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DATA-FAIR report on exchange of sustainability information in the pork supply chain

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N. Bondt,[1] T. Ponsioen,[1] L. Puister-Jansen,[1] T. Vellinga,[2] D. Urdu,[1] R.M. Robbemond[1]

1 Wageningen Economic Research
2 Wageningen Livestock Research

This study was carried out by Wageningen Economic Research for the Top sector Agri & Food, in the framework of the Public-Private Partnership project DATA-FAIR, as part of the road map 'Consumer and Chain'.

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The exchange of sustainability information in the supply chain is becoming increasingly important. Relevant attributes are animal welfare, the environment and other issues that are important for the consumer and the buyer.
Wageningen Economic Research contributed to the measurement and exchange of sustainability information through the pork chain, in collaboration with HAS Den Bosch, ZLTO and the Vion Food Group. In this trial, this was concretely elaborated for the carbon footprint of pork. The project was carried out in the framework of a Public-Private Partnership project called DATA-FAIR, which investigates and innovates methods for data exchange in food chains.

Key words: sustainability information, carbon footprint, pig production, pig meat, life cycle analysis, LCA, data collection, data management

P.O. Box 29703, 2502 LS The Hague, The Netherlands, T +31 (0)70 335 83 30,
E communications.ssg@wur.nl, http://www.wur.eu/economic-research. Wageningen Economic Research is part of Wageningen University & Research.

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Erratum for Report 2020-011

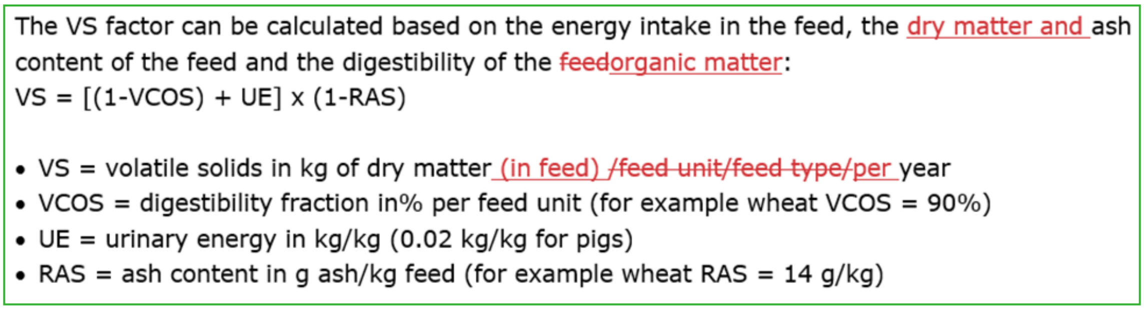
Juli 2022

In the report, the following substantive changes were made:

- Page 15/16, added: 'If the Ecoinvent database is used as background data, in addition to production of fuel and vehicle and combustion of the fuel, production and maintenance of roads are considered as well, so the database does not miss any activity related to transport.'

- Page 16: 'Our recommendation is to allocate emissions of manure storage' (instead of 'Our recommendation is **not** to allocate emissions of manure storage')

- Page 19: A few changes in the text on the volatile solids (VS) and specifically the calculation of the VS factor.



The VS factor can be calculated based on the energy intake in the feed, the dry matter and ash content of the feed and the digestibility of the ~~feed~~organic matter:
VS = [(1-VCOS) + UE] x (1-RAS)

- VS = volatile solids in kg of dry matter (in feed) ~~/feed unit/feed type/~~per year
- VCOS = digestibility fraction in% per feed unit (for example wheat VCOS = 90%)
- UE = urinary energy in kg/kg (0.02 kg/kg for pigs)
- RAS = ash content in g ash/kg feed (for example wheat RAS = 14 g/kg)

- Page 20:

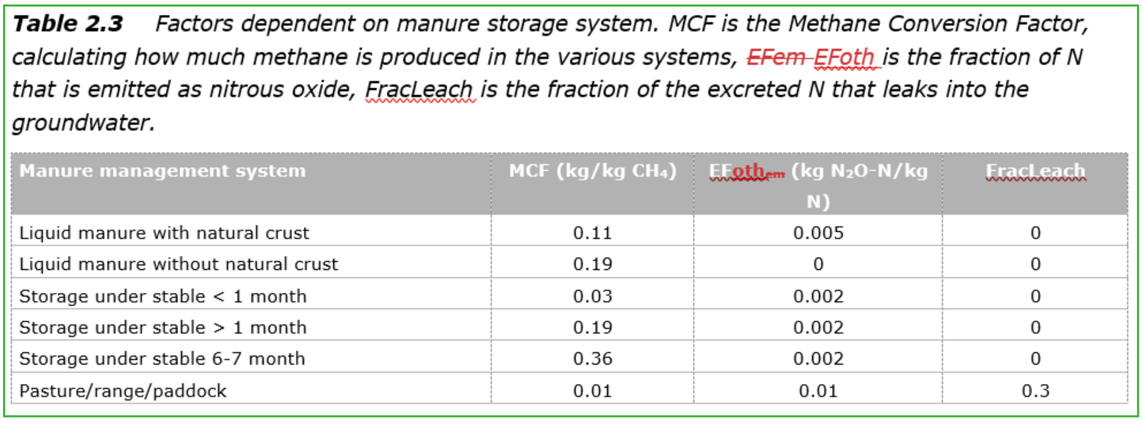


Table 2.3 *Factors dependent on manure storage system. MCF is the Methane Conversion Factor, calculating how much methane is produced in the various systems, ~~EFem~~ EFoth is the fraction of N that is emitted as nitrous oxide, FracLeach is the fraction of the excreted N that leaks into the groundwater.*

Manure management system	MCF (kg/kg CH_4)	EFoth~~em~~ (kg N_2O-N/kg N)	FracLeach
Liquid manure with natural crust	0.11	0.005	0
Liquid manure without natural crust	0.19	0	0
Storage under stable < 1 month	0.03	0.002	0
Storage under stable > 1 month	0.19	0.002	0
Storage under stable 6-7 month	0.36	0.002	0
Pasture/range/paddock	0.01	0.01	0.3

- Page 24: adjusted explanation of the Ecoinvent values on transport, especially regarding the classification of transport vehicles, average load fraction and standard empty return drive.

- Pages 28, 31 and 34 - Changes in Calculation 2, Calculation 4, Calculation 8:
  - As default choice of EURO category '6' was added, plus the additional text :'(choose lower when highest EURO category is not applicable)'
  - 'Load rate' and 'Loading capacity' were deleted
  - Also the structure of the calculations was changed, including 'total weight of transport (tonnes)' instead of 'number of deliveries' or 'number of times'

- Page 36: correction of two calculation errors in Table 3.1.

Contents

1 Introduction

1.1 Background

The DATA-FAIR project aims to accelerate innovation by organising a number of large-scale trials by industry in which a number of data- and IoT-based apps and services are developed, for sharing data between various platforms and creating added value. The farmer is a key stakeholder, as user and manager of data, on whose dashboard the data from various sources should be integrated.
The project leads to a more data-based agri-food sector that can improve business and supply chain management, transparency and thus consumer trust. Business results will improve through better (operational) benchmarking. By avoiding that data have to be entered more than once, the administrative burdens can be reduced. Ultimately, this will lead to a stronger Dutch agri-food knowledge and technology complex.

One of these large-scale DATA-FAIR trials is ‘Carbon footprint pig production’. Measuring sustainability performance is becoming increasingly important. In this trial, Wageningen Economic Research has offered to contribute to the measurement and exchange of sustainability information through the pork chain, in collaboration with the Vion Food Group, HAS Den Bosch and ZLTO. This was concretely elaborated for the carbon footprint of pork.

The mission of Vion is to be a world leader and reliable partner, providing people around the world with safe meat products. Currently, a strong focus is placed on the calculation of CO_2 and sustainability food prints of pork. As part of its Building Balanced Chains (BBC) strategy, Vion is building demand-driven chains in which the exchange of sustainability information throughout the chain plays an important role.

1.2 Research questions

The core of this study is sustainability measurement of primary production, primarily focused on carbon footprint, with the following research questions:

A. What are the (scientific) requirements for the carbon footprint calculation?
B. How do we make all relevant elements for the carbon footprint calculation measurable, collectable, processable?
C. How should the calculation rules of the carbon footprint look like?
D. What does the meta model look like for several CSR-attributes? (including international standardisation of attributes/interface and data transport from farm to CSR-systems)

1.3 Objective

For this trial the following targets were formulated:

- Defining the requirements for the carbon footprint calculation, based on LCA expertise, relevant international guidelines and standards
- Developing a concrete and practical plan for the collection of all relevant data for the carbon footprint calculation
- Describing calculation rules for the calculation of the carbon footprint
- Development of a CSR meta model, applicable for a range of CSR attributes, which can also be used for the data warehouse of the meat processing company.

This report describes the results of the first project phase, in which a model was developed for the calculation of the CO_2 footprint of pork meat, in accordance with internationally recognised methods (LEAP, PEFCR). Additionally, a start was made with the CSR meta model, information architecture and the required platform for data collection and data transport.

As part of its Building Balanced Chains (BBC) strategy, Vion is building demand-driven chains in which the exchange of sustainability information throughout the chain plays an important role. In this trial, this was concretely elaborated for the carbon footprint of pork.

1.4 Method

To answer the four research questions, a programme for sustainability measurement of primary production has been set up with five work packages. This confidential working document only relates to the first two work packages: 1) development of a meta model and 2) collection and transport of data for calculating the carbon footprint.

Work package 1: Development of the meta model
The first step is to work on the model for the calculation of a carbon footprint of pork meat, as part of the broader CSR meta model. The calculation is based on internationally recognised methods (LEAP or PEF) and this is realised with input of expertise from Wageningen Economic Research and Wageningen Livestock Research. The activity in this block consists of determining the steps required to be able to calculate the carbon footprint: which data is needed for this, where does it come from, how is support organised to provide the required input (e.g. by suppliers of compound feed fluid products), how and by whom is the authorisation register managed, how can the calculations be made auditable, etcetera. Where possible, already developed and used indicators are used, such as from management information systems, the Farm Accountancy Data Network (FADN) of Wageningen Economic Research and the European FLINT project (Vrolijk en Poppe, 2018/EuroChoices paper).

Work package 2: Data collection and data flow
This work package mainly concerns the information architecture in which optimum use is made of data and software that farmers are already using (Farmingnet and systems from third parties such as AgroVision), and of the JoinData platform with which data is exchanged and software with which data can be made available for the meat processing company. Components are:

a. Investigate how indicators and underlying data can best be collected
b. Make the data collection suitable for data sharing via the JoinData platform
c. Realise a pilot for CFP calculation on pig farms.

The realisation of the pilot, with involvement of actors in the supply chain to provide the data, is not reported in this working document. The same goes for the work packages 3 (International dimension), 4 (Action perspective in the supply chain) and 5 (CSR report).

2 Scientific requirements for carbon footprint calculations

2.1 Introduction to Life Cycle Analysis (LCA)

This DATA-FAIR trial aims to calculate the carbon footprint of pig meat products in an efficient and robust way and to report the results to retailers and other supply chain partners. A carbon footprint is the sum of all greenhouse gas emissions that can be attributed to a product, expressed in kg of carbon dioxide equivalents per unit of product. The technique for calculating a carbon footprint is life cycle analysis (LCA). Various standards have been developed for this technique. The ISO14040 (ISO, 2006a) and ISO14044 (ISO, 2006b) in particular provide the basic rules that are followed by all LCA experts. It states that the following steps must be followed:

1. **Goal & Scope definition**: the goal of the LCA must first be determined and all methodological choices are then made based on the goal.
2. **Inventory analysis**: the required data is then collected from the production locations, supplemented with secondary data from background databases and literature; software is used to create a model for linking the data and calculating environmental interventions such as emissions, land use and raw material extraction.
3. **Impact assessment**: all environmental interventions are converted into indicators in this step; in the case of climate change, all greenhouse gas emissions are converted into kg carbon dioxide equivalents (hereafter for convenience: kg CO_2 eq) by using characterisation factors.
4. **Interpretation**: the final step is interpretation of the results; methodological choices are generally reconsidered here and additional data questions are formulated, so that the first three steps must be repeated in an iterative process (Figure 2.1).

These four steps will be elaborated in the following four sections.

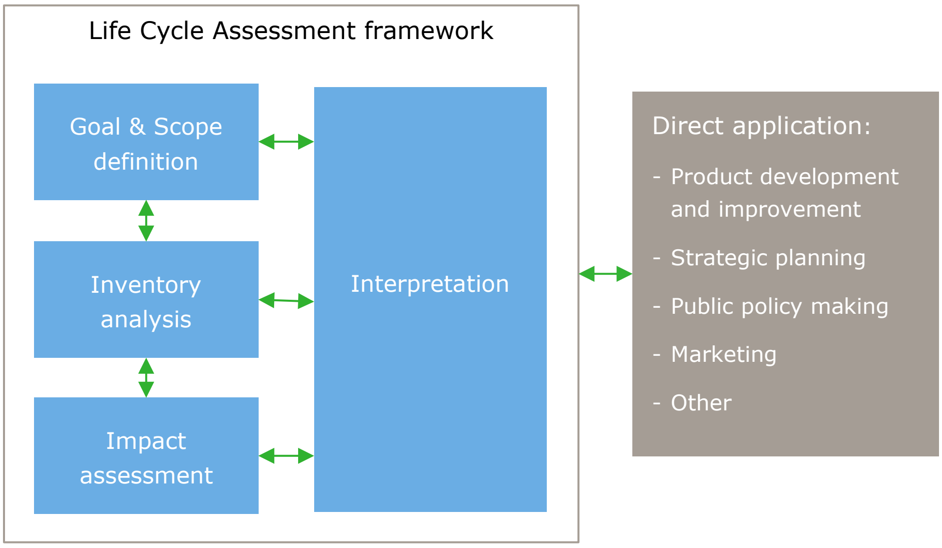


Figure 2.1 *Phases of a Life Cycle Analysis (source: ISO, 2006a)*

In addition to the basic rules of the ISO standards 14040/44, there are specific guidelines and methodological rules for LCAs of pig supply chains and pig meat published by various parties:

1. **LEAP guidelines**: The FAO published a report in 2016 in the context of the multi-stakeholder initiative LEAP (see Box 1 below) for the implementation of LCAs from pig supply chains (FAO, 2016) and a report in 2018 for the implementation of LCAs for animal feed (FAO, 2018).

2. **Draft PEFCR standard for red meat**: A consortium of meat processing companies and the European trade association UECBV drafted a standard in the context of the Single Market for Green Products initiative (also known as the Environmental Footprint initiative; see Box 1 below) of the European Commission, for environmental footprints of red meat (including pork), referred to as the Product Environmental Footprint Category Rules (PEFCR) or Red Meat (UECBV et al., 2016).
3. **Official PEFCR standard for animal feed**: From the same initiative, a consortium of animal feed companies and the European branch organisation FEFAC published an official standard for the environmental footprint of animal feed, the PEFCR animal feed (FEFAC et al., 2018).
4. **Rules for drafting PEFCR standards**: The European Commission's Joint Research Center (JRC) published a report in 2019 with rules for implementing Product Environmental Footprints (PEF) and developing product-specific rules (PEFCRs), including specific rules for pig farming and slaughtering/meat cutting (Zampori and Pant, 2019).
5. **Alternative rules UECBV**: The UECBV has published a report with alternative rules for calculating the environmental footprint of red meat (UECBV et al., 2019), which deviate from the rules drawn up by the European Commission (Zampori and Pant, 2019).

Since the different documents are not in agreement with each other on multiple methodological choices and none of them are mandatory, we have done an analysis of how the different documents deal with each choice in the Goal & Scope section below and made a recommendation for each choice. The main consideration here is to follow as close as possible the rules of the European Commission (Zampori and Pant, 2019) and the PEFCR for animal feed (FEFAC et al., 2018) as these are considered as most authoritative.

The LEAP initiative

LEAP is a multi-stakeholder initiative for benchmarking the environmental performance of companies in the chains of animal products worldwide. It was initiated after a stakeholder consultation in October 2010 between the FAO and a number of companies in the private sector. The initiative has since published 8 Guidelines:

1. Principles for the assessment of livestock impacts on biodiversity (2015)
2. Greenhouse gas emissions and fossil energy demand from poultry supply chains (2016)
3. Greenhouse gas emissions and fossil energy demand from small ruminant supply chains (2016)
4. Environmental performance of large ruminant supply chains (2016)
5. Environmental performance of animal feeds supply chains (2016)
6. Environmental performance of pig supply chains (2018)
7. Water use in livestock production systems and supply chains (2018)
8. Measuring and modelling soil carbon stocks and stock changes in livestock production systems (2019)

The document for pig supply chains was published in 2018 and the document for animal feed chains was published in 2016. The Guidelines are documents that partly contain rules and partly recommendations for measuring environmental performance. There is still a fair amount of freedom for methodological choices depending on the goal of the study. The goal may be, for example, to manage greenhouse gas emissions or to deal with multiple environmental issues. It can also be to report the environmental performance. The LEAP Guidance for pig supply chains supports comparison of the performance of animals for slaughter, but does not support comparisons of pig meat products.

The Single Market for Green Products initiative

In the same period that the LEAP initiative was launched, DG ENV of the European Commission initiated the Environmental Footprint Pilot Phase (2013-2018) within the Single Market for Green Products initiative. It is more known as the Environmental Footprint initiative. The scope of this initiative is broader, namely all sectors within the manufacturing industry. The aim is to develop product-specific standards together with companies and other stakeholders so that companies do not communicate environmental performance on the basis of calculations that best suit them and on the basis of many different methodologies.

Out of a large number of applications, 24 were accepted by the Commission, 4 of which have dropped out during the process:

1. Batteries and accumulators
2. Beer
3. Coffee (discontinued)
4. Dairy
5. Decorative paints
6. Feed for food-producing animals
7. Footwear
8. Hot and cold water supply pipes
9. Household detergents
10. Intermediate paper product (JRC)
11. IT equipment
12. Leather
13. Marine fish (discontinued)
14. Meat (bovine, pigs, sheep) (discontinued)
15. Metal sheets
16. Olive oil
17. Packed water
18. Pasta
19. Pet food (cats & dogs)
20. Photovoltaic electricity generation
21. Stationery (discontinued)
22. Thermal insulation
23. T-shirts
24. Uninterruptible Power Supply
25. Wine

The pilot for animal feed has been successfully completed, but the pilot for meat (beef, pig and sheep) was discontinued in 2016. The reason for this seems to be disagreement between the working group of this pilot and the European Commission and other related pilots (pet food, feed and leather) on how to distribute the upstream impact between meat and slaughter by-products. The PEFCR Meat working group wants the distribution to be done on the basis of the energy required for growth of each part of the animal (for meat almost the same as mass) or on the basis of mass and the other parties want it to be done on the basis of economic value (which means a greater impact for meat and many times smaller for by-products; see detailed explanation later in the report). The working group of the PEFCR Meat has now decided to register for the new phase (Transition Phase) of the initiative. This has started during the writing of this report (October 2019).

In July 2019, the UECBV published an amended version of the draft PEFCR meat as Footprint Category Rules Red Meat Version 1.0. The organisation wants to present this version to the European Commission in the new phase. However, this version still conflicts with the position of the European Commission.

2.2 Goal & scope of the LCA

2.2.1 Goal

The goal of the LCAs is initially to report the carbon footprints of the pig meat products from Vion to retailers and other supply chain partners. To be able to define mitigation options to reduce carbon footprints, Vion needs insight into the most relevant sources of greenhouse gas emissions in the various stages of the supply chain. Pig farmers and feed producers must be able to monitor the climate change-related carbon reduction performance of their own products over time and compare them with a benchmark. In the long term, it should be possible to extend the LCA to other environmental issues, so that the effect of management measures can be evaluated in full extent. An additional goal is to compare the carbon footprint of pig meat products with other protein-rich products, based on actual data and a scientifically solid method.

In five bullet points:
- Report carbon footprints of pig meat products
- Hotspot analysis (most relevant sources of emissions)
- Monitoring and benchmarking
- Possibility to extend the environmental impact categories
- Compare footprints of pig meat products with other protein-rich products

2.2.2 Scope

Functional unit
The functional unit describes:
- the function of the product
- the reference unit of the carbon footprint
- how well the product fulfils its function, i.e. the product quality and
- how long the product fulfils its function.

The LEAP document for pig supply chains describes pigs supplied by livestock farmers for slaughter in kg live weight or carcass weight. The functional unit of these guidelines is therefore not suitable for determining the carbon footprint of pig meat products. For the purpose of comparing and benchmarking the performance of the pigs for slaughter from different farmers, however, a functional unit of 1 kg of live weight is suitable.

The PEFCR Red Meat concept (UECBV et al., 2016) describes the functional unit as follows:

> ‘100 g of fresh meat from a specific animal species, as sold at retail to the consumer for preparation at home, available for consumption for the period advised for the storage method, containing the naturally available nutrients and according to legal quality requirements.’

In the amended rules of the UECBV (UECBV et al., 2019) this was changed to (translated):

> ‘1 tonne of red meat product, [...] as sold to the retailer, secondary processor and or food service. The weight of packaging is not included in the 1 tonne but in scope of the analysis.’

The proposal for the current project is to formulate it as follows:

1 kg of packed fresh pig meat product

- as sold to the supermarket
- for home consumption
- to provide nutritional value to the consumer
- consumable for a period at the advised storage method and
- where the weight of the packaging is not included.

To compare the carbon footprint with other protein-rich products, it is recommended to use the reference unit of 1 kg of protein by dividing the carbon footprint per kg of fresh pig meat by the protein content of the meat. See for example Blonk et al. (2008) and Poore and Nemecek (2018). For this purpose the reference unit of 1 kg protein can be used.

System boundaries

The system boundaries describe which processes are included in the carbon footprint. The LEAP guidelines for pig supply chains (FAO, 2016) describe the supply chain from feed production up to and including livestock farming. This is not sufficient for the purpose of delivering data to a retailer or other supply chain partner. In order to calculate the carbon footprint of fresh pig meat, the slaughterhouse and meat-cutting stage must be included. The PEF rules (Zampori and Pant, 2019) require that the retail, use stage and waste processing are also included when it comes to consumer products. However, the energy use at the use stage and the amount of wasted meat in particular are highly variable, which means that a great deal of data is needed or rough assumptions have to be made. No definitive rules have yet been drawn up for pork. Moreover, producers in the pork chain have little or no influence on the use stage. This is more relevant with products such as detergents and coffee, where the use stage is responsible for a major contribution and producers can influence the usage. However, we recommend that the distribution, retail, and the waste processing of the packaging and wasted meat during retail will be included in the analysis, because there is general data for this, and the amount of packaging material per kg of meat and the type of material influence the result.

We recommend for the current purpose of the LCA to place in principal all stages in Figure 2.2 within the system boundaries. In the next chapter this will be restricted when we only discuss data delivery of suppliers to Vion. The preparation of the pig meat products by the consumer and the processing of wasted meat during the use stage can be disregarded due to large variability. Manure processing is only included when it is considered as waste. Animal feed production, including by-products used as animal feed, sow breeding system, pig fattening system, manure storage and slaughtering, cutting, cooling and packaging are considered as the most relevant foreground processes. Other processes are expected to have a relatively small contribution to the total environmental impact, for example packaging, distribution and retail, and processing of packaging and wasted meat. Furthermore, the main partners in the pig meat supply chain, meat processing companies, pig farmers and animal feed producers, do not always have direct control over these processes.

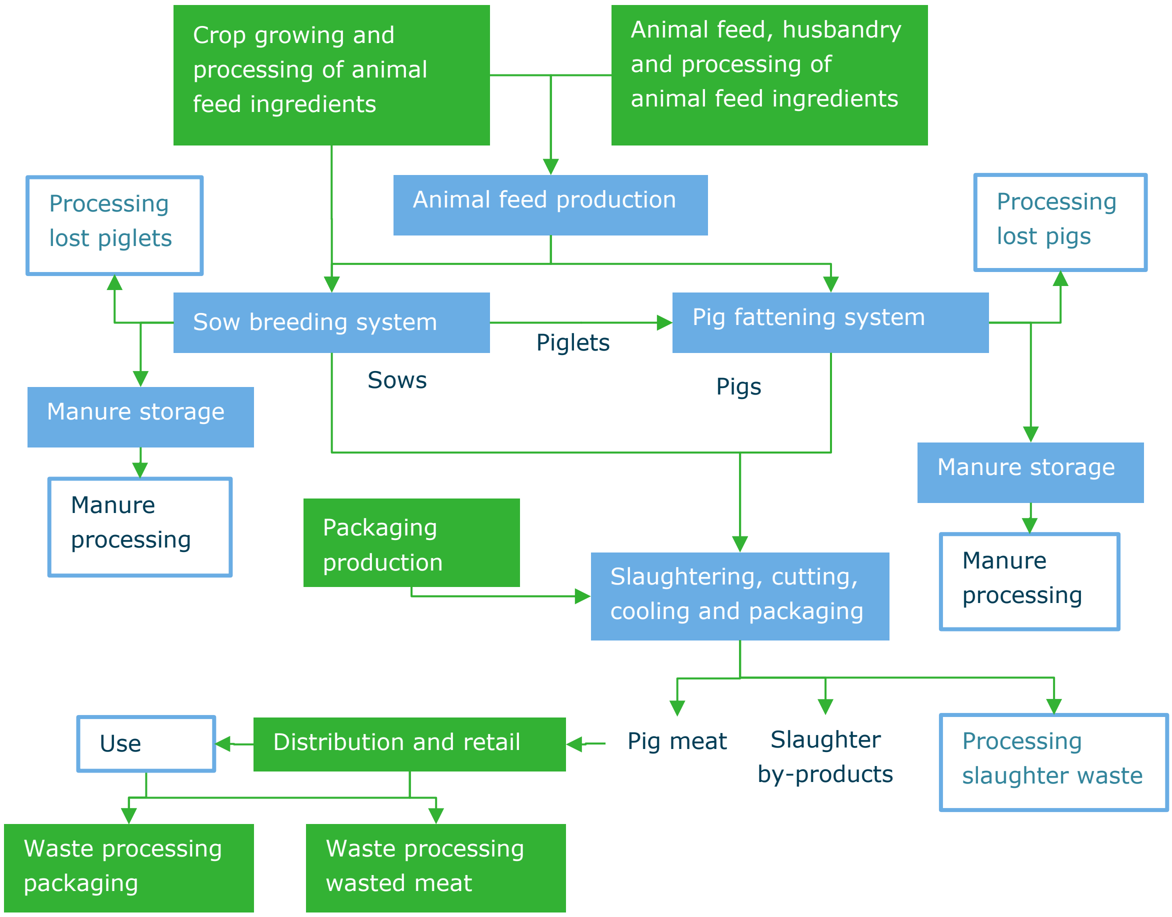


Figure 2.2 *System boundaries and all stages included in the production and processing of pig meat products*

Figure 2.3 shows the impact of different life cycle stages on the carbon footprint. It should also be possible to analyse the footprint in more detail, to the contributions of the different types of emissions of processes, and the production of various inputs and processing of manure and waste streams. This is also important when comparing individual business results with the benchmark. In this way it is possible to determine exactly what impact each source of emissions has on the total footprint, to identify improvement options.

Please note that this CFP-calculation includes the parts of the supply chain after the pig farm, such as further transport, slaughter and processing, and is expressed per kg of fresh meat in the store. All calculations of the supply chain up to slaughterhouse are normally expressed per kg of live weight. In the slaughter process part of the pig production emissions are allocated to the fresh meat and part to the by-products, based on the economic value of the fractions. Furthermore, note that this example also includes the contribution of the pig house (stable) to the carbon footprint.

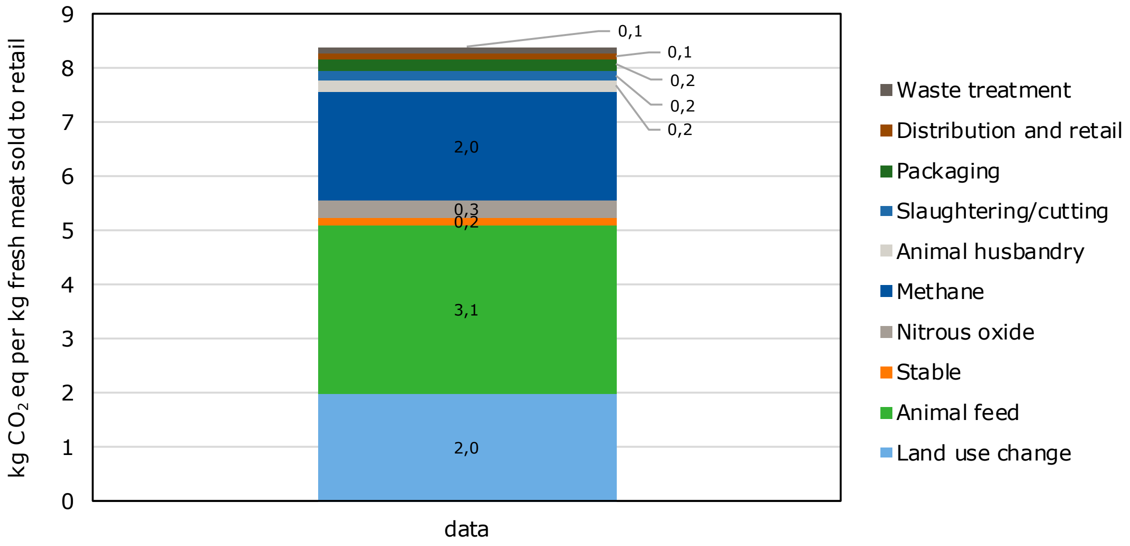


Figure 2.3 *Example of a hotspot analysis of the carbon footprint of pig meat products (manure is stored under the pig house for 6-7 months) PEF Guide (Zampori and Pant, 2019); PEFCR Feed for food producing animals (v.4.1 2018), PEFCR Red Meat draft (UECBV et al., 2019), Agri-footprint 4.0 (Blonk Agri-footprint BV 2017), Ecoinvent 3.5 (Wernet et al., 2016)*

Inputs and capital goods

All inputs of the processes must be included. These are basically all materials and energy used. In order to limit the workload of data collection, materials with a very small contribution can be disregarded. A very small contribution can be estimated by the mass contribution. For example, the production and transport of antibiotics likely have an insignificant contribution due to the very small mass contribution. Some related activities, such as transport of the veterinarian and of hired workers are usually not included, because of a likely small contribution and high costs for collecting such data. It is recommended to use factual data, if possible. Default values can be used if factual data are not available or can only be collected at high costs, and also in case of a small contribution to the total carbon footprint.

In addition to the variable inputs, capital goods must be included. The capital goods and their maintenance are depreciated over the number of expected years of use. Only if the capital goods apparently do not make a significant contribution to the result may they be omitted. The PEF rules (Zampori and Pant, 2019) state that processes that contribute up to a total of 3% to the overall environmental impact maybe excluded. Pig houses have an estimated contribution of around 2%, based on data from a Canadian pig house from the internationally recognised Ecoinvent database. Similarly, the emissions for production of solar panels or biodigester installations are excluded from the CFP of pig production.

Conclusion: emissions for the production of pig houses and installations may be excluded.

Waste processing

All waste processing is included in the outputs. When the waste material is converted into or used directly as a useful product or as useful products, part of the emissions from transport and processing is allocated to the products obtained, and part to the process from which the waste material originated. See further elaboration for manure under the Multi-functionality (of livestock farming) section and for packaging see the section Allocation waste disposal packaging.

Transport

The transport of all inputs and waste from the processes must be included. This includes the production of the fuel and the vehicle and the combustion of the fuel. See Section 2.3.2 on how to address data collection for the different types of transport. If the Ecoinvent database is used as background data, in addition to production of fuel and vehicle and combustion of the fuel, production and maintenance of roads are considered as well, so the database does not miss any activity related to transport.

Multi-functionality

A number of processes in the life cycle of pig meat products are multifunctional, that is to say that several co-products arise from these processes. The most important are the cultivation and processing in the feed chain (for example grains and straw, and vegetable oil and meal), the sow breeding system (sows, piglets and manure), the pig fattening system (fattening pigs and manure) and the slaughterhouse and cutting plant (fresh meat and slaughter by-products). Recycling and reuse of waste and residual streams can also be seen as multi-functionality. An important methodological choice in LCA is how to deal with this multi-functionality.

In the case of livestock farming, the first question is whether the manure that leaves livestock farming is a co-production, waste or a material that can be collected without costs and can be reused for bioenergy and/or soil enrichment:

- **Waste**: in the case that the manure is regarded as waste (i.e. there are manure disposal costs), all emissions from transport and processing must be attributed to the livestock sector. Land application for arable farming or horticultural production is not seen as waste processing, it is reuse.
- **Reuse**: in the case of reuse, it must be determined which part of the transport and processing is allocated to livestock farming and which part to cultivation. The European Commission developed a complex formula for this, but does not provide any values for the allocation of manure. Our recommendation is to allocate emissions of manure storage to livestock farming and emissions for transport and application to crop production, which is not contrary to the formula and is a widely used method, known as the cut-off method.
- **Co-product**: The emissions from the bioenergy production are allocated to the bioenergy and the digestate, based on economic value. This is considered as a separate process, as nutrients do not change by the manure digestion process. When the bioenergy is used for livestock farming the allocated emissions are then attributed to the livestock farming, including the benefits of using biogas.

We recommend a pragmatic approach of applying the cut-off rule for manure in all cases, which is also regular practice in other footprint calculations. There is an ongoing discussion on this issue, but for now this pragmatic approach is the best option.

For the division between the sows and piglets, the biophysical allocation would in theory also be applied, but as stated, this method is not yet well developed and, moreover, is not necessarily the best solution. The European Commission prescribes average European prices for sows and piglets, namely €0.95 per kg live weight of the piglets and €40.80 per sow of 84.8 kg. Vion is not obliged to use these prices. We do, however, recommend economic allocation with a robust, consistent and transparent method to determine prices, considering a multi-year average of prices achieved at farm level. We recommend a 5-year moving average, updated every year.

The fraction of economic value coming from selling all sold sows compared to the economic value of all sold sows and piglets in that year reflects the allocation factor. For example, if the sows represent 5% of the total economic value, then 95% of the total carbon footprint should be allocated to the piglets and 5% to the sows.

Note on choice of allocation rules

The ISO standard 14044 (ISO, 2006b) prescribes that economic allocation may only be used as the last option. However, there are different interpretations of this rule. Some experts believe that the first option (i.e. biophysical allocation) should always be applied: system expansion by deducting the impact of avoided production from by-products from the main product (for example, that pig manure replaces a certain amount of fertiliser, so that the emissions of the avoided fertiliser are deducted from the emissions of the pigs). However, in the case of environmental foot printing (reporting, hotspot analysis, monitoring, benchmarking), this is not applicable because it leads to arbitrary choices of avoided products (for example, that the by-product sows replace chickens for slaughter), complex situations (the avoided products are also by-products or main products with by-products) and incomparable results. It is more appropriate for scenario analyses in, for example, policy choices, whereby extensive sensitivity and uncertainty analyses can be performed.

The second option of the ISO standard is to establish a physical relationship between the inputs and the outputs. However, in case the co-products arise from one raw material, plant or animal, no ambiguous physical relationship can be established, because the physical ratio between the co-products cannot be changed significantly or is at least not changed significantly in practice by changing the inputs. This is not the case, for example, with the transport of different products in one truck. There is a clear physical relationship between the mass of the products and the fuel use and related emissions. The option of allocating based on a physical relationship is therefore more suitable for this type of situation.

However, some scientists are creative in finding physical relationships because they do not consider economic allocation as scientific. Some companies and sector organisations are eager to go along with this because the physical allocation is favourable for their products. As a result, the dairy industry, for example, has defended its biophysical allocation method 'on the basis of the ISO rules' at the European Commission and is accepted in the PEFCR standard for dairy, despite being highly inconsistent with the allocation rules in case the manure from the dairy farm is considered as a co-product and elsewhere in the chain, where economic allocation is consistently applied. For the case of an average Dutch dairy farmer, the factors with biophysical allocation and economic allocation are shown in Table 2.1. For the cows, biophysical allocation means the upstream impact is more than double compared to economic allocation. In any case, the sum of the allocation fractions must always be 100% and debating how much 'burden' is allocated to each co-product does not provide solutions to the question on how to mitigate environmental impact.

The conclusion is that biophysical allocation is preferred, if it is possible to adequately determine the physical relationships. If this is not possible in a scientifically robust way, economic allocation should be chosen.

Table 2.1 *Allocation fractions for dairy farming with two different allocation methods*

Co-product	Biophysical allocation	Economic allocation
Milk	86%	92%
Cows	12.4%	5.2%
Calves	1.7%	2.6%
Total	**100%**	**100%**

Source: Agri-footprint 4.0 database

Allocation feed supply chain

The official PEFCR standard for animal feed stipulates that almost all processes in the feed supply chain must be subject to economic allocation when it comes to the cultivation or processing of vegetable or animal raw materials. For the determination of the greenhouse gas emissions related to the feed raw materials, background databases are generally used in which the allocation rules of the PEFCR are applied. For the Dutch dairy industry, the feed companies will report the carbon footprint data in the near future on the basis of the FeedPrint database, in which the PEFCR rules are applied. In the case of manure digestion, co-products can be used to improve the digestion process. Sometimes these co-products could be used as feed as well. However, the emissions of these materials should be part of the sub-process 'manure digestion' and not be added to the feed material inputs of the pig production process.

Manure digestion

The digestion of pig manure can be considered as a separate process. The process can be mono-digestion of pig manure, but can also be a co-digestion process, where other materials are added to boost the methane production.

In the case of co-digestion, the process can be split in two subprocesses, one for manure and one for the co-products. Both have their own inputs and their own gas production. In the case of manure, avoided methane emissions can be calculated; in the case of co-products, the footprint of input materials has to be included in the footprint of the biogas production. Energy inputs for the digestion process can be allocated on the basis of the gas production of manure and co-products. The emissions related to the biogas production process should be allocated to manure and co-products, based on the contribution to the total gas production.

The avoided methane emissions from manure can be allocated to the pig production process. The biogas production can be considered as green energy which can be used at the own farm, or be sold. Both biogas products have their own specific emissions.

Allocation at the slaughterhouse/cutting plant

The European Commission has prescribed economic allocation for the distribution of emissions over fresh meat and slaughter by-products. The UECBV does not agree with this. Initially, the organisation wanted biophysical allocation to be applied, but the scientists who are developing this have not been able to elaborate on this properly. The UECBV prescribes mass allocation in the 2019 publication, but there is no chance that this will be accepted by the European Commission. The European Commission has published European average prices in their 2019 report (Zampori and Pant, 2019). It is not mandatory for Vion to use these prices. We do, however, recommend using a robust, consistent and transparent method to determine prices. It is advisable to use multi-year averages for this so that the influence of price fluctuations is minimal. We recommend a 5-year moving average to be updated each year.

Biophysical allocation (in dairy supply chain)

The allocation between milk and sold cows and calves, at the end of the dairy production chain, is based on biophysical allocation. All subsequent process steps in dairy and slaughter are subject to economic allocation.

Table 2.2 *Standard European prices for fresh pork and slaughter by-products (Zampori and Pant, 2019); the mass fractions must be entered specifically, the mass fractions below and calculated allocation fractions are only an example*

Part	Mass fraction (F) (%)	Price (P) (€/kg)	Economic allocation (EA) (%)
a) Fresh meat and edible offal	67	1.08	98.67
b) Food grade bones	11	0.03	0.47
c) Food grade fat	3	0.02	0.09
d) Cat. 3 slaughter by-products	19	0.03	0.77
e) Hides and skins (cat. 3)	0	0	0
Total	**100**		**100**

Slaughter waste is treated the same way as animal losses from the animal husbandry systems. As stated before, our recommendation is to allocate the emissions from transport and processing of the waste to the bioenergy, because allocating all to the slaughtering and cutting, and subtracting the avoided energy production, introduces questionable assumptions and is inconsistent with applying economic allocation for other multi-functional processes.

Allocation disposal packaging

We recommend to use the European Commission's Circular Footprint Formula for the disposal of packaging, which assumes that 33% of the plastics in the Netherlands is recycled, 2% goes to landfill and 65% is incinerated. However, if actual data on recycling percentage etc. are available, it would be preferable to use these. Half of the emissions from the recycling process is attributed to the product from which the packaging waste comes. There are also figures for other materials.[1] Incineration is

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[1] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml (link Annex C to the PEF/OEF methods)

based on avoided heat and electricity elsewhere and recycling is based on avoided virgin material production. This is not consistent with allocation choices elsewhere and the formulas are rather complex, but it is the result of many discussions between experts and other stakeholder, and each alternative method is criticised by some of the experts and other stakeholders.

2.2.3 Emissions from animals and manure

For the calculation of methane and nitrous oxide emissions from the animals and from manure, we recommend not to use the simple Tier 1 method of the IPCC 2006 Guidelines (IPCC, 2006). This is permitted by the LEAP Guidelines, because it must be applicable throughout the world, where in certain situations no data is available for the more complex Tier 2 or 3 methods. The PEFCR does not allow Tier 1 for these calculations. For the Netherlands, the recommendation is to follow the details for the Netherlands, as described by Lagerwerf et al. (2019).

Methane emission from enteric fermentation
The methane emission from enteric fermentation of pigs is calculated with a fixed emission factor per animal per year. This is set at 1.5 kg CH_4/animal/year.

Methane emissions from manure storage
The methane emission from manure storage is more complex. The emission factor is calculated as follows:
$EF = VS * B0 \times 0.67 \times MCF$

- EF = emission factor for methane due to manure storage in kg CH_4/unit feed/year
- VS = volatile solids in kg of dry matter/unit feed/year
- B0 = maximum capacity of the manure to produce methane in m^3 CH_4/kg VS (default of IPCC is 0.45 m^3/kg, but for the Netherlands this is 0.31 m^3/kg)
- 0.67 = conversion factor in kg CH_4/m^3 CH_4
- MCF = methane conversion factor in kg/kg CH_4.

The MCF depends on the storage system. For long-term storage (6-7 months) in the Netherlands it has been determined that this factor is 0.36 kg/kg. For manure storage under the stable of less than a month it is 0.03 and more than a month 0.19 under Dutch circumstances. Slurry with natural crust has a factor of 0.11 and without natural crust 0.19 kg/kg. See also Table 3.3.

The VS factor can be calculated based on the energy intake in the feed, the dry matter and ash content of the feed and the digestibility of the organic matter:
$VS = [(1-VCOS) + UE] \times (1-RAS)$

- VS = volatile solids in kg of dry matter (in feed) per year
- VCOS = digestibility fraction in % per feed unit (for example wheat VCOS = 90%)
- UE = urinary energy in kg/kg (0.02 kg/kg for pigs)
- RAS = ash content in g ash/kg feed (for example wheat RAS = 14 g/kg)

The VS can be calculated using the CVB tables,[2] in which the required data can be looked up.

Nitrous oxide emissions from manure storage
There are direct nitrous oxide emissions and indirect nitrous oxide emissions. Direct nitrous oxide emissions are emissions from manure storage, indirect nitrous oxide emissions are the emissions that originate from the deposition of ammonia and nitrogen oxides from the manure.
The direct nitrous oxide emissions are calculated as follows:
$N_2Odir = Nex \times EF_{oth} \times 44/28$

- N_2Odir = direct nitrous oxide emissions from manure storage in kg N_2O/kg live weight
- Nex = nitrogen excretion in kg N/kg live weight

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[2] http://www.cvbdiervoeding.nl

- EF_{oth} = Emission factors for other gaseous N-losses (% of N excretion)

In case of free-range pig farming, the fraction of the manure that is excreted on the paddock is calculated based on the time the pigs spend there. In this case, the MCF is much smaller, 0.01, but the direct N_2O emission factor is higher, 0.01 kg N_2O-N/kg N. The volatilisation fraction is 0.2 kg N/kg N.
The nitrogen excretion is calculated as follows:
Nex = Nintake – Nretention

- Nintake = daily nitrogen intake from animal feed in kg N/kg live weight
- Nretention = daily nitrogen part that is recorded in pigs = 25 kg N/kg live weight in pigs.

Nintake = feed conversion * RE/6.25 (average RE from all feed)

- RE = Raw protein

The indirect nitrous oxide emissions are calculated as follows:
$N_2Oindir$ = (NH_3-N x EF_c (IPCC table) +NO_3-N x EF5) x 44/28 (emission of N_2O from volatilised NH_3-N)

- $N_2Oindir$ = indirect nitrous oxide emissions from volatilisation of ammonia of leaching of nitrate from the manure in kg N_2O/kg live weight
- NH_3-N = ammonia nitrogen
- NO_3-N = nitrate nitrogen
- EFc (IPCC table) = EFconvert default emission, volatilisation and leaching factors for indirect soil N_2O emissions.
- EF5 = emission factor for nitrous oxide from leached nitrate-N from the manure in kg N / kg N; this is 0.0075 by default.
- 44/28 = conversion factor in kg N_2O/kg N

NH_3 = TAN x EF_{em} (emission of NH_3 from TAN in manure)

- TAN = fraction of total ammonia nitrogen volatilised as ammonia and nitrogen oxides kg N/kg N
- EF_{em} = EFemission NH_3-emission factors for pig housing (% of TAN excretion)

TAN = Nex – Norganic

- Norganic = Part of not digestible N

Norganic = Nintake x (1-VCRE)

- VCRE is digestibility of crude protein (in %), average for all feed

NO_3-N = FracLeach x Nex

FracLeach is the fraction of excreted N that is leached from manure management systems. With complete confinement, all manure is collected in concrete pits and no nitrogen is lost via leaching during storage. Only in the case of free-range pig farming, a part of the manure is excreted outside on natural soil and is subject to leaching. In this situation, the fraction of N lost through leaching is assumed to be the same as when applied to agricultural soils. The figure provided by Lagerwerf et al. (2019) is not applicable, because it is used for normal manure application and not for free-range pigs. In the free-range situation, a larger fraction of the excreted N will leak away.

Table 2.3 *Factors dependent on manure storage system. MCF is the Methane Conversion Factor, calculating how much methane is produced in the various systems, EFoth is the fraction of N that is emitted as nitrous oxide, FracLeach is the fraction of the excreted N that leaks into the groundwater.*

Manure management system	MCF (kg/kg CH_4)	EFoth (kg N_2O-N/kg N)	FracLeach
Liquid manure with natural crust	0.11	0.005	0
Liquid manure without natural crust	0.19	0	0
Storage under stable < 1 month	0.03	0.002	0
Storage under stable > 1 month	0.19	0.002	0
Storage under stable 6-7 month	0.36	0.002	0
Pasture/range/paddock	0.01	0.01	0.3

2.2.4 Software

It is possible to develop the software to calculate the carbon footprint. The alternative is to use standard LCA software. Using SimaPro has the advantage that it is the most used LCA software in the world and contains the most relevant data. The software contains a large amount of background data and all characterisation factors to calculate the environmental indicators. The data can be viewed in a well-arranged manner and adjusted if necessary. The foreground processes (shown in Figure 2.2) can be modelled in a consistent way and provided with parameters, so that large quantities of production locations can be processed.

The software ensures that all different types of emissions are specified in sufficient detail (for example, ammonia emissions to the air in rural areas or nitrate leaching to groundwater) and are linked to specific characterisation factors. The connection of background data and the characterisation factors in particular is a lot of precise work, which means that most LCA experts use SimaPro or other commercial LCA software instead of developing software themselves, especially since there are regular updates of the background databases and characterisation factors. If only the carbon footprint is needed, then the amount of work for implementing and updating tailored software is relatively limited, but when it is extended to several environmental indicators it becomes very costly. In addition, data can be entered automatically in SimaPro with different programming languages and results can be retrieved automatically.

2.3 Inventory data

2.3.1 Foreground data

The required primary data are shown in Tables 2.4 through 2.9. How to collect this data from the different production locations is not described here. How the crude farm data needs to be converted to the units in the tables is not described here either (see Chapter 3). The tables are not exhaustive and may need to be extended with other flows that turn out to be significantly contributing to the results.

Table 2.4 *Required data for slaughtering and cutting*

Parameter	Unit	Supplementary information
Outputs		
Fresh meat	kg/kg live weight	Price
Slaughter by-products, food grade	kg/kg live weight	Price
Slaughter by-products, feed grade	kg/kg live weight	Price
Slaughter by-products, other	kg/kg live weight	Price
Waste water	Litre/kg live weight	kg BOD/m^3 and kg COD/m^3
Inputs		
Electricity	kWh/kg	Production mix/own production; green and grey
Natural gas	MJ/kg	Calorific value, type of boiler
Tap water	kg/kg	
Transport pigs	km	EURO number (based on load capacity and load fraction)
Primary packaging	kg/kg	Material composition
Secondary packaging	kg/kg	Material composition

Table 2.5 *Required data for the pig fattening system*

Parameter	Unit	Supplementary information
Slaughter weight	kg live weight/animal	
Number of piglets from breeding system	# animals/year/animal place	
Percentage of pig mortality	%	
Transport piglets	km	EURO number (based on load capacity and load fraction)
Feed raw materials	kg/year/animal place per type of raw material	Quantity and origin of feed ingredients, electricity and natural gas use
Liquid feed supplements	kg DM/year/animal place per type of liquid feed	Per raw material and origin raw material
Fermentation of feed raw materials	kg lactic acid mixture/year/animal place (plus energy use)	Footprint of the lactic acid mixture should be included, probably footprint of sugar as a proxy (value from Simapro). Also the energy use for heating the feed should be included in the total footprint.
Straw	kg/year/animal place	
Transport feed	km	EURO number (based on load capacity and load fraction)
Transport liquid feed	km	EURO number (based on load capacity and load fraction)
Electricity	kWh/year/animal place	Production mix/own production; green or grey
Natural gas	m^3/year/animal place	Calorific value, boiler type
Diesel, LPG, Gasoline	Litre/year/animal place	In case of fuels used for the own production of feed raw materials, alternatively, a CFP value of the feed raw material can be used.
Liquid detergents	Litre/year/animal place	
Solid detergents	kg/year/animal place	
Tap water	m^3/year/animal place	
Water from own source	m^3/year/animal place	
Manure management	Fraction per type of manure management	Duration of the storage
Manure transport	km	EURO number (based on load capacity and load fraction)

Table 2.6 *Required data for the breeding system*

Parameter	Unit	Supplementary information
Number of sold piglets per sow	# sold piglets per sow	
Percentage of piglet mortality	%	
Slaughter weight sows	kg live weight per sow	Price
End weight piglets	kg live weight	Price
Electricity	kWh/year/sow	Production mix/own production
Natural gas	m3/year/sow	Calorific value, boiler type
Diesel, LPG, Gasoline	Litre/year/animal place	In case of fuels used for the own production of feed raw materials, alternatively, a CFP value of the feed raw material can be used.
Liquid detergents	Litre/year/animal place	
Solid detergents	kg/year/animal place	
Tap water	m^3/year/animal place	
Water from own source	m^3/year/animal place	
Feed raw materials for sows	kg/year/sow	Quantities and origin of feed ingredients, electricity and natural gas use
Feed raw materials for piglets	kg/year/sow	Quantities and origin of feed ingredients, electricity and natural gas use
Liquid feed for sows	kg/year/sow	Quantities and origin of liquid feed
Liquid feed for piglets	kg/year/sow	Quantities and origin of liquid feed
Straw	kg/year/sow	
Transport feed	km	EURO number (based on load capacity and load fraction)
Transport liquid feed	km	EURO number (based on load capacity and load fraction)
Manure management	Fraction per type of manure management	Duration of the storage
Transport manure	km	EURO number (based on load capacity and load fraction)

Table 2.7 *Required data for the manure digester system*

Parameter	Unit	Supplementary information
Biogas	m^3/year	Calorific value
Digestate	kg/year	
Processed manure	tonne/year	
Sodium hydroxide	kg/year	
Glycerine	kg/year	
Electricity	kWh/year	Production mix/own production; green or grey
Construction		
Expected lifetime	Years	
HDPE material	kg	
PVC material	kg	
Concrete	kg	
Steel	kg	

Table 2.8 *Required data for distribution and retail*

Parameter	Unit	Supplementary information
Transport pig meat products	km	
Electricity use at retail	Wh/kg	
Fraction of food loss	kg/kg	

Because of the small contribution of distribution and retail, estimates can be used for transport and electricity use. For example, the average electricity use per square meter surface of a supermarket and the food loss of meat products are given in the Organisation Footprint Sector Rules for Retail (Quantis, 2018).

Table 2.9 *Required data for waste treatment (applies to each type of waste)*

Parameter	Unit	Supplementary information
Transport municipal waste collection	Km	
Fraction of waste recycled	kg/kg	
Fraction of waste incinerated	kg/kg	
Fraction of waste to landfill	kg/kg	
Allocation factor for recycling	%	
Allocation factor energy recovery	%	

Because of the small contribution of waste treatment, an estimate can be used for the transport distance for municipal waste collection and default values for the Netherlands can be used as given by the European Commission.[3]

2.3.2 Background data

For feed raw materials the background database FeedPrint can be used. This database contains a large number of raw materials, has recently been updated and is in line with the European standard PEFCR animal feed. FeedPrint is not yet available in SimaPro, but the developers (Wageningen Livestock Research and Blonk Consultants) have given permission for making the data available in SimaPro and technically this is not a large amount of work. In case pig farms partly produce their own feed raw materials, it is recommended to assume that these raw materials were purchased, and use Feedprint for the CFP values. The alternative would be that farmers provide the primary data for inputs and crop yields.

For electricity and natural gas, it is recommended to use Ecoinvent data. The amounts from renewable energy (green) sources and fossil fuel based (grey) energy sources should be clear. The electricity production mix can be adjusted to make it more specific and the natural gas combustion process can be adjusted for calorific value and efficiency.

For transport, the Ecoinvent database is based on the average load fraction for different transport means. Transport vehicles are classified based on their load capacity and their fuel class (EURO 5, 6). Furthermore, Ecoinvent assumes that the trucks pass one way with the average load fraction and return empty. The result can then be used as standard for transport processes.

Ecoinvent can also be used for tap water, packaging materials and waste processing.

2.4 Impact assessment

There are several scientific models for converting different types of environmental interventions, such as emissions of carbon dioxide, methane and nitrous oxide. There is much debate among scientists about what the best approach is, leading to increasingly sophisticated models. This causes the factors to change regularly. There is currently international consensus that the IPCC GWP100 factors with carbon feedback are used from the fifth assessment report AR5. Table 2.10 shows the factors for the most important greenhouse gases. The sixth assessment report is expected in 2022 and the factors may then change.

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[3] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml (link Annex C to the PEF/OEF methods)

Table 2.10 *GWP100 factors for the most important greenhouse gases from the IPCC AR5 report (* the factor for biogenic methane has been corrected for the carbon dioxide captured by plants at the start of the chain; the same applies to biogenic carbon dioxide.)*

Greenhouse gas	GWP100 factor (kg CO_2 eq/kg)
Carbon dioxide	1
Carbon dioxide, biogenic*	0
Methane, biogenic*	34
Methane, fossil	36.8
Nitrous oxide	298

Expansion with other environmental indicators is possible. It is advisable to use the indicators selected by the European Commission for PEF calculations. A number of other emissions must then be calculated for the livestock farming systems. Calculation rules have been established for this by Langerwerf et al. (2019). The background data for materials and energy contain a large number of types of emissions and other environmental interventions. The background data for feed materials FeedPrint is not that extensive, but contains interventions for the most important impact categories. The full list of impact indicators of the European Commission has 16 impact categories (Table 2.11). Of these, a number are not relevant for pig meat products, in particular ionising radiation and ozone reduction. The toxicity indicators may be relevant, but the methods and the emission data are so uncertain that no conclusions can be drawn with the results and are therefore only indicative.

Table 2.11 *Impact categories and methods and associated units selected by the European Commission (Zampori and Pant, 2019)*

Impact category	Method	Unit
Acidification	Accumulated Exceedance (AE)	mol H+ eq
Climate change	Global Warming Potential (GWP100)	kg CO2eq
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems	CTUe
EF-particulate Matter	Impact on human health	Disease incidence
Eutrophication marine	Fraction of N reaching marine water	kg N eq
Eutrophication, freshwater	Fraction of P reaching freshwater	kg P eq
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq
Human toxicity, cancer	Comparative Toxic Unit for human	CTUh
Human toxicity, non-cancer	Comparative Toxic Unit for human	CTUh
Ionising radiation, human health	Human exposure efficiency relative to U235	kBq U235
Land use	Soil quality index	Pt
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11 eq
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq
Resource use, fossils	Abiotic resource depletion fossil fuels	MJ
Resource use, minerals & metals	Abiotic resource depletion (ultimate reserve)	kg Sb eq
Water use	User deprivation potential	m3 world eq

2.5 Transparency and communication

Variations over time can make it hard to interpret the results of the carbon footprint calculations. In particular, changes in feed composition and origin of the raw materials can have a major impact on the carbon footprint values. It is recommended to be transparent and clearly show the real year-to-year fluctuations, and add effective communication to explain changes that are a result of unforeseen circumstances, like for example trade barriers on the animal feed market. An alternative approach would be to show a more stable, multi-year running average, with the disadvantage that important improvements such as adapted manure processing and switching to other feed raw materials will be less visible.

3 Carbon footprint calculation in practice

Chapter 2 described the LCA method and the options for calculating a carbon footprint with the required data for the full food chain. This chapter describes how the data required for Vion's pork production is collected and processed concerning the stages up to the slaughterhouse. Figure 3.1 schematically shows the most relevant processes in pork production that release greenhouse gases. This figure also serves as a framework for the final calculation of the carbon footprint (CFP), expressed in CO_2 equivalents per kg of live pig weight at the farm gate. The calculation steps correspond to the numbers in the diagram.

This chapter discusses the greenhouse gases carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) and their conversion to CO_2 equivalents.

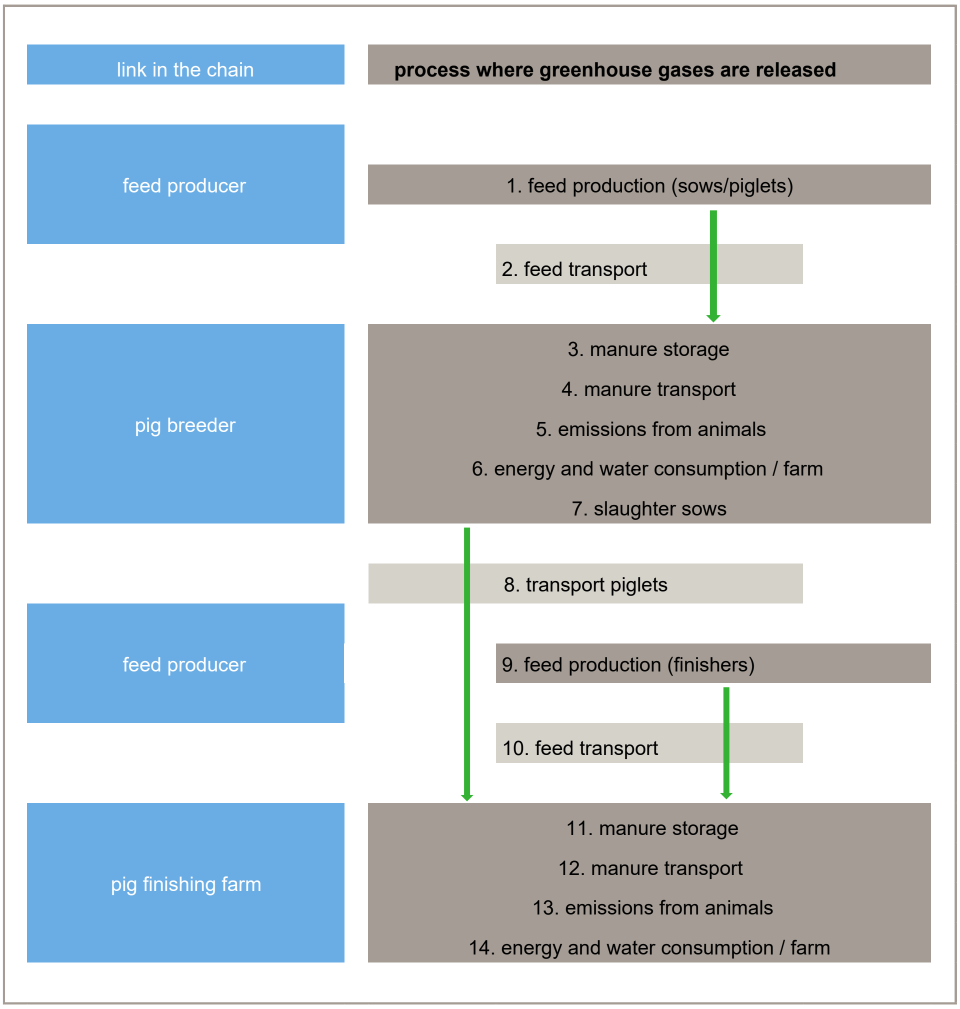

Figure 3.1 *Schematic overview of the carbon footprint calculation*

Calculation 1. Emission of greenhouse gases during the cultivation and production of feed for the pig breeding farm

Required data

The following information has to be made available through the feed supplier (s) of the pig breeder:

- Amounts of feed raw materials sold per type in kg
- Country of origin per feed raw material

  - For several countries of origin of one raw material, provide % per country of origin on the basis of quantity
- Electricity, natural gas and water use for the production of feed per unit of feed produced

The following data must be retrieved from an LCA database (for example FeedPrint or SimaPro):

- Value of CO_2 equivalent per unit weight of the raw material per country of origin

The following data must be retrieved from the Ecoinvent database:

- CO_2 equivalent value per unit of gas used
- CO_2 equivalent value per unit of electricity used
- CO_2 equivalent value per unit of water used

Calculation 1a shows how the calculation should be performed for one raw material from one country of origin. This calculation must be repeated as many times as raw materials have been purchased (taking into account stocks on 1 January and 31 December) per country of origin, on the basis of the total quantities purchased in the relevant year.[4]

Calculation 1a: CO_2 equivalents of raw material production and country of origin

Quantity of raw material X from country of origin Y purchased, in kg per year[5]

x

corresponding value (CO_2 equivalents per kg) from the LCA table

=

Carbon footprint in kg CO_2 equivalents for the total purchased **feed X from country Y**

Please make sure that the units in the calculation match.

Result: a value for all feed types purchased by the pig breeder, taking into account the country of origin. The sum of all these values is the emission of greenhouse gases expressed in CO_2 equivalents for all the feed used at the pig breeding farm, excluding the emissions from the production process at the feed factory itself.

For feed products and by-products that are not in the LCA table, first try to get the information from the feed producer or the pig farmer. If that’s not possible, use the information of a similar product, or ask an expert (e.g. WUR animal feed expert) to provide relevant information. The last option is, in case it’s only a small part of the total feed use, ignore it.

Calculation 1b: CO_2 equivalents of the feed production at the feed supplying company

(Quantity of gas used per unit of feed produced x value of CO_2 eq. per unit of gas)

+

(Quantity of electricity used per unit of feed produced x value of CO_2 eq. per unit of electricity)

+

(Quantity of water used per unit of feed produced x value of CO_2 eq. per unit of water)

=

Total CO_2 equivalents for energy use in feed production per kg feed

Please make sure that the units in the calculation match

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[4] We propose to calculate the Carbon Foot Print on a yearly basis and not (yet) for each delivery of piglets or pigs. That has the advantage of less work and less influence of (estimates of) stocks of feed and animals (although these should be taken into account). However it involves a delay in the availability of data (consumers cannot be informed on the real foot print of their purchases).

[5] Taking into consideration the stock on January 1 and December 31

Combining calculation 1a and 1b:

Sum of all 1a calculations is value for all raw feed materials up to the feed factory.
The result of 1b is the value per unit of feed produced. The total feed consumption is known.

Sum of all 1a outcomes + 1b x total feed consumption [unit]
=
Total CO_2 equivalents for all purchased feed from the feed factory

Please make sure that the units in the calculation match

For farms growing (a part of) their own feed, it is recommended to use FeedPrint, as if they bought it.

Calculation 2. Emission of GHG during transport from feed factory to pig breeding farm (if FeedPrint is used, transport to farm is already included)

Required data
The following data must be retrieved from the Ecoinvent database:
- Value CO_2 equivalents per tonnekm, based on load capacity in tonnes and EURO category (emissions for diesel)

Default values
- Type of transport: EURO category 6 (choose lower when highest EURO category is not applicable)
- Distance feed supplier - buyer: 93 km

Calculation 2: Transport feed factory – pig breeding farm

Average number of km single trip (transport distance from feed factory to pig breeder)
x
total weight of feed transport (tonnes)
x
value for CO_2 equivalents per tonnekm from Ecoinvent

=
Total CO_2 equivalents for transport of feed to pig farm

Calculation 3. Emission of GHG in manure storage on pig breeding farm

Required data
From pig breeder:
- Type of manure storage (only at start-up and at the moment the farmer makes changes)
  - slurry with natural crust formation
  - slurry without natural crusting
  - manure storage under the pig house <1 month
  - manure storage under the pig house > 1 month
  - manure storage under the pig house for 6-7 months
- Farm storage systems can also be derived from the RAV codes of the systems, which are about 150 different systems that could be linked to the above classification.[6]

Search in CVB table per feed material
- VCOS = Organic matter digestibility in%

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[6] https://wetten.overheid.nl/BWBR0013629/2019-04-26#Bijlage1

- Crude ash content (RAS)
- Crude protein (RE)
- Digestible crude protein (VCRE)

In the calculation of GHG emissions from the manure storage, methane and nitrous oxide are calculated separately.

Calculation 3a: Volatile solids per feed raw material

$$VS = [(1- VCOS)+UE] \times [(1-RAS)]$$

$$VS = [(1- VCOS)+0{,}02] \times [(1-RAS)]$$

Example wheat:

$$VS = [(1- 0{,}9)+0{,}02] \times [(1-0{,}014)]$$

$$= 0{,}118/kg\ feed$$

- VS = volatile solids in kg of dry matter (in feed) /year
- VCOS = digestibility fraction in% per feed unit (for example wheat VCOS = 90%)
- UE = urinary energy in kg/kg (0.02 kg/kg for pigs)
- RAS = ash content in g ash/kg feed (for example wheat RAS = 14 g/kg)

Calculation 3b: Methane emissions per feed raw material

$$\text{Emission of methane } [CH_4/\text{unit feed/year}] = VS \times 0{,}31 \times 0{,}67 \times MCF$$

MCF: methane conversion factor in kg/kg CH_4

Manure storage system (see Chapter 2)	MCF (current value)
slurry with natural crust formation	0.11
slurry without natural crust formation	0.19
manure storage under the pig house < 1 month	0.03
manure storage under the pig house > 1 month	0.19
manure storage under the pig house 6-7 month	0.36

The sum of the results per feed raw material forms the emission factor methane from manure [CH_4/farm/year].

Calculation 3c: Nitrous oxide emissions per kg live weight delivered

Emission factor [N_2O total farm] = N_2O total [per kg live weight] x total kg live weight delivered[7]/year

N_2O total = N_2Odir + $N_2Oindir$ [per kg live weight]

N_2Odir = Nex x EF_{oth}(NEMA table) x 44/28
- Nex = Nintake - Nretention
  - Nintake = feed conversion * RE/6.25 (average RE from all feed)
    - feed conversion
    - RE= crude protein (CVB tables)
  - Nretention = 25,0[8]
- EF_{oth} from NEMA table[9] in % of Nex

$N_2Oindir$ = NH_3 x EF_c(IPCC table) x 44/28 (emission of N_2O from volatilised NH_3)
- NH_3 = TAN x EF_{em}(NEMA table) (emission of NH_3 from TAN in manure)
  - TAN = Nex – Norganic
    - Nex is already calculated
    - Norganic = Nintake x (1-VCRE)
      - Nintake is already calculated
      - VCRE is digestibility of crude protein (in %), average for all feed
  - EF_{em} from NEMA table[10]
- EF_c from IPCC table[11]

- N_2Odir = direct nitrous oxide emissions from manure storage in kg N_2O/kg live weight
- $N_2Oindir$ = indirect nitrous oxide emissions from deposition of ammonia and nitrogen oxides from the manure in kg N_2O/kg live weight
- Nex = nitrogen excretion in kg N/kg live weight
- Nintake = daily nitrogen intake from animal feed in kg N/kg live weight
- EF_{oth}(NEMA table)[9] = Emission factors for other gaseous N losses (% of N excretion (Nex))
- 44/28 = conversion factor in kg N_2O/kg N
- RE = Raw protein
- NH_3 = ammonia
- EF_c (IPCC table)[11] = $EF_{convert}$ default emission, volatilisation and leaching factors for indirect soil N2O emissions.
- TAN = fraction of total ammonia nitrogen volatilised as ammonia and nitrogen oxides kg N/kg N
- EF_{em} (NEMA table)[10] = $EF_{emission}$ NH_3-emission factors for pig housing (% of TAN excretion)
- Norganic = Part of not digestible N
- VCRE = digestible raw protein, average for all feed

Leaching is not taken into account.

Combining calculations 3b and 3c:

Emission manure storage in kg CO_2 eq./year

=

Emission methane [CH_4/year] x 34

\+

Emission [N_2O/year] x 298

---

[7] See for the calculation to kg live weight delivered, the number of delivered finishers and the final weight of the finishers at the end of this calculation.

[8] https://www.cbs.nl/-/media/imported/documents/2009/23/2008-c72-pub.pdf (WUM data, table 38 page 52)

[9] https://edepot.wur.nl/499382 (NEMA, table 2.14, page 33)

[10] https://edepot.wur.nl/499382 (NEMA, table 2.11, page 31)

[11] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf, table 11.3, page 11.24

Conversion factors manure storage on the pig breeding farm.

Greenhouse gas	GWP100 factor (kg CO_2 eq/kg)
Carbon dioxide	1
Carb**on dioxide, biogenic***	0
Methane, biogenic*	34
Methane, fossil	36.8
Nitrous oxide	298

In case there is a digestion system on the farm, it is a little bit different.
-if the manure is transported to the system daily, the emissions from the manure are assumed to be zero. The only emission of the system is some leakage, assumed to be 4% of the total emissions of methane from pig houses without digestion systems.

-if there is a digestion system on the farm and the manure is *not* transported to the system daily, the emission of GHG is 54% from farms without a digestion system. 50% emission in the stables, and 4% emission methane leakage from the system.

Of course, the emission for transporting manure is zero at farms with manure-treatment systems.

Some farms have a manure digestion system using co-products, like maize. The digestion system is not part of the pig production, but intended for energy production. So we recommend not to include the emissions from the cultivation of purchased by-products in the footprint of pig production. The manure digestion system reduces the emissions from manure as described above.

Calculation 4. GHG emissions during manure transport from the pig breeding farm

Required data
The following data must be retrieved from the Ecoinvent database:
- CO_2 equivalents value per tonnekm, based on load capacity in tonnes and EURO category (emissions for diesel)

Default values:
- Type of transport: EURO category 6 (choose lower when highest EURO category is not applicable)
- Distance manure transporter - buyer: 93 km[12]

Calculation 4: Transport pig breeder to manure destination

average km (transport distance from pig breeder to manure destination)
x
total weight of manure transported in the relevant year (tonnes)
x
value for CO_2 equivalents per tonnekm from Ecoinvent
=
Total CO_2 equivalents for transporting all manure delivered

---

[12] Estimated based on average transport distance of feed transports in the Netherlands, at the moment no better estimation is available

Calculation 5. GHG emissions from pigs

Required data
From the pig breeder the following information should be made available:

- Average number of sows present
- Average number of rearing sows present
- Average number of piglets present

Calculation 5: Emissions via enteric fermentation from pigs

(Average number of sows present
+
Average number of rearing sows present
+
Average number of piglets present)
x
1,5 kg CH_4/pig/year
=

Total methane emission from entire pig population/year

Convert to CO_2 equivalents by multiplying by 34
=
CO_2 equivalents from all pigs/year

The methane emission of pigs is defined as 1.5 kg CH4/pig/year.[13]

Calculation 6. GHG emissions from use of energy and water on the farm[14]

Required data
The pig breeder provides the following information:

- Use of gas, water and electricity for the piglet production
- Possibly supplemented with data about the private household to calculate a default value for the private use of energy and water, if no separate data are available.

The following data must be retrieved from the Ecoinvent database:

- CO_2 equivalent value per unit of gas used (different value for normal ('grey') and environmental friendly ('green') gas)
- CO_2 equivalent value per unit of electricity used (different value for normal ('grey') and environmental friendly ('green') energy)
- CO_2 equivalent value per unit of water used

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[13] Regardless of whether it is a piglet, a rearing sow or an adult sow

[14] The purchases can be entirely attributed to the piglets, otherwise consumption must be requested from the breeder (or the type of feed bought should be labelled by the supplier as specific types of feed for sows and piglets) Furthermore, it is assumed that there are no other activities on the farm for which electricity and water are used (e.g. arable farming, dairy cattle) and that private use is measured and invoiced separately. Otherwise, a default value should be deducted for private use of energy and water.

Calculation 6: CO_2 equivalents from the piglet production process on the breeding farm

(Quantity of gas used on the farm x value of CO_2 eq per unit of gas)

\+

(Quantity of electricity used on the farm x value of CO_2 eq per unit of electricity)

\+

(Quantity of water used on the farm x value of CO_2 eq per unit of water)

=

Total CO_2 equivalents for energy and water use in piglet production process

If there are systems at the farm, to generate energy, the energy purchased is less or zero.

Calculation 7. GHG emissions from the sows (part will be deducted)

Required data
The pig breeder should provide the following information:
- Total price sold sows/year
- Total price sold piglets/year
- Average number of piglets produced/sow/year

Calculation 7: slaughtering sows
To calculate the CO_2 equivalents of the sows economic allocation should be applied. This means that the economic value (in euro) of all slaughtered sows is given as a percentage compared to the economic value of all piglets produced in that year.

Suppose the slaughtered sows represent 5% of the total economic value, then that percentage should be deducted from the total calculated below and is allocated to the sows. The remainder will be allocated to the piglets.

Summary calculations pig breeding farm

The findings are:
Calculation 1: Total CO_2 equivalents for all feed purchases at the feed factory gate
Calculation 2: Total CO_2 equivalents for transport of all feed purchased
Calculation 3: Emission manure storage in kg CO_2 equivalents/year on the farm
Calculation 4: Total CO_2 equivalents for manure transports
Calculation 5: Total CO_2 equivalents for emission from the pigs per year
Calculation 6: Total CO_2 equivalents for the piglet production process (energy and water use)
Calculation 7: Total CO_2 equivalents for the production of slaughtering sows

The sum of all these values from calculation 1 to 6, with deduction of the value from calculation 7, gives a value for the total number of CO_2 equivalents per farm that must be allocated to the piglets.

Converting the total CO_2 equivalents per farm (CO_2 farm) to the total CO_2 equivalents per piglet (CO_2 piglet):[15]

CO_2 piglet = CO_2 farm/average number of piglets produced per year[16]

Average number of piglets produced per year

=

Average number of piglets produced per sow per year x Average number of sows per year

---

[15] The assumption is that we are dealing with a constantly producing, stable system.

[16] The total number of piglets delivered can fluctuate per calendar year, depending on the number of delivery times. This has a major impact on the CFP value per piglet. To prevent this, the calculation should be based on the average number of piglets delivered per sow per year x average number of sows present in that year.

Calculation 8. GHG emissions during transport of piglets to the pig finishing farm.

Required data
From the Ecoinvent database the following data are needed:

- Value CO_2 eq per tonnekm, based on load capacity in tonnes and EURO category (emissions for diesel)

Default values

- Type of transport: EURO category 6 (choose lower when highest Euro category is not applicable)
- Distance pig breeding farm - pig producing farm: 100 or 93 km[17]

Calculation 8: pig breeding farm - pig finishing farm

Average km (transport distance pig breeding farm - pig producing farm)

x

total weight of piglets transported in the relevant year (tonnes)

x

value for CO_2 equivalents per tonnekm from Ecoinvent

=

Total CO_2 equivalents for transport of all piglets in that year

Calculation 9. Emission of greenhouse gases during the cultivation and production of feed for the pig finishing farm.

This calculation is the same as calculation 1 at the breeding farm.

Calculation 10. Emission of GHG during transport from feed factory to pig finishing farm.

This calculation is the same as calculation 2 at the breeding farm.

Calculation 11. Emission of GHG in manure storage on pig finishing farm.

This calculation is the same as calculation 3 at the breeding farm.

Calculation 12. GHG emissions during manure transport from the pig finishing farm.

This calculation is the same as calculation 4 at the breeding farm

Calculation 13. GHG emissions from pigs

Required data
From the pig finisher the following information is available:

- Average number of finishing pigs present

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[17] Estimation based on average transport distance of feed transports throughout the Netherlands (93 km), or value from agri-footprint (100 km)

Calculation 13: Emissions from pigs

Average number of finishing pigs present

x

1,5 kg CH_4/pig/year

=

Total methane emission from entire pig population/year

Convert to CO_2 equivalents by multiplying with 34

=

CO_2 equivalents from all pigs/year

The methane emission of pigs is defined as 1.5 kg CH_4/pig/year.

Calculation 14. GHG emissions from use of energy and water on the farm

This calculation is the same as calculation 6 at the breeding farm

Summary calculations pig finishing farm

The findings are:
Calculations 1 - 7: CO_2 equivalents/piglet purchased[18]
Calculation 8: Total CO_2 equivalents for transport of piglets purchased
Calculation 9: Total CO_2 equivalents for all feed purchases at the feed factory gate
Calculation 10: Total CO_2 equivalents for transport of all feed purchased
Calculation 11: Emission factor manure storage in kg CO_2 equivalents/year on the farm
Calculation 12: Total CO_2 equivalents for manure transports
Calculation 13: Total CO_2 equivalents for emission from the pigs per year
Calculation 14: Total CO_2 equivalents for the finishing production process (energy and water use)

Total CO_2 equivalents at the pig finishing farm/year:

CO_2 equivalents piglet purchased x number of piglets purchased

+

Total CO_2 equivalents for transport of all piglets purchased/year

+

Total CO_2 equivalents for all feed purchases at the feed factory gate/year

+

Total CO_2 equivalents for transport of all feed purchased

+

Emission factor manure storage in kg CO_2 equivalents/year on the farm

+

Total CO_2 equivalents for manure transports

+

Total CO_2 equivalents for emission from the pigs per year

+

Total CO_2 equivalents for the finishing production process (energy and water use)

=

Total CO_2 equivalents/year at the finisher farm

---

[18] This is the number of piglets the finisher needed to buy in a year, to deliver the average number of finishers/year. Also have a look at point 21 and at calculation 'number of finishing pigs delivered per year'

Converting the total CO_2 equivalents per farm (CO_2 farm) to the total CO_2 equivalents per finisher (CO_2 finisher)[19]

Required data
The pig finisher should provide the following information:

- Average number of pigs present per year [number]
- Average initial weight of piglets [kg]
- Average final weight of finishers [kg]
- Daily growth [gram]
- Mortality [%]

Converting the total CO_2 equivalents per farm (CO_2 farm) to the total CO_2 equivalents per finisher (CO_2 finisher)[20]

Calculation of the average number of finishers delivered/year:

Total growth [kg] finishers: average final weight of finishers - average initial weight of piglets
Growth period [days]: total growth/(daily growth/1,000)
Production cycles per year (PC-present): 365/growth period
Production cycles/year for average number of delivered pigs (PC-delivered): PC-present * (1 - mortality/2)
Number of finishers delivered/year = average number of pigs present per year * PC-delivered

Amount of CO_2 equivalents/finisher delivered

=

Total CO_2 equivalents per year (total farm)

/

Number of finishers delivered per year

Table 3.1 *Example calculation number of finishing pigs delivered per year*

Average number of pigs present per year [number]	4,000
Initial weight of piglets [kg]	25
Final weight of finishers [kg]	121.2
Daily growth [gram]	830
Mortality [%]	2.5%

Total growth [kg] finishers: 121.2 – 25 = 96.2 kg
Growth period [days]: 96.2kg/(830 gram/1,000 gram) = 115.9 days
Production cycles per year (PC-present): 365/115.9 days = 3.15
Production cycles/year for average number of pigs delivered (PC-delivered): 3.15*(1 – 2.5%/2)= 3.11
Number finishers delivered/year = 4,000 * 3.11 = 12,439 finishers
Number piglets purchased/year = 12,439 * 102.5% = 12,750 piglets

Overview of variables

See Appendix 3 for an overview of all variables, including the source of the data, and information on the expected impact on the carbon footprint, and the influence of the pig farmer.

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[19] The total number of delivered pigs can fluctuate per calendar year, depending on the number of delivery times. This has a major impact on the CFP value per meat pig. To prevent this, you have to calculate with the average number of pigs delivered per year.

[20] Source: KWIN 2019-2020, page 260 'Aantal afgeleverde vleesvarkens per varken per jaar'

4 Data platform and flows

In Chapter 2 the requirements for the CFP calculations were described based on the LCA methodology, resulting in a list of relevant indicators. In Chapter 3 for all indicators the data sources and calculations were given concerning a CFP up to the slaughterhouse. In this chapter the data flows are described, based on available systems and existing standards for data messages. Besides, Section 4.1 describes the data collection through the JoinData platform, and pays extra attention to data quality, auditability and information standards.

4.1 Data collection

4.1.1 Auditability

The CFP of a pig meat and therefore of a batch of pigs delivered to a Vion slaughterhouse should have a correct ('true and fair') value, as in principle Vion guarantees the correctness of this value to the retailer, other supply chain partners and end consumer. Its reputation would be damaged if values turn out not to be in line with the reality.

This implies that in the end the data have to be auditable: an independent auditor (certification scheme or certified public accountant) has to be able to guarantee that the data is correct and that no fraud has taken place. As long as the CFP is only used for management purposes, this is not a big issue. But once that financial rewards (e.g. price for the pigs or selection of farmers into a certain sustainability scheme with higher rewards) come in sight, the CFP data exchange should be fraud-resistant. This is also the case when, in a parallel action, the government starts regulating farms based on CO_2 emissions.

Preventing fraud requires a risk analysis with an inventory where risks of fraud can occur, and how likely it is detected and repaired. A full risk analysis is outside the scope of this project. For a first approach, the results of earlier risk analysis in the sector can be taken into account in designing the data flows. These risks analysis has been carried out in the analysis of reporting mineral and manure material flows, especially in the MINAS system for mineral accounting (Projectbureau Mineralenboekhouding, 1995; Breembroek et al., 1996). Applying that knowledge to the CFP it is likely that there are two main risks in auditability of the data.

The first one is the fact that farmers (and others) could report an incomplete set of data. If for instance all the documents of feed input have to be reported for a CFP calculations, a farmer could have an incentive to (accidently or on purpose) under-report. Some invoices or delivery notes could be lost. Or a farmer could buy some of its feed from a second supplier, without reporting that flow of feed. That is not easily detected by assessing the feed conversion ratio of farmers: it are farmers with a low feed conversion ratio who are not very profitable and have an incentive to underreport, with the effect that their reported feed conversion ratio and their CFP improves to average level. There are two measures that would improve the auditability of the data and reduce this risk. One is to build up a national database in with all national and international feed suppliers report to which farmers (participating in CFP programs) they deliver which helps Vion to check if a farmers provided access to all its feed input data. Another measure is the one implemented in the MINAS system: link the data on the material flow to the payment (bank) data of the farm. The fact that farmers have paid for their feed (and have reported that in their fiscal accounts) should be in line with reporting their feed intake for the CFP. Be aware that also this solution is not perfect: with cash transactions, self-produced feed and manure that has a strong negative value (and thus contributes to the CFP), fraud can still occur.

The second main risk in auditability is the fact that many farms are mixed: they not only produce pigs, but also have some arable farming (ranging from a few ha of silage maize to a large arable operation with sugar beets, potatoes, etcetera), a dairy farm, or they produce their own energy with solar panels or a wind turbine. On such farms some of the inputs that contribute to the CFP at farm level are a common input for the pigs operation and the other operation(s): electricity is bought in via one meter for the pig house as well as for storage of the potatoes and the private house. Some feed (like products coming from the beer or potato industry) could be fed to pigs as well as cows, or at least could be claimed to be used in both ways. The solution to this risk is to have access to the full accounting of the farm so that it can be judged if reported results for all operations are likely.

In the analysis below we have not (yet) incorporated the data needs that result from the auditing process. This to reduce complexity and as this is not needed for a first voluntary trial (pilot). However, in taking decisions on how to organise the data flows and in setting up databases and writing software the extension of the data set with data and procedures to make data auditable have to be taken into account. That will imply that more data has to be exchanged (e.g. payment data, data on whole farm level in addition to those of the pig operation) and have to be made available to an auditor (with the outcome of the audit as a data item to be exchanged too). Technologies like block-chain and artificial intelligence could be of some help here, but will not solve the basic issue of data quality at the point of entry of the data into a system (garbage in – garbage out also holds in high technological systems).

4.1.2 Datahub and authorisations register: JoinData

One of the building blocks for the Building Balanced Chains (BBC) concept of Vion is to implement it in a secure and transparent data infrastructure. The alignment with the platform JoinData is a criteria, since it is the connection with systems for farmers. For the calculation of CFP, Vion wants data from pig farmers. This data is partially digitally available at different suppliers and sub-contractors. The main focus of JoinData is its multi-stakeholder fit through two types of roles. Users can use the system as (1) a postman, which is transporting the data and managing the authorisations or (2) solely managing the authorisations with JoinData and transporting the data with existing direct interfaces. Moreover, there are three types of stakeholders being classified, and all these stakeholders are able to use JoinData from their own perspective. In Table 4.1, these different roles are presented. Data governance role reflects the different roles and its responsibilities each user has. Portal represents the interface of JoinData which is available for different users of JoinData.

Table 4.1 *Types of roles in JoinData*

Data governance role	Description	Example Vion CFP pig farming	Portal
Data Consumer/Application Developer	Organisations in this portal are able to create ‘purposes’, invite farmers and consume data. Currently, this is based primarily on the Chamber of Commerce Number (Dutch KVK).	Vion	My JoinData for Partners
Data Owner	As application users, farmers are able to manage their invitations and purposes.	Pig Farmer	My JoinData
Data source/data custodian	Organisations that manage data on behalf of farmers can unlock and distribute this data with JoinData taking into account farmers’ consent.	Feed Supplier, Utility Company, RVO (Dutch Paying Agency)	My JoinData for Partners

Concerning information models, JoinData strives to align as much as possible to existing standards. Currently, the standard ICAR-ADE[21] (International Committee for Animal Recording) is adopted since the JoinData initiative had its beginning in dairy farming. Additionally, the systems endeavor for having small number of message types, which should be generically applicable. For example in the

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[21] https://github.com/adewg/ICAR

dairy domain, using EDI (Electronic Data Interchange), quantity liters of milk, quantity of protein, milk delivery etc.

For the calculation of CFP of pigs, permission of the farmer is needed to get access to his data via authorisations. Subsequently, JoinData looks for which parties already are connected and which should be available.

Moreover, JoinData makes a distinction in four types of data:

1. Raw Data: often this data is without any interpretation. For example sensor data.
2. Free Data: this data is recognisable for the farmer. The data custodian/data provider has no specific benefits for this.
3. Licensed Data: for this data the farmer (data owner) as well as the data custodian should provide permissions with a signature.
4. Aggregated Data: this data is used for benchmarks. Since this data is not traceable, the farmer does not have to provide permissions.

4.1.3 Information standards in the fresh food chain

A relevant initiative for this project is called Fresh Upstream. Fresh Upstream is a foundation in the international fresh food chain which aims to promote the application and acceptations of information standards. A relevant concept which has been developed in this foundation is the ‘information roundabout’. This concept is being studied and worked out for this project in Section 4.2.1. Moreover, in Fresh Upstream mainly GS1 standards are proposed for increasing transparency and traceability in the chains.[22]

Relevant GS1 standards for this project are:

- GPC (Global Product Classification), helps partners in the chain to group products in the same way. An example for the hierarchy of pigs is presented in *Appendix A*
- GTIN (Global Trade Item Number), used by partners in the chain to uniquely identify all of its products or services which are priced, ordered or invoiced at any point in the supply chain.[23]
- GLN (Global Location Number), used by partners to identify their locations, having the flexibility to define any type or level of location. It is encoded in either a barcode or EPC/RFID tag to identify locations like destination of a batch or the origin of a product.[24]

For the calculation of CFP, it is important to agree on different levels of using GS1 standards. For example: who provides the GLN? Is that a specific farmer in southern Brazil? Or the collector at the harbor in Brazil? If a feed supplier purchases soy from a trader at the harbour, it can be a mix from different states in Brazil.

4.1.4 CFP supply chain process model

In the previous chapter a process model for CFP calculations is presented, showing three different key actors concerning CFP in the pigs supply chain: pig breeder, pork producer and feed producer (see Figure 3.1). In Chapter 2 the allocation of all supply chain activities, including the abattoir, for the CFP measurement are described.

The main focus in this CFP trial is the perspective of the pig farmer, who is accountable for feed purchasing, transportation (of piglets, pigs, manure) and manure processing, and who can take action to reduce the carbon footprint.

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[22] https://freshupstream.com/en-us/About
[23] https://www.gs1.org/standards/id-keys/gtin
[24] https://www.gs1.org/docs/idkeys/GS1_GLN_Executive_Summary.pdf

4.2 Data flows

Several data flows between the feed provider and pig farmer and the abattoir and pig farmer currently exist: contracts, delivery notes, invoices. Having business as usual in mind, the farmer makes a request for order for the feed provider, containing its specifications for pig feed. Subsequently, the farmer receives a delivery note, comprising the batch of products as the delivery itself and an invoice. Finally, the farmer pays the feed supplier afterwards.

Obviously, the farmer has to organise other activities which contributes to CFP in pig farming or produce data for the CFP calculation. For example, the farmer has one or more utility companies for energy consumption (electricity, water etc.), a software provider for a farm management information system, a service provider for accounting data, etc. It has to be taken into consideration that there are cases where pig farmers have a farm business with multiple pig farms (different locations), for which the same data flows are applicable.

It is been suggested for each party to provide the CFP value for each delivery of a batch of products the party produces, whether it is feed or pigs. Besides the CFP value, in the future also other sustainability indicators could be provided for each batch delivered. In the past similar data flows were operationalised for exchanging information on minerals and manure accounting.

4.2.1 Information roundabout

The information roundabout is a concept developed by the Fresh Upstream foundation. The rationale behind the concept is to have an understanding of data flows, data users and data producers. This understanding can be used to involve different key-stakeholders without an IT background. Questions are who is ‘driving’ into the roundabout (producing data) and who should be ‘driving’ out the roundabout (using data). The foundation organises workshops on several themes, for example on medical treatment for cows.

The concept makes a distinction between two types of data:
- *Masterdata*, which is a set of persistent unique attributes and identifiers that describes the core entities of the enterprise. It is classified as master data because the organisation considers it mission critical (Fleckenstein & Fellows, 2018) (Master Data Management (MDM), 2019). For this project master data are the supplementary information, as mentioned as ‘Supplementary information’ in Chapter 2 for calculating the CFP value. It should have a validity date and a status, since the calculation should be done over different timescales.
- *Process data* is generated during the production process of a product. This could be quantity (i.e. feed, pigs, labour, energy consumption (including solar panels)), input (i.e. feed ingredients, piglets) and output (i.e. slaughter pigs, manure). This data is mentioned as ‘Parameters’. It should have a date stamp and additional information like who produced the data and for whom.

In Figure 4.1 the information roundabout for CFP Pig Feed is presented.

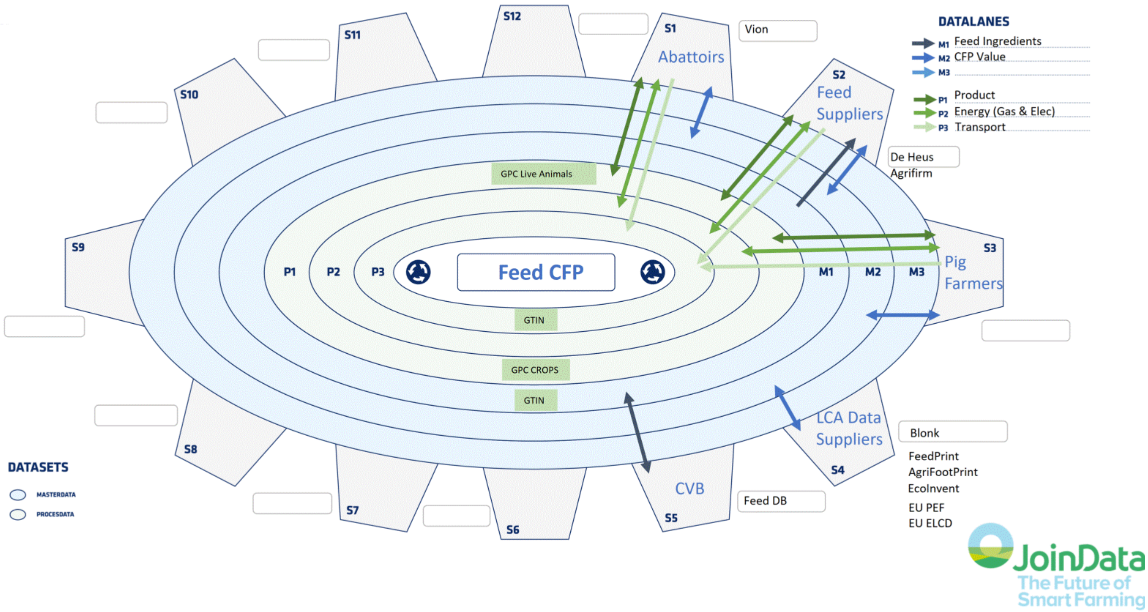

Figure 4.1 *Information Roundabout CFP Pig Feed, adopted from Fresh Upstream*

Besides feed, also manure significantly contributes to the carbon footprint of pig meat. However, this is not worked out in the information roundabout, since it would illustrate many types of datasets which significantly affect the readability. In Table 4.2 a description is given for each relevant element for the CFP calculation for pig meat.

The level of detail and perspective could be presented in different ways. For example manure storage concern other parties and datasets, while another sustainability indicator e.g. child labour could be quantifiable using country of origin of feed raw materials as an extra parameter.

4.2.2 Steering information

Moreover, as an incentive for the farmer (the purpose), it is important to notice the flows of data and information towards the farmer. The farmer could possibly be interested in certain steering information or benchmarking, in the form of KPI (Key Performance Indicator), for his/her farm management. For this the Dutch farmers interest organisation ZLTO (Zuidelijke Land- en Tuinbouworganisatie) and HAS Hogeschool, University of Applied Sciences in Agro, Food and Living Environment, have the ambition to develop dashboards for farmers. Currently, this is already operationalised for dairy farmers as OptiCow.[25] For CFP, first the information need of pig farmers should be assessed, as essential input for the development of the CFP pigs dashboard.

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[25] https://www.zlto.nl/opticow

Table 4.2 Explanation of the Information Roundabout CFP Pig meat

Element in roundabout	Description	Remark
P1 arrow at Abattoirs	**Retrieving:** quantity of delivered pigs, provenance and pig information. **Publishing:** quantity of delivered meat, product information and customer information	
P2 arrow at Abattoirs	**Retrieving:** Energy consumption **Publishing:** Energy supply to the grid	In case of having solar panels, energy could be supplied back to the grid.
P3 arrow at Abattoirs	**Publishing:** The quantity of distance transported for batch of meat delivery in km.	
M2 arrow at Abattoirs	**Retrieving:** CFP Value per batch of delivered pigs **Publishing:** CFP Value per kg/protein/per meat product	
M1 arrow at Feed Supplier	**Retrieving:** Code lists of feed ingredients	From CVB (Central Feed Bureau)
M2 arrow at Feed Supplier	**Retrieving:** CFP Values of feed ingredients **Publishing:** CFP Values of feed ingredients	Retrieving from Blonk DB and FeedPrint
P1 arrow at Feed Supplier	**Retrieving:** Types of feed raw materials, quantity of delivered batch, provenance (origin country), date, supplier information **Publishing:** Types of feed raw materials, quantity of delivered batch, provenance (origin country), date, customer information	
P2 arrow at Feed Supplier	**Retrieving:** Energy consumption (electricity, water, gas) **Publishing:** Energy supply in case of having solar panels	
P3 arrow at Feed Supplier	**Publishing:** The quantity of distance transported for batch of feed delivery in km.	
M2 arrow at Pig Farmer	**Retrieving:** CFP value of feed raw materials **Publishing:** CFP value of a batch of delivered pigs	This could be done to support the farmer for having insights in feed environmental impact with a dashboard
P1 arrow at Pig Farmer	**Retrieving:** Quantity and type of feed raw materials received **Publishing:** Quantity and type of batch of delivered pigs	
P2 arrow at Pig Farmer	**Retrieving:** Energy consumption (electricity, water, gas) **Publishing:** Energy supply in case of having solar panels	
P3 arrow at Pig Farmer	**Publishing:** The quantity of distance transported for batch of pig delivery in km.	
M3 arrow at LCA Data Suppliers	**Publishing**: existing CFP values and code lists **Curating:** existing CFP values and code lists	
M1 arrow at CVB	**Publishing**: existing feed ingredients via the feed database. **Curating:** existing feed ingredients via the feed database.	CVB[26] (Central Feed Bureau database) provides information on digestibility, ash content and energy in order to calculate the volatile substance as described in Section 2.2.3.

4.3 Data model

In order to have the CFP quantifiable, relevant elements for this project are incorporated in a data model. The data model provides a conceptual description of which data should be registered in an information system, how it is structured and what the relations are between the elements. The data model is a representation of the reality in which the frameworks and preconditions are proposed. Moreover, it is a design of how the data base should look like. As stated before, data needed for the

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[26] http://vvdb.cvbdiervoeding.nl/Manage/Tools/VwCalc.aspx

CFP calculation are for example quantity of feed ingredients (raw materials), CFP value of feed ingredients, transportation distances, etc. The data model contains entities which can be used to express these data for a specific application.

Example: Quantity of feed ingredients is the relevant entity, this is called 'raw material' in the model, which is a subclass of Product. It should be expressed in kg as unit of measure and additional information must be provided like name of ingredients, provenance or location. All location information should be specified with the GS1 standard GLN, etc.

The data model can have different intentions of use. For example, a data base administrator can use the data model to decide on how (e.g. which columns are in which table) and which (e.g. adding or removing certain types of information) maintenance operations he/she can execute. Also, the data model can be used by a software developer to develop a specific application or to develop an interface between two information systems. In the latter case the data model can form the basis for the content of the messages to exchange.

4.3.1 Existing models

After a preliminary analysis several relevant models were identified. During the pilot phase it is important to have an alignment between these models and the data model which is proposed in this document. The models are described in Table 4.3.

Table 4.3 *Relevant existing models*

Model	Description	Relevance	Status
ISO 11788 - 3	International standard from ISO. Electronic data interchange between information systems in agriculture. Part 3: Pig farming	The only formal (deprecated) domain model for pig farming.	Deprecated since 2016
FLINT (Farm Level Indicators on sustainability)	EU Framework 7 project which provides a data infrastructure with farm-level indicators for policy evaluation.	Sustainability indicators of FLINT could be used to operationalise indicators as pursued in Vion's BBC	Excel list of indicators and additional information
rmAgro[27]	Reference Model Agro. A normative model which contains multiple class models covering many sub agricultural domains in the primary sector. Started in the arable domain in the 80's.	Source of existing class models in the farming domain. Used among others by FMIS providers.	Latest version from October, 2019
Uniformeringsafspraken Varkenshouderij	'Unification Agreements on pig farming'. Agreements on Dutch national level for standard lists of indicators for pig farming.	Standard definitions and terms for the domain of pig farming.	Started in 2012, revised in 2016.
Class model Pig Farming	AgroConnect Working Group Pig has developed a class model for data exchange between pig breeder, pig finisher and the abattoir.	The class model is probably being developed by the relevant software parties.	Concept version October, 2019.
GS1 GPC	Taxonomy of different products. Used in combination with the preferred identifier: GTIN	See Appendix A for the taxonomy which is proposed by GS1 GPC.	

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[27] ftp://pragmaas.com/rmCrop/rmAgro_SNAPSHOT/

4.3.2 Class Diagram

As mentioned before, this study attempts to define relevant building blocks for a meta model which supports the operationalisation of sustainability indicators for the Building Balanced Chains of Vion. The data model is part of this meta model, since it describes the domain of the pig farmer. The data model should have a certain extent of compatibility with other models in order to sustain interoperability. This ensures the flexibility for different allocation rules and data: e.g. a switch from using a different CFP assessment method than PEFCR.

In Figure 4.2 the data model is presented as an class diagram with the syntax of Unified Modeling Language (UML). Most classes of the class diagram are adopted from rmAgro. rmAgro is based on a series of standardisation activities, wherein robustness is pursued by developing the domain model (drmAgro) as a platform independent model. The platform independent model, then, can be transformed to platform specific model, like XML, JSON, RDF, etcetera. The semantics, which are the content of presented notation, is incorporated in the elements of the model. The user can look up for the through Enterprise Architect for a description of each entity. From a pragmatics perspective, the intent of use of this model is to have an alignment with specific parties to integrate different information systems, in the upcoming phase of the project. Currently, the model is platform independent. In Table 4.4, preferred entities are presented with a description of existing classes from rmAgro as adopted in the data model. Preferred entities raised during the project while identifying the goal of the project with the relevant elements to capture.

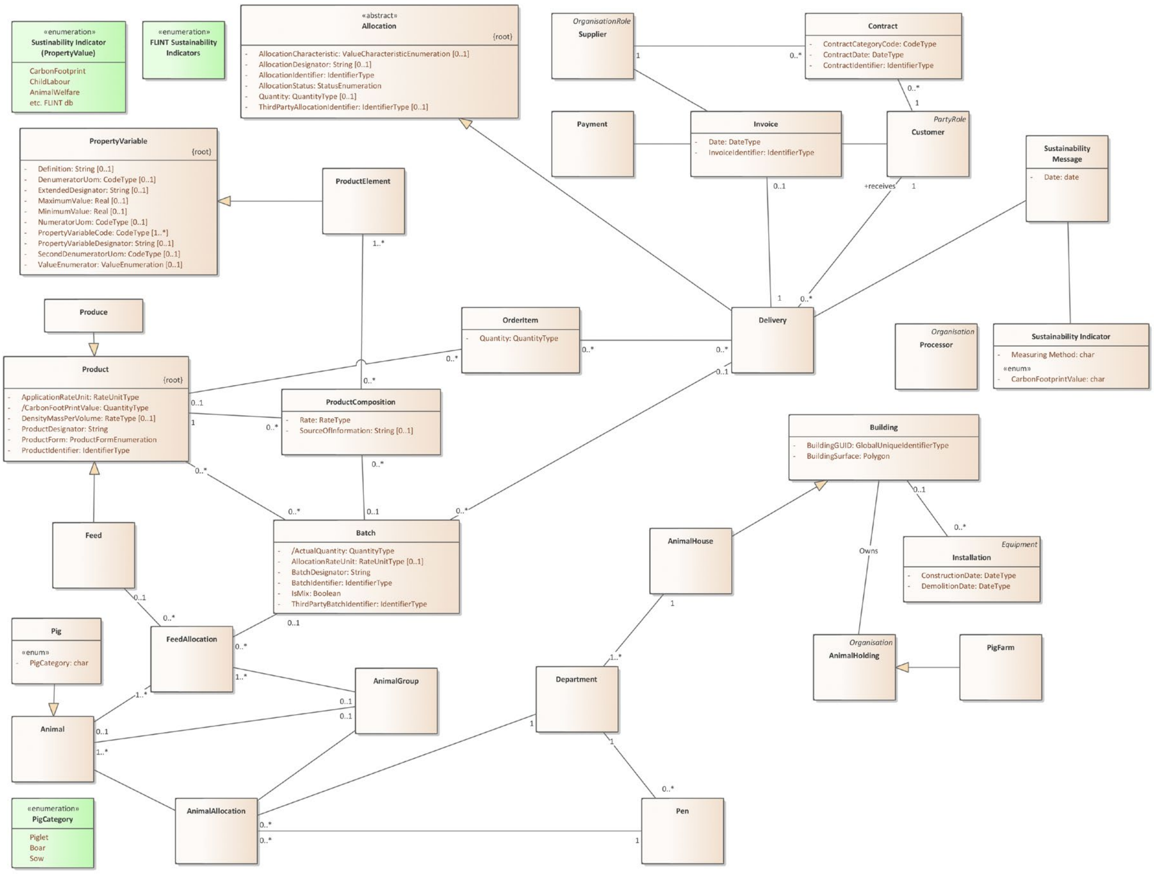


Figure 4.2 *Class model CFP Pig Farming*

Table 4.4 *Preferred entities with description of existing classes from rmAgro*

Preferred entity	rmAgro Classess (expressed in *italic)*
Supplier	*Organisation* contains different roles: Supplier or Customer
Delivery	*Delivery* is proposed as the class for specifying delivery. The transformation of *Animal* and *Produce* is currently implicit.
Delivery Note	*Delivery* is a subclass of *Allocation*. From which transport, location of origin, and destiny can be specified. Through *Delivery* a *Batch* can be specified. A *Delivery* could be based on the *Order* of a *Customer*, which could be a pig farmer or an abattoir, to a *Supplier*. The *Order* is based on a *Contract* between the *Supplier* and a *Customer.* The *Order* contains one or more *OrderItems* and the latter concerns one *Product*.
Delivery Message	A message with a collection of *Deliveries.*
Invoice	*Invoice* is based on one or more *Deliveries.*
CFP Value	Is added as an attribute to *Product*. It is proposed to specify it as a derived variable. This means that it is not registered in the management system, but it is calculated from object values of other classes.
Product Name	*ProductDesignator* as an attribute of *Product*
N, P, K value	Specified through a ProductComposition which specifies a *Rate* of a specific *ProductElement.*
Pig Farmer	Enumerative value of *AnimalHolding*
Consumption allocation	*FeedAllocation,* which is derived from either a specific *Feed* or from a *Batch* of *Feed.*
Animal	*Animal* it is proposed to have *Pig* as a subclass, containing three categories as enumeration.
Group	*AnimalGroup* is the class to specify groups of pigs.
Pig Stable	*AnimalHouse* contains *Departments,* which contains *Pens*
Location	Is being specified with *BuildingSurface,* of the type of Polygon as an attribute of *Building.*
Emission	Emission is a result of production activity and climatic conditions. It is modelled in rmAgro as a sub class of *Produce* and defined as: A produced substance which is generally seen as harmful for the environment.
Manure	*Produce* is proposed as the class for specifying manure. It is not explicit yet, what the relation should be with *Animal* and *AnimalHolding*. *Produce* is in rmAgro collected from a specific harvesting zone (*HarvestingZone*) during a specific time period (*AbsoluteTiming*) by means of an *Operation* (in this case harvesting). For manure there is an *Operation* (which can be called manure collection) over a quit long period (*AbsoluteTiming*) performed on a specific area, in this case most likely on a *AnimalHouse* or a *Department* of an animal house, which results in *ProduceCollection* and results in a specific *Batch* of manure.
Manure processing	Currently not available in rmAgro. Presumably, it has a relation with *Allocation.* This is one or a series of operations, executed on a batch of manure resulting in batches of another produce.
Sustainability report	In case of the pig farmer, de delivered animals are seen as *Produce*. *Produce* is a subclass of *Product,* which contains in this case the CarbonFootprintValue as a derived attribute.
Abattoir	*Processor* is proposed as the class for specifying abattoir. In case of the relation with the pig farmer, it is recognised as a *Supplier*.

In case of integration with JoinData, several aspects need to be considered. For farmers there is a need for KVK (Kamer van Koophandel) numbers, which is the registration number in the Dutch Chamber of Commerce. Dutch farms require also a UBN number to be allowed that pigs are transported to or from their farm location. For this project, this implies a mapping between GLN and KVK. rmAgro foresees this mapping, since most classes apart from their identifier also have the attribute *ThirdPartyIdentifier*, in which other identifiers are specified, apart from their chosen identifier. Also, invoices are standardised with UBL (Universal Business Language), which means that the accounting system of the farmer should support UBL. Also, for the class Delivery of the class diagram it is important to notice to which Party the information flows.

5 Next steps

This report describes in detail the carbon footprint calculation for pig meat, as a solid basis for running a first CFP pilot, and also as a basis for the development of a software solution, including a dashboard for pig farmers.

For the implementation of the software solution, the coming months should be used to define the data queries and data messages in a further specified data model. In a pilot with a number of selected pig farms and a feed supplier, concrete experience will be gained with data collection and the practical implementation of the carbon footprint calculation. Relevant experiences with the Annual Nutrient Cycling Assessment (in Dutch: Kringloopwijzer) and Opticow-dashboard for the dairy sector will be taken into account.

For the realisation of the pilot the following actions will be taken:
- Selection/recruitment of pig farms for the pilot
- Selection of a few FADN pig farms
- Consultation with pig farmers about their information needs and action perspective
- Consultation with data suppliers (especially feed factory, energy suppliers, LCA databases) about supplying data for CFP calculation
- Make agreements with JoinData about processing of data flows, also check if required data flows are already ready for processing by JoinData
- Develop calculation model for CFP calculation
- Drawing up a letter requesting data from pig farmers
- Develop a dashboard for interpreting and using the CFP data by the pig farmers

Simultaneously with the implementation of the pilot, the data model could be further specified, in preparation for the development of a desired software solution. Prior to that, it must be decided which tool will be used for the Carbon footprint calculations.

References and websites

Blonk et al., 2008. Milieueffecten van Nederlandse consumptie van eiwitrijke producten; Gevolgen van vervanging van dierlijke eiwitten anno 2008. Blonk Milieu Advies, Gouda.

Blonk Agri-footprint BV, 2017. Agri-Footprint - Part 1 - Methodology and basic principles. Gouda, the Netherlands.

Blonk Agri-footprint BV, 2017. Agri-Footprint - Part 2 - Description of data. Gouda, the Netherlands.

Breembroek, J.A., B. Koole, K.J. Poppe and G.A.A. Wossink, 1996. Environmental Farm Accounting: the case of the Dutch nutrients accounting system. In: Agricultural Systems 51 (1996), p. 29-40.

Bruggen, C. van, A. Bannink, C.M. Groenestein, J.F.M. Huijsmans, L.A. Lagerwerf, H.H. Luesink, S.M. van der Sluis, G.L. Velthof and J. Vonk, 2019. Emissies naar lucht uit de landbouw in 2017. Berekeningen met het model NEMA. WOt-technical report 147, WOT Natuur & Milieu, Wageningen.

FAO, 2016. Environmental performance of animal feeds supply chains: Guidelines for assessment. Livestock Environmental Assessment and Performance Partnership. FAO, Rome, Italy.

FAO, 2018. Environmental performance of pig supply chains: Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance Partnership. Rome, FAO. 172 pp.

FEFAC et al., 2018. PEFCR Feed for food producing animals. Version 4.1, April 2018. Date of expiration: 31st December 2020.

Fleckenstein, M. and L. Fellows, 2018. Master Data Management. In: M. Fleckenstein, & L. Fellows, Modern Data Strategy (p. 269). Springer, Cham.

IPCC, 2006. Emissions from livestock and manure management, Guidelines for National Greenhouse Gas Inventories, Geneva, Switzerland.

ISO, 2006a. ISO 14040 International Standard. In: Environmental Management – Life Cycle Assessment – Principles and Framework. International Organisation for Standardization, Geneva, Switzerland. http://www.iso.org/iso/catalogue_detail?csnumber=37456

ISO, 2006b. ISO 14044 International Standard. In: Environmental Management – Life Cycle Assessment – Requirements and Guidelines. International Organisation for Standardisation, Geneva, Switzerland. http://www.iso.org/iso/catalogue_detail?csnumber=38498

Lagerwerf, L.A., A. Bannink, C. van Bruggen, C.M. Groenestein, J.F.M. Huijsmans, J.W.H. van der Kolk, H.H. Luesink, S.M. van der Sluis, G.L. Velthof and J. Vonk, 2019. Methodology for estimating emissions from agriculture in the Netherlands; Calculations of CH4, NH3, N2O, NOx, NMVOC, PM10, PM2.5 and CO2 with the National Emission Model for Agriculture (NEMA) – update 2019. WOT-technical report 148, The Statutory Research Tasks Unit for Nature and the Environment, Wageningen.

Master Data Management (MDM), 2019. Retrieved from Gartner 28-10-2019. https://www.gartner.com/en/information-technology/glossary/master-data-management-mdm,

Poore, J. and T. Nemecek, 2018. Reducing food’s environmental impacts through producers and consumers. In: Science 01 Jun 2018, Vol. 360, Issue 6392, pp. 987-992. DOI: 10.1126/science.aaq0216.

Quantis, 2018. Organisation Environmental FootprintSector Rules (OEFSR); RetailVersion 1.0 of April 20, 2018 (accepted by the PEF/OEF Steering Committee on April 19, 2018).

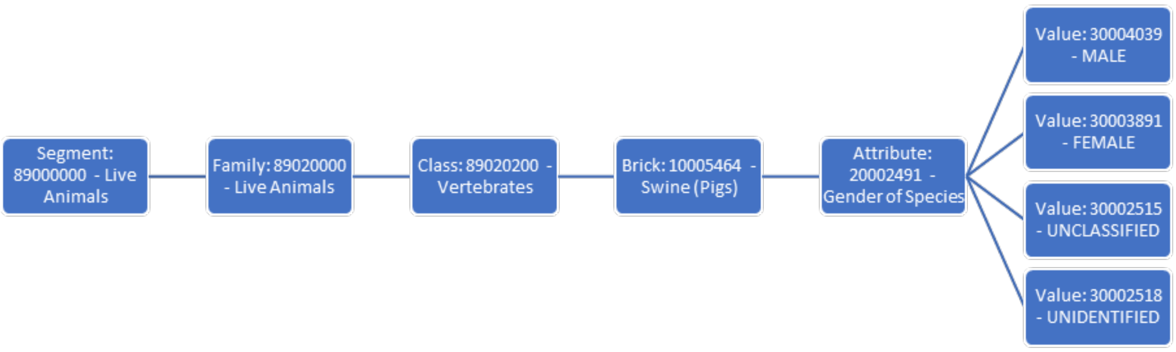
UECBV et al., 2016. PEFCR Red Meat Version 1.4; Draft version 1.4 for public consultation of 29 July 2016. Technical Secretariat for the Red Meat Pilot.

UECBV et al., 2019. Footprint Category Rules Red Meat; Version 1.0. of July 2019. Technical Secretariat for the Red Meat Pilot.

Wernet, G., C. Bauer, B. Steubing, J. Reinhard, E. Moreno-Ruiz and B. Weidema, 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, [online] 21(9), pp.1218–1230.

Zampori, L. and R. Pant, 2019. Suggestions for updating the Product Environmental Footprint (PEF) method. EUR 29682 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76- 00654-1, doi:10.2760/424613, JRC115959.

Appendix 1 GS1 GPC Classification Pigs



Definition Brick: 10005464 - Swine (Pigs):
Includes any products that may be described/observed as any of omnivorous, even–toed animals the family Suidae, which typically have a stout body, thick skin, a short neck, and a movable snout.

Includes such products as pigs, hogs and boars.

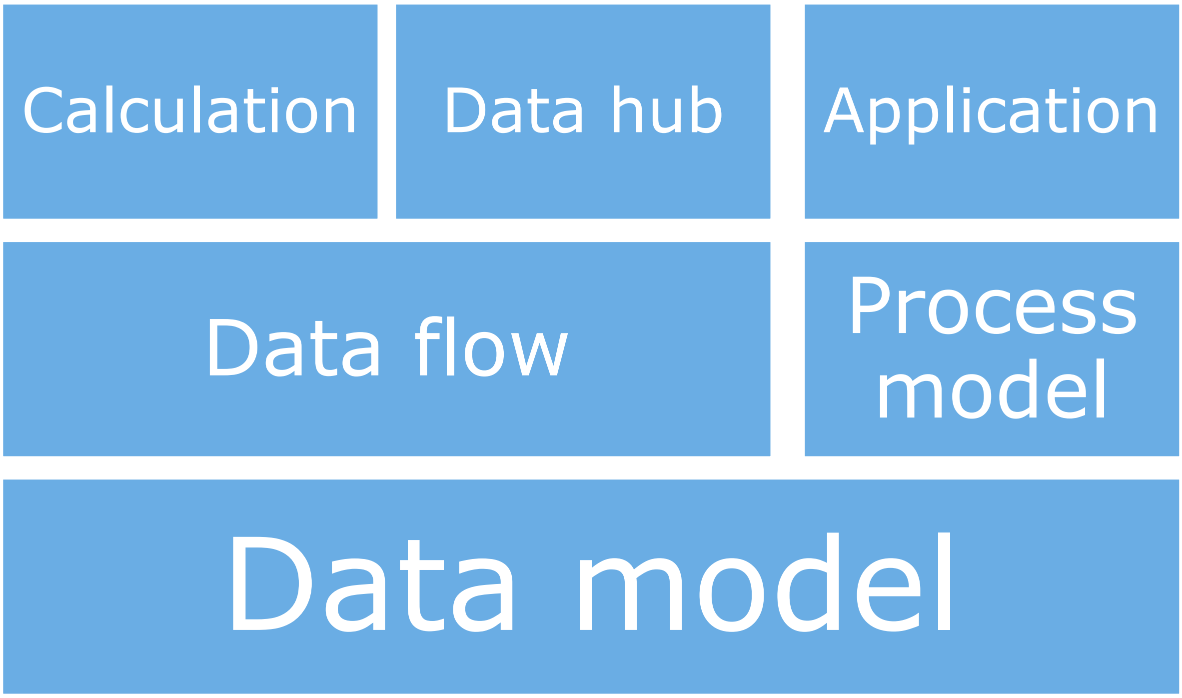
Excludes products such as goats, sheep and any pork meat.

Definition Attribute: 20002491 - Gender of Species:
Indicate, with reference to the product branding, labelling or packaging, the descriptive term that is used by the product manufacturer to identify the gender of the animal species.

Definition Value: 30002515 – UNCLASSIFIED:
This term is used to describe those product attributes that are unable to be classified within their specific market; e.g. goat’s cheese – goat’s cheeses is often generically labelled and cannot be further classified.

Definition Value: 30002518 – UNIDENTIFIED:
This term is used to describe those product attributes that are unidentifiable given existing or available product information.

Appendix 2 Meta model



Appendix 3 Overview of variables

Source: Feed producer

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
Feed sold to farmer	For all types of feed	Kg/year	Large	Limited	No
Origin raw materials	For all types of feed	In %/feed/country	Large	Limited	No
Quantity of gas used		per unit of feed produced	Small	Limited	No
Quantity of electricity used		per unit of feed produced	Small	Limited	No
Quantity of water used		per unit of feed produced	Small	Limited	No
Type of electricity	Green or grey		Small	Limited	No
Number of feed deliveries at the farm		Amount	Small	Limited	No

Source: FeedPrint/Sima pro

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
Value/feed type and origin	For all types of feed	CO2 equivalents per kg feed	Large	No	Yes

Source: Ecoinvent

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
value of CO_2 eq. gas		per unit of gas	Small	No	Yes
value of CO_2 eq. electricity		per unit of electricity	Small	No	Yes
value of CO_2 eq. water		per unit of water	Small	No	Yes
value of CO_2 eq. transport km		Per km transport	Small	No	Yes

Source: Default

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
Transport distance	93 km		Small	Limited	Yes

Source: Pig farmer

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
Type manure storage	If more different types, %/type		Large	Yes	No
Total kg live weight delivered	Piglets and/or finishers	Kg/year	Small	Yes	No
Feed conversion		Kg feed/kg meat	Large	Limited	No
Average number of pigs present in the year calculating	Piglets; sows; rearing sows; finishers		Small	Yes	No
Quantity of gas used		Total for pig farm	Small	Yes	No
Quantity of electricity used		Total for pig farm	Small	Yes	No
Quantity of water used		Total for pig farm	Small	Yes	No
Type of electricity	Green or gray		Small	Yes	No
Total price sold sows		Euro total/year	Small	Limited	No
Total price sold piglets		Euro total/year	Small	Limited	No
Average number of piglets produced/sow/year			Large	Yes	No
Number of piglet deliveries at the farm		Amount	Small	Limited	No
Total kg live weight delivered	Piglets breeder farm and finishers finishing farm		Small	Yes	No
Average weight piglets purchased		kg	Medium	Yes	No
Average live weight finishers sold		Kg	Medium	Yes	No
Daily growth		Gram	Large	Yes	No
Mortality rate finishers		%	Large	Yes	No

Source: CVB table

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
fraction of digestibility in %	VCOS	In %/feed type	-	No	Yes
Raw ash content	RAS	In %/feed type	-	No	Yes
Crude protein	RE	In %/feed type	-	No	Yes
Digestible raw protein	VCRE	In %/feed type	-	No	Yes

Source: other tables, sources in footnotes

Variable	Remarks	Unit	Impact [S/M/L]	Influence farmer [Y/L/N]	Reference value [Y/N]
Urinary energy in kg	0.02 kg/kg for pigs	Kg/kg	-	No	Yes
methane conversion factor in kg/kg CH_4	Depends on manure storage	Manure storage type	-	No	Yes
Emission factors for other gaseous N losses	EF(table2.14)	% of N excretion	-	No	Yes
Nretention	25,0	kg N/kg live weight	-	No	Yes
Default emission, volatilisation and leaching factors for indirect soil N_2O emissions	EF(IPCC table)		-	No	Yes
NH_3-emission factors for pig housing	EF(table2.11)	%	-	No	Yes
Conversion table from GHG to CO_2 equivalents			-	No	Yes
Methane emission of pigs	1,5 kg	Kg CH_4/pig/year	-	No	Yes

Wageningen Economic Research
P.O. Box 29703
2502 LS The Hague
The Netherlands
T +31 (0)70 335 83 30
E communications.ssg@wur.nl
www.wur.eu/economic-research

Wageningen Economic Research
REPORT
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The mission of Wageningen University & Research is “To explore the potential of nature to improve the quality of life”. Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 5,000 employees and 12,000 students, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.

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the potential
of nature to
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quality of life

Wageningen Economic Research
P.O. Box 29703
2502 LS Den Haag
The Netherlands
T +31 (0)70 335 83 30
E communications.ssg@wur.nl
www.wur.eu/economic-research

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