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P.F. Mostert[1], A. Kool[2], N. Bondt[3], J. Snoek[3]

1 Wageningen Livestock Research

2 Kool Planet

3 Wageningen Economic Research

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Summery UK. This report is a guideline to calculate greenhouse gas emissions of pig meat from cradle to slaughterhouse for the Dutch situation. Calculation rules for the carbon footprint of Dutch pig meat are described for every stage, up to and including the slaughterhouse. These calculation rules comply as much as possible to product environmental footprint guidelines. Finally, some strengths and limitations of this guideline are described.

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1 Introduction

The Dutch pork sector has set the goal to reduce greenhouse gas (GHG) emissions in their sector. To obtain these goals, several stakeholders within the Dutch pork sector started to calculate GHG emissions using life cycle assessment (LCA). LCA is a method to quantitatively assess the environmental impact of a product or process considering its complete life cycle (or part of it). Results of an LCA can be used to find possibilities to reduce the environmental impact and to inform other stakeholders. Guidance in using the LCA method is needed because users have to make choices about e.g. input and background data, equations to calculate emissions, system boundary, and several other assumptions. Ideally, a detailed LCA standard guideline can be followed to reduce inconsistencies in environmental calculations within a sector. Several LCA guidelines such as Product Environmental Footprint (PEF) (EC, 2021), Livestock Environmental Assessment and Performance (LEAP) (FAO, 2018), Category rules red meat (UECBV et al., 2019), or protocols such as GHG protocol and Science Based Target Initiative (SBTI) have been developed. The PEF is an European LCA guideline commissioned by the European Commission. Having the same LCA standard (e.g. PEF) and using the same background data reduces inconsistencies between countries and different production sectors, although it must be mentioned that PEF and the LCA method are in general not meant for comparing between different type of products. In the Netherlands the dairy- and feed sector embraces the PEF standard. Subsequently, PEF category rules (PEFcr) standard have been developed for these sectors which describe in more detail the calculation rules and use of background data (EDA, 2018; FEFAC, 2018). Currently there is no PEFcr standard for the pork sector. Without one accepted LCA guideline for the pork sector, different stakeholders in the Dutch pork sector used different background datasets and made different methodological choices to calculate GHG emissions. This resulted in incomparable results and was noticed within the Dutch pork sector. Subsequently differences between three stakeholders (Van Loon Group, Vion Food Group, Westfort) in the Dutch pork sector were firstly explored (Vellinga et al., 2023) and secondly calculation rules were analyzed in detail (Kool and Gort, 2024). These two studies showed a need to have one guideline for the Dutch pork sector. This study will describe harmonized calculation rules of the carbon footprint of pig meat for stakeholders in the Netherlands.

1.1 Objective

The objective of this study is

- To describe calculation rules for the carbon footprint of Dutch pig meat, up to and including the slaughterhouse
- These calculation rules comply as much as possible to PEF guidelines (EC, 2021)

1.2 Readers Guide

In chapter 2, LCA and existing LCA guidelines are introduced, goal and scope of the LCA are determined, data collection and impact assessment are described. Chapter 3 describes how the GHG emissions shall be calculated for the different stages in the chain. In chapter 4, strengths and limitations of this guideline are described.

The term 'shall' is used to indicate what is a required to be in conformance with this guideline.
The term 'should' is used to indicate a recommendation, but not a requirement.
The term 'may' is used to indicate an option that is permissible or allowable.
If a user of this guideline deviates from a requirement of this guideline, this must be mentioned when reporting GHG emissions.

2 Scientific requirements for carbon footprint calculations

2.1 Introduction to Life Cycle Assessment (LCA)

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 (CO_2e or CO_2-eq) per unit of product. A method for calculating a carbon footprint is life cycle assessment (LCA). In an LCA all processes and related emissions in the pork production chain are included. Various standards have been developed for this method. 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:

Goal & Scope definition: the goal of the LCA must first be determined and all methodological choices are then made based on the goal.

Inventory analysis: in this section data collection is described, supplemented with secondary data from background databases and literature. Calculation rules to estimate GHG emissions are described.

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 by using characterisation factors.

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.

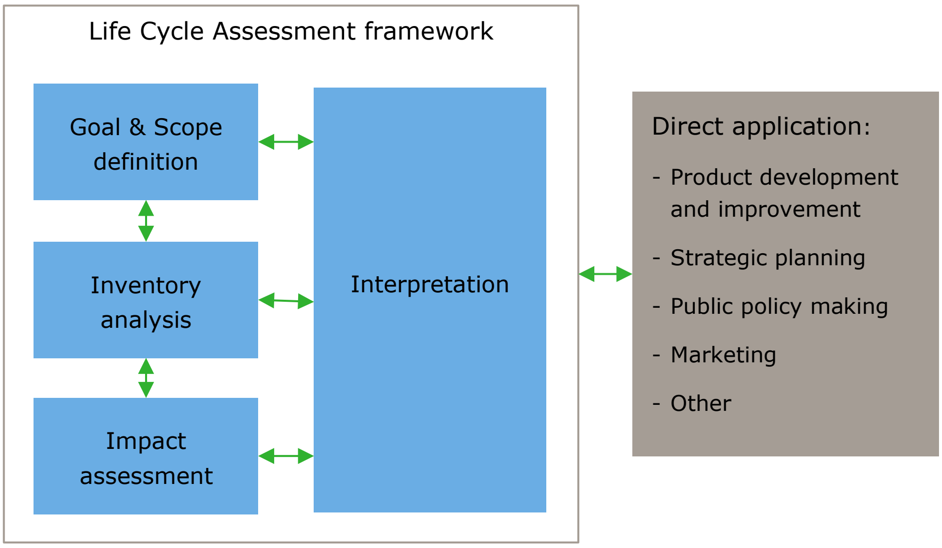

Figure 2.1 *Phases of a Life Cycle Analysis (source: ISO, 2006a).*

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:

LEAP guidelines: The FAO published a report in 2018 in the context of the multi-stakeholder initiative LEAP for the implementation of LCAs from pig supply chains (FAO, 2018).

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) of the European Commission, for environmental footprints of red meat (including pork), referred to as the Product Environmental Footprint Category Rules (PEFCR) of Red Meat (UECBV et al., 2016).

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, 2018).

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). In 2021, an update was released (EC, 2021).

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 (EC, 2021).

Carbon footprint pig production; *DATA-FAIR report on exchange of sustainability information in the pork supply chain:* Wageningen Economic Research has published a report with calculation rules for the carbon footprint of Dutch pig production (Bondt et al., 2020)

Other relevant guidelines (not specifically for pig meat production) are GHG protocol (GHG protocol, 2024), ISO 14067:2018 (ISO, 2018), and PAS 2050 standard (BSI,2011). The CFP calculations here will follow as closely as possible the rules of the European Commission (EC, 2021) and the PEFCR for animal feed (FEFAC, 2018).

2.2 Goal & scope of the LCA

2.2.1 Goal

The goal of the LCA is to report the carbon footprint of pig meat products to supply chain partners. Pig farmers can monitor the carbon footprint of their product over time and compare them with a benchmark.

2.2.2 Scope

System boundaries
The system boundaries describe which processes are included to calculate the carbon footprint of pig meat.

In this guideline, GHG emissions are estimated from cradle to sow breeding farm, cradle to fattening pig farm, and cradle to slaughterhouse. Figure 2.2 shows all stages from cradle up to and including the slaughterhouse, where the carcass is produced. Table 2.1 describes what is included and excluded in the main life cycle stages.

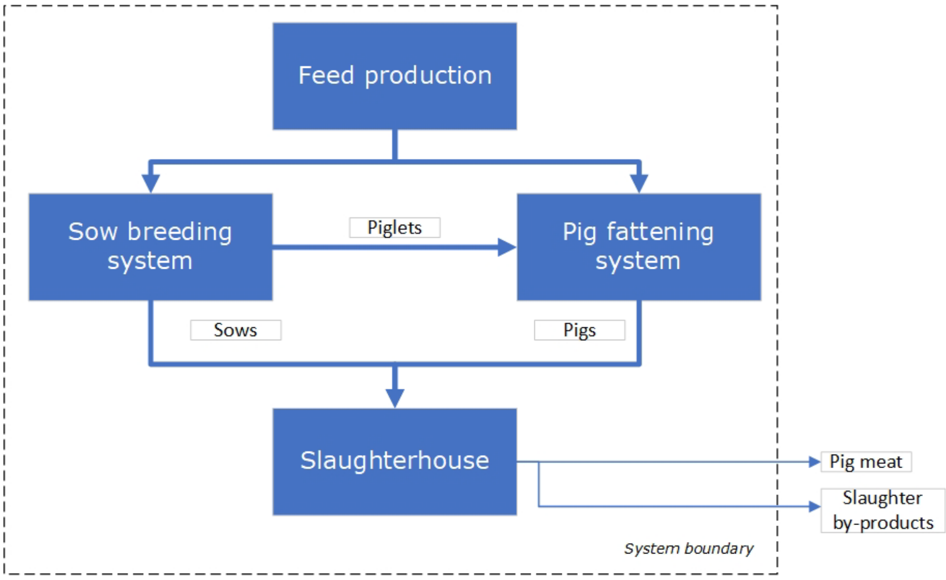

Figure 2.2 *System boundaries and stages included in the production and processing of pig meat products.*

Table 2.1 *Short description of life cycle stages and included and excluded processes.*

Life cycle stage	Included processes	Excluded processes
Feed production	This stage includes extraction of raw materials, cultivation of crops (e.g. production and application of fertilizer, transport and application of animal manure, energy use), processing of crops, storage, transport, feed mill.	
Sow breeding system	This stage includes growth of (rearing) sows and piglets, enteric fermentation from animals, manure storage and processing, energy use and production, water use.	Capital goods. Processing of dead animals. Medication. Transport and application of animal manure of the farm.
Pig fattening system	This stage includes growth of (growing finishing) pigs, enteric fermentation from animals, manure storage and processing, energy production and use, water use.	Capital goods. Processing of dead animals. Medication. Transport and application of animal manure of the farm.
Slaughterhouse	This stage includes the slaughter process of animals, energy production and use, water use.	Capital goods. Packaging and further processing of carcass. Treatment of slaughter waste. Slaughter process of sows.
Transport	Between the different life cycle stages mode of transportation is included.	Construction and maintenance of infrastructure. Transport of sows.

Excluded processes within the system boundary
Some processes within the system boundary are excluded. The PEF rules (EC, 2021) state that processes that contribute up to a total of 3% to the overall environmental impact may be excluded. 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. This can also be expected for capital goods. The capital goods and their maintenance are depreciated over the number of expected years of use. Although limited data are currently available about this, a small contribution is expected and therefore capital goods are excluded. This is also excluded in PEFcr dairy (IDA, 2018). At slaughterhouse, packaging and further processing of the carcass, and treatment of slaughter waste is excluded.

Functional unit
The functional unit defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated (EC, 2021). There are two different functional unit at the different stages

1. At sow breeding system and pig fattening system, emissions are expressed per 1 kg liveweight (i.e. piglet, sow, growing finishing pig) leaving the farm (cradle-to-farm-gate).
2. At slaughterhouse stage (cradle-to-slaughterhouse-gate), emissions are expressed per 1 kg fresh meat leaving the slaughter process.

Allocation
When different products leave the system, allocation is required. Allocation is a method to divide emissions over the different products. Several co products leave the system at the sow breeding system (sows, piglets, and manure), the pig fattening system (growing finishing pigs and manure), and the slaughterhouse (fresh meat and slaughter by-products). To comply to the PEF standard, economic allocation shall be applied. Manure is considered by default as residues (no economic value) with no upstream burden allocated. Emissions from transport and application of manure off the livestock farm are allocated to the user of the manure (e.g. digester or crop farmer).
For economic allocation of the various products delivered by the sow breeding system, the Dutch prices based on KWIN 2023-2024 shall be used (5 year averages) (Vermeij et al., 2023), namely €47.50 per piglet of 25 kg, €1.30 per kg higher or lower weight of the piglet, €181.84 per sow of 230 kg live weight, €146.26 per rearing sow (6 months of age).

In the sow breeding system, the fraction of economic value coming from 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.

At the slaughterhouse, the European Commission has prescribed economic allocation for the distribution of emissions over fresh meat and slaughter by-products (Table 2.2).

Table 2.2 *Standard European prices for fresh pork and slaughter by-products (EC, 2021), the mass fractions, and allocation fractions.*

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**

Emissions from a digester on or off farm
If pig manure is treated in an anaerobic digester on farm or off farm, emissions related to manure storage on farm, anaerobic digestion process on or off farm, and storage of digestate on farm or off farm shall be allocated. Emissions related to manure storage on- or off farm are allocated to the pig farm.
The emissions related to the anaerobic digestion process shall be allocated to the electricity and heat produced. If a farmer uses energy from the digester, this emission factor (CO_2e/MJ) for energy from the digester should be calculated and used (Chapter 3). If this is not possible, a default emission factor may be used.
The residues of the anaerobic digestion (digestate) can be stored on farm, off farm, or can be processed. No LCA guideline describes specifically the allocation of these emissions. Therefore, we follow the PEF guidelines that states that emissions up to the farm gate are allocated to the other outputs of the farm where manure is produced. To have equal allocation rules for an on farm and off farm digester, emissions related to the storage of digestate on- or off farm are allocated to the pig farm. Emissions factors for storage of digestate are based on IPPC (2019). If digestate is further processed, than these emissions are allocated to digestate.

Energy production from wind, solar, on farm or at the slaughterhouse

Energy production on the farm or slaughterhouse is considered as a separate process. For energy from e.g. wind, solar, or a digester that is produced on the farm, only the energy that is used on the farm shall be included. Energy that is sold from or not used by the farm is excluded as the user of this energy shall include these emissions. This avoids double counting.

2.3 Inventory analysis

The inventory analysis describes the required data and the calculation rules for GHG emissions. Primary data, that shall be collected for the sow breeding, pig fattening and slaughterhouse can be found in Appendix I. If primary data are not available, defaults shall be used. Emission factors shall be collected from secondary datasets. These can also be found in Appendix I. More details about required data and calculation methods per life cycle can be found in chapter 3.

2.3.1 Emissions from feed production

Feed ingredients can be cultivated on farm and off farm. Required input data that shall be collected are total purchased feed ingredients and compound feed for a specific year. There shall be no correction for stock changes in feed, meaning all purchased feed for a specific year shall be included. Geographical origin of different feed ingredients shall be collected and if not available a standard market mix shall be used. If there are feed ingredients cultivated and produced on the pig farm (called home grown feed in this guide), total amount of these feed ingredients used for pig production shall also be included.

For emission factors from feed ingredients, the Nevedi list[1] shall be used. This list follows the PEFcr feed (FEFAC, 2018). The Nevedi list includes all GHG emissions until the feed ingredient enters the pig farm and includes different origins of feed ingredients. All feed companies that are member of Nevedi have access to this list and can report per feed ingredient or per compound feed the carbon footprint. If users have no access to the Nevedi list, the Global Feed LCA Institute[1] (GFLI) database shall be used, that also follows the PEFcr feed (FEFAC, 2018). The GFLI database, however, does not include emissions from transport of feed ingredients to the Netherlands and to the pig farmer. Also, emissions at the feed factory are excluded, and therefore these emissions (i.e. from transport and feed factory) shall be included according to PEFcr feed (FEFAC, 2018). If emission factors of feed ingredients are not available on Nevedi list or GFLI database, FeedPrint (Vellinga et al., 2013) should be used. If emission factors of feed ingredients are not available on any of these lists, a crop group average should be taken if available. If also no group average is available or users have no access to the different lists or databases, default values for single feed ingredients, wet-byproducts, and compound feed may be taken (Appendix I) (SFR, 2024). If users of this guideline do not use the Nevedi list, or GFLI database, or use default values for single feed ingredients, wet-byproducts, or compound feed, than users shall report this when communicating results.

2.3.2 Emissions at sow breeding system, pig fattening system, and slaughterhouse

Emissions from enteric fermentation and manure storage occur at sow breeding system and pig fattening system. Emissions from energy use occur at sow breeding system, pig fattening system, and slaughterhouse. Calculation methods of GHG emissions and emission factors shall be in line with IPCC method (IPCC, 2019). However, calculation methods and emission factors used by the National Emission Model for Agriculture (NEMA) shall be used in this guideline if these are proved to be more accurate for the Dutch situation than the IPCC method.

Methane emissions from enteric fermentation

The methane emissions from enteric fermentation of pigs should be calculated with a TIER 2 approach (IPCC, 2019). Required input data are total feed ingredients (purchased and used home grown feed) for piglets, sows (and rearing), growing finishing pigs, and gross energy (GE) content per feed ingredient or compound feed. GE should be collected per feed ingredient or compound feed. If GE is not available, default values may be used (Appendix I).

If required data for a TIER 2 approach are not available, a TIER 1 approach may be used, which is a fixed emission factor per animal per year. This is set at 1.5 kg CH_4/animal place/year (IPCC, 2019). It is not allowed to use different TIER levels for different animal categories (e.g. piglets, sows, growing finishing pigs), so either TIER 1 or TIER 2 is used for all animals in the chain.

Nitrous oxide emissions from manure storage

Direct nitrous oxide emissions and indirect nitrous oxide emissions shall be calculated with a TIER 2 approach (IPCC, 2019). Required input data that shall be collected are total feed ingredients (purchased and used home grown feed), crude protein of total feed ingredients, digestibility of crude protein (DCCP, VCRE in Dutch), sold animals, nitrogen content of meat, housing and manure management system. Total nitrogen excretion shall be calculated based on nitrogen intake from feed ingredients and nitrogen retention in the animals. Total Ammoniacal Nitrogen (TAN) shall be calculated based on nitrogen intake, VCRE, and nitrogen retention. Emission factors for direct and indirect nitrous oxide emissions shall be used from table 2.3 and table 2.4.

If VCRE of feed ingredients cannot be collected per feed ingredient or compound feed, a default value for VCRE should be used (Appendix I). Defaults of VCRE values were provided by the sector (SFR, 2024) (Appendix I).

[1] Using Nevedi list or GFLI database can result in license costs

Table 2.3 *NH_3-N emission factor per housing type (% NH_3-N/ TAN-excretion) (Bruggen et al., 2023).*

Livestock category	2021
Sows incl piglets up to 25 kg	
regular housing	26.5
air scrubber	6.9
low emission floor and/or manure pit	17.7
Breeding boars	
regular housing	26.2
air scrubber	5.7
low emission floor and/or manure pit	26.2
Fattening pigs	
regular housing	
pit underneath slatted - and solid floor, ≤ $1m^2$/animal place	47.3
pit underneath slatted - and solid floor,> $1m^2$/animal place	57
pit underneath slatted floor, ≤ $1m^2$/animal place	31.9
pit underneath slatted floor, >$1m^2$/animal place	37.7
low emission housing	
air scrubber ≤ 1 m^2/animal place	7.2
air scrubber > 1 m^2/animal place	8.5
floor and/or pit adaptation, ≤ 1 m^2/animal place	29.2
floor and/or pit adaptation, > 1 m^2/animal place	32.6

Table 2.4 *Methane Conversion Factor (MCF), and N_2O, NO emission factors dependent on manure storage system and duration.*

Manure management system[6]		MCF[1]	N_2O (kg N_2O-N/kg N)[1](EF_3)	NO (kg NO-N/kg N)[2]
Liquid/slurry, and pit storage below animal confinement	Daily	0.036[3]	0.002	0.002
	1 month	0.13	0.002	0.002
	3 months	0.24	0.002	0.002
	4 months	0.29	0.002	0.002
	6 months	0.36[4]	0.002	0.002
	12 months	0.55	0.002	0.002
Pasture/range/paddock		0.0047	0.004	0.21[5]

1: IPCC 2019

2: Bruggen et al., 2023

3: Based on Booijen et al., 2023

4: Groenestein et al., 2016

5: Also includes NH_3-N, IPCC 2019

6: Other manure managements systems and related factors can be found in IPCC 2019, table 10.17 (MCF), table 10.21 (N_2O)

Methane emissions from manure storage

The methane emissions from manure storage shall be calculated with a TIER 2 approach (IPCC, 2019). Required input data that shall be collected are organic matter, digestibility of the organic matter (DOM, in Dutch VCOS), crude protein, and digestibility of crude protein (DCCP, in Dutch VCRE) of the feed ingredients (purchased and used home grown feed), manure management system and duration of storage of manure. Methane conversion factors (MCF) shall be used from table 2.4.

Calculating volatile solids based on excretion of Total Ammoniacal Nitrogen (TAN) and digestible organic matter proves to be more accurate for the Dutch situation than the IPCC method (Zom and Groenestein, 2015) and this method shall be used to calculate volatile solids excretion. This method is also used by the National Emission Model for Agriculture (NEMA) and ANCA (Kringloopwijzer) tool that is used by the dairy sector.

If VCOS of feed ingredients cannot be collected per feed ingredient (purchased and used home grown feed), a default value for VCOS should be used. Defaults of VCOS values were provided by the sector (SFR, 2024) (Appendix I).

Emissions from the digester and storage of digestate

If pig manure is treated in an anaerobic digester, emissions occur during the process (leakage) and storage of the pig manure (digestate) afterwards. Data are available about the impact of treating manure in an anaerobic digester on CH_4 emissions. Therefore, if manure is treated in a digester, CH_4 emissions from manure storage, during the process (leakage), and from digestate storage shall be included.
Methane emissions from manure storage shall be calculated with a TIER 2 approach (IPCC, 2019) and required input data that shall be collected are described in chapter 'Methane emissions from manure storage'. However, MCF is different when slurry is daily removed and treated in a digester. Currently, IPCC (2019) gives no MCF value for removing slurry daily. Research in the Netherlands showed a high reduction of methane emissions when removing slurry daily from storage (Booijen et al., 2023). Based on this study, a minimum of 90% reduction in methane emissions from manure storage can be expected compared to storing the manure for 6 months. This reduction is included in the MCF for daily removal of slurry (Table 2.4).
Emissions that occur during the process (leakage) in the digester are assumed to be 4.3% from the total methane production in the digester. These emissions are allocated to energy production.
Also, methane emissions occur during storage of the digestate. Different MCF for storage of digestate with different gastight storage level shall be used from IPCC (Annex 10A.4, table 10A.11, IPCC 2019).
Limited data about emissions of NH_3, N_2O, and NO, during the storage of digestate are available. Because these gases have a limited impact on total GHG emissions, this will not be further elaborated and these gases shall be included as if there was no digester.

Emissions from energy use on the farm and slaughterhouse

Required input data that shall be collected are energy use of electricity and heat. The amount from renewable energy (green) sources and fossil fuel-based energy (grey) sources shall be clear. The electricity production mix should be adjusted to make it more specific. Energy production on farm or on slaughterhouse from wind, solar, or digester shall be collected and use of energy from these sources on farm or slaughterhouse shall be collected. Sold energy produced on the farm or slaughterhouse shall not be accounted for. Emissions factors for energy use and production on farm or slaughterhouse shall be used from co2emissiefactoren.nl.

2.3.3 Emissions from others

Type of transport shall be collected. For transport, co2emissiefactoren.nl shall be used. Depending on type of transport and load fraction, emission factors can be selected. For tap water, European reference Life Cycle Database (ELCD) database shall be used.

2.4 Impact assessment

The sixth assessment report showed the latest GWP potential factor for methane and nitrous oxide (IPCC, 2021).

Methane and nitrous oxide are expressed in CO_2 equivalents using the factors from table 2.5.

Table 2.5 *GWP100 factors methane and nitrous oxide from the IPCC AR6 report (IPCC, 2021)*

Greenhouse gas	**GWP100 factor (kg CO_2e/kg)**
Carbon dioxide	1
Methane, biogenic	27
Methane, fossil	29.8
Nitrous oxide	273

3 Carbon footprint calculation in practice

Chapter 2 described the LCA method and the options for calculating the carbon footprint with the required data. This chapter describes how to calculate GHG emissions in the different stages up to the slaughterhouse. Required activity data and background data can be found in Appendix I. Figure 3.1 serves as a framework for the final calculation of the carbon footprint (CFP), expressed in CO_2 equivalents per kg of fresh meat at the slaughterhouse. The calculation steps correspond to the numbers in the diagram.

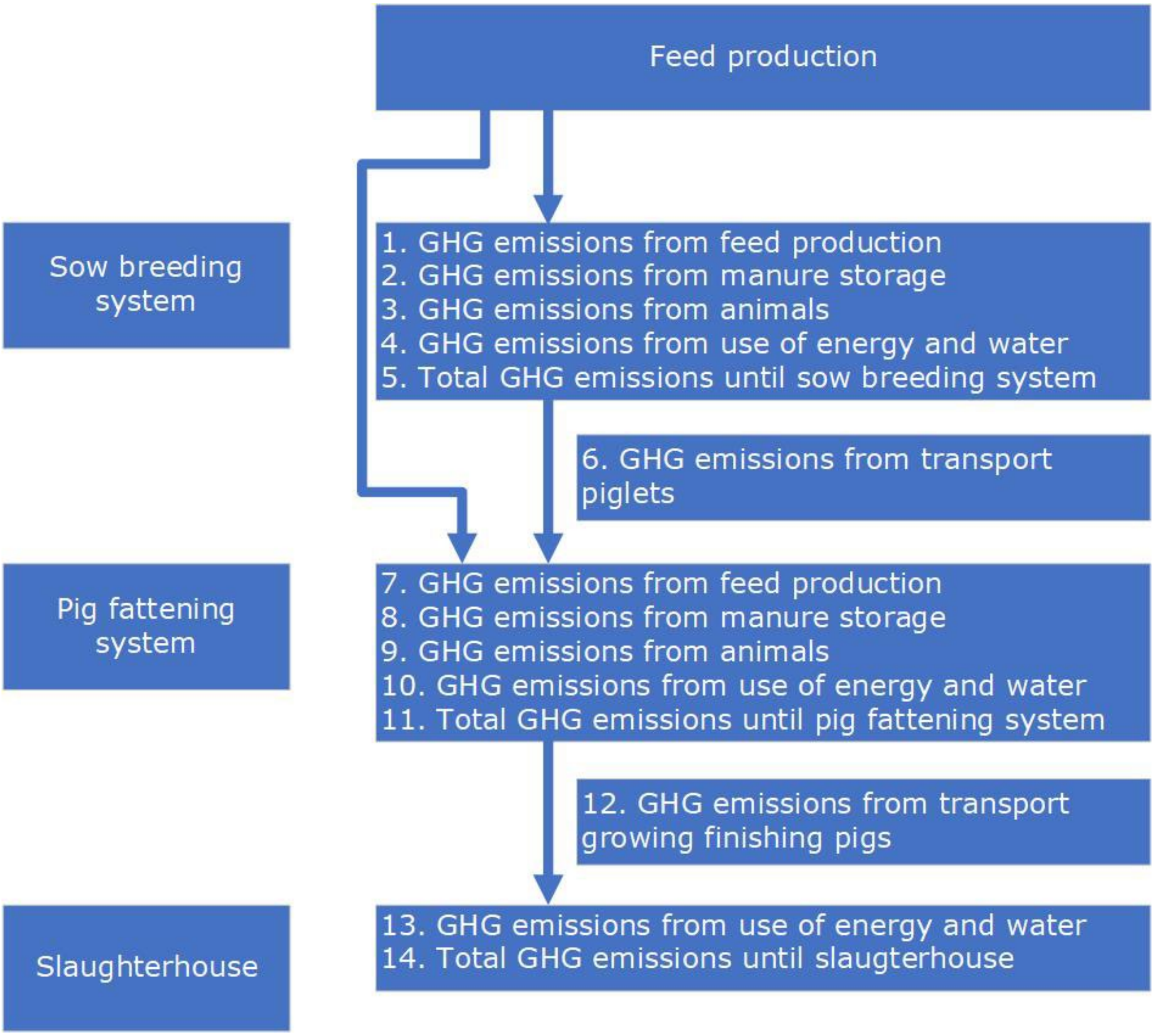

Figure 3.1 *Schematic overview of the calculation of greenhouse gas (GHG) emissions of pig meat from cradle to slaughterhouse.*

Calculation 1. GHG emissions from feed production of the sow breeding system

Emissions from feed production shall be calculated for feed ingredients (purchased and used home grown feed). Calculation 1 shows how the calculation shall be performed for one feed ingredient from one country of origin. This calculation shall be repeated as many times as feed ingredients have been purchased per country of origin, on the basis of the total quantities purchased in the relevant calendar year (January 1 to December 31). There shall be no correction made for change in stock.

For farms growing (a part of) their own feed, emissions factors for feed ingredients shall be taken from the same databases as if they bought it.

Calculation 1: GHG emissions from feed production (kg CO_2 equivalents/year)

Feed ingredient A from country-of-origin B, in kg per year

x

Emissions feed ingredient (CO_2 equivalents per kg)

=

Carbon footprint in kg CO_2 equivalents for the total purchased feed A from country B

Please make sure that the units in the calculation match.

Additional calculations when using GFLI database

The GFLI database does not include transport of feed ingredients to the pig farms and does not include energy use in the feed mill. Therefore, additional data collection and calculations are required if GFLI database is used for calculation of emissions for production of feed until the feed arrives at the sow breeding system or pig fattening system. The required data and calculations can be found in FEFAC (2018) and will not be further elaborated in this guideline.

2. GHG emissions from manure storage of the sow breeding system

In the calculation of GHG emissions from the manure storage, nitrous oxide (calculation 2a) and methane (calculation 2b) shall be calculated separately and subsequently summed to total emissions from manure storage (calculation 2c). For calculation of nitrous oxide emissions, first excretion of total nitrogen and of total ammonia nitrogen (TAN) shall be calculated.

Calculation 2a: Nitrous oxide emissions from manure storage (kg N_2O/ year)

$$N_2O \text{ total farm} = N_2O\text{dir} + N_2O\text{indir}$$

$$N_2O\text{dir} = \text{Nex} \times EF_3 \times 44/28$$

$$N_2O\text{indir} = ((NH_3\text{-N} + \text{NO-N}) \times EF_4 + \text{N leaching} \times EF_5) \times 44/28$$

$$NH_3\text{-N} = \text{TAN} \times EF_{NH3\text{-}N}$$

$$\text{TAN} = \text{TANurine} + \text{TANmin} - \text{TANimmob}$$

$$\text{TANurine} = \text{Nintake} \times \text{VCRE} - \text{Nretention}$$

$$\text{TANmin} = (\text{Nex} - \text{TANurine}) \times \text{frac slurry} \times 0.1$$

$$\text{TANimmob} = \text{TANurine} \times \text{frac solid manure} \times 0.25$$

$$\text{NO-N} = \text{Nex} \times EF_{NO\text{-}N}$$

$$\text{N leaching} = \text{FracLeach} \times \text{Nex (on range/pasture/paddock)}$$

N_2Odir = direct nitrous oxide emissions from manure storage (kg N_2O/year)
Nex = Nitrogen excretion (kg N/year)
Nex = Nintake (kg N/year)– Nretention (kg N/year)
Nintake = nitrogen intake from total feed ingredients (purchased and used home grown feed) (kg N/year)
Nintake = total feed ingredients (purchased and used home grown feed) (kg/year) x CP/6.25/1000 (kg N/year)
CP = average crude protein (CP) content of total feed ingredients (purchased and used home grown feed) (g CP/kg)

Nretention = nitrogen part that is retained in sold animals per year (kg N/year)
Nretention = (sold animals x nitrogen content animals – purchased animals x nitrogen content animals)/1000 (kg N/year)
Sold animals = total kilogram liveweight sold animals (kg LW/year) (for different animal categories (e.g. piglets, sows, growing finishing pigs))
Purchased animals = total kilogram liveweight purchased animals (kg LW/year) (for different animal categories (e.g. piglets, sows, growing finishing pigs))
Nitrogen content animals = Nitrogen content animal (g N/kg LW) (for different animal categories (e.g. piglets, sows, growing finishing pigs)), (Appendix Table A.3, A.5)

EF_3 = Emission factor (kg N_2O-N /kg N excreted) for manure management system (Table 2.4)
44/28 = conversion factor from kg N_2O-N to kg N_2O

$N_2Oindir$ = indirect nitrous oxide emissions from volatilisation of ammonia and leaching of nitrate from the manure (kg N_2O/year)
NH_3-N = ammonia nitrogen (kg NH_3-N/year)
NO-N = nitrogen oxide nitrogen (kg NO-N/year)
EF4 = Nitrous oxide emission factor for indirect emission following atmospheric deposition of NH_3 and NOx (kg N_2O–N /(kg NH_3–N + NOx–N volatilised)), by default 0.014 (IPCC, 2019)
EF5 = N_2O leaching emission factor (kg N_2O–N/ kg N leaching/runoff), by default 0.011 (IPCC, 2019)
TAN = total ammonia nitrogen excretion and is the sum of excretion of Urine-N (TANurine) and mineralisation (TANmin) or immobilisation (TANimmob) of N (kg TAN/year)
TANurine = total ammonia nitrogen of excretion of Urine-N (kg TAN/year)
TANmin = total ammonia nitrogen produced by net mineralisation (kg TAN/year)
TANimmob = immobilisation of total ammonia nitrogen (kg TAN/year)
EF_{NH3-N} = NH_3-N emission factors for pig housing (% NH_3-N/kg TAN excretion) (Table 2.3)
EF_{NO-N} = NO-N emission factor (kg NO-N/kg N excretion) (Table 2.4)
VCRE = digestibility of crude protein (%), average for all feed ingredients (purchased and used home grown feed) (%)
Frac slurry = fraction of nitrogen stored as slurry
Frac solid manure = fraction of nitrogen stored as solid manure
N leaching = total nitrogen leached (kg N/year)
Nex (on range/pasture/paddock) = total nitrogen excreted on range/pasture/paddock (kg N/year)
FracLeach = is the fraction of nitrogen leaching and running off from total N excreted on the soil, by default 0.13 (Bruggen et al. 2023). 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.

For calculation of methane emissions, first volatile solids excretion shall be calculated.

Calculation 2b: Methane emissions from manure storage and storage of digestate (kg CH_4/year)

Emission of methane [kg CH_4/year] = VStotal x B0 x 0,67 x MCF
If manure removal from storage and manure put in digester Emissions of methane from manure storage and storage of digestate [kg CH_4/year] = VStotal x B0 x 0.67 x (MCF + 0.01)
VStotal = VSfecestotal + VSurine
VSfecestotal = SUM (VSfeces) VSfeces = OSfeed x (100% - VCOSfeed) OSfeed = DMfeed × (1000 - RAS) / 1000
VSurine= TANurine x 60/28

VStotal= total volatile solids (VS) in feces and urine (kg VS/year)
VSfecestotal = total volatile solids in feces from all feed ingredients (purchased and used home grown feed) (kg VS/ year)
VSfeces= volatile solids in the feces (kg VS/year), calculated per feed ingredient (purchased and used home grown feed)
VCOS feed= organic matter digestibility of specific feed ingredient (%)
OSfeed = organic matter of specific feed ingredient (kg/year)
DMfeed= dry matter (dm) content of specific feed ingredient in (kg dm feed ingredient/year)
DMfeed = total kg feed specific feed ingredient (kg year) x dry matter content specific feed ingredient (kg dm/ kg feed ingredient), calculated per feed ingredient (purchased and used home grown feed)
RAS = ash content of specific feed ingredient (g ash/kg dm feed ingredient)

VSurine= volatile solids in urine (kg VS/year)
TANurine= calculated in calculation 2a (kg TAN/year)
60/28= molecular weight N in ureum
MCF= methane conversion factor and can be found in table 2.4
B0 = maximum capacity of the manure to produce methane (m^3 CH_4/kg VS) (for the Netherlands this is 0.31 (Groenestein et al., 2016))
0.67 = density of methane (kg/m^3)
0.01= MCF for a high quality gastight storage of the digestate. Different MCF for storage of digestate with different gastight storage level shall be used from IPCC (Annex 10A.4, table 10A.11, IPCC 2019)

Calculation 2c: Total GHG emissions manure storage (kg CO_2 equivalents/year)

Emission manure storage in kg CO_2e/year = Emission methane [kg CH_4/year] x 27 + Emission nitrous oxide [kg N_2O/year] x 273

Calculation 3. Enteric fermentation from pigs on the farm of the sow breeding system

Calculation 3a shows how emissions from enteric fermentation should be calculated and calculation 3b how emissions from enteric fermentation may be calculated.

Calculation 3a: Emissions from enteric fermentation from pigs (kg CO_2 equivalents/year)

Emission of enteric methane [kg CH_4/year] = GE x (Y_m/100) / 55.65

GE= feed ingredients x GE feed

Convert to CO_2 equivalents by multiplying by 27

=

CO_2 equivalents from all pigs/year

GE= total gross energy intake from all feed ingredients (purchased and used home grown feed) (MJ/year)
Ym = methane conversion factor, per cent of gross energy in feed converted to methane (0.6)
55.65 =energy content of methane (MJ/kg CH_4)

Feed ingredients = total purchased feed and used home grown feed (kg feed/year)
GE feed = average gross energy content total feed ingredients (purchased feed and used home grown feed) (MJ/ kg feed)

Calculation 3b (optional, if 3a is not possible): Enteric fermentation from pigs (kg CO_2 equivalents/year)

(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 all pigs in sow breeding system /year

Convert to CO_2 equivalents by multiplying by 27

=

CO_2 equivalents from all pigs/year

Calculation 4. GHG emissions from use of energy and water on the farm of the sow breeding system

Calculation 4 shows how emission from energy and water use on farm shall be calculated. For every type of energy use (e.g. green, grey electricity, or own produced energy and used from solar panels), emissions shall be calculated separately and subsequently summed to total emissions from use of energy and water on farm.

Calculation 4: GHG emissions (kg CO_2 equivalents/year) from the use of energy and water on the sow breeding farm of the sow breeding system

(Quantity of gas used on the farm x value of CO_2e per unit of gas)

+

(Quantity of electricity purchased on the farm x value of CO_2e per unit of electricity)

+

(Quantity of water used on the farm x value of CO_2e per unit of water)

+

(Quantity of own produced electricity from solar panels or wind and used on farm x value of CO_2e per unit electricity from solar panels or wind)

+

(Quantity of own produced energy from digester and used on farm x value of CO_2e per unit of own produced energy from digester)

=

Total CO_2 equivalents for energy and water use on the sow breeding farm

Emissions from leakage from the digester are allocated to energy production. If energy is used from the digester by the farmer, a farm specific emission factor should be calculated.

Value of CO_2-e per unit of own produced energy from digester = methane production digester x 0.043 / energy production x 27

Methane production = methane production from digester (m^3 CH_4/year)
0.043 = fraction leakage from digester (Bruggen et al., 2023)
Energy production = energy produced by digester (MJ/year)
It can be expected that maximum methane production in the digester is 95% (Bruggen et al., 2023).
Methane production from the digester is calculated as:

Methane production of the digester = VStotal * B0 x 0.67 x (0.95 – MCF)

VS total= total volatile solids (VS) in feces and urine (kg VS/year)
MCF= methane conversion factor and can be found in table 2.4. Storage time includes pre-storage time at the digester.
B0 = maximum capacity of the manure to produce methane (m^3 CH_4/kg VS) (for the Netherlands this is 0.31)(Groenestein et al., 2016))
0.67 = density of methane (kg/m^3)

Calculation 5. Total GHG emissions from the piglets (allocation) of the sow breeding system

All emissions are calculated in calculations 1 to 4. Therefore, first all emissions until the farm shall be summed (calculation 5a).

Calculation 5a: Total GHG emissions (kg CO_2 equivalents/year) of the sow breeding system

Total CO_2 equivalents of the sow breeding system =

Calculation 1 + Calculation 2 + Calculation 3 + Calculation 4

At the breeding farm, sows and piglets leave the farm. To allocate emissions between piglets and sows, economic allocation shall be applied (calculation 5b).

Calculation 5b: allocation factor to piglets and sows

Allocation (fraction) to piglets=

Economic value piglets / (economic value sows + economic value rearing sows + economic value piglets)

Allocation (fraction) to sows=

Economic value sows / (economic value sows + economic value rearing sows + economic value piglets)

Economic value piglets = number of sold piglets/year x economic value piglets
Economic value sows = number of sold sows/year x economic value sows
Economic value rearing sows = number of sold rearing sows/year x economic value rearing sows

Suppose the sold piglets represent 95% of the total economic value, then that percentage should be allocated to the piglets. The remainder will be allocated to the sows. Subsequently emissions will be expressed per kg live weight of piglet (calculation 5c) and per kg liveweight of sow (calculation 5d).

Calculation 5c: Total GHG emissions per kg live weight piglet (kg CO_2e/kg live weight) of the sow breeding system

Total CO_2 equivalents one kg piglet (kg CO_2e/kg live weight) =
Total CO_2 equivalents on the sow breeding farm x Allocation (fraction) to piglets /
(number of sold piglets x average kg live weight per sold piglet)

Calculation 5d: Total GHG emissions per kg live weight sow (kg CO_2e/kg live weight) of the sow breeding system

Total CO_2 equivalents one kg sow (kg CO_2e/kg live weight) =
Total CO_2 equivalents on the sow breeding farm x Allocation (fraction) to sows /
(number of sold sows x average weight per sold sow)

Calculation 6. GHG emissions during transport of piglets to the pig fattening system

Calculation 6 shows how emission from transport of piglets to the pig fattening farm shall be calculated. These emissions are included at the pig fattening system.

Calculation 6: GHG emissions (kg CO_2 equivalents/year) from transport piglets from sow breeding system to pig fattening system

Average km (transport distance from sow breeding system to pig fattening farm)
x
total weight of piglets transported in the relevant year (tonnes)
x
value for CO_2 equivalents per tonnekm
=
Total CO_2 equivalents for transport of all piglets in that year

Calculation 7. GHG emissions from feed production of the pig fattening system

This calculation is the same as calculation 1 of the sow breeding system

Calculation 8. GHG emissions from manure storage of the pig fattening system

This calculation is the same as calculation 2 of the sow breeding system

Calculation 9. GHG emissions from enteric fermentation of pigs on the farm of the pig fattening system

This calculation is the same as calculation 3 of the sow breeding system

Calculation 10. GHG emissions from use of energy and water on the farm of the pig fattening system

This calculation is the same as calculation 4 of the sow breeding system

Calculation 11. Total GHG emissions of the pig fattening system

All emissions until pig fattening system are calculated in calculation 5 to 10. Therefore, first all emissions until the farm shall be summed (calculation 11a).

Calculation 11a: Total GHG emissions (kg CO_2 equivalents/year) of the pig fattening system

Total CO_2 equivalents at the pig fattening system =
Calculation 5c x kg live weight purchased piglets + Calculation 6 + Calculation 7 + Calculation 8 + Calculation 9 + Calculation 10

Subsequently emissions shall be expressed per kg live weight (calculation 11b)

Calculation 11b: Total GHG emissions per kg live weight growing finishing pigs (*kg CO_2e/kg live weight)*

Total CO_2 equivalents one kg growing finishing pig (kg CO_2e/kg live weight) =

Total CO_2 equivalents at the pig fattening system /(number of sold growing finishing pigs x average kg live weight per sold growing finishing pig)

Calculation 12. GHG emissions from transport of the growing finishing pigs to the slaughterhouse

Calculation 12 shows how emission from transport of growing finishing pigs from fattening pig system to slaughterhouse shall be calculated. These emissions are included at the slaughterhouse stage.

Calculation 12: GHG emissions (kg CO_2 equivalents/year) from transport of growing finishing pigs of pig fattening system to slaughterhouse

Average km (transport distance finishing from pig fattening system to slaughterhouse)

x

total weight of growing finishing pigs transported in the relevant year (tonnes)

x

value for CO_2 equivalents per tonnekm

=

Total CO_2 equivalents for transport of all growing finishing pigs in that year

Calculation 13. GHG emissions from use of energy and water in the slaughterhouse

Calculation 13: GHG emissions (kg CO_2 equivalents/year) from the use of energy and water in the slaughterhouse

(Quantity of gas used in the slaughterhouse x value of CO_2e per unit of gas)
+
(Quantity of electricity purchased in the slaughterhouse x value of CO_2e per unit of electricity)
+
(Quantity of water used in the slaughterhouse x value of CO_2e per unit of water)
+
(Quantity of own produced electricity from solar panels or wind and used in the slaughterhouse x value of CO_2e per unit electricity from solar panels or wind)
=
Total CO_2 equivalents for energy and water use in the slaughterhouse

Calculation 14. Total GHG emissions at the slaughterhouse gate (allocation)

Total emissions at the slaughterhouse are calculated by summing calculation 11 to 13. (calculation 14a).

Calculation 14a: Total GHG emissions (kg CO_2 equivalents/year) at the slaughterhouse gate

Total CO_2 equivalents at the slaughterhouse gate =
Calculation 11b x total kg live weight growing finishing pigs + Calculation 12 + Calculation 13

At the slaughterhouse, the output is fresh meat and by-products. Total GHG emissions are expressed per kg fresh meat. To allocate emissions between fresh meat and by-products, economic allocation shall be applied (calculation 14b). Mass fraction fresh meat and economic allocation factors are fixed (table 2.2).

Calculation 14b: Total GHG emissions (kg CO_2 equivalents/kg fresh meat) at the slaughterhouse gate

Total CO_2 equivalents growing finishing pigs (kg CO_2e/kg fresh meat) =
Total CO_2 equivalents at the slaughterhouse gate / mass fraction fresh meat x economic allocation

4 Strengths and limitations of this guideline

This guideline provides a method how to calculate the (cradle-to-slaughterhouse-gate) CFP of Dutch pig meat. With this guideline the sector can calculate the GHG emissions of its products in a consistent way, so that results are comparable. This is very important for communicating results to other stakeholders and consumers. The Dutch pork sector can use this guide to communicate their CFP.

In this guideline, we follow the PEF guidelines (EC, 2021) as much as possible. For feed production, the PEFcr feed was followed. The PEF guidelines, however, do not describe the minimum TIER level for calculation of emissions from enteric fermentation or manure storage in pig production. We, therefore, included the highest TIER level (TIER 2) to calculate these emissions that is currently available for pig production (e.g. TIER 3 level for enteric fermentation is not available). In addition, country specific emission factors or calculation methods were used in this guideline if these are proved to be more accurate for the Dutch situation than the IPCC method.
This guideline may also be used by other countries. We, then, recommend to analyse whether the country specific emission factors used in this guideline are also applicable for other countries.
A data quality system is not yet included, although this should be included, according to the PEF guidelines. We advise the pig sector to further develop this over the next few years and, if necessary, to include it in the guideline. Moreover, the system boundary can be extended until end-of life and number of environmental impact categories may be extended. Moreover, there are still many discussions about allocation method (economic, mass, system expansion) and functional unit (kg product, kg protein, nutritional value). Decisions made about this become especially important when different type of products are compared. We, therefore, emphasize that it is not recommend to use the results from this guideline for comparison of different type of products and if so, caution should be taken when interpreting this comparison.
This guideline may become outdated after some time, because emission factors from e.g. energy production may change, calculation rules may change (e.g. enteric methane) or more detailed (emissions) data become available. Moreover, although we tried to be as clear as possible, users of this guideline may experience unclear or new situations in practice. Therefore, we recommend to update this guideline every two year.

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Appendix I: Overview of data requirements and sources

In this appendix, required activity data and background data are described. Input data, units, sources and supplementary information are described. For some input data, users can choice between primary data (farm/company specific) or secondary data (external databases and defaults). In all cases, the preferred option is primary data.

Table A.1 *Required activity data for feed production for the sow breeding and pig fattening system.*

Parameter	Unit	Source data	Supplementary information
Purchased feed	Kg/year	Primary	For all types of feed
Origin feed ingredients	In %/feed/country	Primary or default country market mix	For all types of feed
Used home grown feed	Kg/year	Primary	For all types of feed
Optional (this requires additional calculations to be performed by user of this guide)			*If GLFI database is used*
Number of feed deliveries at the farm	*Amount/year*	*Primary*	
Energy use feed mill	*MJ/year*	*Primary or secondary*	*Include all type of energy use*
Transport feed ingredients to feed mill	*km*	*Secondary*	*Defaults from FEFAC, 2018*
Transport feed ingredients to farm	*km*	*Primary or secondary*	*If primary, include type of transport. If secondary, defaults from FEFAC, 2018*

Table A.2 *Required background data for feed production for the sow breeding and pig fattening system.*

Parameter	Unit	Source data	Supplementary information
Emissions feed production	Kg CO_2-e/kg feed, with sub categories: fossil (excl peat), fossil peat, biogenic, land use change, total	Nevedi list or GFLI database	For all types of feed, purchased or produced on farm. If the feed ingredient is not available on Nevedi list/ GFLI database, than a group average of product groups shall be taken, or FeedPrint (Vellinga et al., 2013) should be used.
Emissions feed production	*kg CO_2e/kg feed*	*Optional: Default values (SFR, 2024)*	*If users do not use Nevedi list or GFLI database, this shall be mentioned when reporting GHG emissions. It is not recommended to use default values.* *The following default values shall be used per kg feed ingredient (compound (88% dm/kg), single (88% dm/kg), wet-byproducts (in 88% dm/kg)):* *Weaner 1: 1.443* *Weaner 2: 1.400* *Pig 25-50 kg: 0.769* *Pig 50-85 kg: 0.744* *Pig 85-120 kg: 0.711* *Sows (non-lactating): 0.909* *Sows (lactating): 0.795*

			Rearing sows: 0.909 *Boars: 0.909*
Optional (this requires additional calculations to be performed by user of this guide)			*If GLFI database is used*
Transport feed ingredients to feed mill	*CO_2e/kg feed*	*GFLI (2023)*	*https://globalfeedlca.org/wp-content/uploads/2023/01/GFLI-Methodology-and-Project-Guidelines.V2.pdf*
Transport feed ingredients feed mill to farm	*CO_2e/kg feed*	*If activity data primary than GLFI (2023), else default (6.5 g CO2-e/kg feed)*	*Primary, type of transport*
Energy use at feed mill	*CO_2e/kg feed*	*FEFAC, 2018*	

Table A.3 *Required activity data for the sow breeding system.*

Parameter	Unit	Source data	Supplementary information
Number of sold piglets per year	# sold piglets per year	Primary	
Number of sold sows per year	# sold sows per year	Primary	
Slaughter weight sows	kg live weight per sold sow	Primary	
Total weight piglets	kg live weight sold piglets	Primary	
Weight animals	*kg live weight/ animal*	*Optional default (5 years average from Dierlijke mest en mineralen 2022 | CBS)*	*Piglet: 25.9* *Sows: 230* *Rearing sows: 145* *Boars: 325*
Electricity (green and grey)	kWh/year	Primary	Electricity used from the grid
Natural gas	m3/year	Primary	
Diesel, LPG, Gasoline	Litre/year	Primary	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.
Tap water	m^3/year	Primary	
Energy used from own solar panels	kWh/year	Primary	
Energy used from own wind turbine	kWh/year	Primary	
Energy used from own digester	MJ/year	Primary	
Energy produced by own digester	MJ/year	Primary	
Feed ingredients for sows	kg/year/sows	Primary	Quantities and origin of feed ingredients
Feed ingredients for piglets	kg/year/piglets	Primary	Quantities and origin of feed ingredients
Straw	kg/year/sow	Primary	
Nutritional values of feed			For all feed
Crude protein level	g CP/kg feed	Primary	Use CVB table to calculate, or from feed company
Digestibility crude protein	% VCRE	Primary	Use CVB table to calculate, or from feed company
Digestibility crude protein	*% VCRE*	*Optional defaults (SFR, 2024)*	*The following default values shall be used per feed ingredient (compound, single, wet-byproducts):* *Weaner 1: 74.4* *Weaner 2: 75.5* *Sows (non-lactating): 59.4* *Sows (lactating): 73.0*

			Rearing sows: 78.6 (Bruggen et al., 2023) *Boars: 75.7 (Bruggen et al., 2023)*
Dry matter	g dry matter/kg feed	Primary	Use CVB table to calculate, or from feed company
Ash level	g RAS/kg dm feed	Primary	Use CVB table to calculate, or from feed company
Ash level	*g RAS /kg feed (88% dm)*	*Optional default (SFR, 2024)*	*The following default values shall be used per kg feed ingredient (compound (88% dm/kg), single (88% dm/kg), wet-byproducts (88% dm/kg)):* *Weaner 1: 50* *Weaner 2: 47* *Sows (non-lactating): 46* *Sows (lactating): 54* *Rearing sows: 46* *Boars: 46*
Digestibility organic matter	% VCOS	Primary	Use CVB table to calculate, or from feed company
Digestibility organic matter	*% VCOS*	*Optional defaults (SFR, 2024)*	*The following default values shall be used per feed ingredient (compound, single, wet-byproducts):* *Weaner 1: 82.3* *Weaner 2: 81.8* *Sows (non-lactating): 77.9* *Sows (lactating): 78.8* *Rearing sows: 83.1 (Bruggen et al., 2023)* *Boars: 81.8 (Bruggen et al., 2023)*
Gross Energy feed	MJ/kg feed	Primary	
Gross Energy feed	*MJ/kg feed*	*Optional default (SFR, 2024)*	*The following default values shall be used per kg feed ingredient (compound (88% dm/kg), single (88% dm/kg), wet-byproducts (in 88% dm/kg)):* *Weaner 1: 16.7* *Weaner 2: 16.6* *Sows (non-lactating): 16.4* *Sows (lactating): 16.5* *Rearing sows: 16.4* *Boars: 16.4*
Manure management	Fraction per type of manure management	Primary	Duration of the storage
Nitrogen content animals	Nitrogen /kg live weight	Defaults, Dierlijke mest en mineralen	Dierlijke mest en mineralen 2022 | CBS (table 4.2.1)
Prices of sows, rearing sows, piglets	€ animal	Defaults based on 5 year averages from KWIN 2023-2024	€47.50 per piglet of 25 kg, €1.30 per kg higher or lower weight of the piglet, €181.84 per sow of 230 kg live weight, €146.26 per rearing sow (6 months of age).

Table A.4 *Required background data for the sow breeding system.*

Parameter	Unit	Source data	Supplementary information
Emissions feed production	CO_2e/kg feed	Explained in table A.2	
Electricity from grid	CO_2e/kWh	Groene and grijze stroom STREAM Personenvervoer 2022 (ce.nl)	Table 49, includes all emissions
Energy used from own solar panels	CO_2e/kWh	Zonne-energie www.co2emissiefactoren.nl	Include emissions from building and end-of life
Energy used from own wind turbine	CO_2e/kWh	Windkracht www.co2emissiefactoren.nl	Include emissions from building and end-of life
Energy used from own digester	CO_2e/kWh	Primary, own calculation	See chapter 3 (calculation 4)
Natural gas	CO_2e/m^3	www.co2emissiefactoren.nl	Use WTW
Diesel, LPG, Gasoline	CO_2e/litre	www.co2emissiefactoren.nl	Be specific for all type of energy and use WTW
Tap water	CO_2e /m^3	ELCD database	
Methane conversion factor for different manure management system and storage time	share of Bo that will actually be converted into methane	Table 2.4	
NH_3 emission factor per housing type	% NH_3-N/TAN	Table 2.3	
N_2O emissions factor different manure management system and storage time	kg N_2O-N/kg N	Table 2.4	
NO emissions factor different manure management system and storage time	kg NO-N/kg N	Table 2.4	

Table A.5 *Required activity data for the pig fattening system.*

Parameter	Unit	Source data	Supplementary information
Weight animals	kg live weight/animal	Primary	
Weight animals	*kg live weight/animal*	*Optional default (5 years average from Dierlijke mest en mineralen 2022 | CBS)*	*Piglet:25.9* *Growing finishing pig:123.6*
Sold growing finishing pigs	# animals/year	Primary	
Number of piglets from breeding system	# animals/year	Primary	
Transport piglets	km	Primary or default (100 km)	EURO number (based on load capacity and load fraction)
Electricity (green and grey)	kWh/year	Primary	Electricity used from the grid
Natural gas	m^3/year	Primary	
Diesel, LPG, Gasoline	Litre/year	Primary	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.
Tap water	m^3/year	Primary	
Energy used from own solar panels	kWh/year	Primary	
Energy used from own wind turbine	kWh/year	Primary	
Energy used from own digester	MJ/year	Primary	
Energy produced by own digester	MJ/year	Primary	
Feed ingredients for growing finishing pigs	kg/year	Primary	Quantity and origin of feed ingredients
Straw	kg/year	Primary	
Nutritional values of feed			For all feed
Crude protein level	g CP/kg feed	Primary	Use CVB table to calculate, or from feed company
Digestibility crude protein	% VCRE	Primary	Use CVB table to calculate, or from feed company

Digestibility crude protein	*% VCRE*	*Optional default (SFR, 2024)*	*The following default values shall be used per feed ingredient (compound, single, wet-byproducts)* *Pig 25-50 kg: 75.5* *Pig 50-85 kg: 76.2* *Pig 85-120 kg: 75.6*
Dry matter	g dry matter/kg feed	Primary	Use CVB table to calculate, or from feed company
Ash level	g RAS/kg dm feed	Primary	Use CVB table to calculate, or from feed company
Ash level	*g RAS /kg feed (88% dm)*	*Optional default (SFR, 2024)*	*The following default values shall be used per kg feed ingredient (compound (88% dm/kg), single (88% dm/kg), wet-byproducts (in 88% dm/kg)):* *Pig 25-50 kg: 45* *Pig 50-85 kg: 40* *Pig 85-120 kg:36*
Digestibility organic matter	% VCOS	Primary	Use CVB table to calculate, or from feed company
Digestibility organic matter	*% VCOS*	*Optional default (SFR, 2024)*	*The following default values shall be used per kg feed ingredient (compound, single, wet-byproducts):* *Pig 25-50 kg: 80.0* *Pig 50-85 kg: 82.0* *Pig 85-120 kg: 81.8*
Gross Energy feed	MJ/kg feed	Primary	
Gross Energy feed	*MJ/kg feed*	*Optional default (SFR, 2024)*	*The following default values shall be used per kg feed ingredient (compound (88% dm/kg), single (88% dm/kg), wet-byproducts (in 88% dm/kg)):* *Pig 25-50 kg: 16.7* *Pig 50-85 kg: 16.5* *Pig 85-120 kg: 16.2*
Manure management	Fraction per type of manure management	Primary	Duration of the storage
Nitrogen content animals	Nitrogen /kg live weight	Defaults, Dierlijke mest en mineralen	Dierlijke mest en mineralen 2022 | CBS (table 4.2.1)

Table A.6 *Required background data for pig fattening system.*

Parameter	Unit	Source data	Supplementary information
Emissions feed production	CO_2e/kg feed	Explained in table A.2	
Emissions from purchased piglets	CO_2e/kg piglet	Primary (from sow breeding system)	
Emissions from purchased piglets	*CO_2e/kg piglet*	*Optional default*	*3.29 kg CO_2e/kg live weight piglet based on Mostert et al. (2023)*
Electricity from grid	CO_2e/kWh	Groene and grijze stroom STREAM Personenvervoer 2022 (ce.nl)	Table 49, includes all emissions
Energy used from own solar panels	CO_2e/kWh	Zonne-energie www.co2emissiefactoren.nl	Include emissions from building and end-of life
Energy used from own wind turbine	CO_2e/kWh	Windkracht www.co2emissiefactoren.nl	Include emissions from building and end-of life
Energy used from own digester	CO_2-e/kWh	Primary, own calculation	See chapter 3
Natural gas	CO_2e /m^3	www.co2emissiefactoren.nl	Use WTW
Diesel, LPG, Gasoline	CO_2e /Litre	www.co2emissiefactoren.nl	Be specific for all type of energy and use WTW

Tap water	CO_2e /m^3	ELCD database	
Transport piglets	CO_2e/ ton km	vrachtwagen 10-20 ton, www.co2emissiefactoren.nl	Use WTW
Methane conversion factor for different manure management system and storage time	share of Bo that will actually be converted into methane	Table 2.4	
NH_3 emission factor per housing type	% NH_3-N/TAN	Table 2.3	
N_2O emissions factor different manure management system and storage time	kg N_2O-N/kg N	Table 2.4	
NO emissions factor different manure management system and storage time	kg NO-N/kg N	Table 2.4	

Table A.7 *Required activity data for slaughtering.*

Parameter	Unit	Source data	Supplementary information
Live weight of slaughter animals	Kg live weight	Primary or secondary	If only carcass weight is available, use the following equation: live weight (kg)= 5,0 + (carcass weight (kg) x 1,21)
Mass fraction fresh meat and by products	% /kg live weight	Table 2.2	
Allocation factors	%/kg live weight	Table 2.2	
Electricity	kWh/year	Primary	Electricity used from the grid
Natural gas	m3/year	Primary	
Diesel, LPG, Gasoline	Litre/year	Primary	
Tap water	m^3/year	Primary	
Energy used from own solar panels	kWh/year	Primary	
Energy used from own wind turbine	kWh/year	Primary	
Transport pigs and sows	km	Primary or default (100 km)	

Table A.8 *Required background data for slaughtering.*

Parameter	Unit	Source data	Supplementary information
Electricity from grid	CO_2e/kWh	Groene and grijze stroom STREAM Personenvervoer 2022 (ce.nl)	Table 49, includes all emissions
Energy used from own solar panels	CO_2e/kWh	Zonne-energie www.co2emissiefactoren.nl	Include emissions from building and end-of life
Energy used from own wind turbine	CO_2e/kWh	Windkracht www.co2emissiefactoren.nl	Include emissions from building and end-of life
Natural gas	CO_2e /m3	www.co2emissiefactoren.nl	Use WTW
Diesel, LPG, Gasoline	CO_2e /Litre	www.co2emissiefactoren.nl	Be specific for all type of energy and use WTW
Tap water	CO_2e /m^3	ELCD database	
Transport sows and growing finishing pigs	CO_2e/ ton km	vrachtwagen 10-20 ton, www.co2emissiefactoren.nl	Use WTW

To explore the potential of nature to improve the quality of life

Wageningen Livestock Research
P.O. Box 338
6700 AH Wageningen
The Netherlands
T +31 (0)317 48 39 53
E info.livestockresearch@wur.nl
www.wur.nl/livestock-research

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