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of the International Dairy Federation

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Environmental / Ecological Impact of the Dairy Sector:

Literature review on dairy products for an inventory of key issues

List of environmental initiatives and influences on the dairy sector

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Environmental / Ecological Impact of the Dairy Sector:

Literature review on dairy products for an inventory of key issues

List of environmental initiatives and influences on the dairy sector

Foreword

The International Dairy Federation (IDF) is strongly committed to improving the environmental performance of the dairy sector worldwide. The present report is part of a series of IDF publications addressing a variety of environmental sustainability issues and possible strategies and approaches on how to minimize and control environmental impacts throughout the dairy production chain.

The study on environmental/ecological impacts of the dairy sector was undertaken by an independent team of consultants between August and November 2008 with the objective of providing active assistance to ongoing IDF work and consideration of the future IDF work programme related to sustainability with focus on the environment. The report comprises an in-depth analysis of the existing scientific and technical literature, including IDF publications, and a review of existing country positions and regulations, standards and guidelines.

As a follow-up from the key findings of this report, IDF has initiated new work on Life Cycle Analysis / Life Cycle Management and Carbon Footprint in the Dairy Sector with the main objective of developing a common LCA methodology for dairy products.

IDF would like to thank the authors of the study : Cécile Guignard, Francesca Verones, Yves Loerincik and Olivier Jolliet (Ecointensys - Life Cycle Systems, Switzerland) and the group of experts from the IDF Standing Committee on Environment who reviewed the report : Jim Barnett (NZ), Anna-Karin Modin Edman (SE), Rolando A. Montessori (NL) and Janne Sahlstein (FI).

Special thanks must be given to Ines Coldewey (DE) for the overall co-ordination of the successful brainstorming exercise with regard to the establishment of the future IDF work programme related to sustainability with focus on the environment.

IDF would also like to acknowledge the IDF National Committee of New Zealand for its sponsorship of the research work that has lead to the publication of the present report.

Joerg Seifert
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Christian Robert
Director General

April 2009

Environmental / Ecological Impact of the Dairy Sector:
Literature review on dairy products for an inventory of key issues
List of environmental initiatives and influences on the dairy sector

Study commissioned by

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Executive Summary

This report was commissioned by the IDF Brainstorming Task Force on the Establishment of an IDF Work Programme related to Sustainability with regard to the Environment.

The study has two aims :

- Highlight the ***key issues*** for the dairy sector based on a literature review focused on Life Cycle Assessment (LCA) studies.
- Give an overview of ***initiatives and labels*** that play a role for the dairy sector and what they imply for the various industry sectors.

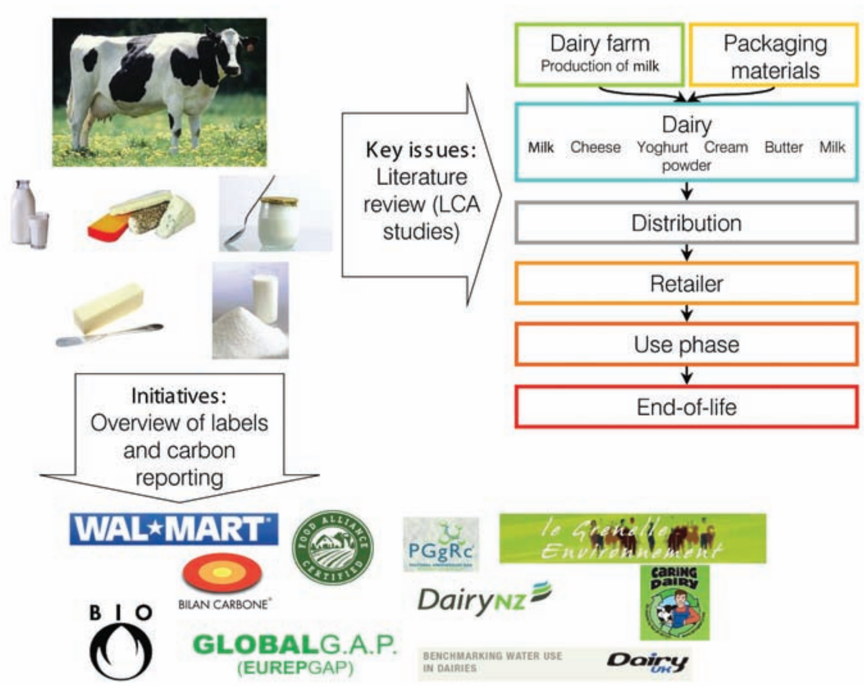

Figure 0.1: Objectives of the study, key issues and initiatives for the dairy sector.

This report is composed of two parts, each dealing with one of the aims formulated above.

Key issues for the dairy sector have been identified on the basis of 60 scientific articles, research reports and theses (mainly LCA studies). Most of the studies are based on a European context, with some for New Zealand, Australia and USA situations. The results presented in this report are therefore representative of a European situation or a "western agriculture type" situation. The studies give information on the different phases of life cycle of dairy products: dairy farm, dairy processing, packaging, distribution, retail, use phase and end-of-life.

A ***LCA*** is an environmental study focusing on the complete life cycle of a product or a service: from resource extraction to end-of-life of products (i.e., recycling, incineration or landfill) considering all steps in between (i.e., transport, transformation, distribution, use). A LCA quantifies the environmental impacts within a variety of damage categories, such as: climate change, ecosystem quality, human health, resources and water use.

The ***indicators*** considered for this literature review are *climate change, resources* (energy and water), aquatic *acidification* and *eutrophication* (which are components of ecosystem quality). The system studied considers the following *phases*: the dairy farm (fodder production, cow raising, milking, at farm refrigeration), the packaging, the dairy processing (processes for production of various dairy products), the distribution (transports and retailers), the use phase (refrigeration but not cooking), and end-of-life.

The results obtained show that the ***dairy farm has the highest impact for all impact categories*** and all dairy products examined here.

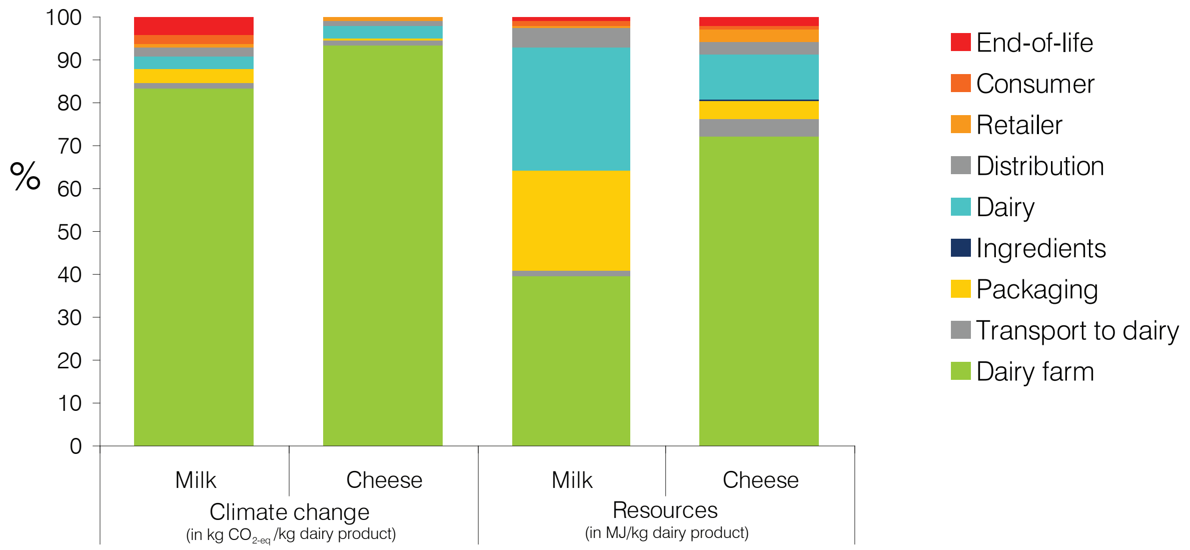

Figure 0.2: Contribution of the different life cycle phases for climate change and resources for 1 kg of milk and 1 kg of cheese.

For ***greenhouse gas (GHG) emissions***, the dairy farm contributes more than 80% of the impact for milk and more than 90% for cheese. Among these emissions, about 50% are due to methane (CH_4) emissions from enteric fermentation. About one-third is due to nitrous oxide (N_2O) emissions, mainly from manure management and nitrous fertilizers. The final one-sixth is due to carbon dioxide (CO_2), coming from tractors, trucks and electricity production. Among the non-farming phases, those of most importance for GHG emissions are the dairy processing and packaging production.

For ***non-renewable primary energy use***, the dairy farm is also the most important contributor. Considering the impacts to the farm-gate, about 60% of the energy use is for the feed production, i.e. fodder, silage, gazing, concentrates and their transport, as well as fertilizer production. Depending on the cow's diet, the feed production can vary because of the more energy consuming processes to produce feed concentrates compared to hay for example. Around 25% of the non-renewable primary energy use is on-farm electricity for drying fodder, milking, manure handling, ventilation, electrical fencing, lighting, refrigerated storage, etc. Diesel truck and tractor use represent the majority of the remainder (~15%). In intensive farming, a large part of the energy use is located off-farm (outside of the dairy farm studied) and is due to fodder production from other farms, concentrated feed production from the feed industry and fertilizer production. In organic farming, fodder is largely produced on-farm, since the use of concentrated feed is limited. Within the other phases, the dairy processing and packaging production are again the most important. It should be pointed out that in cases where infrastructure is considered (buildings and machinery production and maintenance), it seems to represent the major contributor to energy use, but it is often not taken into account.

With regard to ***water use***, the dairy farm is again the major contributor due to fodder production (cultivation water needs), drinking water for cows and cleaning farm and milking machinery.

Among other indicators considered here, ***acidification*** impacts occur mostly in the dairy farm phase (97%, of which 80% comes from ammonia due to fertilizer use). The main contributor to ***eutrophication*** are fertilizers. Milk has a high eutrophication potential compared to other agricultural productions.

The other important contributors to the environmental impacts are the dairy processing (energy consumption, wastes and water used) and the packaging production (plastic, cardboard, etc). The distribution chain, retailers and consumers, have smaller impacts that are nearly negligible in comparison to the farming phase.

There are many improvements in LCA methodology expected in the ***future***, especially regarding impact assessment (such as concerning ***water use***, ***land occupation***, ***ecotoxicology***, ***pressure on biodiversity***, etc.). It can be expected that newly developed impact assessment methods for such categories will also show a large influence of the dairy farm within the life cycle.

Little accurate information is available on the environmental impacts of ***other dairy animals***. From the available information, the major impacts seem to be GHG emissions and impacts related to grazing: destruction of rare vegetation, soil erosion leading sometimes to desertification and overgrazing.

The ***initiatives*** considered to reduce the environmental impact of the dairy industry include a variety of projects and programs that aim to improve the environmental performance of some stages of the dairy products life cycle. An institution leading these may be a governmental agency, a retailer or simply a private organization. These initiatives cover very different aspects with varying levels of complexity. Most initiatives do not cover the whole dairy products' life cycle but only part of it and most of them still operate on a voluntary basis. There are some that will become mandatory by law, while others will be mandatory standards of retailers or dairy product producers. Others are expected to draw participation, simply by social pressure.

Most of the initiatives summarized take into account ***greenhouse gases*** (19 initiatives). Eight also cover ***water aspects***. ***Energy*** (renewable and/or non-renewable) is being looked at in 7 of the summarized initiatives and ***nutrients*** are covered in 5 initiatives. Further aspects include ***biodiversity***, ***waste*** or ***human health***. Some are quite wellknown and well established, while others are still in the research or pilot stage.

Depending on the country, certain initiatives are likely to become mandatory and to be adopted by the necessary stakeholders. Also included are environmental legislations or subsidy policies. Globally, there will be more mandatory initiatives in the future, aiming at the producer and processor stages. It is therefore recommended that the dairy industry take a ***proactive approach*** for implementing the future and potentially mandatory initiatives.

This study concludes with an assessment of key concerns for the dairy sector. Figure 0.3 below shows both the timescale over which various ***areas of concern*** are anticipated to become important (currently ***GHG*** and ***Energy***, with increasing importance on ***Water***), and also the dairy product life cycle stages that are of primary importance for each area of concern. The figure summarises the main impacts to manage, and which parts of the value chain are expected to be under pressure.

Figure 0.3: Anticipation of importance of areas of concern.

1. Introduction and objectives

This chapter describes the objectives of this report and its place in a global environmental strategy for the dairy industry.

1.1. Context

The International Dairy Federation (IDF) is the international representation of the dairy sector, represented in 56 countries and covering approximately 86% of worldwide milk production. IDF is a centre of scientific and technical expertise for all parts of the dairy sector. The IDF Brainstorming Task Force on the Establishment of an IDF Work Programme related to Sustainability with regard to the Environment commissioned the present report to fulfil the dual purpose of providing an analysis of the key issues in the dairy sector based on Life Cycle Assessment (LCA), and of providing an inventory of environmental initiatives that have an influence on this sector.

1.2. Aim of the study

The first objective of this study is to assess and quantify available scientific publications measuring the ***environmental impact*** of the dairy sector and its products in order to identify ***key issues*** for the dairy sector. This objective is addressed through a literature review of the existing scientific literature and other unpublished information, with a focus on LCA studies. Emphasis is put on ***greenhouse gas emissions***, ***energy*** and ***water use***. The second objective is to give an overview of ***regulations and standards*** in ***labels and carbon footprint initiatives*** affecting the dairy industry. This review takes into account well established, newly adopted and forthcoming initiatives to give information on potential key environmental constraints that are affecting or will affect the dairy sector.

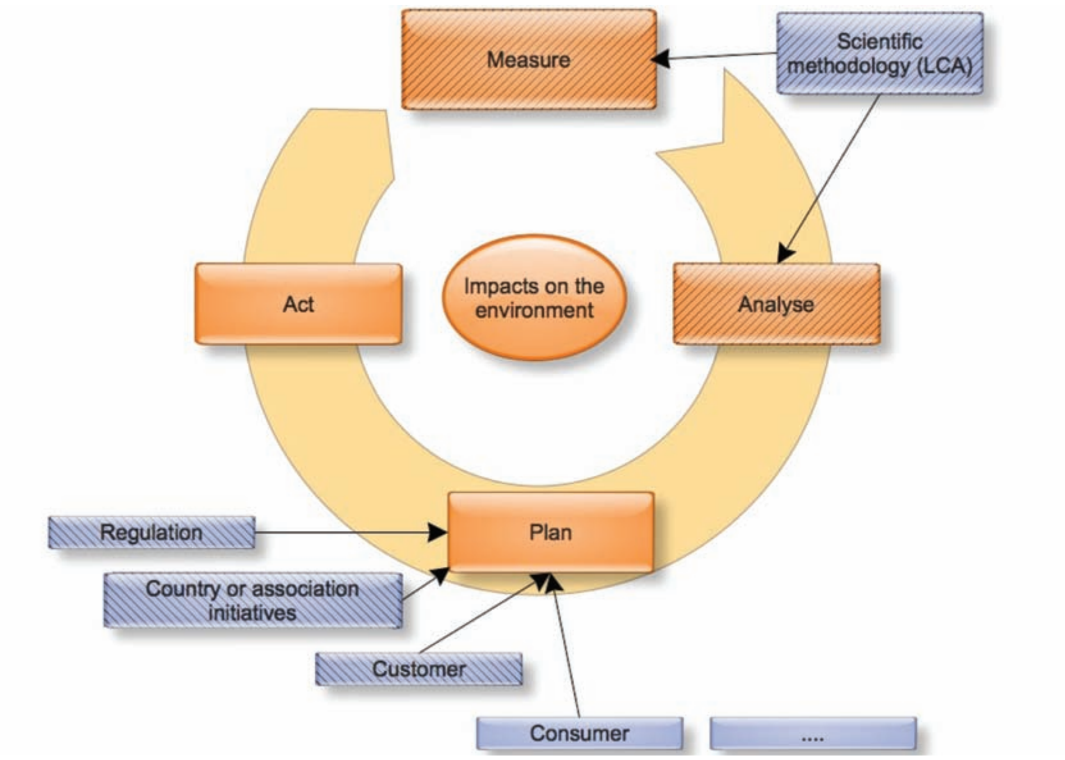

Figure 1.1: Phases of an environmental strategy.

Implementing an environmental strategy involves a continuous iteration of the following phases (Figure 1.1):

1. Measure the environmental impact (put it in numbers)
2. Analyse the environmental impact (understand its causes)
3. Plan the strategy
4. Act (implement the strategy)

The first part of this report focuses on how to measure the environmental impact through a literature review of LCA studies in this sector. LCA is the only accepted method for measuring the full environmental impacts of a product.

The second part is focused on regulations, initiatives of associations or customers (e.g., retail-ers), which is crucial information for the definition of a strategy.

PART I : Key issues of the dairy sector

Summary

The aim of this part of the work is to establish an inventory of the existing LCA studies on dairy products, to evaluate them and to collect quantitative or qualitative information on the different environmental impacts that occur during the life cycle of dairy products.

The following 2 chapters focus on bovine dairy products. Chapters 3 and 4 give information on the inventory literature and the LCA methodology while Chapter 5 gives the results obtained from the literature review. Chapter 6 deals with the future improvement in LCA methodology and the involvement of the dairy sector. The last Chapter (7) of this first part discusses the environmental impacts of non-bovine dairy animals.

Main findings

- The information on key issues of the dairy sector comes from **60 scientific articles, research reports and theses** (mainly LCA studies). Most of the studies give data for the European context, with some for New Zealand, Australia and USA.
- For the production of milk, 85% of the GHG and 40% of the energy consumption are linked to the dairy farm. For cheese it is 95% and 75% respectively.
- On average, the production of **1 kg of milk** is responsible for **1 kg of $CO_{2\text{-eq}}$**, 1 kg of cheese produces 8.8 kg of $CO_{2\text{-eq}}$ and 1 kg of yoghurt produces 1.1 kg of $CO_{2\text{-eq}}$.
- CH_4 emissions from enteric fermentation and manure represent 35% to 80% (mean 50%) of the total GHG emissions of the dairy farm, depending on the study. One dairy cow emits around 100-150 kg CH_4/year. Nitrous oxide (N_2O) is the second largest contributor to the greenhouse gas emissions from dairy farms.
- After the dairy farm, the dairy production and the packaging are the major contributors to non-renewable primary energy consumption.
- A high level of variation exists between the different farms studied, suggesting that the influence and management of the farm represents an area of high improvement potential.
- The field of **water footprinting** is just at its beginning and will become a major issue in the coming years. **Eutrophication** is likely to gain in importance in the dairy industry.
- Developments in Life Cycle Assessment are likely to modify the above mentioned figures by: including *GHG emissions from land use change* (e.g. forest clearing in Brazil), including *sinks from pasture*, and better inclusion of *land use impacts* and *human health* effects.

2. Literature inventory

This chapter discusses the studies considered for the literature review. It classifies these studies and defines the subjects covered by them.

2.1. IDF literature

A considerable number of studies have already been undertaken on sustainable development issues by the IDF over two decades, including a Guide on Life Cycle Assessment in the Dairy Chain. These studies are not included in this report, but are summarised in a separate publication reviewing IDF work on environmental sustainability issues.

The review covers publications on:

- GHG emissions on the farm and post-farm: *Reduction of Greenhouse Gas Emissions at Farm and Manufacturing Level (IDF Bulletin 422/2007)*
- Life Cycle Assessment in the dairy chain: *Guide on LCA Towards Sustainability in the Dairy Chain (IDF Bulletin 398/2005)*
- Energy use in dairy processing: *Energy Use in Dairy Processing (IDF Bulletin 401/2005)*
- Water treatment and reuse: *Freshwater Treatment and Reuse of Process Water (2005)*
- Wastage prevention in dairy plants: *Guide for Dairy Managers on Wastage Prevention in Dairy Plants (IDF Bulletin 382/2003)*
- Nutrient removal practices in the dairy industry: *Nutrient Removal Practices in the Dairy Industry (IDF Bulletin 366/2001)*
- Disposal and utilisation of dairy sludge: *Disposal and Utilisation of Dairy Sludge (2000)*
- Anaerobic treatment of dairy effluents: *Anaerobic Treatment of Dairy Effluents (IDF Bulletin 252/1990)*

2.2. Literature studied

The information presented here on key issues of the dairy sector comes from:

- Scientific studies (mainly LCA): in scientific journals, reports of research and theses
- Generic data from external Life Cycle Inventory (LCI) databases (for example ecoinvent, Frischknecht et al. 2005, 2007)
- Expert advice

60 studies are considered for this literature review. Most of them deal with milk only (39 studies), 3 of them are devoted only to cheese, 2 only to yoghurt and the remainder cover several dairy products in the same study.

The studies considered come from different sources, as shown in the following figure.

Type of source	Number of studies
Theses	4
Conference reports	11
Research reports	23
Scientific journals	22

Figure 2.1: Type of sources and number of studies. Total number of studies: 60

The studies that are taken into account for the literature review were published between 1990 and 2008, with most of them being published relatively recently (from 2001 to 2008). Figure 2.2 gives the year of publication and the type of study (whether based on LCA methodology or another type of study).

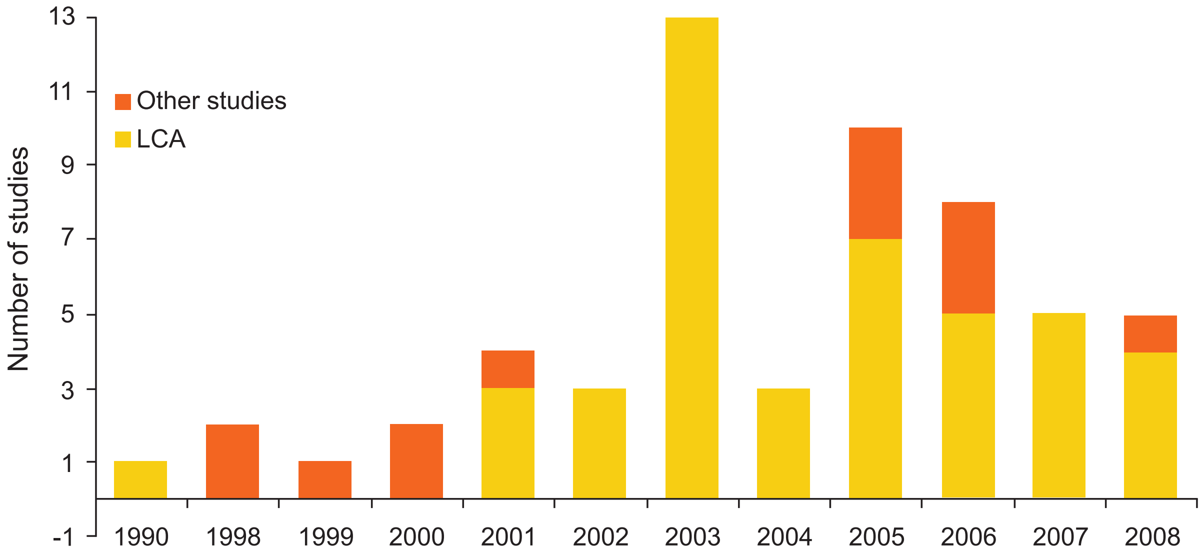

Figure 2.2: LCA and other types of studies. Total number of studies: 60.

The different reports correspond to different countries as follows:

- Scandinavia: 22
- United Kingdom: 5
- Other European countries: 14
- Australia and New Zealand: 6
- India: 2
- USA: 1
- Brazil: 1
- Unspecified countries: 9

The present report is therefore representative of a European or a "western agriculture type" situation. Indeed, dairy farming as well as dairy processing or the transport distances, retailer etc. conditions can vary from one country to another. The species of dairy cows or the manure management as well as the electricity mix vary depending on the region of the world. In Europe and North America, cows have higher milk yields than in other regions, but emit more methane. In Africa or Asia, manure is used partly as a substitution fuel and in Europe manure is transformed into slurry and spread on the fields. The emissions related can vary accordingly. Transport distances also vary from one country to another: longer in the USA than in the Netherlands, for example. The results presented reflect the situation in Europe and; European products, and cannot lead to the right conclusions for an African or Asian situation.

The different studies evaluated focus on various phases of the life cycle of dairy products: 34 studies deal only with the dairy farm phase, 13 take into account the whole life cycle of dairy products, 6 deal with only the dairy processing phase (of which 1 is devoted only to cleaning methods) and 3 focus on only the packaging phase. The remaining four studies consider several phases but not the whole life cycle.

Due to limits of data availability, the present report focuses on the following products: milk, cheese, yoghurt, cream, butter and milk powder.

3. Life Cycle Assessment methodology

Data available in the identified LCA studies have been collected and then aggregated to show the environmental impacts of different indicators. To understand from where the data collected in the studies are derived, some information about LCA methodology is provided below. The damage categories considered for the present report and the system analysed are then presented.

3.1. General information on LCA

The increased awareness of the importance of environmental protection and the possible impacts associated with products and services throughout their life cycle has increased the interest in the development of methods in order to better understand and address these impacts. One of the techniques being developed for this purpose is the life cycle assessment (LCA).

LCA can assist in identifying opportunities to improve the environmental performance of products at various points in their life cycle, informing decision-makers in industry, government or non-governmental organizations (e.g., for the purpose of strategic planning, priority setting, product or process design or redesign). The selection of relevant indicators of environmental performance, including measurement techniques and advertising (e.g., implementing an eco-labelling scheme, making an environmental claim or producing an environmental product declaration) are also potential outcomes of an LCA.

LCA addresses the environmental aspects and potential environmental impacts (e.g., use of resources and the environmental consequences of following releases of pollutants) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle-to-grave).

There are four phases in an LCA study: a) the goal and scope definition phase, b) the inventory analysis phase, c) the impact assessment phase and d) the interpretation phase.

The principles and framework of LCA as well as the specific requirements and guidelines to perform a LCA are described by the international ISO 14040[2] standards [9, 10].

The Appendix 10.4 gives a generalized introduction to LCA.

It must be noted that LCA does not analyse the social impacts related to the different life cycle phases. For example, it does not consider the workers' conditions or worker health and safety.

The data collected from the various sources are aggregated to determine an average level of the environmental impacts of dairy products. Results are presented for the following damage categories:

I. Climate change (i.e. greenhouse gas emissions)
II. Resources:
  II.1 Energy
  II.2 Water
III. Others, mainly Ecosystem Quality (including acidification and eutrophication)

Although water consumption is discussed, there is less data available on this subject and there are few methods currently available to make a thorough and accurate assessment of water consumption impacts.

3.2. Damage categories

Environmental impacts correspond to the impacts of substances emitted and extraction of materials on the environment. Various methods exists to relate the emissions of substances and the material extraction to a quantified effect on the environment (e.g. IMPACT 2002+, see Appendix 10.4) . The numerous substances emitted can be classified and grouped to create some categories of impact (midpoint): for example, various substances emitted are responsible

[2] The current standard ISO 14040:2006 includes as indispensable part ISO 14044:2006.

for terrestrial ecotoxicity and they can be grouped. Then various categories of impact can be aggregated in damage categories (endpoints), for example, terrestrial ecotoxicity can be aggregated with other midpoints like land occupation, aquatic acidification, aquatic ecotoxicity, etc. to form the damage category *Ecosystem quality*. This chapter presents the damage categories of IMPACT 2002+.

Climate change

The impacts on climate change are given in kg CO_2 equivalent (i.e. the impact of the sum of greenhouse gases (GHG) is converted to an impact in CO_2 only, considering a time-horizon of 100 years). For example, 1 kg of CO_2 equals 1 kg $CO_{2\text{-eq}}$, 1 kg of CH_4 corresponds to 25 kg $CO_{2\text{-eq}}$ and 1 kg of N_2O corresponds to 298 kg $CO_{2\text{-eq}}$ [9] (respectively 21 and 310 in IPCC 2001 [8]). These 3 gases are the major GHGs emitted in the agricultural phase. In the retail and use phases, the greenhouse gases emitted are mostly CO_2 but also CFCs and HCFCs (refrigerant gases).

Resources

Energy

The impacts on resources are measured in MJ, which represent the energy contained in the fossil fuel and uranium (for energy consumption) plus the energy necessary to extract the resources (for mineral consumption). The resource depletion is taken into account: over time more energy is necessary for the extraction of non-renewable resources.

Water

This indicator measures the water use, in litres. In this study, this indicator is not available for each phase.

Ecosystem quality

Ecosystem quality is measured in Potentially Disappeared Fraction of species (PDF) over a certain area (m^2) during a certain time (year), i.e. in PDF·m^2·year. For this study, the total damage category "ecosystem quality" is not considered but acidification and eutrophication are discussed and these will affect ecosystem quality.

3.3. Limits

This study was not intended to be reviewed by an external panel of LCA experts and therefore should not be used for comparative assertions or studies.

3.4. Studied system

3.4.1. System boundaries

The system studied includes the different subsystems that comprise the dairy sector:

- Dairy farm: including the cows, the feed for them, the milking and the storage at farm
- Transport from dairy farm to the dairy processing
- Dairy processing: homogenisation, pasteurisation, sterilization and cleaning (cleaning-in-place methods)
- Transport from dairy processing to retailer
- Retail: cold storage rooms and refrigerated displays
- Transport by the consumer : shopping displacement
- Use phase: storage in the refrigerator/freezer.

This system is studied for different dairy products: liquid milk, skimmed-milk, milk powder, cheese, yogurt, cream, butter.

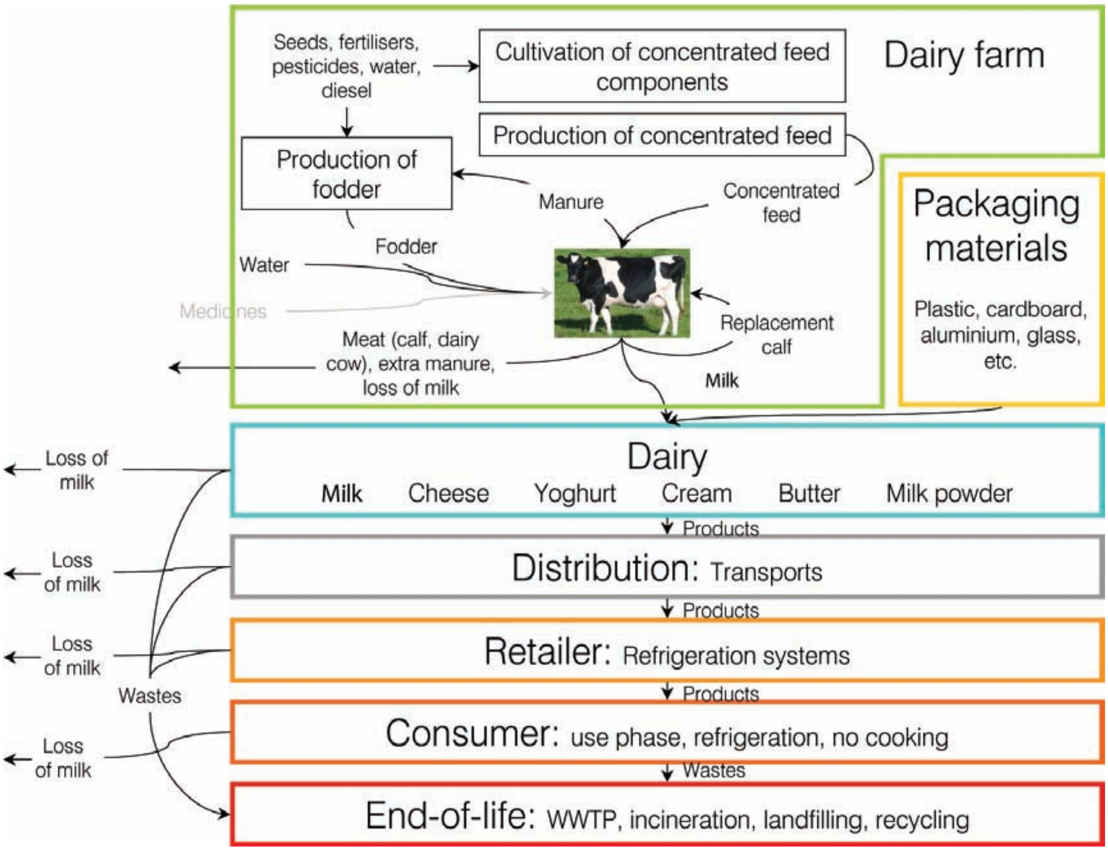

Figure 3.1: boundaries: all phases described are included in the system studied.

Figure 3.1 shows that losses occur at each phase of the life cycle. Losses are due to cleaning (dairy farm and dairy processing), transformation (at the dairy), "accidents" (all phases) or out-of-date (retailer and consumer). The losses during dairy processing are restricted for milk but may be important for other products (for example for yoghurts) and are considered in some of the studies for these products. According to IMPRO, it is estimated that up to 20% of dairy products are thrown away by consumers in Europe and the US [126] due to out-of-date products wasted, losses during cooking or product left in the packaging. These are usually not represented in the LCA studies because of the high variations in consumer behaviour. Consumer behaviour may therefore add up to 20% to all environmental impacts in the dairy chain reported in this study.

The system boundaries can significantly vary between studies and be a major source of variation in LCA-figures provided by companies.

3.4.2. Function and functional unit

To compare one product with another and to give information on a product's life cycle, it is necessary to define a unit. In LCA, this unit is called a "functional unit" (FU) and the impacts are given per FU, providing a common basis on which two products can be compared.

The objectives of eating/drinking are to ingest nutrients and water for survival as well as for enjoyment. The function of a dairy product is therefore to satisfy hunger, thirst and taste. However, the satisfaction of taste is very difficult to quantify and not really objective. Most LCA on dairy products define the functional unit as 1 *kg of dairy product (milk, cheese, etc.) at farm gate/packaged/at consumer*. The FU we have selected for comparing the various studies is:

1 kg dairy product to the consumer

This FU does not cover any cooking. It considers the impacts until the consumer takes the dairy product out of the refrigerator to consume it (as well as impacts of disposing of packaging). The impacts of refrigeration are accounted for but not the impacts of cooking or dishwashing.

Milk is not functionally comparable to cheese or butter. It does not have the same use in cooking nor the same chemical composition or nutritive value. For these reasons, 1kg of milk is not functionally comparable to 1 kg of cheese or butter but only to another kg of milk. The different products could for example be compared in the future in impacts per serving, per recommended daily intake, protein or lipid contents or nutritional provision.

3.4.3. Allocation

For dairy products some problems of allocation are encountered due to the fact that cows produce meat and leather in addition to milk. Therefore the impacts of cows at the dairy farm must be allocated partly to milk and partly to meat (leather is in general not accounted for). These allocations are generally based on economic criteria: the value of the milk produced during the life of a cow and the value of meat from the cow and her calves. Biological allocations are used in some studies: the impacts are distributed depending on the quantity of feed that will be turned into milk or meat respectively. The allocation must be done for the impacts at the dairy farm. The next life cycle phases are not concerned by this allocation problem between milk and meat.

There are similar allocation problems in the dairy processing phase: some products are co-products of milk or by-products like cream or whey. Which part of the impacts at the dairy must be given to the different products? For this phase, allocation according to nutritional value or other physical unit related to the product function would be an option but for this report, economic allocation is applied like in most of the studies on which it is based.

The type of allocation done is an important factor of variation for the results of different studies. The choice of economic, mass, volume, biological, or other allocation can explain many differences in the results between studies.

4. Analysis and Results

This chapter presents the results of the literature review. The results presented are obtained by aggregating the data from the studies evaluated. All data found in these studies have been transcribed to calculate the means, minima, maxima, etc. Some of the data collected were not directly usable and have been transformed for the calculations. Also some intermediate aggregations have been made to group some processes of the life cycle together. The available data allows for good and quite precise results on milk, quite accurate information on cheese and little information and sparse results on other dairy products. The results are presented for global warming, non-renewable energy use and acidification, first for milk and then for different dairy products. The results and problems related to water use are outlined and eutrophication is briefly discussed.

Results presented in the figures correspond to the means of the data collected. Some box plots are presented to show the distribution and variation of the data from the different studies.

4.1. Global warming

4.1.1. Milk

Figure 4.1 shows the **greenhouse gas (GHG) emissions** for the different phases of the life cycle of **1 kg of milk**, multiplying each emission by its corresponding Global Warming Potential (GWP) to yield an overall Global Warming Scores in kg CO_2 equivalents. The GWP used in most studies are calculated for a time-horizon of 100 years.

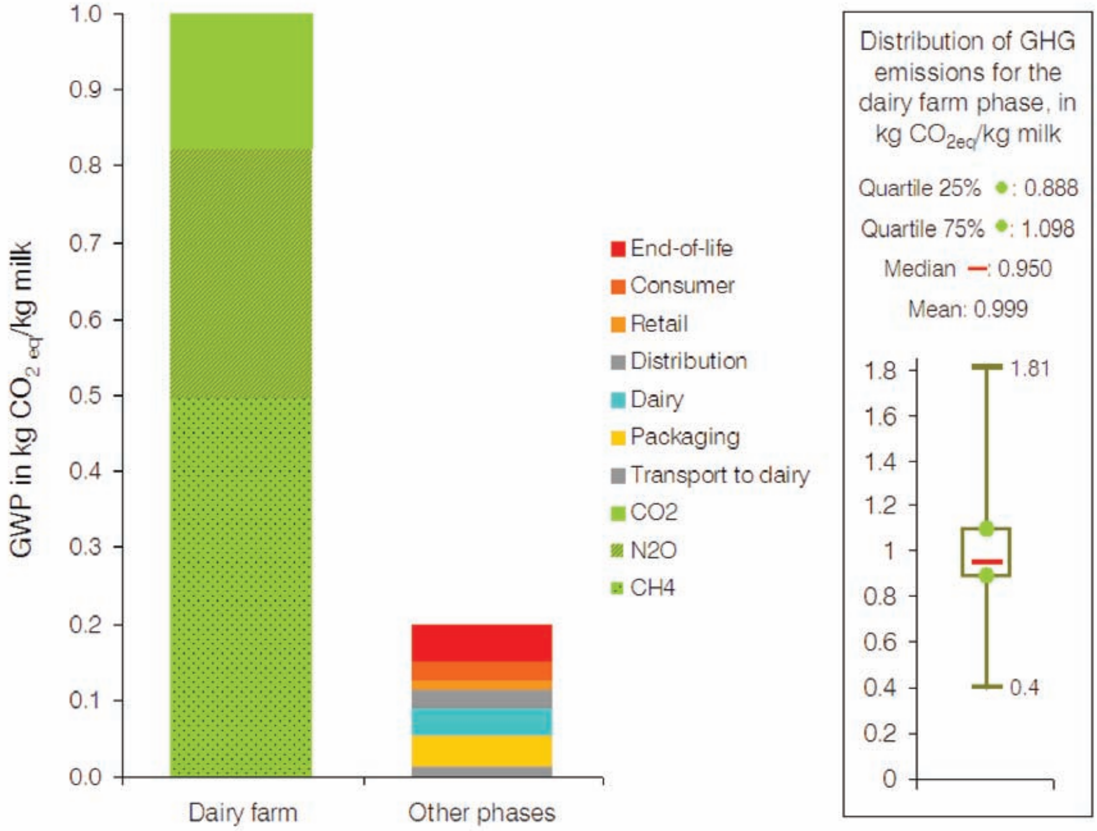

Figure 4.1: On the left, Global Warming Potential in kg $CO_{2\text{-eq}}$ for 1 kg of milk in the different phases of the life cycle (data correspond to means). On the right, the box plot showing the distribution and variation of the collected data in the different studies for the dairy farm phase. The percentile 5% and 95% are respectively 0.61 and 1.61 kg CO_{2eq}/kg milk.

The largest emissions of GHG are due to dairy farming. The sum of GWP of all other phases represents only one fifth of the dairy farm phase. The causes of GHG emissions at the dairy farm stage are mainly enteric fermentation, manure management and feed production [27, 33, 39, 47, 55, 58, 67, 70].

CH_4 is the main GHG emitted at the farm level [70]: it represents 35% to 80% (mean: 50%), depending on the study. The methane emissions are due mainly to enteric fermentation (one cow emits 100-150 kg CH_4/year) but also to manure management.

Nitrous oxide (N_2O) is the second largest contributor to the greenhouse effect at dairy farms (varying from 9% to 53% depending on the study, with a mean of 30%) and comes mainly from manure management and from nitrogen fertilizers. Carbon dioxide (CO_2) is less important in the farm phase. On-farm it is emitted mainly from fossil fuel combustion, i.e. tractors and trucks (transport of herds, feed and fodder). Off-farm CO_2 emissions are related to non-renewable energy consumption, mainly for fertilizer production and transports. The share of milking impacts is negligible in the total impact of dairy farming (~0.02 kg $CO_{2\,eq}$/kg milk) [4]. The results show that the emissions of the **dairy farm** phase represent around **80%** of the **GHG** emissions of the total life cycle of 1 kg milk. The activities at dairy farms that contribute most to Global Warming are enteric fermentation, manure management and fodder production and storage.

The other important phases are the waste management (packaging is incinerated and the plastics that the packaging contains emit GHGs), the production of packaging (corresponding to the extraction of raw materials, as well as to the transporting and manufacturing of the milk containers) and the dairy processing phase. The GHG emissions at the dairy processing level come mainly from energy use. The emissions from the different stages of the transport (to dairy processing, distribution and to consumer) are caused by transport by trucks (fossil fuel combustion). The emissions from transportation to retailer are not very important compared to the other phases because the distances in fresh milk systems are often not very long. The impact of shopping is highly sensitive to the assumptions that are used (transport distances and total mass bought that can vary a lot depending on the country) and allocation type (economic or physical). Few LCA studies used for this report gave data on the shopping impact and it results in a low contribution to the GHG emissions. One study shows, however, that the share of shopping for dairy product is not negligible [126]. This arises from the fact that the impact of the trip was mainly allocated to fresh products like dairy products.

The main impacts of the retailer and consumer stages come from refrigeration (i.e. GHG emissions from electricity production): refrigerated displays and cold storage rooms for the retailer and refrigerator and freezers for the consumer. The impacts of these stages can vary depending on the composition of fuels used for electricity production in different countries, electricity consumption of the cooling systems and the period of time milk is stored in the shop and in the consumer's refrigerator. Even if this time span is rarely long for milk, the refrigeration is a large contributor to the impacts at the retailer and the consumer phase.

Considering the whole life-cycle of milk, all the post-farm phases emit mainly CO_2 from electricity generation and fossil fuels combustion, while the emissions of GHG from the dairy farm phase come mostly from CH_4 and N_2O. The higher GWP of methane and nitrous oxide compared to CO_2 (GWP of 25 and 298 kg of $CO_{2\ eq}$ for 1kg CH_4 and N_2O respectively compared to 1 kg of $CO_{2\ eq}$ for 1kg C_{O2}, [9]) and the large amounts emitted explain why the GHG emissions are much more important for the dairy farm than from the other phases of the life cycle.

Organic farming does not seem to be better regarding the GWP due to the nature of the fodder and the lower productivity of cows in organic systems compared to cows in conventional systems. The type of diet used for production of organic milk emits a little bit more methane but there is a wide variation between the different studies.

The data on GHG emissions have been collected from 25 different studies. A lot of data was available on the dairy farm stage and their variation and distribution is presented in Figure 4.1 (box plot part, on the right). The box plot has been constructed taking into account all the data available for the GHG emissions at farm level: it shows the variation between studies and a range including most of the results. The data vary a lot: from 0.4 to 1.8 kg $CO_{2\ eq}$/kg milk, but half of the data are between 0.9 and 1.1 kg $CO_{2\ eq}$/kg milk. The box plot shows that there is a large variation but globally half of the data are gathered in a small range. For the GHG emissions, the main source of error is related to uncertainties of N_2O release, because even small changes in the N_2O emissions influences a lot the total GHG emissions due to the high global warming potential of N_2O (298 kg $CO_{2\text{-}eq}$). This report exposes the global warming potential on a 100 years time-horizon. With a longer time horizon (500 years), the contributions of methane and nitrous oxide would be reduced due to their persistence compared to CO_2.

4.1.2. Other dairy products

Figure 4.2 shows the **GHG** emissions for **1 kg** of different **dairy products**. The impact of the different phases is detailed for milk and cheese; for yogurt only the total impact is given.

The GHG emissions of 1 kg cheese are much higher than for 1 kg milk because around 10 kg of milk are necessary to produce 1 kg of cheese [19, 48]. Therefore the impact for cheese should be around 10 times higher than those of milk (in this study they are around 7 times higher). The difference is due to allocation. During cheese making, cream or butter are also manufactured as co-products. These also have their share of the impact of milk production and dairy processing phases. Therefore, only a part of dairy processing impact and milk production impact is allocated to cheese, the remainder is allocated to cream or butter. The dairy farm phase corresponds to 80-95% of the total impacts (transport to dairy processing included). The other phases are practically negligible. The distribution of impacts for yogurt could be expected to be similar.

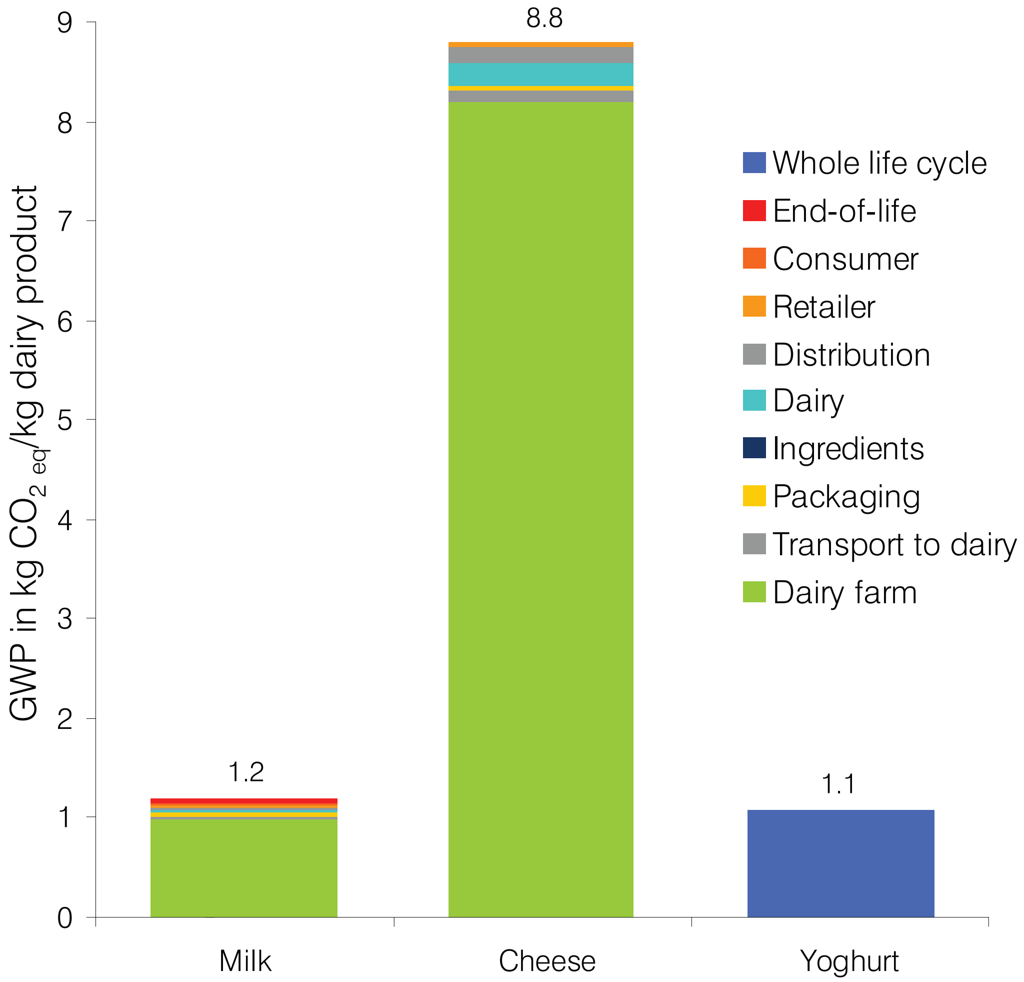

Figure 4.2: Global Warming Potential in kg $CO_{2\text{-}eq}$ for 1 kg of different dairy products. The results correspond to the means of the collected data. For milk and cheese, the different phases are shown. The value above each bar represents the GWP for the whole life cycle.

4.2. Resources (Energy)

4.2.1. Milk

Figure 4.3 shows the consumption of non-renewable primary energy for the different life cycle stages of 1 kg milk. Results differ significantly from greenhouse gas emissions, since the dominant contributions of methane and nitrogen dioxide have no relationships to energy use.

The main contributor to energy use is the dairy farm phase. For this phase, the contribution of the different energy uses is further segmented. The dairy farm represents around 40% of the total energy use in the life cycle of milk while the dairy processing and packaging phases each account for ~20%. The cleaning operation and distribution of packaged milk to retailers together amount to ~10% of the energy consumption of the whole life cycle. These values do not consider the potentially considerable energy use embodied in infrastructures. Infrastructures are buildings and machinery construction and are rarely considered in the studies. According to Rossier [67], it represents 1/3 of the total resources consumption of the total life cycle of 1 kg milk and further studies are needed to better characterize it. Therefore the impact related to infrastructures is shown with a dashed line.

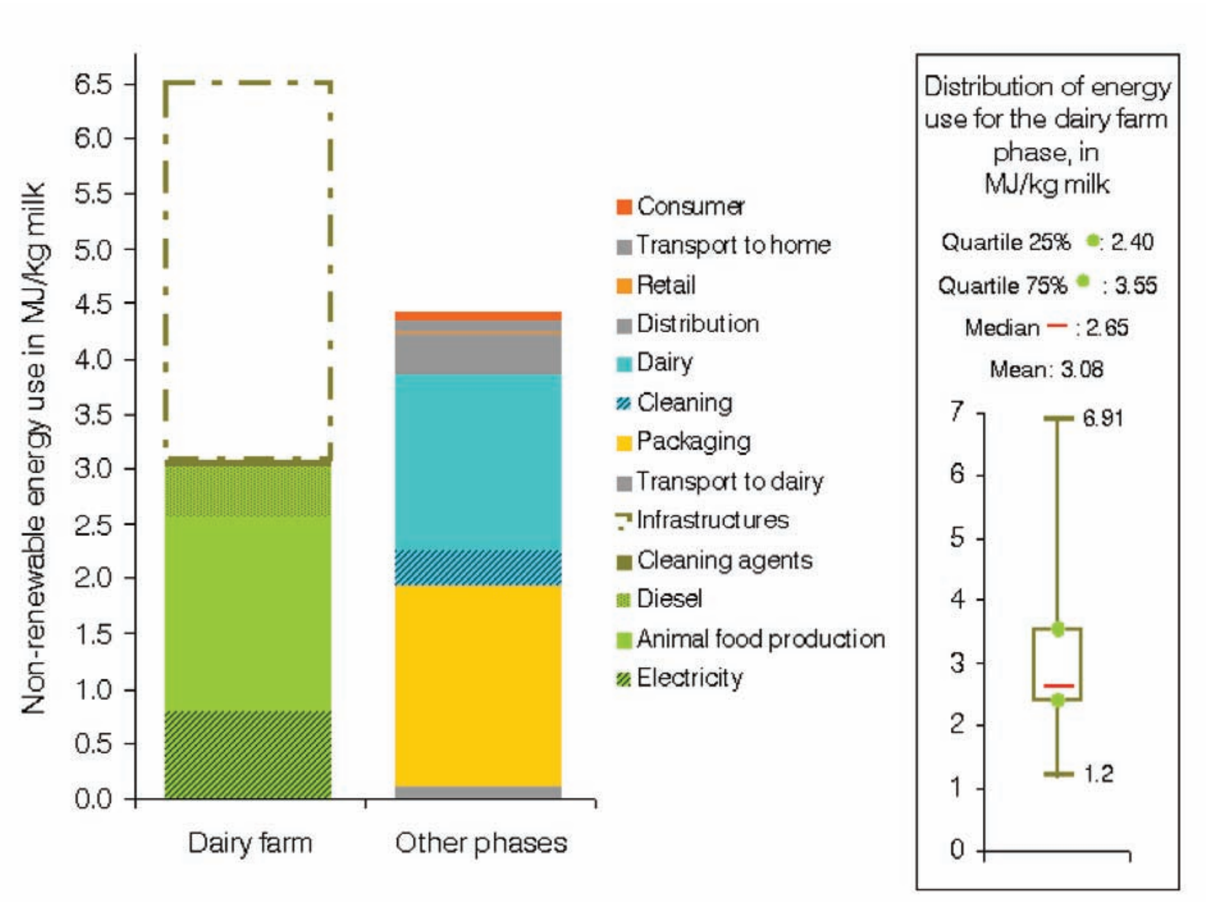

Figure 4.3: On the left, the consumption of resources for 1 kg of milk in the different phases of the life cycle (data correspond to means). On the right, the box plot shows the distribution and variation of the collected data in the different studies for the dairy farm phase (infrastructure not included). The percentiles 5 and 95% are respectively of 1.31 and 6.57 MJ/kg milk.

At the dairy farm, the major contributors to energy use are the feed production and electricity consumption. The feed production (fodder, silage, grazing, concentrates) requires mineral fertilizers whose production demands a lot of energy, but also transport by truck (seeds, fertilizers) and tractor displacement which combusts diesel. Depending on the cow's diet, the impact of feed production can vary because the processes to produce concentrates are more energy consuming than to produce fodder. Electricity is used for drying fodder, milking, manure handling, ventilation, electrical fencing, lighting and for storage in refrigerators and represents around 25% of the non-renewable energy use at the dairy farm. The diesel, corresponding to around 15% of energy consumption, is used for trucks and tractors. The cleaning agents' production consumes non-renewable energy. In intensive farming, a large part of the energy use is located off-farm (outside of the dairy farm studied) and is due to fodder production from other farms, concentrated feed production from the feed industry and fertilizer production. In organic farming, the fodder is largely produced on-farm and the use of concentrated feed is limited, the non-renewable energy use is thus mainly located on-farm.

The more important phases regarding resources consumption after the dairy farm are the dairy processing and the packaging. The production of packaging materials consumes non-renewable energy for the extraction of raw materials, their transformation and the transport to the dairy processing. During the dairy processing, electricity is used by machinery and fossil fuel is used for steam production and heating operations. The consumption of resources for cleaning operations at the dairy is not negligible. It comes from the production and transport of cleaning agents (alkaline and acid solutions), the electricity, the steam and hot water production. The different phases of transport (transport of milk to the dairy processing, distribution and the transport to the consumers' homes) are not very energy consuming for the same reason as explained above for the GHG emissions: the distances are short and for the transport to the consumers' home, an allocation between all products bought has to be conducted. The energy use of retailer and consumerphases comes mainly from refrigeration systems that consume electricity.

Organic dairy farming generally consumes a little less energy than conventional farming [16, 27, 30, 33, 53, 87]. This is mainly due to the different diet of cows and the origin of fodder (for organic farming, the major part of fodder must be produced on-farm, i.e. there are lower transport inputs) as well as the lower use or no use of mineral fertilizer (the production of fertilizers is energy consuming).

The box plot in Figure 4.3 shows that data on resources consumption for the dairy farm are a little bit more scattered than those for the Global Warming Potential.

4.2.2. Other dairy products

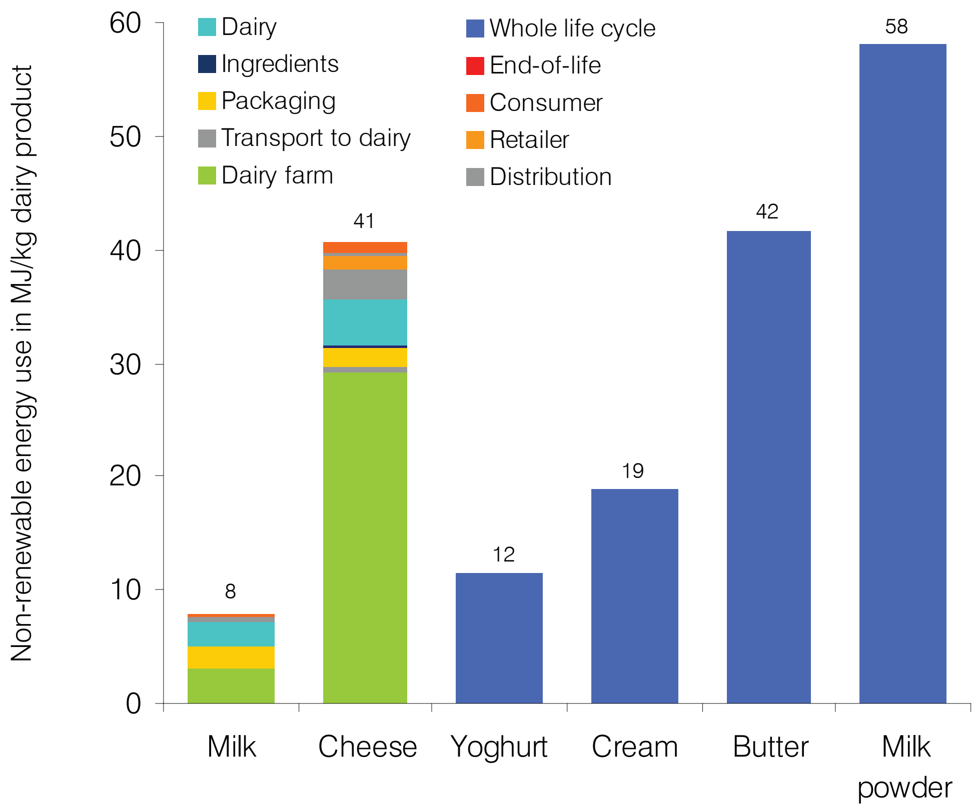

Figure 4.4: Resources use in MJ for 1 kg of different dairy products. The results correspond to means of the collected data. For milk and cheese, some different phases are shown. The value above each bar represents the consumption of resources for the whole life cycle.

Figure 4.4 shows the consumption of resources of the total life cycle of different dairy products, providing additional available details on process contribution for milk and cheese. For cheese, the farm phase dominates the total life cycle energy use, followed by the dairy processing phase and finally the packaging phase. The remainder are negligible for milk but for cheese, the refrigeration in retailer's and consumer's phases has a small but significant importance probably due to the longer time of storage of cheese in the refrigerator or in refrigerated displays because it is less perishable than milk.

The energy consumption for 1 kg yoghurt is just a little higher than for 1 kg of milk, the energy use for 1 kg of cream is about 2.5 times higher than for 1 kg milk. These differences are explained by the different quantities of milk necessary for the manufacturing of the different products and also by the allocation made (often economic allocation). The results come from various studies and thus the methodology used can differ. This can explain that for some results, not everything is interpretable by considering only the allocation made and the quantities of milk required. For example, the energy use for cream is expected to be higher than just a factor 2.5 compared to milk if we consider only the quantity of milk necessary for 1 kg cream and the economic allocation. The results are different than expected for this case because the result for milk is an average of numerous studies while for cream only one study was available. Moreover the system boundaries, the processes that are accounted for (e.g. in one study a highly modernized dairy is considered while in another one old machinery is regarded) and the calculations made can differ in the various studies. These aspects help to explain why the energy use of cream is not as high as could have been expected.

The same pattern is found for the other dairy products. For milk powder, the higher degree of processing (large quantity of energy necessary to dry milk) makes the dairy phase more important. For products that are stored a longer time in the refrigeration system, both in the retail or consumer phase, these phases earn importance. Overall, the dairy farm is the main contributor to global warming and energy use for cheese, but farm and after farm treatments generate comparable energy use for milk.

4.3. Resources (water)

The main contributor phase to water use is the dairy farm. The water use at the dairy farm comes from feed production, drinking water for cows and cleaning milking machinery. The most important consumer of water is feed production. Indeed, depending on the region of production, a lot of irrigation water may be necessary to produce the feed for the cows and its impact will be allocated partly to milk and partly to meat.

Around 6 L water per kg milk are used at the dairy farm for the cows' drink, 2 or more L water per kg milk are used for cleaning purposes (farm and milking machinery) at the dairy farm, and about 1.5 L at the dairy for the production of 1 kg milk (mostly cleaning/rinsing water). The production of cheese at the dairy requires around 6 L water per kg cheese, the butter is in the same order of magnitude and around 4 L water are used to produce yoghurt or other dairy products [44]. The packaging can use various amounts of water depending on its form (glass bottle, cardboard brick) but can be estimated at around 5 L water per kg of milk. These amounts of water corresponds to the "direct" water use and do not include the irrigation water for food production or soil moisture, neither for the great amounts of water used to produce electricity, to cool installations or to produce other inputs (for example fertilizers) nor the volume of polluted water due to pesticides for example. If these quantities of water are included, 1 kg milk requires around 1000 L water for production, 1 kg cheese requires 5000 L and 1 kg milk powder requires 4600 L [31, 32, 42, 43, 44, 56]. The water footprint is not influenced by the irrigation because it reflects the needs of the plants to grow whether the field is rainfed or irrigated.

The amount of water used can vary greatly depending on the irrigation system efficiency, the amounts of fertilizers used for the fodder production or the toxicity of products used (pesticides for example) that influences the volume of water polluted.

Water use is rarely accounted for in LCA, since it is very difficult to get reliable data and to as-sess the impacts reasonably. One also has to distinguish several different types of water use like consumptive or degradative use. Consumptive use means that the water used will not be returned to its original watershed (for example if it is used for irrigation or drinking water for cows). Degradative water use signifies that the water used will be returned to the watershed of origin, but with altered quality (for example if the temperature of the water is increased or if it is polluted).

In the agricultural sector it is often possible to at least estimate the water use, which is predominantly consumptive. However, it is very difficult to evaluate water use in industries (e.g. also dairies) because the largest part of the water here is degradative use and is rarely recorded. Also it is the question of how to assess the impacts of degradative water use. If it is done per m^3 of water used this may not be the best option since a larger amount of water can be less polluted and hence have a smaller impact on the environment than a smaller amount which is heavily polluted.

Another problem with assessing water is the prevalent water scarcity. The same amount of water used (e.g. for irrigation or drinking water for cows) in a very humid or a very arid region can have totally different impacts on the environment.

There are different methods being currently researched to improve water use assessment, but at the moment reporting on water use can foremost only be done by stating the amount in litres of water used, and accounting for different types of use (e.g. turbined versus non-turbined water).

4.4. Other damage indicators

4.4.1. Acidification potential

a) Milk

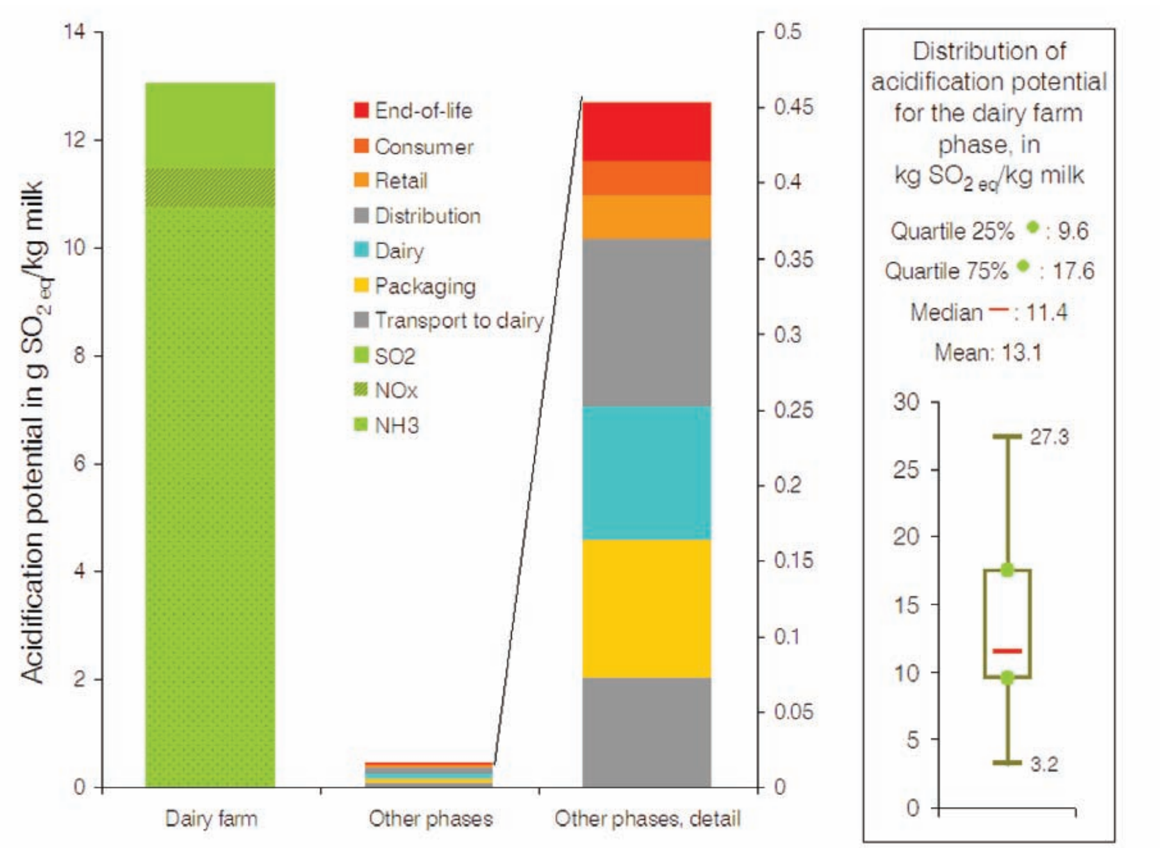

Figure 4.5: On the left, the acidification potential in g $SO_{2\,eq}$/kg milk in the different phases of the life cycle (data correspond to means, the left caption is for dairy farm phase, the right one for the other phases of the life cycle of 1 kg milk). On the right, the box plot shows the distribution and variation of the collected data in the different studies for the dairy farm phase. The percentiles of 5 and 95% are respectively of 5 and 21.2 g SO_{2eq}/kg milk.

The acidification score is clearly dominated by the dairy farming (97%). The other phases are negligible compared to the farm phase. Acidification at farm level comes mainly from nitrogen fertilizers, manure degradation and nitrification-denitrification processes in soils and manure.

NH_3 contributes to 79% of the overall acidification score over the whole life-cycle. Ammonia originates mainly from mineral fertilizers but also from organic fertilizers. NO_x and SO_2 are responsible for around 5% and 12% of the acidification potential over the whole life-cycle respectively [30, 33, 47, 48, 58, 67]. This is due to non-renewable energy consumption: diesel for tractors and trucks, mineral fertilizer production, production of electricity for the milking process and refrigerated systems for milk storage.

The emissions of acidifying substances per hectare are higher for conventional than for organic farming but the acidification potential for 1 kg organic milk is higher than for 1 kg conventional milk. This is due to the milk yield (kg milk/hectare), which is higher in conventional systems than in organic ones.

Damage to the environment will occur if a certain concentration of acidifying substances is reached in a given ecosystem. Intensive farming emits large quantities of substances to rather small areas, leading to high concentrations in the environment and hence to damage to the ecosystem. However, it is not so easy to conclude which systems have less impact on the environment.

The box plot on the Figure 4.5 shows that the acidification potential at dairy farm level varies from 3.2 to 27 g $SO_{2\,eq}$ per kg milk and that the results are more scattered than for Global Warming and energy use. There are fewer reports available for the acidification potential than for energy use or GHG emissions.

b) Other dairy products

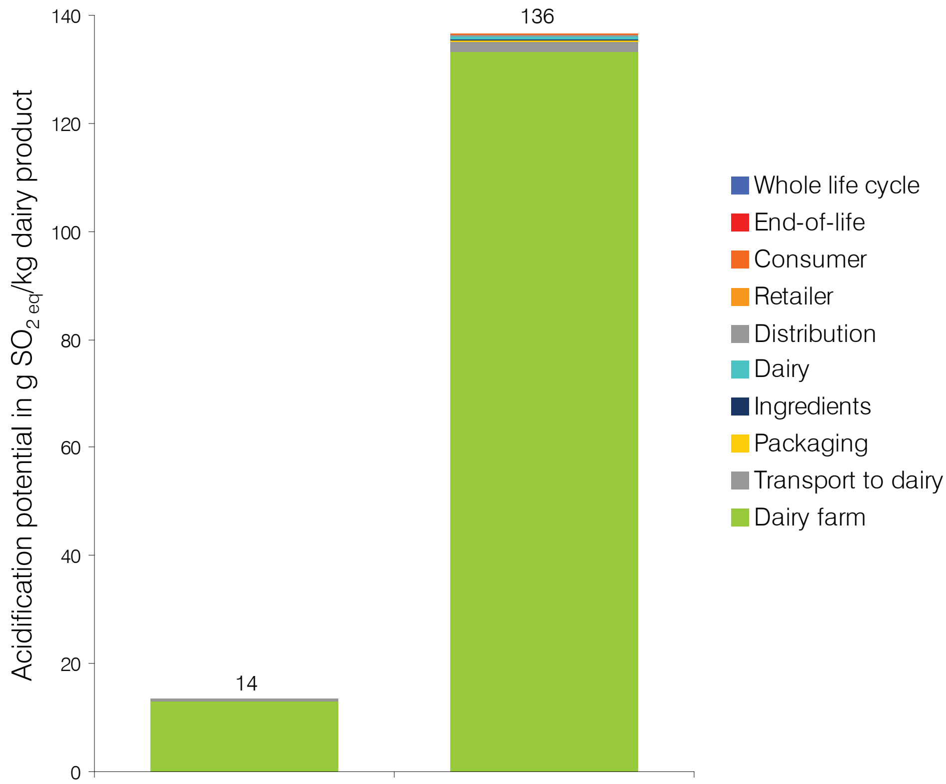

Figure 4.6: Acidification potential in g SO2 eq for 1 kg milk and on 1 kg cheese.

Figure 4.6 shows the difference between the acidification potential of 1 kg of milk and 1 kg of cheese. The acidification potential for cheese is 10 times higher than for milk. The reason for this difference is the same as explained for the GWP and energy use, since around 10 kg of milk are necessary for producing 1 kg of cheese.

4.4.2. Eutrophication potential

The main contributor to eutrophication is the use of mineral and organic fertilizers. There are large variations between studies because of different methods to evaluate nitrogen and phosphorus surplus and it makes it difficult to compare the results and to treat the data. The emissions of ammonia are generally the most important emissions. Nitrate leaching is also an important contributor to eutrophication. The eutrophication potential for the dairy farm is 6.2 g $PO_4^{3-}{}_{eq}$ per kg of milk [33, 34, 45, 47, 53, 58, 67, 80]. The eutrophication potential at farm level for different products is presented in Figure 4.7.

Sugar cane	0.00001
Sugar beet	0.00002
Potatoes	0.00005
Rye	0.0002
Wheat	0.0002
Barley	0.0002
Sorghum	0.0003
Fava beans	0.0004
Protein peas	0.0004
Rape seed	0.0005
Sunflower	0.0005
Soy beans	0.0006
Rice	0.0007
Milk	0.006
Kenaf fibres	0.006
Jute fibres	0.006
Cotton fibres	0.010

Figure 4.7: Eutrophication potential in kg $PO_4^{3-}{}_{eq}$ per kg of agricultural production. All data except for milk come from the ecoinvent database [4]. Beef meat would be equal to 0.02 kg $PO_4^{3-}{}_{eq}$ per kg [67] but can vary from a study to another. Other meat (porc, poultry) are in the same order of magnitude.

Eutrophication potential for 1 kg milk at farm level is important compared to other agricultural production. The fodder production necessary for 1 kg milk is the reason for a higher eutrophication potential of milk compared to other products.

For the dairy processing phase, the eutrophication potential varies from 0.02 in one study to 1.5 in another.

5. Other dairy animals

In the present chapter, the environmental impacts of non-bovine dairy animals are presented and discussed.

From a global perspective, dairy products from animals other than cows are only niche products and this is at least a partial reason why very little information on other dairy products is available. Also, being generally smaller than and fewer in number than cows, their emissions will be lesser than those from cows on a global scale (but not necessarily per kg milk, depending on milk yield). However, in some countries non-bovine dairy products are already important or will likely gain in importance in the future, especially in dry countries, but also developing countries. For example, buffalo milk was India's second largest food and agricultural commodity in 2005 [90]. Non-bovine dairy animals are less demanding than cows and can be satisfied with very difficult conditions, for example arid climate, sparse and dry vegetation. For these reasons, these animals cannot be compared directly to cows because in most cases they are not really in "competition": cows are not adapted to dry areas while goats, sheep or camels are. These non-bovine dairy animals are the solution to inhabitants of dry regions allowing them to have dairy products.

The most often mentioned impact for camels [158], sheep [159], water buffalos [161] and goats [160] was overgrazing, leading consequently to soil loss and erosion and, even adding to desertification in some areas. Feral camels and goats, but also water buffalos can become invasive species, disturbing an ecosystem thoroughly (for example in Australia). Camels also feed on rare plants and trample vegetation while frequenting salt lakes in Australia, disturbing the fragile ecosystem of these areas. Feral camels are also known to foul waterholes and damage stock fences and infrastructure at cattle watering points. Yaks have been implicated in causing trampling damage [162]. Impacts of water buffalos, apart from overgrazing, are destruction of vegetation by creating "swim channels" (pathways for buffalos) in inundated floodplains. This also leads to soil erosion and creates new drainage channels, thus altering floodplain hydrology. In Australia it has even been stated that the water buffalos are to blame for sea-water intrusions due to this altering of floodplain hydrology. Goats cause not only overgrazing as already mentioned but can lead to a loss of biodiversity, because plants (woody and non-woody) have little chance to regenerate while goats are around. Land degradation through soil damage, partly caused by overgrazing, and partly by trampling and thus breaking the soil's crust are other impacts caused by goats. The overgrazing impacts can be reduced if a good pasture management is established according to the dry/wet seasons with a regulated pasture round: i.e. fixed time of pasture in a place and fixed time at the beginning of pastoral season to let grass grow.

The reported environmental impacts of these non-bovine livestock are predominantly overgrazing and its consequences, as well as trampling damages. Environmental impacts like GHG emissions are a less studied and reported on issue for these livestock. In France [87], cows were responsible for 92% of methane emissions from enteric fermentation in 2003, while sheep were responsible for 6% and goats for only 1%. In 1997 the numbers were similar, being 91% for cows, 7% for sheep and 1% from goats. Sheep and goats emit about 10 times less methane than cows per animal, but also produces less milk so that a per kg milk approach is needed. In France (1997) methane emissions per kg milk averaged 50, 25 and 20 g in dairy ewes, goats and dairy cows, respectively. Per kg product, dairy cows show here the lowest emissions because they have the largest milk yield. In India [88], [89] buffalos and then cattle show the largest methane emissions per head, while goats, sheep and "others" (including yaks, camels) have much lower methane emissions. Average methane emission in lactating animals has been estimated to be about 54 g CH_4/kg milk. When all livestock (productive and non-productive male and female) were considered in the estimation the value was about 160 g CH_4/kg milk. Methane emission in relation to milk production (g CH_4/kg milk) is lowest in crossbred cattle followed by buffalo and indigenous cattle.

6. Issues for dairy stakeholders

This chapter discusses the future changes expected in LCA studies and their involvement concerning the different stakeholders of the dairy sector.

LCA methodology is not immutable but in perpetual change and improvement to be consistent with new research. This new research reflects the present environmental priorities and is related to future legislation or labelling initiatives.

The current literature review once carefully selected and harmonized enables to provide a first order of magnitude for the GHG emissions and the non-renewable energy use. However, individual reported studies may widely vary, depending on the allocation type used, the assumptions made and the various case study (various countries, organic or conventional farming, etc).

The human health and ecosystem quality indicators are well developed also. In the near future, LCA will better take into account water, reflecting a growing demand for water use information. Dairy farming is the largest water consuming phase, mainly because of irrigation and energy consumption for fertilizer production (turbined water). The increasing importance of water use impacts will therefore influence the dairy farm sector. The dairy processing is also an important consumer of water, mainly for cleaning and rinsing and also for electricity generation.

LCA will better take into account soil quality and land occupation in the future. The reduction of biodiversity and bioactivity (due to fertilizers or to compaction for example) will be assessed. The type of land occupation will also be considered: intensive farming causes loss of biodiversity, but at the same time it leaves some land in natural ecosystem. These issues are directly related to dairy farming.

Allocation methodology can also change and distribute impacts differently. For example, the impacts of cows are now typically allocated to milk and meat but not to leather or farm subsidies. A change of allocation method can influence how dairy farm impacts are accounted for. Similar considerations also apply to the dairy processing (allocation between the various products).

Future research will possibly enable inclusion of social issues in LCA to create a new impact category. The social conditions of workers could be accounted for at farms as well as dairies or retail phases.

The dairy farm has the highest impacts with the present LCA methodology and for all the damage categories. The future research and development in LCA will further quantify the impacts at the dairy farm and potentially lead to more constraints for this sector.

7. Conclusions, recommendations and limits

7.1. Recommendations and strategies

There are several possibilities to decrease environmental impacts at the dairy farm stage.

Different studies show varied results regarding the comparison between organic and conventional production of milk and dairy products. There is therefore not a clear overall recommendation to be made regarding organic farming based on the available literature [16, 27, 30, 33, 53, 87].

To decrease GHG emissions, research is being conducted to alter cows' diets, mainly with the aim to decrease methane. Fodder production and pastures can be produced in a more organic way, with less fertilizers and pesticides. Manure can be converted into biogas with an anaerobic digestion. The biogas produced can replace fossil fuels and so diminish the GHG emissions twice: less methane and nitrous oxide from manure management and less carbon dioxide from ordinary fossil fuels combustion like, for example, coal. The sludge obtained in biogas production can then be used as a fertilizer, replacing artificial fertilizers [92].

For the dairy processing phase, it has been demonstrated that better QES (quality – environment – security) management can have a great influence [17, 18]. Altering the order in which equipment is used to produce the different products in a dairy (yoghurt flavours for example) is a possible way of reducing impacts. Some products require complete cleaning before producing the next one, while for others only a short rinsing or even no cleaning is necessary. With good sequence management, it is possible to significantly reduce the product losses, the water use and the detergent use and hence to reduce the environmental impacts.

7.2. Limits

The results of this study deal with a part of the impacts of dairy products: GHG emissions, energy use, acidification and water consumption. Ecotoxicological problems have rarely been taken into account in the available LCA studies. The effects on microorganisms due to pesticide use, the impacts of cleaning agents in the dairies, and the antibiotics and pharmaceuticals for the cows are usually not assessed in LCA.

As specified above (chapter 3.4.1) the losses at the consumer phase are not included in the results. The quantities lost at this phase have a direct impact because the increase in consumption directly applies to the whole life cycle. The rate of losses varies from 1.5 to 20% depending on the region studied, the sample of population questioned or the estimates made and the study [47, 128]. Considering the whole life cycle until the consumer phase, could therefore add up to 20% to all the impacts. The quantities of dairy products wasted at the retailer phase (due to out-of-date products mainly) may be added to consumer losses but are not documented.

The scientific studies used as reference for this report have been carefully selected and harmonized when possible to make results comparable. Variations among the results of individual reports may be significantly larger, depending on differences in the system boundaries, in type of allocation used and assumptions made or statistics used.

In relationship to the high diversity of farms (size, location, organic or intensive farming etc.) the relevant information concerns a limited part of them. For this reason, it would be of interest to improve the knowledge on the influence of the important variation parameters.

7.3. Conclusions

The data available come primarily from studies made in Europe and very few studies have been conducted in non-European countries. Information on where impacts occur is crucial. Perhaps farms or dairy companies have more information on this, but it was not accessible for this work.

For all dairy products and all damage categories, the impacts of the dairy farm phase dominate the total life cycle. On the dairy farm, the impacts come mainly from the feed production for all impact categories and also from the cow for GHG emissions.

It must be noted that important variations exist between the different cases studied, suggesting that the influence of the farmer and his management techniques represent a high improvement potential at farm level [67, 70]. A part of variation can be also due to calculation errors, truncated system boundaries or arbitrary allocation choices and shall be treated as system noise.

After the dominant dairy farm phase, dairy processing has important impacts, as well as the production of packaging. The impacts of retailers and consumers are relatively limited even though refrigeration systems are often used. The transportation does not have a great environmental impact as long as the distances covered are generally not very long in the dairy product systems. The transport distances of milk powder are more important but this product is lighter and has a long life (it can be transported by ship).

It must be recognized that in most cases a dairy cow also produces meat (calf and replacement cow) and therefore this allows a decrease of beef cow production, offsetting impacts that would otherwise occur if the dairy cows did not produce meat.

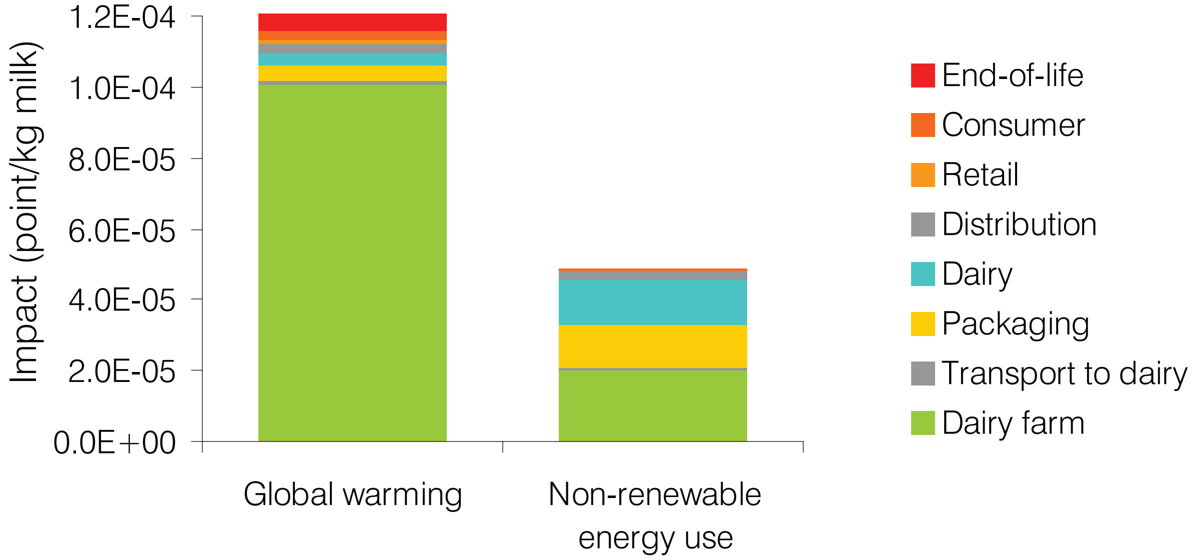

Figure 7.1: Normalised impacts for global warming and non-renewable energy use in points (normalisation is based on the IMPACT 2002+ methodology).

Figure 7.1 shows the impacts in points (a normalized impact scale based on the IMPACT 2002+ methodology, giving no additional weighting to the two indicators) for global warming and for non-renewable energy. With this method, it is possible to compare these two categories of impact. Figure 7.1 suggests that the GHG emissions are more than twice as important as the energy use. The share caused by the dairy processing and packaging phases is more important for the energy use.

Additional aspects that will be considered (or more accurately considered) in future LCA studies (biodiversity, land occupation, water, allocation, etc.) will mainly influence the dairy farm phase.

Little accurate information is available on the environmental impacts of other dairy animals. Further studies on this theme would be very useful because camel or buffalo milk are taking increasing importance in global milk production.

Figure 7.2 shows both the timescale over which various areas of concern are anticipated to become important (currently GHG and Energy, with increasing importance on water), and also the dairy product life cycle stages that are of primary importance for each area of concern. The figure summarises the main impacts to manage and which stakeholder in the value chain will be under pressure. The evaluation of the importance of areas of concern is based on experts judgment.

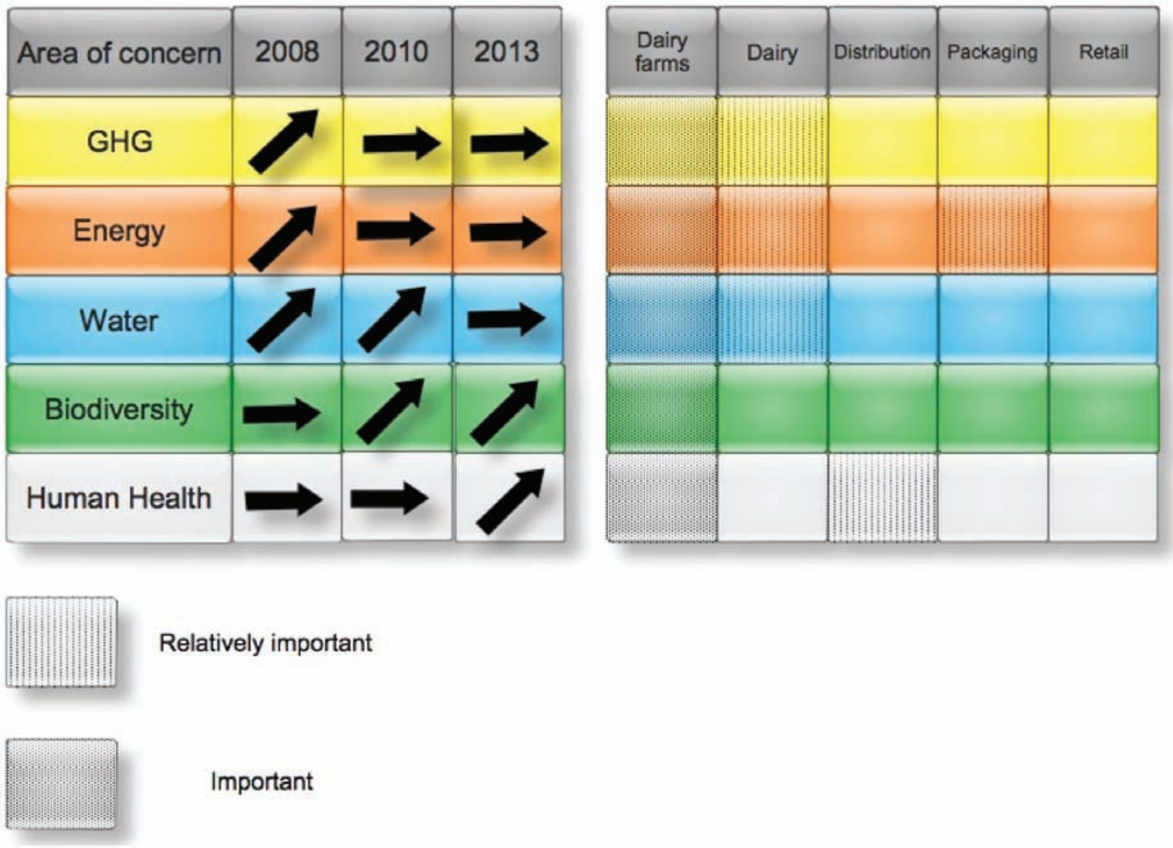

Figure 7.2: Anticipation of importance of areas of concern.

PART II : Environmental initiatives and the dairy sector

Summary

There is a large variety of initiatives targeting different environmental aspects and stages of the life cycle. Some of the initiatives are or will be become mandatory, these have to be adopted in a foresighted way.

Most initiatives take Greenhouse gas emissions into account, but also water and energy issues are often covered. The initiatives presented focus predominantly on bovine dairy products, although some can also be applied for non-bovine dairy products.

Main findings

- There are many different initiatives that have an influence on the life cycle of dairy products in a variety of ways. 52 initiatives have been identified in this report, covering various aspects of the complicated dairy life cycle.
- Different initiatives will become mandatory by law (New Zealand, US), some others will be pushed by private initiatives (retailers, companies) and suppliers will be "forced" to adopt them.
- The ISO is working on a carbon footprint standard that will most likely be available within a time frame of 2 to 3 years.
- In some countries, different initiatives are being developed and pushed by different retailers. There' s therefore a risk for a producer to have the "obligation" to participate to more than one of these initiatives.
- Bovine dairy products are predominant in the initiatives since most stem from industrialized countries which rather use bovine instead of non-bovine dairy products. However, some initiatives (e.g. organic labels) can also be used for non-bovine dairy products.

8. Environmental initiatives and the dairy sector

An ***initiative***, as used in this part, is a project or a program of an institution with the goal of ameliorating the environmental performance of dairy products on different levels of complexity and different stages of the life cycle. Institutions carrying out such initiatives are governmental agencies, retailers, research institutes or private organizations.

There are many different initiatives that have an influence on the life cycle of dairy products in a variety of ways. 53 initiatives have been identified in this report, covering various aspects of the complicated dairy life cycle. Given the complexity of this field and the nearly endless variety of initiatives, it is not practical to have a closer look at each of them. Some of these initiatives influence the dairy sector directly while others do not. However, they may still have some importance when the whole life cycle is considered (e.g. refrigeration). In addition, there are initiatives, which are, or may become mandatory through governments or retailers which have established their own standards or simply by (social) pressure, though most initiatives still operate on a voluntary basis. The section of retailer initiatives shows a very broad and large spectrum in particular. This chapter shall help to give an idea what the future constraints and commitments of the dairy sector will be to enable the sector to react and prepare appropriately.

In the following tables (Figure 8.1 and 8.2), 24 initiatives plus a summary of organic labels are shown. Each covers different aspects and has a different focus within the aspects mentioned. Some assign a label (see column "label") while others do not.

The following points offer additional explanation of the tables:

- The ***health*** aspect that is covered by some of the initiatives aims in most cases at ***animal*** or ***crop health***. In the Plan 'A' (initiative of Marks and Spencers [93]), the Dairy Stewardship Alliance [135], the Environmental Improvement of products (IMPRO) [126, 127, 128] and the Food Alliance [94] initiatives ***human health*** is covered via working conditions, human toxicity or community health.
- ***Water*** aspects are considered with different complexity. Some (e.g. the initiatives of Wal Mart [95]) declare to combat water pollution, while others like the Milk Roadmap [114] or Plan 'A'[93] focus more on water efficiency at farm level and retailer/supplier level respectively. In connection with the Milk Roadmap there are the guidelines "waterwise on the farm" [96] which shall help to protect and save water on the farms. The Caring Dairy [137] and Dairy Stewardship Alliance [135] talk very broadly about water management, including minimizing water pollution and water use with more efficient technologies for water use, re-use or rainwater harvesting.

The category "mandatory" includes initiatives or programs that are or will become mandatory by law (e.g. New Zealand GHG Reporting Strategy [107] or the US EPA GHG Registry [111]) as well as private initiatives (retailers, companies). Some private initiatives are considered mandatory because if one wants to deliver dairy products to these companies (e.g. Sainsbury's [139], Tesco [140, 141], Ben&Jerry's [135,136]) their regulations regarding dairy products and agriculture must be met, thus forcing the farmers to adopt and follow the respective initiative. Some initiatives will also likely become mandatory by social pressure and pressure from other companies (e.g. the Japanese labelling system [97] will be used by almost all companies even though it is not mandatory by laws).

From the international organization for standardization (ISO), several standards are available or under development which focus especially on greenhouse gases. Existing standards are the ISO 14064 (published 2006) and ISO 14065 (published 2007) norms. ISO 14064 is split up into three parts. Part 1 [98] specifies principles and requirements at organization level concerning the quantification and reporting of GHG emissions and removals. The requirements concerning the design, development, management, reporting and verification for a GHG inventory of an organization are specified. Part 2 [99] concerns "the project level for quantification, monitoring and reporting of GHG emission reductions or removal enhancements". Therefore it specifies principles and requirements and offers guidance. Part 2 includes the requirements for the planning of a GHG project, the identification and selection of the relevant GHG sources, sinks and reservoirs which are relevant for the project and baseline scenario as well as the requirements for the monitoring, quantifying, documenting and reporting of the GHG project performance and the management of the data quality. Part 3 of ISO 14064 [100] covers "specifications with guidance for the validation and verification of greenhouse gas assertions". It provides guidance, principles and requirements for people conducting or managing the validation and/or verification of GHG assertions. It contains specifications for the requirements of the selection of GHG validators/verifiers, the establishing of the level of assurance, objectives, criteria and scope and for the determination of the validation/verification approach when assessing GHG data, information, information systems and controls. It also specifies requirements for evaluating GHG assertions and preparing validation/verification statements.

ISO 14065 [101] has been published in 2007 and covers the "requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition". This standard is specifying the principles for bodies performing validation or verifications of GHG assertions. This standard is GHG program neutral. "If a GHG programme is applicable, the requirements of that GHG programme are additional to the requirements of ISO 14065:2007".

A new document under development (ISO/WD 14066) [102] covers the "competency requirements for greenhouse gas validators and verifiers document".

The ISO is working on a carbon footprint standard that will most likely be available within a time frame of 2 to 3 years.

ISO, the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) have announced in December 2007 that they will work together to promote their GHG accounting and reporting standards and they have signed a memorandum of understanding. By working together it will be possible to better deal with technical issues [102, 103].

Country	Name	Takes effect in	Aspects covered				
			GHG	Energy	Water	Biodiversity	Human/ animal health
UK	PAS 2050	September/October 2008	X				
UK	Milk roadmap of the Dairy Supply chain forum	May 2008	X	X	X	X	
UK	Plan "A" (Marks & Spencers)	Since 2007	X	X	X		X
UK	Tesco Sustainable Dairy Project	Since 2007	X		X		X
UK	Sainsbury's dairy development group initiatives	Since 2006	X				X
UK	Sustainable consumption Institute (SCI)	Since 2007	X				
Japan	Japanese guidelines on Carbon Footprinting	Around April 2009	X				
New Zealand	NZ GHG Footprinting Strategy	Mandatory reporting starting 2011	X				
New Zealand	Pastoral GHG research Consortium	Since 2002	X				
New Zealand	Dairy Industry Strategy for Sustainable Environmental Management	Since 2006	X	X			
USA	US EPA GHG registry	Final rule June 2009	X				
USA	Food Alliance	Since 1997			X		X/X
USA	Sustainability initiative of Wal Mart	Since 2007, more aspects developed	X	X	X		
USA	AgSTAR	Since 1994	X				
USA/Europe	Dairy Stewardship alliance, Caring Dairy Ben&Jerry's	Since 2003		X	X	X	X/X
EU	Environmental improvement of products (IMPRO)	Research since 2006, policy implications follow	X	X			
Europe	GLOBAL G.A.P.	Since 1997			X	X	X/X
Germany	Product Carbon footprint	Preliminary statements: end of 2008, on this basis a continuation is discussed	X				
France	Le grenelle environnement	Since October 2007, label in 2011	X	X	X	X	X
France	Bilan carbone	Since 2002, updated regularly	X				
Various	Organic lables (e.g. Bio Suisse, ECOCERT, QCS, USDA organic, Bio -Siegel)	Different, starting from 70s			X	X	X
-	WRI/WBCSD GHG protocol	June 2008	X				
-	Carbon disclosure project (for supply chain emission disclosure)	Since 2007 for supply chain emission disclosure	X				
-	Sustainable Agriculture Initiative	Since 2002		X	X	X	X
Netherlands	The Sustainable Dairy Chain	July 2008	X	X	X	X	X

Figure 8.1: Characterization of some initiatives and labels and link with the dairy sector. The third column shows when the initiative has been established or will be established. Green means it is already established, orange that i twill be finally established in about two years (or shorter time period) and red means that it takes longer until the initiative is finally established. There are more aspects that are covered by some of the initiatives, but those listed here are considered the most important ones.

Country	Name	stage						mandatory by			life cycle phase					
		wellest	new	pilot phase	research Phase	label	voluntary	law	retailer company	(social) pressure	Farm	Transfor-mation	Packaging	Delivery	Use	End-of-life
UK	PAS 2050				X		X				X	X	X	X	X	X
UK	Milk roadmap of the Dairy Supply chain forum		X				X	X			X	X	X	X		
UK	Plan "A" (Marks & Spencers)	X				X			X			X	X	X		X
UK	Tesco Sustainable Dairy Project			X					X		X					
UK	Sainsbury's dairy develop-ment group initiatives		X			X			X		X					
UK	Sustainable consumption Institute (SCI)		X				X				X	X	X	X	X	X
Japan	Japanese guidelines on Carbon Footprinting			X		X				X	X	X	X	X	X	X
New Zealand	NZ GHG Footprinting Strategy			X				X			X	X	X	X	X	X
New Zealand	Pastoral GHG research Consortium				X		X				X					
New Zealand	Dairy Industry Strategy for Sustainable Environmental Management	X					X				X					
USA	US EPA GHG registry				X			X			X	X	X	X	X	X
USA	Food Alliance	X				X	X				X					
USA	Sustainability initiative of Wal Mart		X			X			X/X			X	X	X		X
USA	AgSTAR	X				X	X				X					
USA/Europe	Dairy Stewardship alliance, Caring Dairy Ben&Jerry's	X							X		X					
EU	Environmental improvement of products (IMPRO)				X			X/X			X	X	X	X	X	X
Europe	GLOBAL G.A.P.	X					X				X					
Germany	Product Carbon footprint			X		X	X				X	X	X	X	X	X
France	Le grenelle environnement		X			X		X/X		X/X	X	X	X	X	X	X
France	Bilan carbone	X					X					X	X	X	X	X
Various	Organic lables (e.g. Bio Suisse, ECOCERT, QCS, USDA organic, Bio -Siegel)	X				X	X				X	X				
-	WRI/WBCSD GHG protocol		X				X					X	X	X	X	X
-	Carbon disclosure project (for supply chain emission disclosure)		X				X					X				
-	Sustainable Agriculture Initiative	X					X				X					
Netherlands	The Sustainable Dairy Chain				X		X				X	X				

Figure 8.2: Characterization of some initiatives and labels and link with the life cycle phases. In the label green denotes existing labels, blue planned labels. In the voluntary and mandatory columns dark green signifies that it already is mandatory (voluntary), orange means that it will probably become mandatory in the next 2 years and red that it will become mandatory only after two years or longer or the moment is not clear yet. In the life cycle phases those are yellow which are more importantly covered by this initiative, violet the less important phases. Life cycle phases which are not or barely covered do not have a cross.

Some initiatives like the Caring Dairy initiative [137] or the Tesco Sustainable dairy project [140, 141] focus uniquely on the dairy sector and dairy products. All organic labels take an approach which considers the whole agricultural sector. There are also some like PAS 2050 [129, 130] or the "Grenelle Environnement"[117] which adopt a broader focus. They include dairy products and agriculture but focus also on many other areas (e.g. in the "Grenelle environnement" one issue is building energy efficiency). Two initiatives shown here (the carbon disclosure project [105] and the WRI/WBCSD GHG protocol [106]) do not show any clear link to the dairy sector. Regarding the category "mandatory" and "voluntary" respectively it has to be noted, that there can be changes. Some initiatives, which are still being researched or are in their pilot stage are not yet declared mandatory but this might eventually change (e.g. IMPRO [126, 127]). Some others might become mandatory because the pressure from consumers for environmental friendly or e.g. organic dairy products increases. This might then lead to a request of retailers to producers to adopt e.g. an organic label in order to be able to still deliver their products. So far this is however not the case.

Those initiatives which are thought to be among the most important are summarized below. There are others that could be judged as equally or even more important initiatives, which will have an influence on dairy products and their life cycle. After each summary there is a coloured box with influences and on whom the initiative predominantly focuses. For initiatives which will become mandatory by law the boxes are red, for those that will be made mandatory by a retailer the boxes are blue and for the voluntary ones the boxes are green.

8.1. New Zealand Greenhouse Gases Footprint strategy (New Zealand)

This strategy was developed by the Ministry for Agriculture and Forestry in partnership with the primary industrial sectors in 2007 [107, 108, 109]. The goal of this strategy is to enable the primary industries to operate with credibility in markets and to use internationally recognized, transparent and validated GHG footprinting methodologies. An outcome of the whole strategy should also be that the primary producers measure and improve their GHG performance.

The strategy involves work in two main areas: international engagement (aimed at positioning New Zealand at the forefront of international work around GHG footprinting of primary products) and sector-led initiatives to establish GHG footprints for primary sector supply chains. The latter approach aims to facilitate sectors to measure, manage and possibly also mitigate GHG emissions across the supply chain. One of the 7 projects of the first funding round was the dairy industry.

Under the plan of action of the Ministry for Agriculture and Forestry for sustainable land management and climate change the GHG footprinting strategy is placed under the second pillar: reducing emissions and enhancing sinks. It has been stated that from 1 January 2013 all agricultural emissions would be introduced into the New Zealand Emission Trading Scheme (ETS) and monitoring and reporting of agricultural GHG emissions would be mandatory. The new government (in place since November 2008) is reviewing the proposed ETS legislation, hence the timeframes may change [110]. At the moment, the monitoring and reporting are purely voluntary prior to the introduction of an ETS.

This is an initiative which will result **in mandatory regulations** for the dairy sector regarding the problem of the **GHG emissions.**

- Targeted at: **primary sector supply chain.**
- Constraints and influences: **mandatory GHG reporting and monitoring starting in 2011 for the primary sector.**

8.2. US EPA GHG registry (USA)

The "Clean Air Act" (CAA) enables the US Environmental Protection Agency (EPA) to establish a rule for mandatory GHG emission reporting [111, 112] (for CO_2, CH_4, N_2O, HFC, PFC and SF_6). This reporting of GHG emissions "above appropriate thresholds" applies to all sectors of the economy. A draft rule should be established by the end of September 2008 and the final rule will be ready in June 2009. The objectives of the program are to collect comprehensive and accurate data relevant to future climate policy decisions, including potential future regulations under the Clean Air Act. EPA will build on existing approaches to create this registry.

During the rulemaking, advance notices are being published and other departments can provide their viewpoints.

In the draft rule [113], EPA contemplates regulating agricultural GHG emissions under the three primary CAA programs—National Ambient Air Quality Standards ("NAAQS"), New Source Performance Standards ("NSPS"), or Hazardous Air Pollutant ("HAP") standards. It is the view of the Department of Agriculture (USDA) that these programs were not designed and are therefore not suited for regulating GHG emissions from agricultural sources. USDA claims that the regulatory burden would be too high for many farmers. It is also suspected that even relatively small farmers (e.g. dairy facilities with more than 25 cows or farms with over 500 acres of corn) would need to get a so-called Title V permit. This permit is subject to a public notice and comment period and contains detailed requirements regarding emission estimations, monitoring, reporting, and record keeping.

However, as no final rule is yet decided upon, the exact requirements regarding GHG reporting and monitoring for the agricultural sector are still unclear.

This is an initiative which will result in **mandatory regulations** for the dairy sector regarding the problem of the **GHG emissions.**

- Targeted at: **all sectors of the economy, i.e. also dairies transporters etc. Probably also agriculture (farmers) but no final rule yet.**
- Constraints and influences: **mandatory GHG reporting for all sectors, also for potential future legislation.**

8.3. Milk Roadmap of the dairy supply chain forum (UK)

The Department for Environment, Food and Rural Affairs (Defra) is producing 10 pilot roadmaps of which the Milk Roadmap was the first to be released in May 2008 [115]. This Roadmap was produced by the Dairy Supply Chain Forum's Sustainable Consumption & Production Taskforce [114]. Although it is for England only, much of the research quoted and used in the Milk Roadmap could apply to the UK as whole. It is the first stage of a comprehensive action plan, helping the dairy sector to address the environmental footprint for production and consumption of liquid milk. The Roadmap does not consider alterations to the size of the dairy sector.

Defra intends its roadmap's to be initiatives that identify the environmental impacts of a specific product throughout the supply chain [116] and then set short, medium and long term targets for reducing that product's environmental footprint. The targets are focused on producers (farmers), processors and retailers (supermarkets) of milk. Short-term targets (until 2010) for producers are, for example, the entering of 50% of farmland into the Environmental Stewardship scheme, 5-15% decrease in water usage per liter of milk or that 95% of farms will have a manure management plan. In the medium term (until 2015), example targets include that 65% of farms should be entered into the environmental stewardship scheme and an example long-term goal (until 2020) is the reduction of GHG by 20-30% on farms compared to 1990. Targets are also formulated for processors and retailers, although sometimes not so clearly as for producers.

The Roadmap states that there are different incentives for producers to adopt an environmental initiative, e.g. as a response to consumer demands (through retailers), efficiency and monetary gains through environmental improvements but also regulatory approaches have an important part to play. Also the reform of the CAP in 2003, which removed any incentive for farmers to produce for subsidies only, can be seen as incentive to close unprofitable enterprises. Also Environmental Regulation Environmental regulations are driving changes in practice. Proposed changes to the Nitrates Action Plan, the Water Framework Directive and Climate Change and air quality legislation impact on the dairy sector. All these factors and more will influence the implementation of the Roadmap.

The scientific tools for quantifying the various impacts in the milk supply chain are still under development in some areas, such as the PAS 2050 method which is being developed by BSI British Standards, the Carbon Trust and Defra (see chapter 8.7).

This is an initiative which will result **in different short-, medium-and long-term goals** for the dairy sector regarding the problems of the **GHG emissions, energy, water and biodiversity** etc. associated with **liquid milk.**

- Targeted at: **Producers (farmers), processors and retailers.**
- Constraints and influences: **No alteration of the size of the dairy sector is considered. Changes in environmental legislation, subsidy schemes etc. will influence the implementation and adoption of the different methods for reaching the goals but also voluntary participation.**

8.4. "Le Grenelle environnement" (France)

This initiative [117] consists of various themes targeting more sustainable development [118]:

- Climate change [119,120]
- Biodiversity and natural resources [121]
- Environment and health
- Production and consumption [122]
- Governance and education
- Competitiveness and work
- GMO
- Wastes

For each theme, working groups, consisting of persons from the government, local authorities, NGOs, employers and employees, had to decide upon concrete and quantifiable measures by October 2007.

The different themes have different primary measures. The dairy sector will probably be most influenced by the production and consumption theme which deals with agriculture and in the climate change theme which deals with promoting more adapted strategies and methods, but also in the other themes in which measures that might have an influence on the dairy sector can be found. For example, an adapted and low-emission energy generation is part of the energy reduction section. Farms should be made energetically autonomous, by enhancing the energetic production capacity of farms. Protection from chemical pollution (diffuse pollution from farms, prohibition of risky fertilizers) influences the agricultural and therefore also the dairy sector.

There is a component on "diversified, productive and sustainable agriculture", one goal of which is to have 20% organically produced products for communal feeding in 2012 and 20% of the agricultural land should be managed organically in 2020. There is an introduction of a voluntary environmental certification scheme in 2008, with the goal of having certified 50% of the farms by 2012 (with the help of incentives, aid for young farmers etc.). Under the theme of establishing an "ecological democracy" [123], the education of farmers regarding sustainability and biodiversity is targeted to be enhanced (by 2012 20% of farmers should have attended such an education).

Also all companies with more than 50 persons have to establish a carbon balance.

A mandatory label will be part of the "grenelle environnement", labelling some 90'000 products, but it has not been established yet and is in preparation. There will be about 17 different product categories with specific rules and one of these categories will deal with edibles. The specific rules for each category have not been defined yet, but it will for sure take on a broader approach, not only covering GHG.

The label will probably be launched in 2011.

To reach the goals of the "grenelle environnement" there are various incentives. Some are financial incentives like bonuses or tax relief if certain measures are taken, while others are prohibitions, regulatory guidelines or a mandatory label. Education can be seen as an additional incentive.

This is an initiative which will result **in mandatory regulations and labeling** for the dairy sector regarding the problems of the **GHG emissions, biodiversity, health, energy, water etc.**

- Targeted at: **Producers, transporters, processors, retailers etc.; very broad focus.**
- Constraints and influences: **mandatory standards (e.g. for buildings), mandatory Carbon balance for companies with more than 50 people, mandatory label starting in 2011, etc.**

8.5. Pastoral Greenhouse Gas Research Consortium (PGgRC) (New Zealand)

This consortium started its research in 2002 and is still ongoing [124]. The chair of this consortium is held by Fonterra (dairy industry), and other members include AGResearch, DairyNZ, Lincoln University, the Ministry of Agriculture, the Foundation for Research, Science and Technology, Meat&Wool New Zealand, PGG Wrightson, FRST Research, NIWA.

The aim of this consortium is to find ways to provide New Zealand livestock farmers with the knowledge and tools to mitigate greenhouse gas emissions from the agricultural sector. The goal is to decrease the total agricultural emissions of greenhouse gases by 10% per unit of output in 2013 compared to 2004 and to decrease ruminant methane and nitrous oxide emissions by 20% in 2012.

According to the Consortium, none of the options to reduce GHGs they have researched is a simple, universally applicable mitigation technology. However, if taken as a collective and widely adopted, it is thought that the agricultural emissions of New Zealand will at a minimum be stabilized.

While the ultimate goal is a reduction in methane production per individual animal; the immediate goal is to reduce the amount of methane produced per unit of production (for example per kg of milk or meat).

Research has been done on methanogene genome, rumen microbes, vaccination, diet manipulation, forage mixes, variation of animals, nitrification inhibitors, development of soil management guidelines and more [125].

As all these research subjects aim to reduce the GHG emissions of the livestock, their findings might be helpful to reach goals of GHG emission reductions on dairy farms in various countries. None are yet mandatory and there is also no concrete project to systematically implement the findings. Still these findings may be important to assist in combating climate change and other environmental problems. There are also several other research facilities (for example in the United States) attempting to address the environmental problems of agriculture and livestock (cows especially) and attention should definitely be paid to their findings.

This is an initiative which will not result itself in any mandat ory regulations for the dairy sector regarding the problem of the **GHG emissions.**

- Targeted at: **livestock farmers.**
- Constraints and influences: **different influences, depending on the implementation of the different (voluntary) options e.g. vaccination or diet changes. Some of these options may be adopted to reduce the GHG emissions in view of the mandatory New Zealand GHG reporting strategy.**

8.6. Environmental improvement of products (IMPRO) (EU)

Research on the potential for environmental improvement of products started in 2006. It is done on behalf of the European Union [127] for the European Commission's Integrated Product Policy framework. The research is carried out by the Joint Research Centre (JRC) [126] and the Institute for Prospective Technological Studies. A previous study (EIPRO) that was coordinated by the JRC as well showed that food and drinks are responsible for 20-30% of the environmental impact of private consumption in the EU. Among these food and drinks meat and dairy products contributed most to the emissions.

Recently the report on dairy and meat products has been released [128]. It focuses on three main areas for improvement:

- household improvements (mainly to reduce food wastage and car usage for shopping)
- agricultural improvements (mainly to reduce water and air emissions, in particular nitrate, ammonia and methane and to reduce land requirements)
- power savings (in farming, retail, food industry, catering and for household appliances).

The improvement options include: Planting cash crops during winter (to reduce nitrate leaching, N_2O and ammonia emissions), improving growing practices and intensification of cereal production where yields are low today (to reduce land use and ammonia emissions), optimizing protein feeding in pig and dairy farming (to reduce ammonia emissions and nitrate leaching), liquid manure pH reduction (to reduce ammonia emissions), tightening the rules on manure application (to reduce nitrate leaching and N_2O emissions), copper reduction in dairy cattle and pig diets (to reduce copper emissions), methane-reducing diets for dairy cattle (to reduce methane emissions), biogasification of manure from dairy cows and pigs (to reduce methane and N_2O emissions), home delivery of groceries (to reduce GHG and other air emissions related to car driving), ensuring new cold appliances are only A+ or A++ (to reduce electricity consumption), power saving in farming, food industry, retail and catering (to reduce electricity consumption) and household meal planning tools (to reduce food waste and all environmental interventions throughout the life cycle).

Most of these improvement suggestions are in line with the EU, for example with the strategy paper for reducing methane emissions (EC 1996) and the Directive on the promotion of electricity produced from renewable energy sources (EC 2001a), the Nitrate Directive (EEC 1991) or the Water Framework Directive (EC 2000). It might be possible that a "license-to-operate" is necessary for farms above a certain size (in terms of acreage and animal units).

Two specific measures that are expected to influence farming practice and environmental issues further in the near future are the rural development plan and the single payment scheme of the EU. In the third phase policy implications will be derived.

This is an initiative which will result in different improvement options for the dairy sector regarding the problem of the **GHG emissions, energy and human health.**

- Targeted at: **households, farmers, retailers, food industry (processing), catering.**
- Constraints and influences: **power saving strategies (less energy needs), for farmers tightening rules for nutrient management (manure) etc., large influence by rural development plan and single payment scheme of the EU.**

8.7. PAS 2050 (UK)

This is a new "publicly available specification" (PAS) for the assessment of the lifecycle greenhouse gas (GHG) emissions of goods and services [129, 130, 131, 132, 133, 134]. It is not yet published; the publication date is September/October 2008. The aim of this method is to measure embodied GHG emissions of goods and services to effectively assess the impact of these goods and services on climate change. It is then aimed to improve the services and goods performance related to climate change with this information. GHGs will be measured as completely as possible, however no other environmental impacts are considered. This method will be used, for example in the assessment of GHG emissions in the Milk Roadmap (see chapter 3.3).

It is a methodology to calculate the carbon footprint of all products and services, which might also be used in the establishment of a carbon label. However, it does not mandate a single label. In addition, it could be used for public awareness campaigns (e.g. amount of GHGs of a purchase printed on a shopping receipt). With the draft method Tesco has already released initial carbon labels in April 2008 (although not on dairy products).

The PAS 2050 itself is not mandatory but retailers or companies using it could make the reporting of GHG emissions mandatory and may in a next step try to lower the emissions. As the PAS 2050 is applicable to all goods and services there is a very clear link to the dairy sector.

This is an initiative which will result **in no mandatory regulations** for the dairy sector regarding the problem of the **GHG emissions.**

- Targeted at: **all stakeholders offering products or services (i.e. all actors involved in the dairy sector).**
- Constraints and influences: **Shows the whole carbon footprint of a product or service. When this method shall be applied data is needed and this has to be collected. Otherwise no consequences, just shows the carbon footprint, taking measures is then up to the user itself. PAS2050 is just analyzing the product/service.**

8.8. Dairy Stewardship Alliance (USA) and Caring Dairy (Europe)

These are the initiatives of Ben&Jerry's in the United States [135,136] and in Europe [137, 138]. Although they are not mandatory from a legal point of view, farmers who deliver dairy products (milk, cream) to Ben&Jerry's have to work together with the company on these initiatives. In the USA there is collaboration with the University of Vermont's Center for Sustainable Agriculture, the St. Albans Cooperative Creamery and the State of Vermont Agency of Agriculture for the Dairy Stewardship Alliance, in Europe the members of the Caring Dairy initiative besides Ben&Jerry's are Cono cheese makers, WWF, University of Wageningen and the Netherlands Society of Nature. Both initiatives are similar in that they focus on a rather wide variety of indicators, which is quite remarkable. The Dairy Stewardship Alliance focuses on Animal Husbandry, Biodiversity, Community Health, Energy, Farm Financials, Nutrient Management, Pest Management, Soil Health and Water Management. Caring Dairy initiative takes into account soil fertility & soil health, soil loss, nutrients, pest management, biodiversity, farm economics value chain, energy, water, social human capital, impact on local economy, and animal welfare.

This is an initiative which will result **in mandatory regulations** for the dairy sector regarding **various environmental problems.**

- Targeted at: **farmers delivering milk and cream to Ben&Jerry's.**
- Constraints and influences: **The aspects in the programmes have to be met in a continuous improvement.**

8.9. Sainsbury's dairy development group initiatives (UK)

This group has a variety of initiatives, starting from 2007 [139]. The aims of these initiatives are to enhance the sustainable dairy farming while also increasing the productivity of the group and to reduce the GHG emissions by 10% annually, over the next 3 years. To reach these aims the SDDG (Sainsbury's dairy development group) exclusive standard has been developed, including a carbon footprinting model (the first carbon footprint model in agriculture to be certified by the Carbon Trust).

The farmers delivering milk to Sainsbury's are required to meet the SDDG exclusive standard. This standard covers four areas: Herd Health & Husbandry, Environment & Energy, Collaborative Working and Business Improvement. The first subject area is aimed to enabling members to benefit from more efficient business through better cow health and improved husbandry. A vital part of the health plan for each herd is milk recording. The Environment & Energy area includes measuring the carbon footprint of all farms. Based on this measurement areas for improvement can be identified and, with support, the farmers will be able to make changes.

According to Sainsbury's, this carbon footprinting scheme (with carbon label) is the most in-depth survey of dairy farmers' carbon emissions that has ever been made. The audits on each farm (accomplished by white gold, a part of AB Agri) measured every aspect of the farms operation, including electricity, manure storage, machinery and fuel. The audit will run for three years, with the goal that its recommendations lead to a decrease of emissions of 10% annually. Areas for improvement include better utilization of manure and fertilizer to improve crop nutrition and feed efficiencies, linked to yield and overall stocking rates. The audit is compliant with PAS 2050 (see chapter 8.7) and Sainsbury's thinks it could act as a benchmark for the whole dairy sector. SDDG farms are also required to be members of the Entry Level Stewardship scheme, which rewards farmers for keeping their land in good condition, seen both from an agricultural and environmental perspective. The "Collaborative working" part, the fourth pillar of the exclusive standard, deals with improving returns for cull cows by directly working with the beef producers and processors of Sainsbury's. A second issue in this area of the initiative is to find a solution to the issue (disposal) of black & white bull calves. Business improvements are modelled on the successful Sainsbury's Farm Connection scheme set up for beef and lamb farmers. SDDG provides computers and training for farmer members, depending on individual need.

This is an initiative which will result **in mandatory regulations** for the dairy farmers regarding the problem of the **GHG emissions, energy, animal welfare etc.**

- Targeted at: **dairy farmers delivering products to Sainsbury's.**
- Constraints and influences: **The standard has to be met by the farmers delivering to Sainsbury's . Farmers have to adopt the Entry Level Stewardship scheme.**

8.10. Tesco sustainable Dairy Project (UK)

This initiative was launched in April 2007 [140,141]. Four key areas have been identified: herd health, mobility, calves, and environment. The aim of the herd health pillar is for the farmers to better understand the economic benefits of keeping the herds healthy. To keep levels of lameness to a minimum by routine monitoring of herd mobility by the farmers is the goal of the second pillar, mobility. The calf pillar has for its goal to rear calves and to put them into the beef chain instead of exporting the calves from those cows that supply standard liquid milk to Tesco. Reducing the environmental impact of dairy practices is the aim of the environment pillar. For this pillar Tesco is currently collecting information about the numerous initiatives for good environmental practices that already exist and their farmers are already involved in, such as the entry Level Stewardship (ELS) or similar ones. This is to understand where the group stands in order to take the most appropriate next steps. So far, this Tesco sustainable dairy project (Tsdp) is tested on 12 farms. As soon as it proves viable, Tesco would like all farmers to adopt the recommendations made by this project.

There are three types of milk (Standard, Localchoice and organic) for which the now valid dairy standard is a little bit different. All farms are independently audited annually by the farm assurance scheme to make sure that they comply with the standards, in addition to visits by the Tesco Agriculture Team. After signing a contract with Tesco, the standards become mandatory.

This is an initiative which will result **in mandatory regulations** for the dairy sector regarding the problem of the **GHG emissions, water etc.**

- Targeted at: **farmers, processors.**
- Constraints and influences: **Farmers have to meet the standards of the project when it becomes mandatory (not yet the case, in pilot phase).**

8.11. Organic labels

Organic labels exist in many different countries; however the requirements and directions of most of them are similar. Examples of organic labels include Bio Suisse (Switzerland) [142, 150], QCS (USA) [143, 151], ECOCERT (France) [144], AB (France) [145, 152, 154, 155], USDA organic (USA) [149], Bio-Siegel (Germany) [146, 155, 156, 157], EU organic farming (EU) [147], Aurora organic dairy (USA) [148]. All of these organic labels are voluntary labelling schemes, but of course one has to meet its specifications once having decided to label ones products. The Aurora organic label is the only one interested exclusively in dairy products; all other labels certify organic dairy products in addition to other products. Organic labelling schemes forbid many food additives, synthetic pesticides, fertilizers and GMOs , require a certain percentage of a food product to come from organic farming in order to be labelled organic (e.g. 95% of ingredients from organic farming), demand species-appropriate animal husbandry, require protection of soil, water and air, protect natural resources and biodiversity and reductions in energy use. The requirements may differ slightly from label to label, but basically they all have the same goals. Organic labels can be governmental (e.g. Bio-Siegel in Germany) or private, independent organisations (e.g. Aurora organic dairy).

This is an initiative which will result **in voluntary regulations** for the dairy sector regarding the problem of the **biodiversity, water, health etc.**

- Targeted at: **Producers and processors.**
- Constraints and influences: **The organic production standards have to be met.**

8.12. Sustainable Agriculture initiative (SAI)

This initiative was founded in 2002 by the Groupe Danone, Nestlé and Unilever [158]. It is a food industry based initiative and now has 24 members. The vision of this initiative is to provide a sustainable supply of high-quality and safe agricultural products, meet the food and fiber needs of populations and conserve and possibly improve natural resources. SAI's vision that the farming systems applied enable local communities to maintain their livelihood, safeguard their environment and improve their well-being. To reach these aims, the initiative has defined four key-actions:

- Increasing awareness and communication to relevant audiences of the findings and learning points of the achievements and potential improvements of the sustainable agriculture initiative.
- Manage knowledge of sustainable agricultural practices and share the experiences with others.
- Identify and involve stakeholders in the food chain and interested parties to bring knowledge on sustainable agriculture and local issues.

- Support the implementation of sustainable agricultural practices by evaluating and assessing practices against the principles of sustainable agriculture to explore their potential for contributions.

There are several working groups, among them one for dairy and one for water, which are responsible for pilot projects, general as well as crop-specific frames to assess agricultural practices, guidelines for sustainable agricultural practices and cost/benefit studies on the pilot projects. The dairy working group has been established in 2003 and focuses on the cow and buffalo milk production.

This is an initiative which will result **in voluntary regulations** for the dairy sector regarding the problem of the **GHG emissions.**

- Targeted at: **Producers of cow and buffalo milk.**
- Constraints and influences: **The companies that are part of this initiative try to introduce more sustainable agricultural practices e.g. also training programs for farmers are planned (but not yet started because additional funding is necessary).**

8.13. The Sustainable Dairy Chain (Netherlands)

The Sustainable Dairy Chain is an integral chain initiative of the Dutch Dairy Association (NZO, trade organization of the Dutch dairy processing industry) and the Dutch Horticultural and Agricultural Organization (LTO Nederland, representing the dairy farmers) [159, 160].

It is a private initiative of the sector with a voluntary scheme. The objective is to produce and market natural and healthy dairy products that have been produced in a socially responsible way.

The aim is to convince both consumers and government that:

- dairy products are produced in a socially responsible way and are an essential element of a natural and healthy diet;
- sustainable dairy production and processing can be maintained in the Netherlands in the future.

The initiative aims to work out the objectives of national covenants in relation to environmental, energy and climate policies, like the long term agreement on energy efficiency (MJA3) for the industry and the Agricultural Covenant Clean and Efficient. The Agricultural Covenant Clean and Efficient is an initiative of the Dutch government that set targets for Climate and Energy policy for the total primary sector and processing industry in agriculture. Some goals of this initiative concern the dairy production and aim at a reduction of GHG emissions and an increase of sustainable energy production in this sector. The Sustainable Dairy Chain is closely linked to this Covenant.

The goals have been clustered around three themes, which are dealt with interconnected in order to enhance sustainability in integral approach:

1. *Energy and climate*

The goals are to create an energy-neutral chain of production from raw farm milk to the finished dairy product by 2020. This means that the energy consumed by the Dutch Dairy farming sector and dairy processing in the chain must be generated within the chain itself in a sustainable way. To reach this objective, it is necessary to produce around 25 PJ of renewable energy per year (solar, wind, biomass) within the chain. A parallel goal is to create new insights into how solutions can be found for the other greenhouse gases, with particular emphasis on methane and nitrous oxide.

2. *Focus on the cow*

This theme embraces two main elements: natural grazing and animal welfare. The objective is to let the biological needs of the cow to be leading in the housing, breeding and management of the dairy farm. It is expected to achieve a significant system change by 2015.

3. *Biodiversity*

This focuses on closure mineral loops, eutrophication, sustainable soy production, and the preservation and creation of valuable landscapes. Many already well established initiatives will be brought under this umbrella.

This initiative is based on **voluntary scheme** for the total dairy chain:

- Targeted at: **All dairy chain's stakeholders.**
- Constraints and influences: **The energy goals are to increase the Dutch renewable energy production and decrease the GHG emissions. It is necessary that the various stakeholders work in close collaboration to define their own specific targets in order to meet the energy objectives over the whole dairy chain.**

8.14. Other dairy animals

Of the initiatives that have been reviewed here, some may apply to non-bovine dairy products as well as to dairy products from cows. Among the ones which will also be able to address other parts of the dairy sector (provided enough information and data are available) is PAS 2050 [129, 130]. Others include the WRI/WBCSD GHG protocol[106], "Bilan carbone"[170], the "Grenelle environnement" [117] of France and the US EPA GHG registry [112, 113], which all focus on agriculture and hence also include other livestock and products in addition to cows (beef) and bovine dairy. Also addressing sheep directly (but rather because of the meat than because of the milk) are the New Zealand GHG Footprint Strategy [107], the Pastoral Greenhouse gas Research Consortium [124], Global G.A.P. [171] and the Food Alliance [94]. However, these initiatives do not mention other livestock such as goats or camels. The available organic labels should all be able to label non-bovine dairy products and also the meat of livestock, except the Aurora organic dairy label [148], which seems to focus on dairy cows only. Other initiatives which will explicitly not address other dairy products, are the Dairy Stewardship Alliance [135], Caring Dairy [137], the Tesco sustainable dairy project [140, 141] as well as the Sainsbury's dairy development group initiatives [139].

All the initiatives that were found originate in the industrialized countries, which generally have very few sheep, goats, camels or other animals that could be used for dairy production. Therefore, in most initiatives only dairy cows are mentioned.

There are some projects to introduce and enhance production from dairy goats, e.g. in Kenya and Uganda, promoted by a charity organization called FARM-Africa [161]. However, seeing that goats can also cause a lot of environmental problems (for example, by adding to desertification in areas that are already prone to desertification) it remains questionable if this increased introduction of goats in dry areas is sustainable. In Kenya, FARM-Africa also has a project for Camel husbandry and production. The FAO also sees bright prospects for camel and camel milk [167], not only for providing more food to local people in arid and semi-arid areas but also to give herders (especially nomadic ones) a rich source of income. There is not a clear project, though. FAO has published a book about buffalo production and research [168].

These initiatives will result **in mandatory and voluntary regulations** (depending on the initiative) for the dairy sector regarding different environmental aspects.

- Targeted at: **different stakeholders. For the initiatives which cover bovine dairy products and can be used as well for non-bovine dairy products, the targets remain the same, mostly producers (farmers). Not many initiatives which are only dealing with non-bovine animals have been found, therefore impeding a clear identification of the implications on the dairy sector. But they often also focus predominantly on (small-scale) farmers; retailers are for instance not covered.**
- Constraints and influences: **The implications for stakeholders of the dairy sector of non-bovine animals are the same as for the bovine ones for the initiatives which can be adopted in the same way. The FARM-Africa project and the FAO focus rather on (small-scale) farmers and herders for enabling them directly improved nourishment and income. The implication on the farmers of such projects should precisely be the improvement of livelihoods.**

9. Conclusion

This report shows the spectrum of ***environmental initiatives*** that have a link to the dairy sector. While some focus only on the dairy sector, some focus on agriculture as a whole and others are even broader. One example is for instance a Swiss initiative called Farm-level LCA, which is establishing LCAs on farm level for 300 farms [172]. But data on this approach is scarce and therefore it has not been mentioned further in this report.

The ***broadest initiatives*** presented here are:

- the PAS 2050 [129, 130, 131]
- the "Grenelle environnement » [117]
- the US EPA GHG registry [111,112] (it depends on whether the agricultural sector has to report its emissions or not according to the final rule if there remains a link to the dairy sector)

In addition, the ***aspects*** that are focused on by the initiatives presented here are quite varied.

- Two initiatives (New Zealand GHG Footprinting Strategy [107] and the Pastoral Greenhouse Gas Research Consortium [124]) only take ***Greenhouse Gases*** of the agricultural sector into account.
- The US EPA GHG registry [111, 112] will probably include agriculture but also all other industries and sectors.
- The other initiatives have a ***broader environmental approach***, most of them taking the GHG emissions into account among other environmental concerns.

Of the many other aspects that are covered, the ***water aspect*** is particularly noteworthy because:

- Water is included in many initiatives, at least indirectly, when a life cycle approach is adopted. In that case it is not only the dairy sector but also the transportation, use etc. that will be looked at by the initiative (e.g. PAS 2050 [129, 130, 131]).
- The Milk Roadmap [114] and the two initiatives of Ben&Jerry's [135, 137] explicitly state that water management is also an issue of their program, in the case of the former for production and consumption, for the latter mostly at the farm level.

The New Zealand GHG Footprinting Strategy [107] can surely be judged as one of the most important initiatives because this will be part of the mandatory Plan of Action of the government and the focus on different primary industries like dairy products or forestry will surely help to address the specific emissions more clearly and thoroughly. This could therefore be a good approach for other initiatives as well.

The PAS 2050 [129, 130, 131] seems a promising tool to address the life cycle GHG emissions of goods and services as completely as possible. It will be utilized, for example, by the Milk Roadmap [114] initiative as well as by the Sainsbury's Dairy Development Group initiatives [139] and since it is publicly available it is likely to be a useful tool with a wide basis for application.

Another interesting initiative is the Pastoral Greenhouse Gas Research Consortium [124]. Its aim is to find ways to help the livestock farmers of New Zealand mitigate the GHG emissions from the agricultural sector, e.g. from livestock and manure. Their findings might eventually also be applied in other countries to mitigate the GHG emissions. Attention should be paid to their and other research facilities' findings in order to find innovative and effective ways of minimizing the GHG emissions.

However, it is unfortunate that so many initiatives focus only on GHGs. There is no doubt that GHGs and climate change are among the most pressing environmental issues, but it should not be forgotten that there are also a range of other important environmental impact categories on which to focus, such as ***water***, ***biodiversity*** and **soil conservation.**

Examples of such broader approaches include:

- The Dairy Stewardship Alliance [135] and the Caring Dairy Initiative [137] of Ben&Jerry's in the United States and Europe. They cover, as already mentioned, a wide range of indicators, but do not include GHG emissions directly.
- The EU project "Environmental improvement of products" (IMPRO) [126, 127, 128] also addresses a somewhat broader view of how to environmentally improve dairy and meat products as well, not only focusing on the agricultural sector but also consumers and retailers and not only taking into account GHG. This is an important project, to be closely followed.

The best solution:

- Would be a combination of different initiatives in order to take into account most environmental issues concerning dairy farming and producing.
- Should be sufficiently foresighted to include initiatives and approaches that will become mandatory in the respective country. Initiatives becoming mandatory by law or by companies, and also those which will become nearly mandatory because of (social) pressure, should be adopted. The earlier these can be adopted the more time remains for reaching the goals of the initiative, making a proactive approach advisable.
- Should seek to minimize a wide range of environmental impacts, for instance water use or pollution (for example by following the guidelines "waterwise on the farm" from DairyCo (UK) [96] which is also mentioned in the Milk Roadmap [114]) while focusing on GHG emissions from livestock (for example, with methods from the Pastoral Greenhouse Gas Consortium [124]). It should be possible to cover many more environmental aspects and to improve several of them rather than only the currently prevalent subject of GHG emissions.

Finally, it should be recognized that the important environmental impacts cover a very broad range of areas and they cannot be quickly or easily addressed in total, even though much good work has already been done within the different initiatives. It is not possible to say which initiatives presented here should necessarily be adopted by all stakeholders. This depends on the respective countries which sometimes have specific initiatives of their own and which have different legislation, goals and means for implementing initiatives concerning environmental improvements. In addition, the private sector in the various countries has differing interests and means. Therefore it is also difficult to say in general what the implications on all stakeholders will be. This report may provide guidance to individual stakeholders in selecting the most appropriate initiatives for their context.

10. Appendix

10.1. References

LCA methodology

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10.2. List of all initiatives

Name of initiative	country of initiative	Website
PAS2050: Specification for the assessment of the lifecycle greenhouse gas emissions of goods and services	UK	on BSI Standards: http://www.bsi-global.com/en/Standards-and-Publications/Industry-Sectors/Energy/PAS-2050/ Defra: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15520#RelatedDocuments
WRI/WBCSD GHG Protocol-Product and Supply Chain GHG Accounting & Reporting Standard	-	http://www.ghgprotocol.org/standards/product-and-supply-chain-standard
Product carbon footprint (PCF)	Germany	THEMA1: http://www.thema1.de/
Korean Product based reduction scheme	South Korea	-
EU Ecolabel- the Carbon footprint measuremnt toolkit	EU	MSR: http://www.msr.se/en/About-us/Projects/Project-carbon-footprint/ Pilot toolkit available at: http://www.msr.se/en/About-us/Projects/Project-carbon-footprint/Pilot-toolkit/ EU Ecolabel: www.eco-label.com
Carbon disclosure project (for supply-chain emission disclosure)	independent non-profit organisation	http://www.cdproject.net/
Bilan carbone (ADEME)	France	http://www2.ademe.fr/servlet/KBaseShow?sort=-1-&cid=96&m=3&catid=15730
Japanese guidelines on Carbon Footprinting	Japan	-
international EPD system	non-profit organisation (originally Sweden)	http://www.environdec.com/pageId.asp
New Zealand Greenhouse Gas (GHG) Footprinting Strategy	New Zealand	http://www.maf.govt.nz/climatechange/slm/ghg-strategy/index.htm
US EPA GHG Registry	USA	EPA Site for GHG: http://www.epa.gov/climatechange/emissions/index.html#ggo http://www.epa.gov/climatechange/emissions/ghgrulemaking.html

Name of initiative	country of initiative	Website
Pastoral Greenhouse Gas Research Consortium (PG-gRc)	New Zealand	www.pggrc.co.nz/
Milk roadmap of the dairy supply chain forum	UK	http://www.defra.gov.uk/foodrin/milk/supplychainforum/index.htm
Plan 'A'	UK	http://plana.marksandspencer.com/index.php?action=PublicAboutDisplay
Sustainable Consumption institute (SCI)	UK	http://www.sci.manchester.ac.uk/
Environmental improvement of products (IMPRO)	EU	http://susproc.jrc.ec.europa.eu/activities/IPP/impro.html http://ec.europa.eu/environment/ipp/identifying.htm
Sustainability initiative of Wal Mart	USA	http://walmartstores.com/Sustainability/
Climate Leaders	USA	http://www.epa.gov/climateleaders/index.html
AgSTAR Program	USA	http://www.epa.gov/agstar/index.html
Climate Friendly Farming	USA	http://cff.wsu.edu/Publications/
Climate Change and Northeast Agriculture: Promoting Practical and Profitable Responses	USA	www.climateandfarming.org
J'économise ma Planète	France	http://www.jeconomisemaplanete.fr/actu.php
Dairy Stewardship Alliance	USA	http://www.benjerry.com/our_company/about_us/environment/dsa/
Caring Dairy	Europe	http://www.benjerry.co.uk/caringdairy/index.php
Bio Suisse (Naturaplan)	Switzerland	http://www.coop.ch/naturaplan/default-de.htm http://www.bio-suisse.ch/de/produkte/milch/index.php
GLOBALG.A.P. (G.A.P. = Good Agricultural Practices)	Europe	http://www.globalgap.org/cms/front_content.php?idcat=9
Migros Engagement	Switzerland	http://www.migros.ch/DE/Sortiment/Engagement/Ueber_Engagement/Seiten/Uebersichtsseite.aspx
"CO2 approved by Climatop"	Switzerland	http://www.climatop.ch/
Le grenelle environment	France	http://www.legrenelle-environnement.gouv.fr/grenelle-environnement/
Good environmental choice Australia	Australia	http://www.aela.org.au/introduction.htm
EcoLogo	Canada	http://www.ecologo.org/
blauer Engel(Blue Angel)	Germany	http://www.blauer-engel.de/index.php
Nordic Swan	Sweden, Norway, Iceland, Finland, Denmark	http://www.svanen.nu/Default.aspx?tabName=StartPage
green seal	USA	http://www.greenseal.org/index.cfm
Good environmental choice Sweden Bra Miljöval	Sweden	http://www2.snf.se/bmv/english.cfm
Food Alliance	USA	http://www.foodalliance.org/
QCS	USA	http://www.qcsinfo.org/index.htm

Name of initiative	country of initiative	Website
ECOCERT	France	http://www.ecocert.com
AB (agriculture bilogique)	France	http://www.agencebio.org/default.asp
NF (norme française)	France	AFNOR: http://www.afnor.org/portail.asp?Lang=English NF: http://www.marque-nf.com
USDA organic	USA	http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateA&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPNationalOrganicProgramHome&acct=nop
Bio-Siegel	Germany	http://www.biosiegel.de/index.php
EU organic farming	EU	http://ec.europa.eu/agriculture/organic/splash_en
Greener living	UK	http://www.tesco.com/greenerliving/
Tesco sustainable dairy project	UK	http://www.tescofarming.com/v2/tsdp.asp http://www.tescofarming.com/v2/dairy.asp
Benchmarking water use in dairies	UK	Dairy UK: http://www.dairyuk.org/enviro.html Envirowise: http://www.envirowise.gov.uk/EN740
Aurora organic dairy	USA	http://www.auroraorganic.com/aodweb/site/
Managing farm dairy effluents	New Zealand	http://www.dairynz.co.nz/page/pageid/2145836874
Dairying and clean streams accord	New Zealand	http://www.mfe.govt.nz/issues/land/rural/dairying-accord-may03.pdf
Dairy Industry Strategy for Sustainable Environmental Management	New Zealand	http://www.dairynz.co.nz/page/pageid/2145836756
Sainsbury's dairy development group (SDDG) initaitives	UK	http://www.sddg.co.uk/index.php?p=home
Sustainable Agriculture Initiative	-	http://www.saiplatform.org/

10.3. Acronyms and definitions

GWP	Global Warming Potential
FU	Functional Unit. The FU is a reference to which are normalized the input and output data and the different scenarios assessed in a LCA. The use of a FU enables to make a fair comparison between different products or scenarios.
KWh	kiloWatt•hour = 3'600'000 Joules
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
LCI	Life Cycle Inventory
MJ	MegaJoule = 1'000'000 Joules
Non-renewable	Total energy contained in a fossil fuel (or uranium) at its extraction and primary energy that is not renewed in the natural cycles or extremely slowly.
PDF	Potentially Disappeared Fraction of species
UCTE	Union for the Co-ordination of Transmission of Electricity (www.ucte.org)

10.4. Introduction to LCIA

A life cycle impact assessment methodology (LCIA) is the 3rd step of a life cycle assessment (LCA). It aims at connecting the different elementary flows (emissions, land use, mineral use, etc.) identified in the life cycle inventory (LCI) to different impact categories (human toxicity, global warming, acidification, etc.) allowing a better interpretation of the results by quantifying, classifying and regrouping the impacts of these different elementary flows. The Figure 10.1 presents a schematic view of a LCIA.

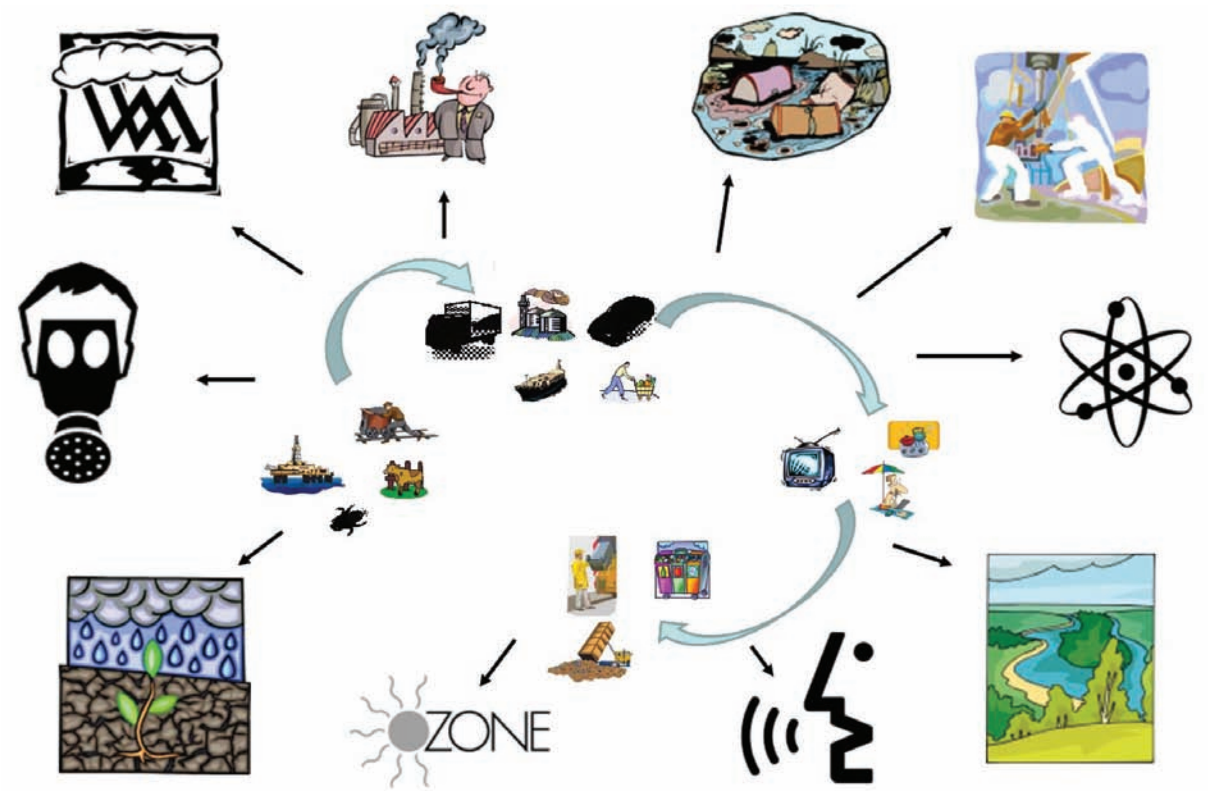

Figure 10.1: Schematic view of a LCIA methodology.

The impact score (S) for a certain impact category is the summation over all substances (or elementary flows) contributing to the specific impact category of the products between the LCI results (E) and respective weighting factors called characterization factors (CF):

$$S = \sum_i E_i * CF_i$$

For example, the impact score on global warming (expressed in kg $CO_{2\text{-eq}}$) from emissions of 4 kg CH_4 and 0.5 kg N_2O, having the respective CF for global warming (GWP500) of 7 and 156 kg $CO_{2\text{-eq}}$/kg is :

$$S = \sum (4\mathrm{kg}_{CH4} * 7\mathrm{kg}_{CO2eq}/\mathrm{kg}_{CH4}) + (0.5\mathrm{kg}_{N2O} * 156\mathrm{kg}_{CO2eq}/\mathrm{kg}_{N2O}) = 28 + 78 = 106\ \mathrm{kg}_{CO2eq}$$

A LCIA methodology provides a list of these CF.

10.4.1. IMPACT 2002+

The LCIA methodology IMPACT 2002+ (v2.1) (Jolliet et al. 2003, Humbert et al. 2008) proposes a combined midpoint/damage-oriented approach. Figure 10.2 shows the overall scheme of the IMPACT 2002+ framework, linking all types of LCI results via 14 midpoint categories (human toxicity, respiratory effects, ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nutrification, aquatic acidification, aquatic eutrophication, land occupation, global warming, non-renewable primary energy, mineral extraction) to 4 damage categories (human health, ecosystem quality, climate change, resources). An arrow symbolizes that a relevant impact pathway is known and quantitatively modelled based on natural science. Impact pathways between midpoint and damage levels that are assumed to exist, but that are not modeled quantitatively due to missing knowledge are represented by dotted arrows. New concepts and methods for the comparative assessment of human toxicity and ecotoxicity (Pennington et al. 2005) were developed for the IMPACT 2002+ methodology. For other categories, methods have been transferred or adapted mainly from the Eco-indicator 99 (Goedkoop and Spriensma 2000) and the CML 2002 (Guinée et al. 2002) methods, from the IPCC list (IPCC 2001), the USEPA ODP list (EPA) and ecoinvent database (Frischknecht et al. 2005, 2007).

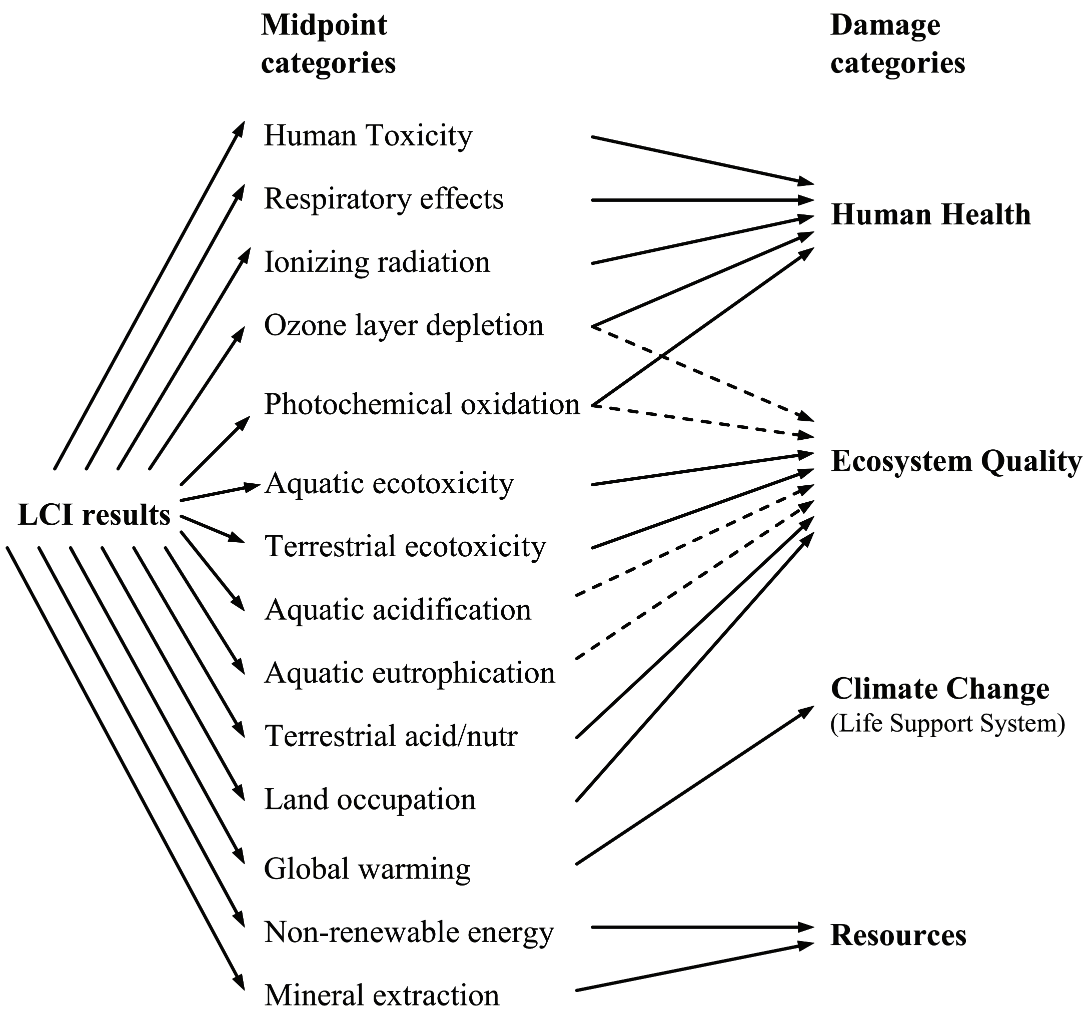

Figure 10.2: Overall scheme of IMPACT 2002+, linking the life cycle inventory results (LCI) and the damage categories, via the midpoint categories (Jolliet et al. 2003).

The following describes the main assessment characteristics for midpoint and damage categories, as well as related normalization factors.

Midpoint categories are:

1. **Human Toxicity** measures the impact on human life related to carcinogenic and non-carcinogenic toxic effects caused by pollutants emitted into the environment and eventually reaching the humans through air inhalation, drinking water and food ingestion. Carcinogenic and non-carcinogenic effects can, in some cases, be represented as two separate indicators.
2. **Respiratory Inorganics** (also called winter smog, or even "London smog") are air pollutants such as fine, primary particles ($PM_{2.5}$) and secondary particles ($PM_{2.5}$ mainly from NO_x, NH_3 and SO_2) that affect human lungs. Heavy industries, electricity and heat production from liquid and solid fuels, as well as road traffic (tailpipes and breaks) are important sources of these pollutants. Farming industry is also an important source of NH_3.
3. **Ionizing Radiation** measures the impact on human life caused by substances emitting ionizing radiation. These substances are mainly released by the nuclear energy sector. Some substances can also be present naturally in important concentration (e.g., radon).
4. **Ozone Layer Depletion** measures the potential for reducing the stratospheric ozone layer (O_3) and thus the increase in UV light reaching the earth. It can then generate impact on human life such as skin cancer and cataracts, and damage terrestrial life and aquatic ecosystems. The pollutants destroying the ozone layer, such as CFCs are emitted by some specific industrial processes, for example those in need, of strong cooling systems.
5. **Photochemical Oxidation** (also called Respiratory Organics) measures the effects on human health (and possibly on crop growth) associated with tropospheric ozone (O_3) formation (also called summer smog, or even "Los Angeles smog"). Pollutants responsible for tropospheric ozone such as NO_x and volatiles organic compounds (VOCs) are mainly emitted by road traffic and industrial activities, as well as from the farming industry and forests.
6. **Aquatic Ecotoxicity** measures the effects on fresh water ecosystems in term of loss of biodiversity caused by toxic emissions (especially heavy metals) emitted into the environment.
7. **Terrestrial Ecotoxicity** measures the effects on terrestrial ecosystems in term of loss of biodiversity caused by toxic emissions (such as heavy metals) emitted into the environment.
8. **Aquatic Acidification** literally refers to processes increasing the acidity in aquatic systems which may lead to declines in fish populations and disappearances of species. Substances causing this effect, such as airborne nitrogen (NO_x and NH_3) and sulfur oxides (SO_x), can be emitted by heavy industries, electricity and heat production from liquid and solid fuels, as well as road traffic (tailpipes) and farming industry.
9. **Aquatic Eutrophication** measures the potential of nutrient enrichment of the aquatic environment, which generates a growth of biomass that pushes this ecosystem population out of balance when decaying. Decrease of dissolved oxygen leads to fish kills and disappearance of bottom fauna. These nutrients are mainly associated with phosphorus and nitrogen compounds in detergents and fertilizers.
10. **Terrestrial Acidification and Nutrification** measures the potential change in nutrient level and acidity in the soil leading to a change of the natural condition for plant growth and competition. A reduction of species is observed with an excess of nutrients and a decrease in terrestrial ecosystem health by soil acidification (effect on biodiversity). Substances causing this effect, such as airborne nitrogen (NO_x and NH_3) and sulfur oxides (SO_x), can be emitted by heavy industries, electricity and heat production from liquid and solid fuels, as well as road traffic (tailpipes) and farming industry.
11. **Land Occupation** measures the reduction of biodiversity caused by the use of land. Agriculture, as well as deforestation, are the main contributors to this category.

12. **Global Warming** covers a range of potential impacts resulting from a change in the global climate. It is the measured heat-trapping effect of a greenhouse gas (GHG) released in the atmosphere. CO_2 emitted by fossil fuel combustion and forest fires is the main GHG. Methane (CH_4) and dinitrogen monoxide (N_2O) emitted from the farming industry are also important sources of GHG.
13. **Primary Non-Renewable Energy Consumption** measures the amount of energy (in MJ or kg crude oil$_{-eq}$) extracted from the earth contained in the fossil energy carrier (coal, oil and natural gas) or uranium ore. These resources are subject to depletion. Electricity, heat and fuel production are the main consumer of fossil fuels and uranium ore.
14. **Mineral Extraction** measures the surplus of energy (in MJ or kg iron$_{-eq}$) associated with the additional effort required to extract minerals from lower concentration ore mines. The concept of surplus energy is based on the assumption that a certain extraction leads to an additional energy requirement for further mining of this resource in the future, caused by lower resource concentrations or other unfavorable characteristics of the remaining reserves.

The indicators of each midpoint impact category have units expressed in kg of substance equivalent that are linked to the following 4 damage indicators (human health, ecosystem quality, climate change and resources depletion).

- Human Health (in DALY). Human toxicity (carcinogenic and non-carcinogenic effects), respiratory effects (inorganics and organics), ionizing radiation, and ozone layer depletion all contribute to damage to human health. The damage is measured in disability adjusted life years (DALY), or number of years of life lost (mortality and morbidity).
- Ecosystems Quality (in PDF·m^2·yr). It measures how far the anthropogenic processes affect the natural development of the occurrence of species within their habitats. The damage can directly be determined as a Potentially Disappeared Fraction of species (PDF) over a certain area (m^2) and during a certain time (yr). It includes the contribution of terrestrial & aquatic ecotoxicity, terrestrial acidification/nitrification, and land occupation. At the current state of knowledge (in IMPACT 2002+ v2.1) aquatic acidification and aquatic eutrophication cannot be linked consistently to PDF·m^2·yr. Thus these two categories are still interpreted at midpoint level.
- Climate Change (in kg CO_{2-eq}). From the authors' point of view, the modeling up to the damage of the impact of climate change on ecosystems quality and human health is not accurate enough to derive reliable damage characterization factors. The interpretation, therefore, directly takes place at midpoint level, which can be interpreted as damage on life support system that deserves protection for their own sake. The global warming is considered as a stand-alone endpoint category with units of kg CO_{2-eq}. The assumed time horizon is 500 years (GWP500) to account for both short-term and long-term effects (as opposed to GWP20 and GWP100) as there is little evidence that global warming effects will decrease in the future.
- Resources Depletion (in MJ). The two midpoint categories contributing to this damage are mineral extraction and primary non-renewable energy consumption.

<table>
<tr><th>LCI coverage</th><th>Midpoint category</th><th>Reference</th><th>Midpoint reference substance</th><th>Damage unit</th><th>Damage unit</th><th>Normalized damage unit</th></tr>
<tr><td>769</td><td>Human toxicity (carcinogens + non-carcinogens)</td><td>IMPACT 2002</td><td>kg chloroethylene$_{\text{-eq}}$</td><td rowspan="5">Human Health</td><td rowspan="5">DALY</td><td rowspan="8">point (=pers·yr)</td></tr>
<tr><td>12</td><td>Respiratory (inorganics)</td><td>Ecoindicator 99</td><td>kg chloroethylene$_{\text{-eq}}$</td></tr>
<tr><td>25</td><td>Ionizing radiations</td><td>Ecoindicator 99</td><td>kg $PM_{2.5\text{-eq}}$</td></tr>
<tr><td>95</td><td>Ozone layer depletion</td><td>USEPA and Ecoindicator 99</td><td>Bq carbon-14$_{\text{-eq}}$</td></tr>
<tr><td>130</td><td>Photochemical oxidation</td><td>Ecoindicator 99</td><td>kg CFC-11$_{\text{-eq}}$</td></tr>
<tr><td>393</td><td>Aquatic ecotoxicity</td><td>IMPACT 2002</td><td>kg ethylene$_{\text{-eq}}$</td><td rowspan="4">Ecosystem Quality</td><td rowspan="4">PDF·m²·yr</td></tr>
<tr><td>393</td><td>Terrestrial ecotoxicity</td><td>IMPACT 2002</td><td>kg triethylene glycol$_{\text{eq}}$ into water</td></tr>
<tr><td>5</td><td>Terrestrial acidification/nutrification</td><td>Ecoindicator 99</td><td>kg triethylene glycol$_{\text{eq}}$ into soil</td></tr>
<tr><td>15</td><td>Land occupation</td><td>Ecoindicator 99</td><td>m² organic arable land</td><td>point (=pers·yr)</td></tr>
<tr><td>10</td><td>Aquatic acidification</td><td>CML 2002</td><td>kg $SO_{2\text{-eq}}$ into air</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>10</td><td>Aquatic eutrophication</td><td>CML 2002</td><td>kg $SO_{2\text{-eq}}$ into air</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>77</td><td>Global warming</td><td>IPCC 2001 (500 yr)</td><td>kg $CO_{2\text{-eq}}$</td><td>Climate Change (life support system)</td><td>kg $CO_{2\text{-eq}}$</td><td rowspan="3">point (=pers·yr)</td></tr>
<tr><td>9</td><td>Non-renewable energy</td><td>Ecoinvent</td><td>MJ or kg crude oil$_{\text{-eq}}$</td><td rowspan="2">Resource</td><td rowspan="2">MJ</td></tr>
<tr><td>20</td><td>Mineral extraction</td><td>Ecoindicator 99</td><td>MJ or kg iron$_{\text{-eq}}$</td></tr>
</table>

Figure 10.3: Number of substances covered, source and units of IMPACT 2002+ (v2.1) (Jolliet et al. 2003, Humbert et al. 2008).

Midpoint category	Damage factor	Unit
Carcinogens	2.80E-6	DALY/kg chloroethylene$_{\text{-eq}}$
Non-carcinogens	2.80E-6	DALY/kg chloroethylene$_{\text{-eq}}$
Respiratory (inorganics)	7.00E-4	DALY/kg $PM_{2.5\text{-eq}}$
Ionizing radiations	2.10E-10	DALY/Bq carbon-14$_{\text{-eq}}$
Ozone layer depletion	1.05E-3	DALY/kg CFC-11$_{\text{-eq}}$
Photochemical oxidation	2.13E-6	DALY/kg ethylene$_{\text{-eq}}$
Aquatic ecotoxicity	5.02E-5	PDF·m²·yr/kg triethylene glycol$_{\text{-eq}}$ into water
Terrestrial ecotoxicity	7.91E-3	PDF·m²·yr/kg triethylene glycol$_{\text{-eq}}$ into soil
Terrestrial acidification/nutrification	1.04	PDF·m²·yr/kg $SO_{2\text{-eq}}$
Aquatic acidification	1	kg $SO_{2\text{-eq}}$/kg $SO_{2\text{-eq}}$
Aquatic eutrophication	1	kg $PO_4^{---}{}_{\text{-eq}}$/kg $PO_4^{---}{}_{\text{-eq}}$
Land occupation	1.09	PDF·m²·yr/m² organic arable land
Global warming	1	kg $CO_{2\text{-eq}}$/kg $CO_{2\text{-eq}}$
Non-renewable primary energy	45.8	MJ/kg crude oil$_{\text{-eq}}$
Mineral extraction	5.10E-2	MJ/kg iron$_{\text{-eq}}$

Figure 10.4: Units of midpoint impact categories and conversion factors between the midpoint categories and the damage categories of IMPACT 2002+ (v2.1) (Jolliet et al. 2003, Humbert et al. 2008).

The normalization is performed by dividing the impact scores by the respective normalization factors (Figure 10.5). A normalization factor represents the total impact of the specific category in Europe during one year divided by the total European population. The total impact of the specific category is the sum of the products between all European emissions and the respective damage factors. The normalized characterization factor is therefore determined by the ratio of the impact per unit of emission divided by the total impact of all substances (or elementary flows in general like land use or resources use) of the specific category, per person per year. The unit of all normalized characterization factors is therefore « $\text{point/unit}_{\text{emission or elementary flow}}$ » = « $\text{pers·yr/unit}_{\text{emission or elementary flow}}$ », i.e. it is the impact caused by a unitarian emission or elementary flow, which is equivalent to the impact generated by the given number of persons during 1 year. Additional details are provided by Humbert et al. (2008).

Damage categories	Normalization factors	Units (point = pers·yr)
Human Health	0.0071	DALY/point
Ecosystems Quality	13’700	PDF.m^2.yr/point
Climate Change	9’950	kg $CO_{2\ eq}$/point
Resources	152’000	MJ/point

Figure 10.5: Normalization factors relative to the four damage categories for Western Europe (Jolliet et al. 2003, Humbert et al. 2008).

ENVIRONMENTAL / ECOLOGICAL IMPACT OF THE DAIRY SECTOR:
LITERATURE REVIEW ON DAIRY PRODUCTS FOR AN INVENTORY OF KEY ISSUES
LIST OF ENVIRONMENTAL INITIATIVES AND INFLUENCES ON THE DAIRY SECTOR

ABSTRACT

Survey commissioned by the IDF with the aims of highlighting the key issues for the dairy sector based on a literature review focused on Life Cycle Assessment (LCA) studies and of giving an overview of initiatives and labels that play a role for the dairy sector and what they imply for the various industry sectors.

Keywords: Carbon, Ecology, Emissions, Environment, Footprint, Gas, GHG, Greenhouse, LCA, Sustainability, Sustainable, Warming

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

" .... Usually double quotes and not single quotes
? ! .... Half-space before and after question marks, and exclamation marks
± .... Half-space before and after
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
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