

Towards a tool for assessing carbon footprints of animal feed

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Project group

On behalf of the Product Board Animal Feed, this project was guided by a project group with representatives from the Dutch Feed industry.

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Summary

The Product Board Animal Feed (Productschap Diervoeder, PDV) wants to develop a dynamic and interactive tool for assessing carbon footprints of animal feed, and make this available to stakeholders in the animal feed sector (a carbon footprint is the sum of attributed greenhouse gas emissions, expressed in carbon dioxide equivalents). The objectives of this tool are twofold: first, to gain insight in the greenhouse gas emissions arising from the production and supply chain of animal feed and from feed utilization; and second, to use the resulting information as a starting point for identifying potential options for reducing these emissions. The tool is not intended for use in the carbon labelling of products. PDV proposed an interactive development route that consists of three phases: Phase 1) inventory of available knowledge and design of an architecture – a ‘blueprint’ – for the calculation tool; Phase 2) development, testing and distribution of the calculation tool; Phase 3) maintenance and further development of the calculation tool. This report is the result of Phase 1. The objectives of Phase 1 were to identify and evaluate relevant knowledge on assessing carbon footprints of animal feed, draw up a strategy for further development and a blueprint for the carbon footprint assessment tool. Inventories and evaluations were done on existing methodologies and data sources for assessing carbon footprints, parallel initiatives similar to the project, and improvement options for reducing greenhouse gas emissions. Subsequently, the functional requirements and possible organizational consequences of developing a carbon footprint assessment tool were analysed. These activities resulted in follow-up conclusions and recommendations for Phase 2.

Inventory and evaluation of methods and data. The inventory and evaluation of relevant knowledge began with an evaluation of the existing standards, guidelines and protocols on carbon footprints of agricultural products. The recently developed PAS2050 protocol and the Dutch Horticulture Protocol were the most important sources. They were also chosen as the basis from which other sources could be explored, where the two protocols provide no solutions for calculating and attributing greenhouse gas emissions from processes or activities specific to the animal feed chain. The life cycle assessment (LCA) standards and literature provided further information for defining certain default methods, based on expectations of most likely acceptance as a standard in the scientific LCA community and in the international animal feed and animal production sectors. Besides the most likely acceptance of standard methods, data availability may also be a reason for using a particular method for assessing the carbon footprint of animal feed. In this study, an inventory was made of the required and available data for developing a carbon footprint calculation tool for animal feed and compiling an extensive set of default data.

Inventory and evaluation of parallel initiatives. This study also includes an inventory of relevant parallel initiatives in other sectors and other countries to identify possible and desirable cooperation partners for Phase 2. This inventory focuses on methodologies for assessing carbon footprints and labelling initiatives for food products.

Inventory of methods for improvement options. Improvement options can be evaluated by comparing the carbon footprints of alternative situations. Some examples are: a) alternative feed compositions with and without certain feed raw material additives, b) differences in production efficiency of crop growing and processing feed raw materials, and c) alternative origins of feed raw materials where production techniques differ. However, conclusions from such analyses should be treated carefully. Proper evaluation of any positive effect of the adoption of the alternative situation requires additional analysis of the accompanying effects of the changes that take place when shifting from one situation to the other. This report gives recommendations on the additional analyses to be done when evaluating improvement options in different situations.

Functional requirements, organizational implementation and maintenance. Potential users were interviewed about what they expect from a carbon footprint calculation tool, what their reasons might be for using the tool, and what type of information they would like to analyse with the tool. Within the technical limitations, an architecture/blueprint for a tool that accommodates most user wishes was drawn up. The 'blueprint' can be regarded as an inspiring and descriptive design for the calculation tool, including a set of functional requirements, a data infrastructure and recommendations for the development route for the tool. Because methods and data for assessing carbon footprints are constantly evolving, the calculation tool should be designed with frequent updates in mind. Recommendations are given on how such updates can be done and the type of organizations that could be involved.

Conclusions and recommendations for Phase 2. The following conclusions and recommendations for Phase 2 were formulated as a result of Phase 1:

1. Methodologically there are no great obstacles to develop a carbon footprint assessment tool for animal feed. However, four issues need to be discussed internationally to gain wider support. These four issues are the different approaches to land use and land use change, economic allocation, system boundaries and improvement options. Phase 2 needs to focus on resolving these issues.
2. Further study on the carbon footprint effects of feed additives is required. Data need to be collected on the production of enzymes, mineral additives and synthetic amino acids.
3. A lot of background data needs to come from crop growers and suppliers of feed materials; so, a great effort is needed to develop a robust and publicly available database. It should be developed in cooperation with suppliers of feed materials.
4. Calculation models and background data are needed to describe the conversion of feed into animal products, methane emissions from enteric fermentation, faeces and urine and nitrous oxide emissions in different animal housing systems. Descriptive models will be sufficient for the first version of the carbon footprint assessment tool. In later versions, more mechanistic model can be included.
5. Development of the tool in Phase 2 should involve several coordinated parallel activities on methodology and database development and the development of the carbon footprint assessment tool.
6. Methodology and database development should be done preferably by a consortium of international organizations to engender broad support for the approach.

I. Introduction

I.1 PDV project: towards a tool for assessing carbon footprints of animal feed

The Product Board Animal Feed (Productschap Diervoeder, PDV) wants to develop a dynamic and interactive tool for assessing carbon footprints¹ of animal feed, and make this available to stakeholders in the animal feed sector. The objectives of this tool are twofold: first, to gain insight in the greenhouse gas emissions arising from the production and supply chain of animal feed and from feed utilization; and second, to use the resulting information as a starting point for identifying potential options for reducing these emissions. The tool is not intended for use in the carbon labelling of products. PDV proposed an interactive development route consisting of three phases:

- Phase 1: Inventory of available knowledge and design of an architecture – a ‘blueprint’ – for the calculation tool
- Phase 2: Development, testing and distribution of the calculation tool
- Phase 3: Maintenance and further development of the calculation tool

This report is the result of Phase 1. The objectives of Phase 1 were to identify and evaluate relevant knowledge on assessing the carbon footprints of animal feed products, and to draw up a strategy for further development and a blueprint for the carbon footprint assessment tool.

This introductory chapter summarizes the activities that were done to meet the objectives. These began with several inventories and evaluations: existing methodologies and data sources for assessing carbon footprints; parallel initiatives similar to the project; and improvement options for reducing greenhouse gas emissions. Then the functional requirements and possible organizational consequences of developing a carbon footprint assessment tool were analysed. These activities resulted in follow-up recommendations for a plan for Phase 2.

Inventory and evaluation of methods and data

The inventory and evaluation of relevant knowledge began with an evaluation of the existing standards, guidelines and protocols on carbon footprints of agricultural products. The recently developed PAS2050 protocol and the Dutch Horticulture Protocol were the most important sources. They were also chosen as the basis from which other sources could be explored where the two protocols provide no solutions for calculating and attributing greenhouse gas emissions from processes or activities specific to the animal feed chains.

The life cycle assessment (LCA) standards and literature provided further information for defining certain default methods, based on expectations of most likely acceptance as a standard in the scientific life cycle assessment community and in the international animal feed and animal production sector. Besides the most likely acceptance of standard methods, data availability may also be a reason for using a particular method when assessing the carbon footprint of animal feed. In this study an inventory was made of the required and available data for developing a carbon footprint calculation tool for animal feed and compiling an extensive set of default data.

Inventory and evaluation of parallel initiatives

¹ Carbon footprints are life cycle assessments of the environmental effects of products due to greenhouse gas emissions (expressed in carbon dioxide equivalents based on values for global warming potential over 100 years, as

This study also includes an inventory of relevant parallel initiatives in other sectors and other countries to identify possible and desirable cooperation partners for Phase 2. This inventory focuses on methodologies for assessing carbon footprints and labelling initiatives for food products.

Inventory of methods for improvement options

Improvement options can be evaluated by comparing the carbon footprints of alternative situations. Some examples are: a) alternative feed compositions with and without certain feed raw material additives; b) differences in production efficiency of crop growing and processing feed raw materials; and c) alternative origins of feed raw materials where production techniques differ. However, conclusions from such analyses should be treated carefully. Proper evaluation of any positive effect of the adoption of an alternative situation requires additional analysis of the accompanying effects of the changes that take place when shifting from one situation to another. This report gives recommendations on the additional analyses to be done when evaluating improvement options in different situations.

Functional requirements, organizational implementation and maintenance

Potential users were interviewed about what they expect from a carbon footprint calculation tool, what their reasons might be for using the tool, and what type of information they would like the tool to analyse. Within the technical limitations, an architecture/blueprint for such a tool was drawn up that accommodates most user wishes. This 'blueprint' can be regarded as an inspiring and descriptive design for the calculation tool, including a set of functional requirements, a data infrastructure and recommendations for the development route for the tool. Because methods and data for assessing carbon footprints are constantly evolving, the calculation tool should be designed with frequent updates in mind. Recommendations are given on how such updates can be done and the type of organizations that could be involved.

Plan for Phase 2

The plan for Phase 2 consists of the blueprint for the calculation tool. Depending on the methods to be used, potential organizations for cooperation in the development of the tool were contacted and consulted. This report presents some components and recommendations for the plan.

1.2 Outline of this document

Chapter 2 gives a summary of greenhouse gas emissions from Dutch animal feed production and animal feed utilization, and specifies greenhouse gas emissions attributed to feeding animals in the main livestock categories in the Netherlands.

The methodological framework and complexities of developing a carbon footprint assessment method are explained in Chapter 3. Besides methods for calculating carbon footprints and evaluating improvement options (reducing greenhouse gas emissions), it addresses the issue of dealing with uncertainty arising from the dynamics in methodology development. Chapter 4 looks in more detail at typical methodological issues in calculating the carbon footprint of animal feed. The main issues are allocating greenhouse gas emissions to co-products, greenhouse gas emissions related to land use and land use change (LULUC), and calculating the greenhouse gas emissions from animal feed utilization (Ponsioen and Blonk 2009).

Calculating the effects of improvements requires special attention in cases where animal feed optimizations lead to a shift in demand for raw materials that are co-products of a production process. Chapter 5 treats methods for assessing the effects of shifting demands and methodological issues related

to improvement options, with suggestions on how to incorporate improvement options in a carbon footprint assessment tool.

Animal feed producers and formulators (processors) have limited access to the data needed for calculating greenhouse gas emissions from the production and utilization of feed. Selecting, acquiring and maintaining background data is therefore of major importance. Chapter 6 explores data quality criteria, data sources and the data gathering and maintenance process.

Chapter 7 presents the results of an inventory of initiatives on this topic in several countries. Recommendations are made for the further development of the PDV carbon footprint assessment tool.

Parallel to the exploration of methodological issues, a demonstration carbon footprint assessment tool was presented in several sessions as part of the development of a blueprint and recommendations for its further development in Phase 2. Chapter 8 outlines the blueprint, explores the required functionality and possible development routes for the PDV carbon footprint assessment tool, and gives recommendations for the follow-up process in Phase 2.

2. Introduction to assessing carbon footprints of animal feed

2.1 The production and use of animal feed

A carbon footprint of animal feed describes all the relevant steps, activities and processes in the production and supply chains that significantly contribute to greenhouse gas emissions. Figure 2.1 summarizes the animal feed production chain, including its utilization. Feed production is defined here as all activities and processes involved in producing feed and transporting it to the animal’s mouth. Feed utilization refers to all activities and processes related to the digestion of feed and the destination of undigested feed components that leave the animal.

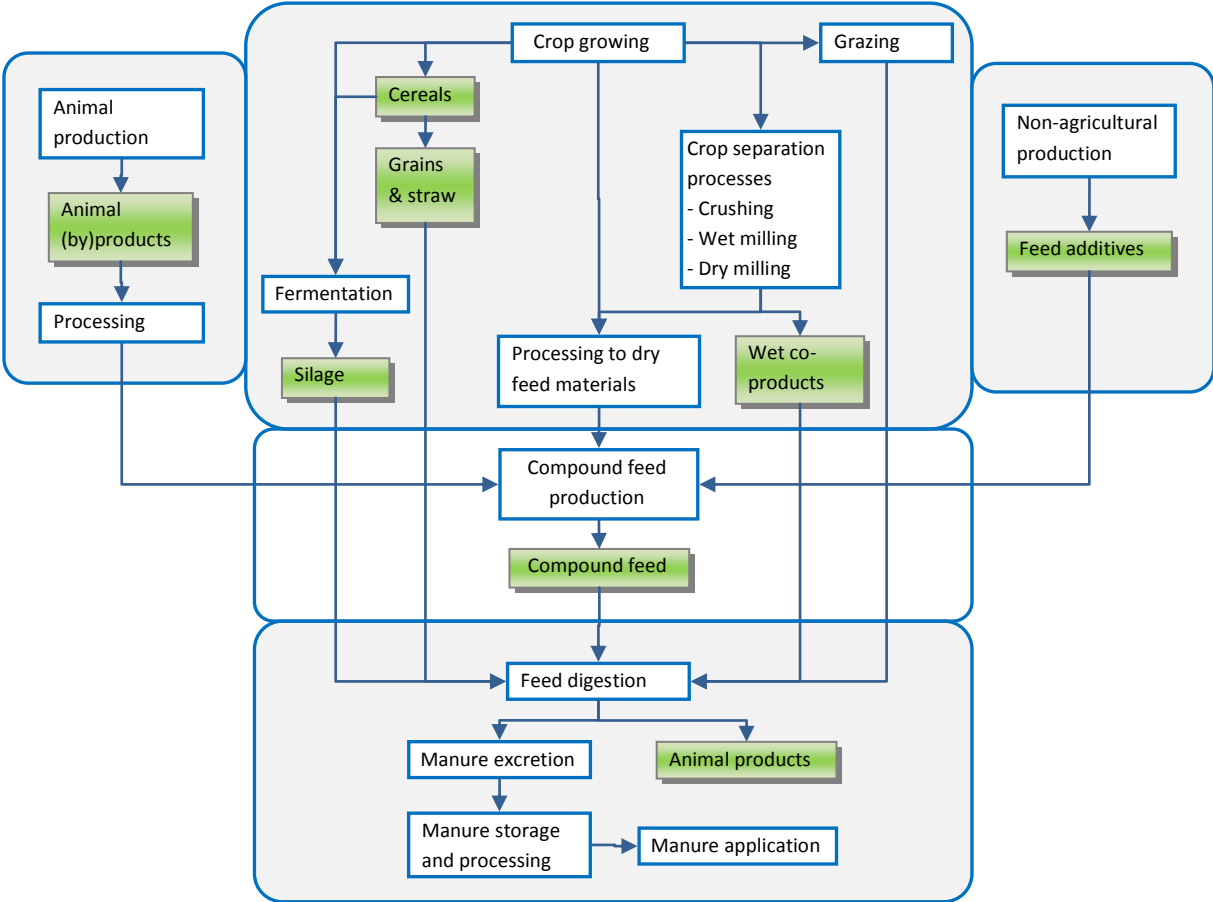


Figure 2.1 Summary of the production chain of animal feed, including its utilization (processes in blue-lined boxes and products in green boxes)

Most feed raw materials are vegetative and their production starts with crop growing. Crop products follow different routes to the animals. The shortest routes are through grazing, direct feeding of cereal grains, straw and hay. Some crops, such as grass and silage maize, are fed as silage. Some crop products are dried, toasted or otherwise processed without generation of co-products, examples being tapioca meal from cassava tubers and toasted beans. Other crop products are processed into several co-products that are used for making feed, food and non-food products. The most important co-products used for animal feed are from dry and wet milling of wheat and maize grains, and vegetable oil extraction from rapeseed, oil palm and soybean. Most of these are processed into feed concentrates, but some products are directly fed to animals without drying and mixing with other feedstuffs. To some extent, the introduction of large-

scale ethanol production in the USA. and Europe for use as a bio-fuel has resulted in an increased supply of protein-rich co-products, such as distillers' grains with solubles (DGS), which can be used in its dry or wet form.

There are two other important sources of raw materials for feed concentrates: animal production and non-agricultural production (feed additives). Animal (co)products used in animal feed are mainly dairy products, pig fat, blood plasma and fish oil. Feed additives are for example synthetic amino acids, organic acids, vitamins and enzymes.

The greenhouse gas emissions from the utilization of feed differs widely between animal species due to differences in digestive systems, feed composition and properties, enteric fermentation resulting in methane emission and nitrogen excretion resulting in nitrous oxide emission. Greenhouse gas emissions are also influenced by several factors such as temperature and type of animal housing systems. Manure storage and utilization for crop production can emit considerable volumes of greenhouse gases, depending mainly on the type of storage and method of application. These emissions can be allocated partly to feed use and partly to manure use in cropping.

2.2 Use of raw materials for animal feed in the Netherlands

More than half of the diet fed to animals in the Dutch animal production sector consists of feed concentrates. The remainder consists mainly of silage for cows and sheep and small amounts of wet co-products for cows and sheep (about 4% of the total ration) and more for pigs (about 11% of the total ration). The share of co-products in feed concentrates decreased from about 70% to 40% between 1994 and 2007 (Vellinga et al. 2009).

Figure 2.2 shows the breakdown of apparent feed raw materials use in compound feed concentrates in the Netherlands in 2005/2006. About 90–95% of feed raw materials used in the production of feed concentrates in the Netherlands are cultivated abroad. Some cereals for feed, such as wheat, barley, triticale and oats, are grown in the Netherlands, but most come from France and Germany and to a lesser extent from other European countries. Rapeseed meal comes mainly from Germany and France. Soybean meal and soy oil come from South and North America, although some soybean meal is produced in the Netherlands and surrounding countries from soybeans grown in South and North America. Oil palm products like palm kernel meal come mainly from Southeast Asia. Molasses comes from sugar cane processing in South America or Pakistan, and from sugar beet processing in the Netherlands or other European countries. Dairy products come mainly from Dutch production.

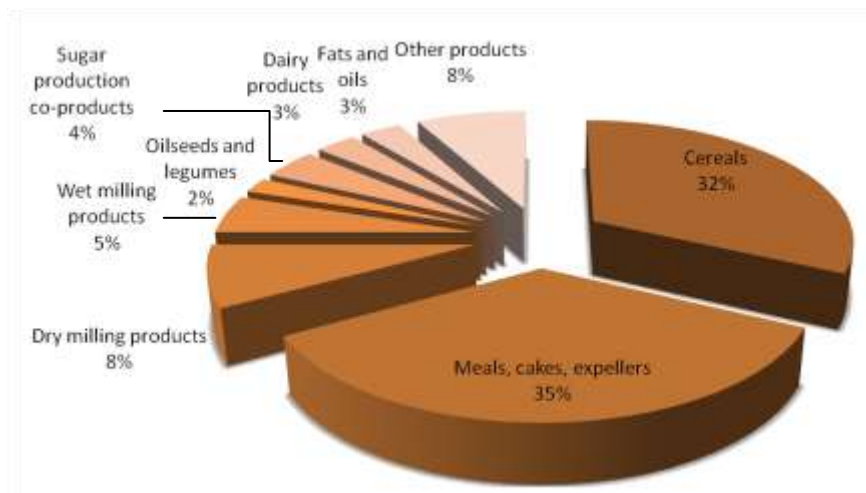


Figure 2.2 Breakdown of apparent feed raw materials use in compound feed concentrates in the Netherlands in 2005/2006 (based on statistics from PDV, CBS, FAO and HPA, and own estimates) (the proportions apply to the indicated time period and can change over the years as the prices of raw materials change)

2.3 Greenhouse gas emissions from feed production and feed utilization

2.3.1 General overview

The most important greenhouse gas emissions from agricultural production are carbon dioxide, methane and nitrous oxide. The sum of the environmental impacts of these emissions can be calculated using the values for global warming potential over 100 years from the IPCC 2006 guidelines. According to these values, the global warming potential of methane is 25 times that of carbon dioxide, and nitrous oxide has 298 times the impact. The sum of the three types of greenhouse gas emissions can therefore be expressed as carbon dioxide equivalents.

There are six important processes and activities that contribute to greenhouse gas emissions in the feed production chains:

1. Crop growing
2. Processing of crop products to (by-)products used as animal feed material
3. Animal production
4. Processing of animal product to (by-)products used as animal feed material
5. Transport of plant and animal products
6. Feed processing

Although a large amount of carbon dioxide is emitted due to the use of electricity and natural gas in processing and diesel and oil for transport, crop growing is responsible for the largest share of greenhouse gas emissions attributed to animal feed. Most of these GHG emissions originate from the use of nitrogen fertilizers for cropping, biological nitrogen fixation, and other sources of nitrous oxide emissions.

There is a general consensus among life cycle assessment practitioners on how to attribute most of the greenhouse gas emissions to processes and activities in cropping, transport and processing. However, there is one category of greenhouse gas emission sources for which this is not straightforward: 'land use and land use change' (LULUC). Land use refers to 1) the loss of the sink function under agricultural production, which prevents the fossilization process that occurs under natural ecosystems, and 2) oxidation of organic matter in the soil (which can take decades or centuries following conversion of land to agriculture). The land use change part refers to the greenhouse gas emissions from the destruction of

above-ground biomass in natural ecosystems when converting land from nature to agriculture. The problem is that calculating the LULUC greenhouse gas emissions requires specific information on the history of the land on which the crops for each specific animal feed was grown, and that is rarely known. Even if such information were available, it would still be difficult to determine which part of the land use change emissions should be attributed to the specific crop production. Nevertheless, depending on the methods, LULUC greenhouse gas emissions can make a considerable contribution to the carbon footprint of animal feed. It is therefore recommend to report the results of any method for including LULUC emissions separately.

Emissions from feed utilization includes all emissions from on-farm animal production resulting in live weight gain or animal products such as meat, milk and eggs. Animal feed consumption results in methane and nitrous oxide emissions from enteric fermentation, manure storage and application of manure. These emissions occur on the farm inside the housing system, outside during grazing, in storage or in the field when applying manure. The emission profile is different for each animal type (Figure 2.3 and 2.4)

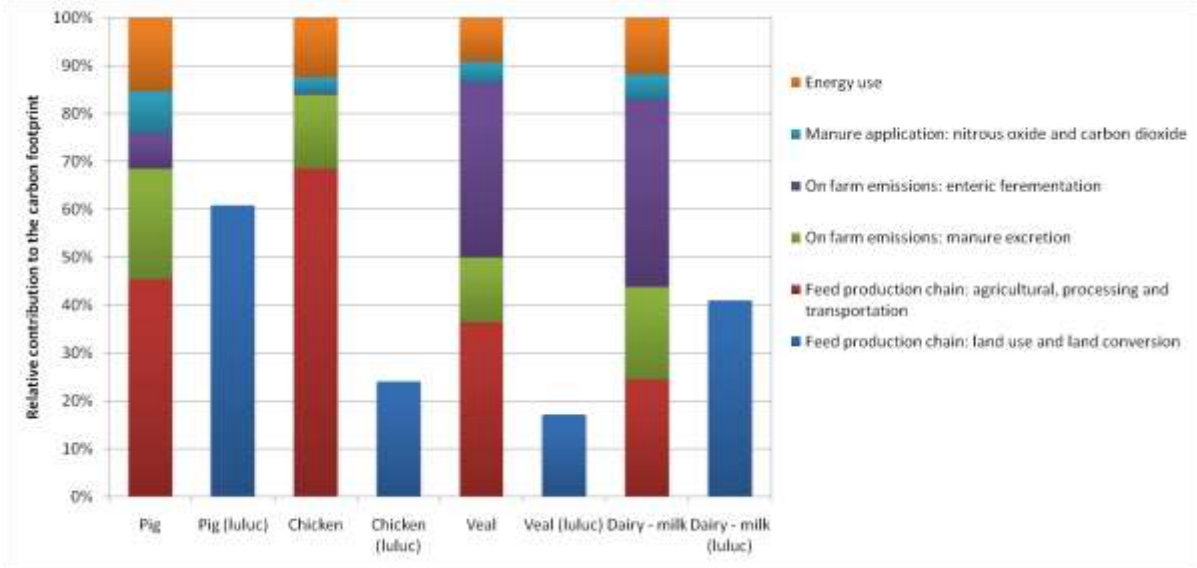


Figure 2.3 Relative contributions to carbon footprints of animal products (live weight or milk) (tentative results)

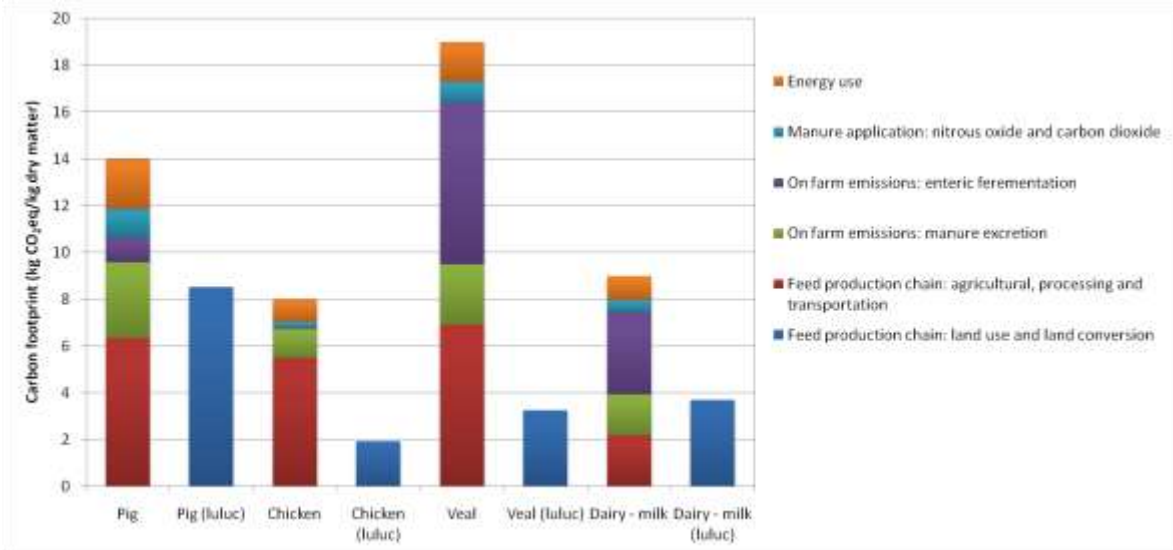


Figure 2.4 Carbon footprints of animal products (kg CO₂eq per kg dry matter live weight or, in case of dairy, kg dry matter milk) (tentative results)

2.3.2 Tentative carbon footprint of Dutch raw materials for feed use

Figure 2.5 shows the results of a tentative carbon footprint assessments of the production of feed raw materials used in the Netherlands for feed concentrate production. This figure only includes the carbon footprint of fertilizers, energy and nutrients used in the feed production chain. The results are tentative, so they only give an indication. The development of the tool for calculating carbon footprints of animal feed will enable more precise estimations. In the tentative results, the total attributed greenhouse gas emissions of Dutch consumption of feed raw materials were 7.7 million tonnes (Mtonnes) CO₂ equivalents per year. Dairy products and animal fats make up only 3% each of the total contents of feed concentrates in the Netherlands. However, the total calculated contribution of dairy products and animal fats to the carbon footprint of feed concentrates is 26% and 7% respectively, because these products have high carbon footprints compared to the other animal feed components. The contribution made by the use of energy for feed production to the carbon footprint of animal feed is, at about 6.5%, relatively small (this is equal to 500,000 tonnes CO₂ equivalent per year).

When attributing greenhouse gas emissions from land use change to crop production in countries where large-scale land conversion occurs – such as for soybean production in Brazil and Argentina, and oil palm production in Malaysia and Indonesia. a comparable greenhouse gas emission of 8 Mtonnes has to be added. However, the magnitude of this contribution depends on the assumptions made when assessing and attributing greenhouse gas emissions from land use change. The 8 Mtonnes are calculated using a draft method described in this report.

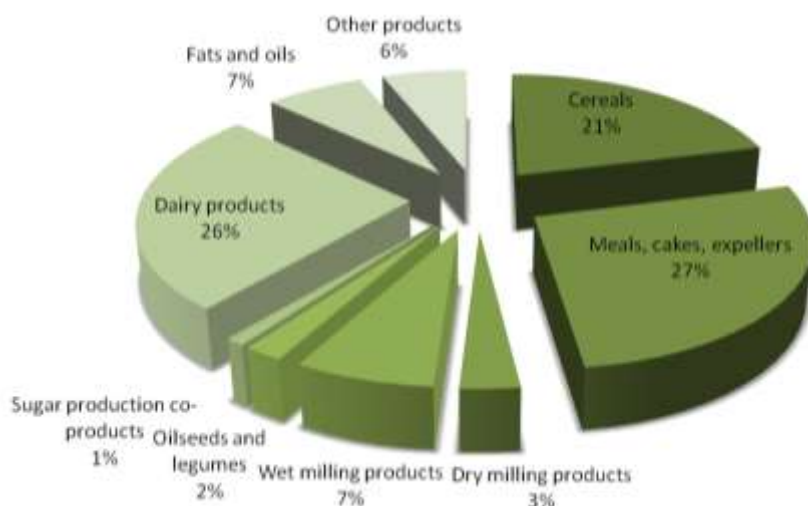


Figure 2.5 Contribution by different groups of feed raw materials to the carbon footprint of total compound feed production in the Netherlands in 2006 (excluding LULUC emissions) (tentative results).

2.4 Concluding remarks

Assessing carbon footprints of animal feed and animal products is complex for a number of reasons. First, many different feed raw materials are used, each with a complete chain of cropping, transport, processing, and in some cases animal production. Second, agricultural production activities and processes emit large amounts of methane and nitrous oxide, which are more difficult to quantify than carbon dioxide emissions. Moreover, the difference in impact on global warming of nitrous oxide and methane emissions compared with carbon dioxide emissions is subject to much uncertainty and may change in the light of new insights and assumptions. Third, data availability is a problem in agricultural life cycle assessments because of the wide diversity of producers and changing environmental factors like weather variables and biological processes. Finally, assessing carbon footprints of animal feed is complex because of the large

number of interactions between different systems within the feed production chain. This means that a carbon footprint of animal feed needs to be based on a thorough study that addresses the complexities and on reliable data that represent the actual processes and activities in the production chains.

A tentative carbon footprint of animal feed production and consumption in the Netherlands shows that animal feed contributes considerably to greenhouse gas emissions, at about 30 Mtonnes CO₂ equivalents per year. This footprint includes about 14 Mtonnes from feed digestion by animals (feed utilization), about 8 Mtonnes from the use of energy, materials and fertilizers in the feed production chain, and about 8 Mtonnes from land use and land use change. A large proportion of these emissions take place outside the Netherlands. This is a large amount (about 14%) compared with the total estimated emissions in the Netherlands in 2008, which was 220 Mtonnes CO₂ equivalents. The carbon footprint assessment tool will enable users to evaluate the contribution made by Dutch animal feed products to the greenhouse effect more precisely and in more detail. The tool will also enable the users to determine how this contribution can be reduced.

3. Methodological issues for assessing carbon footprints of animal feed

3.1 The methodological framework

Generic methodological initiatives and developments

An important conclusion from the inventory of initiatives is that the carbon footprint calculation tool for animal feed should be developed in conjunction with standards relevant for calculating greenhouse gas emissions from activities and processes in the animal feed production chain. These standards are not static and are updated regularly in the light of the latest scientific insights and feedback from users. The ideal starting points for deriving calculation rules for a carbon footprint tool for animal feed are the PAS2050 standard and the specifications for horticulture in the Dutch carbon footprint protocol for horticultural products. Starting with these protocols implies a logical sequence of currently available standards. The Dutch Horticulture Protocol, which is also valid for most arable farming activities, is based on PAS2050, which itself is based on the generic worldwide IPCC and ISO standards.

Figure 3.1 shows the interrelationships between the most important standards. The information flows from global to local levels are about the further specification of guidelines and rules in worldwide standards, in which guidelines and calculation rules are made more specific. The group of actors is also more diverse at higher integration levels, and in some cases the same type of specifications are made in several countries or regions at the same time. This makes it important to identify parallel initiatives. It is crucial that the information flows to lower integration levels (countries or sectors) are followed by information flows in the other direction on standardizing sector or product specifications on a more generic scale.

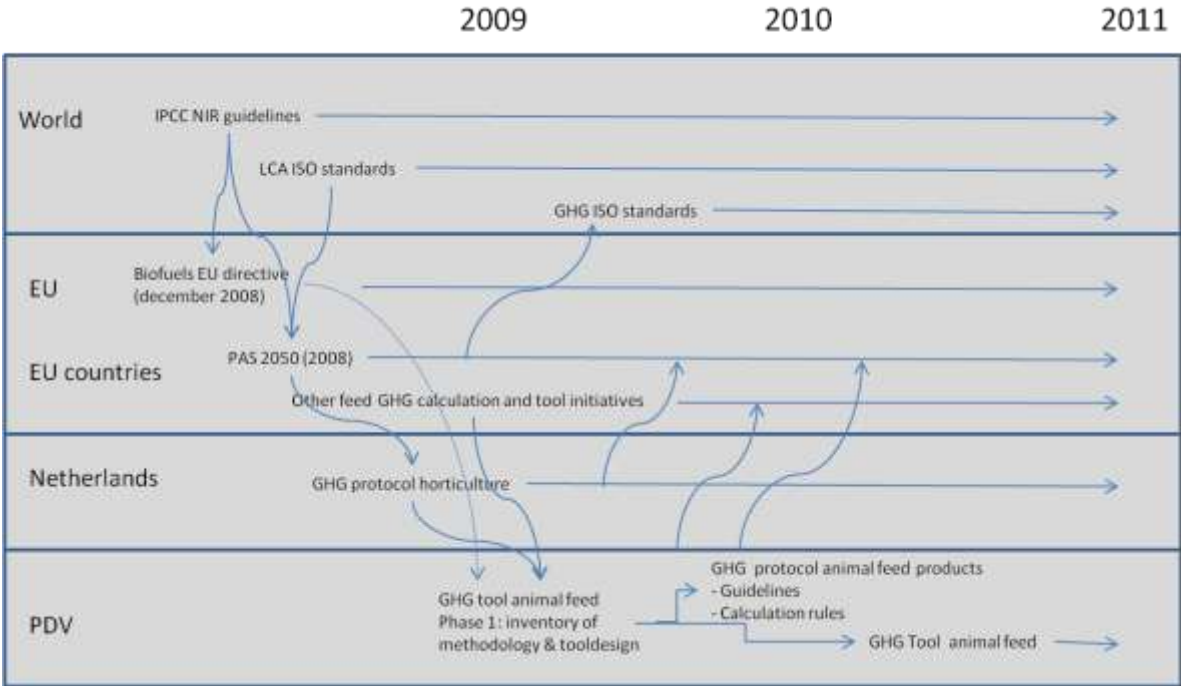


Figure 3.1 Interrelationships in standards development

It is important to note that the objective of the current phase of the project, Phase 1, is not to make a protocol for assessing carbon footprints of animal feed. The objective here is to identify methodological issues which require resolution in Phase 2, when the calculation rules will be further specified to develop the tool. Depending on progress in Phase 2, it may also result in a protocol drawn up in cooperation with other interested parties aiming to set a generic standard. A more detailed inventory of parallel initiatives and discussion of possible consequences for making the carbon footprint tool are presented in Chapters 7 and 8.

***Deriving calculation rules for assessing carbon footprints of animal feed
(in relation to PAS2050 and generic standards)***

The methodological framework for assessing carbon footprints, as defined in the recently published PAS2050, is a combination of the IPCC method for calculating greenhouse gas emissions in countries (IPCC guidelines of 1996 and 2006) and life cycle assessment methodology for determining the emission sources to be included and how to allocate the emissions to a specific product. The ISO14040 standards give general guidance on how to assess a product's life cycle properly. The standards are generic and leave some freedom of choice on several methodological issues, which complicates harmonization of carbon footprint calculations of products because some choices have a large effect on the results. The recently founded European Platform on Life Cycle Assessment (EPLCA) proposes practical solutions for making methodological choices in life cycle assessment studies, and is therefore helpful in interpreting the ISO14040 standards and providing methodological guidance on the development of a carbon footprint protocol.

The PAS2050 (developed by the British Standards Institute) is the first standard for assessing carbon footprints and is expected to be an important document for the development of a European and/or worldwide standard. Because the PAS2050 lacks detail on assessing carbon footprints of agricultural products, Blonk Milieu Advies and LEI recently developed a more detailed protocol as a supplement to PAS2050 for the Dutch Commodity Board for Horticulture (Productschap Tuinbouw). This carbon footprint protocol for horticultural products gives more specific guidance on calculating carbon footprints of crop products and the intention is to upgrade it to a PAS (compliant) standard. The Dutch Horticulture Protocol is therefore a sound starting point for assessing carbon footprints of vegetable animal feed ingredients, at least for the cropping part. Additional calculation rules are required for processing raw materials and producing animal products for feed ingredients. Further rules are also needed for calculating greenhouse gas emissions from feed utilization and allocating emissions to the co-products from animal production. The level of detail of the calculation rules has to be matched to the level of detail of the available data (Figure 3.2).

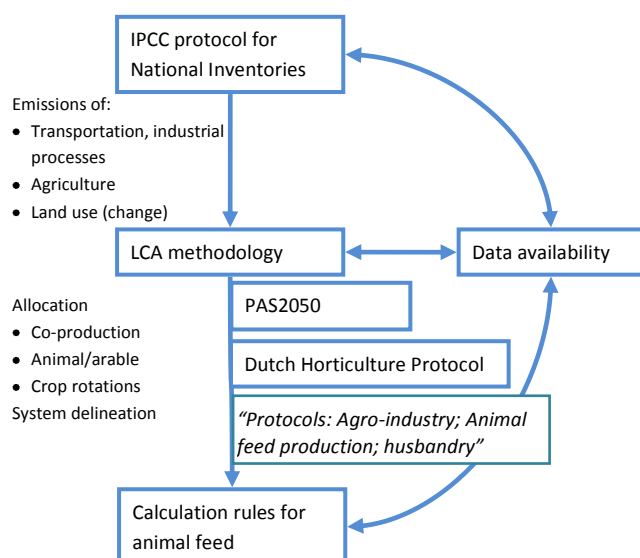


Figure 3.2 The process of making calculation rules for assessing carbon footprints of feed

Available guidance and calculation rules for assessing carbon footprints of animal feed

The PAS2050 and the Dutch Horticulture Protocol address relevant methodological issues and provide guidance and/or calculation rules for assessing carbon footprints of animal feed. Table 3.1 summarizes the methodological issues and guidance given in the protocols. In many cases, the available guidance and calculation rules are also adequate for assessing carbon footprints of animal feed.

Table 3.1 Available guidance and calculation rules for assessing carbon footprints of animal feed

Methodology issue	Life cycle stage	Available guidance and calculation rules for animal feed
System boundaries	Generic	All relevant emissions, capital goods excluded. Emissions may be excluded if the contribution is proven to be very low. Horticulture protocol gives a classification of processes to be included.
Allocation of impacts to products in joint production	Cropping, feed raw materials production	PAS2050 and Dutch horticulture protocol prescribes economic allocation. Bio-fuel directive prescribes allocation on energy content.
Allocation of impacts to products in crop rotation	Cropping	PAS2050 gives no guidance. Dutch Horticulture protocol gives specific calculation rules.
Allocation of impacts to products in combined production	Raw materials and husbandry	PAS2050 gives no guidance. Dutch Horticulture Protocol gives guidance.
Allocation of impacts of manure application	Cropping and feed use in husbandry	PAS2050 gives no guidance. Dutch Horticulture Protocol gives specific calculation rules.
Soil and fertilization emissions in agriculture	Cropping	PAS2050 gives no guidance. Dutch Horticulture Protocol gives specific calculation rules.
Emissions from animal husbandry	Feed utilization	PAS2050 (and horticulture protocol) gives no specifications on animal production other than following the IPCC guidance on calculation of agricultural emissions of CO ₂ , N ₂ O and CH ₄ .
Land use	Cropping and feed use in husbandry	PAS2050 gives no guidance. Dutch Horticulture Protocol gives specific calculation rules.
Direct land use change	Cropping	PAS2050 and Bio-fuel directive give calculation rules which are not adopted in the horticulture protocol.
Indirect Land use change	Cropping	PAS2050 and Bio-fuel directive give no calculation rules. The horticulture protocol gives calculation rules.

Three methodological issues are of special importance for the further development of a carbon footprint assessment tool for animal feed:

- Allocation of emissions to co-products from arable farming and raw materials processing, on which the EU bio-fuel directive and the PAS2050 differ (energy versus economic allocation), and questions about specific system definitions in relation to prices and data collection.
- Calculating emissions from land use and land use change: calculation methods have been defined for loss of carbon sink function, soil organic matter losses and land use change, but consensus is not expected to be reached in the short term.
- Allocating emissions from application of manure to animal and vegetable production, which is relevant where manure surpluses are produced.

Chapter 4 examines these methodological issues. For the other issues listed in Table 3.1, the PAS2050 and the proposed guidance and calculation rules in the Horticulture Protocol provide a sufficient basis for developing a calculation tool.

3.2 Assessing carbon footprints and improvement options (attributional versus consequential life cycle analysis)

There are two basic types of life cycle assessment: attributional and consequential. An attributional life cycle assessment describes the pollution (for example greenhouse gas emissions) and resource flows within a chosen system (or chain of systems) attributed to the delivery of a specified amount of a relevant functional unit (this definition is based on Thomassen et al. 2008). A carbon footprint is an attributional life cycle assessment of greenhouse gas emissions. A consequential life cycle assessment estimates how pollution and resource flows within a system (or chain of systems) change in response to a change in the output of functional units (Thomassen et al. 2008).

The attributional approach is used in the PAS2050 and the Dutch Horticulture Protocol. Where co-production occurs in the chain, the greenhouse gas emissions are allocated according to physical or economic criteria. Defining which sources and activities are to be included is more straightforward in this approach than in consequential life cycle assessments, in which many sources of greenhouse gas emissions within and outside the production chain can change in response to the changes in output of functional units being investigated. A complete market analysis is needed to cover all possible interactions, such as the indirect effects of changing demand for a co-product on the other co-products or similar products.

The attributional approach involves allocation rules and system boundaries, which are especially suitable for describing existing situations. Incorporating some of the features of consequential life cycle assessment into a carbon footprint assessment tool will be difficult because the data requirements for the consequential approach are very high and many assumptions need to be made, which in turn means that the reliability of the results depends heavily on the available information. This implies that the tool will not be able to calculate all mitigation options (reducing greenhouse gas emissions), unless a massive data collection effort is made. For some options, further analysis based on a consequential approach will be required. Chapter 5 gives some guidelines for such an analysis.

4. Specification of some methodological issues for feed

4.1 Introduction

This chapter discusses the most important methodological issues for assessing carbon footprints of animal feed and studying improvement options. Section 4.2 deals with the methodological consequences of assessing carbon footprints of animal feed and studying options for reducing greenhouse gas emissions in the life cycle of a feed product. Section 4.3 deals with the system boundaries issue in assessing carbon footprints. Section 4.4 presents the allocation rules for assessing carbon footprints and for studying changes. The method used to account for greenhouse gas emissions from land use and land use change (LULUC) is explained in section 4.5. Finally, section 4.6 gives some suggestions for modelling greenhouse gas emissions from feed utilization, which includes feed digestion and manure application.

The emphasis in this chapter is on those issues that are not specified in generic LCA (ISO14040), carbon footprint guidelines (PAS2050) or agricultural specifications, such as the Dutch Horticulture Protocol (PT 2009), and which have a major impact on the results. The recommendations on methodology given in this chapter should be considered as starting point for the further development of a protocol for assessing carbon footprints of animal feed, which is the purpose of the second phase of this project.

4.2 Setting the scope: carbon footprint assessment and studying carbon reduction options

Where system boundaries are drawn and how allocation rules are applied depend on the scope of the study. In the process of defining the key issues for improvement in a particular feed production and consumption chain, it is recommended that the first step should be to assess the current carbon footprint. This gives insight into the magnitude of emissions and the relative contribution made by different processes and activities to the carbon footprint of animal feed. This information is helpful in setting the focus for improvement options. The LCA approach to assessing carbon footprints is characterized as an attributional approach. For studying changes a consequential approach is often required.

The level of accuracy of the carbon footprint assessment must be sufficient to indicate the order of magnitude of emissions and the relative contributions made by the different processes and activities. This means that the modelling of greenhouse gas emissions must be consistent and state of the art, and the resulting data must be reliable enough to assess the carbon footprint. For this purpose an overall uncertainty level of 5% can be regarded as acceptable. Attempts to achieve a higher level of precision will require considerable additional effort, but generate little additional insight.

Making a carbon footprint of an animal feed (including production and utilization) requires a lot of secondary data. First, much data on feed raw materials production is needed. For instance, assessing the carbon footprint of a mainstream animal feed type throughout the year requires information on the carbon footprint of 30 to 40 types of raw materials with different origins (Blonk draft 2009). The carbon footprints of the raw materials are themselves the result of a carbon footprint assessment and need to be consistently computed. The assessment of carbon footprints of raw materials must not be too complex, otherwise it will not be practically feasible to derive any results for a specific animal feed. The accuracy of modelling and computing these GHG scores needs to be sufficient to obtain a clear picture. Sections 4.3.1

and 4.4.1 explain how the system boundaries and allocation rules are tailored to the purpose of gaining sufficient insight.²

When studying changes, the definition of accurate system boundaries and allocation rules in the case of co-production must be case specific. In some cases, the system boundaries and allocation as used in the attributional assessment can be used. In other cases, however, a specific scenario analysis is needed with a specific definition of system boundaries and allocation rules. For example, when the change from using a dried product to a wet product is studied, it might be sufficient to exclusively focus on the avoided drying step (under the condition that feed composition is not altered and the market volumes of dried and wet products are not altered in a way that marginal effects will occur). Some considerations are given on this topic in sections 4.3.2 and 4.4.2.

The final remark regarding the scope of the study is that tolerating a variation coefficient of 5% in the carbon footprint of a feed product does not mean that changes of a smaller magnitude cannot be studied or are not significant. As the above example shows, within a smaller system (if allowed) these changes can be studied and may be significant.

4.3 System boundaries

4.3.1 System boundaries in assessing the carbon footprint of a feed product

An important issue in calculating the carbon footprint of animal feed is how to set the boundaries of the production chain: which emission sources must be included in the carbon footprint and which emissions sources can be left out? As described in Chapter 2, the production and utilization of animal feed contribute significantly to global greenhouse gas emissions. Changes in animal feed composition and feed rations therefore affect greenhouse gas emissions from production and utilization. In view of this, it is recommended always including the animal feed utilization phase in a carbon footprint of animal feed.

The PAS2050 distinguishes between two approaches to setting system boundaries when making a carbon footprint profile: a cradle to gate analysis and a cradle to grave analysis. In the cradle to gate analysis the boundaries are set at the factory gate, excluding transport to the consumer. The Dutch Horticulture Protocol argues that it is more appropriate to include 'downstream' greenhouse gas emissions that inevitably occur during transport, consumption and disposal/recycling, when these emissions can be (reasonably) estimated. This principle is also followed in setting the boundaries for animal feed, which implicates that all emissions related to intake, digestion, housing and manure management are included. The greenhouse gas emissions of digestion, housing, manure storage and manure application include methane and nitrous oxide from biogenic processes and carbon dioxide emissions from fossil fuel use related to feed application, manure storage and manure management. Carbon dioxide emissions of biogenic origin are not included, in line with IPCC recommendations.

In line with PAS2050, all processes and activities are included that contribute more than one per cent to the total carbon footprint of animal feed or animal products, unless this sums up to less than 95% of the total. In that case, some processes and activities that contribute less than one per cent are also included, so that the sum will be at least 95%. Table 4.1 gives an overview of these processes.

² The recently published draft ILCD handbook 'General guidance document for Life Cycle Assessment' (June 2009) put out for public consultation gives a further explanation and guidelines on choosing system boundaries and allocation rules in line with the scope of the study (see, for example, section 4.5.4). However, depending on the comments received during the consultation procedure, some amendments may be made in the final version.

Table 4.1 Processes and activities contributing more than one per cent of the total greenhouse gas emissions from feed production and feed utilization

Stage	Use of product or biological conversions	Production of applied product
Crop growing	N fertilizers → N ₂ O Urea → N ₂ O; CO ₂ Manure application → N ₂ O, CO ₂ Crop residues → N ₂ O N fixation → N ₂ O Fossil energy carriers → CO ₂ Burning of crop residues → CH ₄ , N ₂ O Liming → CO ₂ of limestone Electricity → CO ₂ Seed, young plant material → N ₂ O	Nitrogen fertilizers → CO ₂ , N ₂ O Other fertilizers (P ₂ O ₅ ; K ₂ O) → CO ₂ Energy carriers → CO ₂ Limestone → CO ₂ Seed and other planting material → CO ₂ , N ₂ O Manure (including transport) → CO ₂ , N ₂ O, CH ₄
Transport of crop, feed raw material, feed, animals, manure	Fossil energy carriers → CO ₂	Energy carriers → CO ₂
Processing of crops	Biogenic energy carriers → CH ₄ , N ₂ O Fossil energy carriers → CO ₂ , CH ₄ Auxiliary materials → CO ₂	Energy carriers → CO ₂ Auxiliary materials → CO ₂
Production of animal feed products	Full GHG LCA according to PAS2050 guidance	Full GHG LCA
Feed products of other industries	Neglected for now	
Feed concentrate production	Fossil energy carriers → CO ₂	Energy carriers → CO ₂
Animal housing systems	Fossil energy carriers for feeding → CO ₂ Enteric fermentation → CH ₄ NH ₃ emissions → N ₂ O Other N ₂ O emissions → N ₂ O Solid manure storage → N ₂ O Liquid manure storage → CH ₄ Liquid manure processing → CH ₄	Energy carriers → CO ₂
Manure application	Fossil fuels → N ₂ O NH ₃ emissions → N ₂ O Other N ₂ O emissions → N ₂ O	Energy carriers → CO ₂

4.3.2 System boundaries in studying changes and improvement options

When studying changes and potential improvement options, different system boundaries may be set (see Chapter 5 for an introduction to some different options). Some changes can be calculated by using a smaller system definition, for instance by focusing on the point where a process is made more efficient, without affecting the raw materials used and the product characteristics. This means that the allocation of GHG impacts over co-products is no longer required or appropriate.

In many other cases, an extension of the system is needed because changes will occur in other production systems. This is the case when changing the origin of crop growing or raw materials processing, but also when changing the feed composition of raw materials. Here it is necessary to gain insight into changes in other production systems (see section 4.4.2).

4.4 Dealing with allocation

4.4.1 Allocation principles for assessing carbon footprints of feed³

Allocation in life cycle assessments refers to the division of upstream environmental impacts over co-products.⁴ Upstream environmental impacts occur due to activities before (from inputs) and during the

³ A recent, more detailed introduction to allocation principles can be found in the draft ILCD handbook .

⁴ A general principle in LCA is that allocation needs to be avoided wherever possible. Here, the focus is on the separation of crops into different raw materials, which means that there is no possibility of avoiding allocation. System expansion, another way of avoiding allocation, is not applied for practical reasons and to avoid arbitrary choices in defining the processes to be included in the system. The ILCD handbook and PAS2050 recommend

co-production process. In the case of greenhouse gas emissions, the upstream impacts can be expressed in kg CO₂-eq per kg of the main ingoing product. Allocation fractions determine how those emissions are divided over the co-products, so that the sum of the fractions is one. The allocation fractions can be based on the mass ratios of the co-products per kg ingoing product or on other characteristics, such as energy content or economic revenue per kg ingoing product.

$$\text{Allocation fraction of a co-product} = \frac{\text{Mass, revenue or energy content of a co-product per kg input}}{\text{Sum of the mass, revenue or energy content of all co-products per kg input}}$$

Table 4.2 shows a simplified example of allocation fractions of the co-products soybean oil and expeller, based on mass, revenue and energy content. This example clearly shows that there can be a large difference between the mass based allocation fractions and those based on other characteristics. The difference between revenue and energy based allocation fractions is smaller, but still significant. Note that the upstream emissions are expressed per kg input and that the carbon footprint of a co-product is expressed in kg CO₂-eq per kg of that product; the allocated upstream emissions per kg input therefore needs to be divided by the co-product’s mass per kg input to obtain the carbon footprint in kg CO₂-eq per kg co-product. In the case of allocation based on economic revenue, the equation is as follows:

$$\text{Emissions per kg output}_i = \frac{\text{value}_i * \text{output}_i}{\sum_{i=1,1}(\text{value}_i * \text{output}_i)} * \frac{1}{\text{output}_i} * \text{Upstream emissions (kg CO}_2\text{-eq/kg input)}$$

where value_i is the price of co-product i per kg co-product and output_i is the mass of co-product i in kg per kg ingoing product.

Table 4.2 Allocation fractions of the co-products soybean oil and expeller based on mass, economic revenue and energy content, where input is soybeans

		Oil	Expeller	Sum
Output	kg/kg input	0.175	0.800	0.975*
Mass allocation fraction	-	0.179	0.821	1.000
Price of co-products	US\$/kg output	700	230	-
Revenue (price of co-products x output)	US\$/kg input	122.5	184	306.5
Economic allocation fraction	-	0.400	0.600	1.000
Energy content of co-products	MJ/kg output	37	18	-
Energy content (energy content of co-products x output)	MJ/kg input	6.475	14.4	20.875
Energy allocation fraction	-	0.310	0.690	1.000

* 0.025 kg water evaporates in the oil extraction process

An issue regarding allocation methodology is which characteristics it should be based on. In the Dutch Horticulture Protocol a set of basic allocation principles for calculating carbon footprints of agricultural products are given. The protocol describes three situations: 1) co-production in the same system, 2) inflow of a co-product from another system, and 3) final processing. Box 4.1 contains guidelines from the protocol on which type of allocation should be applied in each situation. Allocation to co-products is of special importance for assessing carbon footprints of animal feed because many raw materials used in feed concentrates are co-products.

In the case of co-products with distinct characteristics and functionality, the allocation fractions should reflect the ‘economic and social value’ of each co-products. It is clear that mass rarely represents the value

using allocation as the main approach for attributional LCA of a current situation. This method is further specified in the Dutch horticulture protocol.

of products. Co-products can have very different purposes, such as feed, food and fuel, and for each purpose physical characteristics have different values. Where co-products have different purposes, the economic revenue is regarded as the best option. However, because prices fluctuate and are not always publicly known, it was decided to use energy content for bio-fuel co-products in the European Union's bio-fuel directives (EC 2008). A more complete analysis of differences between allocation based on energy content and revenue is described in section 4.4.5. How to deal with data availability for determining the co-products revenues is handled in section 4.4.3. Section 4.4.4 describes price fluctuations and gives recommendations on how to deal with them..

Box 4.1: Allocation guidelines from the Dutch Horticulture Protocol

1. Co-production in the same system

- If the co-products have similar characteristics and or functionality, allocation should be based on one or more physical characteristics.
- If the co-products have distinct characteristics and or functionality, allocation should be based on the economic value of the co-products.
- In both cases, if backflow occurs in the system (closed loop recycling), the primary input should first be compensated by the backflow.

2. Inflow of a co-product from another system

- If no greenhouse gas emission due to a co-product from another system is allocated from that system, the co-product should be treated as a primary input. We assume no emission of primary products before transport from its original system.
- If greenhouse gas emission is allocated from another system and the co-product has no economic value (waste), it should be based on physical characteristics.
- If the co-product does have economic value, it should be based on its economic value.

3. Final processing

- If backflow occurs in a final processing system, the primary input should first be compensated by the backflow and complete primary energy use should be included.
- If no backflow occurs, the allocation in final processing should be handled as in co-production in the same system described above.

4.4.2 Defining products and prices in co-production at company level

To make economic allocation operational for feed products it is important to use coherent mass balance and price data of the co-production systems. What is first required is a description of the production processes within the systems. Figure 4.1 is a schematic representation of an example co-production system in which a crop product is used as input and is separated into a feed product and a non-feed product. The co-products are dried and purified before being sold. Current and historic market price data for these commodities are often publicly available.

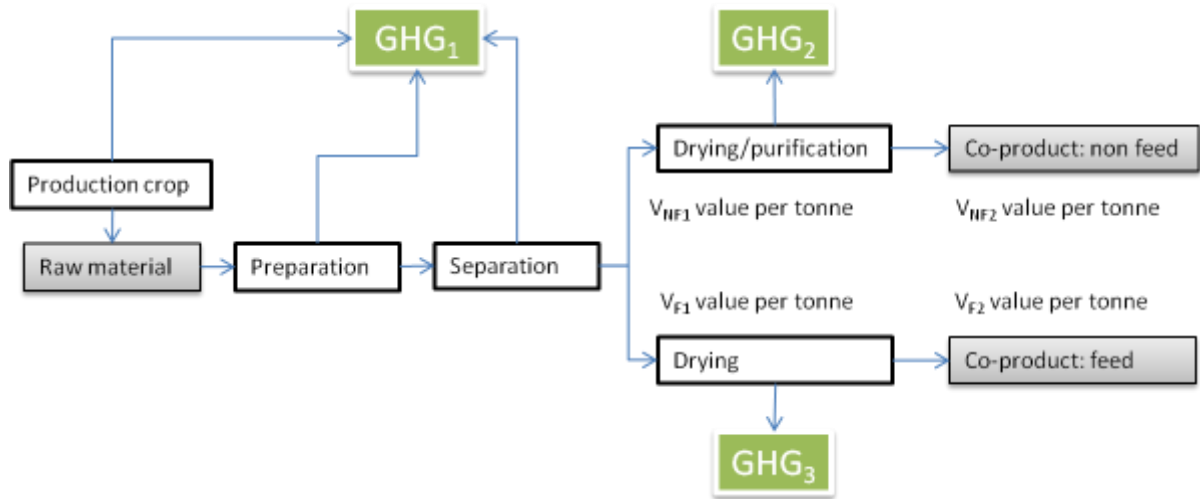


Figure 4.1 Schematic representation of an example co-production system, where a crop product (raw material) is used as input and is separated into a feed co-product and a non feed co-product

$$GHG_{F2(\text{dry purified})} = Q_{IN}/Q_{F2} * V_{F2}/(V_{F2}+V_{NF2}) * (GHG_1 + GHG_2 + GHG_3) \quad (\text{Equation 1})$$

$$GHG_{F2(\text{dry purified})} = Q_{IN}/Q_{F2} * (V_{F1}/(V_{F1}+V_{NF1}) * GHG_1 + GHG_3) \quad (\text{Equation 2})$$

$$GHG_{F1(\text{wet unpurified})} = Q_{IN}/Q_{F2} * V_{F1}/(V_{F1}+V_{NF1}) * GHG_1 \quad (\text{Equation 3})$$

$$GHG_{F1(\text{wet unpurified})} = Q_{IN}/Q_{F2} * V_{F1}/(V_{F1}+V_{NF2}) * GHG_1 \quad (\text{Equation 4})$$

Where: GHG is the greenhouse gas emissions from processes and activities 1, 2 and 3 in Figure 4.1 per tonne ingoing product or allocated per tonne co-product (kg CO₂-eq/tonne); Q is the quantity of a product (tonne); V is the value of a product (€ or US\$/tonne); IN is the ingoing raw material product; F1 is the wet unpurified feed co-product; F2 is the dried purified feed commodity co-product; NF1 is the wet unpurified non-feed co-product; NF2 is the dried purified non-feed co-product.

A strict interpretation of the allocation methodology in the life cycle assessment for dried and purified co-products would be to use prices of co-products the moment after their separation into wet and unpurified form (Equation 2). Some examples of such products are wet beet pulp, wet whey, wet gluten and steepwater. However, the prices of these products are often not publicly available. Market prices may exist where these co-products were sold to local markets. The off-plant market prices of wet co-products can then be used as an approximation for determining the internal economic allocation to the different flows of co-products. If no market prices for wet products are available, potential value prices can be derived by using the market prices of valuable components.

However, many life cycle assessment practitioners solve the problem of not having price data by expanding the system to the whole company and run an input-output analysis at company level. This means that Equation 1 is used for dry commodities and Equation 4 for dry non-feed products and wet feed products. A much smaller group of life cycle assessment practitioners go into further detail and isolate the in-company processes and determine an in-company value for the product, which can be done by looking at comparable products on the market. This detailed approach is often not feasible and not preferable when calculating carbon footprints of animal feed, the purpose of which is to gain insight into the magnitude of emissions and the relative contributions made by processes and activities to the carbon footprints.

Economic allocation can lead to odd and non-desirable results when feed co-products are dried and purified, either in the factory where the separation process takes place or by a different company. The most profound example is whey, a co-product of cheese production. Whey is initially a soluble co-product of cheese production with 4–6% dry matter. It can be concentrated and dried in different forms. In the

Netherlands, whey is available in many products, including as a feed stuff in different forms: whey (6% DM), whey permeate (30% DM), whey condensate (60% DM) and whey powder (96% DM). The processing steps for producing whey powder production are more or less the same whether they are done at the production site itself or at a different company, but applying economic allocation at the company gate gives different results for whey powder, as shown in Table 4.3

Table 4.3 Greenhouse gas emissions (kg CO₂-eq/tonne) based on economic allocation (Background data Blonk Milieu Advies 2008)

Product sold at cheese factory	Whey powder (96% dm) kg CO ₂ -eq/tonne	Cheese kg CO ₂ -eq/tonne	Whey powder & cheese kg CO ₂ -eq/tonne*
Whey (6% dm), dried elsewhere	0.7	10.3	11.0
Whey powder (96% dm), dried in factory	3.2	7.8	11.0

* The sum of the carbon footprints of whey powder and cheese is the same in both cases, because the products are produced in a mass ratio of 1:1

Drying whey costs an energy input equivalent to almost 0.7 kg CO₂-eq per kg of whey powder. If the product is dried outside the cheese factory, the drying costs are allocated entirely to whey powder and a very small proportion of the upstream milk and cheese production because the wet whey makes a small contribution to the economic revenues of the cheese factory. If the whey is dried within and sold by the cheese factory, the revenues from whey production are much higher. In this case the drying costs for whey are divided between whey powder and cheese, but a far greater proportion of upstream emissions are allocated to the whey powder. The result is a significantly higher carbon footprint.

As this example shows, differences in attributed greenhouse gas emissions to whey powder are caused by differences in market prices at the moment the products leave the cheese factory and are not the result of actual differences in processes, other than the location of the processes. (In this example, differences in process efficiencies and transportation are neglected since they have a small effect on the values given). As argued above, it is much easier to make economic allocations for products for which commodity prices are available. For upgrading (purification and drying) inside or outside the company, Blonk (2008) recommends using the in-company production process and commodity values for economic allocation.⁵ In Figure 4.2 this means using Level II prices and the production processes required to come to level II. This recommendation holds for the situation where a carbon footprint of feed is calculated for the application of level II dried commodities.

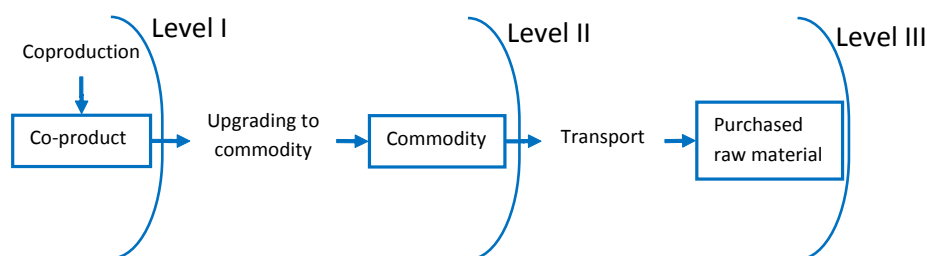


Figure 4.2 Different price levels of a commodity

⁵ This recommendation is in line with the recommendation made in Blonk (2008) to use commodity based allocation for slaughter by-products.

4.4.3 Using consistent commodity prices

A different issue in gathering commodity prices is the precise price definition. There are many types of commodity prices, depending on the place, the type of transport from the place of origin and transport insurance. The most important publicly available prices are Free on Board (FOB)⁶ and Cost Insurance and Freight (CIF).⁷ These prices are also connected to a specific port, like Rotterdam or Hamburg. When performing economic allocation only one type of price at one place must be applied for the different co-products.

Transport costs can considerably increase the price of some feed commodities, especially those commodities which have a relatively low off-plant price. Examples of such commodities are palm kernel expellers or citrus pulp. For these raw materials the attributed GHG emissions are considerably higher when using FOB Rotterdam prices, for instance, than export prices in Malaysia or the USA. FOB or CIF prices can be used for economic allocation after correcting them for transport costs. However, transport costs are not publicly available and a good method for estimating them still needs to be developed.

4.4.4 Dealing with price fluctuations

Economic allocation factors are revenue fractions in each co-product of the revenue per unit of ingoing product. The mass balance (kg co-product per kg ingoing product) is therefore an important factor in calculating the economic allocation factors, and it is relatively constant over time. Prices, on the other hand, can fluctuate considerably. To reduce the effect of price fluctuations, the economic allocation factor can best be calculated from average prices over a certain period. Based on tentative analysis, a five year period is long enough to filter out fluctuations, but short enough to recognize shifts. This can be shown in yearly and five yearly prices for rapeseed and the resulting economic allocation factors (Figure 4.3).

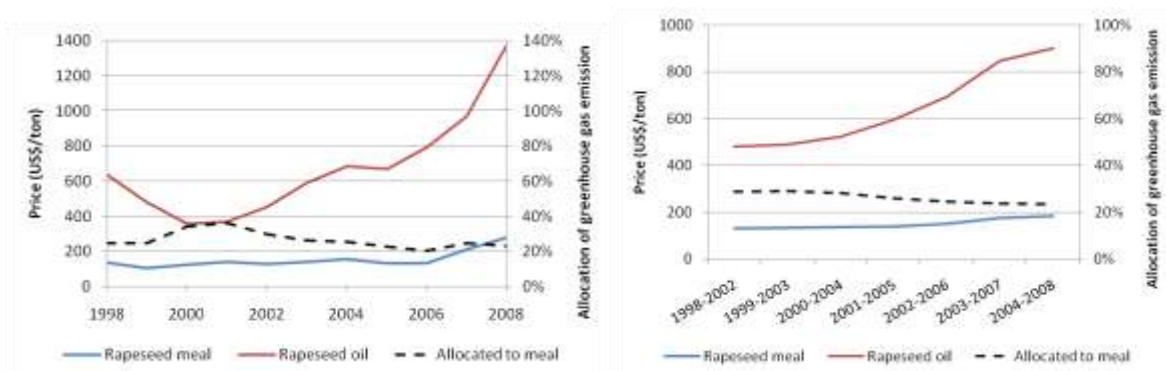


Figure 4.3 Economic allocation of rapeseed based on yearly (left) and five yearly (right) average commodity prices (Hamburg, prices for meal and Dutch FOB prices for oil, source: FAO prices)

Using five-year average prices of soybean oil and meal and sunflower oil and meal results in fairly constant economic allocation factors (Figure 4.4). It must be emphasized that in these examples the FOB or CIF

⁶ FOB: 'Free on Board' means that the seller's responsibility ends when the goods have passed over the ship's rail at the port of shipment. The buyer has to bear all costs and risks of loss or damage to the goods from that point onwards. In using this term, the buyer is responsible for appointing the vessel for transporting the cargo.

⁷ CIF: 'Cost, Insurance and Freight' means that the seller must pay the cost and freight necessary to transport the goods to the named port of destination, as well as procuring and paying the marine insurance. Responsibility for the goods is only transferred to the buyer once the goods have passed the ship's rail in the port of destination. In this instance the seller is responsible for nominating the vessel used for transporting the cargo.

prices were not corrected for transport costs, which would make the allocation factors for meals in these examples a few per cent lower⁸.

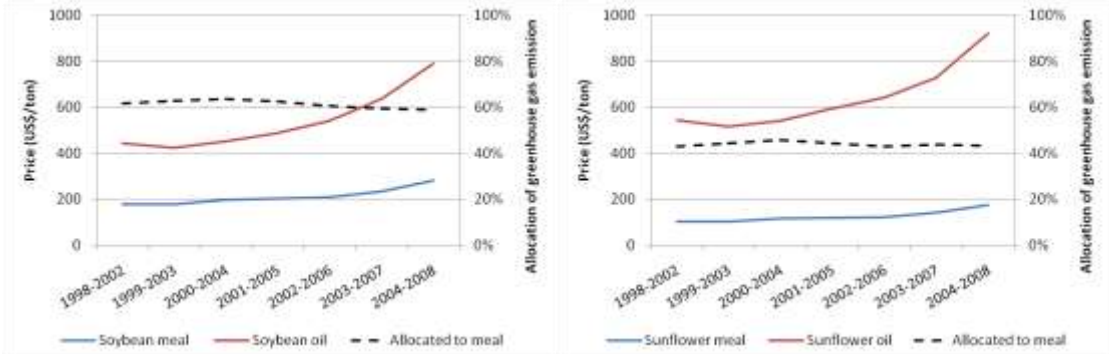


Figure 4.4 Economic allocation based on five-yearly average commodity prices (Hamburg, prices for meal and Dutch FOB prices for oil, source: FAO prices)

4.4.5 Economic allocation and energy-content based allocation

A point of special interest is the synchronization with the EU directive on calculating greenhouse gas emissions for bio-fuels (EC 2008). Some feed ingredients or their co-products can also be used as bio-fuel. Carbon footprints of bio-fuels are often assessed with allocation factors that are based on the caloric value (LHV) of the co-products instead of their prices. As long as this method is accepted as a standard, it is sensible to assess the carbon footprints of animal feed using caloric values to compare them with the carbon footprints using economic values. For many feed raw materials, the differences between allocation factors based on prices and caloric values are small, but for some they are very large (Figure 4.5)

⁸ The allocation fraction of meal is lower when calculated with ex-mill prices than with FOB or CIF prices (which include transport), because the ex-mill prices for meal are lower than those for oil, while transport costs are about the same for both.

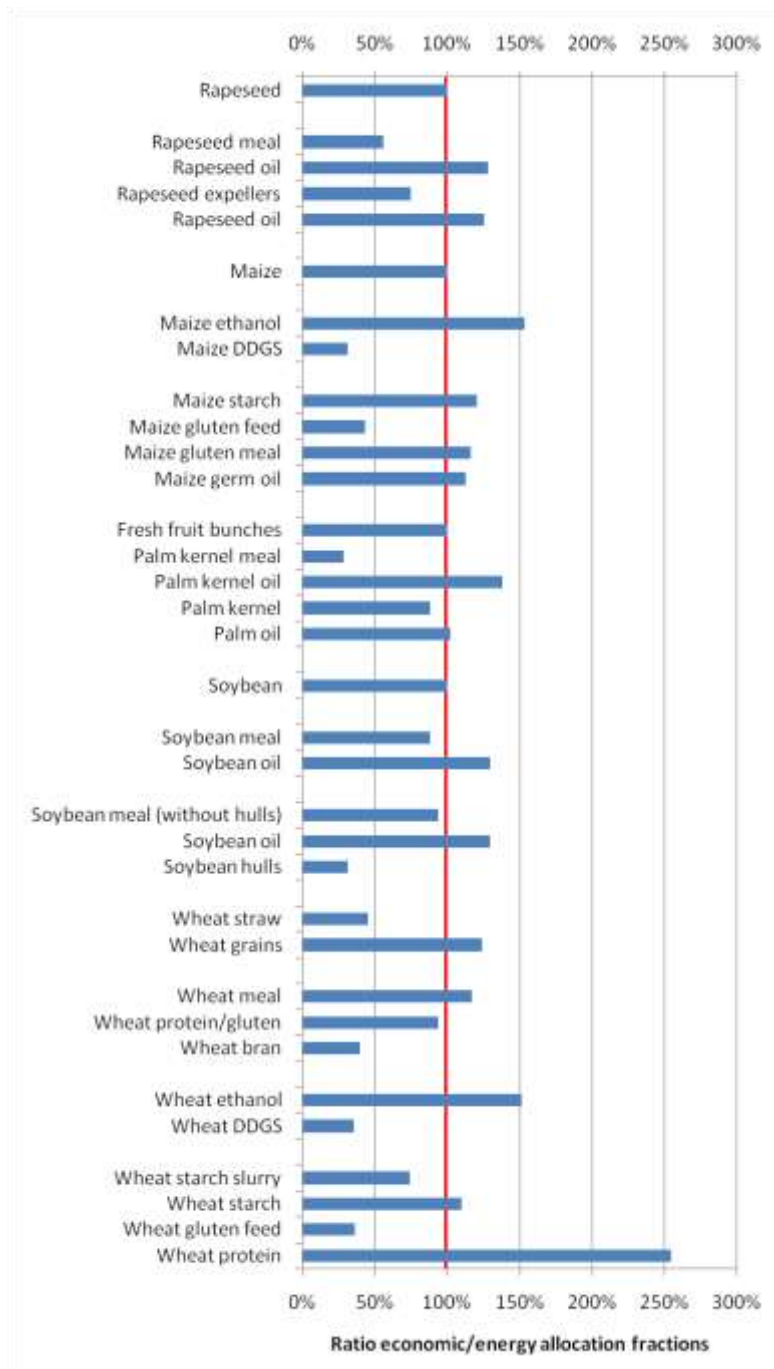


Figure 4.5 Results of greenhouse gas emissions from the production of some feed raw materials using economic allocation compared to using energy allocation (100% is the situation when economic allocation is equal to the energy allocation)

The differences between concentrate feed level in the two methods can be surprisingly low due to the mix of whole grains (which have fewer GHG emissions allocated using energy-based allocation) and co-products. However, this result depends on how the energy-based allocation deals with farming residues like straw. If these co-products are excluded from attributing emissions, which is prescribed in the EU directive, concentrate feed will be allocated more GHG emissions when applying an energy-based than an economic allocation.

4.4.6 Other allocation issues: crop rotation and manure application

Allocation of GHG emissions from the application of fertilizers and manure in crop rotations can have a major effect on the results of the allocated GHG emissions of a crop. The allocation of GHG emissions from manure application, which can occur at the beginning of the production chain as well at the end, can also have a large effect on the results. Allocation rules for these topics were recently published in the Dutch Horticulture Protocol. These rules could also be applied for feed products.

4.4.7 Dealing with co-production when studying improvement options

Which type of allocation is appropriate for studying improvement options depends on the type of change to be studied. Changes in feed composition can lead to changes in the supply and prices of raw materials; some raw materials are replaced by others and those that are replaced may be co-products; co-products that were not used as raw materials for animal feed may be replaced by other products. Also, increased production of other raw materials may result in an increase in the production of co-products that are not used as raw materials for animal feed. However, such changes are difficult to predict and the data requirements for such analysis is much higher than for the attributional allocation method. Currently, there are no standards for applying consequential life cycle assessments of greenhouse gas emissions caused by changes in the demand for commodities, such as feed raw materials. In Phase 2 of this project, different existing consequential life cycle assessment methodologies may be studied for making guidelines.

4.4.8 Generic recommendations on applying economic allocation for feed products

In general, economic allocation can be recommended for the assessment of carbon footprints of feed products because the value of the different co-products cannot be sufficiently described by a single physical parameter like energy or mass. However, the method for applying economic allocation needs to contain strict rules for commodity production systems and the prices used. It is recommended:

- using ex-mill commodity prices that can be calculated from port prices (FOB, CIF) and transportation costs, or from export statistics when available;
- using five-year averages of commodity prices and mass balances for determining economic allocation factors;
- using input/output analysis of a co-production system where all co-products leave the factory as a commodity, which means that drying and often purification of feed raw materials are considered to be part of the processes to be divided by economic allocation;
- avoiding allocation as much as possible when studying improvement options.

To make economic allocation available to users of the animal feed carbon footprint assessment tool (or people calculating carbon footprints of animal feed), a default database of economic allocation factors would be highly desirable. Collecting consistent prices and mass balances for calculating economic allocation factors will require considerable effort. Only when users of the carbon footprint assessment tool can demonstrate that they have more appropriate economic allocation factors, should they apply them.

4.5 Emissions from land use and land use change

4.5.1 LULUC I: Loss of carbon sink function

In a natural forest ecosystem, fossilization of soil organic carbon takes place at a certain rate. The system stores carbon dioxide from the atmosphere under the earth's surface in anaerobic conditions (preventing oxidation and escape to the atmosphere) for a very long time. If the natural forest ecosystem is converted to cropland, fossilization does not continue. The Dutch Horticulture Protocol takes this effect into account when assessing the carbon footprint of horticultural products. Nabuurs and Schelhaas (2002) estimated the average carbon sink function of natural forests to be between zero and 300 years in Europe at 110 kg carbon, or 403 kg carbon dioxide, per hectare per year.

4.5.2 LULUC II: Change in organic matter

Soils typically have more organic carbon in natural ecosystems than in cultivated systems. Depending on the soil type, the transition from a high level of organic carbon to a lower level can take decades or centuries. Although the rate of decline is probably faster in the beginning, for the purposes of assessing carbon footprints, a constant loss of organic carbon and subsequent carbon dioxide emission can be assumed. If large amounts of organic fertilizer are applied to the cropping system, for example in organic cropping, the rate of decline in organic matter content is probably slower. Carbon dioxide emissions resulting from the change in organic matter content therefore depends not only on the soil type, but also on the cropping system. For conventional and organic cropping systems, 1650 and 1150 kg CO₂-eq/ha respectively can be assumed.

4.5.3 LULUC III: Allocating and modelling greenhouse gas emissions from land conversion

Land conversion from forest to agriculture results in large greenhouse gas emissions, but it is difficult to attribute these emissions to different activities that profit from land conversion. Existing methods like PAS2050 and the EU directive on bio-fuels divide the emissions over all land use activities that follow deforestation over a period of twenty or thirty years. An alternative could be a simple and robust method for dividing the total emissions from land conversion in a country proportionally over all land use activities that actually increase in area, proposed by Ponsioen and Blonk (2009).

Summary of the proposed method for allocating greenhouse gas emissions from indirect land use

In the proposed method, actual emissions from land conversion are allocated to the different agricultural land use activities of which the area is expanding or is actually expected to expand in a country, proportional to the expansion rates. The expansion rates can be estimated by trend analysis of historic data, where the length of the time frame should reflect future projections.

Results from case studies with trends from 20 year data showed that there are large differences in emissions from land conversion between soybean in Brazil and Argentina and likewise between oil palm in Malaysia and Indonesia and are of a different magnitude than emissions from common sources. The emissions from land conversion are 3.6 to 8 times as high as the sum of the emissions from common soybean cropping sources in Argentina and Brazil (respectively) and 0.8 to 2 times as high for oil palm in Malaysia and Indonesia (respectively). Allocation between round wood harvest and agricultural land use activities is not yet taken into account because of incomplete data availability. Based on preliminary information, the attributed emissions to agricultural land use activities could be four to five times lower.

The proposed method is in line with global estimations of GHG emissions from land conversion and combines location and displacement effects in a more appropriate way than existing methods. The presented attributional approach gives producers and consumers insight in current emissions from land

conversion. Scenarios for alternative strategies based on this information should be evaluated in additional consequential LCAs for possible (future) indirect effects.

4.6 Emissions related to feed intake, digesting and excretion (utilization)

4.6.1 Introduction

When calculating the carbon footprint of feed it is crucial to include emissions related to feed utilization, as far as these can be modelled, in relation to a specific feed composition. This requires a large volume of input and default data on feed conversion by animals, husbandry systems and manure management in the country where the feed is used.

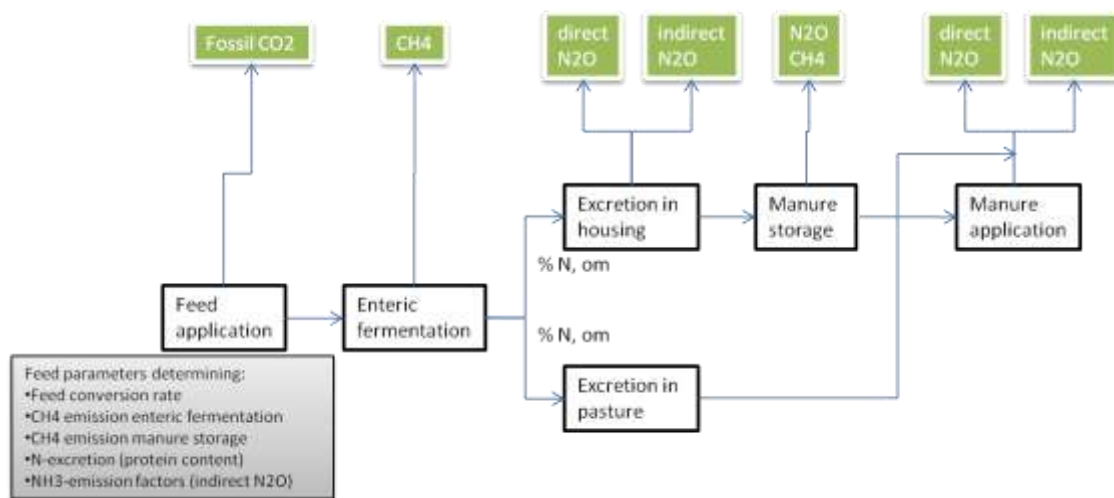


Figure 4.6 Modelling GHG emissions of feed utilization

Figure 4.6 shows a simplified flow chart of the relations between greenhouse gas emissions, feed composition and the processes related to feed utilization. The starting point for a calculation model for feed use in the Netherlands is to define default feed utilization scenarios representative of animal production systems in the Netherlands. The parameters involved are a mixture of technical and management statistics, such as feed conversion rates and other productivity parameters, and applied technologies such as housing systems, manure storage and manure application. Greenhouse gas emissions can be modelled using the interrelationships between feed parameters, technical statistics and farming hardware. In the following sections the outline of a generic model is explored for each activity and recommendations are made for developing an initial method.

4.6.2 Energy use related to feed application

Energy use related to feed application covers on-farm activities for feeding the animals, mostly energy used by machinery like wet feeding systems and tractors. In most case it makes a small contribution to the farm GHG profile. Farm-specific data are hard to obtain because energy use is not usually monitored in detail on farms. Default data are appropriate for most case studies. More specific data only have to be collected if a change in feeding system affects the energy use of feed application.

4.6.3 Methane emissions from enteric fermentation

Methane from enteric fermentation is an important greenhouse gas emission in dairy cow and beef cattle production systems, and to a lesser extent in pig production systems. For these systems and the category 'other animals', the IPCC (2006) provides tables with emission factors per animal by region, average temperature and production. These tables can be used as a first proxy, but because feed composition and feed digestion are only partly included in these emission factors, more precise modelling is required. A good model of enteric fermentation is particularly important for calculating the emissions of ruminants where the contribution of methane emissions in the total GHG profile is high. Tamminga et. al. (2007) reviewed all available models for predicting methane emissions in relation to ration, productivity and cow characteristics (age, breed), which vary from simple static empirical models to dynamic mechanistic models. The empirical model used for calculating greenhouse gas emissions for the GHG National Inventory Report of the Netherlands (Smink 2005) is easy to implement in a carbon footprint assessment tool for animal feed as the results can be used as estimates in calculating the proportion of the carbon footprint of feed that can be attributed to feed use. However, this model cannot calculate methane emissions for different feed composition parameters.

What is needed is a mechanistic model, periodically calibrated and updated, that has the ability to calculate the effects of macro components like carbohydrates and proteins in the ration, and micro components such as feed additives. How this should be linked into the tool is a subject for further research in the follow-up project (Chapter 8). It is unwise to build too much complexity into the carbon footprint from the start, although the models included must be of sufficient quality. The inclusion of the model given in Smink (2005) at least shows the relative contribution of methane emissions according to the Dutch protocol of reporting GHG emissions. Eventually, a dynamic mechanistic model such as the rumen fermentation model of Dijkstra and Bannink (Bannink & Dijkstra 2009) could be linked to the carbon footprint assessment tool, or a derived model could be implemented. How this should be done is a subject for study in the follow-up to this project. A rumen fermentation model is also needed for other ruminants, such as sheep. Methane emissions is a much less important component of the carbon footprint of non-ruminants, and is sometimes insignificant.

4.6.4 Nitrogen excretion and nitrous oxide emissions

Nitrogen excretion can be calculated by subtracting the nitrogen used in animal growth from the production of the nitrogen in the feed intake. According to IPCC and NIR guidance, the *direct nitrous oxide emissions* of excreted nitrogen are 0.1% from liquid and 2% from solid manure. Nitrogen excretion in the field leads to an emission of nitrous oxide of 1% (check). Given the assumed linear relation between nitrogen excretion and emissions from a housing system (solid manure, liquid manure, pasture), calculating nitrogen excretion from feed conversion, protein content in the feed and nitrogen uptake for animal production is important and can be easily integrated into the carbon footprint assessment tool. Average nitrogen content in feed, feed conversion rates and nitrogen uptake for animal production in the Netherlands are published each year by CBS (Van Bruggen 2008). These values can be used in the model as defaults, but for more precise calculations the actual N content of feed and rations must be used in the tool. A recent study by Kool et al. (to be published in 2009) uses this method to calculate the nitrous oxide emissions in relation to feed ration, crude protein content of the ration, feed conversion and housing systems of eight different pig production systems.

The indirect emissions of nitrous excretion are more complex and difficult to calculate since they require knowing how to allocated nitrogen excretion in faeces and urea. In most cases, the indirect emissions related to ammonia emissions make a rather small contribution to the overall carbon footprint. Therefore, simple calculation rules can be sufficient in the carbon footprint assessment tool.

Indirect emissions from field application of manure, for instance during grazing, can make a more considerable contribution via leaching of nitrate. The amount depends on the applied leaching fraction (the default is 30% of nitrogen applied on the field) and the nitrous emission factor, which has recently been adjusted by IPCC (2006) from 2.5% to 0.75% – although the Dutch NIR has not yet adopted this emission factor. Precise modelling of nitrate leaching is rather complex, and a simple model is recommended in the calculation. Moreover, nitrate leaching can only be indirectly influenced by feed composition. However, one may argue that if crude protein content of feed is lowered with no effect on the technical results of animal production, it will result in organic manure with a lower nitrogen content. Since in the current situation organic manure is a valuable source of organic matter and phosphate for arable farming in the Netherlands, field application of nitrogen will be reduced (full compensation with nitrogen fertilizer is not expected on the arable farms due to legal and cost considerations). If the emission factor for nitrate leaching remains 2.5%, consideration should be given to using a more precise model of indirect nitrous oxide emissions from leaching in future updates of the calculation tool.

4.6.5 Methane and nitrous oxide from manure storage

Methane emissions from manure can be calculated using the IPCC method. In this method, two main factors are important: manure management (type and length of storage, cover) and ambient temperature. The IPCC Guidelines 2006 gives defaults for average annual temperature and type of storage. Ouwerkerk (1999) developed a more detailed model in which the methane emissions depend on ambient temperature, storage time and the presence of graft material (old manure which contains methane-producing bacteria). In a recent study by Blonk Milieu Advies and WUR (Kool 2009) a practical method was developed for pig manure based on IPCC guidance (IPCC 2006) and manure storage situations in different housing and production systems (conventional v organic). The modelling in this method is based on feed characteristics such as gross energy, digestible energy, feed conversion, manure type, storage time, storage temperature and climate conditions. This model can be used to calculate emissions in different West European countries.⁹ This type of modelling needs to be extended to other animals.

4.6.6 Single feed versus ration calculations

Animal feed producers often supply only a part of the ration that an animal consumes. This situation can be characterized as a multi-input–multi-output allocation situation, which is well known in life cycle assessment. Waste incineration is the typical example. Physical relationships are the determining factor for the allocation of emissions and revenues, for example from energy production, to the waste components. Some emissions are directly related to the substances in waste, like heavy metals that emit as heavy metal oxide gasses or fossil carbon that emits as carbon dioxide gas and contributes to the enhanced greenhouse effect. Some products like steel or aluminium scrap are also directly linked to the ingoing products. Other less specific emissions and the production of energy, such as NO_x and electricity and heat production, are related to the caloric value of the waste.

The allocation of energy production to the ingoing caloric value of materials is a simplification, which is only valid between a certain range of caloric values, between for instance 8 and 15 MJ (LHV)/kg. Many individual waste components can have a caloric value falling far out of this range, like plastics (35–40 MJ/kg) and household organic waste (2–5 MJ/kg), and can only be incinerated as part of a mixture. The manager of the incinerator is held responsible for maintaining the boundaries for the waste mix to be incinerated.

⁹ The model was needed because the national IPCC regulations on calculating manure emissions were not consistent and unsuitable for calculating differences between housing and production systems (Kool 2009).

The GHG emissions from feed utilization as part of a specific feed can be calculated in a similar way. The composition of the concentrate feed given to dairy cows and other ruminants with a considerable amount of roughage in their ration, or pigs which are mainly fed on wet co-products, deviates from the overall composition of the ration. Calculating the GHG emissions from feed utilization is like the incinerator example – the efficiency of feed conversion is not affected by the specific feed composition of the additional feed. Only if the total ration is known can the effects on FCR of the additional be estimated properly. (Another option is to assume a default composition of the non-supplied part of the ration.)

The best option for the GHG determining parameters in feed is to use the ration values. For example: a) crude protein content, which is related to nitrogen excretion; b) the gross energy and digestible energy values, which are related to methane emissions from storage; and c) the composition of carbohydrates, which are, among others, related to enteric fermentation. However, between certain ranges of application of additional feed in a ration it might be acceptable to presume linear relationships between GHG emissions and these feed parameters. For instance: the nitrogen excretion of dairy cows can be calculated for an average feed application with an average crude protein content and average animal production values and nitrogen content of that production. This calculation results in an overall nitrogen use efficiency. A first proxy would be that this nitrogen use efficiency is the same for both the roughage and concentrate feed in the ration. It is then possible to calculate the effects of differences in nitrogen excretion resulting from differences in crude protein content in feed, which can vary within acceptable nutritive ranges set by the feed formulator. This simplified approach can also be used for calculating effects on enteric fermentation of shifts in carbohydrate composition, based on regression formulas valid for a certain range of feed ration composition and productivity of the cows. See for instance Oenema (2007) for a regression formula for enteric fermentation for dairy cows, which is used by Blonk (2009) to study estimated effects on GHG emissions from enteric fermentation in relation to minimizing the carbon footprint of the raw materials used.

These calculations remain uncertain and can best be used for estimating the effects of the contribution made by feed utilization to the carbon footprint. For studying improvement options it is better to use a more specific model that covers the total ration.

4.6.7 Animal production life stages and GHG emissions of feed utilization

Feed composition, feed digestion, animal production and nitrogen excretion are specific to the life cycle and production stage of the animal. The GHG emissions from the utilization of feed must therefore be calculated specifically for the life and production stage of the animal that consumes the feed. This means that the carbon footprint assessment tool must contain default growth and production models. In the first version of the tool this can be realized by implementing default growth and production models based on empirical data. In future versions more mechanistic modelling might be an option.

4.6.8 Recommendations for a carbon footprint assessment tool

The GHG emissions from feed utilization need to be included because it is a major contributor to the carbon footprint. Calculating these emissions requires a large quantity of default data on animal growth and animal production, production systems, housing systems and manure management. These can be obtained from empirical data that are (or are mostly) publicly available in the Netherlands. Most of the data are regularly updated. Some data are harder to obtain, but these are on aspects that have little effect on the total carbon footprint, such as the effect of improved ammonia-emission-reducing housing systems on indirect nitrous oxide emissions

Using empirical data is sufficient for attributional carbon footprint calculations, but calculating improvement options requires more mechanistic modelling (Chapter 5). It can be questioned whether this mechanistic modelling needs to be incorporated into the carbon footprint assessment tool, at least not in the first versions.

5. Exploring the calculation of improvement options

A carbon footprint assessment is based on an approach that attributes greenhouse gas emissions to a specific animal feed. The assessment is static and descriptive, which means that it sums up emissions from activities and processes that are related to the product; it does not take into account any potential indirect effects of changing those activities and processes. To a certain extent, a carbon footprint can be compared to a company's annual accounts.

This attributional approach could also be used to study changes (improvements) in the animal feed's life cycle by assessing the carbon footprint before and after that change, but there are some limitations. Ideally, the reduction in carbon footprints should be equal to the actual worldwide mitigation in greenhouse gas emissions. However, this is not always the case. A more suitable method for studying changes at global level is the consequential life cycle assessment, which focuses on the marginal effects of a change in production activities and processes. Because a consequential life cycle assessment involves a different type of modelling and input data than the attributional assessment and the results are not comparable, it is not recommended to combine the two in one tool.

The carbon footprint of animal feed can be reduced in many different ways, but the most obvious ways are:

- (1) substitution of feed raw materials;
- (2) changing the origin of crop growing for feed raw materials;
- (3) changing the location where feed raw materials are processed;
- (4) improving existing production chains of feed raw materials (cropping/transport/processing);
- (5) improving the feed conversion rate by altering feed nutritional values;
- (6) reducing emissions related to feed digestion and feed manure emissions by changing feed composition (chemical, physical); and
- (7) using dedicated feed additives.

Because animal feed may contain many raw materials, a combination of the above changes could have the largest impact. To assess the possible indirect effects of shifts in the demand for feed raw materials on greenhouse gas emissions, the scale of these shifts at the national, regional and global levels should be quantified. If the shifts in demand are relatively small, it is probable that the surplus supply will find buyers elsewhere in the market and reserves can satisfy increased demands. In this case, a comparison between the carbon footprints of alternatives is an adequate way to evaluate the effects of changes. If the shifts in demand lead to significant changes in commodity prices, because of price elasticity of demand, certain activities that cause greenhouse gas emissions may be stimulated, for example deforestation for soybean cropping (Searchinger et al. 2008), and other activities may be abandoned. Models that quantify greenhouse gas emissions due to changes in demand for certain commodities are based on future scenarios and elasticity parameters based on statistics; the results should therefore be interpreted with care.

The carbon footprint tool enables users to assess and compare current emissions that are attributed to products. Making changes based on this information can lead to reductions in greenhouse gas emissions if these changes do not lead to indirect emissions, resulting from shifts in commodity demand and supply, that are greater than the apparent reduction. However, quantification of indirect emissions is subject to speculation and is case specific. When making big decisions it is recommended to do an additional exploratory analysis and consequential life cycle assessments in which multiple scenarios and sensitivity analysis are applied.

6. Data needs, data selection and data compilation

6.1 Guiding principles in data use

Foreground and background data

Assessing carbon footprints requires two types of data: foreground and background data.

Foreground data. Foreground data are the specific inputs, such as the composition of raw materials and nutritional values and other physical or chemical properties of the animal feed or ration, and other data that affect GHG emissions from feed utilization, like the type of production (organic or conventional) and the housing system. These data are case specific and should preferably be collected or estimated by the tool's user. If the user is not able to obtain this data, some default values may be used.

Background data. Background data refer to all kinds of emission factors for materials, processes and other parameters required for calculating the greenhouse gas emissions of feed products. Such data are typically not the main concern of the tool's user. These data must be defined and maintained in the background. They must remain consistent with the tool's functionality and this should be managed centrally. Default background data may only be adapted by the tool's user within a reporting framework in which the adaptations are explained.

Theoretically, the most ideal situation is when all data can be collected from primary sources representative of the situation being studied. This requirement can only be set for the foreground data. For background data, it is both unfeasible in practice and not desirable from the viewpoint of managing consistency.

6.2 General outline of the carbon footprint assessment tool

Before exploring data needs and data availability, the architecture of the tool is explained. It was developed with the members of the steering committee of the Animal Feed Product Board (PDV). Figure 6.1 shows the basic dashboard (interface), with the output screen showing the generic results of the tool. User inputs are: functional unit, feed type, animal type, animal live stage and housing type. The feed type needs to be specified in terms of raw materials, nutritional values and other chemical parameters that are important for calculating the carbon footprint of the feed. These data can be read from the results of a feed optimization program, which is assumed is available to the users of the carbon footprint assessment tool. One of the functional requirements of the tool will be the ability to easily import feed optimization results.

Other inputs that the user could use are choices regarding alternative methods. For instance, the emission factors for methane and nitrous oxide can differ depending on IPCC guidelines and insights into animal utilization emissions. Economic allocation may be switched to allocation on energy content, and system boundaries for manure application can be changed. The philosophy behind these methodological choices is that consensus is still lacking on some issues and they allow different methods to be used to answer queries from third parties. The tool must therefore be able to calculate results according different methods.¹⁰ Finally, the user can choose different background data and store their own feed datasets into the tool.

¹⁰ In the results, best practice method results are given next to the results based on the specific method asked for. At the moment some third parties may ask for economic allocations compliant with the PAS2050 guidelines, while others ask for allocation on energy content of raw materials compliant with the EU bio-fuels directives.

Dashboard feed CO₂-footprint tool

Show animal feed characteristics

Show feed ingredients

Show output

Input: system selection		Input: method/data	
Functional unit	growth 1000 kg	Methods	Method
Animal species	Main selection: Pigs Comparison selection: Pigs	Nitrous oxide/methane emissions	Best Practice
Animal life stage	Fattening pigs (>12 weeks) Fattening pigs (>12 weeks)	Allocation rules	Energy content
Feed type	Example with defaults Mix with soy USA	System boundary	Included manure o
Husbandry system	Conventional housing Conventional housing	Data	Reference data
	Go to feed composition Update results	Animal feed composition data	Reference data
		Background data animal feed	Reference data
		Background data animal production	Reference data

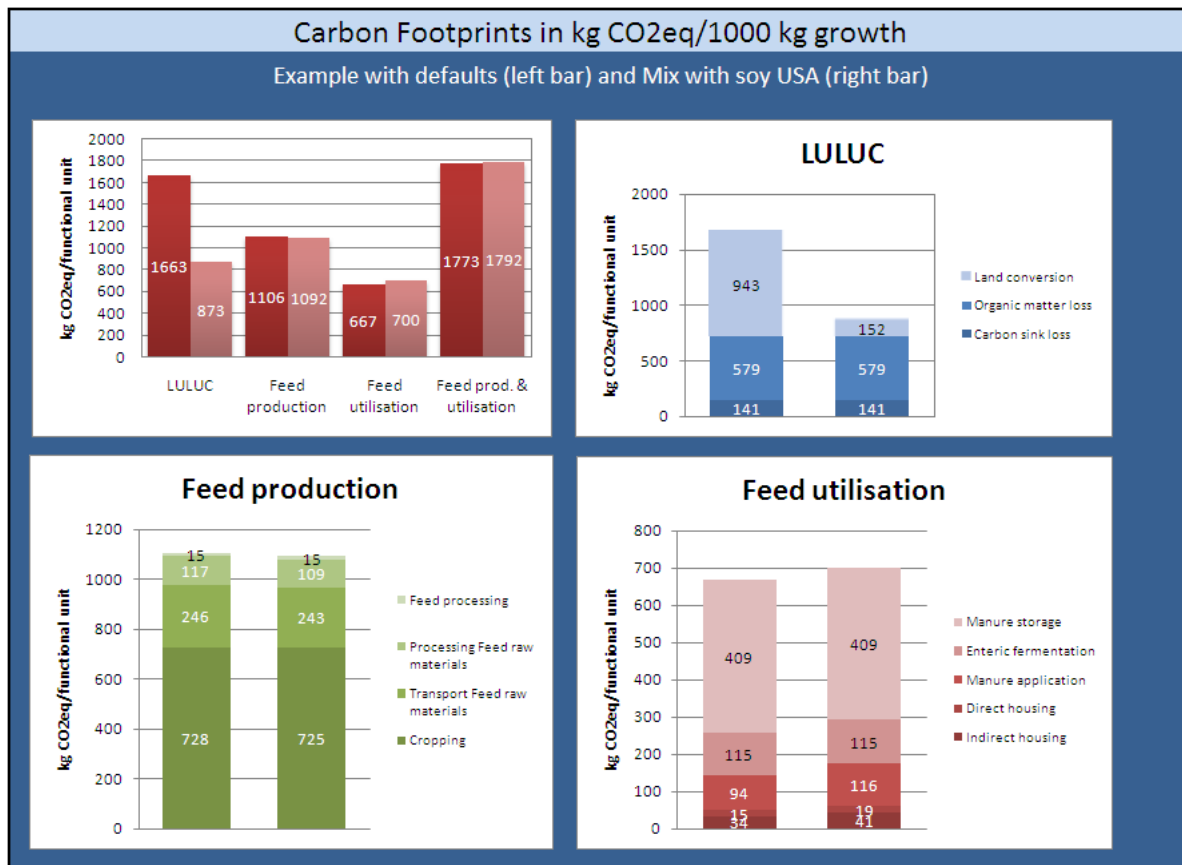


Figure 6.1 The user interface of the tool

The user must be able to calculate the footprints of different feed products for comparison. The output screen displayed in Figure 6.1 illustrates the most important results. Figure 6.1 shows only a part of the functionality of the tool, but is the entry point for understanding the underlying data needs and data management questions.

A more schematic functional representation of the tool is given in Figure 6.2. The carbon footprint assessment tool is supplied with data from two sources: the feed optimization tool and the background database. The feed optimization tool generates the required feed composition data; the background database consists of parameters like emission factors for crop and animal production processes (such as direct and indirect nitrous oxide emissions), and for material (fertilisers, pesticides, auxiliary inputs for crop processing, et cetera) and energy (electricity, natural gas, diesel, et cetera) production, and global warming potential values for normalising methane, nitrous oxide and other greenhouse gas emissions to

carbon dioxide equivalents. The background database also includes the results of empirical modelling of feed utilization data, housing systems and manure storage systems. The core units in the background database are the method-dependent calculation rules.

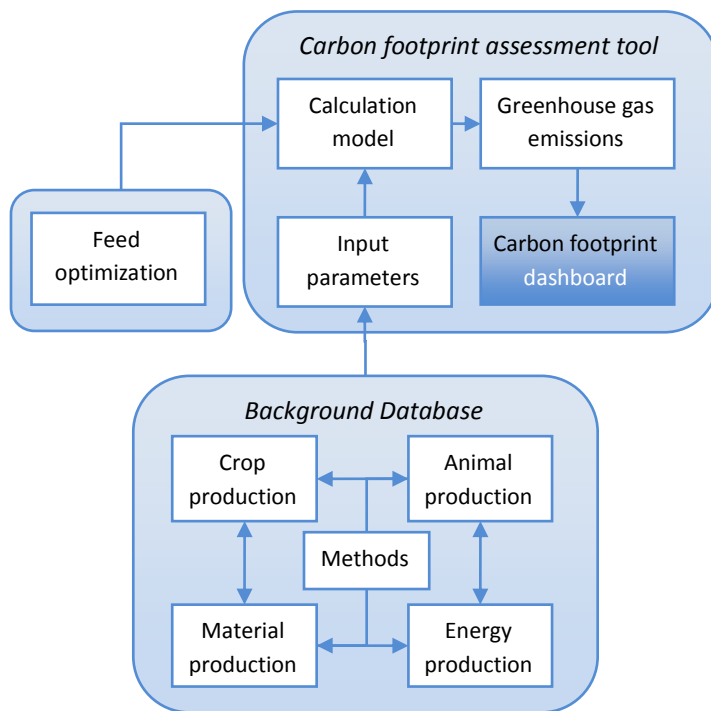


Figure 6.2 Data flows in the carbon footprint assessment tool

6.3 Gathering and calculating background data

6.3.1 Calculating background data

Most background data are based on well defined methods and the most suitable data sources available. The method and the required data need to be defined in a carbon footprint protocol for feed which complies with other protocols like PAS2050 and the EU bio-fuels directive. The interrelationships between different data sources and methods can be illustrated by the greenhouse emissions from the application of CAN (Calcium Ammonium Nitrate) fertilizer as a source of nitrogen in a cropping system. The GHG emission score per kg applied nitrogen in CAN fertilizer is built up as follows:

1. Direct nitrous oxide emission per kg applied nitrogen is 0.01 kg N₂O-N according to IPCC (2006), equivalent to $(44/28) \cdot 0.01$ kg N₂O per kg nitrogen, or $296 \cdot (44/28) \cdot 0.01$ kg CO₂ equivalents per kg nitrogen, based on the GWP100 factor (IPCC 2006).
2. The indirect nitrous oxide emission from nitrogen use is a result of ammonia volatilization and subsequent deposition and nitrate leaching. The leaching fraction in IPCC 2006 default for TIER 1 calculations is 0.30 kg nitrogen per kg applied nitrogen, but more specific approaches are allowed. The nitrous oxide emission factor for leached nitrogen was recently changed from 0.025 kg N₂O-N per kg nitrogen (IPCC 1996) to 0.0075 (IPCC 2006), bringing total emissions via leaching to $296 \cdot (44/28) \cdot 0.30 \cdot (0.025 \text{ or } 0.0075)$ kg CO₂ equivalents per kg nitrogen. This change has not yet been adopted by any West European national inventories. The Dutch organization responsible for the national monitoring reports is not sure whether or when this adaptation will be implemented (PBL 2009, personal communication).

3. Different data sets are available for the GHG emissions from the production of CAN. The Ecoinvent data seem to be the most complete, but include capital goods, which is not consistent with PAS2050 guidelines (BSI 2008). A closer look at the Ecoinvent data reveals that they are mainly based on the inventories by Davis and Haglund (1999), who added more recent data on energy production in Europe. In the near future, Ecoinvent aims to make their data available in tailor-made forms by using different allocation methods and system boundaries to ensure maximum consistency with user requirements.

As the example of CAN fertilizer shows, three data sources are important: (1) IPCC 1996 and 2006 data for global warming factors over 100 years, and for emission factors; (2) background data of the Dutch national inventory reports on GHG emissions (which are a further specification of IPCC guidelines); and (3) LCA databases, which are actually a combination of industry data and energy data from different sources, such as IEA and OECD.

Links between the data sources can also be found for other widely used materials like packaging materials, other fertilizers and materials in cropping and processing. In addition, many required farming and feed processing data are country specific.

The data needs and the sources where data can be collected are listed in Table 6.1. The overview is designed primarily with the feed industry in mind, as the primary user of the tool. As the table shows, the amount of foreground primary activity data needed for calculating the carbon footprint of an animal feed is low compared to the large amount of background data.¹¹ The background data come from diverse sources, including several international and national statistics databases of varying reliability; for example, FAO statistics on crop yields and fertilizer use per crop contain odd or inconsistent data. Some databases are periodically updated and others are not, although the latter could still be relevant. Few statistics on manure application and liming are available, although some countries provide this information in governmental publications (e.g. the national inventory reports on GHG emissions).

Farming data are more publicly available than processing industry data, such as energy use by crushers, the starch industry and the milling industry. Data can be found in international publications, for example on generic LCA and specific greenhouse gas LCA studies. The European Union's promotion of bio-fuels has led to the publication in recent years of large volumes of data on GHG emissions from bio-fuels in comparison with fossil fuels. Many of these are key publications that bring together various industry data, examples being the soybean biodiesel study by Sheehy et al. (1998) and the corn wet milling study by Galitsky et al. (2003). The problem with these 'single point bases' is that it is hard to determine the representativeness of the data. Another striking finding from studying LCA studies and LCA databases is that when economic allocation is used little attention is paid to deriving and updating the economic allocation factors. There is little or no evidence of applying average prices over some years and of using clear and consistent price definitions, as recommended in this study. Poor price data can have a major effect on the results.

¹¹ If the tool were used by a farmer or a processing industry, the need for primary activity data would be different.

Table 6.1. Exploration of the data needs of the carbon footprint assessment tool and available sources (feed factory perspective)

	Importance for GHG Results	Origin of data
Agriculture		
Vegetable raw materials		
Crop production (location specific)		
Yields of all co-products (tonne/ha)	Very high	FAO/Eurostat/National statistics/Agroeconomic handbooks
Crop residue ratio	High	IPCC, scientific literature
Farm gate prices of all co-products (\$/tonne, €/tonne, or other currency)	High	National statistics / FAO prices
Manure use (kg/ha and kg N/ha)	High	National statistics
Nitrogen fertilizer use (kg N/ha)	Very High	FAOstat/Eurostat/National statistics
Phosphate fertilizer use (kg P ₂ O ₅ /ha)	Low	FAOstat/Eurostat/National statistics
Potassium use (kg K ₂ O/ha)	Low	FAOstat/Eurostat/National statistics
Use of limestone (kg CO ₃ /ha)	Moderate	National statistics / IPCC-NIRs/ literature
Electricity use during cropping (kWh/ha)	Moderate	Scientific literature
Diesel and other oil fuels used during cropping (kg/ha)	Moderate	National statistics/ Scientific literature/ IPCC-NIRs/ scientific literatures
Burning of field crops	Moderate	
Transportation of agricultural products to processing or to feed mixing (if no processing)		
Transport distance	Moderate	Internet sites and logistics tools/feed companies
Mode of transportation	High	Internet sites and logistics tools/feed companies
Load factor	Moderate	Internet sites and logistics tools/feed companies
Processing (location specific)		
Mass of co-products per tonne crop product (tonne out /tonne in)	Very high	Sc. literature/ Queries / National statistics/ Queries /Feed industry calculation / Internet sites/Logistic tools
Received prices of all co-products (\$/tonne, €/tonne, or other currency)	Very High	
Electricity use during processing (kWh/tonne in)	High	Sc. literature/ Queries /LCA databases
Diesel or other fuel oils use during processing (kg/tonne in)	High	Sc. literature/ Queries /LCA databases
Natural gas use during processing (m ³ /tonne in)	High	Sc. literature/ Queries /LCA databases
Use of other material inputs	Low	Sc. literature/ Queries /LCA databases
Animal raw materials		
Dairy products	Very High	Sc. literature/ Queries /LCA databases
Animal fats	High	Sc. literature/ Queries /LCA databases
Animal/fish meals	High	Sc. literature/ Queries /LCA databases
Transportation of raw materials to secondary processing or to feed mixing (if no secondary processing)		
Transport distance	Moderate	Primary activity data
Mode of transportation	Moderate	Primary activity data
Load factor	Moderate	Primary activity data, IPCC default/ horticult. default
Feed mixing in feed factory		
Feed composition	Very high	Primary activity data
Electricity use during processing (kWh/tonne in)	Moderate	Primary activity data
Diesel or other fuel oils use during processing (kg/tonne in)	Moderate	Primary activity data
Natural gas use during processing (m ³ /tonne in)	Moderate	Primary activity data
Transportation of feed to farm		
Transport distance	Low	Primary activity data
Mode of transportation	Moderate	Primary activity data
Load factor	Moderate	Primary activity data, IPCC default/ horticult. default
Feed utilization Livestock farming Netherlands		
Ration on farm level	Low	LEI-BIN database/ Feed industries
Feed conversion rate	Very high	LEI-BIN, Agrovision other management systems
Housing system	High	Studies, Government publications
Methane emission factors	Very High	NIRs/ Sc. literature
Nitrous oxide emission factors	Very High	NIRs / Sc. literature
Production of materials and energy		
Materials production	High	LCA databases, industrial data
Energy production	High	IEA/OECD, National statistics, LCA databases

In recent years, several institutes have developed databases on feed raw materials, including SIK in Sweden, Blonk Milieu Advies and WUR (Animal Production Systems) in the Netherlands, and FAT in Switzerland. The database of Blonk Milieu Advies is relatively extensive and contains public data and industry data. The public data are comparable with FAT data and SIK data on feed raw materials. At first sight, the SIK and FAT data seem less extensive and more nationally orientated. A more detailed evaluation of these data and a comparison with the Blonk Milieu Advies data was not part of this phase of the project. Comparison with the WUR data is not possible because these are not publicly available.

Current sources for background data and background modelling on feed utilization are quite diverse. Several WUR departments have developed models for calculating emission factors (in particular methane and nitrous oxide emissions) for feed digestion and housing systems. They are also involved in the reporting process for the Dutch national inventory reports of GHG emissions managed by the Netherlands Environmental Assessment Agency and IPCC working committees. However, they have not yet adapted these models for use in calculating GHG emissions from animal systems. Progress has been made for dairy products by the Department of Animal Production Systems at WUR, which has done much work on LCA modelling of dairy farms (De Boer and Thomassen 2008).

Blonk Milieu Advies and several WUR institutes (Animal Science Group, PPO, LEI) are now working on a methodology proposal for assessing carbon footprints of pork production. This study will develop an integrated model for calculating nitrous oxide and methane emissions of husbandry based on feed input.

6.3.2 Data gathering and data maintenance: realizing a database for background data

The background data required for the carbon footprint assessment tool come from several data sources and must be compiled using a transparent and consistent method. Data organization and data source selection was also a major topic in the development of the GHG calculating tool for Dutch horticulture (Blonk et. al. 2009). For that project, a custom made background database was developed by combining the most adequate data from public data sources. This database needs to be updated regularly (once a year). The same strategy can be followed for feed data. It is advisable to start by further exploring the databases in the Netherlands, Switzerland and Sweden mentioned above and design a strategy for developing an internationally accepted database. Co-operation between international institutes is recommended.

A database for assessing carbon footprints of feed that can easily be updated can be developed by:

1. outsourcing the database development and maintenance to a third party that guarantees quality and independence;
2. developing a database internally, with maintenance by PDV and verification by an external party;
3. developing a database internally, with maintenance by an industry organization (Netherlands, Europe) and verification by an external party;
4. combining the three options above.

These options will be further specified in Phase 2.

6.4 Implications of the need for a background database for developing a carbon footprint assessment tool for animal feed

Developing and maintaining a background database is both a challenge and a risk, and requires considerable effort, preferably a joint effort by several institutes in the EU. Without these data, the carbon footprint assessment tool is of little use and it would only be used by those companies that are able to arrange the necessary data collection. Most would probably not make such an investment because public acceptance of the results (including market parties) can only be achieved by transparency and/or third party verification. The definition and collection of background data has to be of sufficient quality and done in parallel with the development of the carbon footprint assessment tool. Insufficient quality or insufficient acceptance of the database can be a serious risk.

Some sectors, have successfully developed their own databases, which have been widely accepted. Examples are the plastics, steel and aluminium industry, which have been successful in disseminating their data. The case of the plastics industry is particularly encouraging (Box 6.1)

A major challenge facing the further development of the carbon footprint assessment tool for animal feed is the compilation of authoritative background database to accompany the carbon footprint assessment tool and method. The database can have a long useful life and act as a central distribution point for environmental data, which is crucial for supplying sound data for scientific research and for use in the public domain.

Box 6.1: Environmental data dissemination by the European plastics industry (Source: Blonk & Luske 2008)

Plastics were a major environmental concern in the late 1980s and early 1990s. After a period of denial, the plastics industry responded in three ways. First, they drew up eco-profiles for the most important plastics produced in Europe. These profiles contain representative average environmental figures for the European industry and were compiled by an expert consultant, Ian Boustead. The method and the compilation of the figures is well documented and sufficiently authoritative for the scientific community. The figures have been included in the Ecoinvent LCA database, which is the most consulted dataset for LCA in the world. This is remarkable since the allocation rules applied in the dataset provided by the plastics industry is not fully consistent with the other data in the Ecoinvent database. Despite this, the data are considered to be the best and most reliable for plastics production.

Second, the plastics industry commissioned several studies that compared the environmental impacts of plastics and alternative materials over their total life cycle. These studies showed that, from a life cycle point of view, many plastics applications were preferable to alternatives. This helped to alter the way plastic packaging and plastic bags are viewed, at least among experts and decision makers.

Third, they built a website where the curious investigator or stakeholder can find environmental information about plastics. Most environmental scores are freely accessible and the method applied is well documented and downloadable. Data and background documents are regularly updated.

7. Inventory of international initiatives

While writing this report, several international initiatives became publicly known. A selection from these initiatives that are considered to be the most important are reviewed in this chapter, which was last updated in August 2009.

7.1 Carbon footprint protocol development

Within the methodological framework for assessing carbon footprints there are two important international protocols being developed with a global scope:

- WRI/WBCSD standards for
 - 1) product life cycle accounting and reporting guidelines;
 - 2) corporate level value chain accounting and reporting guidelines.
- ISO 14067 standard on the carbon footprint of products; this standard will consist of two parts:
 - 1) Part 1 on the quantification of greenhouse gas emissions related to production;
 - 2) Part 2 on communication.

Both standards are expected to be completed before 2011. The WRI/WBCSD standards are due to be ready at the end of 2010. The organizations are closely coordinating the development of their standards and the ISO standards are expected to be more generic than the WRI standards.

The WRI/WBCSD and ISO14067 standards have, by nature, a higher status than the BSI's PAS2050, which is the starting point for the development of this carbon footprinting tool. However, WRI/WBCSD aim to standardize, harmonize and build on parallel initiatives such as BSI/Carbon Trust/Defra and ISO. WRI/WBCSD embraces the challenge of establishing strategic partnerships with these and other industrial or other initiatives and plays an important role in facilitating information flow and promoting synergies between the various initiatives. With Carbon Trust and Defra represented in the WRI/WBCSD Steering Group, the latter is in the position to learn from the experience gained so far in the use of PAS2050.

Defra, BSI and Carbon Trust will all promote further use of the PAS2050 standard in sectors and companies. This may result in the development of sector-specific carbon footprint protocols, which has been done by some companies and is taken into consideration by the Dutch Commodity Board for Horticulture (PT 2009, personal communication). Further specification and adoption of the PAS2050 by sectors makes it a promising initiative. Representatives from the three British promoters (Defra, BSI and Carbon Trust) also joined the recently launched carbon footprint assessing initiatives in Germany (PCF-Product Carbon Footprint pilot project) and France.

The PCF pilot project in Germany seeks international harmonization. The project committee argues that cooperation between WRI, ISO and BSI is of utmost importance for the long-term acceptance and applicability of GHG standards. The project is represented in both the steering group and the working groups of WRI/WBCSD and also cooperates with ISO. At this stage the PCF pilot project does not intend to introduce a carbon footprint label; its focus is on defining a set of basic requirements which an information instrument should meet. The PCF project will probably result in a set of guidelines.

7.2 Initiatives in assessing carbon footprints of feed and food

Carbon footprint labels could be found on products or in corporate communications before any protocols had been drawn up. Three types of carbon footprint labels can be distinguished: (1) labels that

give an actual GHG emission score; (2) labels that give benchmark information (claiming the product is better than competitors); and (3) carbon dioxide neutral labels. Labels can be developed by companies or third party organizations. Here, only European labels from the first two categories are described.

Lantmännen's carbon feed label (company, label)

The animal feed division of Lantmännen Group in Sweden has introduced a carbon feed label for its animal feed. Lantmännen, which has a market share of 70% of animal feed production in Sweden, computes the greenhouse gas emissions from crop production to manufactured feed. Regional specific average data on crop production and data on transport and milling processes form the basis of the life cycle assessment. For each feed formulation, the carbon footprint is estimated and expressed in grams 'predicted' carbon dioxide equivalents per kg animal feed. Lantmännen now calculates the emissions of all its manufactured feed and these values are included in the invoice. The Group aims at refining the system and gaining a better insight into expected emission values and variations before it can define emission reduction goals. So far Lantmännen has introduced a consumer label only for chicken meat.

Climatop (third party, benchmark)

The consumer oriented label 'Climatop' was created to make the most climate preserving products visible. Products emitting at least 20% less CO₂ than their substitutes can obtain a licence, which is valid for two years. The basis for the computations is a life cycle assessment. The label is still in its pilot phase. French asparagus, sugarcane, cream and several non-food items are currently being evaluated in case studies (www.climatop.ch).

Bilan CO₂ E.Leclerc (company, label)

Bilan CO₂ is a for-profit initiative by E.Leclerc (two stores), with assistance from 'Greenext' and 'Energie Demain'. This business-to-consumer label for food products produced by E.Leclerc declares the number of CO₂ equivalents emitted during a product's life cycle.

L'Indice Carbone Casino (company, label)

Groupe Casino is the body behind the Groupe Casino Indice Carbone initiative, under which 33 different food products have been certified. The business-to-consumer products are given a label showing the amount of CO₂ equivalents emitted from cradle to farm gate.

Carbon Trust carbon reduction label (third party, benchmark)

Carbon Trust consumer labels are evaluated using a full life cycle analysis based on PAS2050 guidelines. Consumer food products carrying the Carbon Trust label are currently potatoes, crisps, orange juice and smoothies. The label shows the CO₂ equivalents emitted within the stages of the system boundary.

Sainsbury certified Carbon Trust UK milk model (company, verified carbon dairy model)

Sainsbury's have launched a scheme that will help dairy farmers estimate their carbon footprint and aims to reduce greenhouse gases by up to 10%. The scheme is the first carbon footprint assessment model in agriculture to be certified by the Carbon Trust. White Gold (part of AB Agri) have done audits compliant with PAS2050 on 325 Sainsbury's Dairy Development Group (SDDG) farms.

Carbon Conscious Product Label (third party label)

The Climate Conservancy is a non-profit organization founded by scientists at Stanford University. This label shows the grams of CO₂ equivalents emitted per dollar of product. The LCA method follows the GHG protocol by WRI and WBCSD.

Tesco

The British retailer Tesco began carbon labelling their products in 2007. The calculations for the labels are based on the PAS2050 protocol, then being developed by The Carbon Trust, Defra and BSI British Standards. At the beginning of 2009 Tesco had carbon labels on more than 100 products and is aiming to do this for 500 products by the end of the year. Tesco's ambition for 2020 is to reduce the sum of the carbon footprints for its products which were calculated in 2009 by 30%.

French Environmental Round Table

France's Environmental Round Table, which was instigated by President Sarkozy, aims to create an 'pedagogical portal on the environmental impact of products', including information on carbon footprints. One of the measures listed in the Round Table's 'Energy efficiency and carbon' programme is to have carbon labels on products sold by the major retailers. The measure should be in place by the end of 2010, just before the French legal requirement for product packaging to contain environmental information comes into force in 2011.

7.3 Recommendations for developing the carbon footprint assessment tool

Protocol development and labelling initiatives are developing rapidly in several European countries. In 2007 several British supermarkets, especially Tesco, began quantifying GHG emissions of products, aiming first to provide consumer information on product labels. These initiatives prompted the development of a protocol by BSI (PAS2050), which was issued in November 2008. In countries like Sweden, Germany and France other labelling initiatives are being developed. In the United Kingdom, it looks like there is now a shift in focus from labelling to carbon footprint management of supply chains. The first certified tool for assessing and benchmarking agricultural products has been launched in the United Kingdom by the retailer Sainsbury's.

The British initiatives on carbon footprint labelling, carbon footprint supply management and carbon footprint protocol development are expected to remain at the forefront next year. The Dutch Commodity Board for Horticulture picked up on these initiatives in an early stage and wants to achieve a joint development of the PAS2050 with regard to horticulture. Other countries, such as France, Germany and Sweden, are catching up and will become more important players in this field. They are expected to follow a similar development route, first focusing on labelling and then shifting to encouraging GHG improvement options with suppliers

The Swedish company Lantmännen initiated the development of a Swedish method and database for assessing carbon footprints of feed and animal products. It is unsure whether labelling will be the strategy for the longer term, however the work by SIK on assessing carbon footprints of feed which is publicly available is a valuable input for the further development of the carbon footprint assessment tool.

The PAS2050 is still a solid starting point for the future development of the carbon footprint assessment tool, but a link to other protocol (WRI/WCSBD) and database initiatives (SIK Sweden) is recommended.

8. Developing a carbon footprint assessment tool

8.1 Definition of users group

Users of the carbon footprint tool are professionals with a broad knowledge of the feed production chain and feed utilization who want insight into the contribution by feed production and feed utilization to the greenhouse gas effect. These professionals could be working in or for the following sectors:

- Feed production industry (concentrates) and premixes
- Processing agro-industry (grain milling, oilseed crushing, bio-fuel industry)
- Animal husbandry and production industry (cattle, swine, poultry)

8.2 Users requirements

An inventory of users requirements was made from a survey of representatives from feed and feed raw materials companies. Demonstration versions of the tool were presented and evaluated in three workshops.

User requirements survey

The agricultural economics research institute LEI-WUR surveyed the user requirements for the carbon footprint tool among representatives of the following industries: compound feed producers, premixers, calf milk powder producers, wet feed producers, suppliers of feed raw materials (crushers, starch producers and dry milling). The project steering committee evaluated the results and formulated conclusions and recommendations.

The conclusions from this inventory of user requirements were the following:

- The information that becomes available from the carbon footprint tool should give insight into the different emission sources at the supply chain level as well as at process level.
- The tool should enable two types of use: 1) it should be easy in use to obtain quick data and an overview of the most important emission sources within a product chain; 2) it should enable more advanced assessments of improvement options that require more user knowledge.
- The tool's results should be used mainly for internal evaluation of existing products and improvement options, and for communication between businesses within the production chain.
- The sets of default input data should be from reliable sources and undisputed. The users should be able to add data and make them anonymously available to other parties after validation. A party or group of parties (within or outside PDV) should be responsible for data management and quality control.
- The tool's results should be reliable and of good quality.

The recommendations from the inventory of user requirements were the following:

- The methods for the tool's calculation rules should be in line with other European initiatives for assessing carbon footprints of agricultural products and should be internationally accepted.
- The tool should enable calculations for average products and for company-specific products. This will require a more detailed inventory of the user requirements of possible user groups.
- The tool should be based mainly on existing data and information on calculation rules. The default data should be complete and possibly linked with existing databases and initiatives.
- The calculation rules and default data should be transparent. Further analysis is required to analyse the possibility (of spreading results to parties other than PDV members)

- The primary objective of the carbon footprint tool should be to identify options for reducing greenhouse gas emissions at company and supply chain level and for communication between businesses. This implies that besides carbon footprints of animal feed and feed utilization, the tool should be able to assess changes in the supply chain.

To be able to comply with all user requirements, the tool will have to include a large volume of default data and calculation rules. Effective documentation and other communication will therefore be crucial. The majority of the interviewees intend to use the tool for internal use only. Whether and how results should be communicated externally was not part of the inventory and will be decided after Phase 1. We recommend including relevant parties within the sector in the tool's development process to create wider support.

Results of the development and evaluation of the demonstration model

Two workshops with the project steering committee and one workshop with an extended group of possible users in the feed industry were held to elicit more understanding of the functional requirements of the model. The results can be considered as a functional design for use as a source of inspiration in the follow-up process and a starting point for the actual development process. The results of the survey of stakeholders were also used in this design. Although not every element is shown in the example screen, the full functionality is explained in the text.

The demonstration tool consists of an input screen (the dashboard that enables the user to define the feed to be studied, the data and method to be used) and four output screens presenting the results, which consist of:

- an overview of results to give an initial understanding of the carbon footprint and the contribution by different processes and emission sources;
- an overview of feed composition and specific feed and system parameters, which are important parameters for the carbon footprint;
- a feed raw materials screen that shows the breakdown of the GHG emissions per feed raw material;
- an improvement options screen that enables the user to define and calculate several improvement options, to the extent possible within the tool.

The input and output screens are displayed together to give the user a direct response when changing input parameters. Both the input and output screens are for analysis of the carbon footprint of feed production. The carbon footprint tool will also be equipped with a default reporting option.

Input screen and overview results (show data)

The input screen enables the user to select the functional unit, the animal feed or ration, the animal species, breed and phase of life, and the production and housing system.

The functional unit can be the carbon footprint per tonne of feed, which does not include feed utilization, or per tonne of animal product, which includes feed utilization. For animal feed producers, the greenhouse gas emissions from feed utilization is important because animal feed characteristics can have large effects on those emissions. Animal producers or users and processors of animal products, however, have much more information about the animal production systems, so they might need a different functionality from the tool. The functional unit per tonne of feed could be used in communication

between animal feed producers and animal producers, so that animal producers can use own data and additional information of the animal feed to calculate the carbon footprint of their products.

In the input screen, different combinations of feed type, animal species/breed/phase of life and husbandry system can be selected. Comparing different animal species/breed/phase of life will generate differences in technical performance (feed conversion rate), which affects the greenhouse gas emissions from digestion and manure management. The husbandry system can be conventional or organic, housing type and manure management system. The demonstration tool includes the following systems:

- conventional, without ammonia emission reduction measures
- conventional, with average ammonia emission reduction (standard 2008)
- conventional, complies to the ammonia emission standard of 2011
- conventional, with air washer
- organic

These options should suffice for carbon footprint assessments. In other versions of the tool, this list could be expanded to include a more complete list of housing and grazing systems.

From the input screen, the user can access the animal feed composition sheet, where the animal feed types can be defined. Primary activity data from feed producers (energy use and transport) and feed conversion rates (affecting methane emissions during feed utilization) can be added to the feed composition sheet by changing the default values.

The users of the tool can also choose different methodological options and background datasets (Chapter 6). These options can be used for comparison with the default method and data, and for communication with third parties that use other defaults.

The first output screen shows the total carbon footprints broken down into the three most important categories:

- Feed production (from raw material production to the animal farm gate)
- Feed utilization (from feed digestion to manure application)
- LULUC (land use and land use change related emissions)

There are currently two methods for including LULUC emissions in life cycle assessments: the method in PAS2050 for carbon footprints, and the method by Searchinger et al. (2008) for consequential assessments (Ponsioen and Blonk 2009).

Output screen: feed characteristics

Figure 8.1 shows an overview of animal feed characteristics and system parameters relevant for the calculated carbon footprint. This screen gives the user information, in combination with the results in the output screen in Figure 6.1, that is needed to explore improvement options. In the example, the nitrous oxide emissions were about 150 kg CO₂-eq per tonne of pork production, compared with total greenhouse gas emissions of 680 kg CO₂-eq from animal feed utilization. The nitrous oxide emissions are linearly related to the protein content of the animal feed. The user can change the feed composition to a feed with a lower protein content and calculate the difference in carbon footprints of the two feeds.

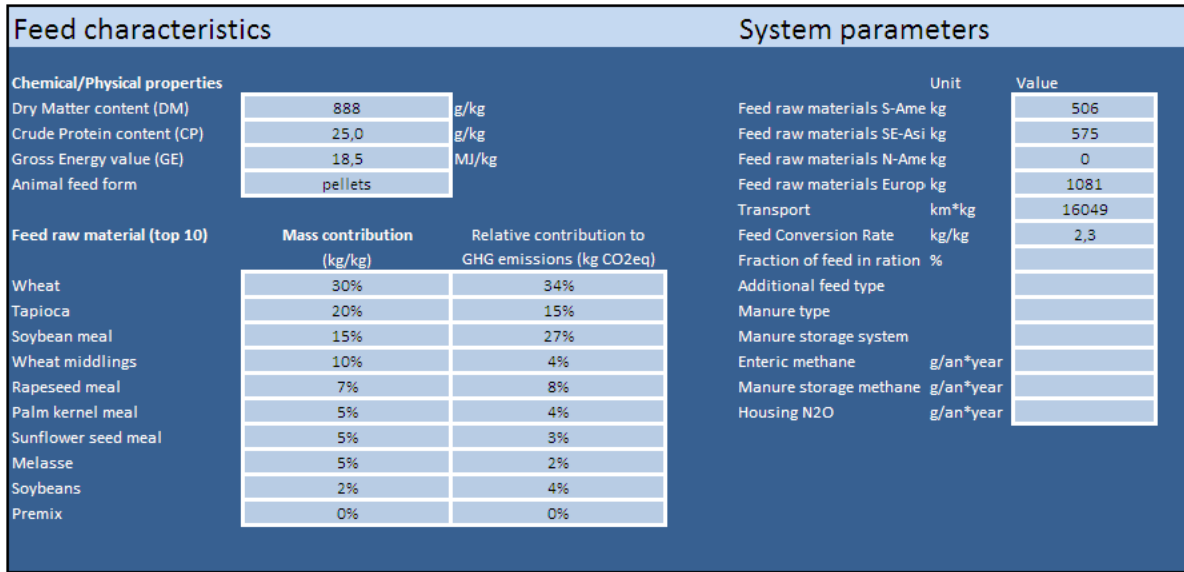


Figure 8.1 Output screen: feed and system characteristics, origin of raw materials and distance, and animal system parameters

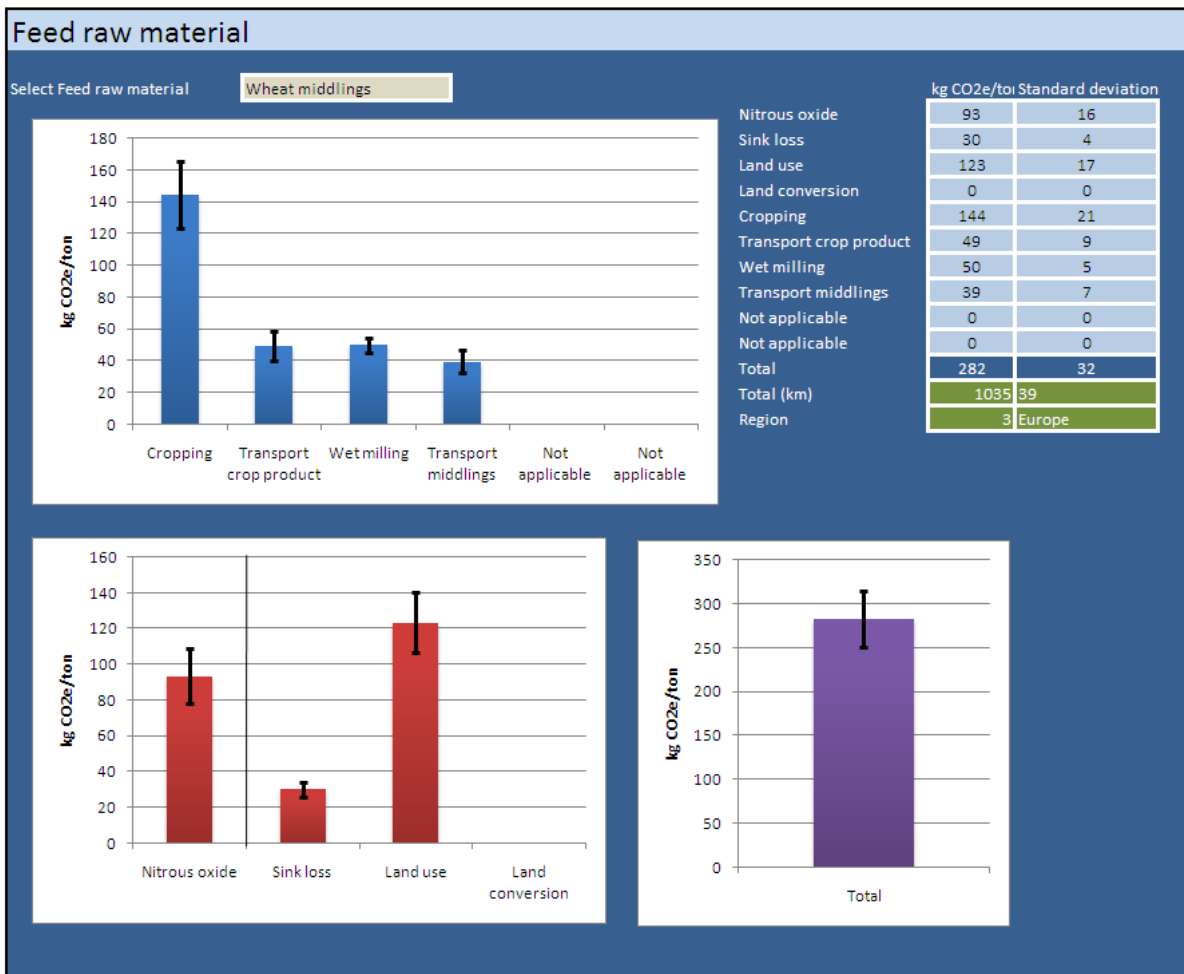


Figure 8.2 Output screen: feed raw materials

In new versions of the tool the feed characteristics and system parameters screen can be extended to include other outputs, characteristics and parameters. For example, the demonstration tool shows the

relative contribution to greenhouse gas emissions made by each feed raw material. This can give the user quick information for determining improvement opportunities. On the other hand, these results need to be interpreted with care using the more detailed results per raw material.

Output screen: feed raw materials

The output screen with the carbon footprints of the feed raw materials and some components of the carbon footprints enables the user to study the results per raw material in more detail (Figure 8.3). The demonstration tool shows the statistical uncertainty of the results per feed raw material. In subsequent versions the uncertainties can be quantified for all results.

Communication of the results

A standard form of communicating the carbon footprint assessment tool's results could prevent misinterpretation by users or third parties. All users should be able to interpret the data input and the results. A consensus should be found for a standard before launching the tool for general use.

8.3 General outline of the development process

Development process

The carbon footprint assessment tool consists of the carbon footprint dashboard, the calculation rules and the background database (the feed optimization software is part of the framework for supplying feed composition and characteristics, but is not part of the tool). These three parts are linked to each other, but their developments depend on different factors – the dashboard depends on user requirements, the calculation rules depend on developments in scientific insight, and the background database depends on data sharing and collection effectors by producers, scientists and researchers – making it likely that some parts will change more rapidly than others. We therefore recommend that updates should be specific for each of the three parts.

Development and maintenance of the background dataset

Because the background dataset needs to be complete, up to date and internationally validated, we recommend that an international consortium of institutes is responsible for developing and maintaining the database. Potential member institutes that are experienced in the field could be Ecoinvent (international life cycle database managed in Switzerland), SIK (Swedish institute for food and biotechnology), Blonk Milieu Advies and Wageningen UR (Crop and Animal Production Science). How such a consortium would be structured needs to be investigated.

Development of the carbon footprint assessment dashboard

The demonstration carbon footprint assessment tool and the inventory of user requirements can be used as a starting point for developing the first version of the dashboard. The technical design will need to be developed in more detail at the start of Phase 2 before making this first version.

Planning the tool development

Developing a carbon footprint assessment tool involves several parallel and interlinked activities. Three streams of activities can be distinguished: further methodological development and consensus building on some specific topics like LULUC and allocation; developing a first version of the carbon footprint assessment tool; and database development. Decision and evaluation moments need to be defined, at which further development can be stopped or continued in a certain direction. These moments should be chosen so that even when development is stopped, the resulting products have value for wider use or can be sold to third parties. Table 8.1 shows a possible timetable for the tool development.

Table 8.1 A possible timetable for the tool development

	Products/parts	Planning	Go/No-Go
Phase 1	* Workshop users * Expert workshop * Stakeholder meetings * Final reporting Phase 1	October 2009	Start before Phase 2
Phase 2a1 methodology	* International validation * Methodology proposal, LULUC , economic allocation, improvement options, etc. * Calculation rules * Papers, workshops and reports	6 months	-
Phase 2a2 tool development first version for PDV members	* Technical functional design * Software development * User tests * First version	8-10 months	Go/no go after software development tender
Phase 2a3 database development	* Assembling international team * Data collection feed raw materials * Data collection processes * First database	3 months preparation 8 months development	
Phase 2b implementation and communication	* Business plan for maintenance and updating * Expansion for other sectors	3 months	

8.4 Preliminary conclusions and recommendations for Phase 2

The conclusions and recommendations given here are preliminary and can be amended after processing the input from the user workshops, the expert workshops and PDV working group meetings.

1. Methodologically there are no great obstacles to developing a carbon footprint assessment tool for animal feed. However, four issues need to be discussed internationally to gain wider support. These four issues are the different approaches to land use and land use change, economic allocation, system boundaries and improvement options. Phase 2 needs to focus on resolving these issues.
2. Further study on the carbon footprint effects of feed additives is required. Data need to be collected on the production of enzymes, mineral additives and synthetic amino acids, which are not easily accessible.
3. With much of the background data having to come from cropping and feed raw material industries, a great effort is needed to come to a sound database that ultimately should be publicly available. It should be developed in cooperation with raw materials suppliers as much as possible.
4. Models and background data are needed that describe the conversion of feed into animal production and emissions of methane, ammonia and nitrous oxide in relation to housing systems. Descriptive modelling will be sufficient for the first version of the carbon footprint assessment tool. In later versions a more mechanistic modelling can be included.
5. Development of the tool in Phase 2 should involve several coordinated parallel activities on methodology and database development and the actual building of the carbon footprint assessment tool.
6. Methodology and database development should preferably be done by a consortium of institutes to engender broad support for the approach. Possible parties are Ecoinvent, SIK, WUR, Blonk Milieu Advies and software developing companies.

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