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Cover photo: Dairy cows on a pasture (property of WUR Livestock Research)

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Foreword

The Annual Nutrient Cycling Assessment (ANCA; in Dutch, 'KringloopWijzer') project aims to develop and evaluate a tool that provides insight into the nutrient cycles and losses of nitrogen, phosphate, and carbon on dairy farms, or farms with a dairy component. The tool provides various metrics to achieve this. These metrics are based on a large number of calculation rules. This report describes these calculation rules and the input data on which they are based. It also indicates the current limitations of using the ANCA tool.

In addition to the authors of this report, other colleagues have contributed to the substantiation of the calculation rules. We would therefore like to extend our special thanks to Jaap Schröder, Leon Šebek, Sjaak Conijn, Theun Vellinga, Frans Aarts and Joan Reijs.

The authors

1 Introduction

1.1 Why an Annual Nutrient Cycling Assessment?

In the pre-industrial era, crop production, processing and consumption all took place in close proximity, making it easy to reuse by-products released in the successive steps. Nitrogen (N), phosphorus (P) and carbon (C) followed a relatively short cycle: they moved from humans and animals, through manure and soil, to crops, to eventually being used again by humans and animals. In the process, N, P and C could be lost from this cycle into the environment, this happened in the past just as it does now. Losses are partly inherent to biological processes. For example, a large portion of the C in food is not stored in the animal (human, livestock, or soil organisms) that consumed the food, but is instead burned and converted into heat and movement, producing carbon dioxide-C. Similarly, the N that becomes available as fertilizer in the form of ammonium from dead plants and animals is not completely absorbed by plants. A portion of this will, after conversion to nitrate-N, eventually be converted into elemental N. This form of N has no fertilization value for most plants and must therefore be considered lost. The aforementioned losses are only partly an unavoidable part of biological processes. Losses are also a result of how humans manage N, P and C flows. This is relevant because losses can have a harmful impact on the environment. For example, losses of nitrate-N, ammonia-N and phosphate reduce the quality of ground and surface water, while losses of nitrous oxide-N, methane and carbon dioxide contribute to the greenhouse effect. Originally, these losses were more or less successfully compensated by biological N fixation by legumes, via the supply of N and P through daytime grazing of 'uncultivated soils', through the supply of N and P via water and wind, through the weathering of rocks which can release P, and through the 'new formation' of organic C via photosynthesis. Nowadays, however, farmers compensate for losses by using synthetic fertilizers or synthetic fertilizers 'packaged' in the form of imported feed.

In contrast to arable and "confined livestock" farms (in other contexts, the latter type of farm is often referred as "intensive livestock industry" or "factory farms"), on dairy farms, the short cycle of N, P and C through animal, manure, soil, and crops is overall still fully encountered. However, even on dairy farms, increasing interactions with the outside world have emerged, and nutrient cycles, where still present, now partially take a longer detour. The processing of milk and meat, and housing of young stock, for example, more often takes place partially or fully off-farm. Moreover, the raw materials needed for animal production and to compensate for losses (synthetic fertilizers, concentrates and other feed ingredients) partially originate outside the farm, or even come from stocks accumulated in the past. Examples of the latter include fossil fuels, phosphate rock and "deep and old" groundwater. On dairy farms that also have arable crops or a "confined livestock" component, connections with the outside world are even more extensive due to the sale of arable products, and/or larger feed imports, and/or greater export of surplus manure.

The Annual Nutrient Cycling Assessment (ANCA; in Dutch, 'KringloopWijzer') project aims to develop, test and introduce a tool that scientifically, holistically, consistently, and reliably maps nutrient cycles and losses of N, P, and C. Initially, the tool was only suitable for specialised dairy farms, but the current version of the ANCA tool is also suitable for farms with other grazing animals (i.e., non-dairy cows with youngstock), an arable crop component, or a "confined livestock" component.

The use of the ANCA tool yields several metrics that agricultural entrepreneurs can use to justify their farm management to governments and processors, and to optimise their farm management. For governments, the ANCA tool provides opportunities to partially replace generic legislation with more tailored approaches. Processors of, for example, dairy can use the results of the ANCA tool to quantify sustainability efforts for the benefit of consumers.

Mapping the farm's nutrient cycles is carried out step-by-step and ultimately results in the calculated annual metrics as shown below. Figure 1.1 illustrates their place within the cycle.

1. Manure production: excretion of nitrogen (N) and phosphate (P_2O_5) by dairy cattle and associated young stock, as well as "other ruminants" (breeding bulls, pasture and suckler cows, red meat bulls, rosé calves, sheep, goats, horses, ponies, donkeys, water buffalo) and the excretion from any "confined livestock" component (pigs, chickens, veal calves);
2. Efficiency of animal nutrition (i.e. conversion of feed into milk and meat): utilisation of N and P_2O_5 (this calculation is currently limited to the dairy herd and associated young stock);
3. Emission of ammonia (NH_3) divided over barn and manure storage, grazing animals, application of manure and synthetic fertilizer;
4. Yields of pasture (including goose grazing), corn silage and other arable crops (roughage and non-roughage): dry matter, kVEM (VEM = Dutch energy unit for lactation), N and P_2O_5;
5. Fertilisation efficiency (i.e., the conversion of fertilizers into crop yield, including non-roughage arable crops): utilisation of N and P_2O_5 present in animal manure (including goose excretion) and synthetic fertilizers;
6. Soil surplus of N and P_2O_5, supply of effective organic matter to grassland soil, corn silage fields, and any other arable crops (roughage and non-roughage) and C-storage in the soil;
7. Nitrate (NO_3) in groundwater; this metric will only be calculated after validation against a recent independent dataset;
8. Greenhouse gas emissions: methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2);
9. Farm surplus N, P_2O_5;
10. Farm efficiency (i.e., the portion of imported minerals that is converted into milk, meat or (to be taken off farm) non-roughage arable crops): utilisation of N and P_2O_5 in purchased feed or fertilizers.

The aim of this report is to describe how the above metrics are calculated and on which input data they are based. These metrics (and a number of additions, such as BEX benefit, BEP benefit, Protein from own land, Ammonia emissions per LU, Share of permanent grassland) are displayed to ANCA tool users on the Output pages. Appendix 1 indicates which section of this report each of these metrics refers back to. Appendix 2 indicates how the aforementioned 'additional' metrics are defined and calculated.

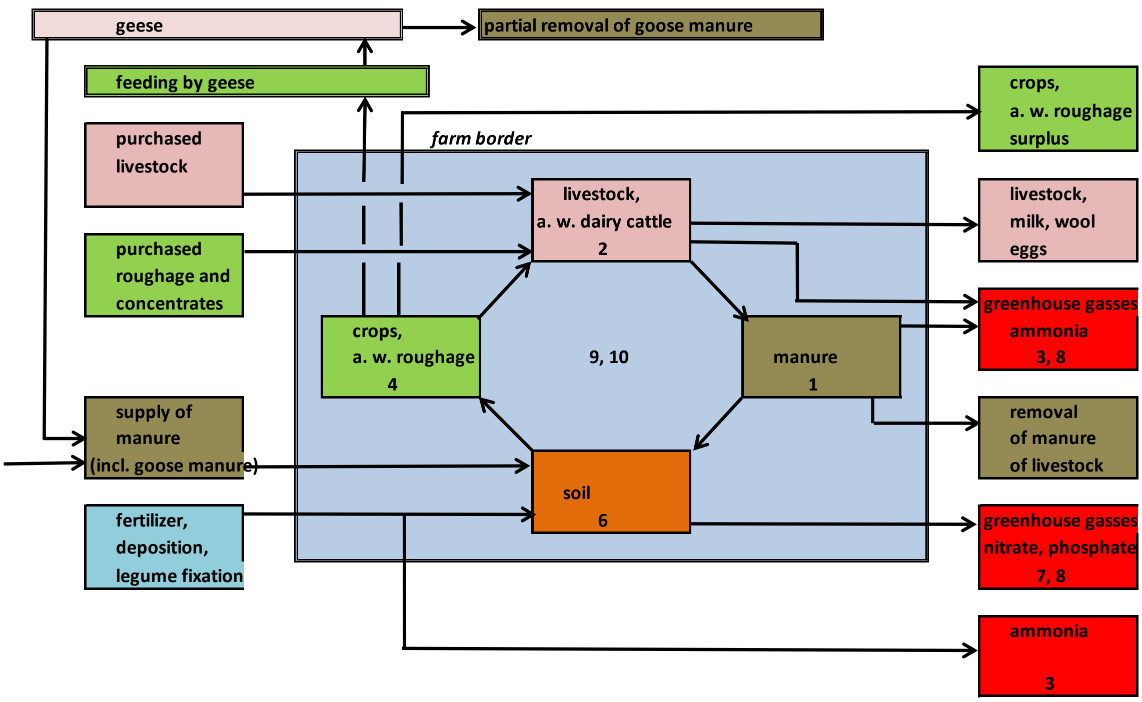

Figure 1.1 *The position of the metrics (see numbers above) in the material flow of farms.*

1.2 The cycles in more detail

To enable comparison of farms based on a given metric, agreements are needed regarding the calculation method of that metric. The calculation method should, as must as possible, account for differences between farms in terms of input and output flows. Figure 1.2 provides an initial impression of this. The figure shows that, according to the law of conservation of mass, the sum of the components through which N, P and C enter the farm (terms A to F) must equal the sum of the components through which they leave the farm (items H to M), plus any changes in on-farm stocks. Within the farm itself, it appears that many more flows can be distinguished (Figure 1.3). Nutrients in the form of deposition, synthetic fertilizer, 'pasture manure' (including the excretion of geese), and 'barn manure' (including feed leftovers) as well as potential biological N fixation and mineralising peat, enable the soil to support crop growth. This growth not only results in a harvestable product but also in a quantity of non-harvestable biomass in the form of roots and stubble, which eventually die, decompose and return to the soil as nutrients. However, even from the harvestable portion of the crop, not everything is usable. As some mowing, harvesting and grazing losses are inevitable, the actual amount harvested or consumed during grazing (including goose grazing) will always be slightly less than the amount grown. The lost portion, similar to crop residues, largely return to the soil. However, even of the harvested part that leaves the field, not all of it can be fully utilized by livestock. During crop conservation part of it will be lost, and additional losses will also occur between silage removal and intake, the so-called 'feed losses'. Table 1.1 provides an overview of the various loss percentages that are currently used in the ANCA tool. These differ by product and, within a product, per substance. In reality, these losses have no fixed value and will vary depending on factors such as management. However, it is impossible to specify the values for each individual farm in a simple and reliable way.

Table 1.1 *Percentage field losses (grazing losses for pasture, mowing losses for cut grass, harvest losses for corn silage and other roughages), conservation losses and feeding losses as used in the ANCA tool. (Source: unless otherwise stated: KWIN 2019-2020 and Dutch Dairy Farm Handbook 2020-2021) (Dutch: KWIN 2019-2020 en Handboek Melkveehouderij 2020/2021).*

	Field losses[1]	Conservation losses[1]				Feeding losses
	DM, VEM, N, P	DM	VEM	N	P	DM, VEM[1], N, P
Pasture grass, limited grazing cows	15[2]					0
Pasture grass, unlimited grazing cows	20[2]					0
Pasture grass, grazing heifers	10[2]					0
Pasture grass, grazing calves	10[2]					0
Pasture grass, indoor feeding	7					0
Cut grass for ensiling	5	6[3]	9[3]	2[4]	0	5
Corn silage	2	3.2[5]	7.1[5]	1	0	5
Alfalfa/red clover	5	4	6	1.5	0	3
Other roughages	0	4	6	1.5	0	3
Wet by-products	0	4	6	1.5	0	3
Single concentrate feeds	0	4	6	1.5	0	2
Compound concentrate feed and milk products	0	0	0	0	0	2
Minerals (salts)	0	0	0	0	0	2

1 When feed is brought onto the farm, any field and conservation losses occur elsewhere.

2 Estimates by Gertjan Holshof (personal communication). The values are based on mowed residues from pasture topping during two consecutive grass cuts and the remaining grass after the final grazing of the season.

3 Estimate by Van Schooten & Philipsen (personal communication). The values are based on Van Schooten & Philipsen (2010), taking into account that the silages were on average well preserved (according to good agricultural practice).

4 Estimate by Van Schooten (personal communication). The values are based on preliminary research results.

5 Based on a dry matter content of 35% (www.handboeksnijmaïs.nl).

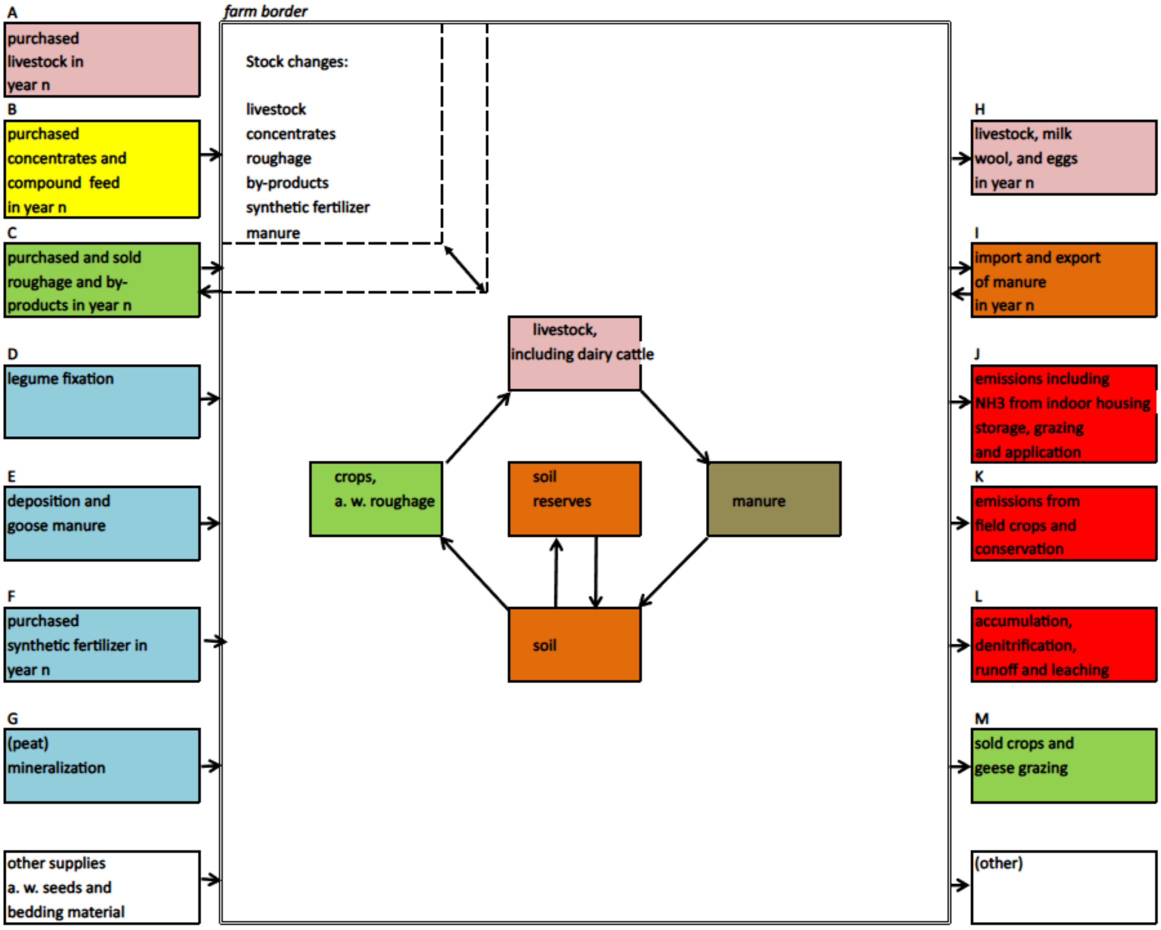

Figure 1.2 *Material input and output flows on a farm: an overview.*

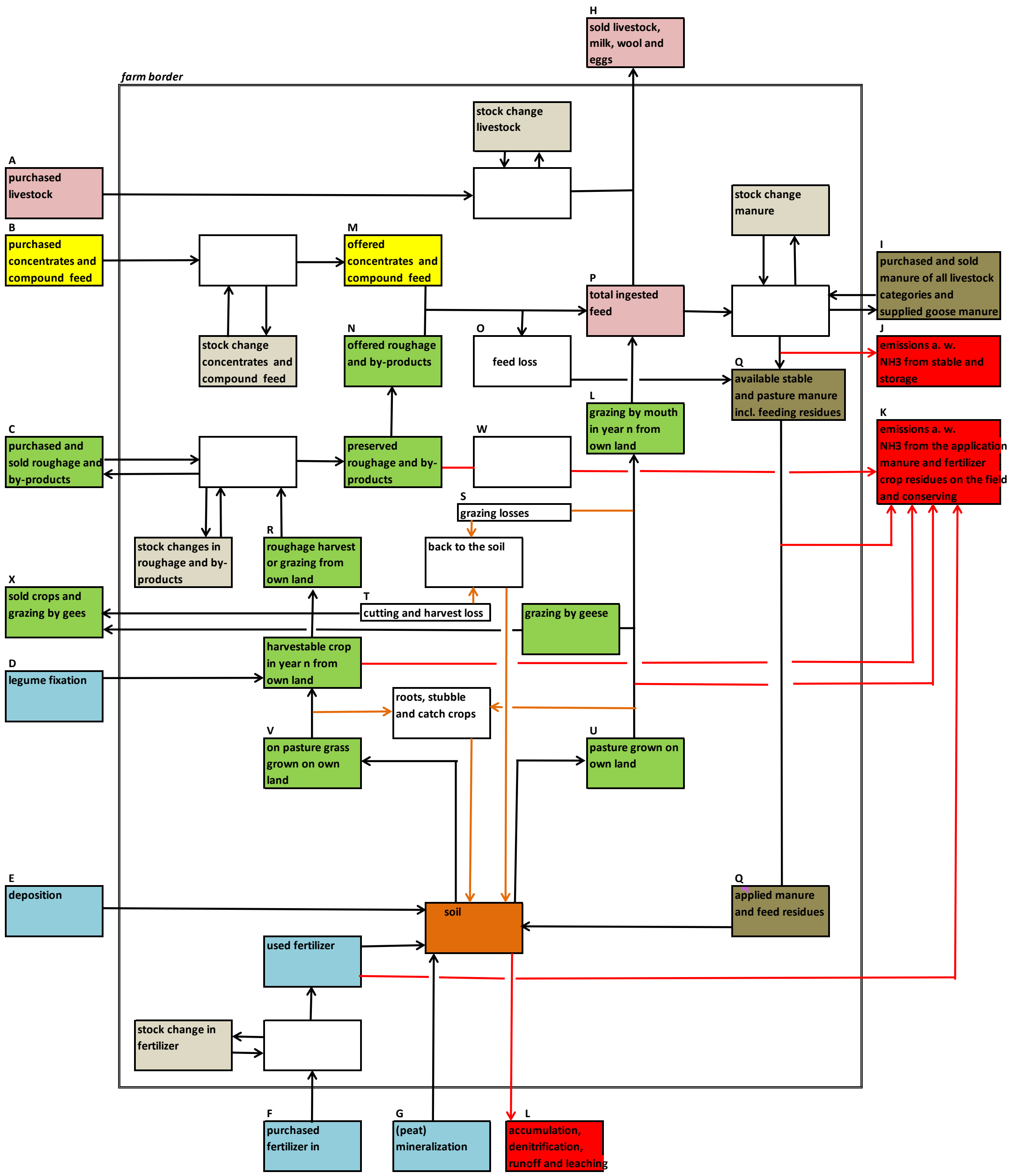

Figure 1.3 *Overview of material input and output flows on a farm, with or without an arable crop production component or livestock housed indoors, including internal flows.*

As farms have more land available per livestock unit, it becomes possible, within usage standards, to apply not only their own manure, but also manure from elsewhere. In that case, data on the composition of the imported manure are required. Table 1.2 lists the standard values used for this purpose.

Table 1.2 *Average composition (standard values) of organic fertilizers (source: www.bemestingsadvies.nl).*

	N (kg/ton)	P_2O_5 (kg/ton)	TAN (% of total N)	SG (ton/m^3)	OS/N -
Grazing livestock slurry (manure code 14)	4.0	1.5	48	1.005	13.5
Manure excreted on pasture by grazing livestock[1]	4.0	1.5	48	1.005	13.5
Grazing livestock solid manure (manure code 10)	6.4	3.2	14	0.9[1]	25.3
Slurry intensive livestock (manure code 50)[2]	6.4	3.8	53	1.04	6.3
Solid manure intensive livestock (manure code 39)[3]	31.1	15.4	25	0.605	15.8
Compost[4]	9.8	5.3	10	0.8	29.9
Liquid fraction (manure code 11)[5]	4.7	1.8	62	1.02	10.4
Solid fraction (manure code 13)[6]	9.1	6.6	26	0.9	20.9
Scrubbing water (manure code 115)	45.0	0.0	100	1.100	0.0
Mineral concentrate (manure code 120)	8.2	0.4	91	1.005	1.7
Digestate[6]	5.5	2.7	69	1.005	5.7
Other[1]	4.0	1.5	48	1.005	13.5

1 As slurry from grazing animals.

2 As slurry from finishing pigs.

3 As solid manure from broilers

4 Average green waste and green compost.

5 Average of calculated values at a P separation efficiency of 30% and 60%.

6 Average of cattle and finishing pigs and degradation of organic N of 25-50%.

1.3 Sources of N loss

Especially N can be lost from the cycle in many forms and from multiple sources, either temporarily or permanently. The main forms of loss are ammonia (NH_3-N), nitrous oxide (N_2O-N), nitrate (NO_3-N), elemental nitrogen (N_2), nitrogen oxides (NO_x-N) and organic N (Norg-N) that is stored in the soil. The farm surplus is equated with the total of losses in one of the aforementioned forms (terms J, K and L in Figures 1.2 and 1.3). Table 1.3 shows the sources from which these N compounds are mainly lost and the ANCA module by which the loss is calculated. In the context of the ANCA tool, the total calculated N loss (the farm surplus according to Figure 1.2) is broken down into the following components:

- NH_3-N loss from (synthetic) fertilizer and crop residues,
- N_2O-N loss from (synthetic) fertilizer, mineralisation, soil and silage,
- NO_3-N loss from the soil,
- the calculated other gaseous N losses (N_2, NO_x) from manure storage and silage,
- the non-calculated other N-losses consisting of accumulation of Norg in the soil and/or errors in the previous calculations, according to:

Non-calculated other N losses =
N farm surplus – NH_3-N – N_2O-N – NO_3-N – calculated other gaseous N losses.

It should be noted that, for convenience, it has been assumed that no leaching losses occur from silage and manure storage, only gaseous losses. This does not fully reflect reality.

Table 1.3 *Types of N-loss and their source, as well as the module (see superscript) in which the loss is calculated.*

Form	Source:							
	Barn and manure pit	External manure storage	Manure application and grazing	Synthetic fertilizer	Mineralisation	Soil	Crop (seed)	Silage
NH_3-N	X[1]	X[1]	X[1]	X[1]			X[2]	
N_2O-N	X[4]		X[4]	X[4]	X[4]	X[4]		
NO_3-N						X[5]		
N_2, NO_x	X[3]					X[6]		X[3]

[1] BEA base.

[2] BEA plus.

[3] BEN: non-NH_3 gaseous losses from barn, manure storage and silage.

[4] BEN: nitrous oxide emissions from (synthetic) manure, clover, mineralisation and soil.

[5] BEN: nitrate leaching.

[6] BEC: portion of the soil surplus that is not lost through nitrous oxide and nitrate.

1.4 Utilizations

1.4.1 General

Nutrient losses are often expressed not only as an absolute amount (kg) per unit area (hectare) or per unit of product (for example, per litre of milk for specialised dairy farms, per kg of nitrogen in the form of removed products for mixed farms, per kg grain-equivalent for specialised arable farms), but also as the complement of the fraction of an incoming nutrient flow that is not usefully utilized, i.e., 1 minus the utilization. The utilization of a nutrient can be defined at the level of the farm as a whole as well as at the level of the underlying internal (sub)flows. It should be noted that any definition is somewhat arbitrary. For instance, the value of a ratio of output to input changes depending on whether the numerator and denominator are expressed as gross flows or as net flows. After all, the fraction 100/200 yields a different number than, for example, the fraction (100+10)/(200+10).

The following utilization percentages are calculated in the ANCA tool.

1.4.2 Utilization at farm level

The utilization at farm level is defined as:

Produced ‘useful’ products (milk, meat, crop products to be sold, goose-grazed crops) as a fraction of the use of concentrates, roughage, by-products, legume fixation, deposition, synthetic fertilizer, manure (including goose manure) and (peat) mineralisation, or (see Figure 1.3):

> *(H - (A - adjusted for changes in herd size) + X) / ((B - adjusted for changes in concentrate feed stock) + (C - adjusted for changes in roughage stock) + D + E + (F - adjusted for changes in synthetic fertilizer stock) + (-I - adjusted for changes in manure stock) G), with a positive value for the corrections if the stock has increased.*

1.4.3 Utilization at animal level

Utilization at animal level is defined as:

Produced milk and meat, as a fraction of ingested concentrates, silage, by-products and pasture grass (= feed offered after deduction of feed residues), or (see Figure 1.3):

> *(H - (A - corrected for changes in herd size)) / (M + N + L - O)*

1.4.4 Utilization at fertilizer level

The utilization at fertilizer level is defined as:

Manure and feed residues that end up 'in' the soil, as a fraction of the excretion plus feed residues (= feed offered - milk and meat, corrected for changes in herd size) minus changes in manure stock (when stock increases), plus any intensive livestock (pigs, poultry) manure production ("housed animals"), and reduced by exported/increased by imported manure, or (see Figure 1.3):

> *(Q) / ((M + N + L) - (H - (A - adjusted for changes in herd size)) - adjusted for changes in manure stock - I)*

1.4.5 Utilization at soil level

The utilization at soil level is defined as:

Nutrients produced in homegrown crops, including pasture, mowing and harvesting losses as well as non-roughage arable crops to be removed and goose-grazed crops, as a fraction of legume fixation, deposition, synthetic fertilizer (after adjusting for stock changes), (peat) mineralisation and available pasture and "barn" manure (including feed residues after deduction of gaseous losses from manure and including goose excretion), or (see Figure 1.3):

> *((R + T + X) + (L + S)) / (Q + D + E + (F - adjusted for changes of synthetic fertilizer stock) + G)*

1.4.6 Utilization at (roughage) crop level

The utilization at (roughage) crop level, that is, the utilisation of roughage until consumption by animals, is defined as:

Ingested feed from home grown (unsold) and purchased roughage (i.e., intake corrected for the intake from compound feed and concentrates), as a fraction of the cultivated and purchased roughage including pasture, harvest and mowing losses, or (see Figure 1.3):

> *(P - ((B - corrected for changes in compound feed and concentrate stock) - O_compound feed and concentrates)) / ((C - adjusted for changes in roughage stock) + (R + T) + (L + S))*

1.5 Limitations and improvements of the ANCA tool

The current version of the ANCA tool has several limitations. These are discussed in more detail in the various sections (see also the Reading Guide later in this chapter). In addition, the ANCA tool is regularly validated by comparing its calculation results with measurement data from commercial farms participating in the "Koeien&Kansen" project. This provides insight into the boundaries of the applicability of the ANCA tool.

A number of limitations/points of attention in the use of the ANCA tool are:

- The ANCA tool provides less reliable results for dairy farms with low milk production, with many other grazing animals, and with few dairy cows in relation to young stock. Therefore, the guidance on farm-specific excretion states that farms with these characteristics cannot make use of the guidance on farm-specific excretion when determining manure disposal (RVO, 2021).
- For farms with an intensive livestock component (e.g., pigs, poultry, white veal calves), the manure N- and P production of this component is not calculated by the ANCA Tool, but is instead estimated externally on a farm-specific basis using the "barn balance", which is subsequently entered in the ANCA tool. The barn balance does not provide information on the distribution of N and P production per animal group. In the ANCA tool, this distribution is determined based on the average number of animals per animal group and the standard N and P production per animal group. In addition, due to the lack of information on inputs and outputs of the intensive livestock

component (feed and animals), the N and P utilisation of the intensive livestock category and that of the total farm as a whole cannot be calculated.
- In the calculation of ammonia emissions per ton of milk produced, any emissions caused by intensive livestock and arable farming components are also included. Ammonia emissions from barns and the storage of manure of intensive livestock (pigs, poultry) are given separately in the ANCA tool output. Regarding ammonia emissions from manure application on cropland, no distinction is made between arable crops and forage crops grown for the dairy farm.
- This version of the ANCA does not yet provide the option to accurately calculate conservation losses from mixed silages of roughage and a dry by-product.

In the 2025 version of the ANCA tool, various adjustments have been made compared to the 2024 version, including:
- *Manure flows in systems with primary manure separation*
  Certain barn types use primary manure separation. Examples include the CowToilet, Lely Sphere, and free stall barns with a sloped floor that use profiled rubber mats and a central slurry gutter (these correspond to barn types HA1.35, HA1.36 and HA1.38). In these systems (besides solid manure), other types of manure are produced in addition to slurry: urine and feces fractions, which may also be partly mixed. Especially the ration of mineral to organic nitrogen in the two separated fractions differs from that in the non-primary separated slurry. This can affect ammonia emissions when the manure is applied to the land. In the 2025 version of the ANCA tool, these manure types are treated as separate manure streams, and the thin urine fraction and the thicker feces fraction are no longer applied together.
- *Soil type loess*
  Up to and including the 2024 version of the ANCA tool, loess was not included as a separate soil type and was calculated in the same way as sandy soil. However, loess has a different effect on soil carbon sequestration and nitrate leaching to groundwater than sandy soil. Therefore, in the 2025 version of the ANCA tool, loess is included and calculated as a separate soil type.
- *Feed materials*
  For the following 6 feed products, digestibility coefficients for crude protein (CP digestibility coefficient), percentage dry matter (DM), crude ash (CA), and digestibility coefficient of organic matter (OM digestibility coefficient) have been added: processed grass fiber silage, sugarcane vinasse, palm oil fatty acid distillate, a mixture of wet by-products (with the option to include a specific carbon footprint), other vegetable meals, and other industrial co-products.
- *Soil carbon – calculated OM/N ratio in animal manure*
  Up to and including the 2024 version of the ANCA tool, the carbon module used a fixed ratio between organic matter (OM) and nitrogen (N) for applied animal manure, based on values from the literature. This OM/N ratio was used to calculate the amount of OM applied based on the amount of N supplied with a manure stream. In the 2025 version, the ANCA tool calculates the OM/N ratio, where possible, based on the farms own manure production. For now, this applies only to animal manure excreted during grazing (pasture manure), slurry from grazing animals, solid manure from grazing animals and primary or mechanically separated slurry. This accounts for the vast majority of animal manure produced on a dairy farm. For other on-farm manure products (especially digestate), too many unknowns exist. For these, a standard OM/N ratio continues to be used. The same applies to imported animal manure and plant-based manure (such as compost). This more specific calculation method is more accurate and better reflects the specific on-farm conditions.
- *Input of OM from crop residues*
  In the 2025 version of the ANCA tool, the OM input from a grass cut as a preceding crop has been reduced.
- *Gaseous nitrogen losses*
  For the calculation of gross to net nitrogen excretion, gaseous N losses (NH_3 and other losses via N_2, N_2O and NO_x) are taken into account. In the 2025 version of the ANCA tool, the gaseous N losses have been increased and are fully attributed to additional emissions of nitrogen gas (N_2).
- *Update of carbon footprints for imported products and energy*
  The metrics for the carbon footprint of imported products (such as feed materials, fertilizers, energy, machinery, livestock, and bedding) have been updated where necessary. This process is carried out annually.

- *Fertilizer-specific carbon footprint*
  Up to and including the 2024 version of the ANCA tool, the carbon footprint of the used synthetic fertilizer was determined based on the nutrient contents of the synthetic fertilizer. This meant that the amounts of ammonium nitrate, nitrate nitrogen, urea nitrogen, phosphate, and potassium in the fertilizer determined the carbon footprint of the used synthetic fertilizer. This approach was used instead of assigning the footprint associated with the production of a specific fertilizer types (for example, calcium ammonium nitrate, triple superphosphate, or urea-ammonium nitrate). From the 2025 version onward, the ANCA tool uses the carbon footprint corresponding to each specific fertilizer type.
- *Calculation of the TAN fraction in on-farm solid manure*
  In the 2024 version of the ANCA Tool, the proportion of total ammonia nitrogen (TAN) in the total N of the solid manure (initial stock, final stock, and exported solid manure) only depended on the proportion of TAN of the produced manure (based on animal excretion and gaseous N losses during storage). This has been improved by also including feed residues and straw (both of which are added to the solid manure) in the calculation of the TAN content in solid manure.

1.6 Reading guide

This report discusses, consecutively, the BEX (Farm-specific excretion, chapter 2), the BEA (Farm-specific ammonia emission, chapter 3), the BEN (Farm-specific nitrate and nitrous oxide emission, chapter 4), the BEP (Farm-specific phosphorus flows, chapter 5), and the BEC (Farm-specific carbon flows and CO_2-equivalent emissions, chapter 6). Each chapter starts with an introduction, followed by an explanation of how the metrics are calculated. At the end of each chapter, several remarks are provided. These address conditions, limitations, and aspects that require further refinement or research. Given that the flows of N, P and C are closely interrelated, it is inevitable that one chapter occasionally refers back to or anticipates another. To assist the reader, Appendix 3 includes both a thematic as well as an alphabetical list of abbreviations.

In this rapport, the words ‘barn manure’ and ‘barn animals’ appear several times. ‘Barn manure’ refers to all manure excreted by a herd indoors (collected and stored), as opposed to pasture manure. This does not necessarily mean barn manure is solid manure: ‘barn manure’ can be slurry or solid manure. Conversely, the term ‘barn animals’ does not refer to all animals that are in some way (partially) kept indoors. For the purpose of this report, “barn animals” are only those that are part of intensive livestock raising (pigs, chickens, veal calves). In this sense, a dairy herd without pasture access is not classified as “barn animal”.

2 BEX: excretions by non-dairy cattle and manure processing

2.1 Introduction

The BEX, as most recently defined in the National Guidance for Farm-Specific Excretion of Dairy Cattle (Handreiking BEX, 2025), calculates the amount of nitrogen (N) and phosphorus (P) in the manure produced by an individual dairy farm. The calculation was developed for farms with predominantly dairy cattle and relates to a calendar year. 'Predominantly dairy cattle' means that in addition to the N and P excretion of the dairy herd (dairy cows plus youngstock), the excretion of any other categories of grazing animals (breeding bulls, beef bulls, pasture and suckler cows, veal, sheep, goats, horses, ponies, donkeys, water buffalo) is also calculated. However, the excretion of the dairy herd is calculated on a farm-specific basis, whereas the excretion of 'other grazing animals' is calculated using standard excretion values (Anonymous, 2015a). The BEX does not calculate N and P excretion in manure produced by any barn animals, such as poultry and pigs. The contribution of these animal categories is discussed in section 2.1.3.

The N and P intake of the dairy herd is calculated as the sum of the intake from all fed feedstuffs. The net energy (VEM) requirement of the animals present, corrected for an assumed 2% exceedance of that requirement, is the starting point for the assumed intake. This is why the BEX requires participating farms to record the quantities of all feedstuffs on the farm and to analyse their VEM, N and P content, and, for grassland and corn silage products, also the CA (Crude Ash) content. For purchased feedstuffs, the quantities are available from supplier invoices, whereas for homegrown roughage, the quantity, if ensiled, is determined by measuring the silage content (by an accredited sample taker) and assuming a constant density in kg per m^3 based on research by Van Schooten & van Dongen (2007).

This research, however, showed that this 'best practice' method for estimating the quantity of silage has a large variation in outcomes. Consequently, the estimated quantity of silage is not accurate enough to equate silage consumption with feed intake. Therefore, in BEX the intake of fresh grass, grass silage and corn maize is calculated based on the VEM requirement (see section 2.1.2.12) whereby the required VEM is allocated across the various feedstuffs according to the ratio between the calculated fresh grass intake and the available stocks of grassland and corn silage products (as determined by an accredited laboratory). This principle is further explained in Oenema *et al.* (2017).

2.2 Excretion calculation method

2.2.1 General

The BEX calculates the amount of N and P in the manure produced. Volatilisation must be taken into account for N. Therefore, a distinction is made between gross and net excretion of N and P in BEX. The gross excretion refers to the excretion 'under the tail' while net excretion equals the gross excretion minus gaseous N losses. For P, volatilisation plays no role, and gross excretion is equal to net excretion.

2.2.2 Calculation of gross N and P excretion

The gross ('under the tail') excretion of N and P is calculated in the BEX using the balance method:

Excretion N (or P) = intake N (or P) – retention N (or P)

2.2.3 Calculation of intake N and P

Intake N = VEM intake x N/VEM
Intake P = VEM intake x P/VEM

In which:

VEM intake = VEM requirement x 102%. This represents the total VEM requirement of the dairy herd, based on the herd composition and milk production.

N (or P)/VEM: VEM, N and P represent the weighted average of the analysed mean VEM, N and P contents of each component of the ration.

2.2.4 Calculation of N and P retention

This concerns determination of N and P in milk and growing animals (foetus + adnexa, calf, heifer, first-lactation cow and second-lactation cow).

Retained N (or P) = kg animal product x N (or P) content of the animal product

The required information consists of a combination of farm-specific information and standard values.

Farm-specific information is available for:
Produced milk, N content in milk, P content in milk (not always available, in that case, a standard value is used), numbers of animals in the categories of young stock under one year (calf), young stock over one year (heifer), animals that have calved (dairy cows) and breed of the dairy cattle.

Standard values are used for:
P content in milk (if not measured by an accredited institute), N and P retained in, respectively, the foetus and adnexa, calf, heifer, first-lactation cow and second-lactation cow. In addition, constants are used for the percentage of pregnant animals (on an annual basis) in the herd to calculate the retention in foetus and adnexa, for the age structure of the dairy herd to calculate the number of first-lactation, second-lactation and older cows and for the animal weights of a selected breed.

2.2.5 Calculation of net N excretion

The calculated gross N excretion must be corrected for the farm-specific gaseous N losses. These N losses are calculated using the BEA (see section 2.2).

Net N excretion = gross N excretion - gaseous N losses from BEA

The required information consists of a combination of farm-specific information and standard values.

Farm-specific information is available for:
Gross N excretion for the herd and for the number of animals in the categories: youngstock younger than one year, youngstock older than one year, number of dairy cows including dry cows, share of slurry and the housing type of the dairy cattle.

Standard values are used for the emission percentage of N from the manure of the herd.
The emission percentage of N from the manure of the herd is calculated using the BEA. For the standard values used, see the description of the BEA in section 3.2.

2.2.6 Age structure of the dairy herd

The dairy herd consists of several animal categories. Animal numbers are determined per category: dairy cows, dry cows, youngstock over 1 year (heifers), youngstock under 1 year (calves). These are the animal categories and counts as defined in the *Implementation Decree* and *Implementation Regulation of the Fertilizers Act* (*Uitvoeringsbesluit en Uitvoeringsregeling Meststoffenwet*). For all animal categories, the number is calculated by dividing the total of the daily counts by 365. Where applicable, a distinction is made between Jersey, Jersey crosses and other breeds. A Jersey is an animal with at least 87.5% Jersey-blood. A Jersey cross has between 50 and 87.5% Jersey-blood. Other breeds have less than 50 percent Jersey blood.

2.2.7 Milk production and milk composition

The milk production equals the total amount of milk produced in kilograms per year as specified in the *Implementation Decree of the Fertilizers Act*, *Article 33*, (*Uitvoeringsbesluit Meststoffenwet*, *artikel 33) the Implementation Regulation of the Fertilizers Act*, *Article 42, (paragraph 3) and Chapter 9, Articles 73 to 75e* (*Uitvoeringsregeling Meststoffenwet, artikel 42 (lid 3) en hoofdstuk 9 (artikelen 73 t/m 75e)*, and the *Regulation on Animal products*, *Section 2, Articles 2.10 to 2.59 (Regeling dierlijke producten, paragraaf 2 (artikelen 2.10 t/m 2.59).*
This concerns the sum of:
- the milk delivered to the processor,
- the milk used for on-farm processing,
- milk fed to calves, and
- other milk production, such as colostrum, mastitis milk, or milk for on-farm consumption.

The fat, protein, and phosphorus percentages in the milk represent the moving average as determined by the dairy industry, calculated per calendar year.

2.2.8 Dairy cow weight

The average weight of adult dairy cows determines the VEM maintenance requirement of the cows, including those with deviating weights, and of the associated youngstock. For this purpose, a so-called 'breed factor' is included in Table 2.1. This is based on the VEM maintenance requirement at adult weight.

Table 2.1 *Average weight of the different dairy cattle categories per breed group and the breed factors for the VEM requirement and animal weights.*

Breed group	Average dairy cow weight (kg)	Breed factor[1] VEM requirement	Young stock weights (kg)[2]			Breed WT factor[3]
			Birth	1 year	At calving	
Jersey	400	0.695	27	197	332	400/650
Crossbreed: Jersey x other breeds [4]	525	0.852	36	258	436	525/650
Other breeds	650	1.000	44	320	540	650/650

[1] The breed factor is based on the ratios of the metabolic weights (weight to the power 0.75). In this guideline, the weight of the dairy cow from 'other breeds' is taken as a starting point: WT = 650 kg.

[2/3] The weights of 'Jersey' and 'Crossbreed' can be calculated using the WT factor, based on the average weights of 'Other breeds' and have been rounded.

[4] The 'Crossbreed' is a cross between 'Jersey' x 'Other breeds' or 'Other breeds' x 'Jersey'.

2.2.9 Grazing

Unlimited grazing means that dairy cows graze both during the day and at night (10-20 hours). Limited grazing means that dairy cows are on pasture only during the day or only at night (2-10 hours). For both systems, the number of grazing days per year must be recorded and, if applicable, the average number of grazing hours per day for the respective system.

If the cows receive fresh pasture grass in the barn, this is referred to as 'summer stall feeding'. In this case as well, the number of days of summer stall feeding as well as the number of times freshly cut grass is offered to the cows each day, both during the day and at night ('unlimited) or only during the day or only at night ('limited), must be recorded.

In addition, a combination of grazing and summer stall feeding may also occur. In this case, in addition to the number of days in the system, the number of grazing hours per day must be specified and a choice must be made as to whether only fresh grass is fed indoors (‘unlimited) or whether roughage is also provided alongside the fresh grass (‘limited’).
For young stock, unrestricted grazing is assumed, with the number of grazing days being registered.

The BEX does not record whether dry cows are grazed. The calculation assumes that dry cows are housed indoors year-round and that no fresh grass is fed to this group.

For grass intake, it must be indicated what proportion comes from natural grassland. For cows, this proportion may not exceed the share of natural grassland in the total grassland area. This restriction does not apply to young stock.

2.2.10 Calculation of VEM intake and VEM requirement of the dairy herd

The VEM intake is 2% higher than the calculated VEM requirement as it is assumed that the VEM coverage is 102%. This assumption is consistent with basis of the standard excretion values for dairy cattle (Tamminga *et al.*, 2004).

The VEM requirement is calculated according to the general calculation rules of the CVB. These calculation rules were also used to substantiate the standard excretion values in the *Implementation Regulation of the Fertilizers Act* (*Uitvoeringsregeling Meststoffenwet*). In calculating the VEM requirement, the herd composition, the production level of the cows, the adult weight of the dairy cows, and pasturing of the dairy cows are taken into account. The requirement calculation for dairy cattle is based on tethered animals. Free-ranging cows in a freestall barn or during grazing have a higher VEM requirement due to their physical activity. In addition, extra energy is required for growth in young animals, if applicable, for pregnancy, and to compensate the Negative Energy Balance (NEB) at the start of lactation. These additional energy requirements are included in the total VEM requirement in the form of surplus energy requirements (see Table 2.2).
The VEM requirement of dairy cattle is calculated as the sum of the VEM requirement for milk production and maintenance, including the above-mentioned surplus requirements. For maintenance, a distinction is made between ‘lactating cows’ and ‘dry cows’. The calculation is based on an average of 326 lactation days per calendar year and a dry period of 39 days per calendar year per average cow present. The VEM requirement of the total dairy herd (in kVEM/year) is the sum of the VEM requirements of the dairy cows, the heifers and the calves.

Table 2.2 *Energy requirements and surpluses in kVEM per average lactating and dry cow for cows with an average weight of 650 kg[1] and per average head of young stock younger and older than one year.*

		Dairy cows and calves		Young stock	
				≥ 1 year	≤ 1 year
		kVEM/year	kVEM/day	kVEM/day	kVEM/day
Maintenance and milk		See page 25	See page 25	-	-
Maintenance and growth[2]		-		2,259/365	1,323/365
Surplus requirements					
Movement[3]	No grazing	201			
	extra with Limited grazing		0.419		
	extra with Combined grazing		0.419		
	extra with Unlimited grazing		0.560	0.784	0.346
Youth[4]		102	0.3175		
Gestation and NEB[5]		194	0.5315	0.2819	

1 For a breed with a different adult weight, the surplus requirement in this table must be multiplied by the breed factor VEM requirement corresponding to the relevant weight in Table 2.1.

2 Only a portion of the calves remain on the farm all year (from birth). This requires a correction. Therefore, the annual kVEM requirement is not 1.380 but 1.324 kVEM. It is assumed that the replacement percentage is 28%, meaning that, according to the *Dutch Dairy Farm Handbook* (*Handboek Melkveehouderij*) 0.376 calves per average dairy cow must be kept. Per average dairy cow present, the number of live-born calves is 1.14 and the number of calves to be sold at the age of half a month (30.4 days on average, so 15.2 days) is 0.7653. Converted to the number of calves per year, this equals 0.7653 x 15.2 / 365 = 0.0319 calves per average dairy cow present, resulting in 0.3760 + 0.0319 = 0.4079 calves in category 101 per average dairy cow present. The requirement in the first month is 54.4 kVEM. Converted to half a month (15.2 days), the requirement is 54.4 / 2 x 24 = 653 kVEM (rounded) on an annual basis (a year consists of 24 half-month periods). The corrected requirement is therefore 1.380 x 0.3760 / 0.4079 + 653 x 0.0319 / 0.4079 = 1.323,2 kVEM per year. The corrected requirement in the first month is then: (54.4 x (0.3760 + (0.7653 x 0.5))) / 0.4079 = 101.2 kVEM per average head of young stock category 101.

3 The movement surplus requirement for 'No grazing' applies to non-tethered animals (10% of maintenance requirement, set at 2010 kVEM/year (Tamminga *et al.*, 2004)). The surplus requirements for movement for dairy cows in this table are 7.5% for 'Limited grazing' and 10% for 'unlimited grazing'. For youngstock, these are based on the assumptions in the BEX youngstock; these are expressed in kVEM per animal per grazing day. For calves, the kVEM surplus is expressed per average calf present. Assuming an energy requirement of 0.375 kVEM per calf per day and 0.3760 / 0.4079 = 0.9218 calves of this animal category present all year round, the grazing surplus is 0.375 x 0.3760 / 0.4079 = 0.346 kVEM per day per calf.

4 The youth surplus requirement per cow was calculated for first and second lactation cows and is based on 660 VEM per day in the first lactation and 330 VEM in the second lactation. Assuming that, on average, 30% of cows are in their first lactation and 25% are in their second lactation, the total allowance per average cow present amounts to: (660 x 0.30 + 330 x 365) x 365 = 102 kVEM per year. For the calculation of the youth surplus requirement for dairy cows, a weight of 540 kg at two years of age, 595 kg at three years of age, and 650 kg at four years of age was assumed for 'Other breeds'.

5 The gestation surplus requirement for a dairy cow amounts to (rounded) 144.7 kVEM per year; the surplus requirement for a heifer (i.e., a young, non-lactating cow) is 90% of that of a dairy cow (144.7 x 0.90 = 130.2 kVEM per year). Assuming an average of 0.7 calves per cow (see Table 2.4), the gestation surplus requirement is 144.7 x 0.70 = 101.3 kVEM per year. The VEM requirement for the Negative Energy Balance (NEB) is the average energy needed to rebuild body reserves mobilised during the first months of lactation; this amounts to 93 kVEM. The total for gestation and NEB is therefore 194.3: rounded 194. For a heifer, assuming an average 0.89 calf per heifer (see Table 2.4), the gestation surplus requirement is 144.7 x 0.9 x 0.89 = 115.9 kVEM per year (that is 0.3175 kVEM per day).

Overview of calculation rules for VEM requirement

kVEM requirement for youngstock per year
Younger than 1 year (calves (CA)) (per animal per calendar year): (1.323 + 0.346 x number of grazing days) x number of CA x breed factor VEM requirement (kVEM).

The VEM requirement takes into account that not all calves remain on the farm for a full year from birth. A large proportion leave the farm at an age of (on average) 15 days and therefore have a significantly lower VEM than the animals that stay on the farm for a full year. The footnote under Table 2.2 describes how this correction is calculated.

Older than 1 year (heifers (HE)) (per animal per calendar year): (2.259 + 130.2 x 0.89 + 0.784 x number of pasture days) x number of HE x breed factor VEM requirement (kVEM).

kVEM requirement for dairy cows per year: milk production
Milk yield / cow = total milk produced (kg) / the number of dairy cows.
FPCM / day = (milk yield / cow (kg) x (0.337 + 0.116 x fat% + 0.06 x protein%)) / 326 (days).
VEM milk production = (442 x FPCM / day x (1 + (FPCM / day -15) x 0.00165)) x 326 (days).
kVEM milk production = VEM milk production / 1000

kVEM requirement for dairy cows per year: maintenance
WT (kg) = live weight depending on the type of cow (see standard values Table 2.1).
VEM maint during lactation = (42.4 x $WT^{0.75}$ x (1 + (FPCM / day - 15) x 0.00165)) x 326 (days).
VEM maint during dry period = 42.4 x $WT^{0.75}$ x (1 + (-15 x 0.00165)) x 39 (days).
VEM maintenance dairy cattle = VEM maint during lactation + VEM maint during dry period.
kVEM maintenance = VEM maintenance dairy cattle / 1000.

Surplus VEM requirement for dairy cows per year
kVEM surplus requirement per cow = (surplus energy required for movement 'No grazing' from Table 2.2 + (number of months of grazing x surplus requirement for movement for 'limited grazing' or 'unlimited grazing' from Table 2.2) * 326/365) + surplus requirement for 'youth' from Table 2.2 + surplus requirement for pregnancy and NEB from Table 2.2.

kVEM requirement of the dairy herd per year
kVEM requirement of dairy herd = ((kVEM milk production + kVEM maintenance + kVEM surplus requirement) x number of dairy cows) + (kVEM youngstock <1 year x number of young stock < 1 year) + (kVEM youngstock > 1 year x number of young stock > 1 year).

2.2.11 Calculation of N and P intake by dairy herd

The N and P intake is calculated by multiplying the VEM intake of each feedstuff by the analysed N/VEM and P/VEM respectively (see section 2.2.3). Subsequently, the total VEM intake is calculated by summing the results of all feedstuffs. However, on commercial farms, the VEM intake is often not known for all feedstuffs. For purchased feedstuffs, intake is calculated as the amount purchased minus changes in stock, but for homegrown roughage, reliable data are particularly lacking on the proportion of pasture grass in the roughage supply. Initially, the total amount of energy from homegrown roughage, corn silage, grass silage and fresh (pasture) grass is estimated as follows:

> *VEM intake from corn silage, grass silage and fresh (pasture) grass = calculated VEM intake herd - VEM intake from other roughage and wet (by)products, concentrates and milk products - feed losses from other roughage and wet (by)products, concentrates and dairy products*

where:

> *calculated VEM intake herd = VEM herd requirement x 102%*

2.2.12 Calculation of VEM intake from corn silage, grass silage and fresh grass

The distribution of the calculated VEM intake from corn silage, grass silage and fresh (pasture) grass across the individual products is done by calculating a ratio between the calculated VEM intake from fresh grass, the measured amount of grass silage fed and the measured amount of corn silage fed. For fresh (pasture) grass, both intake and analyzed nutrient contents are lacking. Depending on the grazing system, a dry matter intake from fresh grass is calculated for the VEM intake from fresh (pasture) grass (Oenema *et al.*, 2017). The following principles are used in the calculation:

- The variation in grazing duration with unlimited grazing is 10 to 20 hours per day. This variation amounts to 2 to 10 hours per day with limited grazing.
- In practice, grazing dairy cows receive at least 2 hours of pasture access. With 2 hours of pasture access, a dairy cow consumes 2 kg of dry matter from pasture grass (type 'Other breeds' - see Tables 2.1 and 2.2 - and with a milk production of 9,500 kg FPCM/year). For each additional grazing hour, 0.75 kg of dry matter is added, with a maximum of 18 extra grazing hours (20h in total) per day. For every 500 kg FPCM more or less, the dry matter intake from pasture grass must be increased or decreased by 2%, respectively.
- For summer stall feeding, it is assumed that the dry matter intake of a dairy cow with 'unlimited' fresh grass in the barn is 87% of the intake under unlimited grazing for 20 hours per day. For a dairy cow with 'limited' fresh grass in the barn, the dry matter intake of fresh grass is equal to 87% of the intake during 9 hours of grazing per day.
- The dry matter intake of Jerseys and crossbreeds (Jersey x other breeds) is respectively 70% and 85% of that of cows of 'other breeds'. The same percentages also apply to the reference level of the measured milk production to calculate dry matter intake (6,650 and 8,075 kg FPCM/year respectively).
- Dry cows do not receive fresh grass.

2.2.13 Calculation of the N/VEM and P/VEM ratio in fresh grass

The composition of fresh pasture grass (dry matter, VEM, N and P) under grazing and summer stall feeding is unknown. In the BEX, a distinction is made between fresh grass from production grassland (production grass) and fresh grass from natural grassland (natural grass). The ratios of VEM to N and P for fresh production grass are derived from the N/VEM and P/VEM of the stored grass silage (based on data from commercial farms from the *Koeien & Kansen* project). The quality of the grass silage(s) must therefore be representative of the quality of the fresh grass that dairy cows receive via grazing or summer stall feeding. Consequently, the ratio between VEM, N and P contents in grassland products (only grass silage, excl. purchased grass and not from natural grassland) is the starting point for estimating the composition of the fresh production grass. If no own grass silage is available, standard values are used (based on data from commercial farms from the *Koeien & Kansen* project). For fresh natural grass, standard values derived from research are applied (Vellinga, 1994; Korevaar *et al.*, 2006).

2.2.14 Correction for feed intake by other grazing animals

If, in addition to dairy cows and associated young stock ('dairy cattle'), other grazing animals are present on the farm and the feed for these animals is not clearly separated from the feed for dairy cattle, a fixed amount of consumption is deducted from the quantity calculated as being fed on the farm (Table 2.3). In this, consumption refers to intake plus feeding losses.

Another point of attention for the careful application of Table 2.3 concerns the method of distributing the feed categories across the animal categories. The basic principle is that the total kVEM intake listed per animal category is achieved. However, if one or more feed categories have been fed little or not at all on a farm, the kVEM intake must come from other feed categories, that are specified per animal category. This is done as follows, always in a specific order, as described below:

- In case of no fresh (pasture) grass: grass products, corn silage, other products, concentrates, milk powder. This applies, for example, when cows are not grazed because no grassland is available. Thus, when no fresh pasture grass is available, it is assumed for grazing cows that the kVEM requirement of 1,792 kVEM from pasture grass is supplied by grass-based products, resulting in a total intake of 3,187 kVEM from those sources.

- In case of no or insufficient artificial milk powder: concentrates, other products, corn silage, grass products, fresh pasture grass;
- In case of no or insufficient concentrates: other products, corn silage, grass products, fresh pasture grass, artificial milk powder;
- In case of no or insufficient other products: corn silage, grass products, fresh pasture grass, concentrates, milk powder;
- In case of no or insufficient corn silage: other products, grass products, fresh pasture grass, concentrates, milk powder;
- In case of no or insufficient grass products: other products, corn silage, fresh pasture grass, concentrates, milk powder.

Table 2.3 *Standard kVEM intake values per year for a number of categories of 'other grazing animals'.*

Feed category:	Artificial milk powder	Concentrates[2]	Pasture grass (grazing)	Grass products[3]	Corn silage, ensiled	Other products[4]	Total kVEM uptake
Feed losses (%):	2	2	n/a	5	5	3	
Animal category[1]							
104 Breeding bulls (≥ 1 year)	0	274	0	2,466			2,740
115 Calves for pink or red meat (< approx. 3 months)	222	406	0	0	140	0	768
116 Rosé calves (approx. 3-8 months)	0	1,122	0	0	655	355	2,132
117 Rosé calves (approx. 14 days to 8 months)	78	880	0	0	482	211	1,651
120 Pasture and suckler cows	0	56	1,792	1,339	0	0	3,187
122 Red meat bulls (> approx. 3 months to slaughter)	0	970	0	0	1,652	68	2,690
550 Breeding sheep (lambed at least once incl. lambs < approx. 4 months and rams)	0	56	328	65	0	0	449
551 Meat sheep (< approx. 4 months, not born on farm)	0	9	47	4	0	0	60
552 Rearing ewes, pasture sheep, meat sheep (> approx. 4 months)	0	11	266	22	0	0	299
600 Dairy goats, conventional (kidded at least once incl. newborn kids and mature bucks)	0	463	0	243	114	0	820
600 Dairy goats, organic (kidded at least once incl. newborn kids and mature bucks)	0	241	95	280	175	0	791
601 Rearing goats and meat goats (< approx. 4 months)	79	60	0	32	53	0	224
602 Rearing goats and meat goats (> approx. 4 months)	0	203	0	107	179	0	489
941 Ponies (standing < 1.56 m at the withers and incl. foals < 6 months)	0	164	497	734	0	47	1,442
943 Horses (standing ≥ 1.56 m at the withers and incl. foals < 6 months)	0	517	909	1,452	0	49	2,927
961 Donkeys (incl. foals < 6 months)	0	38	334	380	0	94	846
991 Water buffalo cows (all water buffalo cows that have calved at least once and are kept for milk production or breeding; also includes water buffalo that are dry or being fattened and milked during the fattening period).	0	734	0	1,608	1,537	306	4,185
992 Water buffalo youngstock (all water buffalo up to 2 years of age)	0	194	0	474	814	219	1,701

1 For an exact description, see Appendix D of the Implementation Regulation of the Dutch Fertilizers Act (Uitvoeringsregeling Meststoffenwet).

2 Dry concentrates: compound feeds plus single dry concentrate feeds.

3 Grass hay, grass silage and/or grass pellets. Strictly speaking, this category should be called 'other grass products'; the previous text has already explained what this feed category comprises.

4 Moist concentrates plus other roughages. The stated values for rosé calves are based on moist concentrates.

2.2.15 Overview of calculation rules for N and P intake

VEM value of fresh production grass = 960 VEM/kg DS

N/VEM and P/VEM fresh production grass:
N/VEM pasture grass = 1.12 x N/VEM ensiled grass
P/VEM pasture grass = 0.97 x P/VEM ensiled grass
N/VEM summer stall feeding = 1.06 x N/VEM ensiled grass
P/VEM summer stall feeding = 0.98 x P/VEM ensiled grass

Contents in fresh production grass when no silage has been made in the relevant ANCA Tool year:
VEM value of fresh production grass = 960 VEM/kg DS
N content of fresh production grass = 213/6.25 g/kg
P content of fresh production grass = 4.4 g/kg DS

VEM value fresh natural grass = 860 VEM/kg DS
N content of fresh nature grass = 189/6.25 g/kg DS
P content of fresh nature grass = 4.0 g/kg DS

Calculation of the amount of intake from pasture grass:

*milk factor = 1 + (measured milk production – 9.500 * breed factor) / 500 x 0.02*

<u>When grazing:</u>
kVEM intake of dairy herd from fresh grass =
(number of grazing days of dairy cows) x ((2 + 0.75 x (grazing hours/day - 2)) x milking factor) x number of dairy cows x VEM value grazed grass / 1,000
In which the following applies:

number of grazing hours/day < 20

<u>For summer stall feeding:</u>
kVEM intake of dairy herd from fresh grass =
kVEM intake dairy herd from fresh grass when grazing x 0.87 =
(number of days summer stall feeding of dairy cows) x ((2 + 0.75 x (grazing hours/day - 2)) x milk factor x 0.87) x number of dairy cows x VEM value grazed grass / 1,000

In which the following applies:

Number of grazing hours/day = 20 with ‘unlimited’ fresh grass in the barn.
Number of grazing hours/day = 9 with ‘limited’ fresh grass in the barn.

N and P retention
The N and P retention is calculated for the whole dairy herd: all lactating and dry cows, plus youngstock. No additional data are required for the calculation of retention. All calculations are done with standard values, except for N and P retained in milk and the number of animals (Tables 2.4 and 2.5).

Table 2.4 *Starting points for N and P retention in dairy herd.*

Live weights of dairy herd categories		Abbreviation
Weight adult dairy cow*	= WT	WT
Weight calf (kg)**	= WT x 44/650	WTcalf
Weight heifer (kg)**	= WT x 320/650	WTheif
Weight first-lactation cow (kg)**	= WT x 540/650	WT1lact
Retention in dairy cows		
During milk production		
Nitrogen (N) content in milk (g/kg)	= protein% in milk x 10/6.38	
Phosphorus (P) content in milk (g/kg)	= phosphorus content in milk/100	
During gestation		
Number of calves born per cow per calendar year	= 0.7	Ncalf
Nitrogen (N) calf content (g/kg)	= 29.4	Ncontcalf
Phosphorus (P) calf content (g/kg)	= 8.0	Pcontcalf
Contents of calf concern the composition at birth		
Growth of first-lactating cows (replacement)		
Share of replacement per dairy cow	= 0.27	Replacement
Nitrogen (N) content first-lactation cow (g/kg)	= 23.1	Ncont1lact
Phosphorus (P) content first-lactation cow (g/kg)	= 7.4	Pcont1lact
Nitrogen (N) content cow (g/kg)	= 22.5	Ncontcow
Phosphorus (P) content cow (g/kg)	= 7.4	Pcontcow
Content of first-lactation cows concern composition at first calving		
Retention in young stock		
Youngstock younger than one year		
Nitrogen (N) calf content (g/kg)	= 29.4	Ncontcalf
Phosphorus (P) calf content (g/kg)	= 8.0	Pcontcalf
Nitrogen (N) content heifer (g/kg)	= 24.1	Ncontheif
Phosphorus (P) content heifer (g/kg)	= 7.4	Pcontheif
N and P content of heifer concern composition at 12 months of age		
Youngstock older than one year		
Number of calves born from youngstock per calendar year	= 0.89	Ncalf1
Nitrogen (N) calf content (g/kg)	= 29.4	Ncontcalf
Phosphorus (P) calf content (g/kg)	= 8.0	Pcontcalf
Nitrogen (N) content heifer (g/kg)	= 24.1	Ncontheif
Phosphorus (P) content heifer (g/kg)	= 7.4	Pcontheif
Nitrogen (N) content first-lactation cow (g/kg)	= 23.1	Ncont1lact
Phosphorus (P) content first-lactation cow (g/kg)	= 7.4	Pcont1lact

* The average body weight of an adult dairy cow depends on the breed: see Table 2.1.

** For 'other breeds' (Table 2.1), the average weight of a calf (at birth) is 44 kg, of a heifer 320 kg (at 1 year of age) and of a first-lactation cow 540 kg (heifer calving at the age of approximately 26 months).

Table 2.5 *Calculation of N and P retention (in kg per year)*.*

Retention in dairy cows		
During milk production		
Nmilk	=	(total milk produced x (protein percentage x 10 / 6.38)) / 1,000
Pmilk	=	(total milk produced x P-milk) / 1,000
During pregnancy		
WTcalf	=	WT x 44/650
Ncalf	=	((WTcalf x Ncalf** x Ncontcalf) / 1,000) x number of dairy cows
Pcalf	=	((WTcalf x Ncalf** x Pcontcalf) / 1,000) x number of dairy cows
Growth of first-lactation cows (replacement)		
WT1lact	=	WT x 540/650
N1lact	=	(WT1lact x replacement x Ncont1lact**) / 1,000
P1lact	=	(WT1lact x replacement x Pcont1lact**) / 1,000
Ncow	=	(WT x replacement x Ncontcow**) / 1,000
Pcow	=	(WT x replacement x Pcontcow**) / 1,000
Nrepl	=	(Ncow – N1lact) x number of dairy cows
Prepl	=	(Pcow – P1lact) x number of dairy cows
Retention in young stock		
Younger than 1 year		
WTheif	=	WT x 320/650
Ncalf1	=	(WTcalf x Ncontcalf***) / 1,000
Pcalf1	=	(WTcalf x Pcontcalf***) / 1,000
Nheif	=	(WTheif x Ncontheif***) / 1,000
Pheif	=	(WTheif x Pcontheif***) / 1,000
Nys < 1	=	(Nheif - Ncalf1) x avg. number of young stock < 1yr x Ncorr
Pys < 1	=	(Pheif - Pcalf1) x avg. number of young stock < 1yr x Pcorr
NCorr	=	0.971****
Pcorr	=	0.961****
Older than 1 year		
Ncalf2	=	(WTcalf x Ncalf1** x Ncontcalf ***) / 1,000
Pcalf2	=	(WTcalf x Ncalf1** x Pcontcalf ***) / 1,000
N1lact1	=	(WT1lact x Ncont1lact***) / 1,000
P1lact1	=	(WT1lact x Pcont1lact***) / 1,000
Nys> 1	=	(NcalfO + (N1lact1 – Nheif) x12 / 14) x avg. head of youngstock > 1yr
Pys> 1	=	(PcalfO + (P1lact1 – Pheif) x 12/14) x avg. head of youngstock > 1yr

* The starting points for the formulas can be found in Table 2.4.

** See Table 2.4 for Ncalf and Ncalf1.

*** See Table 2.4 for N and P contents of dairy cow, heifer, first lactation cow, and calf.

**** These correction factors for retention are needed to account for that fact that, just as with the VEM-intake, not all calves remain on the farm for a full year from birth. A large portion leave the farm at an (average) age of 15 days and therefore retains considerably less N and P than animals that stay on the farm a whole year. In analogy with the correction for VEM requirements, a correction is therefore also applied here for N and P.

2.2.16 Gaseous N losses

Part of the nitrogen excretion of the dairy herd is lost through volatilisation from housing and storage. When calculating the amount of manure that can be applied, these gaseous nitrogen losses need to be taken into account, as the nitrogen standards for animal manure are based on the amount *after* deduction of these gaseous losses from housing and storage. These gaseous N-losses are calculated using the BEA module within the ANCA tool (Chapter 3).

2.2.17 Manure production by ‘other grazing animals’

In the ANCA tool, the calculations of BEX excretion use fixed coefficients (Table 2.6) to estimate the amounts of manure N and Manure P_2O_5 produced by other grazing animals, distinguishing between conventional and organic dairy farming systems. These standard values represent the net excretions, with gaseous N losses already deducted. In addition to the BEX excretion, the ANCA tool also calculates the net N excretion based on the gross N excretion (BEA, Section 3.2.2.2) and the gaseous N losses (BEA, section 3.2.5.2). The ANCA calculation may differ slightly from the BEX calculation because in the ANCA tool, the gaseous N losses are calculated separately for each source (e.g., NH_3, N_2O, NO_x en N_2) and more consideration is given to farm-specific circumstances.

Table 2.6 *Net excretion in the form of manure-N and manure-P_2O_5 per average animal present for ‘other grazing animals’ (source: RVO).*

Animal category	Excretion slurry N	Excretion, solid manure N	Excretion Manure P_2O_5	Organic excretion N	Organic excretion P_2O_5
Breeding bulls > 1 year (cat. 104)	64.4	51.2	25.9	51	25.9
Pasture and suckler cows (cat. 120)	75.4	75.3	26.9	66.2	26.9
Calves for rosé or red meat (cat. 115)	10.5	10.5	3.4	6.6	3.4
Rosé calves, 3 months - slaughter (cat. 116)	26.3	26.3	9.4	26.3	9.4
Rosé calves, 2 weeks - slaughter (cat. 117)	21.5	21.5	7.6	23.4	7.6
Red meat bulls, 3 months - slaughter (cat. 122)	28.2	25.6	9.7	27.2	9.7
Breeding sheep (cat. 550)	9.9	9.9	3.3	9.9	3.3
Meat sheep, < 4 months (cat. 551)	0.9	0.9	0.3	0.9	0.3
Other sheep, > 4 months (cat. 552)	7.2	7.2	2.2	7.2	2.2
Milk goats (cat. 600)	9.4	9.4	4.7	8.9	4.4
Rearing and meat goats, < 4 months (cat. 601)	0.6	0.6	0.3	0.6	0.3
Rearing and meat goats, > 4 months (cat. 602)	4.7	4.7	2.6	4.7	2.6
Ponies (cat. 941)	27.3	27.3	13.0	27.3	13.0
Horses (cat. 943)	58.8	58.8	28.6	58.8	28.6
Donkeys (cat. 961)	16	16	7.3	16	7.3
Water buffalo, cows (cat. 991)	76.5	76.5	29.9	76.5	29.9
Water buffalo, youngstock (cat. 992)	28.7	28.7	10.1	28.7	10.1

2.2.18 Manure production by ‘housed animals’

Because the ANCA Tool, in calculating certain metrics, takes into account the possible presence of an additional branch with ‘housed animals’ (e.g., pigs, poultry), data are required on the contribution of these housed animals to the production, removal, and possible use of N and P in animal manure from these animals. These are not calculated by querying the ANCA Tool for the quantities and composition of purchased feed and input materials, and the quantities and composition of removed animals and/or products, but directly by requesting data from the net barn balance(s) that are available in other frameworks. For the quantities of manure N produced by ‘housed animals’ net excretions are used, from which gaseous losses have already been subtracted. These excretions are also first converted into gross excretions in the ANCA Tool to calculate the soil N surplus in the soil, after deducting gaseous N losses calculated using the BEA module. The environmentally harmful part of the emissions (ammonia-N, nitrous oxide-N, methane) from ‘housed animals’ is added to the emissions of the rest of the farm. This applies to methane emissions both from barns and manure storage, as well as from methane released during digestion. These emissions are determined based on coefficients and the numbers of animals kept (Mosquera & Hol, 2012; Anonymus, 2015b).

To determine the production of manure N and P by ‘housed animals’ the following information is requested:

- Total net barn balances for nitrogen and phosphate (fertilisation plan)
- Average number of animals present (AN)
- Type of manure (slurry or solid manure)
- Housing system (Environmental Regulation)

Based on the requested information, manure N and P production is calculated as follows:

- The total amounts of nitrogen and phosphate from the net barn balance are distributed across the different animal groups using a weighted average of standard nitrogen and phosphate productions, calculated using the manure production and manure contents from Table 2.7:
  - Standard nitrogen production = AN * manure production per AN * N content of manure
  - Standard phosphate production = AN * manure production per AN * P_2O_5 content of manure
- The amount of manure produced in tonnes can be calculated using Table 2.7:
  - Standard manure production = AN * manure production per AN
- In the ANCA Tool, two types of 'barn manure' are distinguished: slurry and solid manure. Therefore, when entering data, it must be specified whether the specific animal category produces slurry or solid manure. The total nitrogen and phosphate production in slurry and solid manure can be determined by summing the net barn balances distributed across the indoor housed animals.
- Finally, the content is determined by dividing the total amounts of nitrogen and phosphate by the produced quantities of manure.

Table 2.7 *Standard net manure production and manure contents for different types of indoor-housed animals and housing systems, based on the Environmental Regulation (codes) (Dutch: Omgevingsregeling (coderingen)).*

Animal species	RV barn type (code)	Manure production, slurry (tonnes per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/tonne)	Nitrogen content solid manure (kg N/tonne)	Phosphate content slurry (P_2O_5/tonne)	Phosphate content solid manure (kg P_2O_5 / tonne)
Laying hens	HE2.1.1	43.7	14.56	16.6	50.1	6.0	18.8
	HE2.1.2	43.7	14.56	16.6	50.1	6.0	18.8
	HE2.2.1	43.7	15.6	9.3	26.3	6.0	24.2
	HE2.2.2	43.7	15.6	15.0	42.3	6.0	24.2
	HE2.2.3	43.7	15.6	14.7	41.5	6.0	24.2
	HE2.2.4	43.7	15.6	14.2	40.1	6.0	24.2
	HE2.2.5	43.7	15.6	14.2	40.1	6.0	24.2
	HE2.2.6	43.7	15.6	15.9	44.6	6.0	24.2
	HE2.2.7	43.7	15.6	15.1	42.6	6.0	24.2
	HE2.3.1	43.7	18.72	15.4	36.2	6.0	24.2
	HE2.3.2.1	43.7	18.72	16.1	37.8	6.0	24.2
	HE2.3.2.2	43.7	18.72	16.1	37.8	6.0	24.2
	HE2.3.3	43.7	18.72	16.7	39.2	6.0	24.2
	HE2.3.4	43.7	18.72	16.5	38.6	6.0	24.2
	LW1.1	43.7	15.6	15.3	43.2	6.0	24.2
	LW1.4	43.7	15.6	15.3	43.2	6.0	24.2
	LW1.6	43.7	15.6	15.3	43.2	6.0	24.2
	LW2.4	43.7	15.6	15.3	43.2	6.0	24.2
	LW2.8	43.7	15.6	16.6	46.6	6.0	24.2
	LW2.9	43.7	15.6	15.32	43.15	6.0	24.2
	HE2.100	43.7	15.6	11.0	31.1	6.0	24.2
Broilers	HE5.1	19.2	11.4	21.4	36.23	6	16.6
	HE5.2	19.2	11.4	20.98	35.53	6	16.6
	HE5.3	19.2	11.4	21.4	36.3	6	16.6
	HE5.4	19.2	11.4	19.62	33.24	6	16.6
	HE5.5	19.2	11.4	19.99	33.85	6	16.6
	HE5.6	19.2	11.4	20.72	35.09	6	16.6
	HE5.7	19.2	11.4	19.78	33.5	6	16.6
	HE5.8	19.2	11.4	20.51	34.73	6	16.6
	HE5.9	19.2	11.4	19.78	33.5	6	16.6
	HE5.10.1	19.2	11.4	20.98	35.53	6	16.6
	HE5.10.2	19.2	11.4	20.98	35.53	6	16.6

Animal species	RV barn type (code)	Manure production, slurry (tonnes per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/tonne)	Nitrogen content solid manure (kg N/tonne)	Phosphate content slurry (P_2O_5/tonne)	Phosphate content solid manure (kg P_2O_5 / tonne)
	LW1.1	19.2	11.4	20.57	34.82	6	16.6
	LW1.6	19.2	11.4	20.57	34.82	6	16.6
	LW2.4	19.2	11.4	20.57	34.82	6	16.6
	LW2.8	19.2	11.4	21.25	35.97	6	16.6
	LW2.9	19.2	11.4	20.57	34.82	6	16.6
	HE5.100	19.2	11.4	18.06	30.59	6	16.6
Farrowing sows	HD2.1	5,000	3,200	4.4	6.9	2.5	13.6
	HD2.2	5,000	3,200	4.4	6.7	2.5	13.6
	HD2.3	5,000	3,200	4.3	6.7	2.5	13.6
	HD2.4	5,000	3,200	4.5	6.9	2.5	13.6
	HD2.5	5,000	3,200	4.3	6.7	2.5	13.6
	HD2.6	5,000	3,200	4.5	6.9	2.5	13.6
	HD2.7	5,000	3,200	4.1	6.4	2.5	13.6
	HD2.8	5,000	3,200	4.6	7.1	2.5	13.6
	HD2.9	5,000	3,200	4.5	7.0	2,5	13.6
	HD2.10	5,000	3,200	4.5	7.0	2.5	13.6
	HD2.11	5,000	3,200	4.5	6.9	2.5	13.6
	HD2.12	5,000	3,200	4.5	7.0	2.5	13.6
	HD2.13	5,000	3,200	4.82	7.43	2.5	13.6
	HD2.14	5,000	3,200	4.6	7.1	2.5	13.6
	LW1.1	5,000	3,200	4.6	7.1	2.5	13.6
	LW1.2	5,000	3,200	4.6	7.1	2.5	13.6
	LW1.3	5,000	3,200	4.6	7.1	2.5	13.6
	LW1.4	5,000	3,200	4.6	7.1	2.5	13.6
	LW1.5	5,000	3,200	4.8	7.4	2.5	13.6
	LW1.7	5,000	3,200	4.59	7.09	2.5	13.6
	LW2.4	5,000	3,200	4.6	7.1	2.5	13.6
	LW2.6	5,000	3,200	5.0	7.7	2.5	13.6
	LW2.7	5,000	3,200	5.0	7.7	2.5	13.6
	LW2.8	5,000	3,200	4.9	7.6	2.5	13.6
	LW4.1	5,000	3,200	4.8	7.4	2.5	13.6
	LW4.2	5,000	3,200	4.8	7.4	2.5	13.6
	LW4.3	5,000	3,200	4.9	7.6	2.5	13.6
	LW4.4	5,000	3,200	4.8	7.4	2.5	13.6
	LW4.5	5,000	3,200	4.6	7.1	2.5	13.6
	LW4.6	5,000	3,200	4.8	7.4	2.5	13.6
	AV100.1	5,000	3,200	3.97	6.11	2.5	13.6
	HD2.100	5,000	3,200	3.5	5.4	2.5	13.6
Other sows	HD3.1	2,800	1,792	5.79	8.93	2.5	13.6
	HD3.2	2,800	1,792	5.97	9.22	2.5	13.6
	HD3.3	2,800	1,792	5.76	8.89	2.5	13.6
	HD3.4	2,800	1,792	5.97	9.22	2.5	13.6
	HD3.5	2,800	1,792	5.85	9.03	2.5	13.6
	HD3.6	2,800	1,792	5.85	9.03	2.5	13.6
	HD3.7	2,800	1,792	5.85	9.03	2.5	13.6
	HD3.8.1	2,800	1,792	5.82	8.98	2.5	13.6
	HD3.8.2	2,800	1,792	5.76	8.89	2.5	13.6
	HD3.9	2,800	1,792	5.73	8.84	2.5	13.6
	HD3.10	2,800	1,792	6.06	9.36	2.5	13.6
	LW1.1	2,800	1,792	6.12	9.45	2.5	13.6
	LW1.2	2,800	1,792	6.12	9.45	2.5	13.6
	LW1.3	2,800	1,792	6.12	9.45	2.5	13.6
	LW1.4	2,800	1,792	6.12	9.45	2.5	13.6

Animal species	RV barn type (code)	Manure production, slurry (tonnes per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/tonne)	Nitrogen content solid manure (kg N/tonne)	Phosphate content slurry (P_2O_5/tonne)	Phosphate content solid manure (kg P_2O_5 / tonne)
	LW1.5	2,800	1,792	6.33	9.77	2.5	13.6
	LW1.6	2,800	1,792	6.12	9.45	2.5	13.6
	LW2.3	2,800	1,792	6.12	9.45	2.5	13.6
	LW2.5	2,800	1,792	6.45	9.97	2.5	13.6
	LW2.8	2,800	1,792	6.39	9.87	2.5	13.6
	LW4.1	2,800	1,792	6.33	9.77	2.5	13.6
	LW4.2	2,800	1,792	6.33	9.77	2.5	13.6
	LW4.3	2,800	1,792	6.39	9.87	2.5	13.6
	LW4.4	2,800	1,792	6.33	9.77	2.5	13.6
	LW4.5	2,800	1,792	6.12	9.45	2.5	13.6
	LW4.6	2,800	1,792	6.33	9.77	2.5	13.6
	AV100.1	2,800	1,792	5.61	8.65	2.5	13.6
	HD3.100	2,800	1,792	5.24	8.08	2.5	13.6
	HD3.101	2,800	1,792	5.24	8.08	2.5	13.6
Weaned piglets	HD1.1	535	343	3.7	5.7	3.9	13.6
	HD1.2	535	343	3.6	5.6	3.9	13.6
	HD1.3.1	535	343	3.7	5.7	3.9	13.6
	HD1.3.2	535	343	3.6	5.5	3.9	13.6
	HD1.4	535	343	3.6	5.6	3.9	13.6
	HD1.5.1	535	343	3.6	5.5	3.9	13.6
	HD1.5.2	535	343	3.5	5.3	3.9	13.6
	HD1.6.1	535	343	3.7	5.7	3.9	13.6
	HD1.6.2	535	343	3.7	5.6	3.9	13.6
	HD1.6.3	535	343	3.7	5.7	3.9	13.6
	HD1.7	535	343	3.4	5.2	3.9	13.6
	HD1.8	535	343	3.8	5.8	3.9	13.6
	HD1.9	535	343	3.7	5.7	3.9	13.6
	HD1.10	535	343	3.7	5.7	3.9	13.6
	HD1.11	535	343	3.66	5.64	3.9	13.6
	LW1.1	535	343	3.7	5.6	3.9	13.6
	LW1.2	535	343	3.7	5.6	3.9	13.6
	LW1.3	535	343	3.7	5.6	3.9	13.6
	LW1.4	535	343	3.7	5.6	3.9	13.6
	LW1.5	535	343	3.84	5.93	3.9	13.6
	LW1.7	535	343	3.66	5.64	3.9	13.6
	LW2.3	535	343	3.7	5.6	3.9	13.6
	LW2.5	535	343	4.0	6.1	3.9	13.6
	LW2.8	535	343	3.9	6	3.9	13.6
	LW4.1	535	343	3.8	5.9	3.9	13.6
	LW4.2	535	343	3.84	5.93	3.9	13.6
	LW4.3	535	343	3.9	6	3.9	13.6
	LW4.4	535	343	3.8	5.9	3.9	13.6
	LW4.5	535	343	3.7	5.6	3.9	13.6
	LW4.6	535	343	3.8	5.9	3.9	13.6
	AV100.1	535	343	3.18	4.9	3.9	13.6
	HD1.100	535	343	2.9	4.4	3.9	13.6
Pigs	HD5.1	1,337	974	7.26	9.84	3.9	13.6
	HD5.2	1,337	974	5.61	7.57	3.9	13.6
	HD5.3	1,337	974	7.45	10.1	3.9	13.6
	HD5.4	1,337	974	7.83	10.62	3.9	13.6
	HD5.5	1,337	974	7.64	10.36	3.9	13.6
	HD5.6	1,337	974	7.71	10.45	3.9	13.6
	HD5.7	1,337	974	7.39	10.01	3.9	13.6

Animal species	RV barn type (code)	Manure production, slurry (tonnes per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/tonne)	Nitrogen content solid manure (kg N/tonne)	Phosphate content slurry (P_2O_5/tonne)	Phosphate content solid manure (kg P_2O_5 / tonne)
	HD5.8	1,337	974	7.39	10.01	3.9	13.6
	HD5.9	1,337	974	7.58	10.27	3.9	13.6
	HD5.10	1,337	974	7.52	10.19	3.9	13.6
	HD5.11	1,337	974	7.39	10.01	3.9	13.6
	HD5.12	1,337	974	7.58	10.27	3.9	13.6
	HD5.13	1,337	974	7.77	10.53	3.9	13.6
	HD5.14	1,337	974	7.98	10.82	3.9	13.6
	AV100.1	1,337	974	7.12	9.64	3.9	13.6
	LW1.1	1,337	974	7.9	10.71	3.9	13.6
	LW1.2	1,337	974	7.9	10.71	3.9	13.6
	LW1.3	1,337	974	7.9	10.71	3.9	13.6
	LW1.4	1,337	974	7.9	10.71	3.9	13.6
	LW1.5	1,337	974	8.18	11.1	3.9	13.6
	LW1.7	1,337	974	7.9	10.71	3.9	13.6
	LW2.3	1,337	974	7.9	10.71	3.9	13.6
	LW2.5	1,337	974	8.37	11.36	3.9	13.6
	LW2.8	1,337	974	8.28	11.23	3.9	13.6
	LW4.1	1,337	974	8.18	11.1	3.9	13.6
	LW4.2	1,337	974	8.18	11.1	3.9	13.6
	LW4.3	1,337	974	8.28	11.23	3.9	13.6
	LW4.4	1,337	974	8.18	11.1	3.9	13.6
	LW4.5	1,337	974	7.9	10.71	3.9	13.6
	LW4.6	1,337	974	8.18	11.1	3.9	13.6
	HD5.100	1,337	974	6.56	8.88	3.9	13.6
White veal calves	HA3.1	2,743	2,469	4.3	4.7	1.4	4.3
	HA3.2	2,743	2,469	4.5	4.9	1.4	4.3
	LW1.1	2,743	2,469	4.7	5.2	1.4	4.3
	LW1.2	2,743	2,469	4.7	5.2	1.4	4.3
	LW1.3	2,743	2,469	4.7	5.2	1.4	4.3
	LW1.4	2,743	2,469	4.7	5.2	1.4	4.3
	LW1.5	2,743	2,469	4.9	5.4	1.4	4.3
	LW2.3	2,743	2,469	4.7	5.2	1.4	4.3
	LW2.5	2,743	2,469	5.0	5.5	1.4	4.3
	LW2.6	2,743	2,469	5.0	5.5	1.4	4.3
	LW2.7	2,743	2,469	5.0	5.5	1.4	4.3
	LW2.8	2,743	2,469	5.0	5.5	1.4	4.3
	LW4.1	2,743	2,469	4.9	5.4	1.4	4.3
	LW4.2	2,743	2,469	4.9	5.4	1.4	4.3
	LW4.3	2,743	2,469	5.0	5.5	1.4	4.3
	LW4.4	2,743	2,469	4.9	5.4	1.4	4.3
	LW4.5	2,743	2,469	4.7	5.2	1.4	4.3
	LW4.6	2,743	2,469	4.9	5.4	1.4	4.3
	HA3.100	2,743	2,469	4.0	4.3	1.4	4.3

2.3 Manure separation

When manure from grazing and indoor housed animals is separated into a solid and a liquid fraction, the composition is calculated based on the assumptions and principles described in Schröder *et al* are used*.* (2009) and Den Boer *et al.* (2012). It is assumed that organically bound N (Norg) and phosphorus (P) are associated with organic matter, while ammonium N (NH_4-N, Nmin) is associated with water. The 'separation efficiency' determines the proportion of each element in the incoming

manure eventually ends up in the solid fraction. Based on this principle, the separation efficiency consists of two metrics:
1. Percentage of dry matter (DM) going to the solid fraction
2. The DM content in the solid fraction (kg/ton)

The separation efficiency of P varies between 30 and 60% for simple separation methods (Schröder *et al.*, 2009). A separation efficiency of P of 60% means that 60% of the P (as assumed part of the DM) ends up in the solid fraction, while 40% remains in the liquid fraction (metric 1). The solid fraction usually contains no more than 200-350 kg DS/tonne (metric 2). The N/P ratio in the farm's own manure (from grazing animals) is determined based on the N/P ratio in the net excretion according to BEX, i.e., after deduction of gaseous losses. The quantity and composition of the farm's own manure on the farm (volume and contents of DS, Norg, Nmin, P) is derived based on the TAN excretion (BEA), corrected for the amount of manure removed from the farm in terms of N and P, and combined with standard values for volume production per type of manure (slurry and solid manure (http://www.rvo.nl/onderwerpen/agrarisch-ondernemen/mest-en-grond/mest/tabellen-en-publicaties/tabellen-en-normen; RVO- Table 6). This calculated composition then serves as the basis for the incoming manure used in manure separation. Based on the two metrics, the concentrations of TAN, organic N (N-total – TAN) and P in the resulting liquid and solid fractions can be estimated. The N/P ratio in manure from housed animals is based on the net barn balance (see section 2.2.18).

In practice, it appears difficult to accurately determine the separation efficiency (metric 1) based on the available information. For manure separation, this often involves analysis results of the solid fraction (delivery receipts). Therefore, there is an alternative for entering manure separation data by requesting information on the solid fraction. These are:
1. Quantity of solid fraction removed (tonnes)
2. N content solid fraction (kg/tonne)
3. P_2O_5 content of the solid fraction (kg/tonne)

With the data above, the separation efficiency can be derived, but only if the amounts of N and P produced in the manure are known.

By default, the N and P_2O_5 contents of the incoming slurry are determined as described above. In practice, the separated slurry is not always the average manure present on the farm, sometimes it comes from a specific manure pit or a particular animal group. In some cases, the incoming manure is also measured. Therefore, it is possible to provide the actual contents of the incoming slurry. As a result, the contents of the remaining (non-separated) slurry will change.

Additional gaseous N losses occur during the separation process. These losses are calculated based on the BEA module of the ANCA Tool (Chapter 3).

2.4 Manure digestion

During manure digestion, part of the organic matter is converted into energy (methane and carbon dioxide). The digested manure contains more mineral nitrogen, less organically bound nitrogen and less carbon.
Manure digestion affects:
1. Energy: production and use (see Chapter 6)
2. Gaseous emissions during manure storage and application (see Chapter 3)
3. Emissions of methane from manure (see Chapter 6)
4. Import of effective organic matter (see Chapter 6)

For manure digestion, the following information is requested:
1. Quantity of manure entering the digester (tonnes)
2. Supply of co-substrates (quantity in tonnes, kg N and kg P_2O_5)

2.5 Air scrubbers

Several barn types as defined in the Environmental Regulation (Dutch: Omgevinsregeling) use air scrubbers (chemical, biological, or combination) or biofilters, and capture a large proportion of the nitrogen from the NH_3 emissions in the washwater. In the ANCA Tool, this washwater is treated as scrubbing water when applied on the fields.

2.6 Notes on BEX and manure production of other grazing animals and 'indoor housed' animals

Constant input parameters in BEX

Input parameters for BEX, which are difficult to determine in practice, have been entered as constants within the BEX calculation methodology (an average value for the Netherlands). The combined effect of all constant input parameters partly determines the accuracy of the BEX calculation. A scientific evaluation by the *Committee of Experts on the Fertilizer ACT (CDM) (Dutch: Commissie van Deskundigen Meststoffenwet (CDM))*, concluded that BEX is sufficiently accurate to be used for policy purposes (Šebek, 2008). This means that the currently set values for the constant input parameters jointly result in a good estimate of the N and P excretion. Adjustment of individual constant parameters without taking into account their interrelationships will affect BEX accuracy.

For example, there is ongoing discussion about the constant VEM coverage assumed in BEX (102% of the requirement). The ANCA Tool uses an VEM coverage percentage of 102%, which guarantees uniformity with other laws and regulations ('Handreiking'). However trials have shown a wide range of VEM coverage values (roughly between 98% and 108%), and in cases of widespread disease (e.g., high incidence of mastitis) or poorly digestible rations, values can even exceed 110%. In practice, it is assumed that a VEM coverage of 105% better reflects reality (especially for corn-based rations), but determining the actual VEM coverage in practice is rarely possible. Due to interlinkages with other assumptions, a possible change of the assumed VEM coverage can only take place if this is accompanied by consistency checks on other constants. Examples of such constants are listed below:

List of constant input parameters in BEX

1. Average VEM herd coverage (102%).
2. Percentage of dry cows (on an annual basis) in the herd, calculated back to the calendar year, is 326 days of lactation and 39 days of dry period (CRV, 2015/2016/2017).
3. Live weight adult cow (Jersey, Jersey cross and Other respectively 400, 525, 650 kg).
4. VEM requirement for young stock younger and older than 1 year (see section 2.2.10).
5. Extra energy requirement (VEM) for movement and growth (see Table 2.2).
6. Weight, N and P content in animals (foetus + adnexa, calf, heifer, first lactation cow, cow; see Table 2.4). With these assumed weights and contents, N and P retention in the herd is calculated.
7. Dairy herd replacement percentage (27%), to calculate the age structure of the herd and retention in growth of first and second lactation cows.
8. The number of calves born per cow per calendar year (= 0.70), to calculate the retention in foetus + adnexa in dairy cattle.
9. The number of calves born per first lactation cow per calendar year (= 0.89), to calculate the retention in foetus + adnexa in young stock.
10. P content in milk = 0.97 g/kg of milk. In the Dutch monitoring project Koeien & Kansen (K&K), a variation has been observed ranging from approximately 0.86 to 1.12 g P/kg milk. This standard value is used only if the P content has not been measured by a certified institution.
11. VEM value of pasture grass from production grassland = 960 VEM/kg DM.
12. VEM value of pasture grass from natural grassland = 860 VEM/kg DM.

Comments

- For silages composed of different feeds (mixed silages), it is not possible to accurately determine the average composition (VEM, N, and P content). Farms with such silages cannot participate in the BEX. Three exceptions apply:

- The mixed roughage silage consists of feeds from the farm itself, or if one of the products is purchased corn silage, provided that the feed value analysis and quantities of the indivual silages and the purchased corn have been determined. Silage losses due to over-silage must also be accounted for.
- 90% of the DM in the silage consists of the same roughage and the rest consists of purchased (moist) roughage that cannot be traced back.
- 80% of the DM in the silage consists of the same roughage and the rest consists of purchased (moist) roughage that can be traced back.

- On farms that apply manure separation to a large extent, it is possible that the volume of manure specified in the ANCA Tool is not available. The manure volume on a farm is difficult to determine, which means that the calculated manure volume can deviate from what is actually present on a farm. Additions in the form of rinse water and rainwater play a role in this. Making a more detailed distinction between different manure streams and types makes it more difficult to achieve a closed manure balance (in terms of both volume and composition) without generating implausible outcomes. For this reason, it is preferred to record the extent of manure separation on the farm as a percentage of the total manure production in the barn.
- Problems in the calculations may arise not only in the separation of manure, but also when determining the ‘destination’ of the different manure types (such as input and removal, stocks, application). Accurate data entry/administration is therefore essential. However, even with correct input, it can still lead to situations in which the outcome of the calculation model deviates too much from reality. For instance, the actual removal of manure may deviate from the outcome of the calculation model. This is especially the case for farmer-farmer export, where mainly standard values are used, sometimes resulting in less manure being exported in reality than calculated on paper. Conversely, if the actual contents are higher than the standard values, less manure remains on the farm than calculated. The imports of manure stocks also often comprise a ‘weak link’. This can lead to unexpected results from the calculation model.

With regard to manure production by ‘indoor housed’ animals, the following should be noted. Because fattening pigs, sows, laying hens, broilers and white veal calves are most commonly present as intensive secondary livestock enterprise on dairy farms, these have only been elaborated on as intensive livestock enterprises. However, this does not cover all possible secondary enterprises with indoor housed animals in the ANCA Tool. To make the ANCA Tool more complete, additional types of indoor housed animals should be included. This applies, for example, to other categories of pigs byond finishing pigs and breeding sows.

To keep the data entry requirements of the ANCA Tool manageable, the (net) manure production of indoor housed animals (in N and P_2O_5) is requested, along with the removal of manure of indoor housed animals and the manure stock balance for these animals. All these parameters are derived from the barn balance and the (mandatory) Fertilization Plan. In this way, the correct amounts of nitrogen and phosphate are incorporated into the nutrient cycle, with a limited number of input parameters. Consequently, the input of nitrogen and phosphate via feed and animals as well as removal of nitrogen and phosphate with animals are not required. However, this also means that the utilisation of nitrogen and phosphate by animals from the intensive enterprise, and therefore the nutrient use efficiency of such farms as a whole, cannot be calculated by the ANCA Tool.

3 BEA

3.1 Introduction

The BEA is a calculation tool to calculate the 'Farm-specific Ammonia Emissions' on a farm. The calculated losses concern the ammonia-N (NH_3-N) released from barns, manure storages, manure and urine excreted during grazing, mechanically applied animal (slurry) manure on grassland and cropland (arable forage crops such as corn silage and arable crops leaving the farm) and from certain types of synthetic fertilizers. In addition, there are a number of other NH_3 emission sources (from standing, grazed and harvested crops) that are also discussed in this part of the ANCA Tool calculation rules. Besides the NH_3 losses, the BEA also calculates the other gaseous N losses (N_2, N_2O and NO_x). The underlying calculation rules are discussed in the section on BEN (Chapter 4). When calculating the TAN content in manure, these losses are taken into account

The BEA uses the *National Emission Model for Ammonia (Dutch: Nationaal Emissie Model voor Ammoniak)* to calculate NH_3 emissions (NEMA, Van Bruggen *et al.*, 2024). This methodology makes an inventory of N flows in manure, i.e.: herd excretion, housing (barn floor and manure storage under the barn), storage outside the barn and manure application. In this process, the proportion of ammoniacal nitrogen in the total nitrogen content (% TAN) plays an important role. At each step, emission factors (EF) are used to calculate how much TAN volatilises as ammonia (NH_3-N) and other gaseous N compounds. EFs are based on the results of scientific research and described by van Bruggen *et al.* (2017) and connect wherever possible with existing Dutch laws and regulations. For example, the EFs for the barn (floor and storage) are based on the NH_3 emissions measurements that are the basis of the *Environmental regulation (Dutch: Omgevingsregeling)* (https://wetten.overheid.nl/BWBR0045528/2024-01-01#BijlageV). In this way, the BEA is, in principle, also aligned with this regulation. However, the way in which the losses are calculated and expressed do differ. The *Environmental Regulation* is based on the relationship between ammonia emissions and the concentration of ammonium in manure and urine on a reference farm. The NEMA and BEA, however, are based on the relationship between ammonia emissions and the amount of excreted TAN for a specific ration (farm-specific). The *Environmental regulation* expresses the emission in kg of ammonia per animal place per year, whereas BEA expresses the emission in kg of ammonia per farm.

The BEA uses the BEX to calculate the amount of N and TAN (the source of ammonia emissions) excreted by the dairy cattle. However, there are additional calculation rules in the BEA, which relate to the conversion from N excretion (=BEX output) to TAN excretion. This concerns a relatively minor addition to the BEX, which is described in section 3.2.

3.2 Calculation method

3.2.1 General

The N and TAN excretion (the emission source) depends on the composition, production and feeding of the herd and the volatilisation of that TAN (ammonia losses and other gaseous N losses), in terms of the emission from the barn, depends on the housing design and manure storage in the barn. Regarding the dairy herd, these factors are taken into account in the ANCA Tool. With regard to the emissions from the housing of 'other ruminants' and 'indoor housed animals', however, the ANCA Tool assumes fixed ration-independent values per animal place (see sections 3.2.2.2 and 3.2.2.3). Part of the manure is stored in manure storage outside the barn (external manure storage), from which ammonia losses also occur. Ammonia emission also takes place when manure is applied to the land. This part of the emission depends on the land use and on the way animal manure is applied. In addition, the type of synthetic fertilizer also plays a role. The calculation procedure for the BEA for specialised dairy farms is depicted schematically in Figure 3.1.

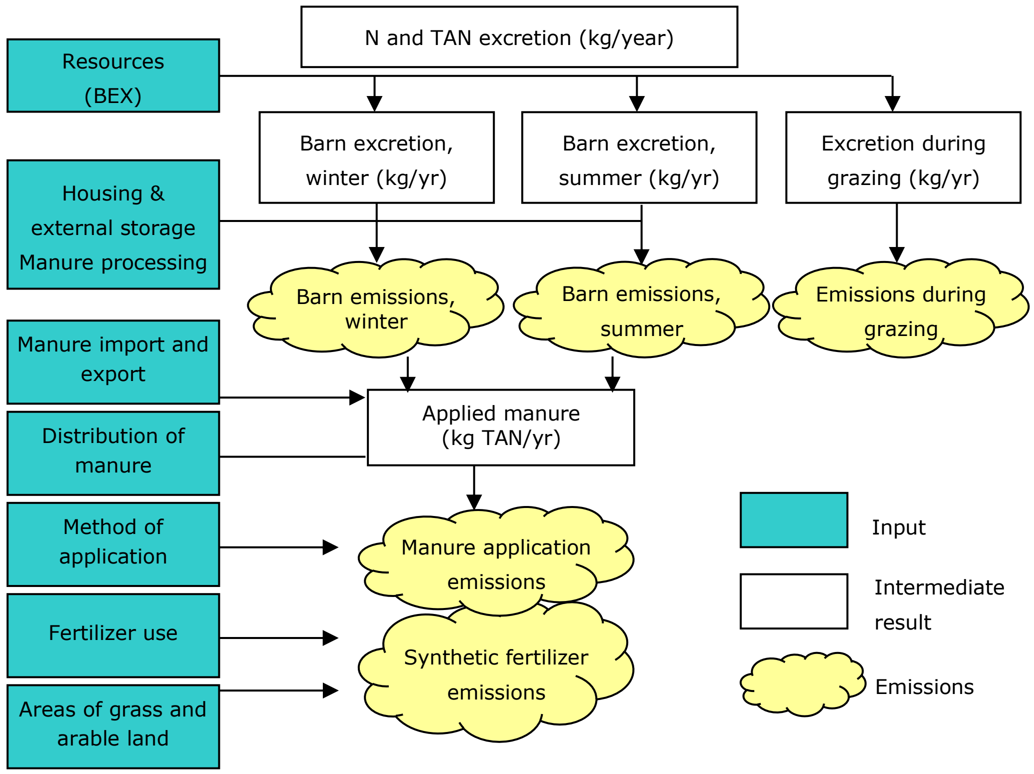

Figure 3.1 *Schematic representation of the calculation of the ammonia emissions (kg NH_3 per year) of a dairy farm.*

The BEA requires information on:

With regard to 'dairy cattle' (dairy cows and associated youngstock)
- Proportion of slurry from cows, heifers and calves.
- The amount of N and TAN produced by the herd (TAN excretion in kg/year).
- The distribution of the N and TAN excretion (kg/year) over the housing period (in summer and in winter) and the grazing period.
- The amount of mineral N (kg/year) formed by mineralisation in the manure storage (slurry).
- The amount of organic N (kg/year) formed by immobilisation in the manure storage (solid manure).
- The amount of TAN (kg/year) that is imported or exported with manure.
- The amount of slurry processed.

As for 'other grazing animals'
- The average number of animals present per animal category.
- The type of manure (proportion of slurry).

As for 'indoor housed animals'
- The average number of animals present per animal category.
- The type of manure (proportion of slurry).
- Housing type *(Environmental regulation) (Dutch: Omgevingsregeling).*
- Data that can be directly derived from the (barn) balances.

With regard to 'dairy cattle', 'other grazing animals' and 'indoor housed animals' together
- The distribution of TAN for application on grass or arable land, including the application method.
- The amount of synthetic fertilizer applied on grass or arable land.

Emission factors (EF and mineralisation coefficient, derived from NEMA)

- EF ammonia for the barn of dairy cattle during the housing period (in percentage of TAN production).
- EF ammonia for the barn of dairy cattle in the grazing period (in percentage of TAN production).
- EF ammonia for manure excreted on pasture by dairy cattle (in percentage of TAN excretion).
- EF ammonia for external manure storage (in percentage of stored N).
- EF ammonia during processing of slurry.
- EF other N-gases for the barn of dairy cattle (in percentage of N-excretion).
- Mineralisation coefficient for organically bound N in the barn storage of dairy cattle.
- Immobilisation coefficient for mineral N in the manure storage of dairy cattle.
- EF manure application for grassland and cropland, and for manure application technique.
- EF synthetic fertilizer application, per fertilizer type.

The following sections describe how the information related to the amounts of TAN mentioned above are calculated.

3.2.2 N excretion and TAN production by livestock

3.2.2.1 Dairy herd including youngstock

The BEA calculates the ammonia emission in the barn per animal group based on the amount of TAN (mineral N) in the excreted manure (urine and feces). Therefore, an accurate estimation of TAN excretion is required. This requires information on the feedstuffs used and on the digestibility coefficient of crude protein (DCCP) in those feedstuffs per animal group. The DCCP is used to calculate which portion of the N excretion is volatilized as NH_3 via the urine. The urine fraction of N excretion is, in principle, volatile (TAN). The remaining N is excreted as organic N in the feces and becomes TAN only when mineralization occurs (in manure storage). Conversely, in solid manure during storage, a portion of the excreted TAN can be converted into organic N through immobilization.

To determine the gaseous N losses from the excreted manure (faeces and urine) of the dairy cattle, the different feed categories that have been fed to the dairy cattle (i.e., dairy cows and associated youngstock) must first be allocated to the different categories of youngstock and dairy cows. The starting point is the VEM requirement of an animal category (which is equal to the total VEM intake of this animal category: see section 2.2.10).

First, a specific allocation of feed categories is assigned to the youngstock. This allocation always concerns the amount of feed (in kVEM) intended for the dairy herd, in cases where other grazing animals are also present (Table 2.3). Allocation takes place in accordance with the methodology of the Dutch Working Group Standardisation of Manure Figures (WUM)[1] and is as follows for young stock:

- Milk replacer powder: all imported milk replacer powder not intended for other ruminants is allocated to calves;
- Fresh grass calves and heifers: calculated based on the number of pasture days and the ratio of the amounts of fresh grass, grass silage and corn silage fed (see section 2.2.12);
- Concentrate feed: the proportion of the VEM requirement from concentrates is 25% for the calves in the barn and 10% on pasture, and for heifers, 5% in the barn and 0% on pasture;
- Roughage: calves receive 75% of their VEM requirement from grass silage and 25% from corn silage while in the barn, while heifers in the barn get 90% from grass silage and 10% from corn silage. The VEM requirement in the barn of both calves and heifers is equal to the total VEM requirement minus the VEM intake from milk powder, concentrates and fresh grass.

The above serves as the basis for the allocation of feed categories to the youngstock. If a certain feed category appears to be missing or is insufficient, the following is applied:

- First allocated to calves, then to heifers;

[1] Basis: WUM (2010). *Gestandaardiseerde berekeningsmethode voor dierlijke mest en mineralen. Standaardcijfers 1990–2008.* Working Group Standardisation of Manure and Mineral Figures (editor: C. van Bruggen). CBS, PBL, Wageningen Economic Research, Wageningen Livestock Research, Ministry of Agriculture, Nature and Food Quality and RIVM. Statistics Netherlands, The Hague.

- The quantities of milk replacer powder and fresh grass are fixed; these are, respectively recorded in the farm records and calculated. However, fresh grass intake may increase as shown in the following points. If extra fresh grass is allocated to the calves or the heifers, this is at the expense of the calculated amount of fresh grass allocated to the dairy cows;
- Concentrate feed: with no or insufficient concentrate feed, the required VEM requirement from concentrate feed is supplemented with (in this order): other products, corn silage, grass products, fresh grass;
- Corn silage: with no or insufficient corn silage, the required VEM requirement from corn silage is supplemented with (in this order): grass products, other products, concentrates, fresh grass;
- Grass products (grass silage): with no or insufficient grass products, the required VEM requirement from grass products is supplemented from (in this order): corn silage, other products, concentrates, fresh grass.

It is then possible to calculate what can be allocated to the dairy cows. The following applies per feed category:

VEM intake_milkcow = VEM intake_total - VEM intake_calves - VEM intake_heifers

Once the feed categories (with various feed types) have been allocated over the youngstock and dairy cattle, these are the quantities consumed by these animal categories over the course of a year. The average daily ration can then be calculated by dividing by the number of days per year. This average daily ration is the starting point for the calculations of the gaseous N-losses for all days of the year. Although this may not be entirely accurate, it provides a fairly good approximation of reality, in accordance with how the NEMA working group calculates annual rations.

The information about the type and quantity of the feed ingredients used and the gross N excretion of the three animal categories (dairy cows, heifers, calves) forms the basis for the final BEX (Chapter 2). The BEX calculates the gross N excretion as follows:

N-excretion 'under the tail' (kg) = N intake (kg) – N retention (kg)

The '*under the tail'* N-excretion consists of faeces and urine. In addition to the information from the BEX, information about the DCCP of the feed ingredients used is required to calculate the distribution of the N-excretion over the faeces and the urine.

The distribution of the N-excretion over faeces and urine is calculated by the BEA as:

N-excretion_faeces (kg) = N-intake (kg) x [1 - DCCP (g DCP/g RE) x 0.91]

N-excretion_urine (kg) = [N-intake (kg) x DCCP (g DCP/g RE) x 0.91] – N-retention (kg)

The calculated N-excretion_urine is equated to the TAN excretion (in accordance with NEMA).

TAN excretion (kg) = N-excretion_urine (kg)

The factor 0.91 in the above formulas is taken from Bannink *et al.* (2018).
An additional source of TAN is mineralisation of organically bound N. For slurry, in accordance with NEMA and for average Dutch conditions (climate and housing system), it is assumed that 10% of the non-ammoniacal N (= organic N) is converted into TAN each year during storage.

N-mineralisation (kg) = [N excretion under the tail (kg) -TAN excretion (kg)] x proportion of slurry x 0.1

For solid manure, part of the mineral N is converted into organic N. For solid manure, in accordance with NEMA, it is assumed that, under average Dutch conditions (climate and housing system), 25% of the ammoniacal N (= mineral N) in the barn and manure storage in the barn is converted into non-ammoniacal N (= organic N). This is a net immobilisation:

N-immobilisation (kg) = TAN excretion under the tail (kg) x proportion solid manure x 0.25

Total TAN production inside the barn is calculated as follows:

TAN barn (kg) = TAN-excretion (kg) + N-mineralisation (kg) – N-immobilisation (kg)

Calculation of crude protein digestibility
The DCCP (digestibility coefficient of crude protein) in feed ingredients is not known to the dairy farmer, but can be calculated using regression equations from the *Central Feed Evaluation Committee (Dutch: Centraal Veevoederbureau)* (CVB, 2023/2025). These equations estimate the digestible protein based the feed composition, including the total crude protein content (CP, including the NH_3-fraction) and crude ash (CA). In the ANCA Tool, 10 categories of feed products are distinguished for calculating the DCCP. For the categories 'grass silage/grass hay/other grassland products', 'grass meal/grass pellets/grass bales', 'corn silage products' and 'pasture grass', formulas are used that are based on the CVB equations. For categories 5 through 9, regression equations were derived based on the CP content and the calculated DCCP (according to the CVB formula) of individual products. It therefore represents an average of the individual products within each respective category. For products that do not fall within one of these categories, an average value is used (Appendix 4). For products with little variation in composition, an average DCCP is used (CVB, 2023/2025; Bannink *et al.*, 2018). In the BEA, the DCCP for the different feed categories (expressed as a fraction, i.e., a value between 0 and 1) is calculated using the above-mentioned formulas based on the CP and CA contents (both expressed in g per kg DM).

1. Category 'grass silage' and 'grass hay' / 'other grassland products'

   DCCP = (0.931 x CP – 43.2) / CP

2. Category ''grass meal/grass pellets/grass bales' (artificially dried) (contents per kg ds)

   DCCP = (0.878 x CP – 38.4) / CP

3. Category 'corn silage products' (contents per kg DM)

   DCCP = (0.969 x CP + 0.04 x CA – 40) / CP

4. Category 'pasture grass' (contents per kg ds)
   The composition of fresh grass is not known for commercial farms. In the BEX, the N/VEM ratio in fresh grass is calculated based on the grass silages produced (see section 2.2.15). From this, the CP content can be determined, based on which the DCCP of pasture grass can be calculated.

   *CP fresh grass = N/VEM fresh grass * 960 * 6.25.*
   DCCP = (0.963 x CP -38.3) / CP

5. Category 'mixture of wet by-products' (contents per kg ds)

   DCCP = (88.6 x (1 – EXP(-0.0102 x CP)))/100

6. Category 'compound feeds'
   For compound feeds, insufficient information is available on commercial farms to determine the DCCP. The relationship between the DCCP and the CP content has been established for a wide range of compound feeds:

   DCCP = 88.7 x (1 – EXP(-0.0120 x CP))

7. Category 'other industrial by-product'

DCCP = (89.2 x (1-EXP(-0.01201 x CP)))/100

8. Category ‘other plant-based meal’

   DCCP = (55.29 + 0.118 x CP – 0.00009362 x CP x CP)/100

9. Category ‘other feedstuffs’
   Estimation formulas are not available for all products. When no formula is available, a fixed DCCP value is used (Appendix 4).

3.2.2.2 Other grazing animals

The TAN production for ‘other grazing animals’ is calculated by dividing the gross manure N production (Table 3.1) into a part that is excreted indoors and a part that is excreted on pasture. Using the TAN proportions of manure-N excreted indoors and on pasture (Table 3.1), the quantities of TAN produced are calculated according to:

TAN production = gross N excretion x % TAN/100

Table 3.1 *Gross N-excretion by ‘other grazing animals’ and % TAN to convert these quantities into the amount of ammoniacal N (TAN).*

Category	Gross N excretion in manure[1] (kg N per animal)	TAN in N-excretion barn manure[2] (%)	TAN in N-excretion pasture manure[2] (%)
Breeding bulls, > 1 year (cat. 104)	82.6	61	61
Pasture and suckler cows (cat. 120)	79.4	63	72
Starter calves, rosé or red meat (cat. 115)	12.3	53	53
Rosé calves, 3 months – slaughter (cat. 116)	30.9	53	53
Rosé calves, 2 weeks – slaughter (cat. 117)	25.2	53	53
Red meat bulls, 3 months – slaughter (cat. 122)	31.97	56	56
Breeding sheep (cat. 550)	13.4	59	87
Meat sheep, < 4 months (cat. 551)	1.2	59	87
Other sheep, > 4 months (cat. 552)	9.8	59	87
Dairy goats (cat. 600)	16	59	59
Rearing and meat goats, < 4 months (cat. 601)	1	59	59
Rearing and meat goats, > 4 months (cat. 602)	7.9	59	59
Ponies (cat. 941)	35.5	69	77
Horses (cat. 943)	76.4	69	74
Donkeys (cat. 961)	20.9	69	77
Water buffalo, cows (cat. 991)	83.2	55	67
Water buffalo, youngstock (cat. 992)	30.5	55	67

1 Animal categories 115, 116 and 117: Groenestein *et al*. (2015); animal category 122: based on net-excretion according to the RVO-table 4 and a retained N loss as for breeding bulls (11,8%); other animal categories: Bikker *et al*. (2019).

2 Van Bruggen *et al.* (2024), Appendix 3.

3.2.2.3 Indoor housed animals

Ammonia emissions from housing and storage by indoor-housed animals are not calculated as the product of gross N excretion (the TAN percentage therein, and the emission factor), but as ammonia emission per animal place (Table 3.9).

3.2.3 TAN excretion in barn and pasture by livestock

3.2.3.1 Dairy herd

For the TAN excretion calculation, a distinction is made between a barn and pasture period because the EF for manure in the barn and storage is considerably higher than the EF for manure deposited on pasture. This is related to the effect of joint (barn) or separate (pasture) collection of faeces and urine.

The distribution of the TAN excretion (kg/year) over the barn and pasture in the summer is based on the number of hours that animals spend on pasture. In this, it is assumed that the same amount of manure is produced during one hour of grazing as during an hour in the barn and that the amount of TAN in the manure does not vary during the day. This means that when the dairy herd has 10 hours of grazing per day, the TAN excretion of the entire herd during the grazing period occurs 10/24 on the pasture and 14/24 in the barn. This differs from both NEMA and the *Environmental regulation (Dutch: Omgevingsregeling)*, which distinguish grazing only in terms of permanent housing, limited grazing, and unlimited grazing.

3.2.3.2 Other grazing animals

The distribution of manure-N and, related to this, TAN excretion (Table 3.1) between the barn and pasture is calculated based on the fraction of VEM intake from grass and the total VEM intake.

*Days on pasture = VEM intake from grass / VEM intake total * 365*

In this, it is assumed that the animals graze for the entire day.

3.2.4 Calculation of manure production

For the calculation of certain metrics, the total weight of the different types of manure produced on the farm is required. This is the case, for example, when calculating CO_2 emissions from the application of animal manure on land, which is based on the dosage of the manure type. This information is also important for barns with primary manure separation, where urine and feces fractions are produced.

The ANCA Tool calculates the total amount of manure (urine + feces) via excretion and the subdivision into urine and feces. This is done based on the manure production table from the *Dairy Farming Handbook (Dutch: Handboek Melkveehouderij)* (www.handboekmelkveehouderij.nl). This table provides the annual manure production in storage (pit and external storage, excluding produced pasture manure) depending on milk production per cow, the proportion of grass silage in the total amount of roughage in the ration (grass silage and corn silage), and the grassland management system. The values of the handbook have been converted to manure production per hour, upon which the regression formulas below are based. Formulas have been developed for both total manure production and the urine fraction in the manure, and a distinction is made between the barn period and the grazing period with different grassland management systems. The total annual volume of manure and urine is then calculated based on the duration of the mentioned periods and the number of animals, and converted to weight using the density of the manure stream. Finally, the weight of feces is calculated as the difference between the weight of total manure and that of urine.

3.2.4.1 Dairy herd

The volume of excreted manure (urine + feces) and urine per animal is calculated using the following regression formulas:

Totale manure:

*VOLmanure_dairy_barn = 1,14155 + 0,05479*M + 0,01142*M2 + 0,71689*GS – 0,01370*M*GS*
*VOLmanure_dairy_past = 0,53306 + 0,35619*M – 0,00436*M2 + 0,20030*GS*
*VOLmanure_dairy_pastl = 1,44305 + 0,15996*M + 0,00578*M2 + 0,06812*GS*
*VOLmanure_dairy_sf = 2,57205 – 0,27339*M + 0,02911*M2 + 0,08626*GS + 0,01783*M*GS*

Urine:

*VOLur_dairy_barn = (0,17374 + 0,04056*M – 0,00190*M2 + 0,26630*G – 0,01567*M*GS) * VOLmanure_dairy_barn;*

VOLur_dairy_past = (0,29196 + 0,02521*M – 0,00118*M2 + 0,21110*G – 0,01283*M*GS) * VOLmanure_dairy_past;
VOLur_dairy_pastl = (0,44385 + 0,00155*M – 0,00032*M2 + 0,06307*G + 0,00247*M*GS) * VOLmanure_dairy_pastl;
VOLur_dairy_sf = (0,35187 + 0,01969*M – 0,00104*M2 + 0,18788*G – 0,01101*M*GS) * VOLmanure_dairy_sf

In which:

- *VOLmanure_dairy_barn/VOLur_dairy_barn = volume manure/urine of dairy cows in the barn period (ltr/cow/hour)*
- *VOLmanure_dairy_past/VOLur_dairy_past = volume manure/urine of dairy cows in de pasture period with unlimited grazing (ltr/cow/hour)*
- *VOLmanure_dairy_pastl/VOLur_dairy_pastl = volume manure/urine of dairy cows in the pasture period with limited grazing (ltr/cow/hour)*
- *VOLmanure_dairy_sf/VOLur_dairy_sf = volume manure/urine of dairy cows in the period with summer stall feeding (ltr/cow/hour)*
- *M = milk production (kg/cow/jaar) / 1000 with a minimum value of 6 and a maximum value of 10*
- *GS = fraction of grass silage in the total amount of grass silage and corn silage in the ration (on dry matter basis)*

The total weight of manure and urine on the farm is then calculated based on the produced volume per animal, the density of the manure stream, and the number of animals. The total produced volume per animal is calculated based on the duration of the barn period and the grazing period under the different grassland management systems:

- Barn period
- Period with unlimited grazing
- Period with limited grazing
- Period with summer feeding indoors
- Period combining unlimited grazing and summer feeding indoors
- Period combining limited grazing and summer feeding indoors.

The calculation is performed using the following formulas:

WTmanure_dairy = (VOLmanure_dairy_barn * DAY_barnp_dairy * 24
+ VOLmanure_dairy_past * DAY_past_dairy * 24
+ VOLmanure_dairy_pastl * DAY_pastl_dairy * 24
+ VOLmanure_dairy_sf * DAY_sf_dairy * 24
+ VOLmanure_dairy_past * DAY_past+sf_dairy * HOUR_past_dairy
+ VOLmanure_dairy_pastl * DAY_pastl+sf_dairy * HOUR_pastl_dairy
+ VOLmanure_dairy_sf * DAY_past+sf_dairy * (24 – HOUR_past_dairy)
+ VOLmanure_dairy_sf * DAY_pastl+sf_dairy * (24 – HOUR_pastl_dairy)) * Dmanure /1000 * N_cows)

WTur_dairy = (VOLur_dairy_barn * DAY_barnp_dairy * 24
+ VOLur_dairy_past * DAY_past_dairy * 24
+ VOLur_dairy_pastl * DAY_pastl_dairy * 24
+ VOLur_dairy_sf * DAY_sf_dairy * 24
+ VOLur_dairy_past * DAY_past+sf_dairy * HOUR_past_dairy
+ VOLur_dairy_pastl * DAY_pastl+sf_dairy * HOUR_pastl_dairy
+ VOLur_dairy_sf * DAY_past+sf_dairy * (24 – HOUR_past_dairy)
+ VOLur_dairy_sf * DAY_pastl+sf_dairy * (24 – HOUR_pastl_dairy) * (Dur /1000 * N_cows)

Where:

- *WTmanure_dairy/WTur_dairy = weight of manure and urine of dairy cows, tonnes*
- *DAY_barnp_dairy = duur stalperiode melkkoeien, dagen*
- *DAY_past_dairy = duur periode onbeperkt weiden melkkoeien, dagen*

- *DAY_pastl_dairy = duur periode beperkt weiden melkkoeien, dagen*
- *DAY_sf_dairy = duur periode zomerstalvoedering, dagen*
- *DAY_past+sf_dairy = duration of the period with combined unlimited grazing and summer stall feeding for dairy cattle, days*
- *DAY_pastl+sf_dairy = duration of the period with combined limited grazing and summer stall feeding for dairy cattle, days*
- *HOUR_past_dairy = hours of unlimited grazing on days with combined unlimited grazing and summer stall feeding for dairy cattle, hours/day*
- *HOUR_pastl_dairy = hours of limited grazing on days with combined limited grazing and summer stall feeding for dairy cows, hours/day*
- *Dmanure = density manure: 1,005 kg/ltr*
- *Dur = density urine: 1,000 kg/ltr*
- *N_cows = number of cows*

Finally, the weight of the feces from dairy cows (GEW) is calculated using:

WTfec_dairy = WTmanure_dairy – WTur_dairy

3.2.4.2 Youngstock

Analogous to dairy cattle, the volume of manure and urine per animal is first calculated using:

*VOLmanure_he_barnp = 0.993 + (1.587 – 0.993) * G*
VOLmanure_he_past = 1.587
*VOLmanure_calf_barnp = 0.514 + (0.719 – 0.514) * G*
VOLmanure_calf_past = 0.719

*VOLur_he_barnp = (0.371 + (0.561 – 0.371) * G) * VOLmanure_he_barnp*
*VOLur_hei_past = (0.556) * VOLmanure_he_past*
*VOLur_calf_barnp = (0.427 + (0.578 – 0.427) * G) * VOLmanure_calf_barnp*
*VOLur_calf_past = (0.581) * VOLmanure_calf_past*

In which:

- *VOLmanure_he_barnp/VOLur_he_barnp = volume manure/urine of heifers in the barn period (ltr/heifer/hour)*
- *VOLmanure_he_past/VOLur_he_past = volume manure/urine of heifers in the grazing period (ltr/heifer/hour)*
- *VOLmanure_calf_barnp/VOLur_calf_barnp = volume manure/urine of calves in the barn period (ltr/calf/hour)*
- *VOLmanure_calf_past/VOLur_calf_past = volume manure/urine of calves in the grazing period (trl/calf/hour)*

Next, the total weight of manure and urine on the farm is calculated based on the produced volume per animal, the density of the manure stream, and the number of animals. The produced volume per animal is calculated based on the duration of the housing period and the duration of the grazing period, respectively. The calculation is performed using the following formulas:

*WTmanure_he = (VOLmanure_he_barnp * (365 – DAY_past_he) * 24 + VOLmanure_he_past * DAY_past_he * 24) * Dmanure /1000 * N_he*

*WTur_he = (VOLur_he_barnp * (365 – DAY_past_he) * 24 + VOLur_he_past * DAY_past_he * 24) * Dur/1000 * N_he*

WTfec_he = WTmanure_he – WTur_he

*WTmanure_calf = (VOLmanure_calf_barnp * (365 – DAY_past_calf) * 24 + VOLmanure_calf_past * DAY_past_calf * 24) * Dmanure /1000 * N_calf*

*WTur_calf = (VOLur_calf_barnp * (365 – DAY_past_calf) * 24 + VOLur_calf_past * DAY_past_calf * 24) * Dur /1000 * N_calf*

WTfec_calf = WTmanure_calf – WTur_calf

In which:
- *WTmanure_he/WTur_he = weight of manure and urine of heifers, tonne*
- *WTmanure_calf/WTur_calf = weight of manure and urine of calves, tonne*
- *DAY_past_he/DAY_past_calf = duration of the pasture period for heifers and calves, days*
- *Dmanure = density manure: 1,005 kg/ltr*
- *Dur = density urine: 1,000 kg/ltr*
- *N_he/N_calf = the number of heifers/calves*

Housing systems with primary separation
In housing systems with primary separation, urine and feces are collected separately. The volume of the resulting urine and feces fractions is not exactly equal to the amount of excreted urine and feces (as calculated above), given that some mixing still occurs. The following metrics are assumed:

- Housing type HA1.35: 65% urine in feces; 0% feces in urine (De Boer, 2023)
- Housing type HA1.36: 11% urine in feces; 12% feces in urine (De Boer, 2025)
- Housing type HA1.38: 11% urine in feces; 12% feces in urine (assumed equal to HA1.36).

In the ANCA Tool, the 'mixed' feces fraction is treated as (slightly thicker) slurry from grazing animals, while the 'possibly mixed' urine fraction is treated as a separated liquid fraction. For all other housing types, it is assumed that excreted urine and feces are completely mixed (slurry).

Additions to excreted manure
In the housing and during storage, additional materials are added to the manure, such as bedding material and feed residues. Table 3.2 shows which non-manure stream ends up in which manure stream. Even when no solid manure is produced, the ANCA Tool considers straw and feed residues as solid manure. In that case, the solid manure does not contain any animal excreta. Streams that would normally end up in the slurry in a slurry-based housing system are, in housing systems with primary separation, added to the feces fraction.

Table 3.2 Allocation of non-manure residual streams to animal manure streams.

Non-manure stream	Dierlijke meststroom			
	Solid manure	Slurry	Urine fraction[1]	Feces fraction[1]
Bedding				
Sawdust, lime		+		+
Straw, other	+			
Feeding residues	+			
Rinse water		+		+
Milk residues		+		+

[1] only in barns with primary manure separation.

3.2.5 Gaseous N-losses from housing

3.2.5.1 Dairy herd

NEMA provides a combined EF for the ammonia emission from the barn (from the floors and the manure storage pit). This EF is therefore called 'N losses from barn and storage' and the BEA calculates with this EF. The EF for TAN in the barn and storage represents the percentage of volatilisation of the total amount of TAN that has entered the barn and storage over a calendar year. The TAN and N excretion on pasture are not included. The TAN in barn and storage concerns the sum of:

- TAN excretion of dairy herd in the barn during the winter period (= 100% of the TAN excretion in that period).

- TAN excretion of dairy herd in the barn during the summer period (% of the TAN excretion in that period depends on whether grazing occurs).
- Mineralisation of the organically bound slurry-N during storage (= 10% of the N-excretion of the dairy herd in the barn during the fully housed period + the period on pasture).
- Immobilisation of mineral N in solid manure during storage, amounting to 25%.

Part of the produced TAN is lost through volatilisation as ammonia, while another part is lost as other gaseous N-losses. The latter concerns nitrogen oxides (N_2O and NO) or elemental nitrogen (N_2). The EF indicates the fraction of TAN (in the case of ammonia losses) or the fraction of total N (in the case of other gaseous N-losses) that is lost.

The part of the TAN that is lost through NH_3 emissions depends on the barn or pasture period, the type of manure (solid manure or slurry) and the type of barn. The NEMA (Van Bruggen *et al.*, 2017) distinguishes between slatted-floor housing and low-emission housing. The ANCA Tool calculates the emissions for a standard barn (Tables 3.3 and 3.4) and through the selected barn from the *Environmental Regulation (Dutch: Omgevingsregeling)*, any potential emission reduction is accounted for (see further in this paragraph).

The NH_3 emission factor in Table 3.3 is based on the year-round barn emission (13.0 kg NH_3 per animal place per year; specific barn according to the *Environmental Regulation (Dutch Omgevingsregeling)*, see also Table 3.5), multiplied by the conversion factor from NH_3 to NH_3-N and divided by the TAN excretion per animal per year, including that from mineralization. The total TAN excretion is calculated based on an N excretion of 129.7 kg N per animal per year with 53.2% TAN (Van Bruggen *et al.*, 2024; Tables B3.1–B3.3, 2007–2012 (the period during which measurements on dairy housing were conducted)), plus an additional 10% mineralization of the remaining N (according to NEMA), i.e., 57.9% of total N excretion. This results in an emission factor of 13.0 * (14/17) / (129.7 * 57.9%) = 14.3% NH_3-N of TAN.

The emission of N as NH_3 from the barn during the summer period depends on the number of grazing hours (Table 3.4). To calculate this emission, a reduction factor of 2.61% per hour of grazing per day (Ogink *et al.*, 2014) is applied to the 14.3% NH_3-N of TAN according to the formula 14.3 * (1 – 0.0261 * U) / (1 – U / 24), where U = number of grazing hours per day.

Table 3.3 *The gaseous N emission in a standard dairy barn through NH_3 and other gaseous N compounds according tot the NEMA (Van Bruggen et al., 2024) and an additional N correction (CDM-advice to the House of Representatives; CDM, 2024).*

Season	Fertilizer type	EF NH_3-N (as % of TAN)		EF other gaseous N (as % of gross-N excretion)	
		Dairy cow	Youngstock	Extra cfm CDM-advice	NEMA
Barn period	Slurry	14.3	14.3	5.83	2.4
	Solid manure	14.3	14.3	31.7	3.5
Grazing period	Slurry	14.3-40.9 (see Table 3.4)		5.83	2.4
	Solid manure	14.3-40.9 (see Table 3.4)		31.7	3.5

The EF values in Table 3.2 for other gaseous N emissions are the sum of the emissions of N_2, N_2O, and NOx (expressed as % of total gross N excretion) according to the current NEMA (2025-03-25), plus an additional correction for gaseous losses. This extra correction is based on recent insights that gaseous losses are higher than currently assumed in NEMA and is based on the advice of the CDM to the House of Representatives (CDM, 2024).

Tabel 3.4 *The emission of N as NH_3 from a standard dairy cow barn during the summer period, depending on the number of grazing hours.*

Hours of grazing per day	Emission factor (% NH_3-N per kg produced TAN)
0	14.3
1	14.5
2	14.8
3	15.0
4	15.3
5	15.7
6	16.0
7	16.5
8	16.9
9	17.5
10	18.1
11	18.8
12	19.6
13	20.6
14	21.7
15	23.2
16	24.9
17	27.2
18	30.3
19	35.5
20	40.9

The EF values for NH_3 in Tables 3.3 and 3.4 can be used for commercial farms, but these barn types only apply in some cases in practice. In the *Environmental regulation (Dutch: Omgevingsregeling)*, 40 barn types are distinguished for the dairy cattle category (Table 3.6), each with their own specific emission factors. The NH_3 emissions are expressed as kg NH_3 per animal place per year and are therefore not readily applicable in the BEA (see section 3.1). In the BEA, emission factors are expressed as a fraction of the produced TAN, in which the effect of the fed diet is also incorporated into the calculation. This means that for the BEA calculations of housing emissions for the barn types from the *Environmental Regulation (Dutch: Omgevingsregeling)*, an emission factor per housing type is required. These emission factors are not available and are therefore generated in the BEA by relating the emissions of each barn type from the *Environmental Regulation (Dutch: Omgevingsregeling)* to the emissions of the barn housing type 'HA1.100 – other housing systems'. It is assumed that the emissions for barn type HA1.100 corresponds to the emissions as calculated according to the NEMA methodology for the 'non-low-emission barn'. For the other barn types from the *Environmental Regulation (Dutch: Omgevingsregeling)*, the calculated housing emission is then multiplied by a housing-type correction factor (see Table 3.6), corresponding to the ratio between the NH_3 emission per animal place of the respective housing type and the NH_3 emission per animal place of housing type 'HA1.100 – other housing systems'. Table 3.5 shows an example of this.

Tabel 3.5 *Example comparison of barn type HA1.7 relative to reference barn type HA1.100.*

Barn-type	Emission factor (kg NH_3 per animal place per year)	Correction relative to barn type HA1.100
HA1.100 (standard)	13	
HA1.7	11.8	11.8 / 13 = 0.91

The BEA first calculates the NH_3 emission from the barn and storage as if the standard housing type HA1.100 is used. If a different housing type is selected (e.g., HA1.7), the standard calculated NH_3 emission from the barn and storage is multiplied by the housing-type correction factor (for housing type HA1.7, this is 0.91).

With the housing-type correction factors, the ANCA Tool deviates from NEMA, in which no distinction is made in ammonia emissions between standard and low-emission housing.

For other gaseous N losses, no distinction is made between housing types. This means, for example, that in housing systems with primary separation, where urine and feces fractions are produced, the same EF value is applied to these manure fractions as for slurry.

Tabel 3.6 *Correction factors for the calculated emissions of NH_3-N depending on the type of dairy barn (source: https://wetten.overheid.nl/BWBR0045528/2024-01-01#BijlageV) .*

Code	Category	NH_3[1]	Factor[2]
HA1	Animal category dairy cows and heifers older than 2 years		
HA1.100	Standard barn	13	1
HA1.1	Tie stall barn with slurry	5.7	0.44
HA1.2	Freestall barn with sloped floor and slurry gutter	10.2	0.78
HA1.3	Freestall barn with sloped floor and flushing system	9,2	0.71
HA1.4	Freestall barn with sloped floor and slurry gutter with flushing system, or slatted floor with flushing system	10.2	0.78
HA1.5	Freestall barn with solid profiled sloped floor	11	0.85
HA1.6	Freestall barn with solid sloped floor with rubber top layer	11	0.85
HA1.7	Freestall barn with slotted floor	11.8	0.91
HA1.8	Freestall barn with slatted floor with convex rubber top layer and sealing flaps in slat gaps, for which an environmental permit was granted before April 12, 2017 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	6	0.46
HA1.9	Freestall barn with slatted floor and convex rubber top layer	7	0.54
HA1.10	Freestall barn with profiled floor with sloped slots and regular manure outlets, for which an environmnetal permit was granted before July 20, 2018 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	11.8	0.91
HA1.11	Freestall barn with profiled floor with sloped slots and regular manure outlets, for which an environmnetal permit was granted before July 20, 2018 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if which a permit was not required, which was lawfully taken into use before that date	12.2	0.94
HA1.12	Freestall barn with slatted floor with cassettes in the slat gaps	7	0.54
HA1.13	Freestall barn with profiled floor with sloped slots and regular manure outlets with sealing flaps	7	0.54
HA1.14	Freestall barn with profiled floor with sloped slots and regular manure outlets with sealing flaps, for which an environmental permit was granted before July 20, 2018 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	10.3	0.79
HA1.15	Freestall barn with V-shaped floor with cast asphalt in combination with a slurry pipe and manure scraper, for which an environmental permit was granted before July 20, 2018 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	11.7	0.9
HA1.16	Mechanically ventilated barn with a chemical air scrubber system, for which an environmental permit was granted before July 20, 2018 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	5.1	1 [3]
HA1.17	Freestall barn with V-shaped floor of profiled floor elements in combiation with a slurry pipe	8	0.62
HA1.18	Freestall barn with slatted floor with sloped grooves or laid at an incline with sealing flaps in the slat gaps	11	0.85
HA1.19	Freestall barn with profiled sloped floor with perforations, for which an environmnetal permit was granted beofre May 6, 2020 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	10.1	0,78

Code	Category	NH_3[1]	Factor[2]
HA1.20	Freestall barn with profiled floor with sloped slots and regular manure outlets with seals	7	0.54
HA1.21	Freestall barn with slot floor with cross slots, holding area, and continuous slatted floor with convex rubber top layer and sealing flaps in the slat gaps	11	0.85
HA1.22	Freestall barn with profiled floor with sloped slots with urine outlet or with regular manure outlets with sealing flaps	6	0.46
HA1.23	Freestall barn with profiled floor with sloped slots, continuous or with regular manure outlets with sealing flaps	7	0.54
HA1.24	Freestall barn with floor with profiled rubber mats with sloped profile and regular manure outlets with sealing flaps, for which an environmental permit was granted before May 6, 2020 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	10.3	0.79
HA1.25	Freestall barn with sloped floor with profiled rubber mats and central slurry gutter	8	0.62
HA1.26	Freestall barn with slatted floor with sloped grooves or laid at an incline with sealing flaps in the slat gaps and spray system	8	0.62
HA1.27	Freestall barn with slatted floor with rubber mats and composite ridges with sloped profile and cassettes in slat gaps	6	0.46
HA1.28	Freestall barn with profiled sloped floor with hollows for slurry collection and removal at the side, for which an environmental permit was granted before January 1, 2019 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	9.9	0.76
HA1.29	Freestall barn with slatted floor with convex rubber top layer	8	0.62
HA1.30	Freestall barn with slot floor with profiled rubber tiles for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	8.1	0.62
HA1.31	Freestall barn with flat concrete floor slabs with slots, provided with a profile with 1% sloped grooves towards a central slurry gutter with slurry holes and manure removal, for which an environmental permit was granted before December 1, 2022 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	9.1	0.7
HA1.32	Freestall barn with profiled rubber resting slot floor with sloped slots with slurry outlet holes, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	7.1	0.55
HA1.33	Freestal barn with a solid profiled floor with rubber mats and composite studs with a sloped pattern, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or, if such a permit was not required, which was lawfully taken into use before that date	9	0.69
HA1.34	Freestall barn with a flat floor with a rubber slatted floor, flat longitudinal slots, and profiled rubber (sloped V-shape), grooves and studs between the longitudinal slots, equipped with a finger manure scraper, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or for which an environmental permit for an environmentally harmful activity was granted between January 1, 2024 and April 26, 2024, or, if a permit was not required, which was lawfully put into use before April 26, 2024.	8.3	0.64
HA1.35	Freestall barn with urine collection station, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or for which an environmental permit for an environmentally harmful activity was granted between January 1, 2024 and June 2, 2024, or, if a permit was not required, which was lawfully put into use before June 2, 2024	8.4	0.65
HA1.36	Freestall barn with a compressible, draining walking floor equipped with a manure scraper, where urine and manure are immediately separated and stored separately, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen	6.4	0.49

Code	Category	NH_3 [1]	Factor [2]
	omgevingsrecht), or for which an environmental permit for an environmentally harmful activity was granted between January 1, 2024 and October 2, 2024, or, if a permit was not required, which was lawfully put into use before October 2, 2024		
HA1.37	Freestall barn equipped with profiled rubber cover mats with a diamond pattern, sloped 2% towards a central slurry gutter, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or for which an environmental permit for an environmentally harmful activity was granted between January 1, 2024 and October 2, 2024, or, if a permit was not required, which was lawfully put into use before October 2, 2024	8.9	0.68
HA1.38	Naturally ventilated freestall barn with a slatted floor fitted with inlays with urine drainage holes in the slat openings, frequent wetting and cleaning of the floor by a manure collection robot and a mechanical pit air extraction system with a chemical air scrubber (95% emission reduction)	3	1 [3]
HA1.39	Freestall barn with a V-shaped floor made of profiled floor elements with a 3.5% slope combined with a slurry drainage pipe, for which an environmental permit was granted before January 1, 2024 as referred to in Article 2.1, first paragraph, opening words and under e, of the General Provisions Environmental Law (Dutch: Wet algemene bepalingen omgevingsrecht), or for which an environmental permit for an environmentally harmful activity was granted between January 1, 2024 and March 9, 2026, or, if a permit was not required, which was lawfully put into use before March 9, 2026	6.2	0.48
HA1.100 [4]	Other housing	13	1

1) Emissions in kg NH_3 per animal place per year in a barn for dairy cows and heifers older than 2 years according to the Environmental regulation (Dutch: Omgevingswet).

2) Correction factor for barn type for the calculated NH_3-N emission relative to housing type HA1.100. If youngstock are housed in the same barn as the dairy cows and heifers, the correction factor for this barn type also applies to the youngstock, as the emission concerns the manure in this barn.

3) Barn type HA 1.16 and HA1.38 is a barn with an air scrubber. NH_3 emission is reduced, but the reduced gaseous N-loss is no longer present in the animal manure, but is contained in the scrubbing water/washwater of the air scrubber. The correction factor for this barn is therefore 1.

4) Emission equated to a standard barn (HA1.100)

The emission of NH_3-N from housing (kg N) is therefore equal to:

$$NH_3\text{-}N_{\ housing} = Barntype_{correction}\ x$$

$$((TAN\ production\ in\ barn_{winter}\ x\ EF\ NH_3\text{-}N\ standard\ barn_{winter}\ ) +$$

$$(TAN\ production\ in\ barn_{summer}\ x\ EF\ NH_3\text{-}N\ standard\ barn_{summer}\ ))$$

If the youngstock is housed in the same barn as the dairy cattle, the ammonia emissions from youngstock are reduced by the same factor as that of the dairy cattle.

The emission of N-other from housing (kg N) is therefore equal to:

$$N\text{-}other = (N\text{-}excretion\ in\ barn_{winter}\ x\ EF\ N\text{-}other\ standard\ barn_{winter}) +$$

$$(N\text{-}excretion\ in\ barn_{summer}\ x\ EF\ N\text{-}other\ standard\ barn_{summer})$$

3.2.5.2 Other grazing animals

By combining the calculated TAN produced by ‘other grazing animals’ (section 3.2.2.2) during the housing period and the emission factors for ammonia-N during the housing period (Table 3.7), the ammonia emissions from the housing can be calculated (NH_3 - N_{barn}). The indicated table also shows the emission factors for the other gaseous N losses ($N\text{-}other_{barn}$). Both types of losses are needed to calculate how much N on balance goes to an external manure storage or directly to the field. The calculation rules are:

$$NH_3\text{-}N_{barn} = TAN\ production\ total * (365 - number\ of\ days\ on\ pasture) / 365 * EF\ NH_3$$

$$N\text{-}other_{barn} = Gross\ N\text{-}excretion\ total * (365 - number\ of\ days\ on\ pasture) / 365 * EF\ N\text{-}other$$

Tabel 3.7 *Emission factors (EF) for ammonia-N and other gaseous losses per category 'other grazing animals' per separate manure type (SL = slurry, SM = solid manure); Source: Van Bruggen et al. (2024).*

Category	Fertilizer type	EF NH_3-N (% of TAN production)	EF N-other (% of gross N excretion)
Breeding bulls, >1 year (cat. 104)	SL	14.3	2.4
	SM	14.3	3.5
Pasture- and suckler cows (cat. 120)	SL	14.3	2.4
	SM	14.3	3.5
Starter calves, rosé- of red meat (cat. 115)	SL	14.3	2.4
	SM	14.3	3.5
Rosé calves, 3 months - slaughter (cat. 116)	SL	22.5	2.4
	SM	22.5	3.5
Rosé calves, 2 weeks - slaughter (cat. 117)	SL	22.5	2.4
	SM	22.5	3.5
Red meat bulls, 3 months - slaughter (cat. 122)	SL	14.3	2.4
	SM	14.3	3.5
Breeding sheep (cat. 550)	SL	27.8	3.5
	SM	27.8	3.5
Meat sheep, <4 months (cat. 551)	SL	27.8	3.5
	SM	27.8	3.5
Other sheep, >4 months (cat. 552)	SL	27.8	3.5
	SM	27.8	3.5
Dairy goats (cat. 600)	SL	16.9	7.0
	SM	16.9	7.0
Breeding and meat goats, <4 months (cat. 601)	SL	16.9	7.0
	SM	16.9	7.0
Breeding and meat goats, >4 months (cat. 602)	SL	16.9	7.0
	SM	16.9	7.0
Ponies (cat. 941)	SL	29.0	3.5
	SM	29.0	3.5
Horses (cat. 943)	SL	19.5	3.5
	SM	19.5	3.5
Donkeys (cat. 961)	SL	29.0	3.5
	SM	29.0	3.5
Water buffalo, cows (cat. 991)	SL	14.3	2.4
	SM	14.3	3.5
Water buffalo, youngstock (cat. 992)	SL	14.3	2.4
	SM	14.3	3.5

3.2.5.3 Indoor housed animals

For 'indoor housed animals, standard ammonia emissions that do not depend on the composition of the ration are used, which are independent of ration composition. These depend on the animal type and barn type, using the equation:

Ammonia emission (kg NH_3 –N) = ANA / (stocking density/100) x 14/17 x ammonia (kg NH_3/animal place)

where:
ANA = average number of animals present (from the input data)
Stocking density = standard stock density (Table 3.8)
Ammonia = emission per animal place (Table 3.9)

Tabel 3.8 *Standard stocking densities for indoor housed animals.*

Animal species	Stocking density (%)
Farrowing sows	89
Dry and pregnant sows	97
Weaned piglets	91
Fattening pigs	97
Laying hens	96
Broilers	82
White veal calves	93

Tabel 3.9 *Ammonia emissions per animal place (place) for various 'indoor housed animals' and barn types from the Environmental regulation (Dutch: Omgevingsregeling).*

Animal species	Barn code	Description barn	Ammonia (kg NH_3/place)
Laying hens	HE2.1.1	Enriched cage - aeration via manure belt	0.030
	HE2.1.2	Colony housing - aeration via manure belt	0.030
	HE2.2.1	Floor system - approx. 1/3 litter floor + 2/3 slatted floor	0.402
	HE2.2.2	Floor system - aeration via Perfosystem	0.110
	HE2.2.3	Floor system - aeration under the slatted floor	0.125
	HE2.2.4	Floor system - aeration via tubes on both sides of nests	0.150
	HE2.2.5	Floor system - aeration via vertical ventilation shafts	0.150
	HE2.2.6	Free run barn – 2 levels	0.068
	HE2.2.7	Free run barn – frequent manure/litter removal	0.106
	HE2.3.1	Aviary housing – minimum of 50% slatted floor and manure removal by belt system once a week	0.090
	HE2.3.2.1	Aviary housing - 45-50% slatted floor and manure belt aeration 0,2 m^3/hour	0.055
	HE2.3.2.2	Aviary housing - 45-50% slatted floor and manure belt aeration 0,5 m^3/hour	0.042
	HE2.3.3	Aviary housing - 30-35% slatted floor and manure belt aeration 0,7 m^3/hour	0.025
	HE2.3.4	Aviary housing - 55-60% slatted floor and manure belt aeration 0,7 m^3/hour	0.037
	LW1.1	Housing – biological air scrubber system, 70% NH_3-reduction	0.095
	LW1.4	Huisvesting - biological air scrubber system, 70% NH_3-reduction	0.095
	LW1.6	Huisvesting - biofilter, 70% NH_3-reduction	0.095
	LW2.4	Huisvesting – chemical air scrubber system, 70% NH_3-reduction	0.095
	LW2.8	Huisvesting - chemical air scrubber system, 90% NH_3-reduction	0.032
	LW2.9	Huisvesting - chemical air scrubber system, 70% NH_3-reduction	0.095
	HE2.100	Other housing systems	0.315
Broilers	HE5.1	Suspended floor with litter drying	0.004
	HE5.2	Perforated floor with litter drying	0.012
	HE5.3	Multi-tier system with slatted floor and manure belt aeration	0.004
	HE5.4	Floor housing with floor heating and floor cooling	0.038
	HE5.5	Mixed air ventilation	0.031
	HE5.6	Tiered system – with manure belt and litter drying	0.017
	HE5.7	Heating based on heaters and fans	0.035
	HE5.8	Air mixing system in combination with heat exchanger	0.021
	HE5.9	Heaters - air mixing system	0.035
	HE5.10.1	Barn with pipe heating (environmental permit granted before 1-Dec-2022)	0.012
	HE5.10.2	House with tube heating	0.021
	LW1.1	Biological air scrubber	0.020
	LW1.6	Biological air scrubber - 70% NH_3-reduction	0.020
	LW2.4	Chemical air scrubber system - 70% NH_3-reduction	0.02
	LW2.8	Chemical air scrubber system	0.007
	LW2.9	Chemical air scrubber system - 70% NH_3-reduction, 70% fine dust reduction	0.02
	HE5.100	Other housing systems	0.068
Farrowing sows	HD2.1	Flush gutter system, flushed with liquid manure	3.300
	HD2.2	Plastic false floor with sliding tray beneath slats	3.700
	HD2.3	Flat coated floor with manure scraper	4.000

Animal species	Barn code	Description barn	Ammonia (kg NH_3/place)
	HD2.4	Sloped coated slurry pit floor with slurry gutter and manure scraper	3.100
	HD2.5	Shallow manure pits with with manure water channel	4.000
	HD2.6	Manure collection in and flushing with acidified liquid	3.100
	HD2.7	Manure channel and sloped (fake)floor under slatted floor	5.000
	HD2.8	Sliding scrapers in manure gutter	2.500
	HD2.9	Water channel with separate manure channel or manure pit	2.900
	HD2.10	Slurry tray	2.900
	HD2.11	Manure gutter with manure removal system	3.200
	HD2.12	Slurry tray with water channel and manure channel	2.900
	HD2.13	Slurry tray with water and manure channels and cooling system	1.3
	HD2.14	Cooling deck system (150% cooling surface)	2.400
	LW1.1	Biological air scrubber system	2.500
	LW1.2	Biological air scrubber system	2.500
	LW1.3	Biological air scrubber system	2.500
	LW1.4	Biological air scrubber system	2.500
	LW1.5	Biological air scrubber system	1.300
	LW1.7	Biofilter for which an environmental permit was granted before 1-Dec-2022	2.5
	LW2.4	Chemical air scrubber system	2.500
	LW2.6	Chemical air scrubber system	0.420
	LW2.7	Chemical air scrubber system	0.420
	LW2.8	Chemical air scrubber system	0.830
	LW4.1	Biological air scrubber system with water curtain	1.300
	LW4.2	Biological and water air scrubber system with odor removal section	1.300
	LW4.3	Biological and chemical air scrubber system with biofilter	0.830
	LW4.4	Chemical air scrubber system (lamella filter) and water air scrubber system	1.300
	LW4.5	Chemical and water air scrubber system with biofilter	2.500
	LW4.6	Chemical and water air scrubber system with biofilter	1.300
	AV100.1	Floating balls in manure	2.343
	HD2.100	Other housing systems	8.300
Other sows	HD3.1	Triangular metal slats	2.400
	HD3.2	Manure gutter with combined slats	1.800
	HD3.3	Flushing gutters	2.500
	HD3.4	Manure collection in acidified liquid	1.800
	HD3.5	Manure scraper	2.200
	HD3.6	Separate manure and urine removal, V-shaped manure belts, metal triangular slats	2.200
	HD3.7	Cooling deck system	2.200
	HD3.8.1	Feeding crates or sow feeder with triangular metal slats	2.300
	HD3.8.2	Feeding crates or sow feeder with slats other than metal triangular	2.500
	HD3.9	Free range barn	2.600
	HD3.10	Water+manure channel, floor feeding, cooling system, water filling/flushing system in manure gutter	1.500
	LW1.1	Biological air srubber system	1.300
	LW1.2	Biological air srubber system	1.300
	LW1.3	Biological air srubber system	1.300
	LW1.4	Biological air srubber system	1.300
	LW1.5	Biological air srubber system	0.630
	LW1.6	Biofilter, 70% NH_3-reduction	1.300
	LW2.3	Chemical air scrubber system - 70% NH_3-reduction	1.300
	LW2.5	Chemical air scrubber system	0.210
	LW2.8	Chemical air scrubber system	0.420
	LW4.1	Biological air srubber system with water curtain	0.630
	LW4.2	Biological and water air scrubber system with odor removal section	0.630
	LW4.3	Biologica land chemical air scrubber system with biofilter	0.420
	LW4.4	Chemical air scrubber system (lamella filter) and water air scrubber system	0.630
	LW4.5	Biological and water air scrubber system with biofilter	1.300
	LW4.6	Biological and water air scrubber system with biofilter	0.630

Animal species	Barn code	Description barn	Ammonia (kg NH_3/place)
	AV100.1	Floating balls in manure	2.982
	HD3.100	Other housing systems (group housing)	4.200
	HD3.101	Other housing systems (individual housing)	4.200
Weaned piglets	HD1.1	Coated floor with rack-and-pinion scraper	0.200
	HD1.2	Flushing gutters	0.240
	HD1.3.1	Manure collection in acidified liquid, fully slatted	0.180
	HD1.3.2	Manure collection in acidified liquid, partially slatted	0.250
	HD1.4	Sloped manure belt	0.230
	HD1.5.1	Water- and manurechannel 0.13 m^2 per piglet	0.260
	HD1.5.2	Water- and manurechannel 0.19 m^2 per piglet	0.330
	HD1.6.1	Sloped pit wall, regardless of group size	0.170
	HD1.6.2	Sloped pit wall, group size until 30 piglets	0.210
	HD1.6.3	Sloped pit wall, group size until 30 piglets	0.180
	HD1.7	Half slatted, max 60% slatted floor	0.390
	HD1.8	Manure collection in water	0.150
	HD1.9	Fully slatted, water- and manure channels	0.200
	HD1.10	Cooling deck system, 150% cooling surface	0.170
	HD1.11	Conditioning of the lying floor temperature, daily manure removal	0.210
	LW1.1	Biological air scrubber system	0.210
	LW1.2	Biological air scrubber system	0.210
	LW1.3	Biological air scrubber system	0.210
	LW1.4	Biological air scrubber system	0.210
	LW1.5	Biological air scrubber system - 85% NH_3-reduction	0.100
	LW1.7	Biofilter, 70% NH3-reduction	0.210
	LW2.3	Chemical air scrubber system	0.210
	LW2.5	Chemical air scrubber system - 95% NH_3-reduction	0.030
	LW2.8	Chemical air scrubber system - 90% NH_3-reduction	0.070
	LW4.1	Combi-flush system (biological) - 85% NH_3-reduction	0.100
	LW4.2	Combi-flush system (biological) - 85% NH_3-reduction	0.100
	LW4.3	Combi-flush system (biological) - 90% NH_3-reduction	0.070
	LW4.4	Combi-flush system (chemical) - 85% NH_3-reduction	0.100
	LW4.5	Combi-flush system (biological) - 70% NH_3-reduction	0.210
	LW4.6	Combi-flush system (chemical) - 85% NH_3-reduction	0.100
	AV100.1	Floating balls in manure	0.490
	HD1.100	Other housing systems	0.690
Fattening pigs	HD5.1	Free range pigs in a bedded barn	1.900
	HD5.2	Entire animal area with a pit underneath, without odor trap	4.500
	HD5.3	Manure collection and flushing with low-ammonia liquid (including acidification)	1.600
	HD5.4	Metal triangular slat floor with manure collection in formaldehyde	1.000
	HD5.5	Metal triangular slat floor with manure collection in water	1.300
	HD5.6	Flush gutters, metal triangular slat floor	1.200
	HD5.7	Flush gutters with slats	1.700
	HD5.8	Separated manure channels	1.700
	HD5.9	Manure pit, other slatted floor	1.400
	HD5.10	Cooling deck system, 200% cooling surface	1.500
	HD5.11	Cooling deck system, 170% cooling surface	1.700
	HD5.12	Pen with convex floor	1.400
	HD5.13	V-shaped manure belt	1.100
	HD5.14	Feed and water supply above water channel, cooling system, water filling/flushing system.	0.770
	AV100.1	Floating balls in manure	2.130
	LW1.1	Biological air scrubbing system	0.900
	LW1.2	Biological air scrubbing system	0.900
	LW1.3	Biological air scrubbing system	0.900
	LW1.4	Biological air scrubbing system	0.900

Animal species	Barn code	Description barn	Ammonia (kg NH_3/place)
	LW1.5	Biological air scrubbing system - 85% NH_3-reduction	0.450
	LW1.7	Biofilter, 70% NH_3-reduction	0.900
	LW2.3	Chemical air scrubber system - 70% NH_3-reduction	0.900
	LW2.5	Chemical air scrubber system - 95% NH_3-reduction	0.150
	LW2.8	Chemical air scrubber system - 90% NH_3-reduction	0.300
	LW4.1	Combi-flush system (biological) - 85% NH_3-reduction	0.450
	LW4.2	Combi-flush system (biological) - 85% NH_3-reduction	0.450
	LW4.3	Combi-flush system (biological) - 90% NH_3-reduction	0.300
	LW4.4	Combi-flush system (chemical) - 85% NH_3-reduction	0.450
	LW4.5	Combi-flush system (biological) - 70% NH_3-reduction	0.900
	LW4.6	Combi-flush system (chemical) - 85% NH_3-reduction	0.450
	HD5.100	Other housing systems	3.000
White veal calves	HA3.1	Sloped slatted floor combined with a sloped false floor underneath the slatted floor	2.5
	HA3.2	Slatted floor with convex rubber top layer, sealing flaps	1.9
	LW1.1	Biological air scrubber system	1.1
	LW1.2	Biological air scrubber system	1.1
	LW1.3	Biological air scrubber system	1.1
	LW1.4	Biological air scrubber system	1.1
	LW1.5	Biological air scrubber system	0.53
	LW2.3	Chemical air scrubber system	1.1
	LW2.5	Chemical air scrubber system	0.18
	LW2.6	Chemical air scrubber system	0.18
	LW2.7	Chemical air scrubber system	0.18
	LW2.8	Chemical air scrubber system	0.35
	LW4.1	Biological air scrubber system with water curtain	0.53
	LW4.2	Biologica land water air scrubber system with odor removal section	0.53
	LW4.3	Biological and chemical air scrubber system with biofilter	0.35
	LW4.4	Chemical air scrubber system (lamella filter) and water air scrubber system	0.53
	LW4.5	Chemical and water air scrubber system with biofilter	1.1
	LW4.6	Chemical and water air scrubber system with biofilter	0.53

Table 3.10 *Gross manure-N excretion of 'indoor housed animals' and emission factor of remaining gaseous losses (excluding NH_3-N) for slurry or solid manure systems, with: Emission of N-remaining (kg N) = Gross N-excretion x EF N-remaining.*

Animal category	Bruto N-excretion (kg N per animal place)	EF N-remaining slurry manure (% of N)	EF N-remaining solid manure (% of N)
Farrowing sows	29.8	2.4	3.5
Dry and pregnant sows	20.7	2.4	3.5
Weaned piglets	2.2	2.4	3.5
Fattening pigs	11.6	2.4	3.5
Laying hens	0.76	1.2	0.7
Broilers	0.43	1.2	0.7
White veal calves	14.3	2.4	3.5

3.2.6 Gaseous N-losses from external storage

Part of the manure goes to the external manure storage. In the ANCA Tool, it is assumed that 20% of the liquid manure produced in the barn (slurry, urine fraction, feces fraction) from grazing animals, 19% of the solid manure produced in the barn, and 100% of the solid manure produced in the barn (average of the values as reported in Van Bruggen *et al.*, 2024) is sent to the external manure storage. Some NH_3 losses also occur in this external storage. These are estimated at 1% of the stored N-manure in grazing animal slurry, 2% of the stored N-manure in barn-produced slurry, and 2% of the stored N-manure in solid manure (percentages based on the total N entering external storage, i.e., after subtracting gaseous N losses in the barn).

NH_3-N loss in external storage = (Gross N-excretion – gaseous N-loss in barn) × fraction of manure sent to external storage × EF

No other gaseous N losses (N_2O, NO, and N_2) are accounted for in external storage.

3.2.7 Gaseous N losses from slurry separation

When slurry is separated, gaseous N losses form. These losses occur both during the process and during the storage of the liquid and solid fraction. NEMA assumes NH_3 losses of 2.3% and 3.18% of the incoming N in manure for slurry from grazing animals and housed animals, respectively. For other N losses (N_2O, NO_x, N_2), 3.5% of the incoming N in manure is assumed for both slurry from grazing animals and housed animals. For slurry from all housed animals, the NEMA percentages for pig slurry are applied.
Regarding ammonia, these losses include the losses occurring during external storage of the slurry prior to separation. The latter are calculated separately in the ANCA Tool, namely at 1% and 2% of the externally stored N for slurry from grazing animals and indoor housed animals respectively (see section 3.2.6). To prevent double counting, the NEMA percentages for manure separation need to be corrected for this. For grazing animal slurry, it is assumed that 20% of the slurry is stored externally. This means that of the 2.3% of the NH_3 loss from manure separation (as per NEMA), 0.2% (1% * 0.2) is already included in the external manure storage in the ANCA Tool. This results in a remaining NH_3 loss of 2.1% for manure separation in the ANCA Tool (Table 3.11). For indoor housed animal slurry, it is assumed that 19% of the slurry is stored externally. This means that of the 3.5% of the NH_3 loss from manure separation (as per NEMA), 0.38% (2% * 0.19) is already included in the external manure storage in the ANCA Tool. This results in a remaining 2.8% in the ANCA Tool for manure separation (Table 3.11).
For the other gaseous N losses, the NEMA loss percentages for manure separation (3.5% of total N) include the emissions occurring in the barn. The ANCA Tool already accounts for these separately as well. To avoid double counting here as well, a correction was applied by reducing the NEMA percentage by the barn losses (2.4%, see Table 3.3). This results in a remaining loss of 1.1% for manure separation in the ANCA Tool (Table 3.11).

Tabel 3.1 *Additional gaseous N-losses during the separation of slurry and the storage of the thin and thick fractions (derived from NEMA). The losses are expressed as a % of the incoming N-slurry.*

Input slurry	NH_3-N (% of N)	N-remaining (% of N)
Grazing animals	2.1	1.1
Indoor housed animals	2.8	1.1

3.2.8 Gaseous N-losses during manure digestion

Some of the manure can be digested. This can be specified in the ANCA Tool. Digestion affects gaseous N losses. There is a change in the TAN content, which affects NH_3-losses, and losses occur during the storage of the digestate. Both are explained in this section.

Changes in TAN content
When manure is digested, part of the organic N is converted to TAN. This concerns 25% of the organic N entering the digester. This percentage is based on fertilisation research in which the N effect of digested manure was compared to undigested manure (Schroder *et al.*, 2007). The extra TAN resulting from this is calculated as follows:

First, the Norg in the slurry is calculated via:

Norg slurry (kg) = [N-excretion under the tail (kg) - TAN excretion (kg)] x proportion of slurry x 0.9 + $N_{sawdust}$

The factor 0.9 concerns the correction for the mineralisation of Norg during storage (10%, see section 3.2.2.1). If sawdust is used in the slurry section of the barn, the N contained therein is added to the Norg in slurry. This happens after correction for the N-mineralisation of the Norg in the manure.

Subsequently, the amount of extra TAN from digestion is calculated:

*TAN digestion (kg) = Norg slurry (kg) x fraction of slurry digested * 0.25*

The digested manure then enters the digestate manure stream and is treated as such in the ANCA Tool.

Gaseous N losses during digestate storage
When slurry is digested, gaseous N losses occur. These losses occur during the storage of the outgoing digestate product. NEMA only provides the total losses, including losses during external storage of the slurry. The NH_3 losses are 1% and 2% of the N in the incoming slurry for grazing animals and indoor housed animals, respectively. A proportion of the NH_3 losses is already included in the calculation of external manure storage, namely 1% and 2% of the stored N for grazing and indoor-housed animals respectively. To prevent double counting, the NEMA percentages for manure digestion need to be corrected for this. For grazing animal slurry, it is assumed that 20% of the slurry is stored externally. This means that of the 1.0% NH_3 loss during digestion (according to NEMA), 0.2% (= 1.0% x 0.2) of the NH_3 loss is already accounted for in the external manure storage in the ANCA Tool. This results in an NH_3 loss during manure digestion of 0.8% (Table 3.12). For indoor housed animal slurry, it is assumed that 19% of the slurry is stored externally. This means that of the 2.0% NH_3 loss during digestion (according to NEMA), 0.38% (= 2% x 0.19) of the NH_3 loss is already accounted for in external manure storage in the ANCA Tool. This results in an NH_3 loss during manure digestion of 1.62% (Table 3.12). No additional other gaseous N losses occur during manure digestion.

Tabel 3.12 *Additional gaseous N-losses when storing the digestate (NEMA). The losses are expressed as a % of incoming N-slurry.*

Input slurry	NH_3-N (% of N)	N-remaining (% of N)
Grazing animals	0.80	0.0
Indoor housed animals	1.62	0.0

3.2.9 Ammonia loss during grazing

During grazing, less N is lost through NH_3 emissions than in the barn. The EF of the TAN excretion during grazing was calculated in NEMA for Dutch circumstances in 2014 as a constant value of 4.0% (Van Bruggen *et al.*, 2017). The ammonia loss from TAN excretion during grazing is calculated as:

NH_3 -N_grazing (kg) = TAN_grazing (kg) x EF_grazing (%),

Where:
EF_ grazing = 4.0%

3.2.10 Ammonia loss during manure application

The ammonia loss during manure application is calculated based on the applied TAN in combination with the EF for the different application techniques.
The amount of TAN (kg N) applied in the form of dairy cattle manure is calculated within BEA by correcting the TAN in the manure storage (TAN barn manure) for manure import and/or export, if any. Manure import and export is expressed in kg total N in BEA. In this, it is assumed that both the imported and exported manure contain the same amount of TAN per kg N as the manure in the farm's storage.

The amount of TAN (kg N) applied is calculated as a percentage of the kg N applied:

TAN applied (kg) =% TAN manure x kg N manure applied,

where:
% TAN manure = TAN ' barn manure' / Net N excretion

Kg N applied = Net N excretion + N manure imported - N manure exported

TAN 'barn manure' = TAN production - total gaseous Nemission$_{housing + external storage}$

The TAN (kg N) applied in the form of manure from 'indoor housed animals' ('intensive livestock branch') is calculated within BEA as:

TAN applied (kg) =% TAN manure x kg N manure applied, where:

Kg N manure applied = Net barn balance + N manure imported - N manure exported + N initial stock - N final stock, and

% TAN manure according to standard shares as shown in Table 3.13

Tabel 3.13 *Standard TAN-fraction (%) in manure for indoor housed animals.*

Animal category	TAN manure (%)
Farrowing sows	67
Dry and pregnant sows	67
Weaned piglets	67
Fattening pigs	64
Laying hens	76
Broilers	62
White meat calves	72

Subsequently, the total TAN application from dairy manure (dairy cows including associated young stock), manure from other grazing animals, and "indoor housed animal" manure is allocated between application on arable land and application on grassland. This is done according to the farm's data in BEA, which specifies the kg N of manure applied to grassland and arable land. Finally, the method of application (see Table 3.13) is also specified, which determines the emission factor (EF) for application. In the BEA module of the ANCA Tool, the percentage of manure applied using each method must be indicated. Three application methods are distinguished for both grassland and arable land.
In barns with primary manure separation, urine and feces fractions are produced (for example, HA1.35, HA1.36, and HA1.38). For the EF at application, the EF of slurry and thin fractions is provisionally used for both manure fractions (Table 3.14).

***Tabel 3.14** Average emission factors (kg NH_3-N per 100 kg TAN applied) per manure type and application method for grassland and arable land (as per Velthof et al., 2012; Van Bruggen et al., 2024).*

Land use	Method of application	Fertilizer type				
		Solid manure, thick fraction & compost	Slurry, thin fraction, digestate	Slurry with half a part of water[1]	Mineral concentrate	Scrubbing water
Grassland	Above-ground	68	68		68	1.8
	Trailing shoe	-		17 [3]	10	
	Slid coulter [2]	-		17 [3]	9	
	Shallow injection	-	17		8	
Arable land	Above-ground	46	69		69	1.8
	Incorporate in a working pass	-	22		22	
	Trailing shoe	-	36		12	
	Deep injection (>10 cm)	-	2		3	
	Shallow injection (<10 cm)		24		8	

[1] Half a part of water means two parts manure with one part water (more water is allowed, but it does not result in emissions lower than those for application of undiluted manure by a shallow injection).

[2] For the mission factor of a slid coulter, the average of the mission factor of a trailing shoe and a sod fertilizer is used.

[3] For the emission factor when applying diluted manure with a slid coulter and trailing shoe machine on grassland, a level comparable to that for sod fertilisation is assumed. The minimum dilution is 2 parts manure to 1 part water.

The ammonia emissions are calculated from the combination of the kg TAN applied and the EF from Table 3.14:

$$NH_3\text{-}N \text{ fertilizer application (kg)} = TAN \text{ application}_{1...n} \times EF\_ \text{ application}_{1...n}$$

Where:
1 ... n = application methods from Table 3.14

3.2.11 Ammonia loss during synthetic fertilizer application

Ammonia can also volatilise from synthetic fertilizers. Therefore, BEA specifies how many kg of N were applied as synthetic fertilizer. When estimating emissions, no distinction is made between soil types or land use. However, a differentiation is made according to the type of synthetic fertilizer-N (Table 3.15).

***Tabel 3.15** Emission factors for the application of synthetic fertilizer (EF_NH3-Nsynthetic_fertilizer, kg N per 100 kg N-total applied (Van Bruggen et al., 2024; Vonk et al., 2018).*

Fertilizer type	Land use	Emission factor
N fertilizers, 100% ammonium	Grassland and arable land	11.3
N fertilizers, 100% nitrate	Grassland and arable land	0.0
N fertilizers, combination of ammonium and nitrate	Grassland and arable land	2.5
Urea, granulated, without urease inhibitor	Grassland and arable land	14.3
Urea, granulated, with urease inhibitor	Grassland and arable land	5.9
Liquid urea without urease inhibitor or acid	Grassland and arable land	7.5
Liquid urea with urease inhibitor or acid	Grassland and arable land	3.1
Liquid urea applied via injection	Grassland and arable land	1.5

The ammonia emission is calculated from the combination of the applied kg of fertilizer-N and the EF from Table 2.2.12:

$$NH_3\text{-}N \text{ synthetic fertilizer applied (kg)} = \text{kg synthetic fertilizer-N applied}_{1...n} \times EF\_ \text{ application}_{1...n},$$

Where:
1 ... n = synthetic fertilizer type from Table 3.15

3.2.12 Ammonia loss from crop residues

Ammonia losses also occur from above-ground crop residues. These losses depend on the N content of the above-ground crop residues and the extent to which they are incorporated after harvest. The calculation method follows NEMA (Van Bruggen *et al.*, 2024).

Grassland

For grassland, NH_3 emissions from crop residues are only calculated for NH_3-emissions from mowing losses and NH_3 losses from tearing of grassland. NH_3 losses from grazing residues are not included according to NEMA, as it is assumed that these are already accounted for in the NH_3 emissions from grazing (Van Bruggen *et al.*, 2024).

De NH_3-emissions from mowing losses are calculated as follows:

$$NH_3\text{-}N\text{-}mowing\_losses = SG \times AF3_{mowing\_grass} \times (MAX(0 , 0.41 \times NCON-5.42)) / 100$$

Where:

- *SG = Surface Grassland (ha)*
- *$AF3_{mowing\_grass}$ = Amount of N in mowing losses (kg/ha, 4.1)*
- *NCON = N-content in mowing losses (g/kg DM)*

With tearing of grassland, the NH_3-emission is calculated as:

$$NH_3\text{-}N\text{-}tearing = (TRO \times FRTSR + TCO \times FRTSC) \times FRAGC \times NCONGS \times EF\text{-}NH_3\text{-}N / 100$$

Where:

- *TRO = area of teared grassland during reseeding (ha)*
- *TCO = area of teared grassland during crop rotation (ha)*
- *FRTSR = fraction of teared grassland that is sprayed dead during reseeding: 0.90*
- *FRTSC = fraction of teared grassland that is sprayed dead during crop rotation: 0.50*
- *FRAGC = fraction above-ground crop residue-N in total crop residue : 0.45*
- *NCONGS = N-content of the grass-sward (above and below ground): 190 kg N per ha*
- *EF-NH_3-N = emission factor, % of N in above-ground crop residue: 4.8*

The fraction of teared grass that is sprayed dead (0.90 for reseeding and 0.50 for crop rotation) is not farm-specific and represents a fixed average value, as also used in NEMA. The EF value of 4.8% of the N in above-ground crop residue-N is also a fixed value.
The amount of N in the grass sward is estimated at an average of 190 kg N per ha (Van Dijk *et al.*, 1996; Conijn & Taube, 2004; Conijn, 2004).

Other crops

For other crops, the NH_3-N emission is calculated as follows:

$$NH_3\text{-}Ncrop = CropS \times (NBYP + NCR \times FRNC) \times EF\text{-}NH_3\text{-}N / 100$$

Where:

- *CropS = Surface crop (ha)*
- *NBYP = N-content of by-product (kg/ha, **Error! Reference source not found.**)*
- *NCR = N-content of crop residue (above and under ground) (kg/ha, **Error! Reference source not found.**)*
- *FRNC = Fraction of N in above-ground crop residues in total crop residue N (Table 3.)*
- *EF-NH_3-N = emission factor, % of N in above-ground crop residue (Table 3.)*

Table 3.16 *Fraction of above-ground N in total crop residue-N and EF NH3-N (kg NH_3-N per kg N in above-ground crop residue-N) for crops, in which EF >0); Source: De Ruijter & Huijsmans (2019).*

Crop (group)	Fraction of above-ground crop residue-N in total crop residue-N	EF, % of N in above-ground parts (by-product + above-ground crop residue)
Alfalfa	0.25	7.29
Red clover	0.25	7.29
Sugar/fodder beets	0.10[1]	1.455
Potatoes	0.50	0.3
Seed potatoes	0.80	5.62
Leafy vegetables [2]	0.90	2.99
Non-leafy vegetables [3]	0.90	0.715
Catch crop after corn	0.80	2.01
Green fertilizer/catch crop after arable crop	0.80	1.52

[1] Excluding by-product (beet tops).

[2] Average of lettuce and heading cabbage.

[3] Average of carrot and chicory.

3.3 Comments on BEA

- No definition of the summer and winter periods has been given. BEA therefore uses an annual feed ration.
- Different EFs are used for barn emissions during the housing and grazing periods. Only when the barn is empty for several hours a day (such as in combination with grazing), the differences in emitting soiled surface area will also be taken into account. As a result (see Table 3.4), with 20 hours of unlimited grazing, the EF is very high (40.9%) compared to 9 hours of limited grazing (17.5%) and summer feeding (14.3%).
- It is assumed that the emission of barn type HA1.100 (standard barn) is equal to the emission calculated by the NEMA method of the ‘non low-emission barn’. This assumption is valid for the purpose of comparing with the EFs of other barn types from the Environmental Regulations (Dutch: Omgevingsregeling). However, this assumption is debatable for a quantitative comparison (based on kg of ammonia) of the emission calculations according to BEA and the Environmental Regulation (Dutch: Omgevingsregeling). There are indeed indications that the NH_3 emission factors for dairy cattle in the Environmental Regulations (Dutch: Omgevingsregeling) are too low (Van Bruggen *et al.*, 2024). Calculations by Smiet *et al.* (2007) indicate that the NH_3-emission factor for dairy cattle can be up to approximately 20% higher.
- For on-farm manure separation, the EF for slurry will be used when applying the liquid fraction to the land, and the EF for solid manure will be used for the solid fraction. For the imported amount of ‘synthetic fertilizer substitutes’ (liquid fraction of separated manure, digestate, mineral concentrate, scrubbing water), it is assumed that these types of fertilizer are applied on land as soon as possible after purchasing. Consequently, no emissions from barn or storage will be accounted for these manure types.
- Different emission factors are used for the application of mineral concentrate and scrubbing water (Table 3.14) than for slurry application. When applying mixtures of mineral concentrate (or scrubbing water) and slurry, the ANCA Tool uses the emission factors of the individual fertilizers.
- The amount of N applied is reported by the dairy farm in BEA by indicating how much N goes to arable land and nature grassland. The other N present is assumed to be applied to production grassland. Here are potential errors in this:
  1. In practice, the N applied on arable land is usually calculated as cubic meters of manure times a *standard value* for N content,
  2. The calculated N in manure and storage is based on the N excretion of the herd for the current calendar year. However, there may have been stock mutations (not shown) and there may be more N in storage than calculated, for example due to N loss from feed.
- The BEA calculation is limited by assuming that on average 20% of the manure goes to closed storage. The calculation can be made more farm-specific by determining more precisely which part of the manure actually ends up (shortly after excretion) in a closed storage, from which hardly any NH_3 is released and for which, given the other temperatures, the assumed 10% extra mineralisation of organic N no longer applies.

- If youngstock are housed in the same housing type as the dairy cows, BEA makes no distinction between dairy cattle and youngstock with regard to emissions. The potential error that results from this is limited because the number of youngstock and TAN excretion per unit of youngstock are small compared to dairy cattle.
- The emission factors used, although specified for housing systems and application techniques, are based on averages. Research has shown a large range around this average value, influenced by barn climate, ventilation, drinking and flushing water use (respectively the dry matter content of manure), deliberate dilution of manure with water, acidification, additives, soil type, weather conditions (precipitation , temperature, wind), crop type and height, manure dosage, distribution of manure over a year.
- The BEA calculates the ammonia losses from the barn and storage as a fraction of the manure excreted, regardless of whether this manure is exported and, if so, at what time after excretion. Accordingly, no ammonia losses from barn and storage are attributed to manure that is imported, even if that manure remains on the farm for some time before being applied to the land. Ammonia losses from application of this manure are, naturally, taken into account. It is assumed that imported manure has the TAN percentage as shown in Table 3.13. In reality, this is not the case.
- Unlike in dairy cattle, the contribution of 'indoor housed animals' to ammonia emissions is not differentiated based on feed ration composition.
- The calculation of the metric 'ammonia-N emission per tonne of milk' is based on all ammonia, including the part that is caused by indoor housed animals or arable production. When other livestock types are present besides dairy cattle, this metric is currently difficult to compare to that of a specialized dairy farm.
- In housing systems with primary manure separation, urine and feces fractions are produced. For NH_3 emissions in the field during application, the emission factors for slurry and liquid fractions are currently used. If ongoing research on NH_3 emissions from urine and feces fractions provides reason to do so, these factors may be adjusted.

4 BEN: farm-specific N flows

4.1 Introduction

The use of nitrogen (N) is necessary to maintain soil fertility and crop yields. However, the use of N in agriculture also leads to unwanted losses to the environment. The quality of the environment is determined, amongst others, by the N concentration in ground and surface water (mainly nitrate-N under sandy soils, and nitrate, ammonium and dissolved organic N from clay and peat soils) and emissions of the greenhouse gas N_2O (nitrous oxide) from the soil and manure storage. The main aim of this part of the ANCA Tool calculations is to identify these nitrogen losses.

4.2 Calculation methods

4.2.1 N soil surplus and N leaching

The basis of the calculation of N leaching is based on the N soil surplus. The amount of leached N can be calculated from the N soil surplus. The latter is also needed for the calculation of indirect nitrous oxide emissions from nitrate leaching (see section 4.2.2.2.).

4.2.1.1 Calculation of N soil surplus

The N soil surplus is calculated based on the terms provided in Table 4.1. Full alignment has been sought with methods that underlie the LMM and substantiation of approved Dutch Action Programs in the context of the *European Nitrate Directive (Dutch: Europese Nitraatrichtlijn)* (Schröder *et al.*, 2007). The soil surplus for all grassland, corn land, land on which other roughage is cultivated and land on which marketable arable crops are cultivated is initially calculated separately.

Table 4.1 *Supply and removal terms to determine the N soil surplus (kg N/ha) with indication ('X') whether the input data relate to the farm as a whole, to crops (grassland, arable land), or to crops with a distinction between the part that is grown in rotation (for example, crop residues) and the part that is grown in continuous cultivation.*

In/output	Code	Term	Level input	
			Farm	Crop [1]
Aanvoer	Aan0	Nmin spring, in year x	X	
	Aan1	Pasture manure		X
	Aan2a	Animal manure [2]		X
	Aan2b	Compost and mushroom compost		X
	Aan3	Synthetic fertilizer		X
	Aan4	N-fixing legumes		X
	Aan5	Deposition	X	
	Aan6	Grazing, mowing, and harvest losses		X
	Aan7	Crop residues		X
	Aan8	Catch crops and green fertilizers		X
	Aan9	Peat mineralisation		X
	Aan10	Excretion of geese	X	X
Output	Af0	Nmin spring, year x + 1	X	
	Af1	Harvested from own land, including eaten by geese	X	X
	Af2	Ammonia losses during grazing, (synthetic) fertilizer application and from crop residues [3]		X
	Af3	Grazing, mowing, and harvest losses		X
	Af4	Crop residues		X
	Af5	Catch crops and green fertilizers		X

[1] Including pre- and post crops.

[2] Sum of the animal manure present on the own farm (including feed residues) and supplied animal manure.

[3] NH_3-N-losses from harvest- and grazing losses.

Input items

The terms In0 (mineral soil N in the spring of year x) and Out0 (mineral soil N twelve months later) are assigned a default value of 30 kg N per ha. These items have been included at the request of the European Commission, but function, from an accounting perspective, as offsetting entries that cancel each other out. Users of the ANCA Tool are therefore not asked for a farm-specific value. The item In1 (pasture manure) is expressed as kg total N per ha of grassland (total, grazed and ungrazed). The items In2a (animal manure), in2b (compost and mushroom compost) and In3 (synthetic fertilizer) are expressed as kg N per ha of grassland and per ha of arable land. In1 is calculated based on the calculated gross N-excretion and the specified number of hours of grazing. In3 is specified by the ANCA Tool users. Within In2, a distinction is made between the animal manure excreted and stored indoors (from grazing animals and, if applicable, 'indoor housed animals'), plus any imported manure (In2a) and imported compost and mushroom compost (In2b). For In2a, the N in the manure produced indoors by grazing animals is derived from the data on gross N excretion within the framework of BEX (Chapter 2), after accounting for all gaseous losses from housing and storage according to BEA (Chapter 3), and from manure removal off the farm. In addition, the amount of N in feed residues is then added. The amount of N in the manure of the present 'indoor housed animals' is derived from the barn balance, based on the calculated imported and exported manure. In addition, a correction is made for stock changes: if at the end of the year there is less manure in stock than at the start, the difference (kg N/ha) is added to In2a (positive value in the equation below); if more manure is in stock at the end of the year than at the start, the difference is subtracted from the total 'barn manure' N to be applied to the field (negative value in the equation):

$$\text{Manure to be applied-N} = \text{excreted manure-N} - (NH_3\text{-}N_{barnl+storage} + \text{exported manure-N}) + \text{feed leftovers-N} + \text{imported manure-N} + \text{stock changes}$$

Feed leftovers-N (kg N/ha) is estimated at 2 to 5%, depending on the type of feed (Table 1.1, feed intake loss), of the total amount of feed-N (kg N/ha) offered to the livestock, as follows:

Feed leftovers-N = 0.05 x (N intake in the form of conserved grass and corn silage / (1- 0.05)) + 0.03 x (N intake in the form of other self-grown roughage and wet (by)products / (1-0.03)) + 0.02 x (N intake in the form of concentrates, compound feed and dairy products / (1- 0.02))

with N intake from the various feed ingredients based on data from the BEX part (Chapter 2).

ANCA Tool users then specify what amount of 'barn manure' is applied (kg N/ha) on grassland ($In2a_{grassland}$), on corn land ($In2a_{corn}$), on land with other roughage ($In2a_{other\_roughage}$), and on the arable land with marketable arable crops ($In2a_{arable\_for\_market}$), as follows:

Manure to be applied-N (kg) = ((SG x $In2a_{grassland}$*) + (SC x* $In2a_{corn}$*) + (SR x* $In2a_{other\_roughage}$ *) + (SM x* $In2a_{arable\_for\_market}$*))*

Where:

- *SG = total surface of grassland (ha)*
- *SC = total surface of corn land*
- *SR = total surface of other roughage*
- *SM = total area of marketable arable crops*

When using compost (and other miscellaneous organic fertilizers), the dosage and N content are specified for each crop, from which the amount of N applied per he is calculated. Subsequently, the total amount of N supplied via compost is calculated using:

Compost to be applied-N (kg) = ((SG x $In2b_{grassland}$*) + (SC x* $In2b_{corn}$*) + (SR x* $In2b_{other\_roughage}$*) + (SM x* $In2b_{arable\_for\_market}$*))*

Instead of specific entries for the aforementioned four destinations of organic manure loads ('areas x applications per ha'), the amount of manure-N in the fourth load can also be calculated from the amount applied in the other three loads. Instead of providing specific entries for the four aforementioned destinations of organic manure loads ('areas x applications per ha'), it is of course also possible to calculate the fourth load based on the total amount of organic manure-N to be applied on the farm and the three other specified loads. By dividing the fourth load by the corresponding area, the amount per ha at that fourth destination can also be calculated.
In the above, it seems to be assumed that, within arable land, there are no more than three 'types' of use (corn, other roughage and marketable arable crops) and that the ANCA Tools therefore only requires data on the application of organic and synthetic fertilizer and the area of the mentioned three uses. In reality, the current version of the ANCA Tool allows the input of these data for three types of corn cultivation (silage corn, MKS, and CCM), four types of other forage crops (whole plant silage of cereals, alfalfa, red clover, and field beans), and more than ten types of marketable arable crops (see Table 4.3). Based on this, an area-weighted average is calculated.

The item In4 concerns the N-fixation by legumes (kg N per ha). The N-fixation in grass/clover pastures is estimated as the product of the estimated amount of dry matter grown (before deduction of field losses) in the form of clover (as 'clover percentage' in harvested amount of grass plus clover) and an assumed fixation of 45 kg N per tonne of dry matter in the form of clover (Elgersma & Hassink, 1997; Schils, 2002). The amount of grown dry matter in the form of grass-clover is defined as the product of kg DM per kg N in the crop and the sum of the net harvested crop and field losses: tonne DM/kg N x ($Out1_{cut\_grass}$ + $Out1_{pasture}$ + $Out3_{cut\_grass}$ + $Out3_{pasture}$). It should also be noted that the aforementioned 'clover percentage' is not equal to the visually estimated 'clover cover' (percentage coverage) in grass-clover swards. The relationship between the two is approximately: clover percentage/clover cover = 0.82 (Schils *et al.*, 2001).

With regard to field beans, peas and lucerne, the contribution to N-fixation is estimated at 100 and 300 kg N per hectare per year, respectively. This concerns a fixed value independent of the achieved yield level. For leguminous green manure crops, an N-fixation of 60 kg N per hectare per year is assumed, based on the assumption that legumes fix 20 kg N per tonne of dry matter and leguminous green manure crops produce 3 tonnes of dry matter per hectare (Schröder *et al.*, 1997; Schröder *et* *al.*, 2003). For leguminous green manure crops sown after corn silage, an N-fixation of 40 kg N per hectare is assumed, due to the relatively late sowing date of the green manure crop.

The item In5 (N deposition) averages about 21 kg N per ha per year, on a national level (Anonymus, 2009) but varies from 17 (Friesland) to 24 (Noord-Brabant, Zeeland) kg N per ha per year (Table 4.2). The ANCA Tool uses provincial values.

Table 4.2 *Average N-deposition values per province (values 2021) as used in the ANCA Tool (Source: www.clo.nl).*

	mol/ha/yr	Kg N/ha/yr
Nederland	1491	21
Groningen	1299	18
Friesland	1206	17
Drenthe	1357	19
Overijssel	1441	20
Gelderland	1545	22
Utrecht	1517	21
Noord-Holland	1379	19
Zuid-Holland	1543	22
Zeeland	1742	24
Noord-Brabant	1736	24
Noord-Limburg	1573	22

The item In6 (cumulative residual effects of grazing, mowing and harvesting losses from previous years) is defined for grassland ($In6_{grassland}$, kg N/ha) as the sum of the grazing and cutting losses ($Af3_{cutting\_grass}$ + $Af3_{pasture\_grass}$, kg N/ha), for corn land ($In6_{corn\_land}$, kg N/ha) and other roughage land ($In6_{other\_roughage}$, kg N/ha) as the harvest losses of those crop groups. Grazing losses are set at 15-20% of the N yield of pasture cuts (see Table 1.1) and the grass and alfalfa mowing losses ('mowing, tedding, raking, loading') at 5% of the N yield of mowing cuts. Harvest losses from corn land ('chopping, loading') are set at 2% of the N yield. For the time being, no crop losses are assumed for roughage crops other than grass, alfalfa and corn, and for marketable arable crops.

Elsewhere in this section it is explained how the above mentioned N-yields are derived. Formally, the assumption that In6 equals the harvest, mowing, and grazing losses is not correct, because within the framework of BEA plus (paragraph 3.2.12) it is assumed that a portion of these losses occurs as ammonia. In theory, these ammonia losses should be deducted from In6. However, because this is a cross-entry and the term is not part of the numerator or denominator of efficiency calculations, the effect on the ANCA Tool is negligible.

The item In7 (crop residues) for grassland ($In7_{grassland}$) is set at 75 kg N/ha (Velthof & Oenema, 2001). It is assumed that this input item in permanent grassland has an equal output every year (see item Out4, later in this section). For corn land (silage corn, MKS and CCM) ($In7_{corn\_land}$), the value of this annual input post, as far as carrots and stubble are concerned, is set at 15 kg N/ha (Schröder *et al.*, 2016). This input item is offset by an equally large output item (Out4) under continuous corn cultivation, regardless of its value. In case of residual effects from grazing, mowing and harvesting losses (In6) and crop residues (In7), it is assumed that in grassland and corn land (corn silage, MKS and CCM), these N-inputs benefit the crops from which they originate. The fact that this is not necessarily the case in all phases of a crop rotation is, for the time being, disregarded.

For several crop (groups), the residual plant material can be used on the farm itself as animal feed or bedding material, or it may be sold. These are referred to as by-products. Examples include straw from MKS, CCM, and grain or seed crops, as well as beet tops. The quantities of by-products and the N and P_2O_5 contents in both the main product and by-product are presented in Table 4.3. The values originate from the Soil and Fertilization Handbook (Dutch: Handboek Bodem en Bemesting) (www.handboekbodemenbemesting.nl). For the major arable crops, the N and P_2O_5 contents have been recently updated (De Ruijter *et al.*, 2020).

In addition to by-products, there are also other above- and below-ground crop residues, the N contents of which are likewise shown in Table 4.3.
For crops, too, the input is balanced by an equally large output. In the ANCA Tool, the size of the input term (In7) is not initially calculated per crop, but rather the output term (Out4). The output can be determined on a crop-specific basis, whereas the input is not determined by the crop itself but by the preceding crop(s). Since the exact crop sequence is unknown, an area-weighted average value of Out4 is calculated, after which the value of In7 for all non-corn forage crops and marketable arable crops combined is set equal to this average Out4 value.

Table 4.3 *Levels in main product and by-product for the indicated dry matter content (kg per ton fresh) of various arable roughage crops and marketable arable crops, as well as the estimated amounts of N in crop residues, in the form of (non-exported and therefore unweighted) by-products (kg per ha) and (based on the estimated main yield) root and stubble residues (kg N per ha), (Schröder et al., 2015).*

Crop	Main product (kg/tonne fresh)			By-product (kg/tonne fresh)			Crop residue		
							By-product	Other above- and below-ground crop residues[1]	
	DM	N	P_2O_5	DM	N	P_2O_5	(tonne fresh/ha)	Min, Max kg N/ha	Factor
GPS grains	550	8.9	3.8	-	-	-	-	10, 30	0.25
Alfalfa	160	5.8	1.4	-	-	-	-	10, 225	0.55
Red clover	160	5.8	1.4	-	-	-	-	10, 225	0.55
Beets	230	1.1	0.7	160	3.4	0.7	34.5	10, 10	1.06
Corn (MKS, CCM)	550	9.3	4.4	840	2.2	0.5	18.8	15, 15	n/a
Grains (based on winter wheat)	850	16.6	7	875	3.7	1.2	4	10, 30	0.62
Other seed crops (based on rapeseed)	840	35	15.9	840	6	3	3	10, 30	0.25
Grass seed	830	21	10.2	830	7.2	3.7	3	10, 40	1.27
Legumes (based on field beans)	840	40	13.6	840	21	4.6	3	10, 30	0.17
Potatoes	240	3.3	0.9	-	-	-	-	10, 60	0.36
Seed potatoes	180	2.5	1.1	-	-	-	-	10, 100	1.60
Onions and bulbs	125	1.8	0.8	-	-	-	-	10, 20	0.17
Leafy vegetables (average of lettuce and cabbage)	75	2	0.7	-	-	-	-	10, 90	0.81
Non-leafy vegetables (average of carrots and chicory)	105	1.9	1				-	10, 70	0.50
Other	1000	5	1.0	-	-	-	-	10, 20	0.30
Catch crop after corn							40		
Non-leguminous catch crop after arable crop							80		
Leguminous catch crop after arable crop							60		

[1] Where: N in above-ground and below-ground crop residues = MIN(Max, (MAX(Min, (factor x N in main product)))).

The value assigned to item In8 (catch crops and green fertilizers) is 40 kg N/ha for (unfertilised) catch crops (mainly cultivated after corn), 80 kg N/ha for non-leguminous (fertilised) green fertilizers and 60 kg N/ha for (unfertilised) leguminous green fertilizers.

The value assigned to item In9 (peat mineralisation) is 234 kg N per ha (Kuikman *et al.*, 2005). If only part of the farm consists of peat soil, the peat mineralisation is reduced proportionately.

The term In10 refers to the input of nitrogen and phosphate by the excretion of grazing geese and is estimated as the total excretion from geese (N_{eg} T, P_{eg} T) multiplied by the part that will have been excreted on the grazed plots. This part is estimated based on the behaviour of the geese. The geese fly with an empty stomach from resting areas (on water) to the plots to be grazed and immediately start to graze. Two hours after flying in, excretion starts. Grazing continues until the animals fly back to a resting area. In that resting area, the last feed consumed is excreted after digestion. A rule of thumb for grazing time per day and excretion is 10 hours. However, the excretion lags 2 hours behind the intake. Intake on the grazed fields therefore lasts 10 hours, and excretion on the grazed fields takes place for 8 hours each day. The proportion of the total excretion excreted on the grazed plot can therefore be estimated at 0.8. Total excretion is derived from the balance between intake and excretion as established in husbandry systems. For this, values were used from the animal group that is most representative of geese in the wild: parent animals of ducks. Nitrogen excretion for this animal group is 84% of the intake, and 80% for phosphate (De Buisonjé *et al.*, 2009).

The grass intake (as dry matter) by geese, above a certain damage threshold, is determined by appraisal. Conversion from dry matter intake to N and P intake (NOP_{goose}) takes place via the N and P content in pasture grass (see BEX section). The goose manure excretions $N_{eg}T$ and $P_{eg}T$ are then calculated as:

$$N_{eg}\,T = N\ intake * 84\% * 0.8$$
$$P_{eg}\,T = P\ intake * 80\% * 0.8$$

Output items
Elsewhere in this section is explained how the item Out1 (harvested from own land, including geese feeding) is calculated.. The term Out2 (ammonia losses during grazing, from manure and synthetic fertilizer, from crops in the field) is derived from the section on BEA (Chapter 3). The term Out3 (grazing, mowing, and harvest losses) is a balancing item equal to term In6. It is considered a balancing item in the sense that the value of In6 is based on the calculated value of Out3. The reasoning behind this is that the input item can only be maintained through a comparable (annual) investment in the soil stock, similar to the balancing items In0 and Out0. Following the same logic, term Out4 (crop residues) is equal to In7. Term Out5 (catch crops) is, as outlined above, set at 40–60 kg N per hectare and only applies to arable land.

Harvested from own land
The item Out1 (harvested from own land via 'intake of grazing animals' or 'leaving the field' (i.e. after deduction of grazing, mowing and harvesting losses but before deduction of conservation and feeding losses), or harvested to leave the farm as arable crops for sale, kg N/ha), is calculated as follows. For the crops that are used on the farm itself ('roughage'), Out1 is calculated based on the amount of ingested roughage included in the BEP part (after conversion based on N/P ratios) in the form of pasture grass ($NOP_{pasture}$, kg N), silage or fresh grass fed indoors ($NOP_{cut\ grass}$, kg N), corn silage ($NOP_{corn\ silage}$, kg N) and grazed by geese (NOP_{goose}, kg N, for calculation, see previous text in this section). The following applies for output in the form of pasture grass ($Out1_{pasture}$) and grazing losses ($Out3_{pasture}$):

$$Out1_{pasture} = (NOP_{pasture} + NOP_{goose}) / GS,$$

With:
GS (ha) = total grassland surface.

The amount of grass grown (above ground, excluding stubble) in the form of pasture grass (kg N / ha) ($Out1_{pasture}$ + $Out3_{pasture}$) is equal to:

$$Out1_{pasture} + Out3_{pasture} = Out1_{pasture} \times (100 / (100\text{-}grazing\ loss))$$

with grazing losses in percentage, according to Table 1.1.

When feeding fresh grass and silage grass, the calculation of what has grown based on what is supposed to be ingested by animals is more complicated, because feeding losses and, possibly, conservation losses will occur besides field losses. In addition, the purchase and stock formation of roughage must be accounted for.

For the amount of harvested grass consumed (barn feeding and silage) (kg N) from own land ($NOP_{cut\ grass\_ownland}$), the following applies:

$$NOP_{cut\ grass\_ownland} = (NOP_{cut\ grass} - NOP_{cut\ grass\_purchased})$$

where $NOP_{cut\ grass}$ is the total amount of grass, both fresh-fed and ensiled, that has been consumed, from grass purchased as well as grown on the farm, and $NOP_{cut\ grass\_purchased}$ is the grass intake (for barn feeding and silage) from purchased grass in a given year (after adjustment for stock changes and feeding losses of that purchased grass):

$$NOP_{cut\ grass\_purchased} = (((purchased\ fresh\ grass\ N\ and\ silage\ grass\ N \times (100\text{-}conservation\ loss)/100) - \Delta N\ grass\ silage) \times (100\text{-}feeding\ loss) / 100)$$

The conservation loss (expressed as a percentage according to Table 1.1) accounts for the fact that purchased grass silage is also subject to conservation losses. The term ΔN grass silage indicates changes in stock of grass silage (positive values indicate an increase) in the past 12 months. The feeding loss (in percentages according to Table 1.1) accounts for the fact that feeding losses also occur with purchased fresh grass or silage grass.

The amount of fresh grass and silage grass (kg N) from own land ($NAAN_{cut\ grass\_ownland}$) is then calculated from $NOP_{cut\ grass\_ownland}$:

$$NAAN_{cut\ grass\_ownland} = NOP_{cut\ grass\_ownland} / (100 - feeding\ loss) / 100$$

Then for the harvested amount of cut grass N (kg N) from own land ($NDAM_{cut\ grass}$):

$NDAM_{cut\ grass} = NAAN_{cut\ grass\_ownland} / ((100\text{-}conservation\ loss) / 100)$, *whereby one must take into account that not all cut grass needs to have been conserved (i.e. in the case of summer stall feeding).*

$Out1_{cut\ grass}$ can be derived from this, as follows:

$$Out1_{cut\ grass} = NDAM_{cut\ grass} / GS$$

Finally, the amount of grass grown (above ground, excluding stubble) in the form of fresh grass (for summer stall feeding) or silage grass (kg N/ha) from own land ($Out1_{cut\ grass}$ + $Out3_{cut\ grass}$) is equal to:

$$Out1_{cut\ grass} + Out3_{cut\ grass} = Out1_{cut\ grass} \times (100 / (100 - mowing\ loss))$$

The above calculation of Out1 for grassland is performed separately for production grassland and natural grassland.

Similarly, for corn silage:

For the amount of corn (kg N) consumed from own land ($NOP_{maize\_ownland}$), the following applies:

$$NOP_{corn\_ownland} = (NOP_{corn} - NOP_{corn\_purchased})$$

where NOP_{corn} represents the total amount of consumed corn from both purchased and home-grown corn (silage corn, MKS and CCM), and $NOP_{corn\ purchased}$ represents the corn intake from purchased corn in the respective year (after adjustment for stock changes and feeding losses of the purchased corn):

$$NOP_{corn\_purchased} = (((purchased\ corn\ N \times (100 - conservation\ loss) / 100) - \Delta Ncorn\ silage) \times (100 - feeding\ loss) / 100)$$

The conservation loss (in percentages according to Table 1.1) accounts for the fact that purchased corn silage is also subject to conservation losses. The term ∆Ncorn silage refers to changes in the stock of corn silage (positive values indicate increase) in the past 12 months. The feeding loss (in percentages according to Table 1.1) accounts for the fact that feeding losses also occur with purchased corn.

The amount of corn (kg N) from own land ($NAAN_{corn\_ownland}$) is then calculated from $NOP_{corn\_ownland}$:

$$NAAN_{corn\_ownland} = NOP_{corn\_ownland} / (100 - \text{feeding loss}) / 100$$

Subsequently, for the harvested amount of corn N (kg N) from own land ($NDAM_{corn}$):

$$NDAM_{corn} = NAAN_{corn\_ownland} / ((100\text{-conservation loss}) / 100)$$

From this $Out1_{corn}$ can be derived by:

$$Out1_{corn} = NDAM_{corn} / TS,$$

with TS = total surface (ha) of corn land (corn silage, MKS and CCM). Finally, the (above ground, excluding stubble) grown amount of corn (kg N / ha) of own land ($Out1_{corn}$ + $Out3_{corn}$), is equal to:

$$Out1_{corn} + Out3_{corn} = Out1_{corn} \times (100 / (100\text{-harvest Loss}))$$ *with harvest loss (%) according to Table 1.1.*

Similarly, for other roughage:

For the consumed amount of other roughage (kg N) from own land ($NOP_{other\ roughage\ own\ land}$), the following applies:

$$NOP\ other_{other\ roughage\ own\ land} = (NOP_{other\ roughage} - NOP_{other\ roughage\_purchased})$$

where $NOP_{other\ roughage}$ is the total amount of roughage consumed from both purchased and home-grown roughage, and $NOP_{other\ roughage\_purchased}$ is the consumed roughage from purchased roughage in the year concerned (after adjustment for stock changes and feeding losses of that purchased roughage):

$$NOP_{other\ roughage\_purchased} = (((N \text{ in purchased other roughage} \times (100\text{-conservation loss})/100) - \Delta N\text{other roughage silage}) \times (100\text{-feeding loss}) / 100)$$

The conservation loss (in percentages according to Table 1.1) accounts for the fact that purchased other roughage is also subject to conservation losses. The term '∆Nother roughage silage' indicates changes in the stock of these types of silage (positive values indicate increase) in the past 12 months. The feeding loss (in percentages according to Table 1.1) accounts for the fact that feed losses also occur with purchased roughage.

Then from $NOP_{other\ roughage\ own\ land}$ the offered amount of other roughage (kg N) from own land ($NAAN_{other\ roughage\ own\ land}$) is calculated:

$$NAAN_{other\ roughage\ \_own\ land} = NOP_{other\ roughage\ own\ land} / (100 - \text{feeding loss}) / 100$$

Then, the following applies to the amount of N in harvested other roughage (kg N) from own land ($Ndam_{other\ roughage}$):

$$Ndam_{other\ roughage} = NAAN_{other\ roughage\ own\ land} / ((100\text{-conservation loss}) / 100)$$

From this $Out1_{other\ roughage}$ can be derived as follows:

$Out1_{other\ roughage} = NDAM_{\ other\ roughage} / ORO,$

Finally, the amount of other roughage (kg N/ha) grown on own land (above ground, excluding stubble) ($Out1_{other\ roughage}$ + $Out3_{other\ roughage}$) is equal to:

$Out1_{other\ roughage} + Out3_{other\ roughage} = Out1_{other\ roughage}\ x\ (100 / (100\ harvest\ loss))$ *with harvest loss (%) as stated in Table 1.1*

The current ANCA Tool can also deal with dairy farms with an arable production branch, of which the harvest is marketed. To this end, the N exported in marketable products ($Out1_{market\_arable}$, kg N/ha) must be calculated. This is done by querying the number of hectares of the arable crops listed in Table 4.3 and the average yield of those crops in the relevant year. Finally, the N output is calculated by multiplying the yields with crop-specific standard values as listed in Table 4.2. For arable crops not included in the table, it is assumed that they have a standard output of 150 kg N/ha. This number is based on the average standard removal of a crop rotation consisting of 25% winter wheat, 25% table potatoes, 25% sugar beets, and five crops each accounting for 5%: spring barley, spring wheat, grass seed, grain corn, and onions grown from seed, each with assumed average yields as reported by Statistics Netherlands (CBS) for the period 2009–2013, with only the main products considered to have been removed from the farm. Hence:

$$Out1_{market\_arable}\ (kg\ N/ha) = (\textstyle\sum_1^n ALn\ x\ ((YMn\ x\ CNMn) + (YBn\ x\ CNBn)))/AMO,$$

With ALn = surface area of arable land with crop n (ha), YMn = yield of main product of crop n (tonnes fresh/ha), YBn = yield of removed by-product of crop n (tonnes fresh/ha), CNMn = N content of main product (kg N/tonne fresh), CNBn = N content of by-product (kg N/tonne fresh) and SM = total surface area (ha) of marketable arable crops.

Figure 4.1 provides a summary flow chart. This flow chart is limited to the crops that are processed on the farm by the livestock (pasture grass, silage grass, corn and other roughage) or that are eaten by geese. On some farms, the complete output (Out1) also needs to be supplemented with the nutrients that are reported to be removed in the form of arable crops.

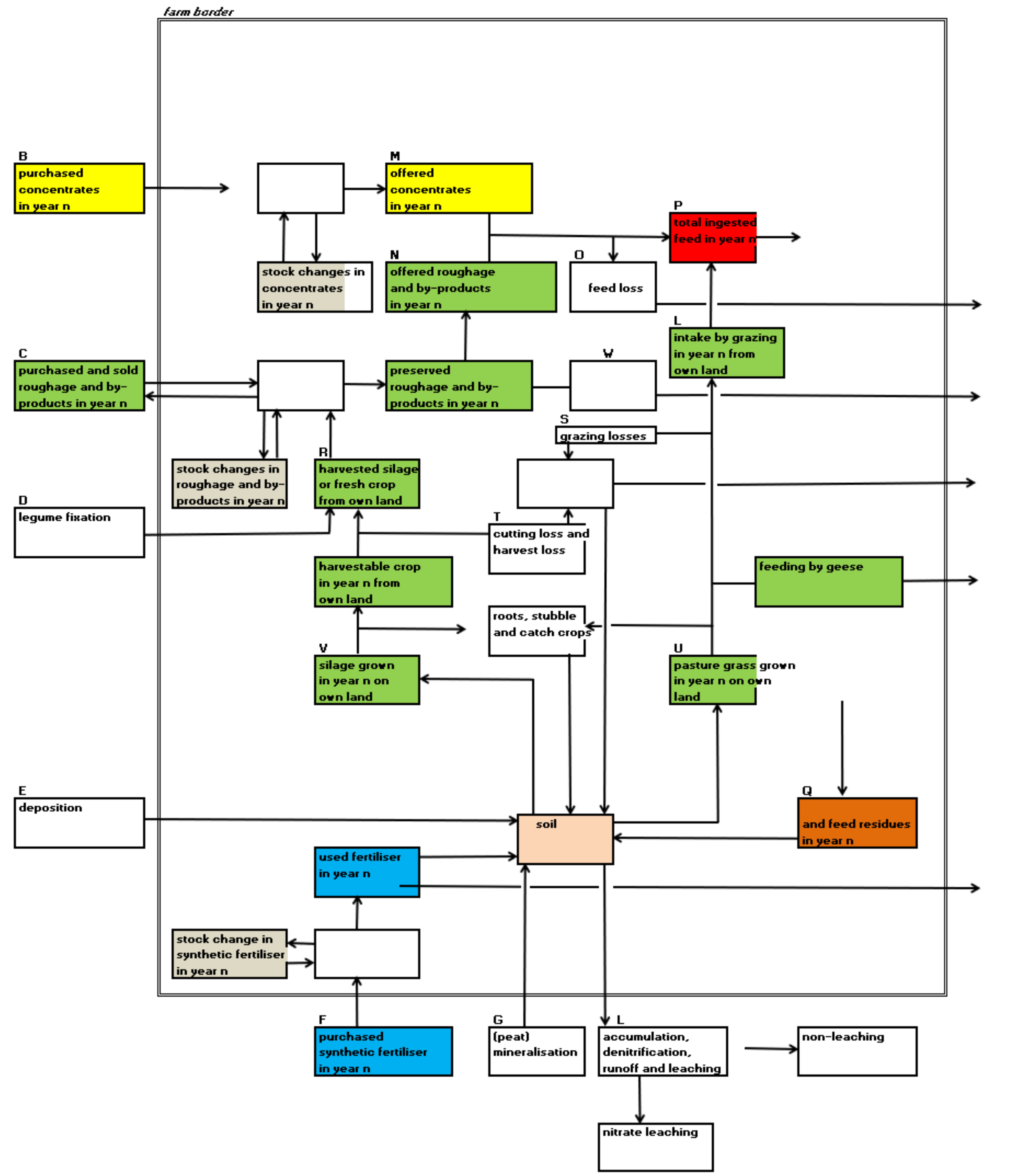

Figure 4.1 *Nutrient flows involved in the calculation of the soil-N surplus (and possibly nitrate concentration in receiving water) based on the estimated feed-N intake for specialised dairy farms without arable crop branch.*

Preceding and succeeding crops

Sometimes, one or several cuts of grass are harvested before corn is sown or after an early-harvested crop (such as grain). It is also possible that after corn, grass is sown as a catch crop, from which one cut is harvested in the following spring. In some cases, a second arable crop is grown (for example, a lettuce crop after winter wheat).

These preceding and succeeding crops are grown on plots for which a different main crop is typically reported in the combined declaration. In the ANCA Tool, the yields of these preceding and succeeding crops were previously attributed to the area of the main crop reported in the combined declaration. When the preceding or succeeding crops fall into a different crop group than the group of the combined declaration (grassland, silage corn, or arable crops), this results in discrepancies in the calculation of certain metrics. For example, when grass is grown as a preceding crop before corn maize, the dry matter, N, and P_2O_5 yields of the preceding crop are attributed to the grassland area (according to the combined declaration). Consequently, the dry matter, N, and P_2O_5 yields of the grassland plots are overestimated, while those of the corn plots where the preceding or succeeding crops were grown are underestimated. This also leads to deviations in the calculated N and P_2O_5 surpluses at the crop level compared to the actual situation. However, the calculation of N and P_2O_5 surpluses at the farm level is not affected by this. Still, there are other metrics, such as nitrate leaching and nitrous oxide emissions, that are calculated based on the N surplus at the crop level. In those cases, the farm-level value will also deviate.

Since the 2021 version of the ANCA Tool, it has become possible to enter the yields of preceding and succeeding crops (such as grass and silage corn) separately within the main crop groups grassland, silage corn, and arable land. The yield of an arable crop used as a preceding or succeeding crop on grassland and/or silage corn land is allocated based on the reported cultivated area of that crop. For alfalfa and red clover as preceding or succeeding crops, one quarter of the yield (equivalent to one cut) is assigned to the main crop group. The data entry has been adjusted accordingly, and the additional harvested crop will be considered part of the main crop of the respective field. Fertilization with both manure and synthetic fertilizer can also be entered separately. As a result, the calculated yields and surpluses per crop will more accurately reflect actual conditions.

Utilization
The discussion above concerns the (im)balance between N-inputs and N-outputs in the soil balance. The N-utilization within this part of the nutrient cycle ($N\text{-utilization}_{soil}$) is equal to the fraction of N-input (according to the convention used in the ANCA Tool, after subtracting ammonia losses during grazing and application of manure and (synthetic) fertilizer) that results in utilizable N-output (i.e., removal by intake of grazing animals, by off-field harvested by cutting, and/or export of harvested products from the farm, including grazing by geese). Further choices must be made regarding whether or not to include cross-terms (Nmin spring, grazing, mowing, and harvesting losses, crop residues, catch crops, and the immobilization and release of N in grassland under crop rotation) in both the numerator and denominator. This also applies to the treatment of the terms In5 (N -deposition) and Out2 (ammonia losses): on a larger scale, these are also cross-terms, as ammonia deposition cannot occur without ammonia emissions.

Conversely, N-input through deposition is beyond the control of an individual ANCA Tool participant and occurs partly outside farm boundaries. This applies indirectly also to In9 (peat mineralization). Although this term cannot be directly influenced by an individual ACNA Tool participant, it is, to some extent, and similar to deposition, the result of collective agricultural management decisions. Taking all these considerations into account, the ANCA Tool defines N-utilization in the soil compartment as follows:

$$N\text{-}utilization_{soil} = (Out1 + Out3) / (In1{+}2{+}3{+}4{+}5{+}6{+}9{+}11 - Out2)$$

4.2.1.2 Allocation N-soil surplus

The amount of leached N is calculated based on the N-soil surplus. To do this, the previously calculated N-soil surplus is first corrected for changes in the N-soil stock. After this correction, the leachable N-soil surplus is obtained as follows:

Leachable N-soil surplus = N-soil surplus – change in N-soil stock

In case of N accumulation in the soil, the correction value is positive, and the leachable N-soil surplus is lower than the initially calculated N-soil surplus. Conversely, if N in the soil decreases, the correction value is negative, and the leachable N-soil surplus is higher than the initially calculated N-soil surplus.

The change in nitrogen stock for mineral soils has been consistently calculated in version 2024 using the formulas below. These apply to the entire area of grassland, corn, and arable land, regardless of whether crop rotation is used or not.

N stock change [kg/ha] = C stock change [kg/ha] × 1/CN ratio

If the user selects region-specific data (see section 6.6), the CN ratio is calculated as follows:

CN ratio = 10 (clay, loess – lutum > 10) or 16 (sand – lutum < 10)

When using field-specific information, the CN ratio from the available soil samples is applied. The stock change for organic soils is by definition equal to zero. This is independent of the mineralization of 235 kg N/ha from the subsoil, which is still applied.

The amount of leached N is then calculated as:

NLEACHED = Leachable N soil surplus × LF

Where:
- *NLEACHED = amount of leached nitrogen (kg/ha)*
- *LF = leaching fraction according to Table 4.4*

The leaching fractions are derived per soil type and land use (grassland or arable land) based on measurements from the *National Monitoring Network for Manure Policy Effects (Dutch: Landelijk Meetnet effecten Mestbeleid)* (*LMM*; http://www.rivm.nl/Onderwerpen/L/Landelijk_Meetnet_effecten_Mestbeleid). The LMM data show that the LF depends on land use (grassland, arable land) and soil type (Table 4.4).

The NLEACHED value is also used for the calculation of indirect N_2O emissions from the soil (see Section 4.2.2).

Table 4.4 *Leaching fractions (LF) in relation to soil type (Brussée et al., 2024).*

Soil type	Leaching fraction	
	Pasture	Arable land
Peat	0.06	0.17*
Clay	0.11	0.33
Moist sand (Gt IV)	0.14	0.38
Moderately dry sand (Gt VI)	0.21	0.58
Dry sand (Gt VII)	0.27	0.74
Loess	0.14	0.74

* Not specified in Brussée *et al.*, 2024, but estimated based on the ratio of values for arable land and grass land for other soil types.

4.2.2 Emissions of N_2O from the soil

This section describes the method of calculating the average annual N_2O emissions from the soil on a farm in the Netherlands. This emission is initially calculated in kg N_2O-N per farm. Soil emissions represent the largest contribution. The other sources of farm N_2O emissions, i.e., those from manure storages, are discussed in section 4.2.3.

The generally accepted 'Tier 1' calculation rules of the IPCC (2019) are used to calculate N_2O emissions from the soil. Where possible, the emission factors of the simple IPCC 'Tier 1' scheme have been replaced by Dutch emission factors as provided in Van Bruggen *et al.*, 2024 and Arets *et al.*, 2023. In addition, the calculations are also tailored to the specific farming situation as indicated by ANCA Tool user (farm-specific N-flows).

The IPCC's calculation method estimates the N_2O soil emission as a fraction of an N input in/to the soil. The total calculation method therefore consists of quantifying the relevant N-flows on the farm and the associated emission factors.

With regard to N_2O soil emissions, a distinction is drawn between direct and indirect soil emissions. Direct emissions take place on the farm. Indirect emissions relate to emissions that do not occur within the farm but are a direct result of N volatilisation, runoff and leaching from the farm.

4.2.2.1 Direct soil emissions

The direct N_2O soil emissions consist of emissions resulting from fertilization (use of synthetic and organic fertilizers), emissions from crop residues, and, in the case of peat soils, emissions due to peat decomposition. The emission factors depend on land use (grassland or cropland) and soil type (mineral or peat soils) (see Table 4.5). As the N inputs per soil type within a given land use (grassland, cropland) are not known, an area-weighted average emission factor is calculated for both grassland and cropland. The N_2O soil emission per unit of N input is then obtained by multiplying the area-weighted emission factor for grassland and cropland by the average N input for grassland and cropland. If the distribution of the two land use types (grassland and cropland) across mineral and peat soils is unknown, the dominant soil type of the farm is used.

Up to and including 2022, the N_2O emission calculation also included background emissions from both mineral and peat soils. Since NEMA does not account for these background emissions, and the ANCA Tool calculations aim to align as closely as possible with NEMA, it was decided to exclude these emissions from the calculation.

Below, the calculation per N input is explained. For grassland, this concerns the area-weighted average of production grassland and natural grassland. For cropland, a distinction is made between silage corn and other arable crops.

Synthetic fertilizer:

$$N_2O\text{-}Nem\text{-}km = GS \times In3_{grass} * EF\text{-}km_{grass} + SC \times In3_{corn\_silage} \times EF\text{-}km_{corn\_silage} + SOC \times In3_{SOC} \times EF\text{-}km_{SOC}$$

Where:

- *GS/SC/SOC = surface of grassland/silage corn land/other cropland (ha)*
- *$In3_{gras/corn\_silage/SOC}$ = N from synthetic fertilizer, kg per ha of grassland, kg per ha of corn silage land, and kg per ha of other cropland*
- *$EF\text{-}km_{grass/corn\_silage/SOC}$ = emission factor for the use of synthetic fertilizer on grassland/corn silage land/other cropland, kg N_2O–N/kg N–km (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

Animal manure:
When applying animal manure, a distinction is made between surface application (S) and low-emission application (LE).

$$N_2O\text{-}Nem\text{-}dm = N_2O\text{-}Nem\text{-}dmS + N_2O\text{-}Nem\text{-}dmLE$$

$$N_2O\text{-}Nem\text{-}dmS = GS \times In2a_{grassS} \times EF\text{-}dm_{grassS} + SC \times In2a_{corn\_silage\_S} \times EF\text{-}dm_{corn\_silage\_S} + SOC \times In2a_{SOC\_S} \times EF\text{-}dm_{SOC\_S}$$

$$N_2O\text{-}Nem\text{-}dmLE = GS \times In2a_{grassLE} \times EF\text{-}dm_{grassLE} + SC \times In2a_{corn\_silage\_LE} \times EF\text{-}dm_{corn\_silage\_LE} + SOC \times In2a_{SOC\_LE} \times EF\text{-}dm_{SOC\_LE}$$

Where:

- *GS/SC/SOC = surface of grassland/silage corn land/other cropland (ha)*
- *$In2a_{grassS/corn\_silage\_S/SOC\_S}$ = N in surface-applied animal manure, kg per ha of grassland, kg per ha of corn silage land, and kg per ha of other cropland*
- *$In2a_{grassLE/corn\_silage\_LE/SOC\_LE}$ = N in low-emission–applied animal manure, kg per ha of grassland, kg per ha of corn silage land, and kg per ha of other cropland*
- *$EF\text{-}dm_{grassS/corn\_silage\_S/SOC\_S}$ = emission factor for surface-applied animal manure on grassland/corn silage land/other cropland, kg N_2O–N/kg N–dmS (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

- *$EF\text{-}dm_{grassLE/corn\_silage\_LE/SOC\_LE}$ = emission factor for low-emission–applied animal manure on grassland/corn silage land/other cropland, kg N_2O–N/kg N–dmLE (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

Compost/mushroom compost:

$$N_2O\text{-}Nem\text{-}comp = GS \times In2b_{grass} \times EF\text{-}comp_{grass} + SC \times In2b_{corn\_silage} \times EF\text{-}comp_{corn\_silage} + SOC \times In2b_{SOC} \times EF\text{-}comp_{SOC}$$

Where:

- *GS/SC/SOC = surface of grassland/silage corn land/other cropland (ha)*
- *$In2b_{grass/corn\_silage/SOC}$ = N in compost and mushroom compost, kg per ha of grassland, kg per ha of corn silage land, and kg per ha of other cropland*
- *$EF\text{-}comp_{grass/corn\_silage/SOC}$ = emission factor for the use of compost/ mushroom compost on grassland/corn silage land/other cropland, kg N_2O–N/kg N–comp (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

Grazing Manure:

Grazing manure refers to the N excreted in the pasture and consists of manure excreted by livestock on pasture (In1) plus the N added in the form of goose manure (Aan11).

$$N_2O\text{-}Nem\text{-}gm = GS \times (In1+In11) \times EF\text{-}gm$$

Where:

- *GS = grassland area (ha)*
- *In1/In11 = N in grazing manure/N excretion from geese (kg per ha of grassland)*
- *EF–gm = emission factor for grazing manure (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

Crop residues

In the IPCC 'Tier 1' calculation methodology, the N that enters the soil through crop residues left on the field is also considered a source of N_2O emissions. The IPCC uses an expanded definition of crop residues: in addition to root and stubble residues from arable land (Out4), crop residues also include grazing, mowing, and harvest losses from grassland and arable land (Out3), as well as green fertilizer/catch crops or catch crops grown after main arable crops (Out5). For N_2O emissions associated with crop residues in the form of root and stubble material from grassland, the IPCC (2019) applies a different calculation method. The IPCC (2019) states that *"the nitrogen residue from perennial forage crops is only accounted for during periodic pasture renewal, i.e. not necessarily on an annual basis as is the case with annual crops."* This means that the average number of hectares of grassland teared each year must be known. This includes both grassland that is teared and reseeded (re-sowing) and grassland that is teared and subsequently converted to arable land.

Based on the previous, the N_2O emission from crop residues is estimated as:

$$N_2O\text{-}Nem\text{-}cr = N\text{-}cr \times EF\text{-}cr + (SG\text{-}WGO)_{teared} \times EF\text{-}reseeded$$

Where:

- *$N\text{-}cr = SG \times Out3_{grassland} + SC \times Out3_{corn} + ORO \times Out3_{other\_roughage} + SA \times Out4_{arable} + SC \times Out5_{corn\ land} + (SA - SC) \times Out5_{non\text{-}corn\ land}$*
- *EF-reseeded = emission factor for tearing grassland for reseeding: 5.5 kg N_2O–N per ha of teared grassland*
- *SG, SA, SC, ORO, WGO, WBO = surface areas (ha) of, respectively, all grassland, all arable land, corn land (corn silage, CCM, MKS), other arable-roughages, grassland in rotation, and arable land in rotation*
- *$(SG\text{-}WGO)_{teared}$ = area of permanent grassland where reseeding takes place (ha)*
- *$Out3_{grassland}$ = amount of N in grazing, mowing, and harvest losses from grass*
- *$Out3_{corn}$ = amount of N in harvest losses from corn*

- *$Out3_{other\_roughage}$ = amount of N in harvest losses from other forage crops*
- *$Out4_{arable}$ = area-weighted average amount of N in crop residues of arable crops including corn, according to Table 4.3*
- *$Out5_{corn\ land}$ = N content of green fertilizers on corn land (40 kg N/ha)*
- *$Out5_{non\text{-}corn\ land}$ = area-weighted average N content of green fertilizers on other arable land excluding corn land, expressed as fallow land (Out5 = 0), non-leguminous green fertilizer (Out5 = 80 kg N/ha), and leguminous green fertilizer (Out5 = 60 kg N/ha)*
- *EF-cr = emission factor N from crop residues, kg N_2O–N per kg of crop residue N (area-weighted according to the fraction of mineral and peat soils, Table 4.5)*

Change in soil N stock – mineral soils

N_2O-N emissions are also included when there is a decrease in the organic N stock in the soil on mineral soils. This occurs, for example, during the arable phase of crop rotations, but it may also take place on continuously cropped arable land. The N_2O-N emission is calculated as follows:

$$N_2O\text{-}N\text{-}em\text{-}DeltaNsoil_{mg} = (Delta\text{-}N\text{-}soil_{CR} + Delta\text{-}N\text{-}soil_{CC}) * EF\text{-}DeltaNsoil_{ms}$$

Where:

- *$Delta\text{-}N\text{-}soil_{CR}$* = decrease in the organic N stock in the soil on the area of arable land within the crop rotation part of the farm, kg/ha
- *$Delta\text{-}N\text{-}soil_{CC}$* = decrease in the organic N stock in the soil on the area of continuously cropped arable land, kg/ha
- *$EF\text{-}DeltaNsoil_{ms}$* = emission factor for the decrease in organic N stock in the soil on mineral soils, kg N_2O-N per kg decrease in N stock (area-weighted correction factor for mineral and peat soils, Table 4.5)

For the calculation of the decrease in N stock on mineral soils, see Section 4.2.1.2.

Change in soil N stock on peat soils

In the Netherlands, drainage of peat soils on dairy farms leads to a gradual subsidence of the soil and enhanced decomposition of the existing soil organic matter, during which N is also released. The N_2O emission associated with peat mineralization is estimated as follows:

$$N_2O\text{-}Nem\text{-}DeltaNsoil_{peat} = TS \times \text{fraction peat soil in } TS \times EF\text{-}\ EF\text{-}DeltaNsoil_{peat}$$

Where:

- *TS = total farm surface*
- *$EF\text{-}DeltaNsoil_{peat}$ = 4.7 kg N_2O-N per ha*

By multiplying the calculated N_2O–N emissions by 44/28, the total direct N_2O farm emission is obtained in kg N_2O per year.

***Table 4.5** The emission factors used in the ANCA Tool for N_2O-emissions from the soil, unless stated otherwise, are expressed in kg N_2O-N per kg N input (Van Bruggen et al., 2024).*

	Input	EF[1]	Grassland		Arable land	
			Minerale soil	**Peat soil**	**Minerale soil**	**Peat soil**
Direct	Synthetic fertilizer[2]	EF-sf	0.008	0.03	0.007	0.03
	Animal manure, above ground[2]	$EF\text{-}am_A$	0.001	0.005	0.006	0.005
	Animal manure, low-emission[2]	$EF\text{-}am_{LE}$	0.003	0.01	0.013	0.01
	Compost en mushroom compost[2]	EF-comp	0.004	0.004	0.004	0.004
	Pasture manure[3]	EF-pm	0.025	0.06		
	Crop residues[4]	EF-cr	0.01	0.01	0.01	0.01
	Grassland renewal[5], *kg N_2O-N/ha*	EF-gr	5.5	5.5		
	Decrease in soil N stock, mineral soil	$EF\text{-}DeltaNsoil_{ms}$	0.01		0.01	
	Decrease in soil N stock, peat soil[6], *kg N_2O-N/ha*	$EF\text{-}DeltaNsoil_{peat}$		4.7		4.7
Indirect	Ammonia[4]	$EF\text{-}NH_3$	0.014	0.014	0.014	0.014
	Nitrate[4]	$EF\text{-}NO_3$	0.011	0.011	0.011	0.011

1 Code emission factor as used in the text.
2 Based on Velthof & Mosquera (2011).
3 Based on Velthof *et al*. (1996).
4 IPCC, 2019.
5 Reseeding of grassland, based on Velthof *et al*. (2010); difference in N_2O-N-emission between grassland tearing in spring (8,2 kg N_2O-N/ha) and not tearing (2,7 kg N_2O-N/ha).
6 Value is based on a net decrease of 235 kg N per ha per year due to oxidation of soil organic matter and an emission factor of 0.02 kg N_2O-N per kg mineralized N (based on Kuikman *et al*. (2005)).

Additive Vizura

Vizura is a nitrification inhibitor that is added to animal manure just before field application. This additive slows down the conversion of NH_4–N into NO_3–N, thereby reducing N_2O–N emissions from animal manure by 50%. It is assumed that Vizura is only applied to slurry and digestate, hereafter referred to as *sldigest*. The calculation of the reduction in N_2O–N emissions is outlined below. The following steps are carried out:

1. Calculation of Vizura consumption

The consumption is calculated based on the amount supplied and the change in stock:

$$Vizura_{consumption} = Vizura_{start} - Vizura_{end} + Vizura_{supplied}$$

2. Calculation of area fertilized with sldigest on grassland and arable land

For the areas fertilized with sldigest, the calculation is based on the surface area per application. That is, if a grassland plot is fertilized three times, the fertilized surface area is three times the actual plot area. To calculate this, an assumption regarding the dosage per fertilization is needed. For grassland and corn land, an application of 20 and 44 tons per hectare, respectively, is used (https://vruchtbarekringloopachterhoek.nl/resultaten-kringloopwijzer-2017-t-m-2022/). The fertilized surface areas are then calculated as:

SurfG_sldigest = applG_tonne / 20
SurfC_sldigest = applC_tonne / 44
SurfOA_sldigest = surface area of other arable crops with sldigest

Where:
- *SurfG/C/OA_sldigest = surface area of grassland/corn land/other arable crops*
- *applG_ton/ applC_ton = amount of applied sldigest on grassland and cornland*

3. Calculation of Vizura use distribution over grassland, corn land, and other arable land

First, the usage is allocated to corn and other arable land based on the proportional distribution of applied manure over the crops, while taking into account a maximum application rate of 2.5 L Vizura per hectare. The remaining portion is assigned to grassland.

VizuraC_ltr = Minimum(Vizura_used x applC_tonne/applT_tonne , 2,5 x SurfC_sldigest)
VizuraOA_ltr = Minimum(Vizura_verbr x applOA_tonne/applT_tonne , 2,5 x SurfOA_sldigest)
VizuraG_ltr = Vizura_used - VizuraC_ltr - VizuraOA_ltr

Where:
- *VizuraG/C/OA_ltr = amount of Vizura applied on grassland/corn land/other arable land, ltr*
- *applC_tonne/applOA_tonne = amount of applied sldigest on corn land/other arable land*
- *applT_tonne = total amount of sldigest applied*

4. Calculation of surface areas fertilized with Vizura

The surface area fertilized with Vizura is calculated by dividing the amount of Vizura used by the dosage of 2.5 L/ha, with the fertilized area as the upper limit:

VizuraG_surf = Minimum(VizuraG_ltr/2,5, SurfG_sldigest)
VizuraC_surf = Minimum(VizuraC_ltr/2,5, SurfC_sldigest)
VizuraA_surf = Minimum(VizuraA_ltr/2,5, SurfA_sldigest)

5. Calculation of fraction of surface area fertilized with Vizura

This is calculated by dividing the previously calculated area where Vizura was applied by the total area fertilized with sldigest.

VizuraG_frac = VizuraG_surf / SurfG_sldigest
VizuraC_frac = VizuraC_surf / SurfC_sldigest
VizuraA_frac = VizuraA_surf / SurfA_sldigest

6. Calculation of N_2O-reduction with application of sldigest

Finally, the reduction in N_2O emissions for the crops is calculated by multiplying the reduction at a dose of 2.5 liters per ha (50%) by the fraction of the area on which Vizura was applied.

ApplG_N_2Ored = 50 x VizuraG_frac
ApplC_N_2Ored = 50 x VizuraC_frac
ApplA_N_2Ored = 50 x VizuraA_frac

The above calculation rules are based on the assessment carried out according to the ZuivelNL procedure (https://cdn2.assets-servd.host/zuivel-nl/production/images/ZuivelNL-Procedure-beoordeling-product-KringloopWijzer-20230606.pdf).

4.2.2.2 Indirect N_2O-emissions

As indicated above, the so-called N_2O emissions result from NH_3 volatilization (NH_3) in the field and N leaching and runoff (nitrate), and are calculated as follows:

N_2O-Nem-NH_3 = EF-NH_3 x NH_3-N-loss

Where:
- *EF-NH_3 = emission factor, kg N_2O-N/kg NH_3-N (see Table 4.5)*
- *NH_3-N-loss = total NH_3-N loss in the field according to the BEA in kg NH_3-N*

and

N_2O-Nem-NO_3 = EF-NO_3 x NO_3-N-loss

Where:
- *EF-NO_3 = emission factor, kg N_2O-N/kg NO_3-N (see Table 4.5)*
- *NO_3-N-losss = N-soil surplus x LF (according to the BEN, Table 4.5)*

By multiplying with 44/28, the total indirect N_2O-farm emission is obtained in kg N_2O per year.

4.2.3 Emission of N_2O from housing and manure storages

4.2.3.1 Dairy cattle

This section describes the method of calculating the average annual N_2O emission from the manure storage facilities of a dairy farm in the Netherlands. This emission is initially calculated in kg N_2O-N per farm. The following manure management systems are distinguished:
- Liquid 'barn manure' in storage (slurry).
- Solid 'barn manure' in storage (solid manure).

Slurry is considered to be stored in a manure pit under the barns and in manure storage facilities outside the barns. Solid manure is considered to be stored in the barn (e.g. deep litter barn) and in an outdoor storage facility (manure heap). On farms with primary manure separation, where urine and faeces fractions are produced, the same emission factors are used as for slurry. This section is limited to N_2O emissions from manure produced in the barn, which is then temporarily stored and/or treated/processed before being removed. N_2O emissions resulting from manure produced on pasture are discussed in section 4.2.2.1.

The emission of N_2O from animal manure during storage and treatment depends on the N and C content of the manure, the storage time of the manure in storage and the method of treatment. During storage, the manure often becomes low in oxygen, which inhibits nitrification and keeps denitrification low. Nitrification is the process of converting ammonium (NH_4^+) into nitrate by bacteria under oxygen-rich conditions. Nitrous oxide can be formed as a by-product, especially if nitrification is inhibited by a lack of oxygen. No organic matter is required for nitrification. Denitrification is the process by which bacteria convert nitrate (NO_3^-) into the gaseous nitrogen compound N_2 under anoxic conditions, with the by-product N_2O. In this process, organic matter is used as an energy source. The N_2O emission from solid manure is higher than the emission from liquid manure, because nitrification hardly occurs in liquid manure due to a lack of oxygen.

The emission of N_2O from animal manure is calculated as follows:

$$N\_2\,O\_((Dmm)) = [\textstyle\sum\_M\,[\textstyle\sum\_T\ 〚Nexcretion〛\_T *\ 〚MS〛\_((T,M))\,)\,] *\ 〚EF〛\_((M))\,] * 44/28$$

Where:
- *$N_2O_{(Dmm)}$ = N_2O-emission of manure management system in kg*
- *Nexcretion(T) = total N excretion per animal category T in kg (with T = dairy cattle, youngstock, or (total) other grazing animals). This N excretion refers to the gross excretion ("under the tail"), i.e., not reduced by gaseous N losses from the barn and storage, as calculated in the BEX (see Chapter 2). This calculation method corresponds to the IPCC methodology (IPCC, 2019). No account is taken of imported or exported manure. According to IPCC conventions, N_2O emissions from manure storage only relate to manure produced on the farm itself*
- *$MS_{(T,M)}$ = fraction of the total N-excretion per animal category T according to manure management system M*
- *EF(M) = emission factor for the defined manure management system M in kg N_2O-N/kg excreted manure-M*
- *M = manure management systems: liquid manure system and solid manure system*
- *44/28 = conversion factor from kg N_2O-N to kg N_2O*

The amount of manure produced is determined using the 'Tier 3' method (i.e. country-specific). Country-specific ('Tier 3') values are also used for the emission factors. The calculations are made according to the National Ammonia Emission Model (NEMA; Velthof *et al.*, 2012; Van Bruggen *et al.*, 2024). In addition to NH_3, the model estimates emissions of N_2O, NO and N_2 from barns and storages (Tables 3.3 and 3.4).

The emission factors use the default values of IPCC (2019) (Table 4.6).

Table 4.6 *Emission factors (EF_S) per manure management system in kg N_2O-N / kg N excreted manure.*

Manure management system	Emission factors (kg N_2O-N / kg N excreted manure in the barn)
Liquid manure	0.002
Solid manure	0.005

Bron: IPCC, 2019

4.2.3.2 Other grazing animals

For 'other grazing animals', the fixed net manure-N production (Table 3.7) is first converted to gross manure-N production based on the net/gross ratio (Table 3.1), similar to the calculation of the TAN production. Then it is calculated how much N_2O-N is formed, using the N_2O-N emission factors (Table 4.7).

Table 4.7 *Emission factors (EF_S) per animal category in kg N_2O-N/kg N excreted manure.*

Animal category	Emission factors in kg N_2O-N / kg N Excreted manure in the barn	
	Liquid manure	Solid manure
Breeding bulls > 1 year (cat. 104)	0.002	0.005
Pasture and suckler cows (cat. 120)	0.002	0.005
Calves for rosé or red meat (cat. 115)	0.002	0.005
Rosé calves, 3 months – slaughter (cat. 116)	0.002	0.005
Rosé calves, 2 weeks – slaughter (cat. 117)	0.002	0.005
Red meat bulls, 3 months – slaughter (cat. 122)	0.002	0.005
Breeding sheep (cat. 550)	0.005	0.005
Meat sheep, < 4 months (cat. 551)	0.005	0.005
Other sheep, > 4 months (cat. 552)	0.005	0.005
Milk goats (cat. 600)	0.01	0.01
Rearing and meat goats, < 4 months (cat. 601)	0.01	0.01
Rearing and meat goats, > 4 months (cat. 602)	0.01	0.01
Ponies (cat. 941)	0.005	0.005
Horses (cat. 943)	0.005	0.005
Donkeys (cat. 961)	0.005	0.005
Water buffalo, cows (cat. 991)	0.002	0.005
Water buffalo, youngstock (cat. 992)	0.002	0.005

4.2.3.3 'Indoor housed animals'

Fixed nitrous oxide emissions, which do not depend on the ration composition, are used for the category 'indoor housed animals'. These depend on the animal type and barn type, using the equation:

*Nitrous oxide emission (kg N2O) = ANA x nitrous oxide (kg N_2O-N per animal) * 44/28*

where:
ANA = average number of animals present (from the input data)
Nitrous oxide = emission in kg N per animal (Table 4.8)

Table 4.8 *Gross N excretion (kg N per animal place) and emission factors of N_2O-N (EF_{N2O}) and of the other gaseous N losses (other than NH_3 (EF_{notNH3})) in kg N per 100 kg gross N excretion for slurry (SLM) and for solid manure (SM).*

Animal category	Gross N excretion (kg N per animal place)	EF_{notNH3}, DM	EF_{notNH3}, VM	EF_{N2O}, DM	EF_{N2O}, VM
Farrowing sows	29.8	2.4	3.5	0.2	0.5
Dry and pregnant sows	20.7	2.4	3.5	0.2	0.5
Weaned piglets	2.2	2.4	3.5	0.2	0.5
Fattening pigs	11.6	2.4	3.5	0.2	0.5
Laying hens	0.76	1.2	0.7	0.1	0.1
Broilers	0.43	1.2	0.7	0.1	0.1
White meat calves	14.3	2.4	3.5	0.2	0.5

4.2.3.4 Emission of N_2O from manure separation

N_2O is also emitted when manure is separated. These losses occur during storage of the solid fraction. NEMA only gives total losses, including losses during storage of the slurry prior to separation. These amount to 0.5% of the input N from slurry. A proportion of this emission is already accounted for in the ANCA Tool during the calculation of barn storage, namely 0.2% of the N in slurry (Table 4.5). To prevent double counting, this quantity must be deducted from the above percentage of 0.5%. The additional N_2O losses for manure separation are shown in Table 4.8.

Table 4.3 *Additional N_2O-losses from the separation of slurry and the storage of the thin and thick fraction (derived from NEMA) in kg N_2O-N / kg N.*

Ingaande drijfmest	Emission factors (kg N_2O-N / kg N incoming slurry)
Grazing animals	0.003
Indoor housed animals	0.003

4.2.3.5 Indirect N_2O-emissions

Indirect N_2O-emissies arise because of volatilization losses (NH_3-N- en NO_x-N) from the barn and manure storage and are calculated as follows:

N_2O-Nem (vol) = EF(vol) x Nloss (vol)

where Nloss (vol) = total NH_3-N loss from the barn and storage according to BEA in kg NH_3-N and the total NO_x-N-loss. For the emission factor EF(vol) the same value is used as for the indirect N_2O emissions from the soil due to NH_3-N-volatilization (see section 4.2.2.2).

4.2.4 Other gaseous N-losses, other than NH_3-N and N_2O-N

In the previous, it was indicated where and how much N is lost as ammonia, nitrate and nitrous oxide. The remaining difference between input and output of N is attributed to stock changes on the farm (synthetic fertilizer/manure, feed, livestock) and in the soil (especially organic N) and gaseous losses other than NH_3-N and N_2O-N. It is assumed that these ‘residual gaseous N losses’ not only occur from the soil but also to a small extent from the barn and manure storages and from silage pits. These are losses in the form of N_2 and NO_x.

In Figure 1.3, the item ‘conserved roughage and by-products’ is shown. It is the sum of the harvested roughage, the balance of sold and purchased roughage (positive value if more is sold than bought) and by-products (adjusted for stock changes). The remaining gaseous N losses from these silage pits are calculated at 3, 1 and 1.5% for ensiled grass, corn (corn silage, MKS and CCM) and additional roughage including wet (b)products, respectively (Table 1.1).

The remaining gaseous N losses from the barn and storage are calculated as the difference between other gaseous N losses according to Tables 3.7 (other grazing animals) and Table 3.10 (indoor housed animals) (for the purpose of calculating non-ammonia losses) and the nitrous oxide losses according to Table 4.7 (other grazing animals) and Table 4.8 (indoor housed animals), with losses always being based on the sum of the gross excreted amount of manure in the barn, the exported manure and the imported manure (corrected for stock changes).

For soil emissions, the 2024 version of the ANCA Tool also includes NO_x (NO + NO_2) emissions. For this, N from all N sources (e.g., organic manure, pasture manure, synthetic fertilizer, and crop residues) is assumed to have a loss of 1.2% of the available N (Van Bruggen *et al.*, 2024). For the annual peat decomposition on peat soils, NO_x emissions are not reported in the NEMA reports. In the ANCA Tool, the same emission factor as for nitrous oxide is used (2%: 235 kg N per ha × 0.02 = 4.7 kg NO_x-N per ha). The remaining gaseous N loss from the soil is N_2. This is calculated as the difference between the total gaseous N-loss and the N_2O-N and NO_x-N losses.

4.3 Comments on BEN

It has been decided not to wait with introducing the ANCA Tool until every conceivable type of farm and, within it, every N-flow can be calculated. The ANCA Tool, therefore, is not yet suitable for:

- Accurately evaluating the crop-specific N utilizations within the grassland and arable land phase of rotation systems is challenging because the N yields do not distinguish between rotation and continuous cropping, and the output items of grazing, mowing and harvesting losses are not yet exactly assigned to the correct subsequent crops as input terms.
- In the ANCA Tool, the mineralisation from peat soil with grassland is set at 235 kg N per ha per year. This number is taken from Kuikman *et al.* (2005). In previous publications, the same mineralisation with reference to Van Kekem (2004) was estimated at 160 kg N per ha, per year. Further research on which of the two numbers is recommended.
- With regard to nitrate leaching, it is noted that the relationship between the calculated N surplus and the nitrate N concentration in the upper groundwater or near surface water is derived from observations on many farms and over many years. The average of these observations was then determined. Even within the same soil type (peat, clay, sand), dewatering class (wet, dry) and type of land use (grassland, arable land), however, there is a very large spread between farms and years. That variation is due to the fact that the terms mineralisation and fixation are not in balance every year, precipitation surpluses vary, and denitrification depends on more factors than mentioned here. From this point of view, assessing farm performance based on only one or a few years is questionable, and the predicted nitrate concentrations should therefore be interpreted as an indication of the nitrate concentration under average conditions for the soil type, dewatering class and land use concerned.
- With regard to the emissions of N_2O from the soil, the following should be noted. These emissions vary greatly in space and time, which often requires many measurements. Total annual emissions are usually determined based on a limited number of measurement periods (e.g. part of the day and a number of days in the year) and by interpolation the total year-round emissions are estimated. Partly as a result of this, there is a great deal of uncertainty and room for improvement in the calculation method and the determination of the emission factors and other parameters. In 2013, national and international experts were invited to talk about improvements and alternative methods (workshop 7-03-2013, Wageningen). The methodology followed in BEN (based on 'Tier 1' of the IPCC (2019)), provides a foundation in which future improvements can be easily incorporated, either in consultation with international experts or not. Based on a limited literature review, the following aspects in particular appear to be eligible for future adjustments:
  - N_2O emission from unfertilised fields.
    The Velthof & Mosquera database (2011) provides a large number of field studies for a new determination of the emission from unfertilised fields.
  - Effect of average soil moisture conditions.
    Major effects are to be expected from the average soil moisture conditions of mineral soils and peat soils. Literature research shows a relationship between the average groundwater level and

the N_2O emissions from peat soils in the Netherlands, which could be used in a subsequent version of the BEN. This, of course, does increase the input requirements of the BEN.

- Grassland renewal.
  Experiments have indicated that grassland renewal also changes the emission factors of the applied fertilizer compared to the situation without renewal. Through additional literature review adjusted emission factors can be determined more accurately.
- Changes in organic matter content.
  The BEN takes into account the extra N_2O production that results from peat mineralisation, but ignores the N_2O production that would occur if the organic matter content of a mineral soil decreases. This should be taken into account in the future version of the BEN.
- Balance method.
  An alternative calculation method is based on the idea that the N_2O emission can be described as a fraction of the total denitrification, or of soil N surplus. In literature, examples have been found that used this method. However, more literature research and consultation with experts is needed to determine reliable emission factors for this method.

5 BEP: farm-specific P flows

5.1 Introduction

The BEP aims to calculate how much P (P_2O_5) is removed from the land through grazing animals (through the intake of grazing animals), harvested crop products (‘off field harvest, before storage’) and, if applicable, eaten by geese. This metric provides insight into how much P must be supplied in the form of manure and / or synthetic fertilizer to maintain a balance between inputs and outputs.

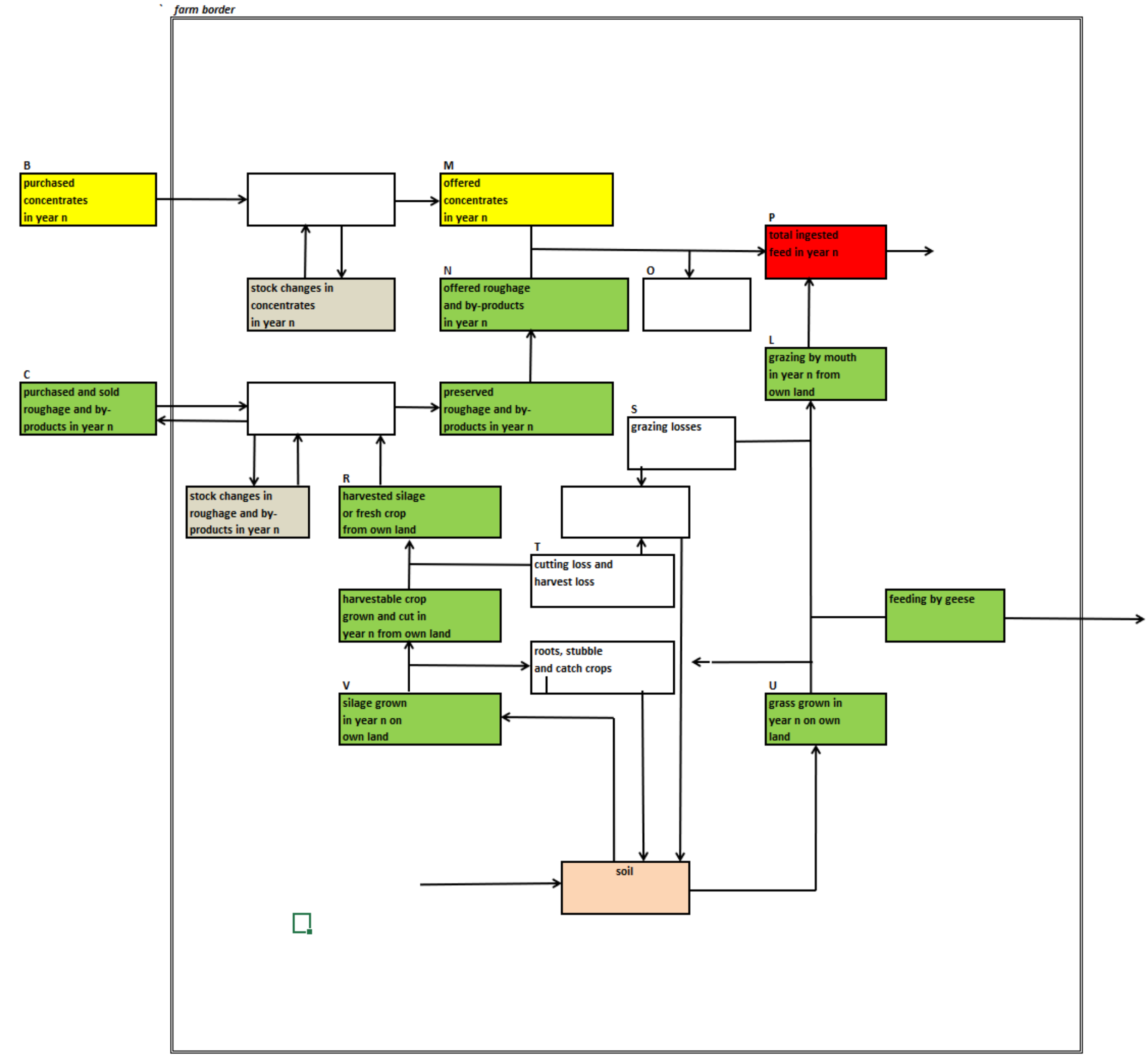

Figure 5.1 *Nutrient flows involved in calculating the amount of P harvested by machines and animals from a dairy farm’s own land without an arable production branch.*

5.2 Calculation method

In the context of the BEX, the total VEM requirement of the dairy herd on the farm is calculated based on herd composition and production. A breakdown is made into purchased feeds (concentrates, purchased roughage) and self-cultivated roughages (pasture grass, silage grass, maize silage (silage maize, MKS and CCM), alfalfa, field beans, whole plant silage of cereals). By multiplying each of these feeds by their farm-specific P/VEM ratio, the amount of P (kg P_2O_5) taken up from homegrown feed and harvested either through animal intake during grazing or via mowing is calculated. Figure 5.1 clarifies this.

P intake from own feed = total P intake - P intake from purchased feed, *(Eq 5.1)*

where:
P intake from own feed = P in roughage harvested by intake of grazing animals or mowing - P feed leftovers$_{own_feed}$, ↔ P in roughage harvested by intake of grazing animals or mownl = P intake from own feed + P feed leftovers$_{ownfeed}$ *(Eq 5.2)*

and:

P intake from purchased feed = P in purchased feed - P stock change - P feed leftovers $_{purchased\_feed}$ *(Eq 5.3)*

It is assumed here that the feed loss is 2 to 5%, depending on the type of feed (Table 1.1), with the feed leftovers calculated as follows:

Feed leftover-P = 0.05 x (P intake in the form of conserved grass and corn silage / (1- 0.05)) + 0.03 x (P intake in the form of other self-cultivated roughage and wet (by) products/(1 - 0.03)) + 0.02 x (P intake in the form of concentrates, compound feed and milk products/(1 - 0.02)) *(Eq 5.4)*

Furthermore, it is assumed that no P is lost during the conservation of purchased or self-cultivated roughage. The sum of the P in roughage harvested by intake of grazing animals or off-farm removal and P in purchased feed ends either up in stocks, or in the manure of the dairy cattle, or in feed leftovers of the dairy cattle, or in milk and meat of dairy cattle:

P in roughage harvested by intake of grazing animals or off-farm removal + P in purchased feed corrected for stock changes = P in manure (including feed leftovers) + P in milk and meat from dairy cattle *(Eq 5.5)*

The amount of P in roughage harvested via intake of grazing animals or off-farm removal is corrected for reported/entered stock changes in inventory and for purchased feed. Since a model deviation arises from the BEX calculation, the stock change and purchased feed are corrected with a so-called ‘roughage factor’. This factor corresponds to the ratio between P intake from grass silage and corn silage according to the BEX module, and the P intake from own grass silage and corn silage according to data entry. This entry is equal to P stock changes in grass silage and corn silage plus the existing stock of grass silage and corn silage. The consequence of this correction is also that the amount of P in roughage harvested via intake of grazing animals or off-farm removal (only the proportions of grass silage and corn silage) changes. In equation format:

*factor_purchase_mutation = (BEX_Pint_gscs_mlk + BEX_Pint_gscs_other) / (Stock_Puse_gscs * (1- PcFeedlossRoughage /100))*

factor_ purchase_mutation = Factor for the ratio between declared P-input and P-stock mutation in the form of grass silage and corn silage and the P intake according to the BEX

BEX_Pint_gscs_mlk = P intake of dairy cattle from grass silage and corn silage

BEX_Pint_gscs_other = P intake of other grazing animals from grass silage and corn silage

Stock_Puse_gscs = P use calculated from declared stocks (start + change - end)

PcFeedlossRoughage = Percentage of roughage feeding losses

Here it is assumed that, unlike with N, no significant losses of P occur by air. Furthermore, the supply to the soil and the discharge from the soil are balanced if:

P in synthetic fertilizer applied to land for roughage cultivation + P in purchased feed for the dairy herd corrected for stock changes = P in milk and meat of dairy cattle ↔

P in purchased feed for the dairy herd corrected for stock changes =
P in milk and meat of dairy cattle - P in synthetic fertilizer applied to land for roughage cultivation. *(Eq 5.6)*

Substitution of Eq 5.6 in Eq 5.5 gives:

P in roughage harvested by intake of grazing animals or off-farm removal + (P in milk and meat of dairy cattle) - P in synthetic fertilizer applied to land for roughage cultivation =
P in dairy manure (including feed leftovers) + (P in milk and meat of dairy cattle)
↔
P in dairy manure (including feed leftovers) + P in synthetic fertilizer applied to land for roughage cultivation = P in roughage harvested by intake of grazing animals or off-farm removal *(Eq 5.7)*

This means that there is equilibrium fertilisation for the land used for the cultivation of the roughage if the P supply via (synthetic) fertilizer for application to land for roughage cultivation is the same as the amount of P in roughage harvested by intake of grazing animals or off-farm removal.

Based on the ratio between the quantities of produced feed stocks of own grass (from production and nature grassland separately) and corn (harvested grass products, intake pasture grass, harvested corn silages (corn, MKS, and CCM), and harvested silages of other roughages (such as alfalfa, field beans, and GPS); see the BEX), a derived P yield is determined for grassland (production and nature grassland separately), corn land, and other roughages. For the amount P from grassland ($P_{grassland}$) the following applies:

$P_{grassland}$ *harvested by intake of grazing animals or off-farm removal = P in roughage harvested by intake of grazing animals or off-farm removal /*
$(P_{cut\_grass} + P_{pasture} + P_{corn\_silage} + P_{other\_silage}) * (P_{cut\_grass} + P_{pasture})$ *(Eq 5.8)*

where:
- P_{cut_grass} = *the amount of P in harvested on-farm produced grass silage or freshly fed grass,*
- $P_{pasture}$ = *the amount of P ingested through grazed grass, including feeding by geese (see section BEN),*
- P_{corn_silage} = *the amount of P in harvested on-farm produced corn silage*
- P_{other_silage} = *the amount of P in harvested silage pits of on-farm produced other roughage.*

For the amount P from corn land the following applies (P_{corn_land}):

P_{corn_land} *harvested through off-farm removal= P in roughage harvested by intake of grazing animals or off-farm removal /* $(P_{cut\_grass} + P_{pasture} + P_{corn\_silage} + P_{other\_roughage}) * (P_{corn\_silage})$ *(Eq 5.9)*

For the quantity P in other roughage from own land the following applies ($P_{other\_roughage}$):

$P_{other\_roughage}$ *harvested through off-farm removal= P in roughage harvested by intake of grazing animals or off-farm removal /* $(P_{cut\_grass} + P_{pasture} + P_{corn\_silage} + P_{other\_silage}) * (P_{other\_silage})$ *(Eq 5.10)*

To determine on dairy farms with an arable and/or 'indoor housed animal' branch whether the import of manure-P and synthetic fertilizer-P is in balance with the export of P in the form of milk and meat from dairy cattle and marketable arable products, the amount of cattle manure calculated in the BEX (pasture manure, barn manure) should be added to the net amount of manure-P derived from the 'indoor housed animal' branch, and the P output in marketable arable crops should be accounted for.

The latter is done by collecting data on the number of hectares of the arable crops listed in Table 4.3 and their average yields for the respective year. Then the P output is calculated by multiplying the yields by crop-specific default values as specified in Table 4.3. For arable crops not included in the table, it is assumed that they have an off-farm removal of 60 kg P_2O_5/ha. This figure is based on the average standard removal from a crop rotation plan consisting of 25% winter wheat, 25% table potatoes, 25% sugar beet and five times 5% of summer barley, summer wheat, grass seed, grain corn and seed onions, each with assumed average yields such as stated by the Dutch Statistical Office (CBS) for the period 2009-2013, whereby only the main products are considered to have been removed. Hence:

P_2O_5 output from the arable category (kg P_2O_5) = $\sum_1^n (SAn\ x\ ((YMn\ x\ CPMn) + (YEn\ x\ CPBn)))$*,*

Where:
- *SAn = surface area arable land area with crop n (ha)*
- *YMn = yield of main product of crop n (tonnes fresh/ha)*
- *YEn = yield of exported by-product of crop n (tonnes fresh/ha)*
- *CPMn = P_2O_5 content of main product (kg N/tonne fresh)*
- *CPBn = P_2O_5 content of by-product (kg P_2O_5/tonne fresh).*

In the BEN (paragraph 4.2.1.1) it has already been indicated that, starting from the 2021 version of the ANCA Tool, it is possible to enter the fertilization and yields of preceding and succeeding crops separately for the main crop groups: grassland, corn silage, and arable crops. As a result, the P_2O_5 yields per crop, as well as the P_2O_5 surpluses per crop, will better correspond to reality.

5.3 Comments on BEP

Earlier research (Oenema *et al.*, 2011) indicates that there is good agreement between the P yield calculated based on estimated P intake from homegrown forages and the actual amount of P harvested. Naturally, the agreement between the two improves when the BEP-calculated P yield is based on data from multiple years.

The figures used for field losses (grazing losses, mowing losses, harvesting losses), conservation losses, and feeding losses are derived from past research. It is strongly recommended to update these figures. The accuracy of the BEP-estimated P yield would also benefit from more precise determination of silage densities, which is currently being studied.

The reliability of the BEP decreases as the proportion of arable farming increases. This is because the P output in the form of marketable arable crops is based on average standardized manure production and contents, which will differ from the actual values.

6 BEC: farm-specific carbon flows and emissions of CO_2 equivalents

6.1 Introduction

One of the aims of the BEC of the ANCA Tool is to estimate how much methane (CH_4) and carbon dioxide (CO_2) are released during the production of milk and meat. This is important because both, like nitrous oxide (N_2O), are so-called greenhouse gases. N_2O emissions are described in the BEN (Chapter 4). These are the emissions that occur on the dairy farm itself as well as the emissions occurring from the production and transport of products imported from outside, such as feed, synthetic fertilizer etc.

The BEC module not only calculates the carbon (C) involved in the production of the greenhouse gases CH_4 and CO_2, but also calculates inputs of effective organic matter (EOM) into the soil (see section 6.5). This is the imported organic matter that is still present one year after application and contributes to humus formation in the soil. If imports are higher than the annual decomposition rate, the organic matter content increases and extra C is stored in the soil. In principle, this additional storage could be deducted from the calculated greenhouse gas emissions. Conversely, if there is a negative balance, the organic matter content of the soil will decrease and extra CO_2 will be released. However, the ANCA Tool does not (yet) estimate the soil-C-balance because it cannot yet be calculated sufficiently accurately. The soil-C-balance is therefore not (yet) included in the quantification of greenhouse gas emissions.

6.1.1 Where do which emissions occur?

Figure 6.1 provides a schematic illustration of where greenhouse gas emissions occur.

CH_4 is released during the digestion of primarily ruminants, during manure storage, and from peat soils. When purchasing feed from external sources, raw materials may also be involved, with methane being produced during their cultivation or processing. This is, for example, the case with rice products and palm kernel meal, as well as purchased roughage that is (partly) grown on peat soils.

To start, CO_2 emissions are related to the use and, if any, the generation of energy on farms. This is because CO_2 is released when fossil energy is used, and CO_2 emissions are avoided when the use of fossil energy is avoided. Energy consumption occurs, for example, in the production of milk. This concerns energy for, for example, cooling, heating and the use of machines in the field and yard. Energy can be consumed in the form of fuels (diesel, gas, propane, fuel oil) or in the form of electricity. Of these fuels, gas can in principle be 'produced' more or less on the farm itself or sourced externally, and, when supplied from outside, it can be based on either fossil or renewable sources. For milk production, in addition to the energy use on the farm itself, raw materials are often used as well, including fertilizers and (concentrate) feed supplied from outside the farm. The production of these materials energy (fossil or renewable) has been used, even if produced off-farm. In addition, the production and transport of smaller supplied inputs such as water, purchased animals, bedding, crop protection products, and plastic are also taken into account.
Short-cycle CO_2, such as CO_2 absorbed by crops and released from decomposing crop residues and manure, as well as CO_2 exhaled by animals, is not included in the greenhouse gas emissions. CO_2 sequestered in the soil is however included.

N_2O is produced in all processes where N is used. The relevant calculation rules are discussed in detail in Chapter 4.

In the calculation of greenhouse gas emissions, housed animals (e.g., pigs, chickens) have been excluded because only part of the data is available. For example, nothing is known in the ANCA Tool about the supply of feed for this livestock sector.

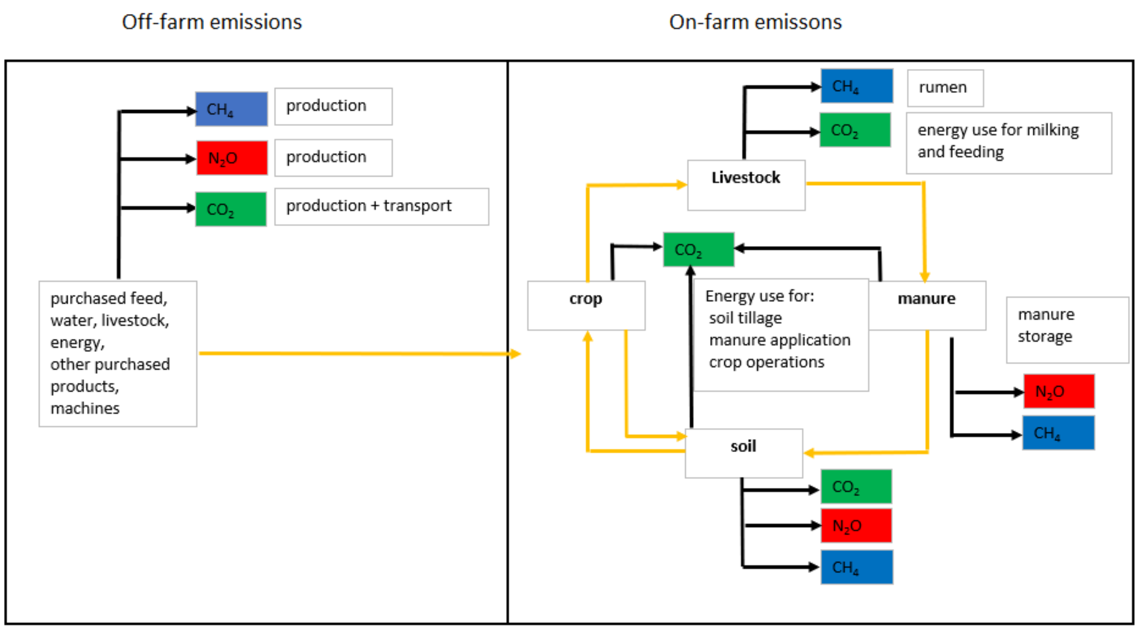

Figure 6.1 *Simplified diagram of greenhouse gas emissions on a dairy farm.*

6.2 Guidelines for calculating emissions

In 2018, the European Commission adopted important rules for calculating greenhouse gas emissions of imported products. The rules are based on the Life Cycle Analysis (LCA). They concern the emissions associated with all inputs and processes required throughout the entire production chain to produce the product. In this way, the BEC calculation differs from the other calculations, as the BEX, BEA, BEN, and BEP are limited to what occurs on the primary farm.

The BEC's chain approach means that, in addition to emissions on the farm itself, the emissions for the following components must also be calculated:

- Production and transport of all inputs on the farm, such as purchased feed, energy (fuels, electricity), water, synthetic fertilizer, crop protection products, ancillary products (e.g. bedding, covering plastic), machinery and livestock;
- Diesel and machine use by contract workers;
- The land use change associated with the cultivation of feed crops outside the farm.

The calculation rules are described in the 'Product Environmental Footprint Category Rules' (PEFCR) for separate products. This includes regulations on:

- Which categories should and should not be included;
- The use of primary data (from the farm itself) and indicate when secondary data (statistical data) are allowed;
- Expressing methane and nitrous oxide in CO_2 equivalents. These are explained in section 6.2.1;
- Including emissions from Land Use Change in the production of crops. This is further explained in section 6.2.2;
- Allocating emissions to milk and live weight on the dairy farm. This is further explained in section 6.2.3;
- The calculation of emissions of methane, nitrous oxide and carbon dioxide are in line with IPCC rules, particularly for methane and nitrous oxide, but leave room for the use of national emission factors. The emission calculations are described in the various parts of this report;

- Reporting of emissions. The PEFCR distinguishes the following categories: a) emissions from fossil sources (including N2O emissions); b) emissions from biogenic sources and c) land use change, including deforestation (Lucf) and emissions from peat soils.

Background information can be found in PEFCR (2018a, b, c).

6.2.1 Expressing methane and nitrous oxide in CO_2 equivalents

To be able to sum the different gases, the greenhouse effect of CH_4 and N_2O is expressed in CO_2 equivalents: 1 kg CH_4 from biological processes corresponds to 27 kg CO_2, 1 kg CH_4 from fossil processes corresponds to 29.8 kg CO_2 and 1 kg N_2O corresponds to 273 kg CO_2 (PEFCR, 2018a).

6.2.2 Calculation of the emission of land use change

The PEFCR Guideline provides clear rules on this. The calculation is strongly based on the method as developed in the PAS2050: 2011 (BSI, 2011) and further developed in the supplement (PAS2050-1: 2011; BSI, 2012). In turn, the PAS calculation is based on calculation methods used in IPCC reporting. The IPCC calculates the total emissions from land use change, the PAS2050 calculates how these are allocated to crops per country. The calculation of these emissions is included in a calculation tool that is part of FeedPrint (Vellinga *et al.*, 2013; Feedprint, 2025) and Agri-Footprint. The PEFCR prescribes that this calculation method may *only* be overridden if certificates are available showing that (for example) soy has been grown in locations where land use change is no longer the case. In the absence of certificates, the standard procedure must be followed.

6.2.3 Allocation of emissions to milk and culled animals

Allocation of emissions occurs in processes where multiple products are created. The calculation rules in LCA and the PEFCR indicate that allocation should be avoided if possible. Therefore, the calculation in the ANCA Tool takes place in two steps:

Step 1
In this step, only the emissions for the dairy cattle branch are included. The emissions that can be clearly calculated and/or measured separately are split into dairy cattle (including youngstock) and other grazing animals+arable farming. This means that, for example, only the energy and feed consumed by the dairy cattle are included, and that if, for example, half of the corn silage is exported, only half of the emissions associated with the cultivation of corn silage is included.

Step 2
In this step, the remaining emissions from the dairy cattle must be allocated to the production of milk (both sold and self-processed) and meat of culled live animals (animals removed off the farm and animals transferred within the farm to a non-dairy branch). This allocation to milk and meat is based on the proportion of energy required required for the production of milk and meat. The following formula is used for this (IDF, 2022):

Milk allocation factor = $NE_m \times M_m / (NE_m \times M_m + \sum(NE_{animal\_culled} \times M_{animal\_culled}))$

Where:
- NE_m = *net-energy for milk production: 3,1 MJ/kg FPCM*
- M_m = *FPCM = kg milk x 0.2534 + 0.1226 * Fat% + 0.0776 * Protein%*
- NE_{animal_culled} = *net-energy need of culled animal (MJ/kg live weight)*
- M_{animal_culled} = *weight culled animal*

The weight of the animals removed from the farm is determined based on the age at which the animal leaves the herd. The average removal age (in months) is provided for the different animal groups (newborn calves, calves, heifers, and cows). Using growth curves for different cattle breeds (Holstein Friesian/other, Jersey, and Jersey crossbreeds), the weight of the removed animals is then determined (M_{animal_culled}), as shown in Table 6.1. Finally, the total amount of net energy for meat production is calculated by multiplying, for each animal group, the weight of the removed animals by the net energy requirement per kilogram of body weight (NE_{animal_culled}, see Figure 6.2 and Table 6.1), and summing these values across all removed animals.

De NE_{animal_culled} is calculated using the following equation (IDF, 2022; IPCC, 2019):

$$NE_{animal\_culled} = 22.02 \times (WT / (c \times MW))^{0.75} \times WG^{1.097}$$

Where:

- *NE_{animal_culled} = Energy requirement per day, MJ/day*
- *WT = Live weight, kg*
- *c = Coefficient (0.8 for dairy cows)*
- *MW = Adult weight cow, kg*
- *WG = weight gain, kg/day*

In Figure 6.2 and Table 6.1 the NE_{animal_culled} is provided for various animal breeds, in relation to animal weight and culling age.

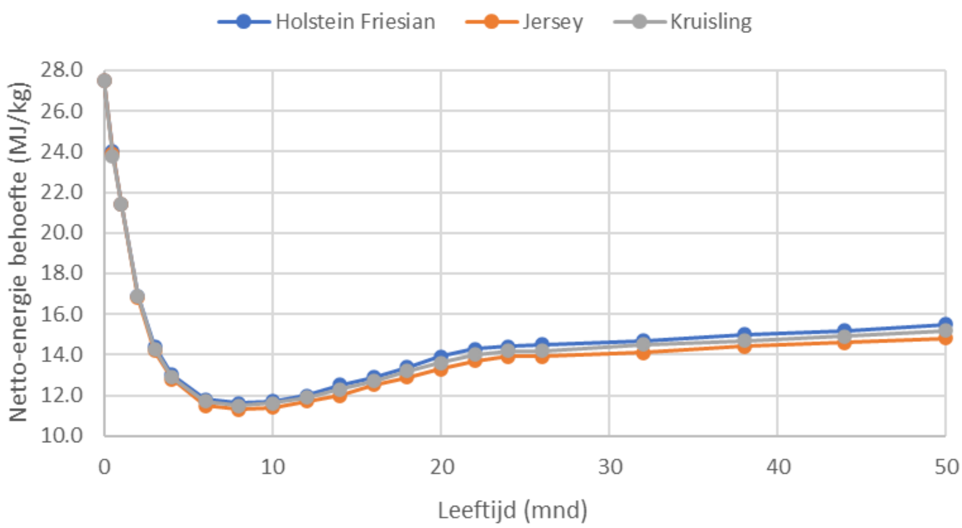

Figure 6.2 *Net-energy requirement (MJ/kg) in relation to the age of the purchased animal (Netto-energie behoefte = net energy requirement; Kruisling = crossbreed; Leeftijd (mnd) = age (months)).*

Table 6.1 *Weight and net-energy requirement per culled animal in relation to age and breed.*

Age	Other (a.o. Holstein Friesian)		Jersey		Jersey-Cross	
	Weight (kg)	Net-energy (MJ/kg)	Weight (kg)	Net-energy (MJ/kg)	Weight (kg)	Net-energy (MJ/kg)
0	44	27.5	27	27.5	36	27.5
0.5	51.5	24.0	32	23.9	42	24.0
1	59	21.4	36	21.4	48	21.4
2	81	16.9	50	16.8	65	16.9
3	105.5	14.4	65	14.2	85	14.3
4	130	13.0	80	12.8	105	12.9
6	184	11.8	113	11.5	149	11.7
8	233	11.6	143	11.3	188	11.5
10	278	11.7	171	11.4	225	11.6
12	320	12.0	197	11.7	258	11.9
14	364	12.5	224	12.0	294	12.3
16	406	12.9	250	12.5	328	12.7
18	444	13.4	273	12.9	359	13.2
20	484	13.9	298	13.4	391	13.6
22	518	14.3	319	13.7	418	14.0
24	534	14.4	329	13.9	431	14.2
26	540	14.5	332	13.9	436	14.2
32	567	14.7	349	14.1	458	14.5
38	595	15.0	366	14.4	481	14.7
44	623	15.2	383	14.6	503	14.9
50	650	15.5	400	14.8	525	15.2

For the allocation factor meat the following applies:

Allocation factor meat = 1 – Allocation factor milk

The CO_2-emission in g CO_2-eq per kg FPCM can now be calculated as follows:

CO_2-emission milk = kg CO_2-equivalents-emission dairy cows/1000 x Allocation factor milk / Production FPCM

6.3 Calculation method for CH_4 emissions

6.3.1 Emissions from rumen fermentation in animals (enteric methane)

With regard to enteric methane emissions, the ANCA Tool is currently limited to ruminants (‘grazing animals’). The methane emission resulting from fermentation in the gastrointestinal tract represents approximately 75-80% of the total methane emission on dairy farms. The rest comes from the manure storage and, if present, from peat soils (currently not yet included). In the calculation, a distinction is made between dairy cattle (including youngstock) and other grazing animals.

6.3.1.1 Dairy cattle (including youngstock)

The emission from the rumen in dairy cattle is calculated according to the most accurate level permitted by the IPCC: the Tier 3 level. This Tier 3 method offers the highest accuracy as well as the greatest steering ability to reduce methane emissions. The Tier 3 method is based on the fact that the methane emission from the rumen depends not only on the level of rumen fermentation (i.e. kg feed ingested and fermented), but also on the particular type of feed material that is ingested and the fermentation conditions in the rumen (acidity). Depending on the nutrient composition and the degree of acidity in the rumen, the ratio between the fermentation products produced in the rumen varies: acetic acid, propionic acid, butyric acid and other volatile fatty acids. With shifts in the ratio of these fermentation products the amount of hydrogen also varies that is produced in the rumen from fermented feed. Because almost no hydrogen disappears from the rumen (< 1%, as shown in experiments), it is assumed that all hydrogen is converted into methane.

The Tier 3 method uses a dynamic mechanistic simulation model to estimate the emission factor (EF) of each of the different feeds (or a total ration) based on the chemical composition and digestion characteristics of the specific feed ingredient. This factor (in g CH_4 per kg DM feed) is then used to calculate the methane emission. The calculation as applied in the ANCA Tool is described below. This is based on Šebek *et al.* (2020).

The EF values for the different feed ingredients take into account the share of corn silage in the roughage part (= fresh grass, grass products and corn silage products) of the ration (based on kg DM). The total of all EF values of all feed ingredients are referred to as 'EF lists' in this report. Because differentiation is made based on the share of corn silage in the roughage part of the ration, EF lists have been derived for rations with different shares of corn silage (0%, 40% and 80%) in the roughage part of the ration (see Appendix 4). A good estimate of the enteric methane emission for every dairy cattle ration with a share of corn silage between 0% and 80% can be done by interpolation with the three EF lists for the rations with 0%, 40% and 80% corn silage in the roughage. This approach is also appropriate for older youngstock feeding on roughage. It is therefore in line with the ANCA Tool approach to calculate rations at the herd level.

The calculation is as follows. First, the share of corn silage in the roughage part of the ration is calculated (% of the dry matter intake):

SOM kg dm from roughages = totale hoeveelheid droge stof uit ruwvoeders
%corn silage in roughage = 100 x (kg DM corn silage / SOM kg dm from roughages)

Roughage is defined as the sum of fresh grass, grassland products and corn silage products.

Subsequently, for three levels of the share of corn silage products in the total dry matter supply from roughage of dairy cattle (0%, 40% and 80%), the methane emission (g CH_4 per kg dry matter) is calculated for the entire ration. This concerns the sum of the emissions of the individual feed components. For many feeds this is a fixed number per kg of dry matter (Appendix 4), but for conserved grass and corn silage products, it is calculated based on the specified feed values (NDF, starch or energy (VEM), CP and crude ash, g/kg) and for compound feed it is supplied by the feed supplier or fixed values are taken. The formulas used for this are explained below.

Then the total emission, called EF_CH_4 _basis (g CH_4/kg DM), is estimated via interpolation based on the share of corn silage in the roughage part of the ration:
- If the calculated % of corn silage is between 0% and 40%, then interpolate with the EF lists 0% and 40%.
- If the calculated % of corn silage is between 40% and 80%, then interpolate with the EF lists 40% and 80%.

After that, a correction must be made for the feed intake level (total dry matter intake) for the adult animals (older than 3 months). This assumes an average change in the calculated methane emission per kg DM (based on EF lists) of 0.21 g methane per kg DM compared to the average feed intake of 18.5 kg DM per animal per day for the average Dutch dairy cow:

EF_correction (g CH_4/kg DM) = 0.21 x (DM intake per day - 18.5).

First the daily DM intake per animal group is determined. For calves, this is animals > 3 months. It is assumed that these animals ingest 85% of the total DM intake, based on 85% of the energy (VEM) requirement.

DMlev_co = DMint_co / number of cows / 365
DMlev_he = DMint_he / number of heifers / 365
*DMlev_ca = DMint_ca * 0.85 / number of calves / (365*9/12)*

Where:
- *DMint_co: total DM intake of cows*
- *DMint_he: total DM intake of heifers*
- *DMint_ca: total DM intake of calves*

This leads to the following EF factors per animal group:

EF_co (g CH_4/kg DM) = EF_CH_4_basis - 0.21 x (DMlev_co – 18.5)
EF_he (g CH_4/kg DM) = EF_CH_4_basis - 0.21 x (DMlev_he – 18.5)
EF_ca (g CH_4/kg DM) = EF_CH_4_basis - 0.21 x (DMlev_ca – 18.5)

The EF factor per kg DM feed intake for adult animals can then be calculated.

*DMint_ca1 = DMint_ca * 0.15 (DM intake of calves < 3 months)*
*DMint_ca2 = DMint_ca * 0.85 (DM intake of calves > 3 months)*
DMint_ad = DMint_co + DMint_he +DMint_ca2 (DM intake of adult animals)
DMint_herd = DMint_co + DMint_he + DMint_ca (DM intake of herd)

*EF_ad = (EF_co * DMint_co + EF_he * DMint_he + EF_ca * DMint_ca2) / DMint_ad*

Finally, the EF factor per kg DM feed intake for youngstock aged 0-3 months must be calculated. The methane emission from youngstock differs from the methane emission from dairy cattle for two reasons, namely feed intake level and a different emission per kg DM as a result of a different rumen effect. The calculation for these animals uses a fixed EF_CH_4 of 5.6 CH_4 per kg DM.

The methane emission factor of the ration (CH_4_EFration) per kg DM is calculated via the EF factors of adult animals and young calves as:

*EF_CH_4_ration (g CH_4/kg DM) = (EF_ad * DMint_ad + 5.6 * DMint_ca1) / DMint_herd*

The CH_4 emission of the total dairy herd (CH_4_ration) is finally calculated as:

CH_4 _ration = EF_CH_4_ration x DM intake of dairy herd

Calculation of EF for conserved grass, corn maize and compound feeds
As indicated above, for conserved grass products and conserved corn silage, the EF values have been derived based on the NDF and starch content or, if unknown, based on the energy (VEM), crude protein (CP) and crude ash (CA) contents. The regression formulae used for this are shown below.

Conserved grass, if NDF known (g CH_4 / kg DM):

*EF0% = 19.5 + 0.03 * (NDF - 465)*
*EF40% = 19.5 + 0.03 * (NDF - 465)*
*EF80% = 21.0 + 0.03 * (NDF - 465)*

Conserved grass, if NDF unknown (g CH_4 / kg DM):

*EF0% = 36.87 - 0.01425 * VEM - 0.0020 * CP - 0.0354 * CA*
*EF40% = 36.87 - 0.01425 * VEM - 0.0020 * CP - 0.0354 * CA*
*EF80% = 38.37 - 0.01425 * VEM - 0.0020 * CP - 0.0354 * CA*
*Minimum: VEM = 579, CP = 71, CA = 48, EF0 = 0.9 * 14.07, EF40 = 0.9 * 14.07, EF80 = 0.9 * 15.57*
*Maximum: VEM = 1012, CP = 265, CA = 337, EF0 = 1.1 * 25.17, EF40 = 1.1 * 25.17, EF80 = 1.1 * 26.67*

Conserved corn silage, if NDF and starch known (g CH_4 / kg DM):

$$EF0\%\_NDF = 18.4 + 0.083 \times (NDF - 374)$$
$$EF40\%\_NDF = 17.5 + 0.083 \times (NDF - 374)$$
$$EF80\%\_NDF = 16.2 + 0.083 \times (NDF - 374)$$
$$EF0\%\_ST = 18.4 - 0.049 \times (Starch - 385)$$
$$EF40\%\_ST = 17.5 - 0.049 \times (Starch - 385)$$
$$EF80\%\_ST = 16.2 - 0.049 \times (Starch - 385)$$
$$EF0\% = (EF0\%\_NDF + EF0\%\_ST) / 2$$
$$EF40\% = (EF40\%\_NDF + EF40\%\_ST) / 2$$
$$EF80\% = (EF80\%\_NDF + EF80\%\_ST) / 2$$

Conserved corn silage, if NDF and/or starch unknown (g CH_4/kg DM):

$$EF0\% = 67.51 - 0.04978 \times VEM$$
$$EF40\% = 66.61 - 0.04978 \times VEM$$
$$EF80\% = 65.31 - 0.04978 \times VEM$$

Minimum: VEM = 807, EF0 = 0.9 x 13.57, EF40 = 0.9 x 12.67, EF80 = 0.9 x 11.37
Maximum: VEM = 1063, EF0 = 1.1 x 26.83, EF40 = 1.1 x 25.93, EF80 = 1.1 x 24.63

The calculation rules for conserved grass products and corn silage are based on the calculation rules in Wageningen Livestock Research report 986 (Šebek *et al.*, 2020). In this, the methane emission is calculated based on the NDF content (conserved grass) and NDF and starch content (conserved corn silage). These parameters gave the best association with methane emission. If NDF and/or starch are unknown, the derived regression formulas are used based on the energy (VEM), CP and CA content. Although these formulas are suitable for representing the range in enteric CH_4 , they are less accurate than the formulas based on the NDF content. Also, the explanatory variables used do not fit well with the logic of the functioning of the rumen.

The derived regressions (when NDF and/or starch values are not available) were performed on data from the '*Koeien en Kansen*' project from 2010 to 2016 for which CH_4 was estimated as EF0%, EF40% and EF80% according to the calculation rules proposed in this report based on NDF. Subsequently, regression analyses were performed with that data set with CH_4 (g per kg DM) as the variable to be explained and the content (in DM) of VEM, crude protein and crude ash as the explanatory variables. All 3 explanatory variables were found to contribute significantly.

For fresh grass, the EF values have recently been revised downward. The values are shown in Appendix 4. The justification for the new values is described in Appendix 8.

For compound feed, the 3 EF values for methane are generally provided by the feed supplier. If these 3 EF values are not provided, 3 fixed EF values are used (see Table 6.2). These values are based on 3 formulations and the use of average compound feeds in 2018/2019.

Table 6.2 *Used fixed EF-CH_4-values in case that these are not provided by the feed supplier (at various corn percentages in the ration).*

Feed type	EF CH_4 with 0% corn (g/kg dm)	EF CH_4 with 40% corn (g/kg dm)	EF CH_4 with 80% corn (g/kg dm)
Compound feed	20.20	19.83	20.51

Additives

From 2023 onwards, calculation rules for the reduction of enteric methane emissions have been implemented in the ANCA Tool for the additives Silvair and Bovaer. The calculation rules are described below. For both additives, the reduction in methane emissions applies only to dairy cows (including dry cows). For Bovaer, the reduction applies only during barn hours.

The calculation rules below are based on the assessment carried out according to the procedure of ZuivelNL (https://cdn2.assets-servd.host/zuivel-nl/production/images/ZuivelNL-Procedure-beoordeling-product-KringloopWijzer-20230606.pdf).

Silvair
First, the annual dosage is calculated in the dry matter intake of the dairy cows. This is expressed as the amount of nitrate, which is the active substance in the additive. The content of the active substance in the purchased feed must be provided by feed manufacturers in g/kg feed.

$$NO_3\_TOT = \sum NO_3\_CONfeed_i \times KG\_SUPPfeed_i$$

and

$$NO_3\_DOS = NO_3\_TOT \times (1\text{-}FEEDLOSS) / DM\_INTYR$$

Where:
- *NO_3_TOT = amount of fed nitrate, g per year*
- *NO_3_CONfeed = nitrate content in feedstuff (1-i) with Silvair, g/kg*
- *KG_SUPPfeed = amount of supplied feedstuff (1-i) with Silvair, kg*
- *NO_3_DOS = dosage of nitrate in the total feed ingested by dairy cows, g per kg dm*
- *FEEDLOSS = feed losses, fraction of offered feed: 0.02*
- *DM_INTYR = total annual dry matter intake by dairy cows*

Subsequently, the methane emission reduction in dairy cattle is calculated via:

$$REDCH4\_SIL = -1 \times (-20.4 – 0.911 \times (NO_3\_DOS – 16.7) + 0.691 \times (DM\_INTCODY – 11.1))$$

Where:
- *REDCH4_SIL = methane emission reduction by Silvair in dairy cows, %*
- *DM_INTCODY = total dry matter intake by dairy cows, kg per cow per day*

Bovaer
Analogous to Silvair, for Bovaer the annual dosage is first calculated in the dry matter intake of the dairy cows. This is expressed as the amount of 3-nitrooxypropanol (3NOP), which is the active ingredient in the product. The concentrations of the active ingredient in the purchased feed are provided by feed manufacturers in g/kg of feed. Bovaer can only be administered during housing periods.

The amount of fed 3NOP (3NOP_TOT) is calculated via:

$$3NOP\_TOT = \sum 3NOP\_CONfeed_i \times KG\_SUPPfeed_i$$

Where:
- *3NOP_TOT = amount of fed 3NOP, g per year*
- *3NOP_CONfeed = 3NOP-content in feedstuff (1-i) met Bovaer, g/kg*
- *KG_SUPPfeed = amount of supplied feedstuff (1-i) with Silvair, kg*

and

$$3NOP\_DOS = 3NOP\_TOT * 10^3 \times (1\text{-}FEEDLOSS) / (DM\_INTYR \times FRAC\_BARN)$$

Where:
- *3NOP_DOS = dosage of 3NOP in the total feed intake of dairy cows during the indoor housing period, mg per kg dm*
- *FEEDLOSS = feed losses, fraction of offered feed: 0.02*
- *DM_INTYR = total annual dry matter intake by dairy cows*
- *FRAC_BARN = fraction of the year that cows are housed indoors = 1 – hours of pasture/(24x365)*

Subsequently, the reduction of methane emissions in dairy cows during the housing period is calculated via:

REDCH4_BOV = -1 x (-30.9 – 0.267 x (3NOP_DOS – 70.5)) x FRAC_BARN

Waarbij:
- *REDCH4_BOV = reduction methane emission Bovaer in dairy cows, %*

If the dosage during the housing period is lower than 60 mg per kg dm, a period correction is applied. Thisi s done because a minimum concentration of 60 mg/kg dm is required. If the dosage during the housing period is lower than this threshold, the number of days on which Bovaer is fed is reduced until the dosage reaches 60 mg/kg ds again.
If the dosage is higher than 130 mg/kg dm, no additional effect is accounted for.

The correction for dosages lower than 60 mg/kg dm (FRAC_YEAR) are calculated as follows:

FRAC_YEAR = 3NOP_DOS/60
REDCH4_BOV = REDCH4_BOV60 x FRAC_YEAR

Where:
- *REDCH4_BOV = corrected reduction of methane emissions in dairy cows, %*
- *REDCH4_BOV60 = calculated reduction with a dosage of 60 ppm, %*
- *FRAC_YEAR = correction factor*

If both Silvair and Bovaer are fed, both reduction percentages are multiplied using:

Reduction = (1 - (1 - REDCH4_SIL /100) x (1 - REDCH4_BOV /100)) x 100 (%)

6.3.1.2 Other grazing animals

Tier 2 is used for grazing animals other than dairy cows and associated youngstock. The Tier2 calculation for the methane emission assumes that a fixed percentage of the intake of gross energy is lost in the form of CH_4. In the IPCC calculation rules, this methane conversion factor Y_M for North West Europe is set at 6.3% for dairy cattle rations. This percentage is used here.

The calculation is as follows. The gross energy intake can be estimated without knowledge of the digestibility of feeds by multiplying the amount of ingested feed in kg dry matter (DM) by the average gross energy value of 18.45 MJ/kg DM. This conversion factor is relatively constant for different ruminant rations and is also recognised as a default value by the IPCC (IPCC, 2019).

GE intake herd = DM intake herd x 18.45*

CH_4 emission (in kg CH_4) = $(GEintake * Ym)/55.65 \ x \, 100$

* Let op: indien opname krachtvoeder wordt weergegeven per kg product, dan eerst omrekenen naar kg DS (vuistregel: kg DS = kg product x 0,88).

Where:
- *GE = Gross energy, in MJ*
- *DM = Dry matter intake herd, in kg*
- *Ym = Methaan conversie factor, set at 6.3%*
- *18.45 MJ/kg = Average gross energy content of a kg DM cattle ration*
- *6.3% = Methane conversion factor for youngstock in North West Europe (IPCC 2019)*
- *55.65 MJ/kg = Energy-content of a kg CH_4*

Based on the DM intake (kg/year) and the IPCC methane conversion factor Ym of 6.3% of the gross energy for the different categories of cattle, sheep and goats, standard values for the other grazing animals present on the dairy farm have been calculated (in kg CH_4 per animal per year, Table 6.3).

For horses and ponies, only IPCC Tier 1 emissions are available (IPCC, 2019) (Table 6.3). There is no separate animal group for ponies in Tier 1. This is derived based on the difference in metabolic weight between ponies and horses.

*Pony CH_4 emissions = ((pony bodyweight)$^{0.75}$/(horse bodyweight)$^{0.75}$) * horse CH_4 emissions*

Pony and horse bodyweights are assumed at 350 kg and 550 kg respectively.

Tabel 6.3 *Methane emissions of other grazing animals.*

Category	Kg DM/yr	Y_M (%)	CH_4 (kg/yr)	CH_4 (kg CO_2-eq/yr)
Breeding bulls, >1 year (cat. 104)	3049	6.3	63.7	1720
Pasture- and suckling cows (cat. 120)	3433	6.3	71.7	1936
Start veal calves, rosé- of red meat (cat. 115)	659	6.3	13.8	373
Rosé calves, 3 mo - slaughter (cat. 116)	2050	6.3	42.8	1156
Rosé calves, 2 weeks - slaughter (cat. 117)	1561	6.3	32.6	880
Red meat bulls, 3 mo - slaughter (cat. 122)	2656	6.3	55.5	1499
Breeding sheep, incl. lambs (cat. 550)	469	6.3	9.8	265
Meat sheep, <4 mo (cat. 551)	62	6.3	1.3	35
Other sheep, >4 mnd (cat. 552)	312	6.3	6.5	176
Milking goats (cat. 600)	833	6.3	17.4	470
Rearing and meat goats, <4 mo (cat. 601)	193	6.3	4.0	108
Rearing and meat goats, >4 mo (cat. 602)	496	6.3	10.4	281
Ponies (cat. 941)	1546	-	12.8	346
Horses (cat. 943)	3126	-	18.0	486
Donkeys (cat. 961)	897		10.0	270
Water buffalo, cows (cat. 991)	4342	6.3	90.7	2449
Water buffalo, youngstock (cat. 992)	1737	6.3	36.3	980

6.3.2 Methane emissions from manure

6.3.2.1 Basic Principles

With regard to CH_4 emissions from manure in the barn, storage and on pasture, the following two source categories are distinguished:
- Dairy cattle and associated youngstock
- Other grazing animals

The calculation of CH_4 emissions in the ANCA Tool is based on the 'Tier 2' approach of the IPCC (2019), but deviates from it in that the ANCA Tool uses emission factors (EF) per kg of manure for each animal category and manure management system, rather than the annual absolute CH_4 emissions per animal (in kg per animal per year).

CH_4 emissions from animal manure arise from fermentation processes that occur in an anaerobic environment. This condition mainly occurs when liquid manure is stored in manure pits under barns and in manure storage facilities outside the barn. With solid manure and pasture manure, the conditions are usually aerobic and the CH_4 production is relatively low.

Cattle manure can be divided into liquid 'barn manure', solid manure (i.e., barn manure in the strict sense) and pasture manure. Because part of the dairy cows in the Netherlands are (partly) housed indoors during the grazing period in summer, in particular during milking and at night, 'barn manure' is also produced during the pasture period.

Any goats present are assumed to be kept indoors all year round and to produce solid manure. Sheep are pastured animals and only housed indoors during the lambing period. Solid manure is produced during this housing period. For horses, ponies, and donkeys, a housing and pasture period is distinguished, producing solid manure during the housing period.

Liquid 'barn manure' is stored in the manure pit under the barns and in manure storage facilities outside the barn. Solid manure is stored inside the barn and in an outdoor storage. In both cases

there may be anaerobic conditions, resulting in the emission of CH_4. This emission can be reduced by preventing anaerobic conditions, for example by aeration or regular mixing and turning. However, the aerobic processes lead to higher emissions of ammonia and nitrous oxide. The share of solid manure in the total manure production in the Netherlands is relatively small.
Pasture manure is produced on pasture during summer grazing. Because of mostly aerobic conditions, the CH_4 emissions from pasture manure are often relatively low. Besides the level of anaerobic conditions, the formation of CH_4 in manure also depends on other conditions under which storage takes place, such as the amount of manure already present (so-called 'inoculum') and the storage duration and temperature. The manure pit can be considered as a so-called accumulation system: there is a constant supply of manure into the 'reactor' (= manure pit) and the manure volume in the pit increases until the pit is emptied for fertilisation or until the moment that the manure is pumped to the outside storage. The CH_4 emission in such a system increases with an increasing amount of manure (= inoculation), a higher manure temperature and a longer retention time (Zeeman, 1994).

CH_4 emissions from manure also depend on the (chemical) composition of the manure. For example, CH_4 emissions are mainly determined by the organic matter content of the manure.

6.3.2.2 Calculation method

The emission of CH_4 from animal manure is calculated as follows:

$$CH_{4Manure} = \sum_S [EF_{(T)} * N_{(T)}]$$

Where:
- $CH_{4Manure}$ = *CH_4-emission from manure in kg*
- $EF_{(T)}$ = *Emission factor for each defined animal category T in kg CH_4 per animal*
- $N_{(T)}$ = *number of animals per animal category T (dairy cows, youngstock and (total) number of other grazing animals)*

The emission factor per animals is calculated as follows

$$EF_{(T)} = (VS_{(T)} * 365) * [BMP_{(T)} * 0.67 * \sum_T (MCF_S/100 * MS_{(T,S)})]$$

Where:
- $EF_{(T)}$ = *emission factor for each defined animal category T in kg CH_4 per animal*
- $VS_{(T)}$ = *the production of volatile solids per animal category in kg dry matter per animal per day*
- *BMP = maximum methane production potential per animal category T in m^3 CH_4 per kg excreted VS*
- *0.67 = methane density (kg/m^3)*
- $MCF_{(S)}$ = *methane conversion factor per manure management system in percentages of BMP*
- $MS_{(T,S)}$ = *fraction of the totale N-excretion of each animal category T in manure management system S*

BMP
The maximum CH_4 formation is determined by the degradability of the organic components in the manure. BMP is expressed in m^3 CH_4/kg VS (Table 6.4)

MCF $_{(S)}$
The MCF indicates the degree to which the amount of degradable substance is actually converted into CH_4 under certain conditions. The IPCC provides default values for MCF per animal category depending on the average temperature in a region (Table 6.2).

$VS_{(T)}$
VS stands for 'volatile solids'. This is the sum of VS from excretion of urine and faeces, and VS from feed residues and bedding material that end up in the manure. The calculation of the amount of VS in the excretion depends on the ration (Zom & Groenestein, 2015) and is explained below:

VS in urine
The VS in urine is the amount of urea present. This is calculated from the amount of TAN nitrogen (N) in the urine (Urine-N). Almost all TAN-N is excreted in the form of urea (CH_4N_2O). Based on the atomic weight of nitrogen and the molecular weight of urea, the excretion of VS with urine (VS_{urine}) is calculated as:

$$VS_{urine}\ (kg) = Urine\text{-}N / 0.466\ (=(14 \times 2) / (12 + 4 \times 1 + 14 \times 2 + 16))$$

Urinary N excretion (kg N/year, TAN nitrogen) is determined in the BEA.

VS in faeces
The VS excretion in faeces is calculated from the dry matter intake (kg DM) by the herd, the crude ash (CA) content in the dry matter (CA, g/kg DM) and the digestibility of the organic matter (DCOM, fraction of organic matter).
The dry matter intake and ration composition of the herd was determined via the BEX. This is calculated using standard dry matter contents from CVB tables (Appendix 4).
The data of the types of feed and grass products/corn silage products of the CA content come from entries in the ANCA Tool. The other CA contents and the DCOM values are values from the CVB tables (Appendix 4). In this way, a dry matter intake, CA content and DCOM value is obtained per feed.

For compound feed, an estimation formula for DCOM has been developed, incorporating the available information on compound feed in the ANCA Tool (VEM, CP, and P)

$$DCOM_{compound}\ feed\ (fraction\ of\ DM) = (44.3 + 0.0489 \times VEM - 2.186 \times P + 0.1167 \times P^2) / 100$$

VEM and P contents are in g per kg product.

This formula was derived through regression analysis based on DCOM values and the VEM and P contents of a large number of dry compound feed ingredients from the CVB tables (Appendix 7).

The net organic matter intake of each feedstuff i, is calculated as:

$$OM_{intake\text{-}i}\ (kg) = DM_{intake\text{-}i}\ (kg) \times (1000 - CA_i\ (g/kg\ DM)) / 1000$$

The total net organic matter intake tot-OM_{intake} (kg), of the total ration with n feed ingredients, is calculated as the sum of the organic matter intake of the individual feedstuffs:

$$The\ tot\text{-}OM_{intake}\ (kg) = \Sigma\ OM_{intake\text{-}1}\ (kg) + OM_{intake\text{-}2}\ (kg) + \ldots\ldots + OM_{intake\text{-}i}\ (kg)\ (i = 1\ldots\ n)$$

The digestible organic matter intake of each feed material i is calculated as:

$$DOM_{intake\text{-}i}\ (kg) = OM_{intake\text{-}i} \times DCOM_{\text{-}i}$$

The total net digestible organic matter intake tot-DOM_{intake} (kg), of the total ration with n feedstuffs, is calculated as the sum of the digestible organic matter intakes of the individual feed ingredients:

$$The\ tot\text{-}DOM_{intake}\ (kg) = \Sigma\ DOM_{intake\text{-}1}\ (kg) + DOM_{intake\text{-}2}\ (kg) + \ldots\ldots + DOM_{intake\text{-}i}\ (kg)\ (i = 1\ldots\ n)$$

Total VS excretion 'under the tail'
VS excretion 'under the tail' (VS-excr) is calculated as:

$$VS\text{-}excr = tot\text{-}OM_{intake}\ (kg) - tot\text{-}DOM_{intake}\ (kg) + VS_{urine}\ (kg)$$

VS from feed losses
In practice feed losses occur, i.e. not all feed is ingested by the animal, feed is also 'spilled'. It is assumed that all feed losses end up in the solid manure. The contribution of feed losses to the VS in manure ($VS_{feed\ loss}$) are calculated as:

The net organic matter intake of each feed ingredient i, including feed loss ($OM\text{-}IFL_{intake\text{-}i}$) is calculated as:

$$OM\text{-}IFL_{\ intake\text{-}i}\ (kg) = DM\text{-}IFL_{\ intake\text{-}i}\ (kg) \times (1000\text{-}CA_{\ i}\ (g/kg\ DM))$$

The total net organic matter intake including feed loss $tot\text{-}OM\text{-}IFL_{intake}$ in (kg), of the total ration with n feed ingredients, is calculated as the sum of the organic matter intake of the individual feedstuffs:

$$\text{The } tot\text{-}OM\text{-}IFL_{intake}\ (kg) = \Sigma\ OM\text{-}IFL_{\ intake\text{-}1}\ (kg) + OM\text{-}IFL_{\ intake\text{-}2}\ (kg) + \ldots\ldots + OM\text{-}IFL_{\ intake\text{-}i}\ (kg)\ (i = 1\ldots\ n)$$

The VS that is attributed to the manure via feed loss is calculated as:

$$VS_{feed\ loss} = tot\text{-}OM\text{-}IFL_{intake}\ (kg) - tot\text{-}OM_{intake}\ (kg).$$

VS from Bedding

Straw as bedding ends up in solid manure, whereas sawdust and lime end up in slurry. Lime is assumed to contain 0% organic matter and for other bedding, 90% of the dry matter is assumed to be organic matter.

$$VS_{bedding} = 0\% * kg\ DM\ lime + 0.9 * kg\ DM\ other\ bedding$$

Total VS excretion

Total VS excretion including feed loss (VS excrincl) is calculated as:

$$VS\text{-}excrincl = VS\text{-}excr + VS_{feed\ loss} + VS_{bedding}$$

The above method for calculating the VS in manure is used for dairy cows and associated youngstock. The following method is used for the other grazing animals.

$$VS = \sum (Nexcretie_T * Factor)$$

Where:

- *Nexcretion$_{(T)}$: total N excretion per animal category in kg per day (dairy cattle, youngstock and (total) other grazing animals). This N excretion is derived from the BEX (Chapter 2), but without deduction of the gaseous N losses from barns and storage.*
- *Factor = Conversion factor from N to VS (OM/N ratio in gross excretion:*
    - *Liquid manure and pasture manure: 15.6*
    - *Solid manure: 25.8*

Table 6.4 *Parameter values for BMP (biochemical methane potential, m³ CH_4/kg VS) and MCF (methane conversion factor, % of BMP) in relation to animal type and manure management systems; values are taken from Groenestein et al. (2016) and are applied to the total amount of VS produced in a manure stream, and in the case of manure handling, to the total amount of VS in the portion of the manure stream that is processed.*

Manure management system	BMP **m^3/kg VS**	MCF
Pasture manure	0.22	1
Barn storage, slurry	0.22	17
Barn storage, solid manure	0.22	2
Separation slurry		
Storage *before* separation	0.22	8.5
Storage after separation		
Thin fraction	0.22	5.85
Solid fraction	0.22	2.65
Total		*17*
Digestion		
Storage *before* digestion	0.22	3
Process	0.22	92
Storage after digestion	0.22	1
Total		*96*

In Table 6.4, a distinction is made between the pre-storage and post-storage of separation products when manure is separated. This is done because the OM/N ratio of applied manure is also calculated via CH_4 emissions based on the grossly excreted organic matter (see section 6.6.1.1.2), making the distinction between separation products relevant. For the purpose of calculating CH_4 emissions for the carbon footprint, a total percentage of 17% is used, and this distinction is not applied.

6.3.2.3 Manure digestion

For manure separation without digestion, it is assumed that CH_4 emissions occur 50% before separation and 50% afterwards in the post-storage (Table 6.4).

In the case of digestion, it is assumed that the manure is digested shortly after excretion (within three days). Therefore, for this amount of manure, an MCF (see Table 6.4) of 3% of the BMP (maximum methane production, see Table 6.4) in the excreted manure is applied, instead of 17% as in the case of no digestion. Subsequently, for methane production during the digestion process, it is assumed that 92% of the BMP is released in the digester, of which 4.3% (Hjort-Gregersen, 2014) is lost through leakage. CH_4 emissions occurring during the digestion process (leakage) are allocated to the "Energy Production" process (see section 6.4.1.2: Energy Consumption and Energy Production). Depending on the final use of this produced energy on the farm, these emissions may be (partially) attributed to the farm. Some methane emissions also occur during the post-storage of the digestate, for which an average of 1% of the BMP is assumed.

6.4 CO_2 emission calculation method

The calculation of CO_2 emissions is described in this chapter. A distinction is drawn between direct emissions on the farm (section 6.4.1) caused mainly by energy consumption (fuels and electricity) in crop cultivation, processing and feeding, emissions from the production, maintenance, and transport of supplied products and livestock (section 6.4.2).

For the production of own roughage, some farm-specific data on inputs are used, which are requested from the ANCA Tool. This concerns the production and application of animal manure and synthetic fertilizer.

Appendix 5 provides an overview of all emission coefficients of carbon dioxide (direct and indirect) by using different products and processes in the management of the dairy farm.

6.4.1 CO_2 emissions on the farm

6.4.1.1 Application of fertilizers (lime and urea)

There are a number of C-containing products that are used in the cultivation of crops. This concerns (Source: IPCC Guidelines 2019; Fifth Assessment Report, 2014):

*Urea = kg Nurea * NURE_URE * EF_CO_2_Nure/1000 x 44/12*

Where:
- *NURE_URE = 60/28: (Urea = CH_4N_2O, so 60/28)*
- *EF_CO_2_Nure = 200 (g CO_2/kg urea)*

*Lime = (kgLime_Dolo * EF_CO_2_Dolo / 1000 + kgLime_Lime * EF_CO_2_Lime / 1000) * 44/12,*

Where:
- *EF_CO_2_Lime = 120 (g CO_2-C/kg limestone)*
- *EF_CO_2_Dolo = 130 (g CO_2-C/kg dolomite)*

6.4.1.2 Energy consumption and energy production

In the ANCA Tool, energy consumption can be reported or calculated using standard values. This can be done separately for each energy source. If consumption of an energy source is reported, the total consumption along with the quantity for categories other than 'Grazing animals and fodder crops' is reported. The ANCA Tool then calculates the proportion of the consumption to be attributed to milk production using the standard consumption (see below). Machine usage for growing crops and feeding is standardised. A detailed description is provided below.

Direct energy consumption for feed production, processing and feeding

A description of how the standard fuel consumption is calculated for each category of processing (grassland, arable land and feeding) is provided below.

Grassland activities (standard calculation)

The number and frequency of actions differs per type of grassland use. Therefore, a distinction is made between:
- Cut grazing
- Cut fresh grass (summer stall feeding)
- Cut grass silage
- Cut hay
- Cut grass drying, fresh grass
- Cut grass drying, pre-dried grass

Table 6.5 shows which activities occur on each type of grassland and how often they occur.

Table 6.5 *Frequency of the activities per cut grassland for pasturing, summer stall feeding, cut grass silage, cut hay, and cut grass drying (FeedPrint, 2025; Vellinga et al., 2013).*

Activity	Cut grazing	Cut fresh grass (summer stall feeding)	Cut grass silage	Cut hay	Cut grass drying, fresh grass	Cut grass drying, pre-dried grass
Synthetic fertilizer	1	1	1	1	1	1
Pasture topping	0.5					
Cutting		1	1	1	1	1
Loading grass		1	1		1	1
Tedding			2	3		2
Swathing			1	1		1
Compaction			1			
Big baler				1		

The following tables indicate which general activities (Table 6.6) and which sowing-related activities (Table 6.7) occur in grassland.

Table 6.6 *Frequency of general activities per hectare of grassland.*

Activity	grassland, field work
Liming	0.25
Dragging	0.5
Rolling	0.5

Table 6.7 *Frequency of activities per hectare of grassland for reseeding, overseeding or for rotational cropping with an arable crop.*

Activity	Reseeding	Overseeding	Rotational cropping
Spraying	1	1	
Weed control	1	1	
Ploughing	1		1
Harrowing	2		2
Sowing	1		1

Some activities are expressed per cut. Because the number of cuts is not requested, it must be estimated based on the annual yield. This is done by assuming a certain cutting yield. The principles used are:

- Gross cut weight fresh grass = 1500 kg DM/ha
- Gross cut weight of summer feeding = 1800 kg DM/ha
- Gross cut weight grass silage, hay and drying = 3000 kg DM/ha

The total emissions from fuel consumption while using machines are then calculated as the sum of:

- the products of the numbers of cuts and the emissions from diesel consumption per cut in each individual operation (Table 6.8),
- the products of the number of hectares and the frequencies per hectare for lime spreading, rolling and dragging and the diesel consumption per operation (Table 6.8),
- the emissions for (re-) sowing and overseeding. The number of hectares that have been sown or re-sown (re-sowing grass after grass and sowing grass after arable crops) is multiplied by the diesel consumption of the operations carried out during sowing (Table 6.6).

Table 6.8 *Diesel consumption per unit of grassland operation.*

Activity	Unit	Diesel (kg)
Ploughing	Ha	23.1
Harrowing	Ha	9.4
Sowing	Ha	4.3
Applying slurry	m^3	0.7
Applying solid manure	tonnes	1.3
Applying synthetic fertilizer	Ha	2.4
Liming	Ha	2.4
Spraying	Ha	2.5
Weed control	Ha	2.5
Pasture topping	Ha	4.2
Mowing	Ha	4.8
Robotic harvester	Ha	25.6
Teddering	Ha	3.2
Swathing	Ha	2.9
Collection wagon	Ha	5.3
Small square bales	Ha	5.7
Large square bales	Ha	11.3
Compacting	Ha	2.5
Rolling	Ha	4.2
Chain harrowing	Ha	4.2

Arable land activities (standard calculation)
For all arable crops, activities have been distinguished, which overall boil down to preparing the land for sowing (ploughing, seedbed preparation, sowing, crop management (synthetic fertilizer, pest and disease control), harvesting and post-harvest activities. For these crops, standard values for energy consumption (diesel and electricity) are used, as calculated by FeedPrint (Vellinga *et al.*, 2013; Feedprint, 2025) (Table 6.9).

Table 6.9 *Diesel and electricity consumption per hectare of arable crop in the ANCA Tool.*

Crop	Diesel (kg)	Electricity (kWh)
Corn silage	95.9	0
GPS grains	95.9	0
Alfalfa	128.1	0
Red clover	128.0	0
Beets	192.9	0.3
Maize (CCM, MKS)	123.8	1.0
Grains, coarse grain	114.8	0
Grains, small grain	112.2	0
Grass seed	114.8	0
Legumes	86.2	0
Potatoes	196.0	1.8
Seed potatoes	196.0	1.8
Onions and flower bulbs	196.0	1.8
Vegetables, leaf	128.1	0
Vegetables, non-leaf	128.1	0
Other arable farming	128.1	0

Feeding activities (standard calculation)
If all products are present on the farm, they still must be fed. Energy consumption is calculated for all feed ingredients, except compound feed, which in turn includes emissions for direct fuel consumption and for production and maintenance. Table 6.10 shows the direct energy consumption per tonne of

product fed. Feeding compound feed takes so little energy that no separate energy consumption is calculated for it.

Table 6.10 *Diesel consumption for feeding, per ton of product of the various feedstuffs. The DM contents belonging to the different feedstuffs are listed in Appendix 4.*

Feeding	Diesel (kg)
Roughage[1] (tonnes of product)	2.5
Other roughage[1] (tonnes of product)	3.9
By-products[1] (tonnes of product)	2.4
Fresh grass[1] (tonnes of product)	0.4

[1] The products belonging to the different feedstuffs are listed in Appendix 4.

Conversion of direct energy consumption into CO_2
Consumption is reported or, as mentioned above, calculated using standard values. To calculate the CO_2 , the total quantities of diesel and electricity must be multiplied by an EF value. These EF values can be found in Appendix 5. Prior to this, the use of diesel in kilograms is converted to MJ's per kg (43.2 MJ/kg) and the use of electricity in kWh is converted to MJ's per kWh (3.6 MJ/kWh).

CO_2 emissions = kg diesel * MJ_per kg Diesel * (EF_DieselCombustion + EF_DieselProduction) + kWh elec * MJ_per kWh Elec * EF_ElectricityProduction

Other direct energy consumption
Energy is also consumed in other ways to produce milk, meat and crops. The ANCA Tool also calculates the standard consumption and maps out the magnitude of the associated CO_2 losses. To this end, the ANCA Tool accounts for:
- Consumption of electricity for milking, cooling and lighting
- Consumption of gas for hot water and heating in general
- Consumption of propane for heating in general and water
- Fuel oil consumption for heating water and general consumption
- Consumption of electricity and diesel for manure separation
- Consumption of electricity for manure digestion

Refer to Appendix 5 for the conversion of this energy consumption to CO_2.

Consumption of electricity, gas, propane, fuel oil (standard calculation)
The following calculation rules (KWIN, 2019-2020) are used in the standard calculation:

Milk cooling (electricity): Depending on the presence or absence of a pre-cooler and a heat recovery installation:
- No pre-cooler and no heat recovery: consumption = 13.0 * milk supply/1000 (KWh)
- No pre-cooler, heat recovery: consumption = 14.0 * milk supply/1000 (KWh)
- Pre-cooler and no heat recovery: consumption = 8.0 * milk supply/1000 (KWh)
- Pre-cooler and heat recovery: consumption = 10.0 * milk supply/1000 (KWh)

Milking (electricity):
- No milking robot: Consumption = 500 * number of milking clusters (KWh)
- Milking robot single box: Consumption = 10950 * number of AMS systems (KWh)
- Milking robot multibox: Consumption = 21900 * number of AMS systems (KWh)

Other, including lighting (electricity):

*Consumption = 1924 + 16.3 * number of cows (KWh)*

Heating water (electricity, gas, propane or fuel oil):

First calculate hot water consumption in litres per day:
- Milking robot single box and hot cleaning: hot water = 220 litres
- Milking robot single box and circulation cleaning: hot water = 228 litres
- Milking robot multibox and hot cleaning: hot water = 325 litres
- Milking robot multibox and circulation cleaning: hot water = 220 litres

Traditional milking parlour:
a: (20 + number of milking clusters * 5) * 0.8
b: (20 + number of milking clusters * 5) * number of milking times
c: (a + b) * 0.40 if generously dimensioned
d: (number of cows * 1.0) * if no heat recovery installation
e: (45 + number of cows * 0.75) / 2

Hot water = a + b + c + d + e

No heat recovery:
- Heat source is electric: Consumption of electricity = hot water * 29.644 (KWh)
- Heat source is gas: Consumption gas = hot water * 5.7631 (m3)
- Heat source is propane: Consumption of propane = hot water * 7.3002 (ltr)
- Heat source is heating oil: Consumption heating oil = hot water * 5.0925 (ltr)

Heat recovery:
- Heat source is electric: Consumption of electricity = hot water * 12.7348 (KWh)
- Heat source is gas: Consumption gas = hot water * 3.6019 (m3)
- Heat source is propane: Consumption of propane = hot water * 4.5627 (ltr)
- Heat source is heating oil: Consumption heating oil = hot water * 3.1828 (ltr)

Manure separation:
With regard to slurry separation, it is assumed that the slurry of grazing animals is separated using an electrically powered screw press filter and the slurry of ‘indoor housed animals’ using a mobile separator (diesel powered).

- Manure of grazing animals: Consumption = 1.0 kWh electricity per tonne of input manure
- Manure of ‘indoor housed animals’: Consumption = 0.8 litres diesel per tonne of input manure

Manure digestion:
For slurry digestion it is assumed that the digestion process takes place in a mono digester. This uses electricity for agitating, pumping, crushing etc. and heating to keep the digester at the desired temperature. Consumption is estimated at 12 kWh per tonne of input manure.

Other grazing animals (electricity and gas):
- For other grazing animals, standard consumption is used (see Table 6.11).

Table 6.9 *Standard consumption of electricity and gas for other grazing animals (Anonymous, 2019).*

Category	electricity (kWh/yr)	gas (m^3/yr)
Breeding bulls, > 1 year (cat. 104)	25	0
Pasture and suckler cows (cat. 120)	20.8	0
Calves for rosé or red meat (cat. 115)	23	9.2
Rosé calves, 3 months – slaughter (cat. 116)	11.3	0
Rosé calves, 2 weeks – slaughter (cat. 117)	14.6	2.9
Red meat bulls, 3 months – slaughter (cat. 122)	25	0
Breeding sheep, incl. lambs (cat. 550)	3.3	0
Meat sheep, < 4 months (cat. 551)	2.7	0

Category	electricity (kWh/yr)	gas (m^3/yr)
Other sheep, > 4 months (cat. 552)	2.7	0
Milk goats (cat. 600)	20.8	0
Rearing and meat goats, < 4 months (cat. 601)	20.8	0
Rearing and meat goats, > 4 months (cat. 602)	20.8	0
Ponies (cat. 941)	41.7	0
Horses (cat. 943)	41.7	0
Donkeys (cat. 961)	41.7	0
Water buffalo, cows (cat. 991)[1]	121.2	0
Water buffalo, youngstock (cat. 992)[2]		

[1] Based on dairy cattle including youngstock (55 kWh per tonne milk, annual production of 2200 kg milk per buffalo).

[2] Value included in the value for water buffalo - cows.

On-farm energy production

Energy can be produced on the farm, for example self-generated electricity and/or self-produced green gas. Producing energy on-farm also results in CO_2 emissions. Equipment is required, and in the case of energy from biomass, energy is needed to operate the digestion installation and/or to upgrade biogas to green gas. The average EF depends on the form of energy generation.

For on-farm electricity production, a distinction is made between electricity from biomass (digestion), wind, solar, and other sources. The EF is calculated as follows:

EFelec_prod = fraction elec Biomass x EF Biomass_elec
+ fraction elec Wind x EF Wind
+ fraction elec Sun x EF Sun
+ fraction Other x emission-coefficient 'other'

At input, another form of energy generation can also be specified. The emission factor for 'other' has been set equal to the weighted average of the well-known renewable sources and is calculated as follows:

(fraction elec Biomass x EF Biomass_elec + fraction elec Wind x EF Wind + fractie elec Sun x EF Sun) / (fraction elec Biomasss+fractie elec Wind + fraction elec Sun)

For the values of EF Biomass_elec, EF Wind, and EF Sun, reference is made to Appendix 5. The value for EF Biomass_elec is additionally summed with the CO2-equivalent emissions from the CH4 released during the digestion process (see Section 6.3.2.3 Manure Digestion).

Instead of combusting the biogas to generate electricity via a generator, the biogas can also be upgraded to natural gas quality ('green gas'). This green gas can be used on the farm and/or fed back into the natural gas grid. For the value of EF GreenGas, reference is made to Appendix 5. As with the production of own electricity, in case of production of own green gas, the EF GreenGas is also summed with the CO2-equivalent emissions from the CH4 released during the digestion process (see Section 6.3.2.3 Manure Digestion). If both electricity and green gas are produced from biomass, these emissions are allocated between the two forms of energy production based on the amount of energy produced (expressed in MJ).
To calculate the CO2 emissions of the total energy consumption, the amount of self-produced energy consumed and the amount of supplied energy consumed must be determined per energy source. In the calculation, only consumption for the grazing livestock and, if applicable, the arable crop activities are included. Other farm enterprises, such as intensive livestock production (e.g., pigs and poultry), a campsite, private use, and other side activities, are excluded. At input, for each energy source, the share used for the grazing livestock and arable crop activities and the share used for other enterprises is specified; this is hereafter referred to as:

- *FR_Elec_BEC =fraction of electricity consumption for grazing livestock and arable crop activities of total electricity consumption*
- *FR_Gas_BEC = fraction of gas consumption for grazing livestock and arable crop activities of total gas consumption*

- *FR_Propane_BEC = fraction of propane consumption for grazing livestock and arable crop activities of total propane consumption*
  FR_Fuel_oil_BEC = fraction of fuel oil consumption for grazing livestock and arable crop activities of total fuel oil consumption

The amount of self-produced energy consumed for the grazing livestock and arable crop activities (indicated as BEC in the formulas) is calculated as:

ConsumptionOwnElecBEC = (production electricity – fed back electricity) x FR_Elec_BEC
ConsumptionOwnGasBEC = (production green gas – fed back green gas) xFR_Gas_BEC

The consumption of supplied energy in the BEC is calculated as follows

Consumption_SuppliedElecBEC = SuppliedElec x FR_Elec_BEC
Consumption_SuppliedGasBEC = SuppliedGas x FR_Gas_BEC
Consumption_SuppliedPropaneBEC = SuppliedPropane x FR_Propane_BEC
Consumption_SuppliedFuelOilBEC = SuppliedFuelOil x FR_Fuel_Oil_BEC

Subsequently, the CO2 emissions for each energy source are calculated by multiplying the energy quantities by their respective emission factors (see Appendix 5).

For CO_2 electricity:

Consumption_SuppliedElecBEC in kWh x 3.6 x (EFelec_grey x share of conventional energy
+ EFelec_green x share of green electricity)
+ ConsumptionOwnElecBEC in kWh x 3.6 x EFelec_prod

For CO_2 gas:

Consumption_SuppliedGasBEC in m^3 x share of normal gas x 31.65 x EFgas_norm
+ Consumption_SuppliedGasBEC in m^3 x share of green gas x 31.65 x EFgreen gas
*+ ConsumptionOwnGasBEC in m3 * 31.65 x EF own green gas*

For CO_2 prop:

Consumption_SuppliedPropaneBEC in ltr x 0.51 x 45.2 x EFpropane

For CO_2 oil:

Consumption_SuppliedFuelOilBEC in ltr x 0.84 x 41.0 x EFFuelOil

In the calculations above, the self-produced green gas on the farm refers to the amount of upgraded gas, i.e., the amount of gas that has been brought to natural gas quality (with other gases such as CO2 removed). This amount is lower than the amount of biogas produced as it comes from the digester. Since the self-produced upgraded green gas is comparable to natural gas, the same calorific value as for gas supplied by a utility company (31.65 MJ/m^3) has been used. The emissions mentioned above exclude transport to the farm.

6.4.2 Indirect emissions from imported products

6.4.2.1 Synthetic feed drying (external)

If feed is dried artificially, this energy must be included in the CO_2 emission as it means that extra CO_2 is supplied. The ANCA Tool now distinguishes between artificially dried grass pellets and grass bales from fresh grass (dried from 200 g/DM to 920 g/DM), artificially dried grass pellets and grass bales from pre-dried grass (dried from 450 g/DM to 920 g/DM), artificially dried corn silage (dried from 355 g/DM to 910 g/DM), artificially dried alfalfa and clover (dried from 300 g/DM to 910 g/DM). For each kilogram of input material, a corresponding amount of CO_2 is accounted for (see Appendix 5 for the EF values).

6.4.2.2 Equipment manufacturing and maintenance

The manufacturing and maintenance of tractors and the equipment used to produce the feed also involve CO_2 emissions, referred to as indirect emissions. These emissions are regarded as an import item and depend on the number of hectares to be worked.

To calculate the CO_2, the total quantities of indirect energy must be multiplied by an EF value. These EF values can be found in Appendix 5.

CO_2 indirect = MJ electricity * EF_Electricity indirect +
MJ natural gas * EF_NaturalGas +
MJ kerosene * EF_Kerosene +
MJ brown coal * EF_Coal

Grassland

The indirect energy consumption per unit of grassland activity is shown in Table 6.12.

Table 6.12 *Indirect energy consumption per unit of grassland activity, for electricity, gas, kerosene and coal.*

Activity	Unit	Electric, indirect (MJ)	Gas, indirect (MJ)	Kerosene, indirect (MJ)	Coal, indirect (MJ)
Ploughing	Ha	12.5	8.3	13.4	1.4
Harrowing	Ha	9.7	6.1	11.9	1.0
Sowing	Ha	7.4	5.0	7.7	0.9
Applying slurry	m^3	0.4	0.4	0.1	0.1
Applying solid manure	tons	3.2	2.9	0.8	0.5
Applying synthetic fertilizer	Ha	1.1	0.8	1.0	0.1
Liming	Ha	1.1	0.8	1.0	0.1
Spraying	Ha	2.8	1.8	3.0	0.3
Weed control	Ha	2.8	1.8	3.0	0.3
Pasture topping	Ha	1.3	0.9	1.2	0.2
Mowing	Ha	2.4	1.7	2.2	0.3
Robotic harvester	Ha	131.7	88.6	137.3	15.1
Teddering	Ha	1.0	0.7	0.9	0.1
Swathing	Ha	4.0	2.6	4.6	0.4
Loading	Ha	7.0	5.4	4.7	0.9
Small square bales	Ha	34.8	27.5	21.0	4.7
Large square bales	Ha	26.7	17.1	30.9	2.9
Compacting	Ha	1.5	1.1	1.1	0.2
Rolling	Ha	2.9	1.9	3.1	0.3
Dragging	Ha	2.9	1.9	3.1	0.3

The calculation of the surface areas (cuts) and the amount of organic manure applied can be found in section 6.4.1.2 above.

Arable land

The indirect energy consumption per hectare of arable land is shown in Table 6.13.

Table 6.13 *Indirect energy consumption per hectare of arable crop, for electricity, gas, kerosene and coal.*

Crop	Electricity, indirect (MJ)	Gas, indirect (MJ)	Kerosene, indirect (MJ)	Coal, indirect (MJ)
Corn silage	124.2	82.4	133.8	14.1
GPS grains	124.2	82.4	133.8	14.1
Alfalfa	187.0	124.9	198.2	21.3
Red clover	187.0	124.9	198.2	21.3
Beets	524.8	338.8	600.0	57.8
Corn (CCM, MKS)	197.4	130.1	215.6	22.2
Grains	176.9	116.7	193.2	19.9
Grains, other	155.7	102.8	169.5	17.6
Grass seed	176.9	116.7	193.2	19.9
Legumes	118.3	78.5	127.5	13.4
Potatoes	410.8	268.4	457.9	45.8
Seed potatoes	410.8	268.4	457.9	45.8
Onions and bulbs	410.8	268.4	457.9	45.8
Vegetables, leaf	187.0	124.9	198.2	21.3
Vegetables, non-leaf	187.0	124.9	198.2	21.3
Other arable farming	187.0	124.9	198.2	21.3

Feeding
The indirect energy consumption for machinery used for feeding is shown in Table 6.14.

Table 6.14 *Indirect energy consumption for feeding, per tonne of product of the various feedstuffs. The products and the DM contents of the different feedstuffs are listed in Appendix 4.*

Feedstuff	Electricity, indirect (MJ)	Gas, indirect (MJ)	Kerosene, indirect (MJ)	Coal, indirect (MJ)
Roughage (tonnes of product)	2.0496	1.3976	2.0665	0.2386
Other roughage (tonnes of product)	4.2212	2.8162	4.4880	0.4808
By-products (tonnes of product)	8.2959	5.2220	9.9837	0.8916
Fresh grass (tonnes of product)	0.2626	0.1816	0.2553	0.0310

6.4.2.3 Imported feedstuffs

For a number of feed ingredients, the CO_2 values for feedstuffs are, in principle, provided by the compound feed supplier (see Appendix 4). If these CO_2 values are not supplied, 4 fixed CO_2 values are used (see Table 6.15). These values for compound feed are based on 3 formulations and on the average types of compound feed used in 2018/2019. For compound feed, interpolation between these 3 values is performed based on the CP content of each feed batch:

- Standard compound feed = 143 g CP/kg
- Protein-rich compound feed = 222 g CP/kg
- Extra protein-rich compound feed = 278 g CP/kg

Table 6.15 *Fixed CO_2 values used (in g/kg) if these are not provided by the compound feed supplier. The CO_2 values exclude transport and processing (grinding/pelleting).*

Feedstuff	CO_2 biogenic	CO_2 fossil	CO_2 LUC	CO_2 peat
Standard compound feed	31	359	158	62
Protein-rich compound feed	24	393	570	59
Extra protein-rich compound feed	10	481	950	36

For roughage, the values are derived from FeedPrint (Vellinga *et al.*, 2013; FeedPrint, 2025) and Agri-Footprint (see also Appendix 4). These sources did not yet account for peat emissions; however, this has been included since 2024. A distinction is made between grass (fresh, silage, hay), other grassland products, corn silage products, and other roughage and moist by-products. For grass (fresh, silage, and hay), the CO2 input from peat through the feed is made dependent on the share of on-farm cultivation on peat and/or peaty soils. For the other crop groups, peat emissions are calculated based on the national share of peat and peaty soils in the total cultivated area of each crop group and an average emission value (distinguishing between high peat, coastal peat, high peaty soils, and coastal peaty soils).

The CO_2 emissions of purchased roughage and compound feed include land use change and transport to the supplier. Transport emissions from the supplier to the farm are calculated separately.
If feed from the opening stock is sold, the associated CO_2 of the quantity sold is subtracted from the purchased amount (i.e., net purchase).

Feed sold within the same accounting year is already accounted for in feed production (separation of processes).

For the feeding of all products, emissions are calculated separately, depending on the type of product.

6.4.2.4 Imported synthetic fertilizer and organic manure

The consumption of synthetic fertilizers must be multiplied by the EF value of the respective synthetic fertilizer types (see Appendix 5). Up to and including the ANCA Tool-2024 version, a single emission factor per kg of supplied N, P_2O_5, and K_2O was used when synthetic fertilizer was supplied. In the ANCA Tool-2025 version, for a number of commonly used synthetic fertilizers, fertilizer-specific EF values (per kg of fertilizer) are applied based on production emissions. This applies to the following fertilizers:

- **N-fertilizers**
  - Ammonium nitrate
  - Calcium ammonium nitrate / N+S fertilizer / N+S blend
  - Urea / NTS / N+S liquid
  - Urea / Urea + Sulfur
  - Ammonium sulfate
- **P-fertilizers**
  - Superphosphate
  - Triple superphosphate
- **K-fertilizers**
  - Potassium chloride / Kali 60 / Korn Kali
  - Potassium sulfate / Kali 50
- **NPK-fertilizers**
  - DAP / NP 18-46 / N+P fertilizer
  - NPK fertilizer
  - PK fertilizer
- **Lime fertilizers**
  - Lime – dolomite
  - Lime – limestone

For all other synthetic fertilizers, the EF values per kg of N, P_2O_5, and K_2O are still used.

For organic manure, only transport emissions are accounted for, except in the case of compost. For compost, both transport and production emissions are included. Appendix 5 also provides a reference to the EF value for compost.

6.4.2.5 Imported pesticides

The use of pesticides in kg active substance (AS) is included as standard in accordance with Table 6.16.

Table 6.16 *Standard consumption of pesticides (kg AS/ha), source: www.agrimatie.nl.*

Type	Land use	Consumption (kg AS/ha)
Nematicide	grassland	0.02
Nematicide	arable land	0
Herbicide	grassland	0.16
Herbicide	arable land	1.15
Fungicide	grassland	0
Fungicide	arable land	0.01
Other	grassland	0
Other	arable land	0.01

The use of pesticides must be multiplied by the EF value of the various pesticides (Appendix 5).

6.4.2.6 Imported bedding

The use of bedding must be multiplied by the EF value of the various bedding types (Appendix 5).

6.4.2.7 Imported water

The ANCA Tool assumes 1.707 m^3 water per tonne of milk for dairy cattle (Agrimatie, 2018).
For other grazing animals, a standard consumption is calculated per animal, see Table 6.17. This consumption is multiplied with the EF value (Appendix 5).

Table 6.17 *Standard consumption of water for other grazing animals (Anonymous, 2019).*

Category	Water (m^3/yr)
Breeding bulls, > 1 year (cat. 104)	13.8
Pasture and suckler cows (cat. 120)	11.3
Calves for rosé or red meat (cat. 115)	4.6
Rosé calves, 3 months – slaughter (cat. 116)	11.3
Rosé calves, 2 weeks – slaughter (cat. 117)	8.8
Red meat bulls, 3 months – slaughter (cat. 122)	13.8
Breeding sheep, incl. lambs (cat. 550)	3.6
Meat sheep, < 4 months (cat. 551)	2.9
Other sheep, > 4 months (cat. 552)	2.9
Milk goats (cat. 600)	11.3
Rearing and meat goats, < 4 months (cat. 601)	11.3
Rearing and meat goats, > 4 months (cat. 602)	11.3
Ponies (cat. 941)	22.5
Horses (cat. 943)	22.5
Donkeys (cat. 941)	22.5
Water buffalo, cows (cat. 991)[1]	3.8
Water buffalo, youngstock (cat. 992)[2]	

[1] Based on dairy cattle including youngstock (55 kWh per tonne milk, annual production of 2200 kg milk per buffalo).

[2] Value included in the value for water buffalo - cows.

6.4.2.8 Imported livestock

In the ANCA Tool, the supply of livestock is expressed in kg. The weight of the supplied animals depends on the breed and the average age at delivery. Starting from the ANCA Tool 2024 version, the calculation method has been revised. Previously, default values from Agri-Footprint were used, which are outdated and less representative of current Dutch dairy farming.

On behalf of ZuivelNL, a new calculation was carried out using a representative set of over 580 dairy farms (year 2023), where the allocation factor to meat was less than or equal to 0.25 and no animal purchases occurred.

For these farms, the CO_2 emissions associated with purchased animals were calculated as follows:

> *CO_2-imported animals (g CO_2-eq/MJ) = Total CO_2-eq emissions farm x allocation factor meat / total energy for animal removal*

For the calculation of the allocation factor and the total energy for animal removal, see Section 6.2.3. On average, the value for supplied dairy cattle was 334 g CO2-eq/MJ (broken down by origin: 170 g, 103 g, 8 g, and 53 g for biogenic, fossil, LUC, and peat, respectively).

6.4.2.9 Imported silage covering material

The consumption of covering material is calculated based on the amount per ton of dry matter of the harvested grass and corn silage products, according to Table 6.18. The consumption is then multiplied by the EF value (Appendix 5).

Table 6.18 *Use of plastic as a covering material for grass silage and corn silage (kg / tonne DM), source: Hospers et al., 2019.*

Roughage type	Use
Grass silage	0.95
Corn silage	1.49

6.4.2.10 Transport

All products have a carbon footprint that is calculated up to a regional delivery point, i.e., a trader in fuels or fertilizers, etc. All these products still have to be transported by truck to the primary farm. In the calculations, the ANCA Tool assumes that no other forms of transport are used than trucks. Standard distances from the regional delivery point to the farm are used for all these products (Table 6.19). The distance then has to be multiplied by the EF value (Appendix 5).

Table 6.19 *Fixed transport distances (km) for various products.*

Product	Standard distance
Fresh grass, grass products and corn silage products	50
Other roughage and wet (by)products	100
Concentrate feeds and milk products	60
Cover materials	50
Diesel	300
Drying	100
Natural gas	100
Pesticides	50
Synthetic fertilizer	100
Oil	100
Organic fertilizer	100
Straw	50
Livestock	250

6.5 Input of effective organic matter

The KringloopWijzer calculates the input of effective organic matter to the soil. This refers to the organic matter that has not decomposed one year after application and therefore contributes to maintaining the soil's organic matter content. The sources of input are shown in Table 6.20. Manure and crop residues are the main sources of organic matter input to the soil. The numbering of the input sources corresponds to that in the BEN (Chapter 4, Table 4.1).

Table 6.20 *Input terms for determining the input of effective organic matter (kg/ha).*

Code[1]	Term
EOMIn1	Pasture manure
EOMIn2	'Barn manure', excl. Feed residues roughage
$EOMIn2_{feedresidues}$	Feed residues
EOMIn6+7	Crop residues (incl. grazing, cut- and harvest losses)
EOMIn8	Catch crops and green fertilizers

[1] Numbering corresponds to the input items of the N balance in the BEN (Table 4.1).

6.5.1 Organic manure

The input of effective organic matter from animal manure and other organic fertilizers (e.g., compost) is linked to the BEN module through the OM/N ratio and the humification coefficient of the organic matter (Table 6.21). For manure produced on the farm itself, except for digestate, a farm-specific OM/N ratio is used (see also Section 6.6.1.1.2). For the other manure types, the OM/N ratios shown in Table 6.21 are applied.

Table 6.21 *Humification coefficients ('HC values') of organic fertilizers, the amount of organic matter per kg N-total in manure, and the fixed effective organic matter contribution of various fertilizers (www.handboekbodemenbemesting.nl).*

Source	HC[1] (kg OM per kg OM applied)	OM/N	E.O.M.[1] contribution	
			(per m³) [2]	(per kg N-total[2])
Feed residues (based on fresh plant material)	0.25			
Grazing animals slurry, manure code 14	0.70	17.8[3]	50	12
Grazing animals solid manure, manure code 10	0.70	20.1[3]	98	14
Pasture manure grazing animals[4]	0.70	17.8[3]	50	12
Indoor housed animals slurry, manure code 50	0.33	11.3[3]	27	4
Grazing animals solid manure, manure code 39	0.70	12.3[3]	84	4
Compost[5]	0.90	30.1[3]	152	27
Grazing animals thin fraction, manure code 11	0.70	11.7[3]	29	8
Grazing animals thick fraction, manure code 13	0.70	24.1[3]	118	17
Synthetic fertilizer substitutes (scrubbing water, mineral concentrate)	0.33	2.9[6]	7	1
Digestate[7]	0.90[8]	6.0[3]	30	5
Other[4]	0.70	17.8[3]	50	12

1 HC: the humification coefficient is the fraction that is effectively present one year after application: 'E.O.M.'.

2 Based on Table 1.2.

3 Den Boer et al., 2012.

4 As grazing livestock slurry.

5 Average household and green compost.

6 Velthof, 2011.

7 Average of cattle and finishing pigs and decomposition of Norg of 25-50%.

8 As from compost, due to prior mineralization.

The input of effective organic matter is initially calculated separately for grassland ('input and output per hectare of grassland') and for arable land ('input and output per hectare of arable land), where arable land consists of arable roughage crops (corn, MKS, CCM, alfalfa, field bean) and marketable arable crops (grain corn, cereals, seed crops, root crops, etc.). Only in a second step is the weighted average of the individual land use types calculated. In the 'per hectare' amounts, therefore, it is not initially about outcomes per hectare of farmland but about outcomes per hectare of a certain type of land use (grassland, arable land).

The term OMIn1 (effective organic matter from pasture manure, Table 6.20) applies to grassland hectares only, as follows:

$EOMIn1 = In1 \times OM / N_{manure} \times HC_{manure}$,

where:
OM / N_{manure} and HC_{manure} : see Table 6.19 for manure from grazing animals

The term EOMIn2 (effective organic matter from 'barn manure', Table 6.20) cannot simply be derived from the crop-specific terms from the BEN calculation if In2 includes manure from grazing animals. This is because in that case manure (In2) is defined as the sum of excreted N in manure (sum of manure-N and urine-N) including feed leftovers-N. Because OM/N_{manure} is not the same as $OM/N_{feed\_leftovers}$ and HC_{manure} is not the same as HC_{fresh_crop}, the contribution of the two separate components must be calculated first. To this end, the weighted average N content of the dry matter (DM) in the ensiled roughage is calculated based on the input data from BEX (N%roughage, % N in DM). Assuming that 90% of the feed-DM consists of organic matter, the following applies:

$OM/N_{feed\_leftover}$ = (kg OM per kg DM) / (kg N per kg DM) = (90/100) / (weighted N content in kg per kg of roughage, by-products and concentrates)

The effective organic matter that is supplied as 'barn manure' (OMIn2) on grassland and arable land, is equal to:

$EOMIn2_{pure\_manure}$ on grassland = Fraction 'real' manure x In2 on grassland x $OM/N_{manure} \times HC_{manure}$

$EOMIn2_{pure\_manure}$ on arable land = Fraction 'real' manure x In2 on arable land x $OM/N_{manure} \times HC_{manure}$

where Fraction of 'real' manure = ((In2 at average farm level, kg N/ha - weighted average feed leftovers of all feedstuffs used, kg N/ha) / (In2 at average farm level, kg N/ha))

In2 refers to the input with organic manure at the farm level. This is calculated by first determining the EOM input for the individual manure types (grazing animal manure, non-grazing animal manure, and compost) based on the manure-specific N input, OM/N_{manure}, and HC_{manure}. A weighted farm average is then calculated from the EOM input of the individual manure types. It is assumed that there is no difference in the input of effective organic matter between non-digested and digested manure. In digested manure, the OM/N ratio decreases and the humification coefficient (HC) increases in such a way that the input of effective organic matter (EOM) is equal to that of non-digested manure.

The effective organic matter applied as feed leftovers via manure on the land ($OMIn2_{feed\ leftover}$) is equal to:

$EOMIn2_{feed\_leftover}$ on grassland = (1 – Fraction of 'real' manure) x In2 on grassland x $OM/N_{feed\_leftover} \times HC_{fresh\_crop}$

$EOMIn2_{feed\_leftover}$ on arable land = (1 – Fraction of 'real' manure) x In2 on arable land x $OM/N_{feed\_leftover} \times HC_{fresh\_crop}$

HC_{fresh_crop} = 0.25 and $OM/N_{feed\_leftover}$ based on the average N content of the ensiled roughage

6.5.2 Crop residues

The input via crop residues and green fertilizers (EOMIn6+7 and EOMIn8, Table 6.20) is calculated in the ANCA Tool using crop-specific values for the input of organic matter from crop residues and the humification coefficient of the organic matter of the crop residue, as reported in the *Handbook on Soil and Fertilization (Dutch: Handboek Bodem en Bemesting)* (www.handboekbodemenbemesting.nl, Table 6.22). By multiplying these values, the EOM input per crop is obtained. For the allocation of the specified area of green fertilizers over early and late sown green fertilizer, see Section 6.6.1.1.

Tabel 6.22 *Organic matter contribution (OM, kg per ha per year) and humification coefficient (HC) of several arable crops and green fertilizers (source: www.handboekbodemenbemesting.nl).*

Crop	Crop residue OM	Crop residue HC	By product OM	By product HC
Grass, permanent, 1e year after reseeding	6800	0.320		
Grass, permanent, other	10200	0.330		
Grass, temporarily	6800	0.290		
Grass, successive crop	4000	0.320		
GPS-grains	5200	0.315	-	
Alfalfa	4000	0.430	-	
Red clover	4000	0.430	-	
Beets	1785	0.210	4215	0.214
Corn	2000	0.338	5000	0.300
Cereals	5200	0.315	3300	0.300
Seed crops-other	3000	0.325	1955	0.330
Grass seed	6575	0.297	2240	0.310
Legumes	1600	0.313	1600	0.313
Potatoes	3850	0.219	-	
Seed potatoes	4400	0.217	-	
Onions and flower bulbs	1275	0.235	-	
Leafy vegetables	4760	0.210	-	
Non-leafy vegetables	2510	0.259	580	0.259
Other crops	4000	0.250	-	
Green fertilizer, early-sown	4000	0.250	-	
Green fertilizer, late-sown	2200	0.250		

The compounds that make up this organic matter contain, besides C, also N and P. The ratio between the three varies but is roughly (C : N : P) 96 : 8 : 1 (Kirkby *et al.*, 2011). This means that there are limits to the extent to which organic matter contents can (continue to) decrease without N and P also being released, but also that with (continued) increase in organic matter levels, net fixation of N and P occurs. These N and P are therefore not available for crop growth, but also cannot be lost to the environment. In this sense, the three cycles are linked via the soil, similar to the linkage via the composition of crops. As organic matter in Dutch soil consists of approximately 54% C (Tol-Leenders *et al.*, 2019), a fixation of 1000 kg of organic matter per ha (i.e. an increase in the organic matter content in a soil layer of 25 cm by approximately 0.03 percentage points) corresponds to approximately 540 kg C (1980 CO_2), 45 kg N and 6 kg P (14 kg P_2O_5).

6.6 CO_2-emission soil

In the 2022 version of the ANCA Tool, a soil carbon module was added with indicative calculations of CO_2 emissions from mineral and organic soils. Various changes were made in the 2024 version, which means the calculations are no longer indicative.

The main features of the 2024 version are:

- Some of the required data are already available within the ANCA Tool. For additional data, users can choose between two options:
  - Region-specific: no extra data entry is required from users; additional data are retrieved using the farm's postal code from tables, which are partly derived from maps.
  - Parcel-specific: additional parcel-level data are retrieved from linked soil analyses or from linked maps.
- Calculations are performed at the crop level, but the output is presented at the level of the crop groups: grass, corn, and other arable land.
- For mineral soils, the RothC soil carbon model is used (Coleman *et al.*, 1997). This method has also been used since 2023 for the Dutch National Inventory Report (NIR) *(Dutch: Nederlandse National Inventory Report (NIR))*.
- Organic soils are divided into coastal lowlands and highland soils.
  - For highland soils, the current NIR methodology is used (Arets et al., 2019; Kuikman et al., 2005)
  - For coastal lowlands, a new method based on the SOMERS model is used (https://www.nobveenweiden.nl/bevindingen-rekenregels/). This method is also being implemented in the NIR.
- Peaty soils that are designated as mineral in the RVO soil types map (Fertilizer Act) are treated as organic soils in the soil carbon module.
- The carbon and nitrogen cycles are considered integrally.
  - Changes in organic N stocks on mineral soils are linked to changes in C stocks via the C/N ratio (see also Chapter 4, BEN).
  - For peat soils, the current default values for N mineralization (235 kg N/ha) and nitrous oxide emissions (4.7 kg N_2O-N/ha) remain, while C mineralization and CO_2 emissions vary depending on soil type, topsoil type, and drainage.
- The metrics for the input of effective organic matter (EOS, see Section 6.5) have been adjusted and aligned with the metrics for organic matter input for RothC.

Figure 6.3 provides an overview of the use of additional data and the applied calculation rules. The overview distinguishes between:
- Use of RVO parcel data (yes/no)
- Soil type (Mineral/Organic)
- Organic soil type (Coastal lowland/Highland)

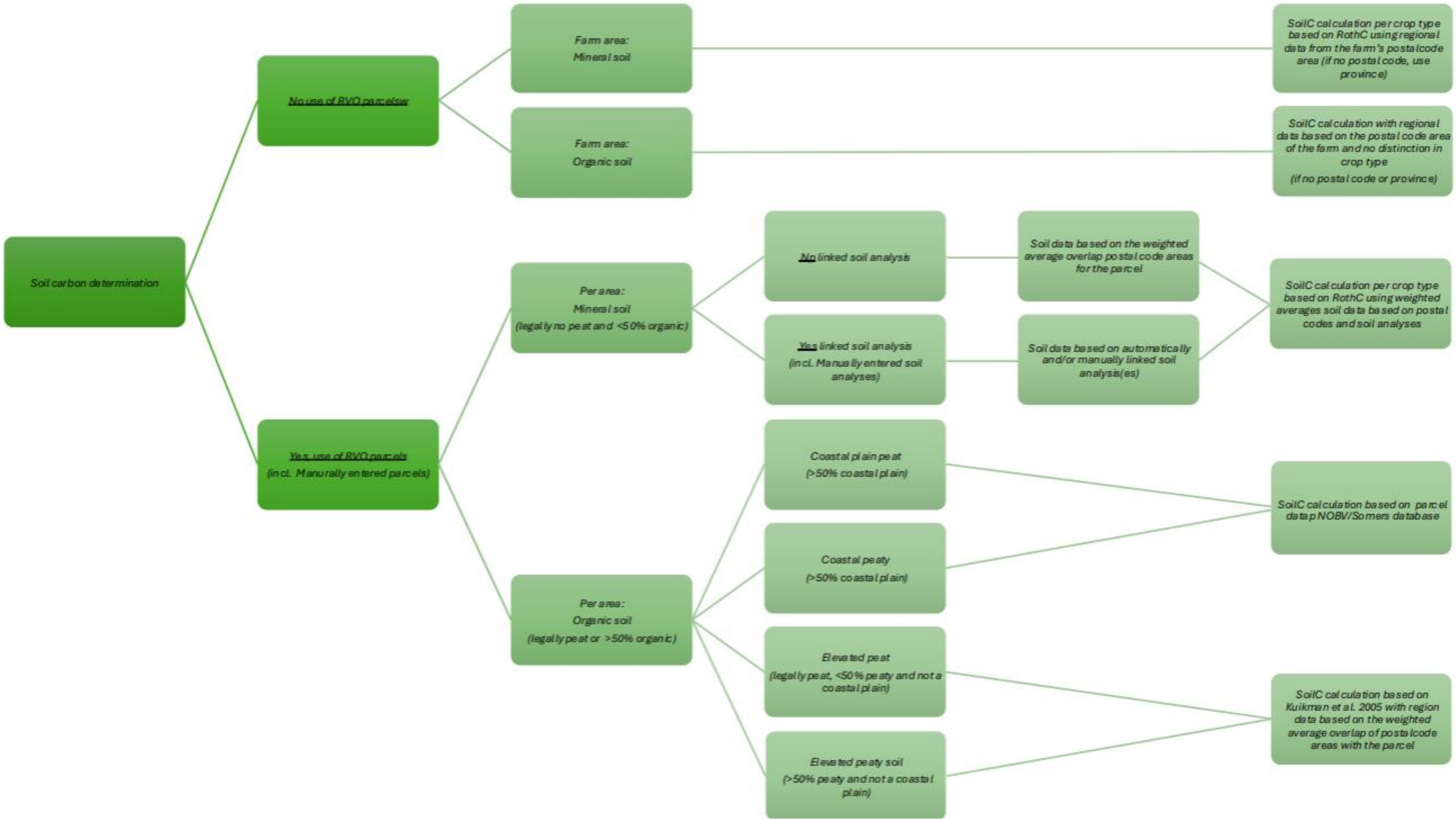

Figure 6.3 Overview of additional data sources and calculation rules in the soil carbon module.

6.6.1 CO_2-emission mineral soils

The CO_2-emission of mineral soils is calculated from the carbon balance of the topsoil (0-25 cm).

CO_2-emission [kg/ha] = C-balance [kg/ha] x 44/12

The carbon balance of mineral soils is calculated using the RothC carbon model (Coleman *et al.*, 1997) with a monthly time step. The approach follows, as closely as possible, the methodology of the *Praktijktool koolstof* (Hendriks *et al.*, 2022). The description of the calculation rules is largely based on the *Praktijktool* and has been adapted where necessary to align with the methodology of the ANCA Tool.
The carbon balance represents the difference between inputs of crop residues and organic manure and losses through the decomposition of organic matter into CO_2. The balance can be either positive or negative. A positive balance indicates an increase in soil carbon stocks, referred to as "carbon sequestration." Carbon sequestration corresponds to a negative CO_2 emission from the soil.
Calculations are performed at the crop level, but results are aggregated for the crop groups grass, corn, and other arable land. Three grassland types are distinguished: (i) Temporary, (ii) Permanent – first year (the first year after reseeding), and (iii) Permanent – other. For corn silage and all other arable crops, four types of arable land are distinguished: (i) Continuous with green fertilizer, (ii) Continuous without green fertilizer, (iii) Rotational with green fertilizer, and (iv) Rotational without green fertilizer.

6.6.1.1 Input

The input of organic matter consists of crop residues (Table 6.22) and organic manure. The organic matter in crop residues and organic manure contains 50% carbon.

6.6.1.1.1 Crop residues

The input of crop residues from grassland is based on Lesschen *et al.* (2020), in which a calibration for permanent grassland was performed using Dutch long-term experiments. From these data, an average carbon input of 5.1 t/ha/year (= 10.2 t organic matter/ha/year) for permanent grassland was derived. For temporary grassland and first-year permanent grassland, insufficient data were available; therefore, an input of 3.4 t/ha/year (= 6.8 t organic matter/ha/year) was estimated using the ratio between the existing EOS metrics for temporary and permanent grassland as reported in the *Handbook of Soil and Fertilization (Dutch: Handboek Bodem en Bemesting)* (www.handboekbodemenbemesting.nl). An average grassland age of three years was assumed. Currently, no distinction is made based on grassland age within crop rotations.
For the C-input from crop residues of arable crops, default values as presented in Table 6.22 are used.

For the input of crop residues from cover crops, a distinction is made between early- and late-sown cover crops, with carbon inputs of 2.0 and 1.1 t/ha, respectively (equivalent to 4.0 and 2.2 t organic matter/ha). The area of cover crops is known for silage maize and for the group of other arable crops as a whole. For silage maize, a carbon input corresponding to a late-sown cover crop (1.1 t C/ha) is applied. For other arable crops, the reported area of cover crops is first allocated to the area of early-harvested crops, with a carbon input of 2.0 t C/ha. If the cover crop area exceeds the area of early-harvested crops, the remaining cover crop area is assigned to the area of later-harvested crops.
If any cover crop area still remains, it is assigned to area of the group of crops after which, in practice, cover crops are generally not grown. For the last two groups, a carbon input of 1.1 t C/ha is used (corresponding to the input from a late-sown cover crop after silage maize).

The annual C-input (Table 6.22), is evenly distributed over 12 months. The quality of the organic matter (its degradability) is expressed by the ratio between decomposable organic matter (Decomposable Plant Matter; DPM) and resistant organic matter (Resistant Plant Matter; RPM), as well as by the share of humus (Humified Matter; HUM).
For crop residues, the DPM/RPM ratio is 1.44 (59% DPM and 41% RPM). Crop residues do not contain HUM.

6.6.1.1.2 Organic manure

In calculating the carbon input from organic manure, a distinction is made between manure produced on the farm and organic manure imported from outside the farm. For manure produced on the farm, the amount of carbon is calculated based on the calculated excretion of organic matter and its degradation during storage (see below). An exception applies to digestate and, if present, its separated liquid and solid fractions; for these, a fixed OM/N ratio is currently assumed (Table 6.21). The same approach is applied to C-input from imported manure.

As noted above, for farm-produced manure, excluding digestate, the C-input is calculated from the calculated excretion of organic matter. However, this refers to the gross excretion ("under the tail"). Before the manure is applied to the field, part of the organic matter is lost through C-emission (CH_4 and CO_2) during pre- and post-storage. In addition, extra C is added to the manure during storage through, among other things, bedding material and feed residues (see Table 3.2).

To calculate the OM-losses between excretion and manure application to the land, CH_4-formation is first calculated from the amount of excreted VS (volatile solids). The amount of CH_4 formed (in kg) is then converted back to the corresponding amount of OM (in kg) using the mass ratio between CO_2 and CH_4 in the emitted gas.

The C-loss is calculated as follows:

C-losssCH₄ = *CH₄-emission * 12 / 16*
C-loss_tot = *C-lossCH₄ / frCH₄-C*
OM-loss = *C-loss_tot / 0.50*

Where:

- *C-lossCH₄* = *CH₄-emission expressed in kg C*
- *CH₄-emission* = *CH₄-emission in kg (for calculation see section 6.3.2)*
- *frCH₄-C* = *the fraction CH₄-C in formed gas, the rest is CO₂-C (= volume fraction)*
- *C-loss_tot* = *total C-loss as a result of the emission of CH₄ and CO₂*
- *0.50* = *C-content in organic matter*

The CH_4-emission and accompanying C-losses are calculated for the following components:

- During storage in the barn and external storage (in the NEMA this is a single item)
- During post-storage of the manure after manure processing (liquid and solid fraction)
- Pasture manure

For CH_4 emissions, reference is made to Section 6.3.2. A value of 0.25 is used for $frCH_4$-C, based on Petersen *et al.* (2024). However, this value is only provided for gas produced during the storage of slurry. Except for digestate streams, this value is also applied to gas produced during the storage of other manure types and with pasture manure.

To prevent the ANCA Tool from using strongly deviating OM/N ratios, minimum and maximum values are applied for each manure type (Table 6.23). If calculated values fall below or above these limits, the fixed OM/N ratios as presented in Table 6.21 are used.

Table 6.23 Minimum- en maximum-values for calculated OM/N-ratio per manure type.

Manure type	Minium	Maximum
Pasture manure grazing animals	5	
Slurry grazing animals[1]	5	
Solid manure grazing animals[2]	10	
Thin fraction grazing animals	1	20
Thick fraction grazing animals	10	50

[1] No maximum, because on farms with only solid manure, the 'slurry' consists of sawdust.

[2] No maximum, because on farms with only slurry, the solid manure consists of straw and feed residues.

The C-input from manure imported from outside the farm is calculated using the nitrogen-to-organic matter ratio of the respective types of organic manure (Table 6.21).

As with crop residues, the annual input is evenly distributed over twelve months. Regarding the quality of the organic matter, it is assumed that animal manure consists of 49% DPM, 49% RPM, and 2% HUM. Compost is already partially decomposed, and it is therefore assumed to contain 15% DPM, 70% RPM, and 15% HUM.

6.6.1.2 Output

6.6.1.2.1 Region-specific input data

For the calculation of the carbon balance of mineral soil types, the following data are used:

- monthly precipitation, temperature and evaporation
- carbon content and clay content of the soil in the 0-25 cm layer
- monthly carbon input from crop residues and organic manure (see section 6.6.1.1)
- monthly crop-specific soil cover

Based on the 4-digit postal code table, the nearest weather station is selected from a set of 14 weather stations distributed across the country. Average weather data for the period 2013–2022 are used, whereby the model is first run for each of the ten weather years, after which the results are averaged over the ten years. 'De Makkink' evaporation is converted to open water evaporation using a conversion factor of 1.25 (Feddes *et al.*, 2003).

The carbon content under grassland and arable land is retrieved from a 4-digit postal code table based on the 2018 LSK dataset (Van Tol-Leender *et al.*, 2019). The clay content is retrieved from a 6-digit postal code table derived from the BOFEK-2020 soil map. A verification is then performed based on the specified soil type and the clay content of sandy soils with values above 10 and of clay soils with values below 10 is set to 10.

The carbon and clay contents are used to calculate soil bulk density using pedotransfer functions for clay and loess (Wösten *et al.*, 2001) and for sand (Hoekstra and Poelman, 1982):

$$SD_{clay\_loess} = 1 / (0.6117 + 0.003601 \times LUT + 0.002172 \times (SOC / 0.54)^2 + 0.01715 \times LN(SOC / 0.54))$$

$$SD_{zand} = 1 / (0.667 + (0.021 \times (SOC / 0.54)))$$

In this, SD is the soil density (g/l), LUT is the lutum content (%) and SOC is the organic carbon content of the soil (%). The initial stock of soil organic carbon in the 0-25 cm layer in then as follows:

$$SOC\_25 = SOC \times SD \times 25$$

Finally, the crop-specific soil cover is retrieved from the data in Appendix 9.

6.6.1.2.2 Input data plot-specific

If the user chooses to use plot-specific information, part of the above region-specific data is replaced by plot-specific data. For each plot, there are two options:

1. SOIL SAMPLES. A plot has a soil sample from no more than four years ago that overlaps at least 80% with the crop plot. In that case, the following data are linked to the crop plot:
   - Carbon content soil in layer 0-25 cm.

     If the carbon content is unknown, it is calculated from the organic matter content:

     Carbon content = Organic matter content x 0.54

     If the sampling depth is 0-10 cm (SOC10) the content is converted to 0-25 cm (SOC25) using the formulas below:

     If clay content <= 10 then SOC25 = -0.21068 + 0.970874 x SOC10
     If clay content > 10 then SOC25 = 0.622093 + 0.581395 x SOC10

   - Organic matter content in layer 0-25 cm. Conversion for non-standard soil depths, as with the carbon content.
   - Clay content soil in layer 0-25 cm. No conversion for non-standard sampling depths.
   - CN-ratio in layer 0-25 cm. No conversion for non-standard sampling depths.

2. REGION. A plot does not have an associated soil sample. In that case, the following data are retrieved from the postal code tables based on the location of the plot.

   - Carbon content soil in layer 0-25 cm.
   - Clay content soil in layer 0-25 cm.

The RothC calculation is carried out using the weighted average of soil properties according to 1. ("soil samples") and 2. ("region"). For example, half of the corn plots have an associated soil sample with an average carbon content of 1.0%. The other half has no associated sample; the carbon content based on the plot locations is 1.2%. In this case, RothC uses 1.1%.

6.6.1.2.3 Calculation rules

The RothC-model distinguishes 5 components (Figure 6.4) of soil carbon, each with their own decomposition rate:

- Decomposable Plant Matter (DPM)
- Resistant Plant Matter (RPM)
- Microbial Biomass (BIO)
- Humified Matter (HUM)
- Inert Organic Matter (IOM)

The standard decomposition constants (per year) for the components DPM, RPM, BIO, and HUM are 10, 0.3, 0.66, and 0.02, respectively, corresponding to average decomposition times of 0.1, 3.3, 1.5, and 50 years. Inert organic matter does not decompose.

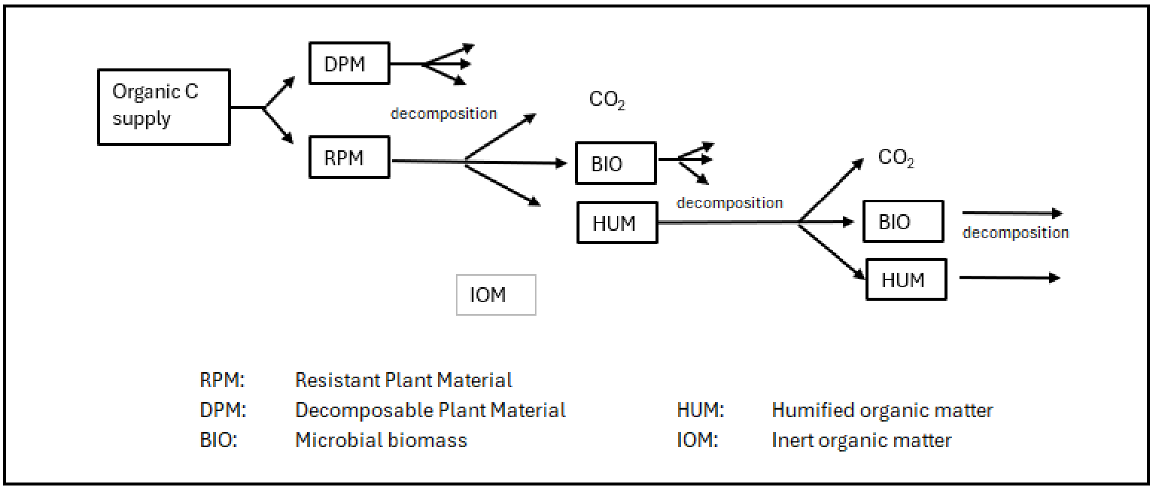

Figure 6.4 *Simplified diagram of the RothC model.*

The standard decomposition constants are affected by temperature, soil moisture, and soil cover. The decomposition rate decreases as the temperature drops, reaching zero decomposition at −5 °C (Figure 6.5, top). The monthly cumulative soil moisture deficit is calculated using precipitation, evaporation, soil cover, and clay content. The decomposition rate decreases when the moisture deficit exceeds 20 mm, up to a maximum moisture deficit (Figure 6.5, bottom). The maximum moisture deficit depends on the clay content and soil cover.

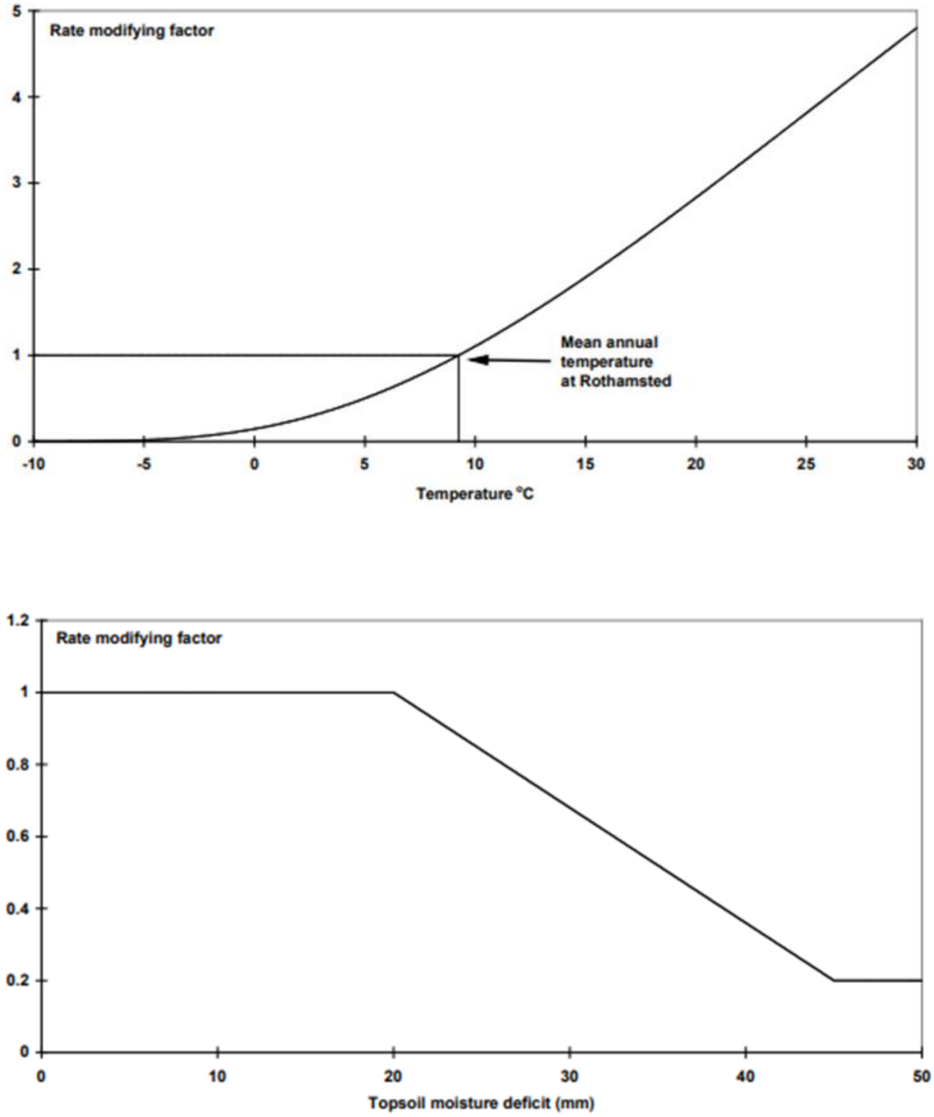

Figure 6.5 *Influence of temperature (above) and soil moisture shortage (under) on the correction factor for decomposition rate (figures are adapted from Coleman et al. (1997)); for more details, including associated formulae, see Coleman et al. (1997).*

The initial stock of soil organic carbon is allocated to the five components. The distribution depends on annual input, crop rotation, weather, and clay content. Using one-month time steps, the input (crop residues and organic manure) and decomposition of organic matter for each component are subsequently calculated. Organic matter in a given component is decomposed into CO_2, microbial biomass (BIO), and humus (HUM). The ratio between CO_2 and BIO+HUM depends on the clay content (Figure 6.6); the higher the clay content, the lower the ratio of CO_2 to BIO+HUM. The relative distribution between BIO (46%) and HUM (54%) remains constant.

After twelve monthly calculation steps, the year-end stock is determined. The balance is then the difference between the year-end and initial stock. The CO_2 emission is calculated as the change in the C-stock multiplied by 44/12, with a positive balance corresponding to a negative emission, and vice versa. For further details, including all associated formulas, reference is made to Hendriks *et al.* (2022).

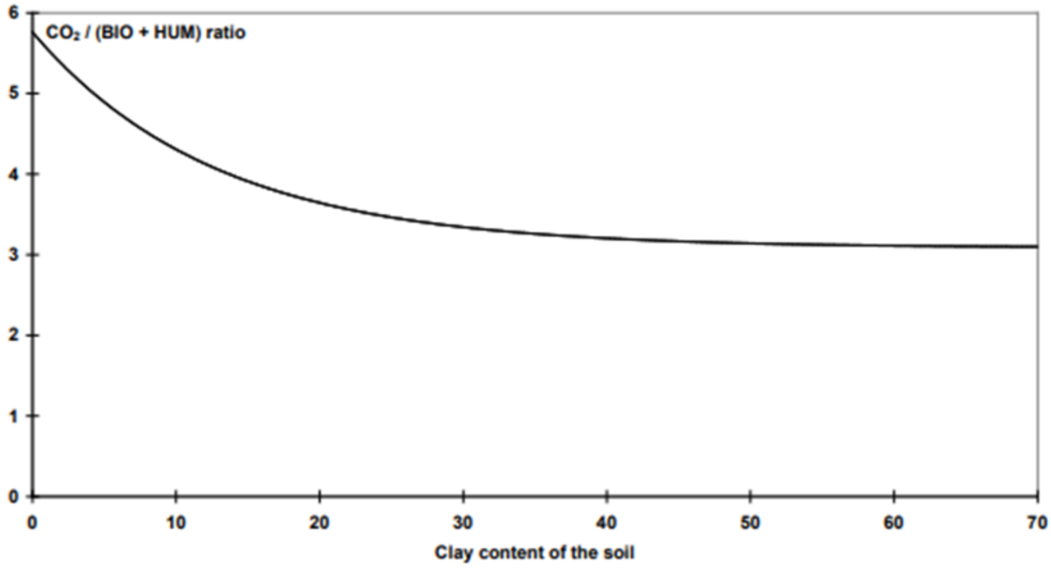

Figure 6.6 *Influence of clay content on the ratio of CO_2 and BIO+HUM (figures are adapted from Coleman et al. (1997)); for more details, including associated formulae, see Coleman et al. (1997).*

6.6.2 CO_2 emission of organic soils

For organic soils, the decomposition of organic matter from the subsoil is calculated. The balance principle used for the topsoil of mineral soils cannot be applied because the stock changes and emissions of the topsoil cannot be distinguished from those of the subsoil.

6.6.2.1 Input data region-specific

Information on soil properties and the calculated CO_2 emissions is retrieved from the following 6-digit postal code tables, based on the farm's postal code:

- Distribution of coastal plain and highland soils.
- Characteristics of highland soils (soil type, topsoil type and drainage, subsidence, CO_2 emissions).
- Characteristics of coastal plain soils (archetype, soil type, profile, ditch spacing, ground level, summer and winter water levels, infiltration measures, and CO_2 emissions).

6.6.2.2 Input data plot-specific

If the user chooses to use plot-specific information, part of the above region-specific data is replaced by plot-specific data. For each plot, there are two options:

1. PLOT. A plot of a farm overlaps at least 50% with a plot from the coastal plain map and receives all soil characteristics from that map. In practice, the overlap is usually greater than 90% when linking. This only occurs for coastal plain soils. No plot map is available for highland soils.

2. REGION. A plot has no linked characteristics from a coastal plain plot. The characteristics are retrieved from the postal code tables based on the plot's location. This applies by definition to all highland soils and may, in a limited number of cases, also occur for coastal plain soils.

The calculation of CO2-emissions is carried out using the weighted average of the soil property according to 1. ("plot") and 2. ("region").

6.6.2.3 Calculation rules

The CO_2-emission is the weighted average of the emissions of highland and coastal plain soils on the farm.

6.6.2.3.1 Highland soils

For highland organic soils, ground level subsidence is calculated based on the soil type, topsoil type, and drainage (poor, moderate, good). With this method, the ground level subsidence varies from 1.5 to 18 mm per year and the CO_2-emission from 6 to 41 t CO_2/ha/year (Table 6.24).

Table 6.24 *Average ground level subsidence (mm/year) and CO_2-emissions of Dutch organic soils (Kuikman et al., 2005) in relation to soil type, topsoil, and drainage. Poor drainage: groundwater classes I and II. Moderate drainage: groundwater classes IIb, III and IIIb. Good drainage: groundwater class IV and higher.*

			Drainage		
	Soil type	**Topsoil**	**Poor**	**Moderate**	**Good**
Ground level subsidence (mm/year)					
	Peat	Mineral	3.0	8.0	13.0
	Peat	Peaty	6.0	12.0	18.0
	Peaty		1.5	2.6	4.2
C-decomposition (kg/ha/year)					
616 kg/mm	Peat	Mineral	1848	4928	8008
616 kg/mm	Peat	Peaty	3696	7392	11088
1093 kg/mm	Peaty		1640	2842	4591
CO_2-emission (kg/ha/year)					
2259 kg/mm	Peat	Mineral	6776	18069	29363
2259 kg/mm	Peat	Peaty	13552	27104	40656
4007 kg/mm	Peaty		6012	10420	16832

6.6.2.3.2 Coastal plain soils

The CO_2 emissions of coastal plain organic soils are calculated using the SOMERS model (version 2.0, https://www.nobveenweiden.nl/bevindingen-rekenregels/). Emissions are calculated annually and depend on weather conditions, the archetype, and hydrology. The archetype describes the soil type and profile (Table 6.25). The hydrology of a plot is determined by ground level, ditch water level, ditch spacing, and the presence of any infiltration measures. Calculations are performed anew each year. In the 2024 version of the ANCA Tool, calculations for 2022 are included.

Tabel 6.25 *Overview of the archetypes of coastal plain organic soils.*

Archetype	Main soil type	Soil type	Profile
kWp	Peaty	Peaty marsh	Clay topsoil with sandy subsoil
zWp	Peaty	Peaty marsh	Sandy topsoil with sandy subsoil
vWz	Peaty	Peaty marsh	Peaty topsoil with sandy subsoil
iWp	Peaty	Fensphagnum peat	Peaty topsoil with sandy subsoil
Wo	Peaty	Peaty marsh	Peaty topsoil with clay subsoil
hVb	Peat	Peat	Peaty topsoil with peaty subsoil
hVc	Peat	Peat	Peaty topsoil with peaty subsoil
hVk	Peat	Peat	Peaty topsoil with clay subsoil
hVz	Peat	Peat	Peaty topsoil with sandy subsoil
hVs	Peat	Sphagnum peat	Peaty topsoil with peaty subsoil
kVs	Peat	Sphagnum peat with a mineral cover	Clay topsoil with peaty subsoil
pVb	Peat	Peat with a mineral cover	Clay topsoil with peaty subsoil
pVc	Peat	Peat with a mineral cover	Clay topsoil with peaty subsoil
kVc	Peat	Peat with a mineral cover	Clay topsoil with peaty subsoil
kVk	Peat	Peat with a mineral cover	Clay topsoil with clay subsoil
kVz	Peat	Peat with a mineral cover	Clay topsoil with sandy subsoil
Vc	Peat	Peat	Peaty topsoil with peaty subsoil
aVz	Peat	Peat	Peaty topsoil with sandy subsoil
iVp	Peat	Sphagnum peat	Peaty topsoil with sandy subsoil
Vk	Peat	Peat	Peaty topsoil with clay subsoil
Vz	Peat	Peat	Peaty topsoil with sandy subsoil
Vp	Peat	Sphagnum peat	Peaty topsoil with sandy subsoil
aVc	Peat	Peat	Peaty topsoil with peaty subsoil
zVz	Peat	Peat with a mineral cover	Sandy topsoil with sandy subsoil
zVp	Peat	Sphagnum peat with a mineral cover	Sandy topsoil with sandy subsoil

Table **6.26** provides an overview of the median emissions for all archetypes at different summer water levels. De data zijn gemiddeld over alle voorkomend winterpeilen, slootafstanden en regio's, zonder toepassing van infiltratiemaatregelen. The data are averaged over all occurring winter water levels, ditch spacings, and regions, without the application of infiltration measures.

Table 6.26 *Median CO_2-emissions (kg/ha/year) of archetypes in relation to summer water level (m below groundlevel), without the application of infiltration measures.*

Archetype	0.2	0.5	0.8	1.1
hVb	6119	11934	18976	24120
hVk	6445	11809	19327	24923
hVs	7626	13675	21007	26632
hVz	3954	9156	16615	22384
iWp	4199	7767	12389	16297
kVk	3348	8113	15252	20584
kVs	6055	10736	16787	21641
kVz	3420	7195	12698	17179
kWp	1806	4967	10375	15060
pVb	5987	11018	17130	21735
Vp	5380	10361	17031	22684
vWz	6218	11443	16860	20422
Wo	6943	10410	13176	14997
zVz	3315	7839	14287	19585
zWp	4382	9179	14800	18581

6.6.2.4 Correction factor peaty soils

In the soil carbon module, peaty soils are also included that are classified as mineral soils according to the *RVO soil type map (Fertilizer Act) (Dutch: RVO grondsoortenkaart (Meststoffenwet))*. If the user chooses region-specific information, a postal code-dependent correction factor is retrieved to adjust the area of mineral soils for the presence of peaty soils. If the user chooses to use plot-specific information, the mineral soil plots on a farm are compared with the peaty soils map. If a plot overlaps more than 50% with the peaty soils map, it is assigned the characteristic "peaty."

Peaty soils follow the calculation rules of organic soils.

6.7 Comments on BEC

- The CO_2 released as a result of a branch of 'indoor housed animals' (pigs, chickens, veal calves), if present, on-farm or 'upstream' fossil fuel use (via purchased feed), is not yet included in ANCA Tool. This means that the total emission of CO_2 equivalents is underestimated when 'indoor housed animals' are present.
- With regard to N and P, the ANCA Tool is mainly limited to losses and efficiencies within the boundaries of the farm. However, by not considering emissions taking place outside the farm, a comparison of farms can lead to a skewed picture. This applies in particular to emissions for which it is not the local environmental impact (nitrate and ammonium, phosphate, ammonia) that is relevant but the global environmental impact: namely the emission of CO_2 equivalents. That is why greenhouse gas emissions resulting from off-farm production processes (synthetic fertilizers, purchased feed ingredients, energy) are also included in the ANCA Tool.
- With regard to the contribution to the organic matter supply per kg of manure-N or per cubic meter of manure, only three types of manure are distinguished. With regard to manure from grazing animals and non-grazing animals, the values used were derived from the characteristics of liquid manures. Because solid manures contain a lot more C per kg N and per cubic metre, the ANCA Tool currently underestimates the organic matter supply when solid manure is used.
- In calculating the input of organic matter from organic manure, a fixed OM/N ratio is used. This differs from the calculation of CH_4 emissions from manure, which is based on a farm-specific OM content in the manure derived from the OM content and digestibility coefficient of the OM in the various ration components. This should ideally be harmonized in the future.

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Appendix 1 Reference of metrics to the corresponding section of this report

Item	Metric	Description in calculation rule report
Farm surplus	Surplus per ha: nitrogen (kg N)	Section 4.2.1
	Surplus per ha: phosphate (kg P_2O_5)	Section 5.2
Soil surplus	Surplus per ha: nitrogen (kg N)	Section 4.2.1
	Surplus per ha: phosphate (kg P_2O_5)	Section 5.2
	Imported effective org. matter per ha (kg EOM)	Section 6.5
BEX excretion farm	Benefit farm-specific excretion: nitrogen	See Appendix 2
	Benefit farm-specific excretion: phosphate	See Appendix 2
	Benefit farm-specific usage standard: phosphate	See Appendix 2
	Fat and protein corrected milk per kg BEX-excretion: nitrogen (kg milk)	The amount fat and protein corrected milk[1] produced divided by the nitrogen excretion [zie section 2.2]
	Fat and protein corrected milk per kg BEX-excretion: phosphate (kg milk)	The amount of fat and protein corrected milk[1] produced divided by the phosphate excretion [see section 2.2]
Feed efficiency	Utilization: nitrogen (%)	Section 1.4.3
	Utilization: phosphate (%)	Section 1.4.3
Soil efficiency	Utilization: nitrogen (%)	Section 1.4.5
	Utilization: phosphate (%)	Section 1.4.5
Grassland yield	Gross yield per ha: DM (kg DM)	See footnote 3
	Net yield per ha: DM (kg DM)	DM grass intake [section 2.2] + (P-yield grassland per ha [section 5.2] – P grass intake per ha [section 2.2])/average P content of grass silage of own land[1] / (1-(percentage feed loss/100))/(1-(percentage conservation loss/100))
	Net yield per ha: KVEM (kvem)	VEM grass intake [section 2.2] + (P yield grassland per ha [section 5.2] – P grass intake per ha [section 2.2]) / average P content of grass silage of own land[1] x average kVEM content of grass silage of own land[1] / (1-(percentage feed loss/100)) / (1-(percentage conservation loss/100)) / (1-percentage conservation loss/100))
	Net yield per ha: nitrogen (kg N)	N grass intake [section 2.2] + (P yield grassland per ha [section 5.2] – P grass intake per ha [section 2.2]) / average P content of grass silage of own land[1] x average N content of grass silage of own land[1]/(1-(percentage feed loss/100)) / (1-(percentage conservation loss/100))
	Net yield per ha: phosphate (kg P_2O_5)	(P yield grassland per ha [section 5.2] x (1-(percentage feed loss/100)) x (1-(percentage conservation loss/100))
Corn yield	Gross yield per ha: DM (kg DM)	Net DM yield of corn silage [section 2.2] / (1-(percentage field loss [Table 1.1]/100))
	Net yield per ha: DM (kg DM)	(P yield corn silage per ha [section 2.1] / average P content of corn silage[1] of own land x (1-(percentage feed loss) x (1-percentage conservation loss)

Item	Metric	Description in calculation rule report
	Net yield per ha: KVEM (kvem)	(P yield corn silage per ha [section 5.2] / average P content of corn silage[1] of own land x average kVEM content of corn silage of own land[1] x (1-(percentage feed loss/100)) * (1-(percentage conservation loss/100))
	Net yield per ha: nitrogen (kg N)	(P yield corn silage per ha [section 5.2] / average P content of corn silage[1] of own land x average N content of corn silage of own land[1] x (1-(percentage feed loss/100)) * (1-(percentage conservation loss/100))
	Net yield per ha: phosphate (kg P_2O_5)	(P yield corn silage land per ha [section 5.2] x (1-(percentage feed loss/100)) x (1-(percentage conservation loss/100))
Ammonia	Emissions per farm: total (kg NH_3)	Section 3.2
	Emissions per tonne of milk: total (kg NH_3)	Divide total emissions (section 3.2) by supplied quantity of milk[1] x 1000
	Emissions per LU: housing and manure storage (kg NH_3)	Divide total housing and manure storage emissions (sections 3.2.1 - 3.2.7) by number of LU on farm[2]
	Emissions per ha: fertilisation and harvest (kg NH_3)	Divide total fertilisation and harvest emissions (sections 3.2.8 - 3.2.11) by number of hectares[1]
Greenhouse gas emissions LCA	Emissions of farm per tonne fat and protein corrected milk (FPCM): on-farm methane (kg CH_4)	Divide methane emissions (sections 6.3) by supplied fat and protein corrected milk[1] x 1000
	Emissions of farm per tonne fat and protein corrected milk: on-farm nitrous oxide (kg N_2O)	Divide nitrous oxide emissions (sections 4.2.2 and 4.2.3) by supplied fat and protein corrected milk[1] x 1000
	Emissions of farm per tonne fat and protein corrected milk: on-farm other (kg CO_2-eq)	Divide other CO_2 emissions (section 6.4.1) by supplied fat and protein corrected milk[1] x 1000
	Emissions of farm per tonne fat and protein corrected milk: on-farm (kg CO_2-eq)	(Multiplication of CH_4 at farm level x 27 + multiplication of N_2O x 273 + on-farm emissions with CO_2) / supplied fat and protein corrected milk[1] x 1000
	Emissions of farm per tonne of fat and protein corrected milk: off-farm (kg CO_2-eq)	Divide farm emissions (sections 6.4.2) by supplied fat and protein corrected milk[1] x 1000
	Emissions of farm per tonne of fat and protein corrected milk: total (kg CO_2-eq)	(Multiplication of CH_4 at farm level x 27 + multiplication of N_2O x 273 + sum of (on-farm emissions with CO_2 and off-farm emissions with CO_2))/ supplied fat and protein corrected milk[1] x 1000
Greenhouse gas emissions NIR	Farm emissions: agriculture sector: methane (kg CH_4)	Total CH_4-emissions from rumen fermentation, total CH_4 emissions from barn and manure storage, and total CH_4 emissions from grazing manure (in total kilograms of CH_4, at the farm level).
	Farm emissions: agriculture sector: nitrous oxide (kg N_2O)	Total N_2O- emissions from barn and manure storage, including indirect emissions from NH_3 emissions from barn and manure storage; total N_2O from feed production (including manure application and N mineralisation in mineral soils, peat emissions from organic soils, indirect emissions from NH_3 manure application, and indirect emissions from NO_3-leaching.
	Farm emissions: agriculture sector: carbon dioxide (kg CO_2)	CO_2-emissions from feed production at the application of lime-based and urea-based fertilizers.

1 ANCA input

2 See Appendix 2 for calculation of LU.

3 Conversion of net grass yield to gross grass yield by:

- dividing calculated intake of fresh grass (DM) by (1-(grazing losses [Table 1.1]/100)) +
- dividing net grass silage yield (DM) by (1-(field losses [Table 1.1]/100))

Appendix 2 Definition and calculation of additional metrics

BEX advantage
The BEX advantage for both nitrogen and phosphate is the difference between the standard excretion and the farm-specific excretion, divided by the standard excretion * 100%.

*BEX advantage (%) = 100 * (standard - BEX) / standard*

Therefore, if the farm-specific excretion is smaller than the standard excretion, there is a BEX advantage. The calculation of the farm-specific excretion is described in Chapter 2.

The standard excretion of nitrogen and phosphate by the herd can be determined by multiplying the number of animals per animal category by the standard excretion factor for each animal category. The standard excretion factors can be found on the Netherlands Enterprise Agency (RVO) website (in Dutch) using the links below:

- https://www.rvo.nl/sites/default/files/2023-02/Tabel-4-Diergebonden-normen-2023.pdf
- https://www.rvo.nl/sites/default/files/2022-12/Tabel-4a-Diergebonden-normen-biologisch-2023.pdf
- https://www.rvo.nl/sites/default/files/2022-12/Tabel-6-Stikstof-en-fosfaat-per-melkkoe-2023.pdf

On-farm protein
The calculation method for the share of on-farm protein was changed in 2021. Until 2020, this metric was calculated as the amount of harvested protein divided by the amount of fed protein. From 2021 onward, only the 'share of on-farm protein in the ration' is calculated, as intended by the *Commission on Farm-Based Production (Dutch: Commissie grondgebondenheid).* Surpluses of roughage and sales of roughage will no longer positively affect the share of on-farm protein. A low supply of (protein-rich) concentrate feed will still have an effect. Thus, from 2021, the calculation method is as follows:

*On-farm protein (%) = 100 * (protein consumed by the herd – purchased protein consumed by the herd) / protein consumed by the herd*

Where:
Consumption = intake + feed losses

This can be broken down by the different ration components:
- Fresh grass
- Grass silage
- Corn silage
- Other roughage
- Moist (by)products
- Concentrates and minerals
- Dairy products

For each component, the share of on-farm protein used in the ration is calculated, as well as the total amount of protein (CP) and the share of the protein of each component in the entire ration. In the output report of the ANCA Tool, the 'share of on-farm protein in the ration' (or 'amount of protein from own farm land') can be found on the pages at the beginning: 'BASIC – Environment & Climate: Dairy Sector Only' and 'BASIC – Environment & Climate: Entire Farm', under the section 'on-farm protein in the dairy ration'.
The composition of this metric can be explored further via the pages 'LIVESTOCK – FEEDING RESULTS' later in the report. Two sections are shown there:
A. Dairy ration composition: CP and
B. Share of on-farm protein in the ration per feed category

The section 'A (Ration composition dairy cattle: CP)' shows how the total amount of CP in the ration is divided among the different ration components, expressed as a percentage. Table B2.1 provides an example of how the total amount of CP is broken down into the various ration components, in percent. This is part of the 'LIVESTOCK – RESULTS Nutrition' page of the output report. For example, the table shows that 15% of the total CP comes from fresh grass and 28% from concentrates and milk by-products.

Table B2.1 *Breakdown of the total amount of CP across the different ration components (%)*

Feed category	Share (%)
Share fresh grass	15
Share of grassland harvest products	31
Share of corn silage harvest products	9
Share of other roughages	2
Share of moist by-products	15
Share of concentrates and milk by-products	28

Section 'B (Share of home-grown protein in the ration by feed category)' indicates, in percentage, what portion of the protein in each ration component is produced on the farm.

Table B2.2 provides an example of the share of home-grown protein per ration component, expressed as a percentage. This is part of the 'LIVESTOCK – RESULTS Nutrition' page of the output report. For example, Table B2.3 shows that 100% of the CP from fresh grass comes from the farm's own land. It also shows that 23% of the protein in moist by-products originates from the farm's own land, whereas 0% of the protein in concentrates and milk by-products is home-grown.

Table B2.2 *Explanation of the share of Crude Protein (CP) in the different ration components that is home-grown. (For example, the CP from fresh grass comes 100% from the farm's own land; the CP in concentrates comes 0% from the farm's own land).*

Feed category	Share (%)
On-farm protein in fresh grass intake	100
On-farm protein in grassland harvest products	100
On-farm protein in corn silage harvest products	100
On-farm protein in other roughages	48
On-farm protein in wet by-products	23
On-farm protein in concentrates and milk by-products	0

Using the information from Table B2.1 and Table B2.2, the total share of home-grown protein in the ration (i.e., the share of protein originating from the farm's own land) can be calculated. This is done by multiplying and then summing the percentages for the different ration components. This calculation is shown in Table B2.3; for instance, 100% times 15% of the CP results in 15%. This multiplication is carried out for each ration component, and it shows, for example, that although 28% of the total CP comes from concentrates, none of it is home-grown. Therefore, the value for concentrates in Table B2.4 is 0%. In this case, the total share of home-grown protein in the ration is 59%.

Table B2.3 *Explanation of the share of purchased CP in the grass silage stored on the example farm (%).*

Ration composition of dairy cattle (share CP)	%	Share of own protein in ration per feed category	%	%
Fresh grass	15	In fresh grass	100	15
Grassland harvest products	31	In grassland harvest products	100	31
Corn silage harvest products	9	In corn silage harvest products	100	9
Other roughages	2	In other roughages	48	1
Wet by-products	15	In wet by-products	23	3
Concentrates and milk by-products	28	In concentrates and milk by-products	0	0
total	100		Total	59

Nitrogen soil surplus per hectare

The N soil surplus is calculated based on the grassland, corn land and the land where (marketable) arable crops are grown. A weighted average of this (across the area) is then calculated.

> *N soil surplus per 'crop' = N import (including manure (net, minus ammonia emissions), N capture and N mineralisation) - N export (crop)*
>
> *Weighted average N soil surplus = [% grassland * N soil surplus (grassland; kg N/ha) + % corn land * N soil surplus (corn land; kg N/ha) + % arable crops * N soil surplus (land under arable crops; kg N/ha)]/100%*

The soil surplus for nitrogen is shown in the 'Environment & Climate' section in the ANCA export report. Imports of nitrogen with manure, with synthetic fertilizer and with mineralisation, deposition and legumes are circled. See also Table B2.4 with the red circled values. This comes to a total of 262 kg per ha in this example. Nitrogen export per hectare with crops amounts to 197 kg, see red arrow in Table B2.4. The nitrogen soil surplus is then 65 kg per ha.

Table B2.4 *Explanation of nitrogen input to the soil and nitrogen output from the soil, resulting in a nitrogen soil surplus. Part "Environment & Climate" of the ANCA Tool output report (for the meaning of the red oval and red arrow, see text).*

BASIC - Environment & Climate: Dairy

Dairy - Nitrogen soil surplus	2024	2023	2022
Surplus soil total (kg N/ha)	65		
Supply of artificial fertilizer (kg N/ha)	62		
Supply of organic and pasture manure (kg N/ha)	156		
Legumes, deposition, mineralization (kg N/ha)	44		
Export of harvested products (kg N/ha)	197		

Ammonia emissions per hectare

> *Ammonia emissions per ha = (NH_3 emissions from barn and manure storage of grazing animals/ha + NH_3 emissions during grazing/ha + NH_3 emissions during manure application/ha + NH_3 emissions from use of synthetic fertilizer/ha + NH_3 emissions from crop residues from harvest losses and tearing of grassland/ha)*

See also 'FARM - RESULT Ammonia' in the ANCA Tool export report for the various components of the ammonia emissions per ha and per LU (Table B2.5)

Table B2.5 *Explanation of ammonia emissions for the different parts of the dairy farm, 'FARM-RESULT Ammonia' of the ANCA Tool output report (for the meaning of the red ovals, see text).*

FARM - RESULT Emission of ammonia				
Emission of ammonia in kg NH3	**Farm**	**Hectare**	**Ton milk**	**LU**
Emission total, farm	1841	32,9	2,24	19,3
Emission total, ruminants	**1841**	**32,9**	**2,24**	**19,3**
Emission from stable+storage	**1006**	**18,0**	**1,22**	**10,5**
Emission from fertilization	**794**	**14,2**	**0,97**	**8,3**
- organic manure appl. grassland	519	9,3	0,63	5,4
- organic manure appl. arable land	50	0,9	0,06	0,5
- artificial fertilizer grassland	137	2,5	0,17	1,4
- artifiacial fertilizer arable land	60	1,1	0,07	0,6
- pasture manure (grazing)	28	0,5	0,03	0,3
Emission from above crop residues	**41**	**0,7**	**0,05**	**0,4**
- harvest and field loss	36	0,6	0,04	0,4
- ploughing of grassland	5	0,1	0,01	0,1

Ammonia emissions per LU

Ammonia emissions per LU = (NH_3 emissions from barn and manure storage from grazing animals / LU + NH_3 emissions during grazing / LU + NH_3 emissions during manure application / LU + NH_3 emissions from use of synthetic fertilizer / LU + NH_3 emissions from crop residues from harvest losses and tearing of grassland / LU)

See also 'FARM - RESULT Ammonia' of the ANCA Tool output report for the various components of ammonia emissions per ha and per LU.

LU calculation

The LUs are calculated as follows (source: https://www.rvo.nl/sites/default/files/2020/06/Brochure-Fosfaatreductiemaatregelen-2017.pdf):

- A cow aged 0-1 year is 0.23 LU.
- A cow aged 1 year or older that has not calved is 0.53 LU.
- A cow that has calved at least once is 1.0 LU.

Proportion of permanent grassland

The proportion of permanent grassland is determined based on the RVO definitions. This method is used every year in the compulsory combined data acquisition (GDI) for the government. RVO uses various codes for grassland. The definitions and codes for permanent grassland are as follows:

- Grassland, permanent: code 265.
- Grassland, natural. Main function agriculture: code 331.
- Margin, adjacent to permanent grassland or a permanent crop, mainly consisting of permanent grass: code 333.
- Margin, adjacent to arable land, mainly consisting of permanent grass: code 334.

Permanent grassland therefore consists of the sum of the area of land with the above codes, i.e. the sum of the areas with codes 265, 331, 333 and 334.
To determine the proportion of permanent grassland, the calculated area of permanent grassland must be divided by the total area farmed by the livestock farmer. However, a livestock farmer can also have (permanent) natural grassland with nature as the main function, which does not fall under the RVO definition of permanent grassland. This concerns the definitions 'grassland, natural, main function nature (code 332)' and 'natural land, including heathland (code 335)'. In practice, this will in fact be permanent grassland, but because the main function of this is nature, it is not classified as permanent grassland. Therefore, to calculate the proportion of permanent grassland, these grasslands are deducted from the total area.

The calculation method for *proportion of permanent grassland* is therefore:

*100% * sum of areas with codes (265, 331, 333, 334) : (total farm area – sum of area with code (332, 335))*

Appendix 3 List of acronyms

Classification by theme

General farm aspects

N:	Nitrogen
P:	Phosphorus
NO_3:	Nitrate
N_2O:	Nitrous oxide
PO_4:	Phosphate
NOx:	Nitrogen oxides
CO_2:	Carbon dioxide
CH_4:	Methane
NH_3:	Ammonia
NH_4:	Ammonium
EF:	Emission factor, %
TO:	Total farm area, ha
SG:	Total area of grassland, ha
SA:	Total area of arable land including corn silage, ha
SC:	Area of corn silage, ha
ORO:	Area of other arable roughages
SM:	Area of arable marketable crops, not roughage, ha
WGO:	Area of grassland in rotation (= rotated between arable land and grassland), ha
WBO:	Area of arable land in rotation (= rotated between arable land and grassland), ha
ESG:	Difference in barn manure application (kg N/ha grassland) between grassland in continuous cultivation and grassland in rotation
ESB:	Difference in barn manure application (kg N/ha arable land) between arable land in continuous cultivation and arable land in rotation
EKG:	Difference in synthetic fertilizer application (kg N/ha grassland) between grassland in continuous cultivation and grassland in rotation
EKB:	Difference in synthetic fertilizer application (kg N/ha arable land) between arable land in continuous cultivation and arable land in rotation
Factor_purchase_mutation:	Ratio between BEX-based P intake and P intake as reported
BEX_Pint_gscs_mlk:	P intake by dairy cattle from grass silage and corn silage
BEX_Pint_gscs_other:	P intake by other grazing animals from grass silage and corn silage
Stock_Puse_gscs:	P consumption calculated from reported stocks (initial + added – end)
PcFeedlossRoughage:	Percentage of feed loss from roughage

Animal

NEB:	Negative Energy Balance
FPCM:	Fat and protein corrected milk production
WT:	Live weight
DM:	Dry matter
CP:	Crude protein
DCP:	Digestible crude protein
VEM:	Dutch energy unit for lactation (Voeder Eenheid Melk)
CA:	Crude ash
DC:	Digestion coefficient, g/g
CI:	Calving interval

Organic matter

EOM:	kg effective organic matter (OM), the organic matter that remains in the soil 12 months after application, kg (E)OM per ha
HC:	Humification coefficient, fraction of organic matter (OM) remaining in the soil 12 months after application, kg OM per kg OM
OM/N:	kg N per kg OM
EOMIn1:	EOM in the form of pasture manure, kg OM/ha
EOMIn2:	EOM in the form of barn manure (including feed leftovers), kg OM/ha
EOMIn6:	EOM in the form of grazing and mowing losses, kg OM/ha
EOMIn7:	EOM in the form of crop residues, kg OM/ha
EOMIn8:	EOM in the form of catch crops and green fertilizers, kg OM/ha
HC_{manure}:	HC of manure
HC_{fresh_crop}:	HC of fresh crop including feed leftovers
$HC_{crop\_residues}$:	HC of crop residues
OM/N_{manure}:	OM/N from manure
$OM/N_{feed\_leftovers}$:	OM/N from feed leftovers (including roughage, by-products and concentrate)
$EOMIn2_{pure\_manure}$:	Effective organic matter in the form of manure without feed leftovers
$EOMIn2_{feed\_leftovers}$:	Effective organic matter in the form of feed leftovers
$OM/N_{cultivated\_grass}$:	OM/N in grazing and mowing losses
$OM/N_{cultivated\_corn}$:	OM/N in corn harvest losses

Soil nitrogen

N:	Nitrogen
P:	Phosphorus
NO_3:	Nitrate
$Out1_{cut\_grass}$:	Net exported N in the form of grass silage or fresh stall-fed grass, kg N per ha grassland
$Out1_{pasture}$:	Net absorbed N in the form of pasture grass ingested by animal, kg N per ha grassland
$Out1_{corn}$:	Net exported N in the form of corn, kg N per ha corn land
$Out1_{other\ roughage}$:	Net exported N in the form of other roughage, kg N per ha other roughage
$Out1_{market\_arable}$:	Net exported N in the form of marketable arable crops, kg N per ha marketable arable crops
$Out3_{cut\_grass}$:	Mowing losses from collection of grass silage or fresh stall-fed grass, kg N per ha grassland
$Out3_{pasture}$:	Grazing losses in grazed grass, kg N per ha grassland
$Out3_{corn}$:	Harvest losses from maize, kg N per ha corn land
$Out3_{other\_roughage}$:	Harvest losses from other roughage (alfalfa), kg N per ha other roughage
$Out3_{market\_arable}$:	Harvest losses from marketable arable crops, kg N per ha marketable arable crops
$NOP_{pasture}$:	N absorbed by animal via grazing, kg N
NOP_{cut_grass}:	N absorbed by animal in the form of fresh grass or grass silage, kg N

NOP_{corn_silage}: N absorbed by animal in the form of corn silage, kg N

$NOP_{cut\_grass\_own\_land}$: N absorbed by animal in the form of fresh grass or grass silage from own land, kg N

$NOP_{cut\_grass\_purchased}$: N absorbed by animal in the form of purchased fresh grass or grass silage, kg N

$NOP_{other\_roughage\_own\_land}$: N absorbed by animal in the form of other roughage from own land, kg N

$NOP_{other\_roughage\_purchased}$: N absorbed by animal in the form of purchased other roughage, kg N

$NAAN_{cut\_grass\_own\_land}$: N offered to animal in barn in the form of fresh grass or grass silage from own land, kg N

$NAAN_{other\_roughage\_own\_land}$: N offered to animal in barn in the form of other roughage from own land, kg N

$NDAM_{cut\_grass}$: N removed by machine in the form of fresh grass or grass silage from own land, kg N

$NOP_{corn\_own\_land}$: N absorbed by animal in the form of corn silage from own land, kg N

$NOP_{corn\_purchased}$: N absorbed by animal in the form of purchased corn silage, kg N

$NAAN_{corn\_own\_land}$: N offered to animal in barn in the form of corn silage from own land, kg N

$NDAM_{corn}$: N removed by machine in the form of corn silage from own land, kg N

$NDAM_{other\_roughage}$: N removed by machine in the form of other roughage from own land, kg N

$Outn_{grassland}$: Export term n on the N balance of grassland, kg N per ha

$Outn_{corn}$: Export term n on the N balance of surface area with corn land, kg N per ha

$Outn_{other\_roughage}$: Export term n on the N balance of surface area with other roughage crops, kg N per ha

$Outn_{market\_arable}$: Export term n on the N balance of surface area with marketable arable crops, kg N per ha

$Inn_{grassland}$: Import term n on the N balance of grassland, kg N per ha

Inn_{corn}: Import term n on the N balance of the area with corn land, kg N per ha

$Inn_{other\_roughage}$: Import term n on the N balance of the area with other roughage crops, kg N per ha

Inn_{market_arable}: Import term n on the N balance of the area with marketable arable crops, kg N per ha

YMn: Yield of main product of marketable arable crop n, tonne fresh per ha

YBn: Yield of removed by-product of arable crop n, tonne fresh per ha

CNMn: N content of main product of arable crop n, kg N per tonne fresh

CNBn: N content of by-product of arable crop n, kg N per tonne fresh

CPMn: P content of main product of arable crop n, kg P_2O_5 per tonne fresh

CPBn: P content of by-product of arable crop n, kg P_2O_5 per tonne fresh

LF: Leaching fraction, kg N/kg N

PS: Precipitation surplus, mm

Gt: Groundwater trap, -

Nitrous oxide

N_2O: Nitrous oxide

EF(vol): Emission factor for nitrous oxide resulting from volatilised N deposited elsewhere, kg/kg

EF(lea): Emission factor for nitrous oxide resulting from leached N, kg/kg

EF(cf): Emission factor for nitrous oxide resulting from use of synthetic fertilizer N, kg/kg

EF(of): Emission factor for nitrous oxide resulting from use of barn manure, kg/kg

EF(an):	Emission factor for nitrous oxide resulting from use of pasture manure, kg/kg
EF(cl):	Emission factor for nitrous oxide resulting from presence of grass clovers, kg/kg
EF(cr):	Emission factor for nitrous oxide resulting from crop residues, crops cultivated after the main crop and ploughed in, mowing, grazing and harvest losses, and new grass sods, kg/kg
EF(pt):	Emission factor for nitrous oxide resulting from presence of peat soil, kg/kg
$EF_{(M)}$:	Emission factor for nitrous oxide from manure storage according to storage system M, kg/kg
$N_2Oem(vol)$:	Emissions of nitrous oxide resulting from volatilised N deposited elsewhere, kg N
$N_2Oem(lea)$:	Emissions of nitrous oxide resulting from leached N, kg N
$N_2Oem(cf)$:	Emissions of nitrous oxide resulting from synthetic fertilizer N, kg N
$N_2Oem(of)$:	Emissions of nitrous oxide resulting from manure N in the form of barn manure, kg N
$N_2Oem(an)$	Emissions of nitrous oxide resulting from manure N in the form of pasture manure, kg N
$N_2Oem(cl)$:	Emissions of nitrous oxide resulting from presence of grass clovers, kg N
$N_2Oem(cr)$:	Emissions of nitrous oxide resulting from crop residues, crops cultivated after the main crop and ploughed in, mowing, grazing and harvest losses, and new grass sods, kg N
$N_2Oem(pt)$:	Emissions of nitrous oxide resulting from presence of peat soil, kg N
$N_2Oem(backgr\_grassl\_m)$:	Emissions of nitrous oxide resulting from background emissions on mineral soils, kg N
$N_2Oem(backgr\_grassl\_p)$:	Emissions of nitrous oxide resulting from background emissions on peat soils, kg N
$N_2O_{(D,mm)}$:	Emissions of nitrous oxide from storage of manure, kg N_2O (!)
Nloss(vol):	Ammonia N leaving the farm according to BEA incl. N from swaths, kg
Nloss(lea):	Nitrate N leaving the farm as nitrate according to BEN, kg
Nipf(cf):	Total synthetic fertilizer N usage, kg
Ninp(of):	Total manure usage in the form of barn manure, kg
Ninp(an):	Total manure usage in the form of grazing manure, kg
Ninp(cl):	Fraction of legume fixation regarded as contributing to nitrous oxide formation, kg
Nipn(cr):	Crop residues, crops cultivated after the main crop and ploughed in, mowing, grazing and harvest losses and new grass sods, kg
Ninp(pt):	Product of the hectares of peat soil on the farm and standard peat mineralisation, kg

Ammonia

NH_3:	Ammonia
NH_4:	Ammonium
NEMA:	National Emission Model for Ammonia
TAN:	Total Ammoniacal Nitrogen

Methane

CH_4:	Methane
CH_4_feed:	kg methane emissions totalled for the various ration components
CH_4_EFcorIntake:	kg methane emissions which must be added to or subtracted from the emissions resulting from emissions from the various ration components, based on a DM intake deviating from a standard level
CH_4_EFbasis:	kg methane emissions as sum of totalled methane emissions for the various ration components (CH_4_feed) and correction for daily dry matter intake (CH_4_EFcorIntake)
CH_4_EFration:	basic methane emissions (CH_4_EFbasis) corrected for share of calves in total dairy LU sum
FJK:	LU share of calves (0-3 mths) in total dairy LU sum
$EF_{(T)}$:	Emission factor for methane from manure storage for animal category T, kg CH_4 per animal
$VS_{(T)}$:	Volatile solids production from animal category T, kg organic matter per animal per day
$BMP_{(T)}$:	Potential methane production from animal category T, m^3 CH_4 per kg excreted VS
MCF_S:	Methane conversion factor for manure management system S, kg per 100 kg
$N_{(T)}$:	Number of animals in category T
$CH_{4Manure}$:	Totalled methane emissions from manure storages (sum of emissions per storage system per animal category, kg CH_4
NexcretionT:	N excretion before deduction of gaseous losses from barn and storage in animal category T, kg
$MS_{(T,S)}$:	Fraction of NexcretionT according to manure management system M, -
GE:	Gross energy, MJ
Y_m:	Methane conversion factor, MJ / 100 MJ

Appendix 4 Metrics for feed ingredients

In the table below, the following metrics are provided per feed ingredient: the dry matter content (DM), crude ash content (CA), digestibility of crude protein (DCCP), digestibility of organic matter (DCOM), methane emissions from feed components from dairy herd including young stock (g CH_4 per kg DM) in relation to the proportion of corn silage in ration (%) (see section 6.3.1.1) and emissions (CO_2 equivalents per kg product) from imported feed ingredients (excluding transport) (see section 6.4.2.3) for the various feed ingredients, subdivided into feed types and subgroups.

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Fresh grass: grazing	FG	160	17	0.82	0.83	FP	17.70[4]	17.70[4]	17.70[4]
Fresh grass: summer feeding	FG	160	17	0.82	0.83	FP	21.60[4]	21.60[4]	21.60[4]
Grass silage	GS	450	55	-[5]	0.78	FP	-[5]	-[5]	-[5]
Grass hay	GS	845	84	-[5]	0.68	FP	19.53	19.48	20.99
Grass bales, fresh-dried	GS	889	93	-[5]	0.76	FP	19.53	19.48	20.99
Grass bales, pre-dried	GS	889	93	-[5]	0.76	FP	19.53	19.48	20.99
Grass pellets, fresh-dried	GS	926	119	-[5]	0.74	FP	20.12	19.94	20.66
Grass pellets, pre-dried	GS	926	119	-[5]	0.74	FP	20.12	19.94	20.66
Grass fibre silage, treated	GS	321	25	0.70	0.81	WUR	21.00	21.00	21.00
Other grass product	GS	749	83	-[5]	0.75	WUR	20.02	19.95	21.01
Corn silage	CS	365	13	-[5]	0.75	FP	-[5]	-[5]	-[4]
Corn, dried	CS	909	49	-[5]	0.73	FP	-[5]	-[5]	-[5]
Corn, other	CS	637	31	-[5]	0.74	WUR	-[5]	-[5]	-[5]
Compound feed	CO	876	65	-[5]	-[5]	NEV	-[6]	-[6]	-[6]
Potato chips	CO	962	35	0.2	0.86	NEV	12.07	12.26	11.38
Potato protein	CO	906	12	0.89	0.88	NEV	16.43	14.76	14.04
Potatoes, dried	CO	897	42	0.39	0.85	NEV	22.74	21.51	20.49
Potato fibre	CO	878	58	0.32	0.82	NEV	21.65	21.22	20.45
Potato starch, dried	CO	863	5	0.99	0.94	NEV	23.98	22.33	20.16
Apple molasses	CO	700	70	0.73	0.9	NEV	34.09	31.06	28.52
Sweat potatoes, dried	CO	878	38	-0.01	0.85	NEV	24.55	23.57	22.13
Bone meal	CO	948	463	0	0	NEV	20.00	20.00	20.00
Brewers' grains, dried	CO	915	46	0.75	0.65	NEV	16.74	16.43	16.27
Brewers' yeast, dried	CO	924	65	0.82	0.79	NEV	19.75	18.63	18.60
Beet pulp, dried	CO	903	70	0.62	0.87	NEV	25.76	25.80	28.31
Biscuit meal	CO	925	20	0.73	0.93	NEV	23.35	22.97	22.52
Blood meal	CO	919	17	0	0	NEV	18.27	16.67	16.77
Buckwheat	CO	865	24	0.74	0.69	NEV	20.00	20.00	20.00
Horse beans, colour-flowered	CO	869	33	0.84	0.9	NEV	21.99	21.60	22.89
Horse beans, white-flowered	CO	867	33	0.85	0.9	NEV	21.92	21.44	22.58
Beans (Phaseolus spp.), heat-treated	CO	862	51	0.78	0.89	NEV	21.29	20.87	21.38
Bread meal	CO	897	27	0.77	0.89	NEV	22.97	23.54	23.20
Cacao shells	CO	883	84	0.6	0.43	NEV	23.10	22.70	23.30
Camelina meal, rumen-protected	CO	905	62	0.77	0.72	NEV	17.94	17.86	18.61
Camelina meal, non-protected	CO	905	62	0.77	0.72	NEV	18.74	19.32	22.84
Casein	CO	916	32	0.95	0.95	NEV	18.27	16.67	16.77
Chicory pulp, dried	CO	897	74	0.56	0.84	NEV	25.01	25.19	27.86
Citrus pulp	CO	912	66	0.49	0.86	NEV	26.98	26.43	28.00
Corn DDGS	CO	903	43	0.83	0.83	NEV	19.43	20.05	22.87
Wheat DDGS	CO	916	46	0.84	0.83	NEV	21.00	21.00	21.00
Dextrose	CO	1000	0	1	1	NEV	0.00	0.00	0.00

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Peas, dried	CO	866	29	0.82	0.9	NEV	22.84	21.99	22.13
Pea fibre, dried	CO	885	23	0.64	0.88	NEV	22.99	23.24	25.18
Phytase	CO	1000	0	0	0.83	NEV	0.00	0.00	0.00
Barley	CO	873	21	0.74	0.85	NEV	22.80	22.07	20.74
Barley, rolled	CO	873	21	0.74	0.85	NEV	19.38	18.76	17.63
Barley grinding meal	CO	884	55	0.78	0.73	NEV	19.66	19.19	18.72
Barley feed meal	CO	886	64	0.73	0.67	NEV	19.11	18.64	18.08
Millet	CO	897	28	0.71	0.8	NEV	20.89	18.74	17.26
Rapeseed glycerol	CO	818	36	1	1	NEV	34.09	31.06	28.52
Soy glycerol	CO	818	36	1	1	NEV	34.09	31.06	28.52
Grass meal	CO	926	119	0.66	0.74	NEV	20.12	19.94	20.66
Grass seed	CO	863	47	0.63	0.61	NEV	22.29	21.50	19.92
Peanuts, unhulled	CO	942	28	0.85	0.79	NEV	8.42	9.13	11.51
Peanuts, dehulled	CO	932	22	0.87	0.93	NEV	3.59	4.02	5.60
Peanut flakes, dehulled and dried	CO	920	51	0.9	0.84	NEV	17.63	17.72	20.03
Peanut flakes, unhulled	CO	933	41	0.89	0.78	NEV	14.06	14.70	17.20
Peanuts flakes, dehulled	CO	932	64	0.91	0.87	NEV	18.05	17.96	20.11
Peanut meal, dehulled and dried	CO	926	56	0.92	0.82	NEV	17.80	17.96	20.33
Peanut meal, unhulled	CO	911	55	0.89	0.78	NEV	17.80	17.96	20.33
Peanut meal, dehulled	CO	913	60	0.91	0.85	NEV	21.00	20.85	23.26
Oats	CO	879	24	0.74	0.76	NEV	19.66	19.78	19.76
Hulled oats/dehulled oats	CO	888	20	0.79	0.9	NEV	21.08	20.80	20.42
Oat hulls	CO	903	42	0.38	0.35	NEV	17.00	17.00	17.00
Oat grits, pellets	CO	903	42	0.38	0.35	NEV	20.06	20.44	22.08
Oat milling waste meal	CO	910	42	0.43	0.53	NEV	17.26	17.81	18.05
Oat feed meal	CO	886	24	0.71	0.75	NEV	18.92	19.22	19.35
Hemp seed	CO	913	48	0.75	0.62	NEV	9.88	9.96	11.33
Carob	CO	897	30	0.02	0.73	NEV	27.20	26.05	26.35
Limestone granules	CO	990	980	0	0.83	NEV	0.00	0.00	0.00
Cottonseed, not dehulled	CO	911	40	0.73	0.68	NEV	17.78	16.84	16.91
Cottonseed, dehulled	CO	935	44	0.8	0.84	NEV	10.38	10.09	11.31
Cottonseed flakes, dried, dehulled	CO	933	60	0.79	0.7	NEV	15.89	15.94	17.40
Cottonseed flakes not dehulled	CO	921	51	0.77	0.66	NEV	15.81	16.03	17.58
Cottonseed flakes dehulled	CO	932	63	0.8	0.74	NEV	13.94	13.96	15.36
Cottonseed meal, dried, dehulled	CO	896	63	0.79	0.69	NEV	17.51	17.69	19.87
Cottonseed meal, not dehulled	CO	945	50	0.77	0.66	NEV	17.95	18.18	20.35
Cottonseed meal dehulled	CO	898	65	0.8	0.72	NEV	17.36	17.40	19.51
Coconut flakes	CO	907	61	0.72	0.82	NEV	18.71	19.08	20.92
Coconut meal	CO	910	69	0.74	0.8	NEV	20.80	21.18	23.22
Chalk (finely ground)	CO	990	980	0	0.83	NEV	0.00	0.00	0.00
Linseed (flax)	CO	922	39	0.8	0.81	NEV	8.56	9.00	10.72
Linseed – rumen protected, crushed	CO	922	40	0.8	0.81	NEV	0.00	0.00	0.00
Linseed flakes	CO	922	58	0.85	0.78	NEV	18.44	18.58	21.03
Linseed meal	CO	872	55	0.85	0.77	NEV	20.63	20.65	23.16
Lentils	CO	873	30	0.84	0.88	NEV	22.26	20.90	19.81
Lupin	CO	887	33	0.9	0.91	NEV	21.35	20.97	22.69
Lupin hulls	CO	907	25	0.47	0.49	NEV	23.10	22.70	23.30
Alfalfa meal	CO	913	104	0.68	0.65	NEV	20.04	20.23	21.65
Magnesium oxide	CO	1000	0	0	0.83	NEV	0.00	0.00	0.00
Dry corn grain	CO	863	12	0.59	0.89	NEV	21.16	19.69	17.83
Cracked corn	CO	876	13	0.6	0.9	NEV	22.65	22.91	21.17
Crushed corn	CO	863	12	0.59	0.89	NEV	15.87	14.77	13.37
Corn gluten meal	CO	899	17	0.95	0.94	NEV	16.64	15.22	13.34
Corn gluten feed	CO	889	57	0.77	0.82	NEV	20.34	19.76	19.37
Corn germ flakes	CO	900	58	0.75	0.82	NEV	19.05	18.98	19.73
Corn germ meal	CO	876	25	0.78	0.81	NEV	21.07	21.53	23.70

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Corn germ-bran flakes	CO	896	44	0.69	0.85	NEV	20.17	19.83	20.06
Corn germ-bran meal	CO	875	39	0.7	0.84	NEV	21.20	21.54	23.47
Corn flakes	CO	883	13	0.66	0.89	NEV	23.28	21.66	19.61
Corn feed flour	CO	877	14	0.61	0.89	NEV	21.90	20.55	18.69
Corn feed meal	CO	867	13	0.63	0.89	NEV	22.39	21.43	20.54
Corn bran grits	CO	894	23	0.65	0.79	NEV	22.14	21.43	20.54
Corn starch	CO	892	1	0	0.96	NEV	23.92	21.99	22.72
Monocalcium phosphate	CO	980	960	0	0.83	NEV	0.00	0.00	0.00
Malt germ kernels	CO	916	50	0.76	0.71	NEV	21.58	20.74	21.47
Sodium-bicarbonate	CO	1000	0	0	0.83	NEV	0.00	0.00	0.00
Ramtil	CO	916	47	0.79	0.76	NEV	7.59	7.26	7.65
Palm kernel flakes	CO	923	43	0.75	0.76	NEV	16.86	17.38	18.58
Palm kernel meal	CO	893	39	0.76	0.76	NEV	19.72	20.85	23.51
Palm kernels	CO	938	20	0.62	0.86	NEV	2.67	3.57	4.40
Premix	CO	1000	0	0.75	0.83	NEV	0.00	0.00	0.00
Propylene glycol, liquid	CO	950	0	1.00	1.00	NEV	20.00	20.00	20.00
Rapeseed, untreated	CO	925	38	0.78	0.83	NEV	4.88	5.68	7.91
Rapeseed flakes	CO	902	62	0.83	0.79	NEV	17.48	17.90	20.94
Rapeseed meal	CO	890	74	0.85	0.78	NEV	18.88	19.36	22.70
Rapeseed meal – rumen protected	CO	877	67	0.84	0.75	NEV	17.94	17.84	18.60
Rice with husk	CO	886	44	0.47	0.75	NEV	18.77	18.10	16.97
Rice dehulled	CO	885	7	0.49	0.91	NEV	22.73	21.29	19.68
Rice residues	CO	912	153	0.43	0.42	NEV	11.99	12.41	12.18
Rice feed meal	CO	901	108	0.64	0.70	NEV	15.95	15.64	15.05
Rice feed flour	CO	907	98	0.64	0.78	NEV	13.32	12.95	12.25
Rye	CO	870	16	0.72	0.87	NEV	23.72	23.32	22.90
Rye grits	CO	872	50	0.77	0.78	NEV	20.05	20.44	22.07
Safflower seed	CO	907	28	0.68	0.45	NEV	7.71	8.91	11.64
Safflower seed flakes	CO	932	41	0.80	0.48	NEV	14.69	14.48	15.78
Safflower seed meal	CO	918	48	0.79	0.52	NEV	19.25	18.62	18.82
Sesame seed	CO	942	75	0.83	0.85	NEV	6.61	6.68	7.85
Sesame seed flakes	CO	943	132	0.90	0.85	NEV	15.43	14.99	16.20
Sesame seed meal	CO	893	60	0.90	0.82	NEV	21.54	20.67	21.88
Candy syrup	CO	645	8	0.07	0.95	NEV	34.09	31.06	28.52
Soda grain	CO	747	42	0.55	0.87	NEV	21.80	21.40	20.90
Soy protein concentrate	CO	920	6	0.90	0.90	NEV	0.00	0.00	0.00
Soybeans unheated	CO	899	50	0.90	0.88	NEV	15.31	15.26	17.50
Soybeans dehulled	CO	885	46	0.58	0.84	NEV	23.34	22.95	23.56
Soybeans, heat-treated	CO	899	50	0.90	0.88	NEV	15.07	15.03	17.33
Soybean flakes	CO	916	64	0.91	0.91	NEV	18.43	18.15	20.32
Soybean meal – rumen protected	CO	873	62	0.89	0.90	NEV	20.40	19.25	18.86
Soybean meal	CO	879	65	0.91	0.91	NEV	21.11	20.50	22.36
Sorghum milocorn	CO	872	15	0.49	0.85	NEV	21.24	19.76	17.86
Sorghum gluten meal	CO	900	32	0.89	0.89	NEV	18.30	17.29	16.17
Spelt	CO	888	30	0.63	0.79	NEV	23.35	22.97	22.52
Spelt hulls	CO	875	55	0.33	0.49	NEV	17.00	17.00	17.00
sugar	CO	1000	0	0	1.00	NEV	34.09	31.06	28.52
Tapioca	CO	878	56	-0.50	0.84	NEV	23.90	23.14	21.96
Tapioca starch	CO	880	1	1.00	0.94	NEV	24.92	23.43	20.86
Wheat	CO	867	15	0.74	0.89	NEV	23.35	22.97	22.52
Wheat - crushed	CO	867	15	0.74	0.89	NEV	23.35	22.97	22.52
Wheat gluten meal	CO	911	9	0.96	0.96	NEV	17.00	15.74	16.21
Dried wheat gluten feed	CO	901	48	0.70	0.73	NEV	20.76	20.35	19.75
Wheat grits	CO	871	47	0.77	0.73	NEV	20.41	20.58	22.01
Wheat germ	CO	869	40	0.86	0.84	NEV	19.94	19.91	21.10
Wheat germ bran	CO	866	40	0.83	0.82	NEV	20.60	20.60	21.64

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Wheat straw, pellets	CO	878	74	0.23	0.42	NEV	17.00	17.00	17.00
Wheat feed flour	CO	869	26	0.81	0.87	NEV	21.93	21.79	22.10
Wheat feed meal	CO	870	43	0.79	0.77	NEV	20.86	20.92	22.08
Wheat bran grits	CO	869	53	0.76	0.68	NEV	20.23	20.30	21.74
Triticale	CO	867	17	0.72	0.89	NEV	23.65	23.29	23.09
Urea	CO	1000	0	1	1	NEV	0.00	0.00	0.00
Field beans hulled and toasted	CO	866	34	0.78	0.89	NEV	20.84	19.85	19.94
Field beans hulls	CO	888	22	0.58	0.61	NEV	20.10	20.40	22.10
Feather meal	CO	938	24	0	0	NEV	0.00	0.00	0.00
Fat based on palm oil, by-fraction, hardened	CO	995	0	1.00	0.59	NEV	-11.75	-10.95	-11.21
Fat based on palm oil, saponified	CO	975	124	1.00	0.76	NEV	-10.69	-9.97	-10.20
Fat based on palm oil, hardened	CO	995	0	1.00	0.59	NEV	-11.75	-10.95	-11.21
Fat based on palm oil, saponified	CO	975	124	1.00	0.76	NEV	-10.69	-9.97	-10.20
Fat based on palm oil, hardened	CO	995	0	1.00	0.59	NEV	-11.75	-10.95	-11.21
Fat based on palm oil, saponified	CO	975	124	1.00	0.76	NEV	-10.69	-9.97	-10.20
Fat based on palm oil, hardened	CO	995	0	1.00	0.59	NEV	-11.75	-10.95	-11.21
Fat based on palm oil, saponified	CO	975	124	1.00	0.76	NEV	-10.69	-9.97	-10.20
Animal fat	CO	996	1	1.00	0.90	NEV	-11.73	-10.94	-11.19
Vegetable fat/oil, high VC	CO	995	0	1.00	0.95	NEV	-11.75	-10.95	-11.21
Vegetable fat/oil, low VC	CO	995	0	1.00	0.95	NEV	-11.75	-10.95	-11.21
Palm oil fatty acid distillate	CO	977	0	1.00	0.95	NEV	-11.75	-10.95	-11.21
Fish meal	CO	913	165	0	0	NEV	16.64	15.22	13.34
Meat and bone meal	CO	941	374	0	0	NEV	16.64	15.22	13.34
Dried sea sand	CO	1000	0	0	0	NEV	0.00	0.00	0.00
Sunflower seed, dried, dehulled	CO	938	32	0.79	0.71	NEV	7.14	7.99	10.14
Sunflower seed not dehulled	CO	940	29	0.76	0.58	NEV	4.62	5.57	7.02
Sunflower seed dehulled	CO	915	37	0.82	0.84	NEV	6.47	6.66	8.26
Sunflower seed flakes dried, dehulled	CO	923	58	0.86	0.66	NEV	14.01	14.61	17.13
Sunflower seed flakes not dehulled	CO	913	56	0.81	0.44	NEV	9.78	10.68	12.61
Sunflower seed flakes dehulled	CO	926	63	0.87	0.72	NEV	16.71	17.10	19.88
Sunflower seed meal	CO	892	65	0.88	0.68	NEV	17.94	18.40	21.22
Sunflower seed hulls	CO	907	34	0.40	0.18	NEV	23.10	22.70	23.30
Salt	CO	998	996	0	0	NEV	0.00	0.00	0.00
Other co-product from industry	CO	901	52	-[5]	0.80	NEV	21.10	21.03	22.40
Other grains	CO	876	23	0.68	0.83	NEV	21.94	21.22	20.40
Other legumes	CO	886	34	0.84	0.86	NEV	22.07	21.38	22.02
Other vegetable meal	CO	901	52	-[5]	0.80	NEV	19.64	19.51	21.83
Other seed crop	CO	916	41	0.77	0.70	WUR	8.73	9.13	10.52
Other single ingredient	CO	901	52	0.75	0.80	WUR	20.20	19.83	20.51
Other mineral, additive, vitamin	CO	990	282	0.75	0.83	NEV	0.00	0.00	0.00
Milk replacer	MP	964	48	0.89	0.93	NEV	26.67	26.47	26.98
Skimmed milk powder	MP	951	79	0.92	0.95	NEV	25.63	28.84	30.11
Whole milk powder	MP	949	59	0.89	0.95	NEV	16.52	15.24	14.53
Whey powder (dry)	MP	982	81	0.77	0.94	NEV	29.64	27.83	27.95
Whey powder (wet 60%)	MP	600	50	0.77	0.94	NEV	29.64	27.83	27.95
Whey powder (wet 30%)	MP	300	25	0.77	0.94	NEV	29.64	27.83	27.95
Whey powder (wet 7%)	MP	70	5	0.77	0.94	NEV	29.64	27.83	27.95
Whey powder delactosed (dry)	MP	959	203	0.88	0.93	NEV	22.77	21.77	22.77
Whey powder delactosed (wet 60%)	MP	600	111	0.89	0.94	NEV	22.77	21.77	22.77
Whey powder delactosed (wet 30%)	MP	300	55	0.89	0.94	NEV	22.77	21.77	22.77
Whey powder delactosed (wet 7%)	MP	70	11	0.89	0.94	AF	22.77	21.77	22.77
Cheese whey	MP	38	4	0.86	0.94	AF	26.63	26.56	30.01
Other dairy product	MP	565	61	0.87	0.94	WUR	25.42	24.63	25.38
Potato syrup	BP	548	159	0.91	0.93	NEV	20.06	21.72	26.74

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Potato pulp fibers	BP	161	7	0.41	0.84	NEV	24.04	24.31	26.04
Potato peels	BP	220	18	0.53	0.85	NEV	19.43	19.43	19.43
Potato flakes	BP	212	7	0.40	0.88	NEV	22.22	21.17	20.50
Steamed potato peels	BP	140	9	0.63	0.88	NEV	23.24	24.90	28.06
Potato starch (wet)	BP	266	9	0.58	0.90	AF	22.60	21.33	19.85
Native potato starch	BP	451	8	0.99	0.93	AF	22.93	21.36	19.18
Endive	OR	52	9	0.85	0.86	FP	20.00	20.00	20.00
Apples	BP	157	4	-0.20	0.88	FP	20.00	20.00	20.00
Gherkin	BP	49	4	0.63	0.79	FP	20.00	20.00	20.00
Brewers' grains	BP	242	11	0.80	0.64	FP	15.68	15.50	15.50
Beet leaves	OR	182	57	0.60	0.73	FP	20.00	20.00	20.00
Beet leaves with tops	OR	160	32	0.79	0.82	FP	20.00	20.00	20.00
Beet pulp	BP	248	19	0.61	0.88	NEV	24.62	24.53	26.17
Beet tips	OR	135	25	0.55	0.78	AF	20.00	20.00	20.00
Bean straw (Vicia)	OR	840	61	0.46	0.52	AF	17.00	17.00	17.00
Bean straw (Phas)	OR	863	98	0.62	0.61	AF	17.00	17.00	17.00
CCM with some core	BP	632	11	0.57	0.86	FP	20.45	19.14	17.29
CCM with core	BP	525	11	0.58	0.84	FP	20.55	19.36	17.52
CCM without core	BP	662	11	0.58	0.87	FP	20.54	19.17	17.29
Cichory tops	OR	175	60	0.34	0.58	FP	20.00	20.00	20.00
Cichory pulp silage	BP	232	22	0.53	0.84	FP	24.79	24.49	25.73
Cichory - cleaned pulled roots	BP	149	12	0.61	0.85	FP	20.00	20.00	20.00
Cichory - dirty pulled roots	BP	122	21	0.61	0.85	FP	20.00	20.00	20.00
Cichory – unpulled roots	BP	200	20	0.49	0.92	FP	20.00	20.00	20.00
Pea straw	OR	710	75	0.58	0.50	AF	17.00	17.00	17.00
Moist pea fiber	BP	197	5	0.77	0.88	NEV	22.99	23.24	25.18
Barley straw	OR	884	63	0.17	0.48	AF	17.00	17.00	17.00
GPS-grains	OR	325	26	0.63	0.68	FP	20.00	20.00	20.00
Wet grain washings	BP	73	4	0.84	0.83	FP	17.62	17.62	17.62
Grass seed hay	OR	844	64	0.36	0.54	FP	17.00	17.00	17.00
Oat straw	OR	840	59	0.19	0.50	AF	17.00	17.00	17.00
Red clover hay	OR	830	83	0.61	0.59	FP	19.53	19.48	20.99
Red clover silage	OR	364	56	0.73	0.64	FP	19.53	19.48	20.99
Red clover artificially dried	OR	899	104	0.62	0.68	FP	19.53	19.48	20.99
Red clover straw	OR	830	56	0.44	0.42	FP	19.53	19.48	20.99
Cucumber	BP	58	6	0.57	0.80	FP	20.00	20.00	20.00
Kale	OR	100	15	0.87	0.83	FP	20.00	20.00	20.00
Cauliflower	OR	72	10	0.91	0.90	FP	20.00	20.00	20.00
Kohlrabi	OR	120	16	0.84	0.83	FP	20.00	20.00	20.00
Cabbage (red/white/Savoy)	OR	105	12	0.85	0.85	FP	20.00	20.00	20.00
Brussel sprouts	OR	162	14	0.87	0.88	FP	20.00	20.00	20.00
Swede	BP	110	14	0.67	0.88	FP	20.00	20.00	20.00
Red beet roots	BP	136	11	0.58	0.89	FP	20.00	20.00	20.00
Alfalfa hay	OR	872	88	0.67	0.62	FP	19.53	19.48	20.99
Alfalfa silage	OR	403	57	0.73	0.65	FP	19.53	19.48	20.99
Alfalfa artificially dried	OR	903	106	0.67	0.63	FP	19.53	19.48	20.99
Corn gluten feed silage	BP	418	16	0.71	0.83	AF	20.97	20.16	19.09
Corn cob silage	BP	553	9	0.58	0.86	FP	20.51	20.51	20.51
Corn straw	OR	840	86	0.27	0.57	AF	17.00	17.00	17.00
Corn steep liquor	BP	476	84	0.87	0.91	AF	21.99	23.32	28.47
Melasse sugarbeet	BP	787	90	0.73	0.90	NEV	30.01	28.71	30.70
Melasse sugarcane	BP	723	101	0.17	0.80	NEV	29.80	22.07	21.16
Mycelium	BP	222	14	0.74	0.78	NEV	18.88	19.36	22.70
Pepper	BP	125	8	0.56	0.72	FP	20.00	20.00	20.00
Pears	BP	165	4	-0.93	0.87	FP	20.00	20.00	20.00
Leek	OR	100	10	0.80	0.83	FP	20.00	20.00	20.00

Name	Feed type[1]	DM[2] (g/kg)	CA[2] (g/kg)	DCCP[2]	DCOM[2]	CO_2-emission Source[3]	EF CH_4 at 0% CS (g/kg dm)	EF CH_4 at 40% CS (g/kg dm)	EF CH_4 at 80% CS (g/kg dm)
Rye straw	OR	840	59	0.14	0.46	AF	17.00	17.00	17.00
Lettuce	OR	61	11	0.82	0.85	FP	20.00	20.00	20.00
Chopped cereal silage	OR	250	20	0.62	0.78	FP	19.53	19.48	20.99
Spinach	OR	94	17	0.84	0.85	FP	20.00	20.00	20.00
Brussel sprouts	OR	180	20	0.85	0.84	FP	20.00	20.00	20.00
Sugar beets	BP	260	49	0.27	0.90	AF	25.00	25.00	25.00
Wheat yeast concentrate (WYC)	BP	259	18	0.79	0.88	NEV	22.13	21.25	21.20
Wheat straw	OR	878	73	0.23	0.42	AF	17.00	17.00	17.00
Tomatoes	BP	63	6	0.76	0.81	FP	20.00	20.00	20.00
Onions/bulbs	OR	118	16	0.75	0.90	FP	20.00	20.00	20.00
Field beans (Vicia)	OR	326	28	0.70	0.64	AF	21.40	21.40	21.40
Sugar beet vinasse	BP	655	137	0.86	0.90	NEV	21.76	22.80	27.02
Sugarcane vinasse	BP	556	137	0.86	0.9	NEV	21.48	22.68	27.07
Fodder beets	BP	129	21	0.60	0.90	NEV	25.00	25.00	25.00
Fodder beets externally cleaned	BP	139	13	0.62	0.90	NEV	25.00	25.00	25.00
Seed potatoes	BP	322	24	0.33	0.88	NEV	19.95	19.95	19.95
Carrots/winter carrots	BP	112	10	0.59	0.90	FP	20.00	20.00	20.00
Steamed carrot peels	BP	52	7	0.64	0.90	FP	24.67	23.93	24.65
Mixture of wet byproducts	BP	288	28	-[5]	0.86	WUR	24.67	23.93	24.65
Other cereal straw	OR	861	64	0.19	0.46	AF	21.68	21.39	21.94
Other leafy vegetable	OR	105	14	0.67	0.88	WUR	17.00	17.00	17.00
Other vegetable	OR	119	36	0.46	0.74	WUR	20.00	20.00	20.00
Other roughage	OR	452	47	0.67	0.68	WUR	20.00	20.00	20.00
Other byproduct	BP	288	28	0.75	0.86	WUR	19.14	19.12	19.48

[1] GS=grass silage; FG=fresh grass; CS=corn silage; CO=concentrates; MP=Milkpowder; OR=Overig roughage, BP=Moist (by)poducts.

[2] VCRE/VCOS: CVB, 2023/2025; DS and RAS: CVB, 2004/2006/2011/2019/2024 and http://www.cvbdiervoeding.nl/pagina/10081/downloads.aspx.

[3] NEV = Nevedilist (Nevedi, 2024); FP = Feedprint (Feedprint 2025; Vellinga *et al.*, 2013), AF = Agri-Footprint 6, WUR = averages calculated by WUR.

[4] for justification, see Appendix 8.

[5] is calculated, see main text.

[6] will be provided by the supplier or calculated/fixed value if this is missing.

Appendix 5 CO_2 emission coefficients

Carbon dioxide emissions (direct and indirect) through the use of various products and processes in the dairy farm's operations. Emission coefficients expressed in CO_2 equivalents per unit displayed.

Process	Product	Specification	Source	Description
Supply	Transport	All	www.co2emissiefactoren.nl	
Supply	Synthetic fertilizer, per kg fertilizer		Agri-footprint 6	Fertilizer-specific values
Supply	Synthetic fertilizer, per kg N	nitrogen as 100% ammonium	Agri-footprint 6	Ammonium sulphate, as 100% $(NH_4)_2SO_4$ (NPK 21-0-0), market mix, at regional storage/RER Economic
Supply	Synthetic fertilizer, per kg N	nitrogen as 100% nitrate	Agri-footprint 6	Nitric acid, in water (60% HNO_3) (NPK 13.2-0-0), market mix, at regional storage/RER Economic
Supply	Synthetic fertilizer, per kg N	nitrogen as 100% urea	Agri-footprint 6	Urea, as 100% $CO(NH_2)_2$ (NPK 46,6-0-0), at regional storage/RER Economic
Supply	Synthetic fertilizer, per kg N	nitrogen as ca ombination of ammonium and nitrate	Agri-footprint 6	Calcium ammonium nitrate (CAN), (NPK 26,5-0-0), market mix, at regional storage/RER Economic
Supply	Synthetic fertilizer, per kg N	nitrogen as ca ombination of ammonium and/or nitrate with urea	Agri-footprint 6	Liquid urea-ammonium nitrate solution (NPK 30-0-0), market mix, at regional storage/RER Economic
Supply	Synthetic fertilizer, per kg N, P_2O_5 and K_2O	nitrogen in ombination with phosphorus and/or potassium	Agri-footprint 6	Ammonia, as 100% NH_3 (NPK 82-0-0), market mix, at regional storage/RER Economic; voor P_2O_5 en K_2O zie hieronder
Supply	Synthetic fertilizer, per kg P_2O_5	phosphate	Agri-footprint 6	Triple superphosphate, as 80% $Ca(H_2PO_4)_2$ (NPK 0-48-0), at plant/RER Economic
Supply	Synthetic fertilizer, per kg K_2O	potassium	Agri-footprint 6	Potassium chloride (NPK 0-0-60), at plant/RER Economic
Supply	Synthetic fertilizer, per kg CaO	lime, limestone	Agri-footprint 6	Lime fertilizer, at regional storehouse/RER Economic
Supply	Synthetic fertilizer, per kg CaO	lime, dolomite	Agri-footprint 6	Dolomite, milled, at mine/RER Economic
Supply	Organic manure	compost	Industry associations BVOR and Dutch Waste Management Association	
Supply	Bedding	stro	Agri-footprint 6	Wheat straw, at farm/NL Economic
Supply	Bedding	sawdust	AGRIBALYSE 3.1	Wood chips, at farm/FR S
Supply	Bedding	lime	Agri-footprint 5 IPCC 2019	Lime production + application
Supply	Bedding	Other		Average
Supply	Livestock	dairy	ZuivelNL	334 gram CO_2-eq/MJ

Process	Product	Specification	Source	Description
Supply	Crop protection	nematicide	Agri-footprint 5	Insecticide, at plant/RER Economic
Supply	Crop protection	herbicide	Agri-footprint 5	Herbicide, at plant/RER Economic
Supply	Crop protection	fungicide	Agri-footprint 5	Fungicide, at plant/RER Economic
Supply	Crop protection	other	Agri-footprint 5	Average
Supply	Cover material	plastic	ELCD	Polyethylene low density granulate (PE-LD), production mix, at plant RER System
Energy	Artificial drying	grass bale	Feedprint 2025	
Energy	Artificial drying	grass pellet	Feedprint 2025	
Energy	Artificial drying	corn	Feedprint 2025	
Energy	Artificial drying	other roughage	Feedprint 2025	
Energy				
Energy	Combustion	diesel	www.co2emissiefactoren.nl	
Energy	Combustion	natural gas	www.co2emissiefactoren.nl	
Energy	Combustion	biogas	www.co2emissiefactoren.nl	
Energy	Combustion	propane	www.co2emissiefactoren.nl	
Energy	Combustion	heating oil	www.co2emissiefactoren.nl	
Energy	Production	grey electricity	CE Delft 2025[1], STREAM passenger transport 2024	
Energy	Production	green electricity	CE Delft 2025[1], STREAM passenger transport 2024	
Energy	Production	diesel	www.co2emissiefactoren.nl	
Energy	Production	natural gas	www.co2emissiefactoren.nl	
Energy	Production	biogas	www.co2emissiefactoren.nl	
Energy	Production	propane	www.co2emissiefactoren.nl	
Energy	Production	oil	www.co2emissiefactoren.nl	
Energy	Indirect	electricity	CE Delft 2025[1], STREAM passenger transport 2024	Electricity, average
Energy	Indirect	gas	www.co2emissiefactoren.nl	
Energy	Indirect	kerosene	www.co2emissiefactoren.nl	
Energy	Indirect	Cokeskolen (basic material)	www.co2emissiefactoren.nl	
Energy	Aanvoer	water	ELCD	Drinking water, water purification treatment, production mix, at plant, from groundwater RER S
Energy	Production electricity	Biomass (digester)	WUR	Calculation conducted by WUR (Pim Mostert)
Energy	Production electricity	wind	www.co2emissiefactoren.nl	
Energy	Production electricity	sun	www.co2emissiefactoren.nl	

Process	Product	Specification	Source	Description
Energy	Upgraded gas production	Biomass (digester)	WUR	Calculation conducted by WUR (Pim Mostert)
Application	Lime	lime, dolomite	IPCC 2019	
Application	Lime	lime, limestone	IPCC 2019	
Application	Urea	-	IPCC 2019	

[1] Source: CE Delft 2025, STREAM passenger transport 2024,
https://co2emissiefactoren.nl/media/sources/CE_Delft_210506_STREAM_Personenvervoer_2024_Def.pdf

Appendix 6 LU standard per animal: based on RVO and WUM phosphate excretions

Animal group	Animal species	LU/animal
Dairy cattle (RVO)	Dairy cows (cat. 100)	1
	Young stock > 1 year (cat. 102)	0.530
	Young stock < 1 year (cat. 101)	0.232
Other grazing animals (RVO)	Breeding bulls, > 1 year (cat. 104)	0.627
	Pasture and suckler cows (cat. 120)	0.651
	Starting calves for rosé or red meat (cat. 115)	0.082
	Rosé calves, 3 months – slaughter (cat. 116)	0.228
	Rosé calves, 2 weeks – slaughter (cat. 117)	0.184
	Red meat bulls, 3 months – slaughter (cat. 122)	0.235
	Breeding sheep, incl. lambs (cat. 550)	0.08
	Meat sheep, < 4 months (cat. 551)	0.007
	Other sheep, > 4 months (cat. 552)	0.053
	Milk goats (cat. 600)	0.114
	Rearing and meat goats, < 4 months (cat. 601)	0.007
	Rearing and meat goats, > 4 months (cat. 602)	0.063
	Ponies (cat. 941)	0.315
	Horses (cat. 943)	0.692
	Donkeys (cat. 961)	0.177
	Water buffalo, cows (cat. 991)	0.724
	Water buffalo, youngstock (cat. 992)	0.245
Intensive (WUM 2018)	Farrowing sows	0.334
	Dry and pregnant sows	0.334
	Weaned piglets	0
	Fattening pigs	0.102
	Laying hens	0.01
	Broilers	0.003
	White meat calves	0.177

Appendix 7 Calculating DC-OM Values of compound feed in the ANCA Tool

From ANCA Tool version 2021 onwards, the DC-OM value of compound feed is calculated differently than before. This appendix provides the background and rationale for the revised calculation method.

Introduction

In the ANCA Tool, the calculation of methane production from manure is based on the DC-OM of feedstuffs. For individually delivered feedstuffs, the DC-OM is known and CVB table values are used (CVB Feed Table 2021; *Dutch: CVB Veevoedertabel 2021*), or a comparable alternative if the feedstuff is not listed in the CVB table.

For compound feeds, this value is not transmitted via EDI messages. Previously, a fixed DC-OM value of 84% was used for compound feeds. This fixed value was derived from the composition of 3 standard compound feeds, for which the DC-OM values were practically identical. In the guidelines for farm-specific excretion (BEX) and the ANCA Tool, dry feedstuffs that are not delivered individually are classified as compound feed. This means that a mixture of 2 raw materials already counts as compound feed.

There were two main objections to using a fixed DC-OM value for compound feeds:

1. The variation in raw material composition of compound feeds is much greater than that of the previously formulated 3 standard production feeds.
2. As mixtures of only a few raw materials can also exist (for example, two or three), the variation is even greater. In compound feeds containing around 10 raw materials, the extremes are averaged out.

Jacob Goelema (Team Leader R&D Ruminants at De Heus Feeds) has clearly demonstrated that there is a substantial variation in DC-OM values for compound feeds, and that there is a clear relationship between the DC-OM value of a compound feed and its content of VEM, P, and RE. In this note, the relationship between DC-OM and VEM, P, and CP has been estimated for:

1. The feedstuffs listed in the CVB Feed Table, and
2. A dataset of raw material mixtures as used in practice.

The fitted relationships presented in this note are ultimately used to predict the DC-OM values of compound feeds and meal mixtures.

Materials and Methods

The compound feed ingredients from the CVB Feed Table 2021 for which both a DC-OM (Digestible Organic Matter) value and a VEM content are known were selected (see Appendix 7A for the feed ingredients used). This resulted in a dataset of 177 feedstuffs (where, for feedstuffs classified into categories, such as soybean meal, each category is treated as a separate feedstuff). Three models, increasing in complexity, were then fitted to the data:

Model 1:

$$DC\text{-}OM\ (\%) = B_0 + B_1 \times VEM\ (g/kg) + error$$

Model 2:

$$DC\text{-}OM\ (\%) = B_0 + B_1 \times VEM\ (g/kg) + B_2 \times P\ (g/kg) + error$$

Model 3:

$$DC\text{-}OM\ (\%) = B_0 + B_1 \times VEM\ (g/kg) + B_2 \times P\ (g/kg) + B_3 \times P^{\wedge 2}\ (g/kg) + error$$

[2] https://www.rvo.nl/sites/default/files/2019/07/20190719%20Handreiking%20Bedrijfsspecifieke%20excretie%20melkvee%202019.pdf

It was also tested whether CP content could serve as an explanatory variable to predict variation in DC-OM in addition to VEM and P content in the dataset of feedstuffs from the CVB Feed Table 2021. However, this was not the case. Results from models including CP content are therefore not presented in this study.

Furthermore, various subsets of the data were examined, excluding feedstuffs with high standardized residuals. Ultimately, it was decided to base the definitively proposed model (Model 3) only on feedstuffs with Crude Fat contents below 130 g/kg and after excluding 4 outlier feedstuffs. This resulted in a final dataset of 135 feedstuffs. This dataset is provided in the appendix.
The model results based on the CVB Feed Table 2021 dataset were subsequently validated using a dataset of compound feed formulations (consisting of mixtures of feedstuffs) used in practice. This dataset was provided by De Heus and comprises 1,095 raw material mixtures produced in 2 factories. These 1,095 mixtures consist of dry compound feed ingredients supplemented with liquid pressing aids such as molasses and vinasse, as well as minerals/premixes and, in some cases, fat-containing products such as palm oil, soybean oil, or their fatty acids.
Table B7.1 presents the average contents of the final dataset of feedstuffs from the CVB Feed Table 2021, which was used to establish the final formula for predicting DC-OM, alongside the average contents of the De Heus dataset, which was used to validate the formula.

Table B7.1 *Average contents (± standard deviation) of the final dataset of feedstuffs from the CVB Feed Table 2021, used to establish the final formulae for predicting DC-OM and the average contents of the De Heus dataset, used to validate the formula.*

Dataset	Nutrient	n	Average	Minimum	Maximum
CVB	DM (g/kg)	135	894±34,1	721	1000
	CP (g/kg)		228±170,4	0	872
	P (g/kg)		5.5±3,85	0	19.6
	VEM (/kg)		946±153,1	434	1284
	DC-OM (%)		81,3±9,40	41,8	100
De Heus	DM (g/kg)	1095	882±8,3	862	917
	CP (g/kg)		196±87,0	68	439
	P (g/kg)		4,1±1,84	0.5	10,2
	VEM (/kg)		973±52,9	794	1276
	DC-OM (%)		85,3±3,00	74,6	90,8

Results and Discussion
An initial analysis of the relationship between VEM content and DC-OM values of feedstuffs from the CVB Feed Table shows a strong linear correlation between VEM content and DC-OM for feedstuffs with VEM content below 1200 VEM per kg of product (Figure B7.1). Feedstuffs with VEM contents above 1200 VEM are generally fat-rich products, such as pure fats/oils and fat-rich products such as oilseeds. Therefore, it was decided to exclude fat-rich products with RVET(h) contents above 130 g/kg of product. This resulted in a strong linear relationship between DC-OM and VEM content (Figure B7.2). The products with RVET(h) contents above 130 g/kg were: rice feed meal, cottonseed, soybeans, whole milk powder, potato chips, cottonseed, hemp seed, peanuts, sunflower seeds, linseed, ramtil, sesame seed, rapeseed, sunflower seeds, palm kernels, and pure fats/oils.

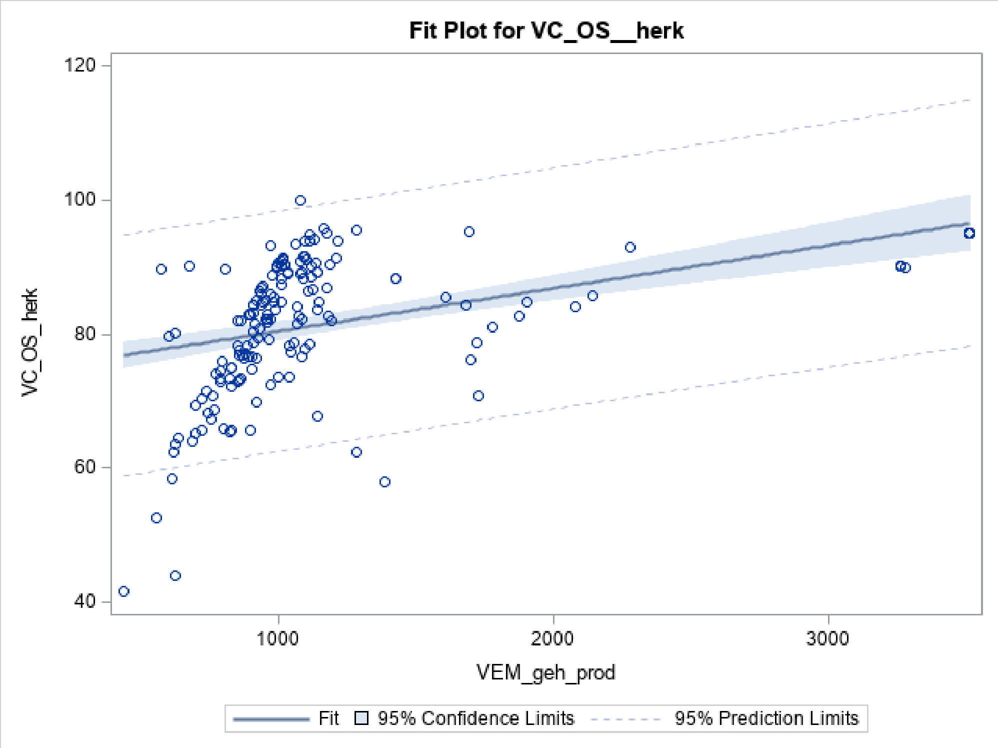

Figure B7.1 *Relation between DC-OM (%) and VEM-content (/kg product) for compound feed ingredients from the CVB Feed Table 2021 (n = 175). DC-OM (%) = 74.1±1.31 + 0.00639±0.000892 × VEM (/kg).* R^2 *= 0.229, %CV = 11.0, RMSE = 9.05, average DC-OM-value of the dataset is 82.1%.*

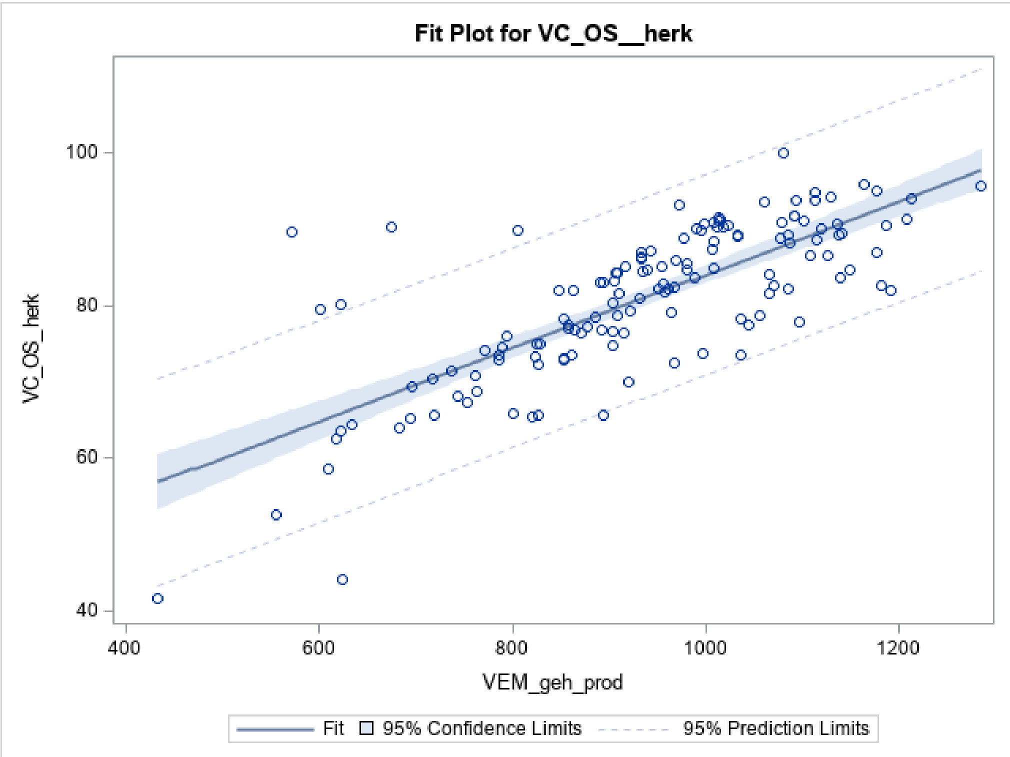

Figure B7.2 *Relation between DC-OM (%) and VEM-content (/kg product) for compound feed ingredients from the CVB Feed Table 2021 with a RVET-content below 130 g/kg (n = 139). DC-OM (%) = 36.1±3.29 + 0.0479±0.00346 × VEM (/kg).* R^2 *= 0.583, %CV = 8.1, RMSE = 6.57, average DC-OM-value of the dataset is 81.0%.*

Subsequently, Model 2 was fitted to the dataset of feedstuffs from the CVB Feed Table with RVET contents below 130 g/kg (with 139 observations):
Model 2:

DC-OM (%) = 40.9±3.23 + 0.0465±0.00324 × VEM (/kg) – 0.641±0.1361 × P (g/kg). N = 139, R^2 = 0.641, %CV = 7.6, RMSE = 6.11, average DC-OM-value of the dataset is 81.0%

Model 2 thus resulted in an improved model fit, with both the effects of VEM content and P content being significant. Adding CP content (model 3) as a third explanatory variable did not improve the model fit, and the effect of CP content was also not significant (P = 0.843).
Furthermore, there appeared to be a quadratic effect of P on DC-OM:
Model 3:

DC-OM (%) = 42.9±2,98 + 0.0485±0.00299 × VEM (/kg) – 2.411±0,3605 × P (g/kg) + 0.1289±0.02463 × $P^{\wedge 2}$ (g/kg). N = 139, R^2 = 0.702, %CV = 6.91, RMSE = 5.59, average DC-OM-value of the dataset is 81.0%

There were 4 clear outliers with studentized residuals greater than 2.5 or less than -2.5. These were sunflower seed hulls (studentized residual of -3.6), oat waste meal (studentized residual of -2.6), and the two qualities of beet vinasse (studentized residuals of 3.3 and 4.0). When these observations were removed, the following relationship for model 3 was observed.

Model 3 without outliers:

DC-OM (%) = 41.8±2,71 + 0.0489±0.00267 × VEM (/kg) – 2.186±0,30260 × P (g/kg) + 0.1167±0.02057 × $P^{\wedge 2}$ (g/kg). N = 135, R^2 = 0.761, %CV = 5.71, RMSE = 4.65, average DC-OM-value of the dataset is 81,3%

In model 3 without outliers, it appears that the P content is an important explanatory variable. However, it is questionable whether P content can be used in compound feed formulations, because in some cases inorganic phosphate is also added, which could lead to an incorrect prediction of the DC-OM value. In the compound feed formulations used by De Heus, however, the use of inorganic phosphate sources has been kept very limited due to the Voerspoor covenant, in which Dutch feed suppliers agreed to keep P levels in compound feed below 4.3 g/kg. Therefore, the likelihood that the use of inorganic phosphate would have a distorting effect on the predictions is very small.

A second objective of this study is to validate the results of model 3 without outliers on compound feed formulations used in practice.
Therefore, the observed DC-OM values from De Heus (dependent variable; y) were plotted against the DC-OM values predicted by model 3 (without outliers) (independent variable; x) using the PROC ROBUSTREG procedure in SAS. The reason for choosing the ROBUSTREG procedure instead of the standard linear regression method is that several compound feed observations in the De Heus dataset were clearly different from other compound feed formulations, as shown by a visual analysis in Figure B7.1. The regression results are presented in Figure B7.3.

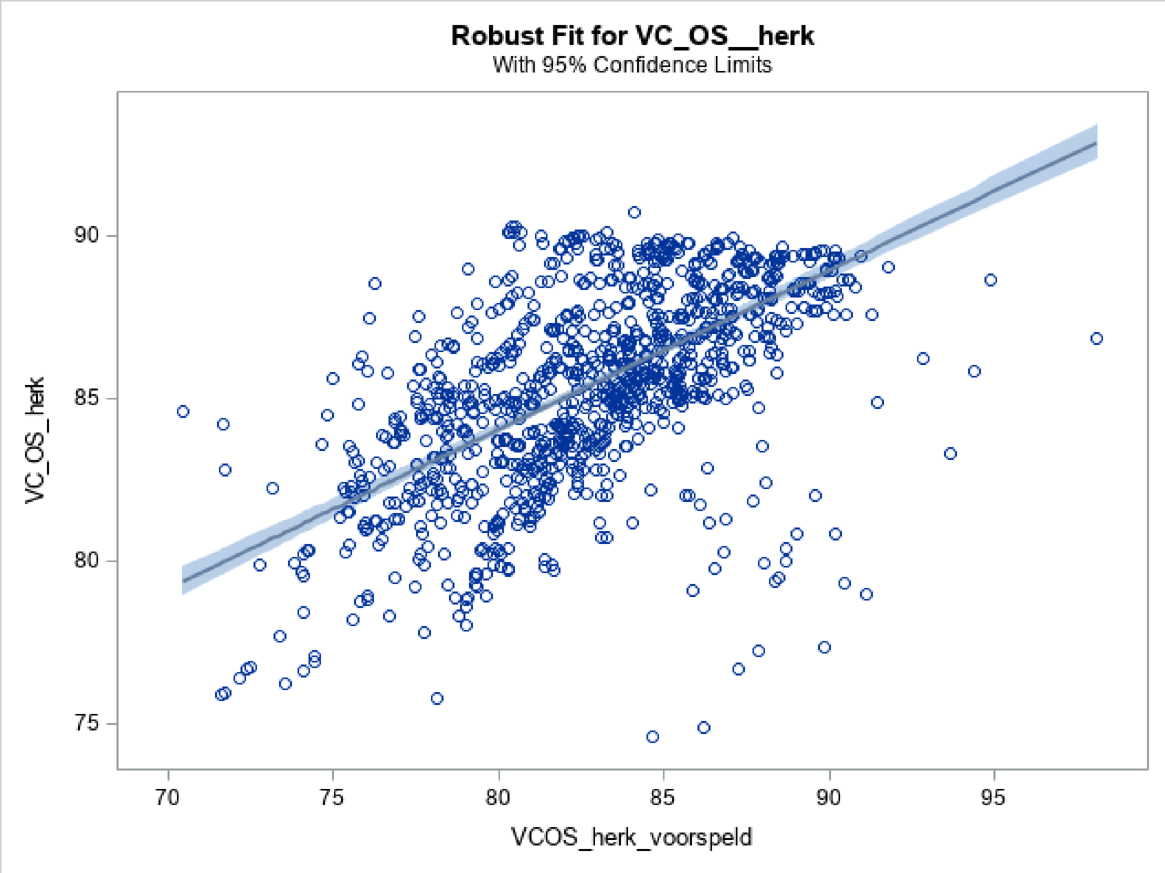

Figure B7.3 *Relation between observed DC-OM values (%) (y-axis) and predicted DC-OM values (%) (x-axis) for the dataset of De Heus compound feeds. The solid line represents the relationship as predicted using the PROC ROBUSTREG method in SAS. DC-OM observed (%) = 44.9±1.45 + 0.490±0.0175 × DC-OM predicted (%).* R^2 *= 0.330. Average observed DC-OM value is 85.3% and the average predicted DC-OM value is 82.8%.*

Figure B7.3 shows that 33% of the variation in DC-OM in compound feed formulations is predicted by model 3. In addition, the average predicted DC-OM value is 2.5% lower in absolute terms than the average observed DC-OM value in the De Heus dataset. This can be explained by differences in the composition of the compound feeds, where certain feed ingredients are used extensively and therefore have a large impact on the average observed DC-OM value.
A pragmatic solution could be to include an additional intercept of +2.5 in the regression formula of model 3. This would ensure that, at the very least, the average observed DC-OM value corresponds to the predicted DC-OM value. When the value 2.5 is included, the adjusted formula becomes as follows:

$$DC\text{-}OM = 44.3 + 0.0489 \times VEM\ (/kg) - 2.186 \times P\ (g/kg) + 0.1167 \times P^{\wedge 2}\ (g/kg).$$

If the above adjusted formula is applied to 979 dairy farms in 2019, it appears that using the new adjusted formula compared to the 2020 formula results in a 1% lower CH_4 emission from manure (newly calculated CH_4 emission relative to the 2020 calculated CH_4 emission is 99%, min–max: 90–104%).
In conclusion, it can be said that the developed regression formula can predict 33% of the variation in DC-OM of compound feed formulations used in practice. Although this proportion of explained variation is not large, it is nevertheless a substantial improvement compared to using an average DC-OM value for all compound feed formulations.

Wouter Spek
Wageningen Livestock Research, 13-September-2021

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Appendix 7A. Overview of compound feed ingredients from the 2021 CVB Feed Table used for the analyses[1]

Compound feed ingredient	Class-name	Sub class-name	DC-OM (%)	CFA(h) (g/kg)	CP (g/kg)	P (g/kg)	VEM (/kg)
Sugar			100.0	0	0	0.0	1080
Molasses, cane-,	SUG < 475 g/kg		79.6	1	51	0.7	601
Molasses, cane-,	SUG > 475 g/kg		80.1	1	41	0.6	623
Potato starch, dried			938	1	6	0.7	1092
Tapioca starch			94.1	2	11	0.4	1129
Potato fibres, dried	CP < 90 g/kg		82.1	2	61	1.0	863
Molasses, beet-			89.8	2	98	0.5	805
Potato fibres, dried	CP 90 - 130 g/kg		81.9	4	96	1.3	848
Potatoes, dried			85.0	4	93	2.4	953
Tapioca, dried	STARCHew 680 - 730 g/kg		85.0	4	23	0.9	917
Tapioca, dried	STARCHew 630 - 680 g/kg		84.3	5	23	0.7	907
Tapioca, dried	STARCHew < 630 g/kg		82.9	5	23	0.7	894
Corn starch			95.7	5	6	0.4	1164
Sweet potatoes, dried			84.7	6	40	1.3	940
Beet pulp, dried	SUG > 200 g/kg		87.1	7	102	0.7	942
Beet pulp, dried	SUG 150 - 200 g/kg		86.9	7	97	0.7	933
Whey powder			93.8	8	130	6.1	1112
Carob (pod)			73.5	8	42	0.5	785
Beet pulp, dried	SUG 100 - 150 g/kg		86.4	8	88	0.7	932
Rice	dehulled, polished		90.9	8	78	0.9	1078
Peanut meal	Partly dehulled, CF 75 - 145 g/kg		82.2	9	529	6.5	950
Beet pulp, dried	SUG < 100 g/kg		86.0	9	75	0.8	933
Sunflower seed meal	Partly dehulled, CF 150 - 195 g/kg		72.9	9	368	11.6	786
Skim milk powder			94.7	10	356	10.2	1113
Faba beans, white-flowering			90.2	10	264	5.1	1012
Peas			90.5	10	201	3.8	1023
Casein			94.9	11	872	5.3	1176
Peanut meal	Dehulled, CF < 75 g/kg		85.4	12	456	6.4	981
Faba beans, colour-flowering			90.3	12	254	5.1	1019
Corn feed flower			91.6	12	76	0.7	1092
Lentils			88.4	13	230	3.8	1009
Soybeal meal	HiPro CF < 45 g/kg	CP > 485 g/kg	91.4	13	489	6.5	1013
Soybeal meal	HiPro CF < 45 g/kg	CP < 485 g/kg	91.3	13	469	6.7	1016
Triticale			89.3	13	103	3.2	1032
Rye			87.3	13	93	3.1	1007
Rye feed meal			70.3	15	143	16.5	717

Compound feed ingredient	Class-name	Sub class-name	DC-OM (%)	CFA(h) (g/kg)	CP (g/kg)	P (g/kg)	VEM (/kg)
Soybeal meal	CF > 70 g/kg		90.6	15	421	5.8	999
Soybeal meal	CF 45 - 70 g/kg	CP < 450 g/kg	90.8	15	436	5.9	1008
Wheat			89.1	15	110	3.0	1033
Soybeal meal	CF 45 - 70 g/kg	CP > 450 g/kg	91.1	15	467	6.4	1012
Sunflower seed meal	hulled, CF > 245 g/kg		58.5	16	272	9.7	610
Sesame seed meal			81.5	16	430	12.9	910
Rumen-protected soybean meal: CovaSoy			90.0	16	462	6.4	991
Soybean hulls	CF > 360 g/kg		83.0	16	101	1.1	890
Palm kernel meal	CF > 190 g/kg		70.8	16	150	5.9	761
Sunflower seed meal	Partly dehulled. CF 195-245 g/kg		65.2	16	308	10.6	694
Cichory pulp, dried			84.3	17	83	1.2	908
Beans (Phaseolus), heated			88.8	16	229	4.6	977
Alfalfa meal/-pellets	CP < 140 g/kg		62.5	18	100	2.4	617
Rapeseed meal	CP > 370 g/kg		78.2	18	383	10.6	852
Rumen-protected soybean meal: Mervobest soy			89.8	17	454	5.7	995
Malt germs	CP < 200 g/kg		65.6	18	186	5.0	720
Malt germs	CP > 200 g/kg		76.9	18	218	5.6	858
Barley			84.7	18	102	3.2	980
Rice	Hulled		74.9	19	73	2.6	825
Potato protein	CA> 10 g/kg		88.2	20	773	2.0	1086
Potato protein	CA < 10 g/kg		88.6	20	797	1.6	1115
Citrus pulp			85.9	21	64	1.0	969
Soybean hulls	CF 320 - 360 g/kg		83.3	21	105	1.2	905
Alfalfa meal/-pellets	CP 140 - 160 g/kg		63.5	22	152	2.5	622
Coconut meal			80.2	23	227	5.7	904
Palm kernel meal	CF < 190 g/kg		76.4	24	158	6.0	871
Grass meal/-pellets	CP < 140 g/kg		71.5	25	122	3.2	737
Alfalfa meal/-pellets	CP 160 - 180 g/kg		64.5	25	168	2.7	633
Wheat milling by-products	Wheat flour		91.6	24	141	4.0	1092
Brewer's yeast, dried			78.6	26	459	10.6	909
Cottonseed meal	Partly dehulled. CF 140-200 g/kg		68.7	25	364	10.2	763
Corn germ meal			80.9	26	226	5.2	932
Sorghum			84.8	28	87	2.7	1008
Rapeseed meal	CP < 370 g/kg		77.5	28	339	10.5	857
Soybean hulls	CF < 320 g/kg		84.4	28	129	1.7	935
Alfalfa meal/-pellets	CP > 180 g/kg		69.5	29	191	2.8	697
Wheat milling by-products	Wheat bran		64.0	29	142	12.3	683
Cottonseed meal	dehulled, CF < 140 g/kg		72.3	31	437	10.7	826
Rumen-protected rapeseed meal, Mervobest			75.0	30	333	10.9	828
Linseed meal			76.8	30	320	8.4	864
Grass meal/-pellets	CP 140 - 160 g/kg		74.1	32	151	3.6	770
Wheat milling by-products	Wheat bran grit		68.2	32	149	10.6	744

Compound feed ingredient	Class-name	Sub class-name	DC-OM (%)	CFA(h) (g/kg)	CP (g/kg)	P (g/kg)	VEM (/kg)
Rye middlings			78.4	32	141	4.4	885
Corn feed meal			88.9	33	86	3.9	1076
Corn gluten feed	CP < 200 g/kg		82.9	35	185	9.5	956
Cottonseed meal	hulled, CF > 200 g/kg		65.9	38	296	10.8	800
Grass meal/-pellets	CP 160 - 200 g/kg		74.6	38	177	3.8	789
Wheat milling by-products	Wheat groats		73.3	36	152	9.6	824
Wheat milling by-products	Wheat feed meal		77.1	36	154	8.6	878
Whey powder, low lactose	CA > 210 g/kg		93.2	41	217	19.6	972
Corn			89.1	37	75	2.5	1085
Barley feed meal			67.2	38	118	4.1	754
Wheat milling by-products	Wheat flour		83.7	38	153	5.5	989
Wheat gluten feed, dried	CA < 40 g/kg		79.3	38	144	6.3	922
Grass meal/-pellets	CP > 200 g/kg		76.0	40	208	3.9	795
Corn gluten feed	CP 200 - 230 g/kg		82.3	40	205	9.6	968
Millet			76.7	40	111	2.8	904
Corn, processed			90.1	40	78	2.9	1120
Corn bran grits			79.1	41	93	4.7	964
Corn gluten feed	CP > 230 g/kg		82.1	41	240	9.5	961
Oats			76.4	43	100	3.0	916
Pearl millet			84.1	45	122	3.3	1065
Oat feed meal			74.8	44	91	3.6	903
Barley polishing meal			73.2	45	133	6.3	853
Wheat gluten feed, dried	CA > 60 g/kg		76.7	46	160	10.1	892
Wheat germ bran			81.7	46	179	9.1	958
Lupins	CP > 335 g/kg		91.1	46	360	3.5	1101
Wheat gluten feed, dried	CA 40 - 50 g/kg		73.4	50	156	8.8	862
Whey powder, low lactose	CA < 210 g/kg		93.5	53	252	14.7	1061
Wheat gluten feed, dried	CA 50 - 60 g/kg		73.0	51	167	9.6	853
Rice by-products			41.8	52	68	11.0	434
Lupins	CP < 335 g/kg		90.6	52	303	3.4	1135
Sorghum gluten meal			89.2	54	430	3.0	1138
Bread meal			89.3	54	124	1.9	1141
Wheat gluten meal			95.5	57	781	1.8	1284
Cottonseed flakes	hulled, CF > 210 g/kg		65.7	61	307	10.3	827
Corn gluten meal			93.9	60	604	4.6	1213
Oats, dehulled			90.4	63	129	4.3	1187
Corn feed meal			86.5	63	89	4.0	1108
Brewer’s grains, dried			65.4	67	248	4.6	821
DDGS, Wheat			82.7	68	324	8.4	1071
Cottonseed flakes	Partly dehulled, CF 140 - 210 g/kg		70.0	74	363	10.2	919
Linseed flakes			78.3	80	340	8.2	1036
Peanut flakes	dehulled, CF < 75 g/kg		87.0	81	476	4.8	1176
Soy flakes			91.4	81	439	6.3	1208
Palm kernel flakes	CF > 180 g/kg		73.7	85	152	5.7	996
Palm kernel flakes	CF < 180 g/kg		77.4	85	159	5.9	1044
Coconut flakes	CFA < 100 g/kg		81.6	85	204	5.5	1066
Peanut flakes	Partly dehulled, CF 75 - 145 g/kg		83.6	87	423	4.7	1139

Compound feed ingredient	Class-name	Sub class-name	DC-OM (%)	CFA(h) (g/kg)	CP (g/kg)	P (g/kg)	VEM (/kg)
Sunflower seed flakes	dehulledt,CF < 200 g/kg		72.5	88	335	11.3	968
Wheat germ			86.6	85	264	7.9	1125
Peanut flakes	hulled, CF > 145 g/kg		77.8	97	346	4.8	1096
Sunflower seed flakes	Partly dehulled, CF 200 - 315 g/kg		65.7	96	298	10.0	893
Corn screenings, dried			82.1	98	260	8.0	1085
Rapeseed flakes			78.6	101	315	10.2	1055
Cottonseed flakes	dehulled, CF < 140 g/kg		73.6	105	416	11.2	1036
Sesame seed flakes			84.7	115	451	9.8	1148
Coconut flakes	RFA > 100 g/kg		81.9	122	210	5.4	1191
DDGS, Corn			82.7	129	268	8.2	1182

[1] SUG = sugar, CP = crude protein, CF = crude fiber, CA = crude ash, CFA = crude fat, DC-OM = digestion coefficient organic matter

Appendix 8 Methane emission factors fresh grass: grazing and summer barn feeding

Background

Grass is a main component of the diet of dairy cows in the Netherlands. It is fed as grass silage, as fresh grass indoors (summer barn feeding), or as fresh grass offered through grazing. As such, grassland management affects ammonia and methane emissions from dairy cattle via the diet. However, the scientific basis for the methane emission factor (g CH_4 per kg of dry matter intake) of fresh grass is limited and, in an inventory study, was often found to differ from measured values (Koning *et al.*, 2020). This prompted the *"Integrated Approach"* programme of the Livestock Climate Envelope (Dutch: "Integraal aanpakken, Klimaatenvelop Veehouderij") to initiate research into the methane emission factor (EF) of fresh grass. This involved a four-year study, the results of which are now available (Klootwijk *et al.*, 2021; Koning *et al.*, 2022; Koning *et al.*, 2024).

Rationale for this briefing note

For Dutch dairy farmers, the effect of grassland management on methane emissions is calculated using the ANCA Tool. The ANCA Tool calculation applies fixed emission factors (EFs) for fresh grass and distinguishes between grazing grass (GG) and summer barn feeding (SBF). These default methane EF values differ only slightly from those for grazing grass (GG) or are somewhat higher for summer barn feeding (SBF) than the average EF of Dutch rations. As a result, the farm-level calculated effect of changes in grassland management is small.
However, the research referred to in the background paragraph shows that the EF for fresh grass, for both grazing (GG) and summer barn feeding (SBF), is lower than the default EF values currently used in the ANCA Tool. With substantial adjustments in grassland management, lower default values for fresh grass result in a visible reduction in methane emissions at the farm level. If the ANCA Tool default values for fresh grass (GG and SBF) are based on the results of the *"Integrated Approach"* research, managing fresh grass intake becomes a concrete and actionable option for Dutch dairy farmers.
This briefing note explores, based on recent research, what scientifically substantiated ANCA Tool default values for fresh grass (GG and SBF) could be and proposes adjustments to the current ANCA Tool default values.

Materials

In 2020, a four-year grazing study was started to gain insight into the reduction potential of fresh grass for CH_4 and NH_3 emissions in the dairy sector.
In 2020 and 2021, an identical experiment was conducted for two consecutive years with an unrestricted supply of fresh grass. Enteric CH_4 emissions (g CH_4 per animal per day) were measured in dairy cows fed 3 diets: a complete grass silage diet (GS), unrestricted grazing (UG), and unrestricted summer barn feeding (USBF). The measured emissions related to the total diet.
In 2022 and 2023, the same experiment was again conducted for two consecutive years, but this time with a restricted supply of fresh grass. Enteric CH_4 emissions (total diet) were again measured in dairy cows fed 3 diets: unrestricted grazing (UG), restricted grazing (RG), and restricted summer barn feeding (RSBF), with grass silage provided as a supplement.
Both two-year experiments were analysed and reported both per year and across both experimental years (meta-analysis). Based on the multi-year research conducted from 2020 to 2023 (see Klootwijk *et al.* (2021), Koning *et al.* (2022), and Koning *et al.* (2024)), the default values for the EFs of fresh grass can be evaluated.

Results experiments

The meta-analysis of 2020 and 2021 (see Appendix 1, Table a) shows that CH_4 production (per cow per day), CH_4 intensity (per kg of fat- and protein-corrected milk), and CH_4 yield (per kg of dry matter intake) were all significantly lowest during unrestricted grazing (UG), followed by unrestricted summer barn feeding (USBF), and highest for the grass silage diet (GS). These differences relate to the total diet and were most pronounced in spring, with notably low CH_4 emissions for diets with fresh grass. Average CH_4 yields were 17.2 g CH_4/kg DM for diets with unrestricted grazing (UG), 18.3 g CH_4/kg DM for diets with unrestricted summer barn feeding (USBF), and 21.0 g CH_4/kg DM for grass silage diets. A nuance regarding the difference between the EFs of diets containing fresh grass and those based on grass silage is that this difference may fluctuate over time, due to interannual variation in the EFs of grass (both fresh grass and average grass silages) and because grass silages are harvested at different times than fresh grass.
The meta-analysis of 2022 and 2023 (see Appendix 1, Table b) again shows significantly the lowest CH_4 emissions during unrestricted grazing (UG). The analysis indicates that CH_4 yield was 15.7 g CH_4/kg DM for diets with unrestricted grazing (UG), 18.9 g CH_4/kg DM for diets with restricted grazing (RG), and 21.1 g CH_4/kg DM for diets with restricted summer barn feeding (RSBF). Few period effects on CH_4 emissions were observed; however, for treatments containing fresh grass, the lowest CH_4 yield was measured in spring.
The results of these WLR experiments are consistent with recent grazing research from Ireland, which also reported lower CH_4 yields for grazing diets in spring (Lahart *et al.*, 2024). Lahart *et al.* reported CH_4 yields of 15.6 g CH_4/kg DM during grazing in spring, 18.3 g CH_4/kg DM in summer, and 19.8 g CH_4/kg DM in fall.

Practical application

In Dutch practice, enteric methane emissions of a dairy farm are calculated using the ANCA Tool. For the calculation, the 2023 version of the ANCA Tool uses default values for the EFs of fresh grass that are derived from independent experimental research and that distinguish only between grazing (GG) and summer barn feeding (SBF), without differentiating between restricted and unrestricted grass supply. The ANCA Tool default values are not used for calculating national enteric emissions, as a mechanistic model is applied for that purpose (Bannink *et al.*, 2011).
The results of the experiments described in this note indicate lower EF values for fresh grass than the current ANCA Tool default values for fresh grass (GG and SBF). These findings are consistent with results from studies using mechanistic models, which reported a model-based overestimation of enteric CH_4 production during summer barn feeding (Bannink *et al.*, 2016; Warner *et al.*, 2015; Lahart *et al.*, 2024).
The current ANCA Tool default values for the EFs of fresh grass are based on experimental research conducted in respiration chambers and in practice largely reflect summer barn feeding. The research described here involves direct measurements under both GG and SBF conditions in a practical farm setting, making the results in principle more suitable for deriving default EF values for fresh grass. It is evident that the current default values in the ANCA Tool are higher than those measured in the four-year study, and that these measurements are consistent with findings from other recently published research. This demonstrates the relevance of revising the default EF values for GG and SBF in the ANCA Tool. In addition, it highlights the relevance of further research into whether the estimation models for enteric CH_4 emissions from fresh grass can be adapted.

Impact of adjusting EF values for fresh grass

The impact of lowering the EF value for fresh grass is that farms feeding fresh grass would achieve lower enteric methane emissions as calculated with the ANCA Tool. Further research is required to determine whether lowering the EF for fresh grass would also result in a meaningful reduction of national methane emissions for the average Dutch dairy ration.
With respect to methane mitigation, lowering the EF value for fresh grass in the ANCA Tool (grazing and summer barn feeding) provides dairy farmers with actionable options and positions the feeding of (more) fresh grass as a steering mechanism for reducing methane emissions. When estimating the emission-reducing effect (in kg methane per year), the farm-level context must be taken into account. Fresh grass is part of the total ration, meaning that both supplementation during grazing or summer

barn feeding and the winter ration largely determine the annual farm-level emissions. Moreover, grazing affects grass silage quality and thereby influences enteric CH_4 emissions based on the winter ration (Veraart *et al.*, 2023).
Based on the experiments described in this note, the mechanistic model estimates (Bannink *et al.*, 2011) cannot be adjusted further. For that, further in-depth research into the underlying mechanisms and drivers of the (variation in) lower EF values for fresh grass is required. Such research has already been initiated, but it will take several years before this can lead to adjustments of the model estimates.
Adjusting the current default values for EF GG and EF SBF for use in the ANCA Tool version 2024 (applied in 2025 for the 2024 reporting year) is, however, possible.

<u>Establishing default values for EF-GG and EF-SBF</u>

Approach

Within the *Integrated Approach* programme (*Dutch: Integraal Aanpakken*), an ad hoc working group was established (A. Bannink, M. de Haan, C. Klootwijk, B. Philipsen, L. Šebek, and E. Verscheijden) to examine how the results of the experiments described in this note (Koning *et al.*, 2022; Koning *et al.*, 2024) can be used to establish default EF values for fresh grass. The working group defined the following guiding principles:

1) The basis for the EFs consists of the two Multiple Experiment Analyses conducted in 2020–2021 and 2022–2023 (Appendix B8.1, Tables B8.1.1 and B8.1.2).
2) No distinction is made between periods within the year or between restricted and unrestricted fresh grass supply.
3) All EF values presented in *Appendix 1, Tables a and b* are adjusted to an EF at a dry matter intake of 18.5 kg per cow per day (EF18.5). This standardises the EFs for intake level (Šebek *et al.*, 2020) and is consistent with the current methodology used in the ANCA Tool.
4) The experimental data from both Multiple Experiment Analyses are included in full, i.e. all data are used without further selection. Weighted averages are calculated across years and across the treatments 'unrestricted' and 'restricted'.
    a) For the overall average EF-GG, the EFs for unrestricted grazing (UG) and restricted grazing (RG) are weighted 50/50 (i.e. the four-year average for UG plus the two-year average for RG, divided by two).
    b) The same approach is applied for the overall average EF-SBF, with a 50/50 weighting of USBF and RSBF.
5) To calculate the EF for fresh grass from the measured diet-level EFs, an assumption is required for the EF of the non–fresh grass component of the ration. It is assumed that the non–fresh grass component has the EF of the Dutch average ration (van Bruggen *et al.*, 2024) for the respective years. The EF18.5 values for 2020, 2021, 2022, and 2023 were 19.40, 19.38, 19.33, and 19.37 g CH_4/kg DM, respectively.

Based on principles 1–5, the diet-level EFs measured in the experiments (g CH_4/kg DM) were first converted to diet-level $EF_{18.5}$ values. Subsequently, using a similarly converted $EF_{18.5}$ for the supplemental feed, the $EF_{18.5}$ for fresh grass was derived. These values were then used to calculate the overall average emission factors for grazing (EF-GG) and summer barn feeding (EF-SBF) (Table B8.1).

Table B8.1 *Methane production data from the experiments (diet-level), methane emissions from supplemental feed (based on data from the national Emissions Registry), and the resulting calculated methane emissions from fresh grass. The calculation involves converting the experimental data to a standardised methane emission factor (EF) at a dry matter intake of 18.5 kg per animal per day ($EF_{18,5}$). These data relate to unrestricted and restricted grazing (UG and RG), and to unrestricted and restricted summer barn feeding (USBF and RSBF). They are subsequently presented for the fresh grass EF as weighted averages for grazing (GG) and summer barn feeding (SBF).*

Data from experiments	**2020 and 2021**				**2022 and 2023**				**Overall average**	
	GS	**UG**	**USBF**		**UG**	**BW**	**RSBF**		**GG**	**SBF**
CH4 production	412	320	395		322	398	448		-	-
CH4 intensity	15	12.4	13.8		11.5	13.8	14.8		-	-
CH4 yield	21	17.2	18.3		15.7	18.9	21.1		-	-
kg DM intake	19.6	18.6	21.6		20.5	21.1	21.2		-	-
% fresh grass	*0.00*	*0.78*	*0.81*		*0.77*	*0.47*	*0.47*		-	-
Calculated values										
kg DM intake 'Standard'		18.5	18.5		18.5	18.5	18.5		18.5	18.5
$EF_{18.5}$ Ration	-	17.2	18.9		16.1	19.4	21.7		-	-
$EF_{18.5}$ Supplement	-	19.4	19.4		19.4	19.4	19.4		-	-
$EF_{18.5}$ Fresh grass	-	16.6	18.8		15.2	19.5	24.3		17.7	21.6

Based on principles 1–5, Table 1 presents average values for fresh grass for the standardised methane emission factor during grazing ($EF_{18.5}$-GG) and summer barn feeding ($EF_{18.5}$-SBF) of 17.7 and 21.6 g CH_4 per kg DM, respectively. These values are consistent with findings from other recent research reports and are lower than the current default values used in the ANCA Tool. It therefore appears appropriate to adjust the default values in the ANCA Tool based on these recent measurements.

Discussion

The calculations presented in this note are based exclusively on the experiments described (Klootwijk *et al.*, 2021; Koning *et al.*, 2022; Koning *et al.*, 2024). These experiments and their reporting are not subject to discussion in this note. The discussion points below relate solely to the practical application of the experimental findings, with a particular focus on their use within the ANCA Tool.

- Significant differences in EFs were found between the 'grazing' and 'summer barn feeding' treatments. This difference was demonstrated for both unrestricted and restricted fresh grass supply. On this basis, a distinction between EF-GG and EF-SBF can be maintained in the ANCA Tool.
- In the second experiment, a direct comparison was made between unrestricted and restricted grazing (UG and RG), in which UG showed a significantly lower EF than RG. However, the EF for UG differed substantially between the first and second experiments (almost 10% higher in experiment 1). At present, the evidence is insufficient to justify differentiation within EF-GG into separate EFs for UG and RG. Based on these results, however, the distinction between EF-GG and EF-SBF can be maintained in the ANCA Tool without differentiation between unrestricted and restricted fresh grass supply.
- In both experiments, numerical (non-significant) differences between periods were observed. These differences were larger in the first experiment than in the second. Based on current knowledge, these differences are insufficiently understood. Model-based substantiation is also not possible, as existing models do not capture the observed variation. As a result, potential period-related differences in the EF of fresh grass cannot be sufficiently substantiated for application in the ANCA Tool. In-depth research has now been initiated. Following completion of this research, it will be assessed whether the EF for fresh grass can be differentiated by period of the year and by unrestricted versus restricted fresh grass supply.
- It was assumed that the non–fresh grass component of the ration has the EF of the Dutch average ration for the respective years. This assumption was necessary because, in the experiments,

methane emissions from supplemental feed could not be distinguished from methane emissions from fresh grass. As a result, the EF for grass can only be derived by making an assumption about the EF of the supplemental feed. This assumption slightly affects the comparison of treatments within experiments, because the supplemental feed was not fully identical across treatments of the various experiments. In addition, this assumption affects the absolute level of the average $EF_{18.5}$. Nevertheless, the difference between $EF_{18.5}$-GG and $EF_{18.5}$-SBF remains reasonably well estimated, even if the absolute level of these EFs may be over- or underestimated.

Conclusions

- The methane emission factor (EF, g CH_4 per kg DM) for fresh grass during grazing (GG) is lower than the EF for fresh grass during summer barn feeding (SBF) and has been quantified based on the most recent available information.
- The methane emission factor (EF, g CH_4 per kg DM) for fresh grass at a standardized feed intake of 18.5 kg DM per animal per day has been established as $EF_{18.5}$GG = 17.7 for grazing and $EF_{18.5}$ SBF = 21.6 for summer barn feeding.
- The results from the experimental studies further provide clear indications that:
  - the EF for fresh grass under unrestricted grazing is lower than under restricted grazing, and
  - the EF for fresh grass in spring is lower than in summer and autumn.

These are indications because the differences were not always significant in both experiments, and it is still unclear how the observed differences can be explained or represented in models. Therefore, there is currently insufficient evidence to quantify these differences and use them to differentiate the default values for fresh grass (for GG and SBF) in the ANCA Tool. Follow-up research has now begun, the results of which may provide a better basis for the observed differences.
Ad hoc working group "Enteric methane emission factor for fresh grass". (*Dutch: "Enterische methaan emissiefactor voor vers gras*

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Appendix 8.1

Table B8.1.1 *Multiple Experiments (REML) Analysis of the experiment conducted in 2020 and 2021, with the fixed model including treatment, period, year, and the interaction between treatment and period, and the random model including block within period within year and period within year. The estimated treatment means for grass silage, unrestricted grazing, and unrestricted summer barn feeding (GS, UG, and USBF) per period (1, 2 and 3) and overall averages are presented, including the LSD for the treatment (average) and the p-values of the fixed effects. Significant differences between treatments are indicated with superscripts (only for the average treatment effect).*

Period	**1**			**2**			**3**			**Average**				**P-values**			
Treatment	**GS**	**UG**	**USBF**	**GS**	**UG**	**USBF**	**GS**	**UG**	**USBF**	**GS**	**UG**	**USBF**	**LSD**	**Per*Treat**	**Treat.**	**Per.**	**Year**
CH_4 production (g CH_4/cow/day)	412	287	366	420	341	436	403	333	385	412[a]	320[c]	395[b]	13.7	<0.001	<0.001	0.408	0.832
CH_4 intensity (g CH_4/kg FPCM)	14.1	9.4	11.5	15.8	14.5	16.2	15.2	13.5	13.7	15.0[a]	12.4[c]	13.8[b]	0.63	<0.001	<0.001	0.085	0.916
CH_4 yield (g CH_4/kg DM)	21.1	14.1	16.0	21.3	19.3	20.8	20.5	18.3	18.2	**21.0[a]**	**17.2[c]**	**18.3[b]**	0.68	<0.001	<0.001	0.077	0.688

Table B8.1.2 *Multiple Experiments (REML) Analysis of the experiment conducted in 2020 and 2021, with the fixed model including treatment, period, year, and the interaction between treatment and period, and the random model including block within period within year and period within year. De estimated treatment averages for unrestricted grazing, restricted grazing and restricted summer barn feeding (UG, RG and RSBF), period averages (1 spring, 2 summer and 3 fall) and yearly averages*

	Treatment					**Period**					**Year**				**Periode × treatment**
	GS	**RG**	**RSBF**	**LSD[1]**	**p**	**1**	**2**	**3**	**LSD[1]**	**p**	**2022**	**2023**	**LSD**	**p**	**p**
CH_4 production (g CH_4/cow/day)	322[c]	398[b]	448[a]	12.0	<0.001	373	396	399	97.2	0.746	372	407	79.3	0.193	<0.001
CH_4 intensity (g CH_4/kg FPCM)	11.5[c]	13.8[b]	14.8[a]	0.50	<0.001	12.1	13.6	14.4	2.93	0.161	12.6	14.1	2.37	0.169	0.104
CH_4 yield (g CH_4/kg DM)	**15.7[c]**	**18.9[b]**	**21.1[a]**	0.62	<0.001	17.7	18.4	19.7	2.32	0.134	17.5[b]	19.6[a]	1.85	0.040	0.035

(2022 and 2023) are presented, as well as the LSD and p-values. Significant differences between treatments are indicated with superscripts.

Appendix 9 Monthly soil cover for the soil carbon module

Dutch crop code	Catch crop	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
AARD	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	NO	NO	NO
AARD	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES
BIET	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO
BIET	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO
GPS	NO	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES
GPS	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO	YES	YES
GRANG	NO	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES	YES
GRANG	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES	YES
GRANK	NO	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
GRANK	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
GRASZ	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GRASZ	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
GROBLA	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	NO	NO	NO
GROBLA	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES
GROOVE	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO
GROOVE	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	NO	YES
MAÏS	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO
MAÏS	YES	YES	YES YES YES	YES	NO	YES	YES	YES	YES	YES	YES	NO	YES
OVERIG	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	NO	NO
OVERIG	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	NO	YES
PEUL	NO	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES
PEUL	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	YES	yes	YES
POOT	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
POOT	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES
UIBOL	NO	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
UIBOL	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	YES	YES	YES
BG_OUD		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
BG_NIEUW		YES	YES	YES	NO	NO	YES	YES	YES	YES	YES	YES	YES
TG		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
SNIJMAÏS	NEE	NO	NO	NO	NO	YES	YES	YES	YES	YES	NO	NO	NO
SNIJMAÏS	JA	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO	YES	YES

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