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of the International Dairy Federation

A common carbon footprint approach for the dairy sector

The IDF guide to standard life cycle assessment methodology

This publication replaces IDF Bulletin 445/2010

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Send any comments or inquiries to:
International Dairy Federation (I.N.P.A.)
Boulevard Auguste Reyers 70/B
1030 Brussels
Belgium
Phone: + 32 2 325 67 40
Fax: + 32 2 325 67 41
E-mail: info@fil-idf.org
Web: www.fil-idf.org

A COMMON CARBON FOOTPRINT APPROACH FOR THE DAIRY SECTOR

The IDF guide to standard life cycle assessment methodology

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Boulevard Auguste Reyers, 70/B - 1030 Brussels (Belgium)
Telephone : +32 2 325 67 40 - Telefax : +32 2 325 67 41 - E-mail : info@fil-idf.org - http://www.fil-idf.org

FOREWORD

Demonstrating IDF's commitment to contribute to further reductions in greenhouse gas emissions by an increasingly sustainable global dairy industry, we have revised 'A common carbon footprint approach for the dairy sector: The IDF guide to standard life cycle assessment methodology' that was published in 2010. The revision ensures that the guide remains practical to use for the dairy industry globally, up-to-date scientifically and aligned with developments in other standards, and with the current draft of the FAO Livestock Environmental Assessment and Performance (LEAP) Partnership guidance, Environmental performance of large ruminant supply chains: Guidelines for assessment. As life cycle assessment often informs policy discussions on the climatic impact of food production, the work of the SCENV Action Team on LCA Development Monitoring has continued relevance.

The global dairy sector has been at the forefront in aligning carbon footprint calculations. Other agricultural sectors are now starting to develop similar approaches and it is important to investigate potential alignment with sectors close to dairy, such as the feed and meat industries. In addition, it is vital to keep a close dialogue with FAO projects involving carbon footprint calculations. The close relationship between IDF and the FAO has been very valuable in the process of exchanging expertise.

Although all areas of concern and current development have been analysed, changes to the standard were limited to those supported by robust scientific evidence in order to ensure the highest degree of consistency, as well as to allow comparability with the first version and subsequent revisions.

The revision started with a survey sent to IDF National Committees, which provided valuable feedback from the users of the standard. IDF expresses its gratitude to the hard work of the experts (listed in the Acknowledgements) involved in the completion of this guide, who made significant efforts in collaboration and dialogue, coming to balanced agreement. We encourage the use of this guide and the continuous and increased involvement of experts in the next phase of evaluation and revision of this living document.

Nico van Belzen, PhD
Director General
International Dairy Federation
Brussels, September 2015

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Our thanks go to:

Those involved in this revision of the guide:

Sophie Bertrand, French Dairy Board, France
Rainer Bertsch, Tübingen Government, Germany
Jude Capper, Washington State University, USA
Paul Crosson, Teagasc, Ireland
Sanne Dekker, FrieslandCampina, The Netherlands
Jean-Baptiste Dolle, Institut de l'Elevage, France
Onur Durmus, Tetra Pak International, Belgium
Marc Dresser, Fonterra, New Zealand
Anna Flysjö, Arla Foods amba, Denmark
Brian Lindsay, Lindsay Consulting, UK
Sven Lundie, PE International, Germany
Anna-Karin Modin Edman, Arla Foods amba, Sweden
D O'Brian, Teagasc, Ireland
Marcin Preidl, German Dairy Association (VDM), Germany
J-P Revéret, Groupe Agéco, Canada
Maartje Sevenster, Sevenster Environmental, Australia
Laurence Shalloo, Teagasc, Ireland
Greg Thoma, Institute for Sustainable Engineering Analysis, USA
Neil Van Buuren, Dairy Australia, Australia
Theun Vellinga, Wageningen University, The Netherlands
Richard Warren, Dairy UK, UK
Ying Wang, Dairy Management Inc., USA

Those involved in the first version of the guide:

Jim Barnett, Fonterra Cooperative Group, New Zealand
Sophie Bertrand, French Dairy Board, France
Peter Darlington, CMS UK, UK
Robin Dickinson, Carbon Trust, UK
Jean-Baptiste Dolle, Institut de l'Elevage, France
Onur Durmus, Tetra Pak International, Belgium
Anna Flysjö, Arla Foods amba, Denmark
Pierre Gerber, FAO AGAL
Jan. D Johannesen, Arla Foods amba, Denmark

John Kazer, Carbon Trust, UK
Park Kyuhyun, National Institute of Animal Science, Republic of Korea
Brian Lindsay, Lindsay Consulting, UK
Sven Lundie, PE International, Germany
Daniel Massé, Agriculture and Agri-Food Canada, Canada
Anna-Karin Modin Edman, Arla Foods amba, Sweden
Richard C Naczi, Dairy Management Inc., USA
Tim Nicolai, Delaval International AB, Sweden
Thais H Passos Fonseca, Biological Systems Engineering Department University of Wisconsin, USA
Nico Peiren, ILVO Animal Sciences, Belgium
Cyrus Poupoulis, Alexander's Technological Educational Institution of Thessaloniki TEI, Greece
Marcin Preidl, German Dairy Association (VDM), Germany
Maartje Sevenster, Sevenster Environmental, Australia
Greg Thoma, Institute for Sustainable Engineering Analysis, USA
Olaf Thieme, FAO AGAL, Rome
Janusz Turowski, University of Warmia and Mazury, Poland
Neil Van Buuren, Dairy Australia, Australia
Theun Vellinga, Wageningen University, The Netherlands
Harald Volden, TINE Rådgivning/TINE Advisory Service, Norway
Erika Wallén, Tetra Pak International, Sweden
Ying Wang, Dairy Management Inc., USA

1 INTRODUCTION

1.1. Background

Climate change remains a top priority among environmental challenges that must be addressed at all levels of society. Most industries are challenged to quantify and reduce their emissions of greenhouse gases (GHGs) to the atmosphere. Both food processors and farming organisations within the international dairy industry have recognised the need to calculate greenhouse gas emissions for production systems and products, that is, the carbon footprint (CF). This has led many to proactively engage professional bodies or specialist organisations to review and calculate the carbon footprints of dairy products.

This guide was developed at the request of the 46 IDF member countries, representing more than 75% of the world's milk production, because it has become evident that the wide range of figures resulting from differing methodologies and data is leading to inconsistencies. This poses a 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. Creating consistency and a clear message is important for the reputation of the industry globally, to highlight the high level of engagement that is already taking place in relation to climate change, and to identify practices that will further reduce greenhouse gas emissions.

1.2. About this guide

This guide was first developed and published in 2010 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).

At the launch of the IDF CF guide, it was decided that the guide was to be continuously reviewed and revised by SCENV to reflect evolving science and standards in CF methodology, in addition to experiences in using the guide by the dairy industry. A questionnaire was circulated to IDF National Committees in 2012 and the valuable feedback was used in the SCENV review and revision process. In this first updated version of the original CF guide, a minor adjustment has been made in the equation for allocation of emissions between milk and meat at dairy farm level, and the section on carbon sequestration has been expanded. Based on a proposal by IDF experts participating in FAO LEAP technical advisory groups (and upon approval by the IDF Standing Committee on Environment), the following guidance provided in the FAO LEAP document, 'Environmental performance of large ruminant supply chains: Guidelines for assessment' [1] has also been referenced or incorporated into this revision: a decision tree for production units and co-products; an improved description of the IDF allocation method for milk and meat; information on the allocation method for manure, which treats manure as a residual (this is a change from the previous IDF guidance); and more detailed information on attributional and consequential LCA methods.

This guide:

- Identifies an approach, based on current best knowledge, for addressing common LCA challenges when calculating carbon footprints of dairy production and dairy products
- 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 organisations that are already involved in improving the standardisation of LCA methodology (see Figure 1) was recognised from the start. These organisations include:

- **International Organization for Standardization (ISO)**, responsible for ISO 14040, 14044 and 14067, which are the original standards for quantifying 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**, who developed Publicly Available Specification 2050 (PAS 2050), the specification for the assessment of the life cycle greenhouse gas emissions of goods and services.
- **The World Business Council for Sustainable Development (WBCSD)** and the **World Resources Institute (WRI)**, which have developed the Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard, the Corporate Value Chain Scope 3 Standard, and the 2011 companion guide, Technical Guidance for Calculating Scope 3 Emissions (version 1.0).
- **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 Organisation (WMO).

- **Food and Agriculture Organization of the United Nations (FAO)**, whose methodology for calculating the greenhouse gas emissions from the dairy sector [3] was developed at the same time as this guide.

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

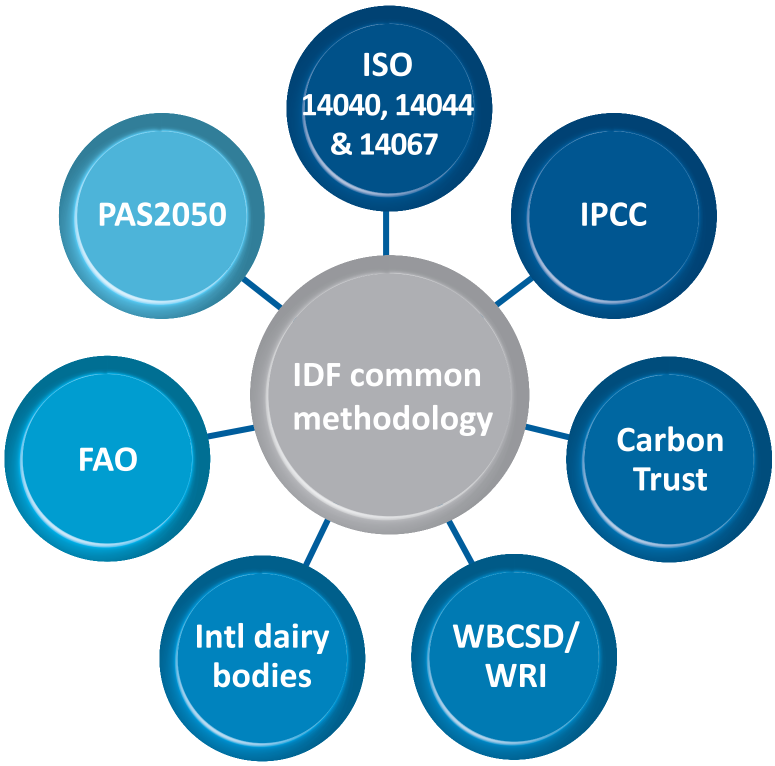

Figure 1: The IDF common methodology embraces a comprehensive range of international knowledge and aspects of existing standards

1.3. Who should use this guide?

This guide was 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 a life cycle assessment (LCA) approach. By incorporating this approach, fair comparison can then be made across different production systems, regions and products as required by applying a standard approach.

The methodology developed in the guide aims to allow:

- Comparison of GHG emissions between cattle 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 nor retailer and 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 change in response to, for example, changes in demand. Consequential LCA can also be useful when evaluating reduction or mitigation strategies, because a mitigation strategy (e.g. increasing milk yield) that has a positive effect on the GHG emissions of a milk production system might have a negative effect elsewhere, for instance on the emissions of a beef production system.

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.

For more detail on the use of attributional and consequential LCA modelling approaches, see Appendix 16 of the FAO LEAP guidance, 'Environmental performance of large ruminant supply chains: Guidelines for assessment'. [1].

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, Chapters 10 and 11 (available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html) [4]
- ISO 14040,14044 and 14067 (available by searching in www.iso.org) [5-7]

- PAS 2050 (available by searching in www.bsigroup.com) [8]
- WBCSD GHG Protocol calculation tool (available from www.ghgprotocol.org/) [9]

1.6. Future reviews and enhancements

The area of LCAs and the environmental impact of food production systems is an area of rapidly evolving science and knowledge. The IDF is committed to continually reviewing new science and standards in the field of LCA and CF calculation, in addition to the practical experiences gained by the dairy industry from using the guide. Relevant outcomes are incorporated into existing guidelines and members informed of advances in specific topics.

The IDF will continue to liaise closely with other organisations working in similar fields, with the aim of sharing information, increasing consistency in approaches and remaining at the cutting edge of developments.

This guide focuses only on GHG emissions, but there are other important environmental impact categories that are commonly included in LCAs, such as water use, toxicity, eutrophication, acidification, land use and biodiversity. Future versions of the guide may include other impact categories, or complimentary guidance will be developed. In 2015, IDF will publish LCA guidance on water footprinting, which will be compatible with the ISO standard on water footprinting (ISO 14046) [10], as well as this IDF guide on common carbon footprint methodology. IDF is also in the process of developing a framework for assessing biodiversity.

1.7. Summary

By developing an internationally harmonised methodology for calculating the carbon footprint of cattle milk and dairy products, the IDF is aiming to:

- Support the production of consistent and comparable carbon footprint figures internationally
- Enable the evaluation of cattle 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
- 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

A product carbon footprint is based on a **Life Cycle Assessment (LCA)** methodology. LCAs were originally used to analyse industrial process chains, but have been adapted over the past 20 years to assess the environmental impacts of agriculture, including dairy production. An LCA analysis systemically accounts for all inputs and outputs for a specific product or production system across a specified **system boundary,** such as a dairy farm, a dairy plant or the entire dairy production system. The system boundary is largely dependent on the goal of the study. Other environmental impacts are commonly included when doing a full LCA (e.g. water use, land use, toxicity, eutrophication, biodiversity), whereas a carbon footprint only includes the climate impact category.

Greenhouse gases are all gaseous substances for which the 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. One example of a carbon footprint is obtained by calculating all the GHGs emitted during the production of one litre of semi-skimmed milk, packed in a specific type of paper carton, up to the point when the milk leaves the manufacturing plant gate.

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 fresh milk of a defined fat and protein content in a defined type of package.

The application of LCA to agricultural systems is often complex because, in addition to the main product, there are usually **co-products** such as meat or energy. This requires appropriate partitioning of environmental impacts to each product from the system on the basis of 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 [5], ISO 14044 [6] and ISO 14067 [7]; the recommendations of PAS 2050 [8] should also be taken into account where advised in this document.

The decision to calculate the carbon footprint of a product is a conscious decision to focus on only one environmental indicator.

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 [11–22]. However, comparison between these studies is difficult because of differences in system boundaries, allocation methodology and emission factors. It may also be difficult to identify where meaningful reductions in GHG emissions can be made when differences in results can depend more on the methodological differences than real differences in the production system or management [23–24].

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 develop 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.

2.3. Existing international standardisation processes

From the outset, the IDF was committed to reviewing existing standardisation work and to collaborate with organisations that were already involved in improving the standardisation of LCA methodology. As emphasised 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 14067

ISO 14040 ‘Life cycle assessments’ [5] provides an important basis for framework and principles, and ISO 14044 ‘Environmental management – life cycle assessment’ [6] provides requirements and guidelines. ISO took up the task of preparing a standard for ‘Carbon footprints of products’ (ISO/TS 14067) in 2009 and finalised it in May 2013 [7]. The standard consists of two parts: one for assessment and quantification, and one for communication. The IDF is engaged with these processes where practicable.

2.3.2. PAS 2050:2011

The British Standards Institute, 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’ [8].

This British pre-standard sets out an initial comprehensive proposal for the methodology of the product carbon footprint. The original version of the PAS was published in October 2008 and was 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 standardised basis for the assessment of greenhouse gas emissions arising throughout the product carbon footprint. An updated version of PAS 2050 was published in 2011 [8].

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 and 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 Standards Organisation 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 1600 stakeholders from around the world to develop new accounting and reporting standards. The GHG Protocol Product Life Cycle Accounting and Reporting Standard [25] and the Corporate Value Chain (Scope 3) Accounting and Reporting Standard [26] were published in late 2011, 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 are 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).

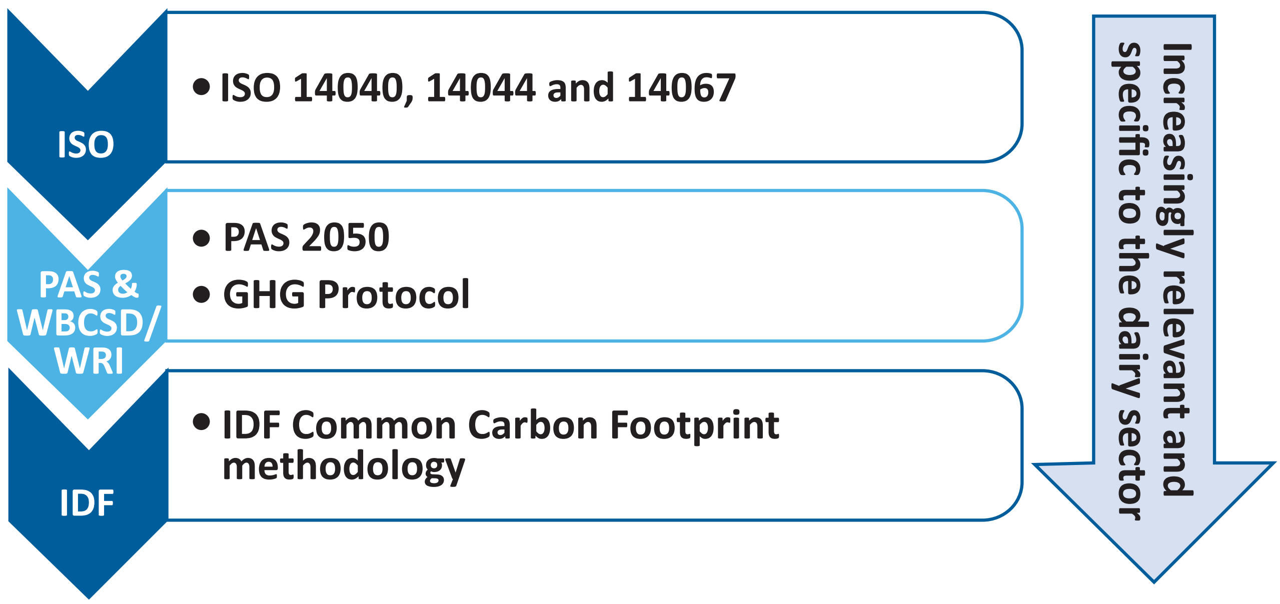

Figure 2: ISO, PAS and WBCSD/WRI protocols feed into the IDF methodology

3 THE STEPS IN AN LCA

3.1. Summary of the steps

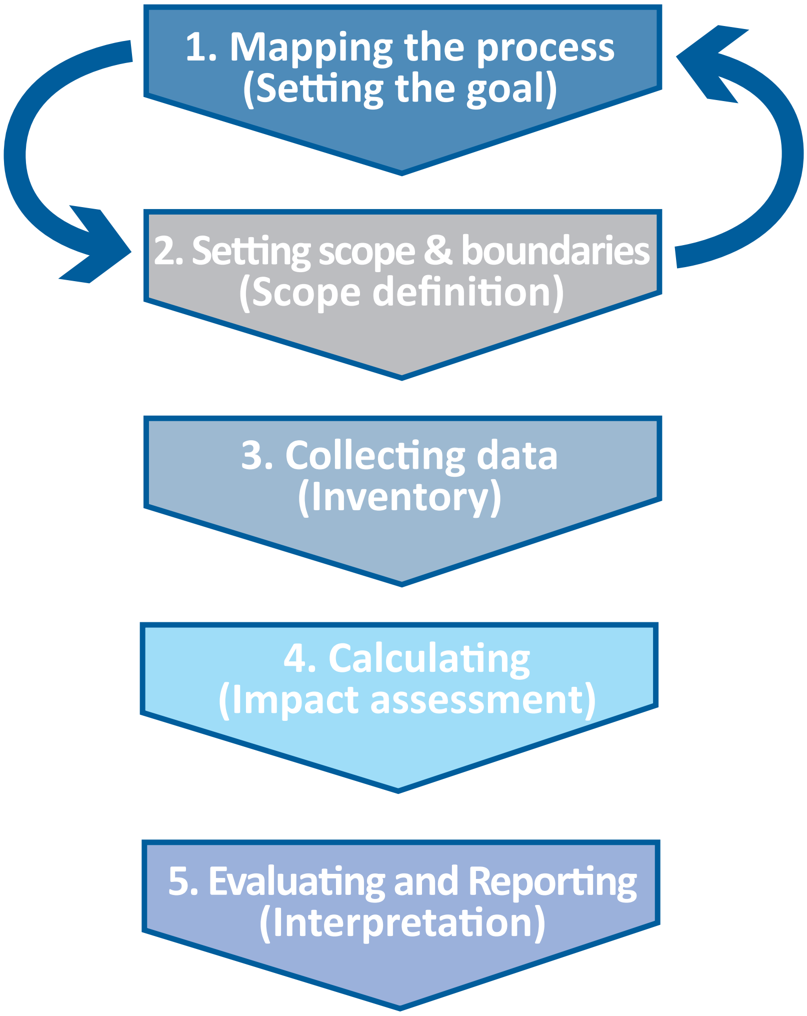

Figure 3: The steps for conducting an LCA are similar, whether based on ISO 14000 or PAS 2050

3.2. Mapping the process

This first step (Figure 3) is about identifying the **goal** of the project, then the **functional unit** that will be the subject of the analysis, and then 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 the Introduction, the attributional approach is used in this guide). Establishing all these at the outset is important for 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 (e.g. 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. A list of the minimum technical data required to calculate 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.

3.6. Evaluating and reporting

It is important that 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 – 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 shows a typical business-to-business or 'cradle-to-gate' model, as described in ISO 14040 [5]. 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.

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

4.2. Defining the process

PAS 2050 explains that to build a process map (see Figure 5), 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 origination (e.g. fertiliser used to grow feed for cow nutrition)

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

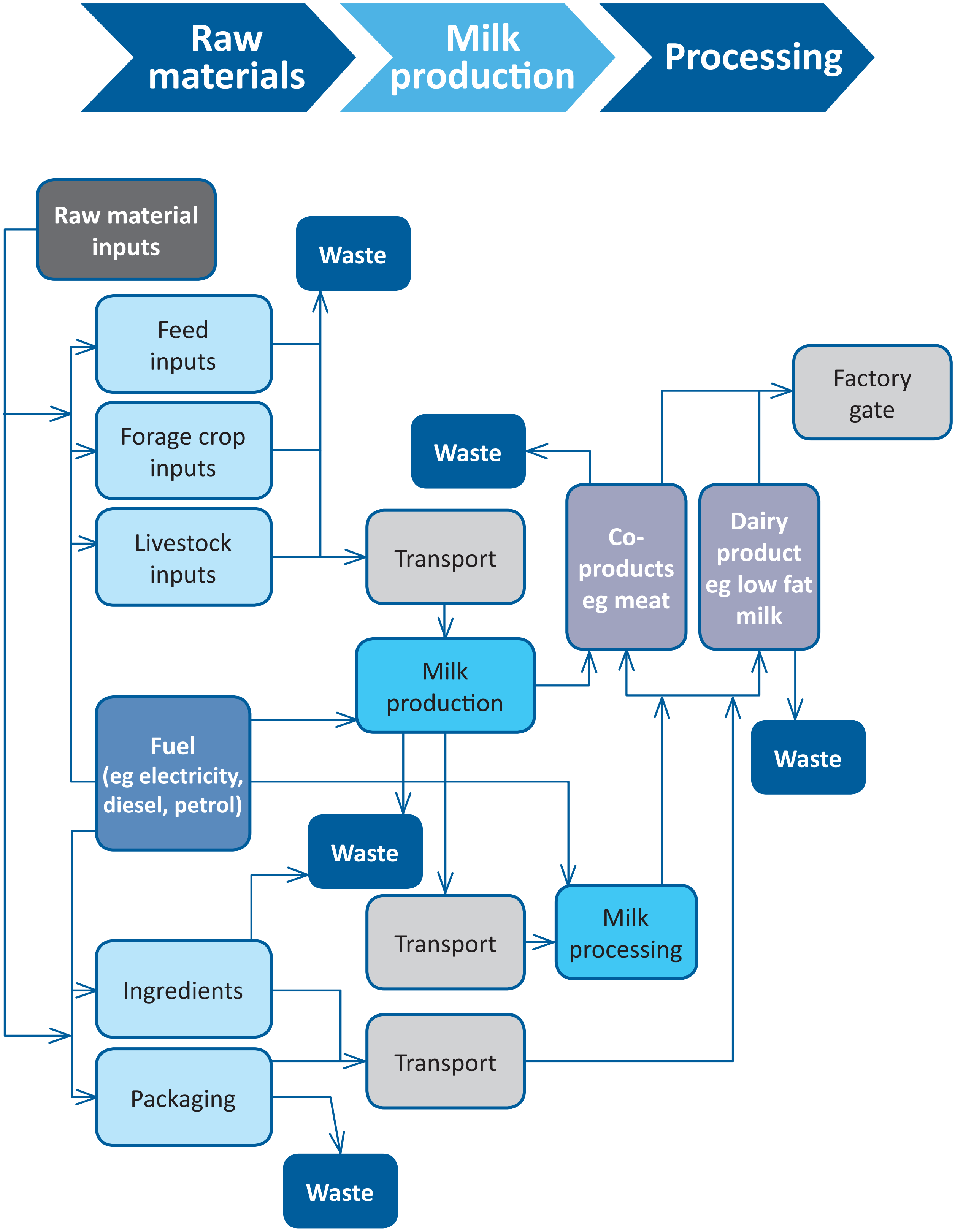

Figure 5: A process map

Example: Milk production with low fat milk as an end product

4.3. The functional unit

4.3.1. Farming

If a study is conducted on-farm, the **functional unit** is one kilogramme 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% fat and 3.3% true protein content (see Figure 6).

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

Figure 6: Formula for calculating the functional unit for farming

If a different milk composition is needed for the standard milk, the energy equation (see Appendix A for more details) can be used to calculate the new standard milk energy and then used to recalculate the coefficients for the FPCM equation. Lactose content is essentially a constant 4.85% of milk.

4.3.2. Processing

At the processing gate, the recommended functional unit is one kilogramme of product, with x% fat and y% 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 (see Figure 7):

- Production of milk on-farm (methane from productive and replacement animals/ enteric fermentation) including:
  - On-farm feed production (diesel, direct and indirect emissions of nitrous oxide from soil, biogenic CO_2 emissions)
  - Farm dairy effluent management (methane and direct and indirect emissions of nitrous oxide)
  - Cow management (fuel)
  - 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 (e.g. pesticides)
- Any activities that take place on other farms (e.g. feed production for the dairy cow replacements and any cows grazed away over the winter)
- Releases resulting from processes, including chemical and ingredient 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 (e.g. electricity and natural gas)
- Wastes that produce greenhouse gas emissions (e.g. waste from feed that is not eaten, waste from plastics from silage making or from packaging material)

These are the major processes and resources for the life cycle emissions from feed production to farm gate, thereby meeting one of the key requirements of the PAS 2050 standard. A threshold of 1% has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources [8]. Therefore, it is considered that, for practicality, if any material or energy flow contributes less than 1% of the total emissions these can be excluded, provided the threshold of accounting for 95% of emissions is met [27].

5.2. Processing

The system boundary encompasses relevant processes within the system and includes, but is not limited to (see Figure 7):

- The transport of raw milk from the farm gate to the processing sites and inter-factory product transport
- Releases resulting from processes, production, delivery and consumption of operating materials (e.g. chemicals, packaging materials, ingredients, manufacturing of refrigerants, losses and other sources of emissions)
- Freshwater usage on-site and wastewater treatment
- 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 (e.g. electricity and natural gas)
- Wastes that produce greenhouse gas emissions

It is also possible to apply and refer to these guidelines 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 (on-farm and processing) is considered separately.

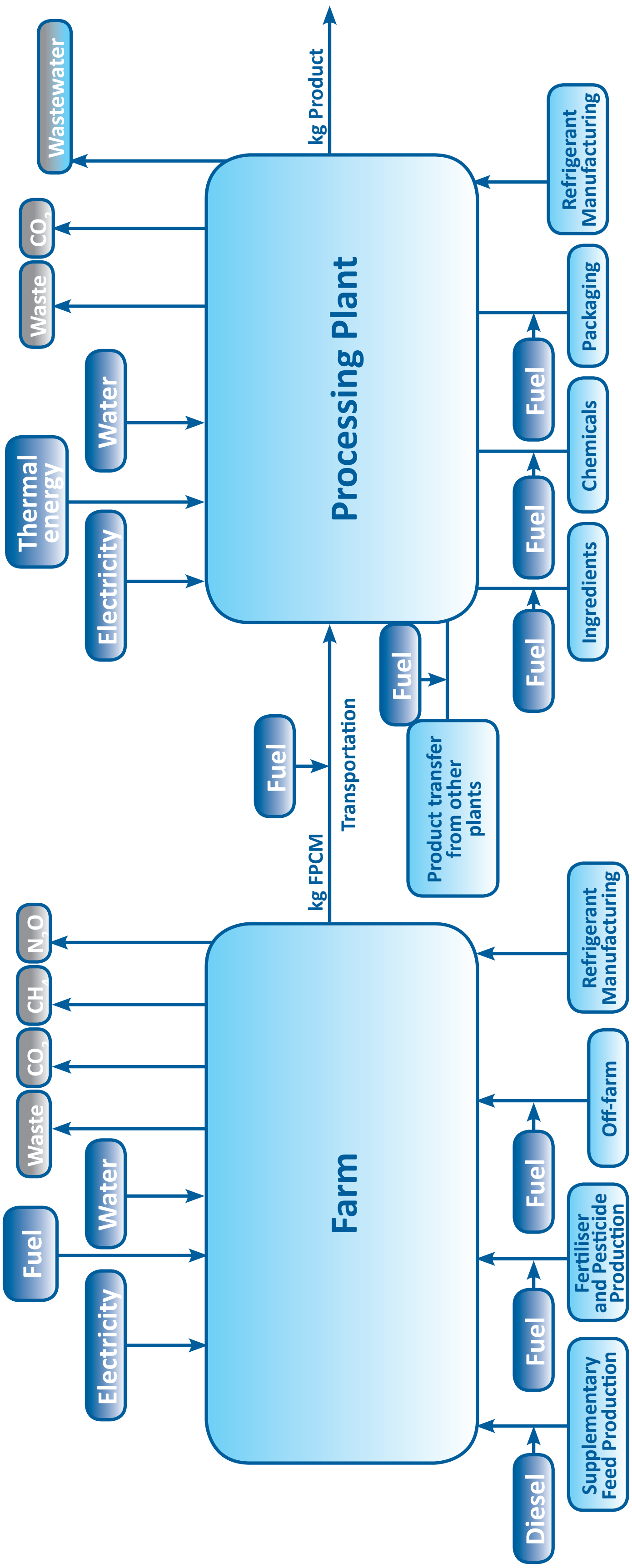

Figure 7: Summary of the flow of resources and input in dairy farming and proces

5.3. Emissions to be included

Main sources of emissions that should be included are:

- Fossil carbon dioxide (energy use, such as combustion of diesel and electricity production)
- Biogenic carbon dioxide from direct land use change (carbon released from deforestation and conversion of natural pasture and shrub lands to agricultural land, carbon dioxide emissions both from removed or degraded above and below ground biomass and soil organic matter)
- Fossil methane emissions (leakage from, for example, natural gas)
- Biogenic methane emissions (enteric fermentation and methane emissions from dairy manure during storage, treatment (e.g. splitting of fractions or drying) and field application)
- Nitrous oxide emissions (N_2O emissions from production and application of chemical nitrogen fertiliser; direct N_2O emissions from manure during storage, treatment and field application; indirect N_2O emissions from leached nitrate and emitted ammonia from fields and manure during storage and treatment).
- Storage of biogenic carbon – as well as release of biogenic and fossil carbon – in packaging material (carbon stored in biogenic material should be accounted for to be able to make an equal comparison with material originating from fossil materials, such as plastic produced from fossil oil); biogenic carbon retained in packaging (paper, card, etc.) if recycled, but biogenic and fossil carbon released if incinerated (with energy recovery) should be included. Both uptake and release of biogenic carbon should be included.

Emissions that should not be included are those that are accounted for in the short (biogenic) carbon cycle (see Figure 8).

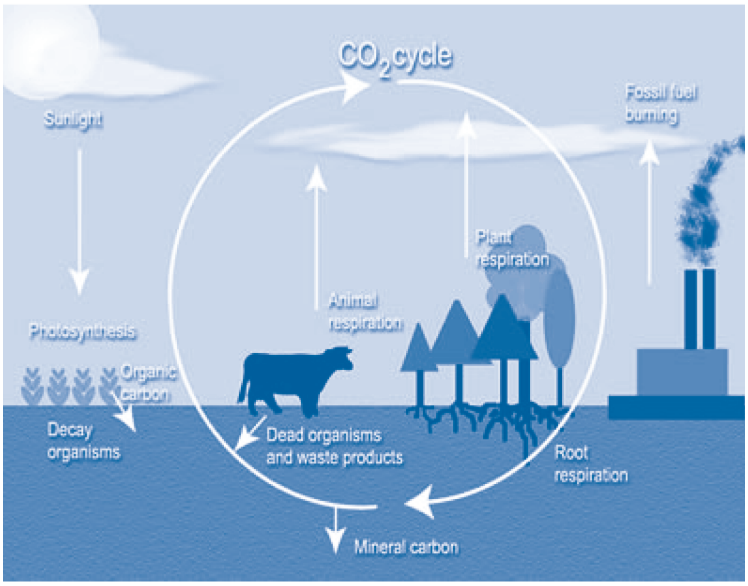

Figure 8: Carbon cycle

Carbon absorbed by animals and crops is carbon-neutral because it is re-released quickly (unless, for example, wood is used to build a house) as it is metabolized again into carbon dioxide and subsequently exhaled or released as biomass (i.e. manure or crop residue) and subsequently degraded.

Carbon transformed into methane becomes a GHG and should be accounted for.

Retained carbon from fossil sources should not be accounted for (e.g. in plastics that breakdown slowly or are recycled), otherwise it should be accounted for as a direct emission.

In the future, there is a potential to account for carbon storage within ecosystems or long-lasting materials. A requirement is that information becomes available to model short carbon cycles. These models should be parameterized and validated on the basis of measurements.

The post-manufacturing transportation of milk and milk products also contributes to GHG emissions, but this guide does not cover this part of the production chain because these processes are located upstream of the dairy sector and, therefore, out of scope.

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 an independent practitioner to reproduce the results.

It should be clearly stated whether primary data (collected), which is preferred, or secondary data (e.g. database, article, report) is used, and from what source the data is taken (e.g. the reference, the company, or the site the data is collected from, or from which database, article or report it is taken). The temporal[1], geographical[2] and technological[3] coverage should be stated as well as how representative[4] 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[5] and uncertainty[6] of data should be estimated, which could be done quantitatively through sensitivity analysis or qualitatively through discussion.

The IDF recommends that data sourcing and utilisation are aligned with ISO 14044, which should be referred to for further details [6].

6.2. Emission factors

Emission factors provide an indication of the 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 is Tier 3.

1 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 that seasonal variations during the year are accounted for) and whether this period representative for the study.

2 Whether the data are representative only locally, nationally or, for example, for European conditions.

3 For example, whether the data used are representative for a modern dairy or older dairy, a large-scale or small-scale dairy, etc.

4 The data used should obviously be relevant for the study (i.e. carbon footprint data for milk produced in the USA cannot be seen as representative for African conditions, since the production system is totally different).

5 Emissions of, for example, N2O are known to have large variations, both in time and space (between places), therefore it is important to conduct a sensitivity analysis to analyse the uncertainties (possible variations) in the calculations.

6 The precision of data can often vary; for example, feed intake can be difficult to estimate, and therefore it is important to conduct a sensitivity analysis of critical parameters, especially those for which it is difficult to get a precise estimate.

For example, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [4] has described all three tiers for estimating methane emission from enteric fermentation. On a Tier 1 basis, the emissions are calculated using standard emission factors from the 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, detailed diet composition, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability, and possible mitigation strategies.

For the purposes of achieving consistency in dairy LCAs, it is agreed that at least a Tier 2 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 [4]
- United Nations Framework Convention on Climate Change (UNFCCC) Training Package on Greenhouse Gas Inventories [28]
- IPCC Emission Factor Database [29]

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

6.3. Allocation

6.3.1. Co-products

Handling co-products is, in many cases, crucial 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 there is no single, common or established method. The allocation procedure described by ISO 14044 [6] follows.

Step 1: Wherever possible, allocation should be avoided by either:

- 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
- 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 (i.e. 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 (e.g. 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 (e.g. biogas production on-farm or electricity produced at the dairy manufacturing site, where surplus electricity can be exported to the 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 of soy oil and soy hull, produced from soy beans)
- Rapeseed meal (co-product of rapeseed oil, produced from rapeseed)
- Palm kernel expels (co-product of palm kernel oil, produced from palm kernels, which is a co-product of palm oil, produced from oil palm)
- Maize gluten meal (co-product of maize gluten feed, maize germ meal and maize starch, produced from maize)
- Wheat bran (co-product of wheat flour, produced from grain)
- Dried distillers grains with solubles (DDGS, co-product of corn ethanol, produced from corn grain)

The guidance here is to use economic allocation for co-products 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 and time consuming to identify the product/s that has/have been substituted by the by-products to apply the system expansion method
- 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, whereas soy oil is used for its energy content, hence applying allocation based on protein content or energy does not give an 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 of prices are advised in order to minimise fluctuations between years.

Example

If meal and oil are co-products, and meal is used for feed as part of the LCA, the economic allocation factor (AF) is the value of the output of meal divided by the value of the combined output, as calculated using the equation below. The output from the process is X kg meal (with the price of A €/kg meal) and Y kg oil (with the price of B €/kg oil). Therefore:

$$\mathbf{AF_{meal} = (X \times A) / (X \times A + Y \times B)}$$

The allocation factor is then multiplied by the environmental impact from the process (e.g. emissions associated with cultivating and transporting the raw material, energy used for processing), and then divided by X to get the carbon footprint for one kilogramme of meal.

In the example shown in Figure 9, for a hypothetical production of 1000 kg of rapeseed yielding 650 kg of rapeseed meal and 350 kg of rapeseed oil, and market prices of 0.2 €/kg rapeseed meal and 0.8 €/kg rapeseed oil, applying the equation above, the allocation factor for the production of rapeseed meal is (650×0.2) / (650×0.2 + 350×0.8) = 0.3

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

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 culled 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 this too should be accounted for.

The approach recommended here is to use a physical allocation method. This aligns with step 2 in ISO 14044 [6] 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% of total on-farm GHG emissions.

The allocation factor for milk and meat can be calculated following the approach of Thoma, Jolliet and Wang [30]. Details can be found in Appendix B. The equation to be used is shown in Figure 10, as follows:

$$\mathbf{AF_{milk} = 1 - 6.04 \times BMR}$$

Figure 10: Formula for the allocation of milk and meat

AF is the allocation factor for milk; BMR is the ratio M_{meat}/M_{milk}; M_{meat} is the sum of live weight of all animals sold (including bull calves and culled mature animals); and M_{milk} is the sum of milk sold corrected to 4% fat and 3.3% protein (FPCM) using the equation given in Figure 6 (Section 4.3.1). The determination of the allocation factor is simple and involves the following steps:

Step 1a: Collect/determine the total kilogrammes of live weight sold per year [kg_{meat}]

Step 1b: Collect/determine the total kilogrammes of FPCM produced per year [kg_{milk}]

Step 1c: Calculate the ratio BMR [kg_{meat}/kg_{milk}]

Step 2: Use the simple correlation: $AF_{milk} = 1 - 6.04 \times BMR$

Step 3: For meat: $AF_{meat} = 1 - AF_{milk}$

As a typical value for BMR, we can take 0.02 kg_{meat}/kg_{milk}, yielding an allocation of 12% to meat and an allocation of 88% to milk.

Note that this allocation factor should only be applied to emission sources that cannot be attributed unequivocally to either meat or milk production. Energy use by milking equipment, for example, should be attributed entirely to milk production and not be allocated to meat.

Example

The example shown in Figure 11 demonstrates the calculation, based on a physical method, of the allocation between milk and meat for a hypothetical farm that produces 1 million kg (1000 Mg) FPCM per year and exports 0.024 kg meat/kg FPCM. For the purposes of this example, the meat export is calculated as the sum of live weights of all animals exported, including bull calves and culled mature animals, but excluding animals culled but not sent to the meat market, for example heifers sold to another dairy. The total unallocated carbon footprint in this example is 1.4 kg CO_2e/kg FPCM.

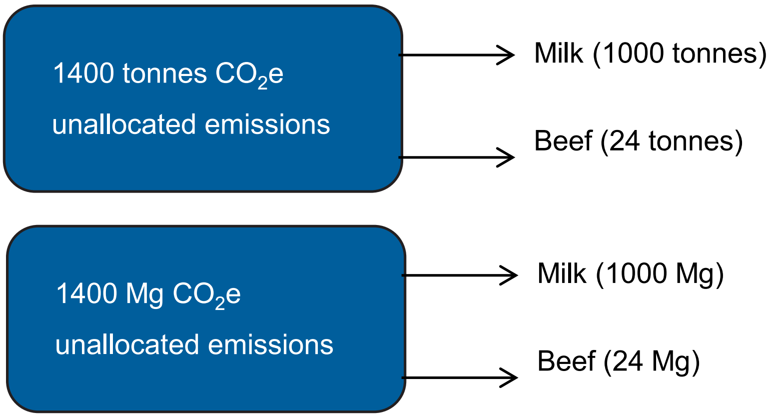

Figure 11: Example of allocation of meat as a co-product

Using the equation for physical allocation (Figure 10), the allocation to milk is:

$$\mathbf{1 - 6.04 \times 0.024 = 0.86}$$

Thus 86% of the unallocated footprint is allocated to milk, yielding a farm-gate footprint of 1.2 kg CO_2e/kg FPCM. The value for meat is (0.14 × 1400) Mg CO_2e/24 Mg meat or 8.17 kg CO_2e/kg meat (live weight).

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

For export of manure from the farm, the recommendation is to treat manure as a residue for allocation purposes, unless it is determined that the manure should be classified as a co-product or waste. When classified as a residue, as stated in the FAO LEAP guidance on large ruminant supply chains in Section 9.3.1(f) [1], "Manure has essentially no value at the system boundary. This is equivalent to system separation by cut-off, in that activities associated with conversion of the residual to a useful product (e.g., energy or fertilizer) occur outside of the production system boundary system. In this recommended approach… emissions associated with manure management up to the point of field application are assigned to the animal system, and emissions from the field are assigned to the crop production system." Also refer to the decision tree in Appendix D. For guidance on allocation of manure classified as a co-product or waste, see Section 9.3.1(f) of the FAO LEAP guidance [1].

6.3.4. Manufacture of dairy products

Dairy manufacturing plants usually produce more than one product because the fat content in raw milk exceeds the product specification for milk powders or fresh milk products (e.g. market milk, yoghurt or dairy desserts). The excess milk fat can be further processed into butter or anhydrous milk fat (AMF).

Another typical example of co-production in the dairy industry is the production of cheese and whey. This creates the need to allocate the environmental impact of production and transport of raw milk and processing to different dairy co-products produced in a specific dairy production plant. In addition, many of the process units (e.g. pasteurization, separation or spray drying) are subsequently used to process different dairy product flows (e.g. skimmed milk, whey and caseinate).

The data collection for each process unit within the plant is resource intensive and in some cases impossible as a result of insufficient metering on a process unit level. In some cases, resource use or emission data are only available on a 'whole-of-factory' basis. Use of aggregated data (i.e. on company or site level) results in lower accuracy of the carbon footprint for a specific product. It is therefore recommended to always try to obtain the highest level of detail for data collection as is realistic with regard to the purpose and timeframe of the study.

Allocation of raw milk and transport from farm to processing plant

Allocation of the carbon footprint embodied in the raw milk as it comes into the processing plant (i.e. including transportation from farm to processing plant) should be carried out on the basis of the milk solids (mass allocation using dry weight) of the final product in all circumstances, even if the actual separation of co-products occurs only after several additional processing steps (as is usually the case).

The allocation factor[7](AF) can be calculated for each product (i) using the following equation:

$$AF_i = \frac{DM_i \times Q_i}{\sum_{i=1}^{n} (DM_i \times Q_i)}$$

Equation 1:
Formula for the allocation factor based on dry matter content

where AFi is the allocation factor for product i; DMi is dry matter content of product i (expressed as percentage dry matter or as weight by mass of dry matter/weight by mass of product i); and Qi is quantity of product i output at the production site or from the unit operation (in kilogrammes of product i).

7 If a country-specific physico-chemical allocation matrix exists that would be applicable to a particular case study, then that can be applied. In no case should allocation factors from different matrices be combined, and in all cases processes should be subdivided whenever possible.

Processing: detailed data is available

Energy and material usage, as well as emissions (other than raw milk at the factory), should be assigned as much as possible to specific processing stages and product flows (step 1 in ISO 14044 [6]). If several different dairy products are subsequently processed in one processing unit (i.e. caseinate and skimmed milk are subsequently dried), the energy and material usage as well as emissions are divided on the basis of available technical knowledge about that processing stage (i.e. retention time, mass balances, etc.) (step 2 in ISO 14044 [6]).

For processes that concern heating, cooling, and drying, the dry weight of the resulting products can be considered a proxy for the energy requirement.

Processing: a mixture of detailed process and co-product data is available as well as whole-of-factory data

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 (i.e. determine where the milk solids go in the various products and use the distribution of the milk solids as the basis for distribution of the environmental burdens).

Processing: data is only available for a whole dairy company or dairy site

If data is only available for a whole company or a whole dairy site, that is, only the inputs (e.g. raw milk, energy) and the outputs (e.g. various dairy products) of the entire operation are known, we recommend that all energy use is allocated according to the dry weight (milk solid content) of the products and co-products. In almost all processing scenarios, energy goes primarily towards heating, cooling and drying processes. In that case, the milk solid content (dry matter) of the final products adequately reflects the share in energy use[8] (for more information see [32]). No distinction is made regarding the type of milk solids, since in the case of heating, cooling and drying the amount of milk solids in the product (not the type of milk solids) is related to processing. Most other inputs (e.g. packaging and ingredients) can generally be directly associated with a specific product. In any other case of material input where allocation is required (e.g. water usage, chemicals, waste water, typically with a very minor contribution to the carbon footprint of dairy products), allocation should be conducted based on the dry matter content using Equation 2 (where AFi is the allocation factor).

$$Allocation_{product\_i} = product_i \times AF_i \Big/ \sum_{ij}^{i} product_{ij} \times AF_{ij}$$

Equation 2: Formula for allocation of co-products during manufacturing

8 The true drivers of energy use in thermal processes would be water content of the ingoing product and the difference in dry matter content between initial and final product, but as all products derive from the same raw milk – generally – this is reflected by the final dry matter content.

The allocation of one product (e.g. whole milk powder) is then multiplied by the total resource use or environmental impact.

Example

In the example shown in Figure 12, a dairy manufacturing site has an annual raw milk intake of 100,000 tonnes. It produces 12,000 tonnes of whole milk powder and 1400 tonnes of AMF. For the production of the two products, thermal energy (among other inputs) is required (i.e. 230,000 GJ per annum). The outputs from the manufacturing site are:

- 12,000 tonnes whole milk powder (with a hypothetical allocation factor of 1.00 for raw milk and 1.00 for thermal energy)
- 1400 tonnes AMF (with a hypothetical allocation factor of 1.05 for raw milk and 0.05 for thermal energy)

Figure 12: Example of allocation of co-products during manufacturing

Applying the hypothetical allocation factors to Equation 2, the allocation factor for raw milk is calculated as:

$(12{,}000\times1.00) / (12{,}000\times1.00 + 1400\times1.05) = 0.891$

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

The allocation factor for thermal energy is calculated as:

$(12{,}000\times1.00) / (12{,}000\times1.00 + 1400\times0.05) = 0.994$

This results in 228,700 GJ energy allocated to whole milk powder and 1300 GJ assigned to AMF.

Note that it is recommended that energy and material usage be assigned as much as possible to specific processing stages, especially in the case of processes known to be energy-requiring (e.g. drying).

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 and then exported for use in other systems, for example, to replace fossil fuel natural gas in heating systems. Likewise, dairy manufacturing can produce a surplus of energy, either in the form of 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 [6]; however, it is important to know which type of energy is being exported.

On dairy farms, biogas is 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 calculation tool [9].

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

6.3.6. Summary on handling co-products

Preferred approach	Allocation situations	Choice	Result
ISO hierarchy	Feed (pre-farm)	Economic	Depends on kind of feed
	Milk/meat and calves (farm)	Physical causality	Based on energy feed inputs to the system and associated milk and meat production
	Manure export (farm)	Residual: system separation by cut-off	Based on the classification of manure as a residual, co-product or waste[9]
	Processing (dairy site)	Physical, Mix	Based on milk solids for raw milk, specific values if available
	CHP (farm, dairy site)	System expansion	Replaces electricity from the national grid or heat

Table 1: The chosen allocation approaches

9 For guidance on allocation of manure classified as a co-product or waste, see Section 9.3.1(f) of the FAO LEAP guidance [1].

For information on how to distinguish production units at the farm level (e.g. mixed dairy and beef farm) or attribute generic farm inputs to different enterprises (e.g. energy for drinking water), IDF recommends the guidance provided in Section 9.2 of the FAO LEAP guidance [1]. This guidance includes a multi-functional output decision tree (see Appendix D) that clarifies how to disentangle production units and co-products.

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 [8].

In summary, the guidance 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 that 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%) 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 because 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. Because of large uncertainties on the calculation of land use change emissions, it is recommended that they are reported separately for greater transparency.

Further clarification about this approach is included in the FAO LEAP guidance, 'Environmental performance of animal feeds supply chains: Guidelines for assessment' [2].

6.4.2. Carbon sequestration

Grasslands and other agricultural vegetation cover a huge amount of the Earth's land surface and span a range of climate conditions. Agricultural ecosystems hold large carbon reserves [33], 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% contribution to the technical potential [34].

Carbon stock changes in agricultural land are closely tied to management practices, which can either enhance or erode carbon stocks. The greenhouse effect can be limited by increasing soil carbon stocks and by maintaining existing stocks. Practices that raise the photosynthetic input of carbon and/or slow the release of stored carbon (e.g. through respiration or erosion) will increase carbon stocks [35]. Carbon accumulation and losses occur mostly below ground. Below-ground carbon pools have slower rates of turnover than above-ground pools, because most of the organic carbon in soils comes from the conversion of plant litter into more persistent organic compounds [36]. 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 in which 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 land – is twice as fast and as great as the soil carbon increase caused by the reverse change from arable land to grassland. Historically, although agricultural management practices can result in either reductions or accumulations in the below-ground pool, agricultural lands are estimated to have released more than 50 Pg of carbon [37–39], some of which can be restored via better management. In a carbon footprint study of a dairy system, the measurement of the current net CO_2 fluxes by region is of greater interest than the sequestration potential [40].

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 physico-chemical conditions of the soil environment and the physical protection of organic matter in the soil [41]. The lack of a globally consistent and regionally detailed set of net CO_2 flux estimates makes it difficult to quantify these potential emission sources and sinks by region, although there are some relevant studies that provide useful estimates of the net fluxes for specific regions. For example, based on research on temperate grasslands in Western Europe, Soussana et al. [42] estimated that grassland sequestration rates average 5±30 g carbon per square metre per year. Nevertheless, in a later publication, Soussana et al. [41] conceded that the uncertainties associated with CO_2 stock changes following changes in management are very high. Further, carbon stocks are very vulnerable to disturbances (including tillage, fire, erosion and droughts) that can lead to rapid reversals of accumulated stocks. Moreover, the authors recommend that further research is needed to separate the influence of management factors from other climate-related factors such as increases in average temperature and atmospheric CO_2, in order to be able to attribute sequestration to direct anthropogenic causes.

For the reasons explained above, the current choice for standard footprinting methodology, and also for this IDF guide, is to not include changes in soil organic matter (carbon) as part of the carbon footprint because of a lack of scientific data at the global level. This applies to grasslands but also to crop cultivation and to both positive and negative changes. However, when data exist, IDF recommends calculating the net fluxes in carbon storage/ emission, provided that they are reported separately for the sake of transparency.

Further clarification about this approach is included in the FAO LEAP guidance, ‘Environmental performance of animal feeds supply chains: Guidelines for assessment’ [2].

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

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.

Because the GWP factors have changed over the years, the most current IPCC GWP factors must be applied when undertaking a product carbon footprint calculation using this methodology.

Currently used factors can be found in the 'Technical Summary' chapter of 'The Physical Science Basis' volume of the IPCC 2007 report on climate change [34]:

1 kg of methane (CH_4) = 25 kg of CO_2e
1 kg of nitrous oxide (N_2O) = 298 kg 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 demonstrates that the exercise has a purpose and that the knowledge will lead to an improvement, even if it is through the quickest and easiest means available.

Because weather conditions vary between years and can have an impact on results, it is recommended that an average carbon footprint is reported, based on three-year calculations.

8.2. Reporting

GHG accounting and reporting practices are new to many businesses and, because of this, 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.

These principles 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 Greenhouse Gas Protocol Product Life Cycle Standard [9]:

- **Relevance** – Ensure that 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 comparison 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 about the integrity of the reported information with a reasonable level of confidence

8.3. Key parameters in the report

To obtain 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 (i.e. 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 into different feed types [as a minimum, the share of roughage feed and 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 2050:2011 [8]

Allocation
Partitioning the inputs or emissions from a shared process or a product system between the product system under study and one or more other product systems.

Attributional
Attributional LCA assessments 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 (CO2e)
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
Retention of carbon from biogenic or fossil sources of atmospheric origin in a form other than as an atmospheric gas.

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

Co-products
Any of two or more products from the same unit process or product system (BS EN ISO 14044:2006 [6], 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 (e.g. kg CO_2e per unit input). Note that emission factor data is 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 whereby 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)
Factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to an equivalent unit of CO_2 over a given period of time (BS ISO 14064-1:2006 [43], Section 2.18).

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 that GHGs include carbon dioxide (CO_2), methane(CH_4), nitrous oxide (N_2O), hydrofluoro-carbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Input
Product, material or energy flow that enters a unit process (BS EN ISO 14040:2006 [5], Section 3.21).

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 (Adapted from BS EN ISO 14040:2006 [5], Section 3.1).

Life cycle assessment (LCA)
Compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle (BS EN ISO 14040:2006 [5], Section 3.2).

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 from any one source of GHG emissions to a product of more than 1% of the anticipated life cycle total GHG emissions associated with the product being assessed. Note that a materiality threshold of 1% 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 that 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 that 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 emissions from processes included in the life cycle of the product. Note that secondary data is used when primary activity data is 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 that the holder discards or intends, or is required to, discard.

10 REFERENCES

1. FAO (2015) Environmental performance of large ruminant supply chains: Guidelines for assessment. Draft for public review. Livestock Environmental Assessment and Performance (LEAP) Partnership. Food and Agricultural Organization of the United Nations, Rome. Available at http://www.fao.org/partnerships/leap/en/

2. FAO (2015) Environmental performance of animal feeds supply chains: Guidelines for assessment. Version 1. Livestock Environmental Assessment and Performance (LEAP) Partnership. Food and Agricultural Organization of the United Nations, Rome. Available at http://www.fao.org/partnerships/leap/en/

3. FAO (2009) Greenhouse gas emissions from the dairy sector: a life cycle analysis. Food and Agricultural Organization of the United Nations, Rome. Available at http://www.fao.org/docrep/012/k7930e/k7930e00.pdf.

4. IPCC (2006) 2006 IPCC Guidelines For National Greenhouse Gas Inventories. Prepared by the IPCC National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., Tanabe K. (Editors). Institute for Global Environmental Strategies (IGES), Japan. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

5. ISO (2006a) Environmental management – Life cycle assessment – Principles and framework. ISO 14040:2006(E). International Organization for Standardization, Geneva, Switzerland.

6. ISO (2006b) Environmental management – Life cycle assessment – Requirements and guidelines. ISO 14044:2006(E). International Organization for Standardization, Geneva, Switzerland.

7. ISO (2013). Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication. ISO/TS 14067:2013. International Organization for Standardization, Geneva, Switzerland.

8. BSI (2011) Specification for the assessment of life cycle greenhouse gas emissions of goods and services. Publicly Available Specification PAS 2050:2011. British Standards Institute, London. Available at http://shop.bsigroup.com/forms/PASs/PAS-2050/.

9. WRI/WBCSD (2006) GHG Protocol calculation tool – allocation of GHG emissions from a combined heat and power plant. World Resources Institute/World Business Council for Sustainable Development.
Available at http://www.ghgprotocol.org/calculation-tools/all-tools.

10. ISO (2014) Environmental management – Water footprint – Principles, requirements and guidelines. ISO 14046:2014. International Organization for Standardization, Geneva, Switzerland.

11. Haas, G., Wetterich, F., Köpke, U. (2000). Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. Agric. Ecosyst. Environ. 83:43–53.

12. Hospido, A. (2005) Life cycle assessment as a tool for analysing the environmental performance of key food sectors in Galicia (Spain): milk and canned tuna. Doctoral Thesis, University of Santiago de Compostela, Spain.

13. Williams, A. G., Audsley, E, Sanders, D. L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Available on www.silsoe.cranfield.ac.uk, and www.defra.gov.uk.

14. Casey, J. W., Holden, N. M. (2004) Analysis of greenhouse gas emissions from the average Irish milk production system. Agric. Sys. 86(6):97–114.

15. Thomassen, M. A., Dalgaard, R., Heijungs, R., de Boer, I. (2008) Attributional and consequential LCA of milk production. Int. J. Life Cycle Assess. 13(4):339–349, doi: 10.1007/s11367-008-0007-y.

16. Basset-Mens, C., Ledgard, S., Boyes, M. (2009) Eco-efficiency of intensification scenarios for milk production in New Zealand. Ecol. Econ. 68:1615–1625.

17. Cederberg, C., Flysjö, A. (2004) Life cycle inventory of 23 dairy farms in South-Western Sweden. Rapport 728. SIK, Swedish Institute for Food and Biotechnology. Göteborg, Sweden.

18. Cederberg, C., Flysjö, A., Ericson, L. (2007). Livscykelanalys (LCA) av norrländsk mjölkproduktion. (LCA of milk in northern Sweden) Rapport 761. SIK, Swedish Institute for Food and Biotechnology. Göteborg, Sweden.

19. Cederberg, C., Mattsson, B. (2000) Life cycle assessment of milk production – a comparison of conventional and organic farming. J. Cleaner Prod. 8:49–60.

20. Flysjö, A., Cederberg, C., Strid, I. (2008) (in Swedish) LCA-databas för konventionella fodermedel – miljöpåverkan i samband med production (LCA-database for conventional feed ingredients – environmental impact at production). Version 1.1, Rapport 772. SIK, Swedish Institute for Food and Biotechnology, Göteborg, Sweden.

21. Arsenault, N., Tyedmers P., Fredeen A. (2009) Comparing the environmental impacts of pasture-based and confinement-based dairy systems in Nova Scotia (Canada) using life cycle assessment. Int. J. Agric. Sustain. 7(1):19-41.

22. van der Werf, G. R., Morton, D. C., DeFries, R. S., Olivier, J. G. J., Kasibhatla, P. S., Jackson, R. B., et al. (2009) CO2 emissions from forest loss. Nature Geosciences 2:738-739.

23. Basset-Mens, C. (2008) Estimating the carbon footprint of raw milk at the farm gate: methodological review and recommendations. In: Proceedings of the 6th International Conference on LCA in the Agri-Food Sector, 12–14 November 2008, Zürich, Switzerland, ISBN 978-3-905733-10-5.

24. Flysjö, A., Cederberg, C., Dalsgaard Johannesen, J. (2009) Carbon footprint and labelling of dairy products – challenges and opportunities. In: Proceedings of the conference Joint Action on Climate Change, 8–10 June 2009, Aalborg, Denmark.

25. WRI/WBCSD (2011) GHG Protocol: Product life cycle accounting and reporting standard. World Resources Institute/World Business Council for Sustainable Development. Available at http://www.ghgprotocol.org/standards/product-standard.

26. WRI/WBCSD (2011) GHG Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard. World Resources Institute/World Business Council for Sustainable Development.
Available at http://www.ghgprotocol.org/standards/scope-3-standard.

27. Frischknecht, R., Jungbluth, N., Althaus, H. J., Doka, G., Heck, T., Hellweg, S. et al. (2007). Overview and methodology. Ecoinvent report no. 1. Swiss Centre for Life Cycle Inventories, Dübendorf.
Available at http://www.ecoinvent.org/support/old-doc/rep/reports-freely-available/

28. UNFCCC (2007) Training package on GHG inventories. United Nations Framework Convention on Climate Change, Bonn.
Available at http://unfccc.int/resource/cd_roms/na1/ghg_inventories/index.htm.

29. IPCC (2012) IPCC Emission Factor Database (EFDB). IPCC Task Force on National Greenhouse Gas Inventories.
Available at http://www.ipcc-nggip.iges.or.jp/EFDB/find_ef_main.php.

30. Thoma, G., Jolliet, O., Wang, Y. (2013) A biophysical approach to allocation of life cycle environmental burdens for fluid milk supply chain analysis. Int. Dairy J. 31(S1):41-49.

31. Cederberg, C., Stadig, M. (2003) System expansion and allocation in life cycle assessment of milk and beef production. Int. J. Life Cycle Assess. 8(6):350–356.

32. Flysjö, A., Thrane, M. and Hermansen, J.E. (2014) Method to assess the carbon footprint at product level in the dairy industry. Int. Dairy J. 34: 86-92.

33. IPCC (2001) Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (Editors)]. Cambridge University Press, Cambridge, UK and New York, NY. Available at http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/index.htm.

34. IPCC (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Editors)]. Cambridge University Press, Cambridge, UK and New York, NY. Available at http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg1_report_the_physical_science_basis.htm.

35. Smith, J. O., Smith, P., Wattenbach, M., Gottschalk, P., Romanenkov, V. A., Shevtsova, L. K. (2007) Projected changes in the organic carbon stocks of cropland mineral soils of European Russia and the Ukraine, 1990–2070. Global Change Biol. 13(2):342-356.

36. Jones, M. B., Donnelly, A. (2004) Carbon sequestration in temperate grassland ecosystems and the influence of management, climate and elevated CO2. New Phytol. 164(3):423-439.

37. Paustian, K., Cole, C. V., Sauerbeck, D., Sampson, N. (1998) CO2 mitigation by agriculture: an overview. Climatic Change 40(1):135-162.

38. Lal, R. (1999) Soil management and restoration for C sequestration to mitigate the accelerated greenhouse effect. Prog. Environ. Sci. 1(4):307-326.

39. Lal, R. (2004) Soil carbon sequestration impacts on global climate change and food security. Science 304(5677):1623-1627.

40. Corsi, S., Friedrich, T., Kassam, A., Pisante, M., de Moraes Sà, J. (2012) Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: a literature review. Integrated crop management, vol. 16. FAO, Rome. Available at http://www.fao.org/fileadmin/user_upload/agp/icm16.pdf

41. Soussana, J. F., Tallec, T., Blanfort, V. (2010) Mitigating the greenhouse gas balance of ruminant production system through carbon sequestration in grasslands. Animal 4(3):334–350.

42. Soussana, J. F., Klumpp, K., Tallec, T. (2009). Mitigating livestock greenhouse gas balance through carbon sequestration in grasslands. In: IOP Conf. Ser.: Earth Environ. Sci. 6(24): 242048, doi:10.1088/1755-1307/6/24/242048

43. ISO (2006c) Greenhouse gases – Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals. ISO 14064-1:2006. International Organization for Standardization, Geneva, Switzerland.

44. Clark, J., Beede, D. K., Erdman, R. A., Goff, J. P., Grummer, R. R., Linn, J. G., et al. (Editors) (2001) Nutrient requirements of dairy cattle, 7th rev edn. National Academy Press, Washington, D.C., p 321.

11 APPENDICES

11.1. Functional unit for farming

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

Milk Energy (Mcal/kg) =
0.0929×Fat% + 0.0588×True Protein% + 0.192

which is equivalent to:

Milk Energy (Mcal/kg) =
0.0929×Fat% + 0.0547×Crude Protein% + 0.192

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

FPCM (kg/yr) = Production (kg/yr) × [0.1226×Fat% + 0.0776×True Protein% + 0.2534]

For details see Clark et al. (2001) [43]

11.2. Allocation – the scientific basis for the approach

Milk: meat

A large study that included collection of detailed farm-level data from 536 US farms was completed in 2012 by Thoma et al. [29]. 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 a 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 meat 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 fitted an empirical relationship for the allocation fraction, shown in Figure 13. For more details, please refer to the published study [29]. Note that the relation used here is in fact a correction with respect to the one derived in the article[10], and that the beef-to-milk ratio used in the article is considered equivalent to the meat-to-milk ratio used in this guide.

The empirical relationship $AF_{milk} = 1 - 6.04 \times BMR$ is robust enough to be applied internationally. Here, AF is the allocation fraction and BMR is the ratio of kilogrammes meat to kilogrammes milk; the milk should be corrected to 4% fat and 3.3% protein. The calculation of kilogrammes meat should exclude animals that die on the farm and are disposed of by burial, rendering, etc. It should also exclude animals sold to another dairy operation. As indicated in the report body [29], allocation is an important and evolving issue, thus validation exercises are being initiated using rations from other milk production regions.

The determination of AF is simple and involves the following steps:

Step 1a: Collect/determine the live weight total kilogrammes animal sold per year [kg_{meat}]
Step 1b: Collect/determine the total kilogrammes milk (4% fat and 3.3% protein equivalent) produced per year
Step 1c: Calculate the ratio BMR [kg_{meat}/kg_{milk}]
Step 2: Use the simple correlation: allocation factor for milk: $AF_{milk} = 1 - 6.04 \times BMR$
Step 3: Allocation factor for meat: $AF_{meat} = 1 - AF_{milk}$

10 Private communication: Greg Thoma, June 2013.

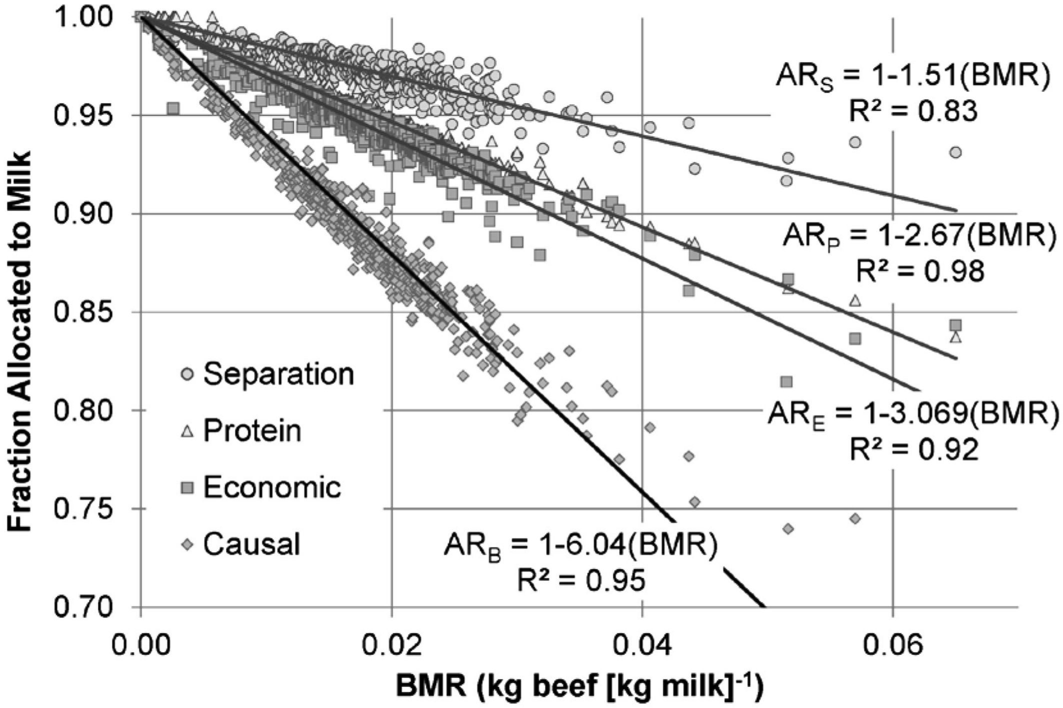

Figure 13: Fraction allocated to milk as a function of beef-to-milk ratio, equivalent to the meat-to-milk ratio (BMR, milk in terms of FPCM). See [29] for details of the technical background of this approach

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

Note that the feed dry matter (DM) calculated is the feed required strictly for growth; maintenance energy is not accounted for in the calculation of the allocation fraction, but is later allocated between the co-products.

The equations for calculating FPCM and energy content of milk are given in Appendix A.

Further clarification about this approach is included in Section A6.3 of the FAO LEAP guidance, 'Environmental performance of large ruminant supply chains: Guidelines for assessment' [1], as follows:

"...the assumption is made that the animal is kept alive for its entire existence for the purpose of providing all of the functions it delivers. Thus, rather than divide the animal's life by time/weight, the energy requirements for growth and lactation are used to divide the inputs required to produce the functions based on NRC equations that define the net energy for growth or lactation. The growth calculation specifically includes gestation requirements for calves. To create the allocation factor for the whole farm, a division of burdens (currently only to milk and sold live animals – cull calves, heifers, and cows on a total live weight basis), one additional step is taken: because the nutritional density (specifically net energy availability) of different feeds for milk production and growth is different (milk is produced between ~1.2 and 2 times more efficiently depending on the individual feed), the net energy requirements are converted to feed intake based on net energy available in the ration consumed on the farm. The allocation ratio (or key) is calculated as the ratio of dry matter intake required for milk production to total dry matter intake required for growth and milk production. In the IDF approach, which is a simplified regression based on Thoma et al. (Thoma et al., 2013a)[14] , the allocation factor is then applied to the whole farm. Thus the IDF approach allocates the ration (and associated emissions) consumed for maintenance through the entire lifecycle proportionally to milk and live weight of animals sold, rather than defining life phase as belonging to one or the other function.

Animals sold from the dairy operation are assigned a burden based on their live weight. In the full analysis, following Thoma et al. (Thoma et al., 2013a[11]), each animal's feed consumption is separately calculated and the impacts due to its feed consumption for growth are assigned to that animal when it is sold. Following the IDF guidelines, the ratio of the total LW of all animals sold to the total weight (FPCM) of milk sold defines a whole-farm allocation factor (from the regression equation provided) which can be used to calculate the impact per kg LW (not distinguishing the type of animal):

$EF_{calf} = \left\{ {EF_{farm}(1 - AF_{milk})}/{TLW} \right\} Calf_{LW}$, where EF_{calf} = environmental footprint of the calf; EF_{farm} = environmental footprint of the production unit; AF_{milk} = allocation fraction assigned to milk (from the regression equation of IDF); TLW = total live weight sold by the production unit; and $Calf_{LW}$ = live weight of the calf as sold; similarly for other animals sold, if needed. The gestation requirement calculation is hidden in the IDF methodology, but was incorporated in the analysis of the farms used for creation of the regression equation.

A separate, as yet unpublished re-analysis of the 536 farms where the feed (and associated enteric and manure emissions) are directly assigned to the meat or milk and only the remaining feed consumed for maintenance and activity are assigned using the allocation ratio yields essentially the same regression equation."

11 Thoma, G., Jolliet, O., Wang, Y. (2013) A biophysical approach to allocation of life cycle environmental burdens for fluid milk supply chain analysis. Int. Dairy J. 31(S1):41-49 [30].

11.3. Technical data

Table 2: 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/l)
Meat production	
Herd	
Reproduction	The numbers of births per annum per animal and the number of young animals per birth (fertility and prolificacy, respectively). An estimate is needed of the number of male animals required for reproduction (natural or artificial) according to 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 between birth and adulthood and adult animals
Replacement	The number of adult animals that are 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 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 (e.g. grains + straw) must be defined
Use of manure and fertiliser	
Energy use by machinery	For crop management (e.g. 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 are 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 is used, according the guidelines of the IPCC [3]
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 (e.g. 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 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 and carbon dioxide used during packaging of finished products Country of origin for packaging material
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

11.4. Decision tree for production units and co-products

For information on how to distinguish production units at the farm level (e.g. mixed dairy and beef farm) or attribute generic farm inputs to different enterprises (e.g. energy for drinking water), IDF recommends the guidance provided in Section 9.2 of the FAO LEAP guidance, ‘Environmental performance of large ruminant supply chains: Guidelines for assessment‘ [1]. This guidance includes a multi-functional output decision tree (see Figure 14), which clarifies how to disentangle production units and co-products.

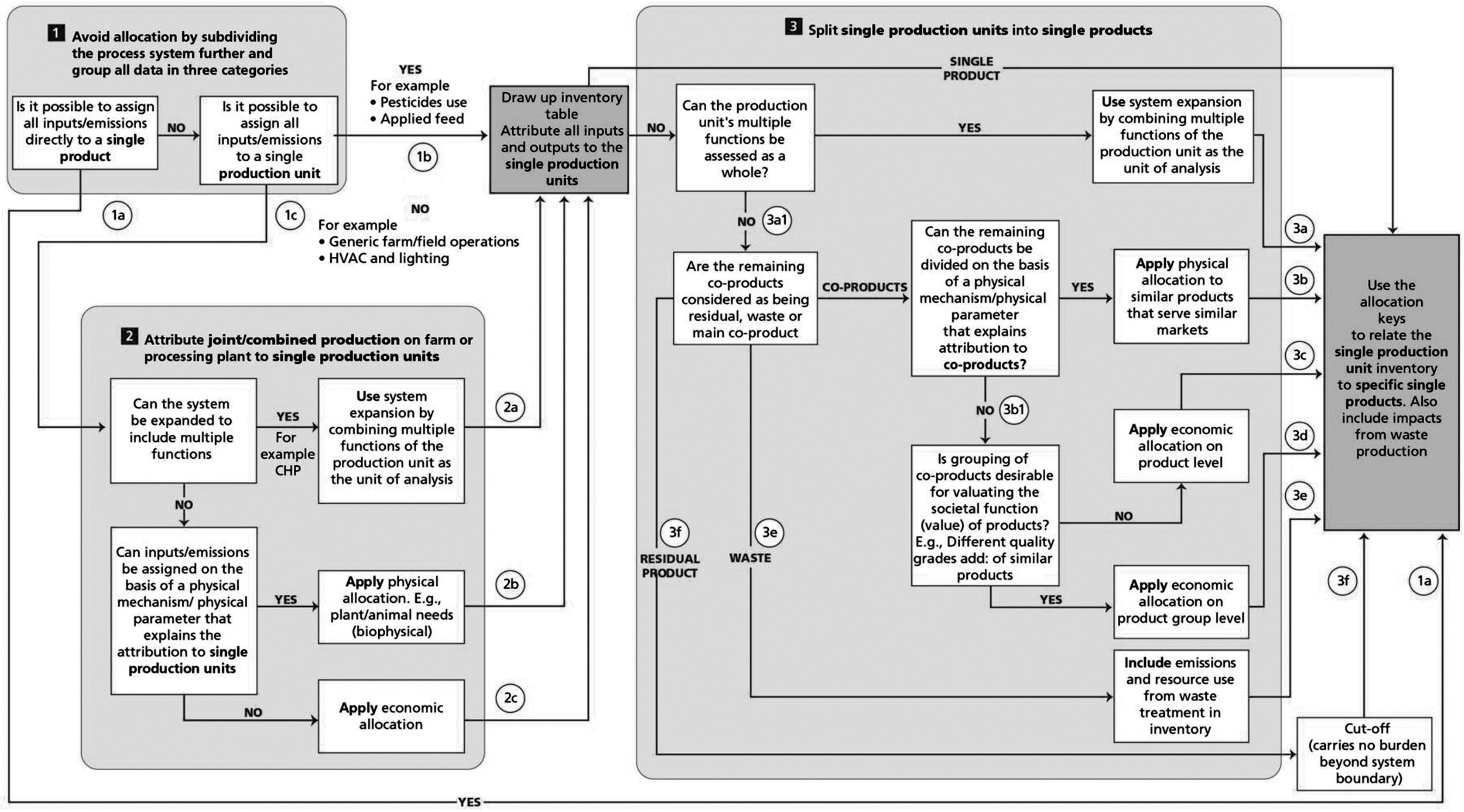

Figure 14: Multi-functional output decision tree

A COMMON CARBON FOOTPRINT APPROACH FOR THE DAIRY SECTOR
The IDF guide to standard life cycle assessment methodology

ABSTRACT

There is a recognized need to calculate greenhouse gas emissions (that is, the carbon footprint) for both dairy cattle farming operations and dairy manufacturers within the global dairy sector. In 2010, the first edition of 'A Common Carbon Footprint Approach for the Dairy Sector: The IDF Guide to Standard Life Cycle Assessment Methodology' was published. The guide has now been reviewed and revised to reflect evolving science and standards in carbon footprint methodology, in addition to experiences in using the guide by the dairy industry. This revised version ensures that the guide remains practical for use by the dairy sector globally, up-to-date scientifically and aligned with developments in other standards. Although all areas of concern and current development were analyzed, changes to the guidelines were limited to those supported by robust scientific evidence in order to ensure the highest degree of consistency, as well as to allow comparability with the first version and subsequent revisions.

This bulletin replaced the version of 2010, the bulletin of IDF N° 445/2010

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

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- Files to be sent electronically by e-mail or via our FTP site. Login details will be sent upon request.
- Final document in Word 2003 or 2007
- All tables/figures included in final document to be sent also in separate Word, Excel or PowerPoint files, in black-and-white or colour format.
- All files to be named with author's surname plus title of paper/tables/figures.

References

- References in the document to be numbered and placed between square brackets.
- Reference lists at the end of the document to contain the following:
  - Names and initials of all authors;
  - Title of paper (or chapter, if the publication is a book);
  - If the publication is a journal, title of journal (abbreviated according to 'Bibliographic Guide for Editors and Authors', published by The American Chemical Society, Washington, DC), and volume number;
  - If the publication is a book, names of the publishers, city or town, and the names and initials of the editors;
  - If the publication is a thesis, name of the university and city or town;
  - Page number or number of pages, and date.

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).

Abstracts

An abstract not exceeding 150 words must be provided for each paper/chapter to be published..

Address

Authors & co-authors must indicate their full address (including e-mail address).

Conventions on spelling and editing

IDF's conventions on spelling and editing should be observed. See Annex 1.

ANNEX 1

IDF CONVENTIONS ON SPELLING AND EDITING

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
micr<u>oo</u>rganisms	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
lit<u>re</u>	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 <u>INTERNATIONAL</u>	Not AOAC<u>I</u>
progra<u>mme</u>	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
<u>t</u>he Netherlands	

Where two or more authors are involved with a text, both names are given on one line, followed by their affiliations, as footnotes

for example A.A. Uthar[1] & B. Prof[2]
[1] University of ....
[2] Danish Dairy Board .....

IDF does not spell out international organizations

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