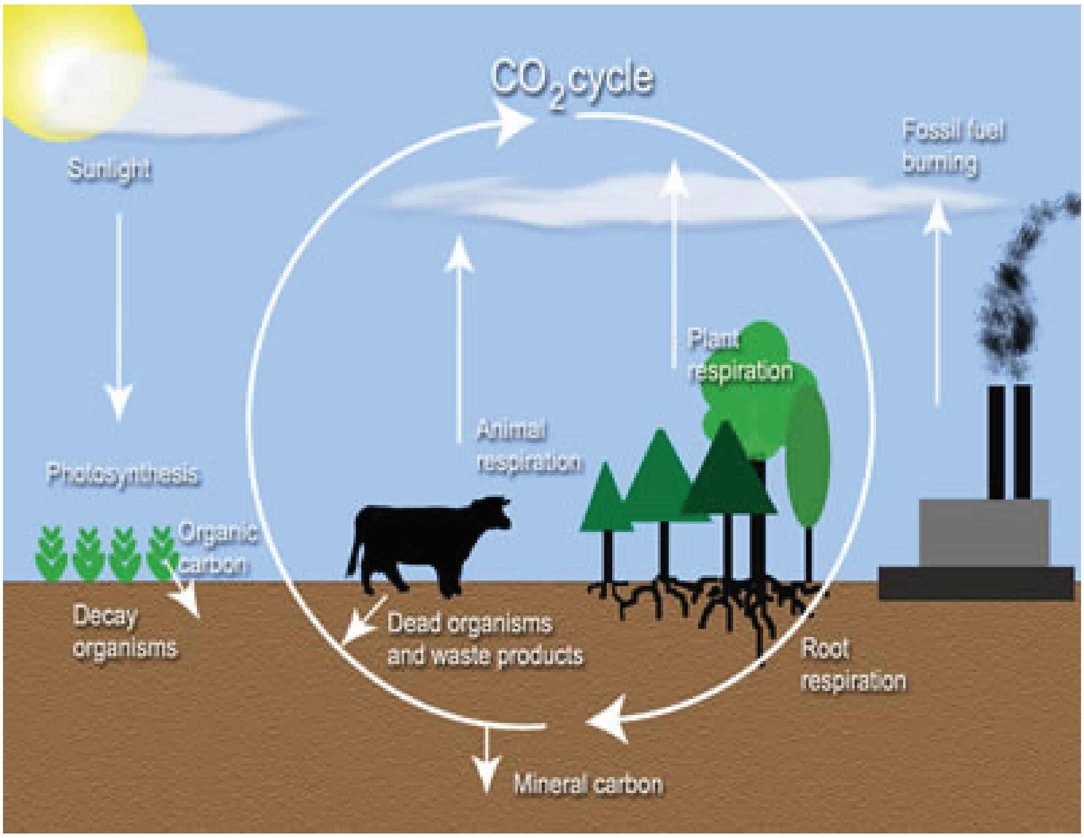

Figure 8. Carbon cycle.

Carbon absorbed by animals and crops is carbon neutral as it is re-released quickly (unless, for example, straw is used to build a house) as it is breathed out, burnt, excreted or decomposed.

Biogenic carbon retained in packaging (paper, card etc) may be retained for a while if recycled. If incinerated with energy recovery then it is essentially carbon neutral.

Carbon transformed into methane becomes a GHG; carbon from fossil sources can be retained (eg in plastics which breakdown slowly or are recycled), otherwise it is generally a direct emission.

In the future, there is the potential for credits once it becomes possible to measure/verify carbon absorbed by plants/soil; in the meantime, carbon may be retained/sequestered or re-released rapidly (eg by burning, ploughing etc), so it remains carbon neutral.

6. Collecting data

6.1 Data quality

One of the crucial issues in LCA calculations is transparency and reporting of the data used in the study. Ideally, the study should be reported in such a way that it allows for an independent practitioner to reproduce the results.

It should clearly be stated if primary (collected) data (which are preferred) or secondary (database, article, report) data are used, and from where the data are taken (eg the reference, from which company, the site the data are collected from or from which database, article, report they are taken). The time-related[6], geographical[7] and technological[8] coverage should be stated as well as how representative[9] these are for the study.

The completeness of the study should also be clearly stated; for example, if some major items are omitted, such as capital goods, this should be made clear. Additionally, the methodology and level of detail throughout the study should be consistent.

Finally, the variation[10] and uncertainty[11] of data should be estimated, which could be done quantitatively through a sensitivity analysis or qualitatively through a discussion.

The IDF recommends that data sourcing and utilisation are aligned with ISO 14044, which should be referred to for further detail.

6.2 Emission Factors

Emission factors provide an indication of amount of GHGs emitted from a particular source or activity. There are various methods and sources for determining emissions, which are tiered according to their accuracy and detail. The simplest approach is described as Tier 1 and more detailed approaches where country specific information is available are described as Tier 2. Individual data constitute Tier 3.

For example the 2006 IPCC Guidelines for National Greenhouse Gas Inventories have described all three tiers to estimate methane emission from enteric fermentation. On a Tier 1 basis, the emissions are calculated using standard emission factors from literature. The Tier 2 level calculation requires detailed country-specific data on gross energy intake and methane conversion factors for specific livestock categories. Tier 3 requires even more accurate and scientifically accepted data from direct experimental measurements concerning, for example, diet composition in detail, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability and possible mitigation strategies.

It is agreed for the purposes of achieving consistency in dairy LCAs, a Tier 2 minimum approach is necessary.

Details of the Tier 1, Tier 2 and Tier 3 methodologies are given in:

'2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use'

http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

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[6] Average data for a longer period or data from a specific year (for agricultural products it is important to have at least one year's average data, so seasonal variations during the year are accounted for) and are representative of this period for the study).

[7] Are the data representative only locally, for a country or for eg European conditions?

[8] Eg, are data used representative for a modern dairy or older dairy, a large scale or small scale dairy etc?

[9] The data used should obviously be relevant for the study, ie CARBON FOOTPRINT data for milk produced in US cannot be seen as representative for African conditions, since the production system is totally different

[10] Emissions of, eg, N_2O are known to have large variations, both in time and space (between places), therefore it is important to conduct a sensitivity analysis analyse the uncertainties (possible variations) in the calculations.

[11] The precision of data can often vary, eg feed intake can be difficult to estimate, and therefore this precision is important with sensitivity analysis of critical parameters, especially those for which it is difficult to get a precise estimate.

'Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories'
http://www.ipcc-nggip.iges.or.jp/public/gl/invs6c.html

Software for Greenhouse Gas Inventories is available at:
http://unfccc.int/resource/cd_roms/na1/ghg_inventories/index.htm

A Search of the IPCC Database of emission factors is available at:
http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_main.php

This guide makes recommendations for technical data requirements in Appendix C. For electricity, the recommendation is to use average electricity, including grid losses, in the country where the LCA is being conducted.

6.3 Allocation

6.3.1 Co-products

Handling of co-products is, in many cases, critical for the outcome of the LCA or carbon footprinting exercise. There are various ways to handle co-products, with some methods more pragmatic and others more scientific, but no single common or established method. The allocation procedure described by ISO 14044 follows.

Step 1: Wherever possible, allocation should be avoided by

a) dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or

b) expanding the product system (known as system expansion) to include the additional functions related to the co-products.

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them, ie, they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Looking at the whole life cycle of milk and dairy products from farm to manufacturing gate out, there are several processes that involve multiple co-products:

- Production of feed (eg soy meal or soy oil)
- Production of milk and meat on farm (where meat and calves are a by-product, and sometimes also manure when it is exported from the farm)
- Manufacture of dairy products at the processing site
- Energy generation (for example biogas production at the farm or electricity produced at the dairy manufacturing site, where surplus electricity can be exported to the national grid.

6.3.2 Production of feed

Many feed ingredients are co-products from a production system generating more than one product, and therefore the environmental burden should be distributed between the co-products. Some of the more commonly used feed ingredients for dairy cows where allocation situations occur are:

- soy meal (co-product to soy oil and soy hull, produced from soy beans)

- rape-seed meal (co-product to rape seed oil, produced from rape-seed)
- palm kernel expels (co-product to palm kernel oil, produced from palm kernels, which is a co-product to palm oil, produced from oil palm)
- maize gluten meal (co-product to maize gluten feed, maize germ meal and maize starch, produced from maize)
- wheat bran (co-product to wheat flour, produced from grain), and
- dry distillers grains with solubles (DDGS), co-product to corn ethanol, produced from corn grain.

The guidance here is to use economic allocation for co-product in feed production. This is identified as the most feasible allocation method to use at this stage because:

- subdivision of the system is not typically possible for feed products
- it can be difficult to identify the product/s that has/have been substituted by the by-products to apply the system expansion method, and it can be time-consuming
- it is difficult to find a physical relationship that reflects the relation between inputs and outputs, for example soy meal is typically used for its protein content, while soy oil is used for its energy content, hence applying allocation based on protein content or energy bases is not a allocation factor that is relevant for both products.

Consequently, economic allocation is the recommended method in this situation. As many feed ingredients are produced regionally or locally, five year averages on prices are advised to minimize fluctuations between years.

Example

If meal and oil are co-products, and meal is part used for feed as part of the LCA, the economic allocation factor is calculated using the equation below. The output from the process is X kg meal (with the price of A Euro per kg meal) and Y kg oil (with the price of B Euro per kg oil).

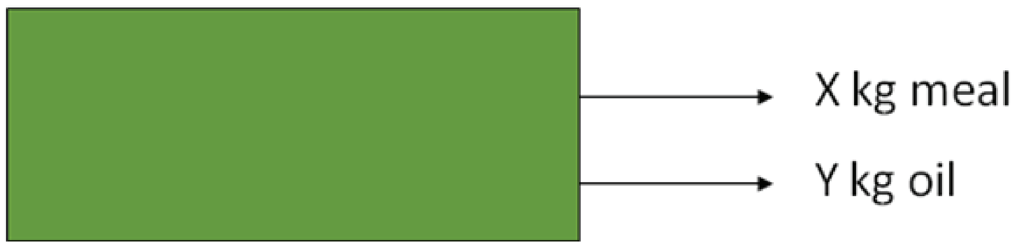

Figure 9. Example of allocation of co-products for feed.

Therefore:

Allocation factor (meal): $(X \times A) / (X \times A + Y \times B)$

The allocation factor is then multiplied with the environmental impact from the process (eg emissions associated with cultivation and transporting of the raw material, energy used for processing) and then divided with X kg meal to get the carbon footprint for one kilogram of meal.

6.3.3 Production of milk and meat

For the dairy farm system where the main focus is on production of milk, the meat generated from surplus calves and cull dairy cows is an important co-product. It is therefore necessary to determine total emissions and to allocate them between milk and meat. In some cases, manure can also be exported off-farm and in, these cases, this too, should be accounted for.

The most appropriate approach here is to use a physical allocation method. This aligns with Step 2 in ISO 14044 and reflects the underlying use of feed energy by the dairy animals and the physiological feed requirements of the animal to produce milk and meat. The feed consumption by animals is also the main determinant of enteric methane emissions and of nitrous oxide and methane emissions from animal excreta which together can make up about 80 per cent of total on-farm GHG emissions.

The allocation factor for milk and meat can be calculated using following equation (further explanation of details and background in Appendix B):

$$\mathbf{AF = 1 - 5.7717} \times \mathbf{R}$$

Figure 10. Formula for the allocation of milk and meat.

Where AF = allocation factor for milk, R = M_{meat}/M_{milk}, M_{meat} = sum of live weight of all animals sold including bull calves and culled mature animals and M_{milk} = sum of milk sold corrected to 4 per cent fat and 3.3 per cent protein using equation in 4.3.1. With this equation the determination of allocation factor is simple and involves the following steps:

- step 1a: collect/determine the total kg animal meat sold per year [kg_{meat}]
- step 1b: collect/determine the total kg milk 4% fat 3.3% protein equivalent produced per year
- step 1c: calculate the ratio R = kg_{meat}/kg_{milk} [-]
- step 2: Use the simple correlation: AF (allocation factor) to milk: AF = 1 - 5.7717R
- step 3: Allocation factor to beef = 1 – AF (allocation factor) to milk

As a default value for R, we can fix a typical ratio of eg 0.025 kg_{meat}/kg_{milk}, yielding a default allocation of 14.4 per cent to meat and a default allocation of 85.6 per cent to milk.

Example

This demonstrates the calculation, based on a physical method, of the allocation between milk and beef for a hypothetical farm that produces 1 million kg (1000 Mg) FPCM per year and exports 0.024 kg beef/kg FPCM. For purposes of this example, the beef export is calculated as the sum of live weight of all animals exported, including bull calves and culled mature animals, but excluding animals culled but not sent to the beef market.

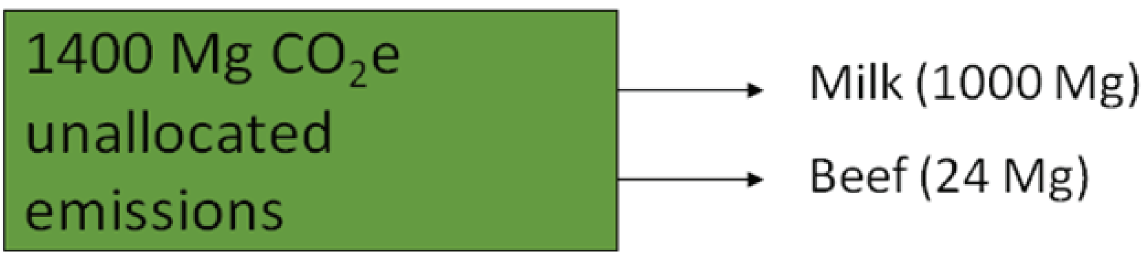

Figure 11. Example of allocation of meat as a co-product.

For this example the US national average of 1.4 kg CO_2e/kg FPCM unallocated GHG emissions will be assumed – for different regions, the local value should be substituted.

Based on the empirical equation for physical allocation (see Appendix B), the allocation to milk is: 1-5.7714x(0.024) = 0.86. Thus 0.86x1400 = 1204 Mg CO_2e is allocated to 1000 Mg milk, yielding a farm-gate footprint of 1.204 kg CO_2e/kg FPCM and (1400-1204) Mg CO_2e / 24 Mg beef or 8.17 kg CO_2e/kg beef (live weight).

For a detailed explanation of this approach, refer to Appendix B.

For export of manure from the farm the recommendation is to apply system expansion[12]. This is in accordance with ISO 14044. When applying manure on farm land, chemical fertiliser requirements are reduced, hence less chemical fertiliser needs to be produced for systems using manure. It is important that data used for these purposes are highly accurate, be they primary or secondary, pertaining to local conditions. Also refer to section 6.1 Data quality.

6.3.4 Manufacture of dairy products

Dairy manufacturing plants usually produce more than one product as the fat content in raw milk almost always exceeds the product specification for milk powders or fresh milk products (eg market milk, yoghurt or dairy desserts). The excess milk fat is normally further processed into butter or anhydrous milk fat (AMF).

However, resource use or emissions data are typically only available on a 'whole of factory' basis. Data collection for each unit process within the plant is resource intensive and there is typically insufficient metering to collect the required information. In addition, many of the unit processes are shared for different products (eg pasteurization, separation or spray drying).

Such aggregation of data poses problems when undertaking an LCA or carbon footprinting exercise for a selected product within a multi-product setting. To compare the life cycle of one dairy product to another therefore requires identification of the material consumption and process energy (electricity and fuel) demand in addition to emissions from a plant for each product.

The recommendation is to allocate raw milk intake and transportation on the basis of the milk solids of the final product. For all other operational materials, energy inputs (electricity and thermal energy) and emissions, more sophisticated allocation factors should be applied.

Three possible scenarios have been identified:

a) detailed process and co-product data are available: energy and material usage as well as emissions can be directly assigned to the specific products

b) a mixture of detailed process and co-product data as well as whole of factory data are available: in this case assign detailed process and co-product data to specific products first, subtract assigned detailed process and co-product data from the factory total and then allocate the remainder based on milk solids.

c) only whole of factory data are on hand: apply allocation coefficients as described in Table 1[13], which is an industry-specific physico-chemical allocation matrix to enable better allocation of resources to dairy products using 'whole of plant' information (Feitz et al 2007) (see end of Appendix B.)

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[12] Cederberg & Stadig, 2003.

[13] This matrix (see Table 1) is a starting point that will be further developed in the future.

Table 1: Industry specific physico-chemical allocation factors relative to milk powder* (Feitz et al 2007)

	Raw milk	Raw milk trasport	Total water use	Electricity	Fuel for termal energy	Alkaline cleaners	Acid cleaners	Total wastewater
Milk powder	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Yoghurt	0.16	0.16	0.28	0.86	0.11	0.08	0.01	0.28
Milk	0.14	0.14	0.15	0.14	0.03	0.08	0.01	0.15
Cream	0.47	0.47	0.15	0.14	0.03	0.08	0.01	0.15
Butter	0.88	0.88	0.40	0.36	0.17	0.10	0.50	0.40
AMF/Ghee	1.05	1.05	0.40	0.36	0.05	0.10	0.50	0.40
Cheese (cheddar)	0.64	0.64	1.40	0.57	0.10	0.70	1.00	1.40
Whey powder	1.01	1.01	1.20	1.50	1.30	0.90	2.00	1.20
UHT	0.14	0.14	0.15	0.29	0.06	0.08	0.01	0.15
Ice cream	0.23	0.23	0.68	1.92	0.004	0.90	0.00	0.68
WPC/lactose**	1.00	1.00	5.82	4.52	2.75	6.26	9.97	5.82

* Coeficients based on factory average resource use and wastewater emissions for different dairy products from 17 multi-product dairy manufacturing sites.

** There was insufficient information to separate energy and mass flows for whey protein concentrate (WPC) and lactose.

Some plants crystallize and dry lactose whereas others treated the lactose as a waste product.

For allocation inputs and outputs at the manufacturing site (ie when two of more are produced from raw milk) physico-chemical allocation should be used. If only whole of plant data are available, the physico-chemical allocation matrix is applied by using the equation below.

$$Allocation_{product\_i} = \frac{product_i \times AF_i}{\sum_{ij} product_{ij} \times AF_{ij}}$$

Figure 12. Formula for allocation of co-products during manufacturing.

with AFi = allocation factor

The allocation of one product (eg whole milk powder) is then multiplied with its specific resource use or environmental impact allocation factor and then divided the sum product of each product quantity and their respective allocation factor.

Example

A dairy manufacturing site has an annual raw milk intake of 100,000t. It produces 12,000t of whole milk powder and 1,400t of AMF. For the production of the two products thermal energy (among other inputs) is required, ie 230,000GJ per annum.

The outputs from the manufacturing site are:

- 12,000t whole milk powder (with an allocation factor 1 for raw milk and thermal energy[14], as given in the allocation matrix in Table 1)
- 1,400t AMF (with an allocation factor 1.05 for raw milk and 0.05 for thermal energy, as given in the allocation matrix in Table 1).

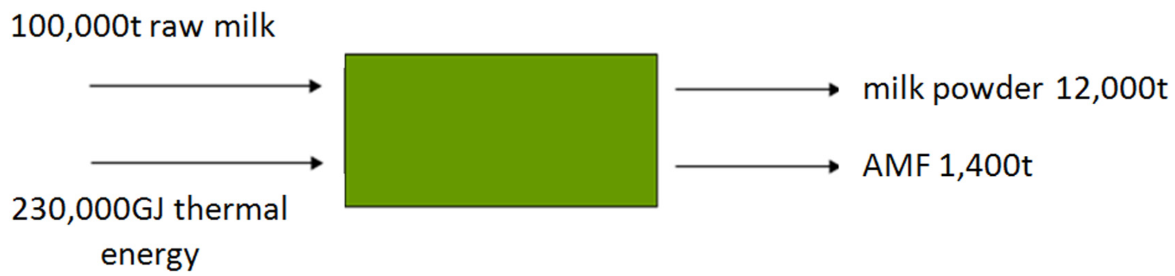

Figure 13. Example of allocation during manufacturing.

Applying the allocation factors from Table 1 and the equation as mentioned in Figure 12, the allocation factor for raw milk is calculated as:

(12,000x1.00) / (12,000x1.00+1,400x1.05) = 0.891

This formula results in 89,100t of raw milk allocated to raw milk, and 10,900t assigned to AMF.

The allocation factor for thermal energy is calculated to be:

(12,000x1.00)/(12,000x1.00+1,400x0.05) = 0.994

This results in 228,700GJ energy allocated to whole milk powder and 1,300GJ assigned to AMF.

6.3.5 On-site energy generation

Generation of energy can occur at the dairy farm or dairy manufacturing plant. Biogas can be produced from manure in anaerobic digestion on dairy farms, then exported for use in other systems, eg to replace fossil fuel natural gas in heating systems. Likewise, dairy manufacturing can produce a surplus of energy, whether it be heat or electricity, which can be exported back to the national grid.

The recommendation is to use system expansion for energy generated within the system and sold outside the system under study. This is in line with ISO 14044; however, it is important to know which type of energy is being exported.

[14] Please note that raw milk is the reference product for the allocation matrix. Hence all allocation factors for milk powder equal 1, while all other products are expressed relative to milk powder.

On dairy farms, biogas might be the most common energy source produced. At dairy manufacturing sites, electricity is likely to be the type of energy exported. Specific guidance on how to treat co-product handling of combined heat and power (CHP) plants can be found in the GHG Protocol Initiative calculation tool[15]

The amount of energy surplus is assumed to replace the same amount of energy based on its energy content, so biogas is assumed to replace natural gas and electricity using the average national or regional grid mix; heat is assumed to replace the same amount of heat originated from gas, black or brown coal.

6.3.6 Summary for handling co-products

Table 2: The chosen allocation approaches

Preferred approach	Allocation situations	Choice	Result
ISO hierarchy	Feed (pre farm)	Economic	Depends on kind of feed
	Milk/meat & calves (farm)	Physical causality	Based on energy feed inputs to the system and associated milk and meat production.
	Manure export (farm)	System expansion	Replaces N, P & K in chemical fertiliser
	Processing (dairy site)	Mix	Based on milk solids for raw milk, specific values for USE OF energy, water etc
	CHP (farm, dairy site)	System expansion	Replaces electricity from national grid or heat

6.4 Land use change and sequestration

6.4.1 Land use change

This is an extremely challenging and complex area of the LCA process. After careful review, the IDF, for the purposes of this document, has decided to adopt the guidance provided in section 5.5 and Annex E of PAS 2050[16].

In summary, it states that GHG emissions arising from direct land use change should be assessed for any input to the life cycle of a product originating from agricultural activities, and the GHG emissions arising from the direct land use change should be included in the assessment of GHG emissions of the product.

The assessment of the impact of land use change should include all direct land use change occurring on or after 1 January 1990. One-twentieth (5 per cent) of the total emissions arising from the land use change should be included in the GHG emissions of these products in each year over the 20 years following the change in land use.

Where it can be demonstrated that the land use change occurred more than 20 years before the assessment being carried out, no emissions from land use change should be included in the assessment as all emissions resulting from the land use change would be assumed to have occurred prior to the application of the PAS.

It is worth noting that direct land use change refers to the conversion of non-agricultural land to agricultural land as a consequence of producing an agricultural product or input to a product on that land. Indirect land use change refers to the conversion of non-agricultural land to agricultural land as a consequence of changes in agricultural practice elsewhere.

[15] 'Allocation of GHG emissions from a combined heat and power plant' from the World Resource Institute (WRI) and World Business Council of Sustainable Development (WBCSD) (2006) at www.ghgprotocol.org/.

[16] PAS 2050 'Specification for the assessment of the life cycle greenhouse gas emission of goods and services'.

6.4.2 Carbon sequestration

Grasslands and other agricultural vegetation cover a huge amount of Earth's land surface and span a range of climate conditions. Agricultural ecosystems hold large carbon reserves[17], mostly in soil organic matter. Soil carbon sequestration (enhanced sinks) is the mechanism responsible for most of the mitigation potential in the agriculture sector, with an estimated 89 per cent contribution to the technical potential[18].

The greenhouse effect can be limited by increasing soil carbon stocks and by maintaining existing stocks. Carbon storage is not a linear process; it is rapid for the first 20 years and then slows down. Storage depends on the kinetics of organic matter decomposition by the soil microbial community; it tends to move, in the long term, towards an equilibrium where inputs and outputs cancel each other out. However, there is no time limit to carbon storage; some very old rangelands are still adding to their carbon stocks

The carbon release prompted by a disadvantageous change in land use – such as converting grassland to arable – is twice as fast and as great as the soil carbon increase caused by the reverse change from arable land to grassland.

Maintaining grassland area or converting arable land to grassland thus makes it possible to store more carbon in the soil. However, it must be remembered that this process is both vulnerable and reversible. Soil carbon dynamics depend on grassland management practices, and some may affect the physical-chemical conditions of the soil environment and the physical protection of organic matter in the soil[19].

While it has to be kept in mind that soil carbon storage is the main potential mitigation option for agriculture, the current choice for standard footprinting methodology, and also for this IDF guide, is to not take changes in soil organic matter (carbon) into account because of a lack of scientific data at the world level. This applies to grassland but also to crop cultivation and to both positive and negative changes. However it does not prevent anybody to calculate the carbon storage in the carbon footprint when data exist, as long as it is reported separately in the results.

Continual monitoring of the scientific developments in this area will continue and where appropriate will be included in future revisions.

[17] IPCC (2001)

[18] IPCC (2007)

[19] Soussana et al 2009.

7. Calculating the footprint

The following method is used to calculate the GHG emissions for a functional unit:

1. Convert primary and secondary data to GHG emissions by multiplying the activity data by the emission factor for the activity. This gives **GHG emissions per functional unit of product**.
2. GHG emissions data are then converted into **CO_2e emissions** by multiplying the individual figures by the relevant global warming potential (GWP) factor (see below).

Thus the equation for product carbon footprinting is the sum of all materials, energy and waste across all activities in a product's life cycle multiplied by their emission factors.

Since the GWP factors have changed during the years, the most current IPCC GWP factors must be applied when undertaking a product carbon foot print calculation using this methodology.

Currently used factors can be found from The Physical Science Basis section of the IPCC 2007 report from 'Technical summary' chapter. The most common factors are:

1kg of methane (CH_4) = 25kg of CO_2e

1 kg of nitrous oxide (N_20) = 298kg of CO_2e

GWP factors for different refrigerants are available from the same reference document.

8. Evaluating and Reporting

8.1 Report evaluation

It is important that any carbon footprint report includes a section identifying ways in which emissions could be reduced; this will demonstrate that the exercise has a purpose and the knowledge will lead to an improvement, even if it is through the quickest and easiest means available.

8.2 Reporting

GHG accounting and reporting practices are new to many businesses, and because of this they are evolving at a fast rate. However, the principles listed below are derived from generally accepted financial accounting and reporting principles, which equally apply in this situation.

They also reflect the outcome of a collaborative process involving stakeholders from a wide range of technical, environmental, and accounting disciplines.

GHG accounting and reporting should be based on the following principles, as described in the WBCSD and WRI's Greenhouse Gas Protocol Product Life Cycle Standard (see 1.2):

- **Relevance** – Ensure the GHG inventory reflects the GHG emissions of the company and serves the decision-making needs of users – both internally and externally
- **Completeness** – Account for and report on all GHG emission sources and activities within the chosen inventory boundary; disclose and justify any specific exclusions
- **Consistency** – use consistent methodologies to allow for meaningful comparisons of emissions over time; transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series
- **Transparency** – Address all relevant issues in a factual and coherent manner, based on a clear audit trail; disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.
- **Accuracy** – Systematically check that the quantification of GHG emissions is neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as much as possible; achieve sufficient accuracy that users can make decisions as to the integrity of the reported information with a reasonable level of confidence.

8.3 Key parameters in the report

To get a better understanding of the studied system it is beneficial for the following 'key parameters' to be included in the report:

- Total carbon footprint divided into
  - fossil and biogenic methane
  - nitrous oxide
  - fossil carbon dioxide
  - biogenic carbon dioxide (biogenic carbon in packaging and carbon emissions of land use change should be reported separately)
- Functional Unit used
- Percentage of emissions attributed to milk (ie allocation factor between milk and meat/ calves, and method used to determine allocation factor)
- Milk yield per cow and milk composition
- Dry matter intake per cow and body weight per animal class
- Dry matter intake divided on different feed types (as a minimum, the share of roughage feed, concentrate feed (grain/protein))
- Manure management system
- All emission and GWP factors used and their sources
- Allocation factor applied in the dairy manufacturing plant for the studied product.

9. Glossary of terms

Primary source: PAS 2050

Allocation

Partitioning the input or output flows of a process between the product system under study and one or more other product systems.

Attributional

Attributional LCAs focus on describing the environmentally relevant physical flows to and from the product or process.

Biogenic

Derived from biomass, but not fossilised or from fossil sources.

Biomass

Material of biological origin excluding material embedded in geological formations or transformed to fossil.

Boundary

Set of criteria specifying which unit processes are part of a product system (life cycle).

Capital goods

Goods, such as machinery, equipment and buildings, used in the life cycle of products.

Carbon dioxide equivalent (CO_2e)

Unit for comparing the radiative forcing (global warming impact) of a greenhouse gas expressed in terms of the amount of carbon dioxide that would have an equivalent impact.

Carbon footprint

The level of greenhouse gas emissions produced by a particular activity or entity.

Combined heat and power (CHP)

Simultaneous generation in one process of useable thermal energy and electrical and/or mechanical energy.

Carbon storage

Retaining carbon of biogenic or atmospheric origin in a form other than as an atmospheric gas.

CHP

see combined heat and power.

Consequential

Consequential LCA assessments describe how relevant environmental flows will change in response to different decisions.

CO_2e

see carbon dioxide equivalent.

Co-products

Any of two or more products from the same unit process or product system [ISO 14044:2006, 3.10].

Data quality

Characteristics of data that relate to their ability to satisfy stated requirements.

Emission factor

Amount of greenhouse gases emitted, expressed as carbon dioxide equivalent and relative to a unit of activity (eg kg CO_2e per unit input). NOTE Emission factor data are obtained from secondary data sources.

Emissions

Release to air and discharges to water and land that result in greenhouse gases entering the atmosphere. The main emissions concerning GHGs from agriculture are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).

Enteric fermentation

Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal

Functional unit

Quantified performance of a product for use as a reference unit.

Global warming potential (GWP)

The intensity of a GHG's warming potential, which is different for each gas. The factors used to convert GHGs into CO_2 equivalents are defined by IPCC guidelines and can be found in section 4.6

Greenhouse gases (GHGs)

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds NOTE GHGs include carbon dioxide (CO_2), methane(CH_4), nitrous oxide (N_2O), hydrofluoro-carbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

GWP

see global warming potential.

Input

Product, material or energy flow that enters a unit process.

LCA

see Life Cycle Assessment

Life cycle

Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to end of life, inclusive of any recycling or recovery activity.

Life cycle assessment (LCA)

Compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle.

Life cycle GHG emissions

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

Material contribution

Contribution of any one source of GHG emissions to a product of more than one per cent of the anticipated life cycle GHG emissions associated with the product. NOTE A materiality threshold of one per cent has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources.

Offsetting

Mechanism for claiming a reduction in GHG emissions associated with a process or product through the removal of, or preventing the release of, GHG emissions in a process unrelated to the life cycle of the product being assessed.

Output

Product, material or energy that leaves a unit process.

Primary activity data

Quantitative measurement of activity from a product's life cycle that, when multiplied by an emission factor, determines the GHG emissions arising from a process. NOTE Examples include the amount of energy used, material produced, service provided or area of land affected.

Product(s)

Any good(s) or service(s). NOTE Services have tangible and intangible elements. Provision of a service can involve, for example, the following:

- an activity performed on a consumer-supplied tangible product (e.g. automobile to be repaired)
- an activity performed on a consumer-supplied intangible product (e.g. the income statement needed to prepare a tax return)
- the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission)
- the creation of ambience for the consumer (e.g. in hotels and restaurants)
- software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.

Raw material

Primary or secondary material used to produce a product.

Secondary data

Data obtained from sources other than direct measurement of the processes included in the life cycle of the product. NOTE Secondary data are used when primary activity data are not available or it is impractical to obtain primary activity data. In some case, such as emission factors, secondary data may be preferred.

System boundary

Set of criteria specifying which unit processes are part of a product system (life cycle).

System expansion

Expanding the product system to include the additional functions related to the co-products.

Waste

Materials, co-products, products or emissions which the holder discards or intends, or is required to, discard.

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Greg Thoma, Institute for sustainable engineering analysis, USA
Olaf Thieme, FAO AGAP
Janusz Turowski, University of Warmia and Mazury, Poland
Neil Van Buuren, Dairy Australia, Australia
Theun Vellinga, FAO AGAL and Wageningen University
Harald Volden, TINE Rådgivning/TINE Advisory Service, Norway
Erika Wallén, Tetra Pak International, Sweden
Wang Ying, Dairy Management inc., USA

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12. Appendices

A. Functional Unit for Farming

The energy content of milk with known fat and protein content is calculated by:

Milk Energy (Mcal/kg) = 0.0929xFat % +0.0588xTrue Protein% + 0.192 which is equivalent to:

Milk Energy(Mcal/kg) = 0.0929xFat %+0.0547xCrude Protein%+ 0.192.

The energy content of standard milk with 4 per cent fat and 3.3 per cent true protein is: 0.7576 Mcal/kg. By dividing the coefficients by the standard milk energy content, the final equation for calculating fat and protein corrected milk (FPCM) is:

FPCM (kg/yr) = Production (kg/yr) x[0.1226xFat% +0.0776xTrue Protein% + 0.2534]

Reference:

Nutrient Requirements of Dairy Cattle: Seventh Revised Edition, 2001. (Eds. J. Clark, D. K. Beede, R. A. Erdman, J. P. Goff, R. R. Grummer, J. G. Linn, et al.) National Academies Press : Washington, D.C., p321.

B. Allocation Milk:Meat – the scientific basis for the approach

A large study which included collection of detailed farm-level data from 531 US farms is nearing completion. In this study a causal relationship between the energy content in the animal ration and milk and beef production was developed. The background and basis of the calculations is presented below.

In short, feed energy available for growth, for a given feed, is lower than that available for milk production. The conversion of feed to milk is more efficient use of the feed. Given this causal connection between feed, the major farm input, and the products, an algorithm to estimate the quantity of feed required to produce the observed milk and beef products of a farm can be created.

This algorithm was applied using detailed rations (160 distinct feeds accounted) and the causal allocation factor computed for each farm. To simplify the application of this approach, we created an empirical relationship for the allocation fraction, shown in the figure below.

There is a wide range of rations represented in the dataset, from strictly pasture-based small operations to large (3000 milking head) confined animal operations. There is also a wide range of available energy content in the feeds (that is, a range of the net energy for lactation values of the feeds) represented in the dataset, indicative of high and low quality rations. Finally, there is also a large variety in the animal class sent to beef, ranging from bull calves through mature animals. As the underlying dataset is robust, it is not necessary to make detailed calculations for each class of animal sent to beef, nor is it necessary to make detailed calculations based on specific rations every time an allocation procedure is needed.

Given this, we feel that the empirical relationship: AF = 1 – 5.7717 R is robust enough to be applied internationally. Here AF is the allocation fraction, and R is the ratio of kg beef/kg milk; the milk should be corrected to 4 per cent fat and 3.3 per cent protein. The calculation of kg beef should exclude animals which die on the farm and are disposed by burial, rendering, etc. As indicated in the report body, allocation is an important and evolving issue, thus validation exercises are being initiated using rations from other milk production regions.

Applying the causal allocation for the feed, the fraction of the farm to gate greenhouse gas emissions that is to be allocated to meat (versus milk) can be calculated as a function of the ratio of the annual quantities of meat divided by the annual quantity of milk produced (Figure 8).

The determination is simple and involves the following steps:

step 1a: collect/determine the total kg animal meat sold per year [kg_{meat}]
step1b: collect/determine the total kg milk 4% fat 3.3% protein equivalent produced per year
step 1c: calculate the ratio $R=kg_{meat}/kg_{milk}$ [-]
step 2: Use the simple correlation: allocation factor to milk: AF = 1 – 5.7717R
step3: Allocation factor to beef = 1- allocation factor to milk

By default, we can fix a typical ratio of eg 0.025 kg_{meat}/kg_{milk}, yielding a default allocation of 14.4 per cent to meat and a default allocation of 85.6 per cent to milk.

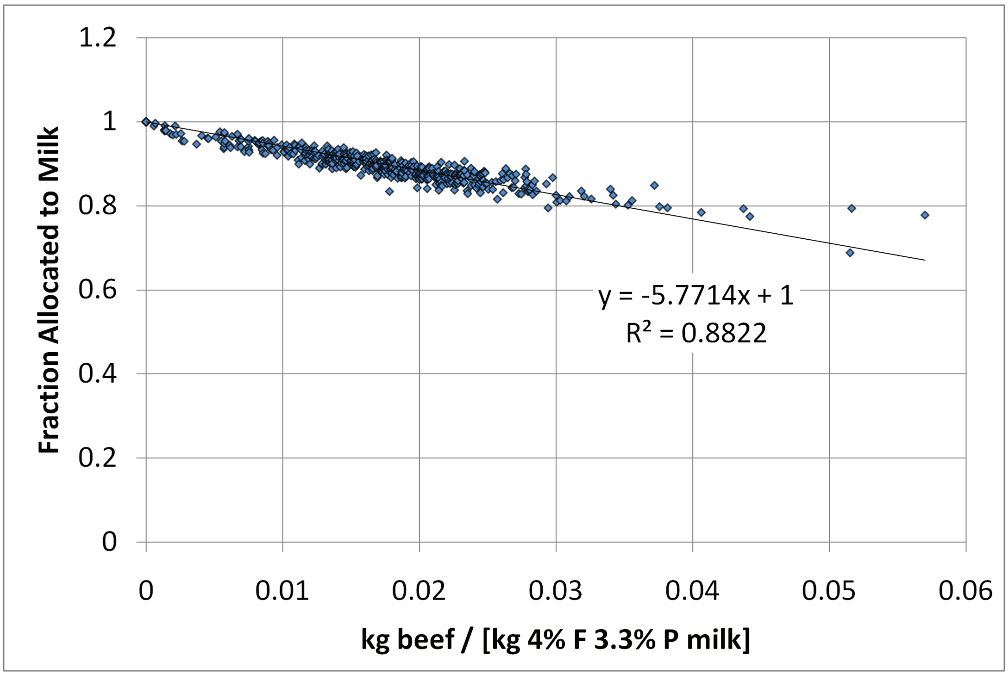

Figure 8. Fraction of the farm to gate life cycle allocated to milk (versus meat).

The approach outlined here avoids some of the shortcomings of economic or fixed allocation algorithms. Specifically, it prevents allocation fraction from changing due to variation in the economics of the milk and beef industries, and it provides an accounting of differences in relative production between milk and beef at scales from single farms to regions.

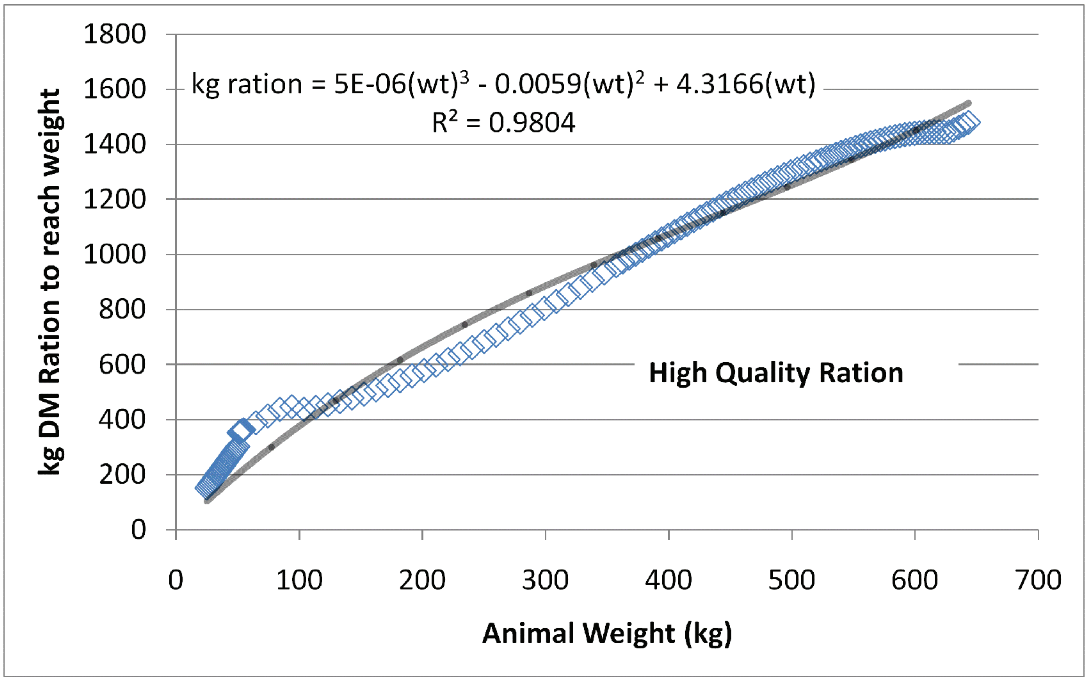

Figure 9. Growth curve for dairy cattle on high quality ration.

Note that the feed DM calculated is the feed required strictly for growth, maintenance energy is not accounted in the calculation. Figure 9 presents the growth curve for animals fed the high quality ration.

The regression equations can be used to calculate the feed necessary to produce the body mass of each animal leaving the dairy to the beef industry (or for local consumption). The total feed consumed on the farm per year can then be summed from the known number of animals in each weight class and the feed consumed for growth by that weight class.

The quantity of 4 per cent fat, 3.3 per cent protein milk (fat and protein corrected milk, FPCM) produced can be calculated from the following equation:

$$FPCM = \{Production\ (kg) \times (0.0929*\%F) + (0.0547 \times \%P/0.93) + 0.192\} / 0.7518$$

The total feed energy required for milk production is calculated as:

(Total kg produced x net energy content of milk)/(feed energy available for lactation).

Thus for a farm with an annual production of 100,000 kg of 4 per cent fat and 3.2 per cent protein milk (0.7518 Mcal per kg) using the high quality ration, the total kg DM of the ration required for this quantity of milk is:

100,000 (kg milk) x 0.7518(Mcal/kg milk)/1.61(Mcal/kg ration) = 46,696 kg ration

Allocation of milk processing

This matrix is the product of an extensive process of subtraction and substitution to determine average resource use and emissions for individual products from numerous multi-product manufacturing plants. This procedure avoids the need for economic, energy or mass allocation and creates a more realistic measure of resource use per product.

In summary, the procedure involves:

- using initial literature and estimates from numerous production sites to establish resource efficiency per product
- normalizing the resource efficiency figures for all products to a reference product, and producing a matrix of resource efficiency 'coefficients' (or physico-chemical allocation factors)
- optimizing the coefficients in an iterative manner for all products using surveyed process data from numerous plants given the constraints of the number of products, mass of different products and total resource use for each plant. The coefficients could be further refined by using an approach similar to the RAS method, used for optimizing input coefficients in input-output tables (see also Ciroth et al, 2007); ideally applied to a large sample of manufacturing sites.

C. Technical Data

List of technical data required to calculate emissions.

Farm Products	
Total quantity of milk supplied	Total quantity of milk supplied by this type of farm.
Milk production	Average annual milk production of a dairy cow (kg/dairy cow/year).
Fat content and protein	Average fat and protein content of milk from the area (g/litre).
Meat production	
Herd	
Reproduction	The numbers of births per annum per animal and the number of young animals per birth. (Respectively fertility and prolificacy), an estimate is needed for the male animals for reproduction (natural or artificial) by the bull to cow ratio
Growth	The adult age is defined as the age at which growth stops and the female animal gives birth for the first time. The age when sold for the market is when the animal is supposed to be at the optimal weight for slaughter or when the animal is slaughtered (optimal weight or not).
Death	The annual percentage of animals dying is split in three groups: young animals at birth, young animals after birth and before adult and adult animals.
Replacement	The number of adult animals that is replaced annually by new younger adult animals.
Animals above replacement	The previous rates define the number of young animals that are necessary to maintain a herd at a constant size. The other animals can be sold or kept within the same production system
Weights	Larger and heavier animals need more energy for maintenance. Also the growth from calving weight to adult or slaughter is more, which also demands more energy.
Ranging, grazing or stall feeding	When animals have to search for their feed and have to walk a lot, the energy requirements are higher than when they are inside and no labour is needed for collecting feed.
Manure management	
Storage	The type of storage and the time of storage define the level of emissions
Manure application	The application type defines the emissions to the environment. Also when manure is used for non feed crops or for fuel, this is defined in the manure compartment.
Feed	
Digestibility	Net energy content of the feed
Nitrogen content	

Feed production (land for feed)	
Dry matter yield per hectare	
percentage of the total crop yield	In the case of crop residues or wastes, a percentage of the total crop yield (eg grains + straw) must be defined.
Use of manure and fertiliser	
Energy use by machinery	For crop management: eg tillage, harvesting and conservation
Transport of feed	Transport of feed components to the animal production site
Further processing of feedstuffs	Further processing of feedstuffs to concentrates in the feed mill
Actual land use	In the case of grassland, grassland management has to be defined in order to estimate whether the condition is improving, constant or decreasing. The latter is the case with overgrazing and land degradation. In the case of arable land the tillage system can play a role.
Previous land use	Large amounts of carbon get lost when forest is converted to grassland or arable land and when grassland is converted to arable land. In the case of land use change a time frame of 20 years will be used, according the guidelines of the IPCC (IPCC, 2006).
Other external inputs	
Energy needed for milking	
Energy needed for heating	
Energy needed for cooling	
Water supply	
Processing	
Raw milk	Total allocated to manufacturing plant Transportation of raw milk to manufacturing plant
Ingredients	Ingredients other than raw milk Country of origin Transportation of ingredients to manufacturing plant
Intermediate Products	Intersite/company transfers eg cream, butter milk, lactose Transportation of intermediate products
Energy	Electrical and thermal energy use Source of energy (black coal, natural gas, oil, LPG and biogas) Cogeneration systems
Chemicals	Main chemicals used in cleaning-in-place (CIP) systems (Caustic, nitric acid, triplex, sodium hypochlorite) Transportation of chemicals to manufacturing plant
Packaging	The quantity of packaging materials and their respective material compositions-paper, cardboard, LDPE, LLDPE Nitrogen, carbon dioxide used during packaging of f inished products Country of Origin for packaging material

Processing (continued)	
Refrigerants	Quantity and type of refrigerants used in manufacture and storage of finished product
Water	Quantity of water and water treatment process
Wastewater	Quantity of wastewater produced and wastewater treatment process
Solids waste	Quantity of solids waste product and amount recycled
Finished product	Quantity of product-milk, yoghurt, cheese, milk powder etc produced at the manufacturing plant

A COMMON CARBON FOOTPRINT APPROACH FOR DAIRY
THE IDF GUIDE TO STANDARD LIFECYCLE ASSESSMENT METHODOLOGY FOR THE DAIRY SECTOR

ABSTRACT

Creating consistency and a clear message on the quantification of carbon footprint is important for the reputation of the world dairy sector to highlight the high level of engagement that is already taking place in relation to this issue, and to identify practices that will further reduce greenhouse gas emissions.

The IDF guide is the first international consensus document describing a common carbon footprint approach for dairy products including addressing the common LCA challenges of allocation to co-products and land use change. The document identifies the key areas in which there is currently ambiguity or differing views on approach while it recommends a science-based approach that can also be inserted into existing or developing methodologies for practical application in developing and developed dairy industries across the world. The IDF guide has been developed in close collaboration and with the active involvement of the Food and Agriculture Organization of the United Nations (FAO) and the Sustainable Agriculture Initiative Platform (SAI Platform).

Keywords: carbon footprint, climate change, emissions, environment, environmental management, environmental policies, greenhouse gas, land use, LCA, milk production, sustainability

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Example: 1 Singh, H. & Creamer, L.K. Aggregation & dissociation of milk protein complexes in heated reconstituted skim milks. J. Food Sci. 56:238-246 (1991).

Example: 2 Walstra, P. The role of proteins in the stabilization of emulsions. In: G.O. Phillips, D.J. Wedlock & P.A. William (Editors), Gums & Stabilizers in the Food Industry - 4. IRL Press, Oxford (1988).

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In the case of native English speakers the author's national conventions (British, American etc.) are respected for spelling, grammar etc. but errors will be corrected and explanation given where confusion might arise, for example, in the case of units with differing values (gallon) or words with significantly different meanings (billion).

"	Usually double quotes and not single quotes
? !	Half-space before and after question marks, and exclamation marks
±	Half-space before and after
microorganisms	Without a hyphen
Infra-red	With a hyphen
et al.	Not underlined nor italic
e.g., i.e.,...	Spelled out in English - for example, that is
litre	Not liter unless the author is American
ml, mg,...	Space between number and ml, mg,...
skimmilk	One word if adjective, two words if substantive
sulfuric, sulfite, sulfate	Not sulphuric, sulphite, sulphate (as agreed by IUPAC)
AOAC International	Not AOACI
programme	Not program unless a) author is American or b) computer program
milk and milk product	rather than "milk and dairy product" - Normally some latitude can be allowed in non scientific texts
-ize, -ization	Not -ise, -isation with a few exceptions
Decimal comma	in Standards (only) in both languages (as agreed by ISO)

No space between figure and % - i.e. 6%, etc.

Milkfat	One word
USA, UK, GB	No stops
Figure	To be written out in full
1000-9000	No comma
10 000, etc.	No comma, but space
hours	ø h
second	ø s
litre	ø l

the Netherlands

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