Calculation rules of the Annual Nutrient Cycling Assessment (ANCA) 2020

Background of BEX, BEA, BEN, BEP and BEC: update of ANCA 2019 version

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Report 1023-UK

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Cover photo: Dairy cows in 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, test and introduce a tool that provides dairy farms with information on the cycle and losses of nitrogen, phosphate and carbon. The tool provides various indicators to achieve this. These indicators are associated with a large number of calculation rules. This report describes these calculation rules and the input data they are based on. It also indicates where there are still limitations on the use of the ANCA.

In addition to the authors of this report, other colleagues have contributed to the substantiation of the calculation rules in the past. At this point we would like to extend special thanks to Jaap Schröder, Leon Šebek, Sjaak Conijn, Theun Vellinga, Frans Aarts and Joan Reijs for their contributions.

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. This made it easy to reuse by-products released during the different steps. Nitrogen (N), phosphorus (P) and carbon (C) from humans and animals were recycled locally, via manure and soil, to crops, before eventually being used again by humans and animals. In the process, N, P and C could be lost from this cycle into the environment. It happened in the past just as it does now. Losses are partly inherent to biological processes. For example, a large part of the C ingested via feed is not stored in the animal (humans, livestock or soil biota), but burned during metabolic processes in the body and converted into heat and movement and released as carbon dioxide. When N becomes available as a fertiliser (ammonium) from dead plants and animals, it is not completely absorbed by plants. Part of the ammonium-N will be converted to nitrate-N and eventually to elementary N. The latter form of N has no fertiliser value for most plants and, as such, should be considered as lost. The aforementioned losses in biological processes are only partly inevitable. Losses are also a result of how N, P and C flows are managed. This is relevant because losses can have a detrimental effect on the environment. For example, losses of nitrate-N, ammonia-N and phosphate reduce the quality of ground and surface water, and losses of nitrous oxide-N, methane and carbon dioxide are greenhouse gases contributing to climate change. Initially these losses were compensated for by biological N fixation in legumes, the supply of N and P from grazing uncultivated soils, the supply of N and P by water and wind, P released by the weathering of rocks and the 'new' formation of organic C through photosynthesis. Nowadays, however, farmers compensate for losses by importing synthetic fertilisers or 'packaged' fertilisers in the form of imported feed.

Unlike in arable farms and intensive livestock farms (e.g. poultry, pigs), the local ('short') cycle of N, P and C via animals, manure, soil and crops is more often found on dairy farms. However, on dairy farms too, interactions with the outside world have increased and the cycles, where still extant, often take longer detours. The processing of milk and meat, and housing of young stock, for example, more often takes place off-farm. Moreover, the raw materials needed for animal production and to compensate for losses (fertilisers, concentrates and other feed ingredients) are often produced off-farm. Sometimes raw materials originate off the farm or from stocks built up in the past, such as fossil fuels, phosphate rock and fossil groundwater (ancient aquifers). Under Dutch law, the 'ruminants' category ('*graasdieren*') includes cattle (excluding white veal calves), sheep, goats, horses, donkeys, Mid-European red deer, fallow deer and water buffaloes.

The Annual Nutrient Cycling Assessment (ANCA; in Dutch, 'KringloopWijzer') project aims to develop, test and introduce a tool that provides a scientific, integrated, unambiguous and reliable overview of the cycle and N, P and C losses. Previously, the tool was only suitable for specialised dairy farms, but the present version of the ANCA is also suitable for farms with arable production or with livestock other than dairy cows and young stock.

The ANCA yields a number of indicators that agricultural entrepreneurs can use to justify their business operations to governments or processors and to optimise their farm management. For governments, the ANCA offers an opportunity to partly replace generic legislation with customisation. Processors (e.g. for dairy or meat) can utilise results of the ANCA to provide insight in to sustainability performance to consumers.

The mapping of the cycles on the farm is done step-by-step and ultimately leads to the following calculated indicators on an annual basis. (see Figure 1.1):

1. Manure production: excretion of nitrogen (N) and phosphate (P_2O_5) by dairy cattle and associated young stock, other ruminants (breeding bulls, suckler cows, red meat bulls, rosé calves, sheep, goats, horses, ponies) and non-ruminants (pigs, chickens, white veal calves);
2. Efficiency of animal feeding (i.e. conversion of feed into milk and meat): utilisation of N and P_2O_5 (this calculation is limited to the dairy herd and associated young stock for the time being);
3. Emission of ammonia (NH_3) divided over barn and manure storage, grazing animals, land application of animal manure and use of synthetic fertiliser;
4. Yields of pasture (including goose grazing), maize 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. conversion of fertilisers into crop yield, including non-roughage arable crops): utilisation of N and P_2O_5 present in fertilisers and animal manure (including goose excretion);
6. Soil surplus of N and P_2O_5 and the supply of effective organic matter to soils under pasture, maize silage and any other arable crops (roughage and non-roughage);
7. Nitrate (NO_3) in groundwater; this indicator will only be shown 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 and C;
10. Farm efficiency (i.e. the share of imported minerals that is converted into exported milk, meat or non-roughage arable crops): utilisation of N and P_2O_5 in purchased feed or fertilisers.

The aim of this report is to describe how the above indicators are calculated and on what input data they are based. These indicators (and a number of additions, such as BEX advantage, BEP advantage, On-farm protein, Ammonia emission per LU, Share of permanent pasture) are shown in the ANCA Export pages. Appendix 1 indicates which section in this report each of these indicators refers to. Appendix 2 indicates how the 'additional' indicators referred to above are defined and calculated.

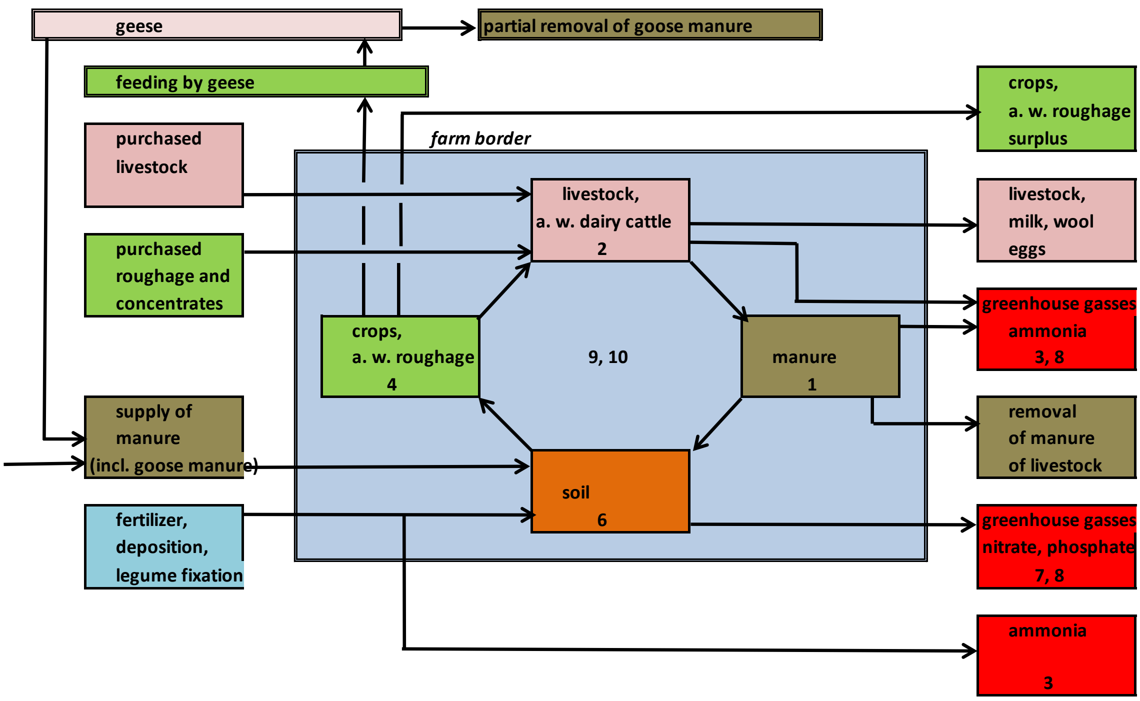

Figure 1.1 *The location of the indicators (see numbers above) in the material flow through farms.*

1.2 The cycles in more detail

In order to compare the performance of farms for these indicators, agreements on the method of calculation are necessary. The calculation must do as much justice as possible to the fact that farms greatly in terms of input and output flows. Figure 1.2 provides an initial impression of this. From this figure, it is clear that the sum of N, P and C in the materials entering the farm (terms A to F) must, due to the law of conservation of mass, be equal to the sum of N, P and C in materials leaving the farm (terms G to M) and in stock changes in the farm. Many more flows can be distinguished within the farm (Figure 1.3). Nutrients enter the farm enable the soil to grow crops. These include: nutrient deposition, fertiliser, 'pasture manure' (manure excreted on pasture, including the excretion of geese), 'barn manure' (manure excreted in the barn, including feed leftovers) and (in some instances) organic N fixation and mineralising peat. The growth of crops leads to both a harvestable product and a part that is not harvested in the form of roots and stubble, which die and decompose in the soil and thus return to the soil as nutrients. Not all of the harvestable part of the product is actually usable. As some mowing, harvesting and grazing losses are inevitable, the actual amount harvested or eaten during grazing (including goose grazing) will always be slightly less than the amount grown. These losses, similar to roots and stubbles, largely return to the soil. Even after the harvested product leaves the field, not all will be fully ingested by the cattle, since part will be lost during conservation of feed, and losses will also occur between feeding out the silage and ingestion; the so-called 'feed losses'. Table 1.1 gives an overview of the various loss percentages that are currently used in the ANCA. These differ per product and, within a product, per substance. In reality, these losses have no fixed value and will vary as a result of management, among other things. However, it is impossible to specify the values per farm in a simple and reliable way.

Table 1.1 *Percentages of field losses (grazing losses in pasture grass, mowing losses in cut grass, harvesting losses in maize), conservation losses and feed losses used in the ANCA. (KWIN, 2019-2020 and Dutch Dairy Farm Handbook 2020/2021)*

	Field loss	Conservation loss				Feed loss
	DM, VEM[1], N, P	DM	VEM	N	P	DM, VEM[1], N, P
Pasture grass, limited grazing	15	0	0	0	0	0
Pasture grass, unlimited grazing	20	0	0	0	0	0
Pasture grass, summer stall-feeding	5	0	0	0	0	0
Cut grass for ensiling	5	10	15	3	0	5
Maize silage	2	4	4	1	0	5
Other home-grown roughage	2	4	6	1.5	0	3
(supplied) wet by-products	0*	4	6	1.5	0	3
Single concentrate feed	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

* Field losses may be present, but take place off-farm.

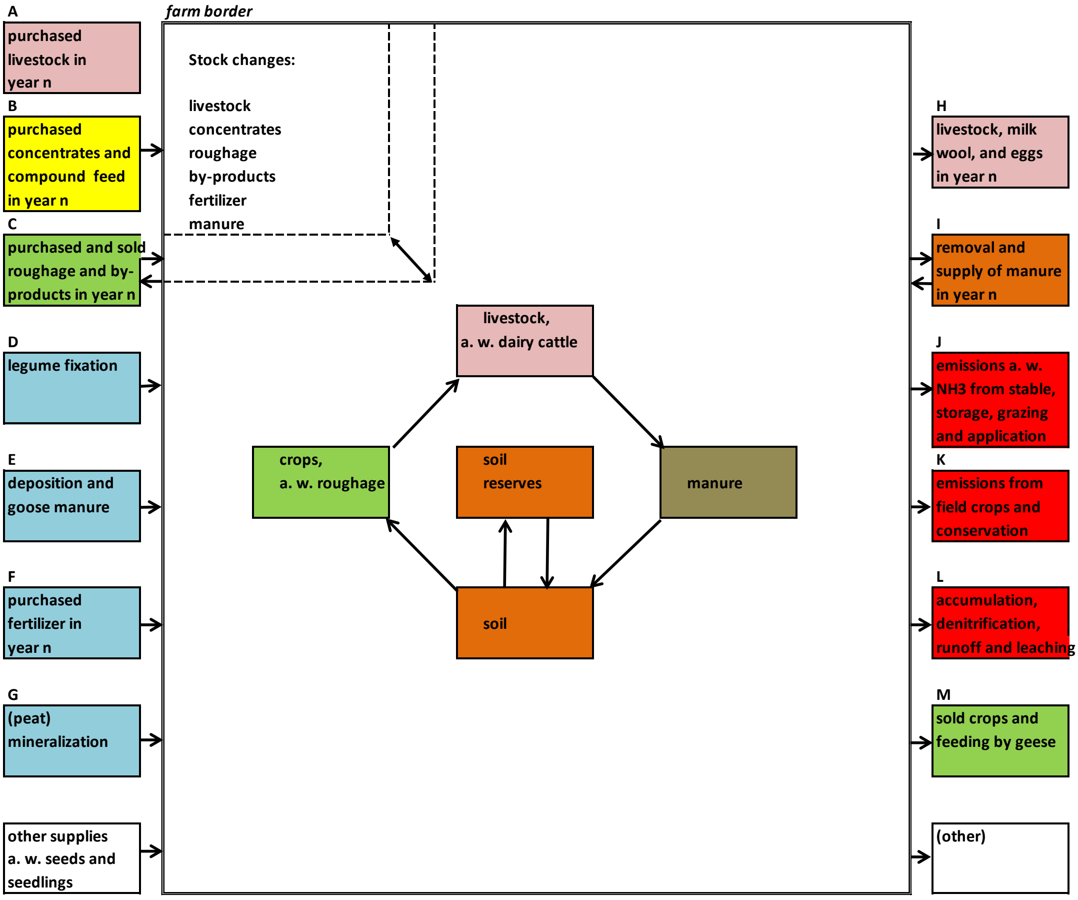

Figure 1.2 *Material input and output flows on a farm: global.*

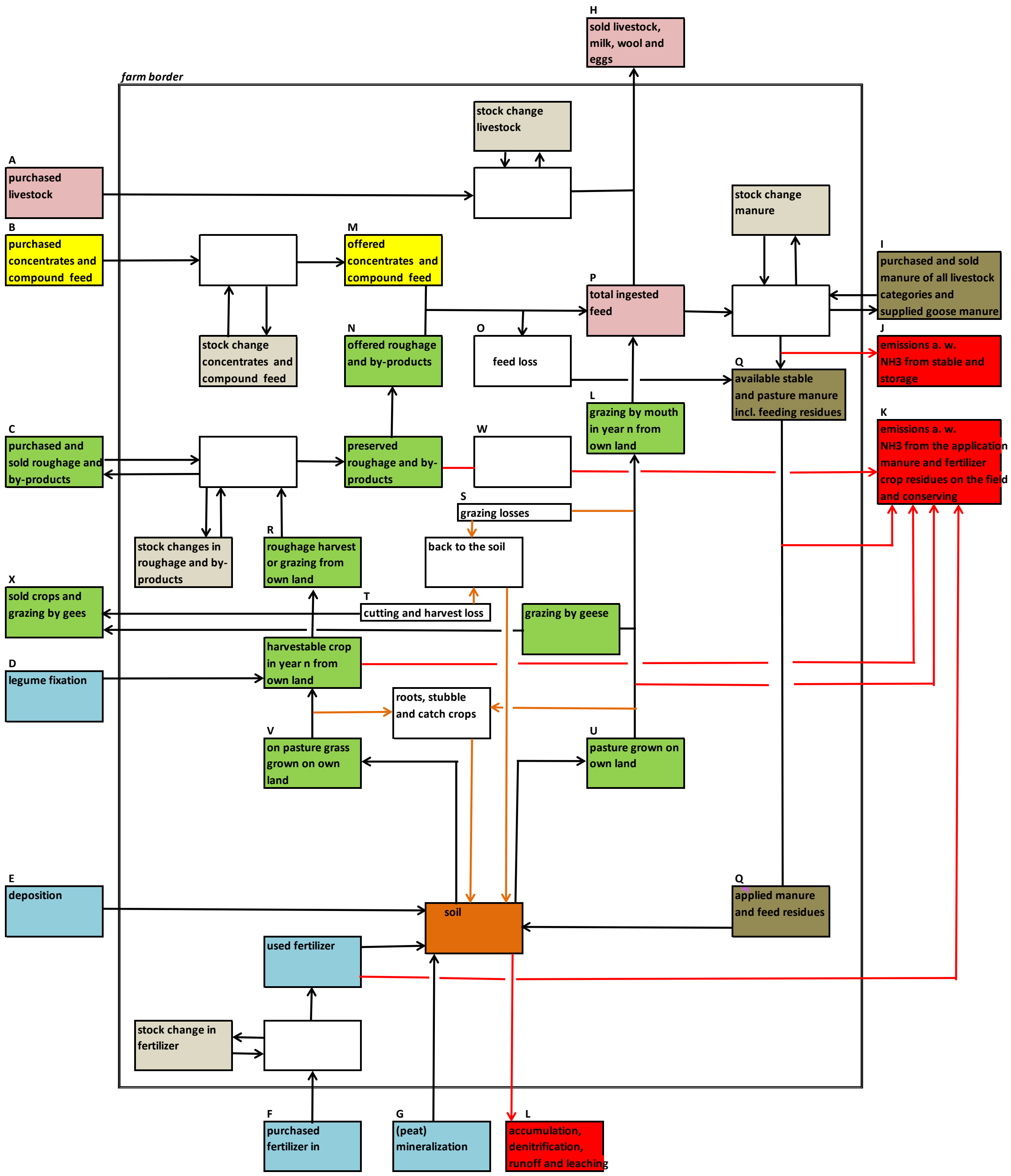

Figure 1.3 *Overview of material input and output flows on a farm, with or without arable crop production and other (ruminant/non-ruminant) livestock, including internal flows.*

When farms have more land available per livestock unit, the possibility arises of using manure from elsewhere in addition to own manure, within manure application restrictions. In that case, data is required on the composition of the imported manure. Table 1.2 lists the standard values used for this.

Table 1.2 *Average composition (standard values) of organic fertilisers.*

	N (kg/ton)	P_2O_5 (kg/ton)	TAN (% from total N)	SG (ton/m^3)	OS/N -
Ruminants slurry (manure code 14)	4.0[1]	1.5[1]	48[1]	1.005[1]	17.8[1]
Manure excreted on pasture[2]	4.0[1]	1.5[1]	48[1]	1.005[1]	17.8[1]
solid manure (manure code 10)	6.4	3.2	14[1]	0.9[1]	20.1[1]
Non-ruminants slurry (manure code 50)[3]	6.4	3.8	53[1]	1.04[1]	11.3[1]
solid manure (manure code 39)[4]	31.1	15.4	25[1]	0.605[1]	12.3[1]
Compost[5]	7.0[1]	3.3[1]	9[1]	0.8[6]	30.1[1]
Liquid fraction (manure code 11)	4.9[1]	2.0[1]	61[10]	1.02[1]	7.0[1]
Solid fraction (manure code 13)	9.2[1]	8.4[1]	29[1]	0.9[7]	16.5[1]
Fertiliser substitutes (mineral concentrate, blowdown lye)	7.3[8]	0.5[8]	90[8]	1.005[1]	2.9[8]
Digestate[9]	5.6[1]	3.1[1]	74[1]	1.005[1]	6.0[1]
Other[2]	4.0[1]	1.5[1]	48[1]	1.005[1]	17.8[1]
(Ruminants, liquid fraction)[10]	(3.4)	(1.0)	(60)	(1.005)	(13.7)
(Ruminants, solid fraction)[10]	(7.3)	(4.1)	(22)	(0.9)	(26.4)
(Non-ruminants, liquid fraction)[10]	(6.1)	(2.6)	(64)	(1.005)	(8.8)
(Non-ruminants, solid fraction)[10]	(10.8)	(9.1)	(29)	(0.9)	(17.1)

1 Den Boer et al., 2012.

2 Same as ruminant slurry.

3 Same as slurry from fattening pigs.

4 Same as solid manure from broilers.

5 Average of biodegradable waste and green compost.

6 www.handboekbemesting.nl.

7 Same as solid manure.

8 Velthof, 2011.

9 Average of cattle and fattening pigs and degradation of N-org of 25-50%.

10 Because the table contains limited plausible values for solid and liquid fractions, which may be due to the use of a limited number of analyses of different types of manure, the additional figures (between brackets) for solid and liquid fractions may be used in future versions of the ANCA. Indicated fractions of 'ruminants' concerns separated cattle manure and indicated fractions of 'non-ruminants' concerns separate fattening pig manure. The mass balance method is followed as shown in www.bemestingsadvies.nl (accessed on 13 February 2019).

1.3 Sources of N loss

Nitrogen in particular can be lost at many points in the cycle and in many ways. 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) which is stored in the soil. The farm surplus is equated to the total of the losses in one of the aforementioned forms (the terms J, K and L in Figures 1.2 and 1.3). Table 1.3 shows the sources from which these N connections are mainly lost and the ANCA module in which the loss is numerically calculated. In the context of the ANCA, the total calculated N loss (the farm surplus according to Figure 1.2) is categorised into the items:

- NH_3-N loss from (synthetic) fertiliser and dying crop,
- N_2O-N loss from (synthetic) fertiliser, clover, 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, as follows:

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 here that, for the sake of convenience, it is assumed that no leaching losses occur from silage and manure storage, but only gaseous losses. This may not be entirely realistic.

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 fertiliser	Clover	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]	X[4]		
NO_3-N							X[5]		
N_2, NO_x	X[3]								X[3]
Norg							X[6]		

[1] BEA base.

[2] BEA plus.

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

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

[5] BEN: nitrate leaching.

[6] BEC: N accumulation as derived from BEC.

1.4 Nutrient use efficiency

1.4.1 General

Nutrient losses are often not only expressed as an absolute amount (kg) per unit area (hectare) or per unit 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 of grain-equivalent for specialised arable farms), but also as the complement of the fraction of an incoming nutrient flow that is not used, i.e. 1 minus the nutrient use efficiency. The nutrient use efficiency can be defined at the level of the farm as a whole and at the level of the underlying internal (sub)flows. It should be noted that any definition is somewhat arbitrary. The value of the ratio of input and output is dependent on whether 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 efficiency percentages are calculated in the ANCA.

1.4.2 Efficiency at farm level

Farm efficiency is defined as:

Produced 'useful' products (milk, meat, arable crops sold, goose-grazed crop) as a fraction of used concentrates, roughage, by-products, legume fixation, deposition, synthetic fertiliser, organic 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 stock of concentrate feed) + (C - adjusted for changes in stock of roughage) + D + E + (F - adjusted for changes in the stock of synthetic fertiliser) + (-I - adjusted for changes in the stock of manure) G), with a positive number for the corrections if the stock has increased.

1.4.3 Efficiency at animal level

Animal-level efficiency is defined as:

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

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

1.4.4 Efficiency at fertiliser level

The efficiency at fertiliser level is defined as:

Manure and feed residues that end up 'in' the soil, as a fraction of the excretion plus feed residue (= offered feed - milk and meat corrected for changes in herd size) minus changes in the stock of manure (when stock increases), plus manure produced by non-ruminants (based on net excretion of N and P) and reduced by exported/increased with imported manure, or (see Figure 1.3):

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

1.4.5 Efficiency at soil level

Soil level efficiency is defined as:

Nutrients produced in homegrown crops, including pasture, mowing and harvesting losses and including sold non-roughage arable crops and goose-grazed crops, as a fraction of legume fixation, deposition, artificial fertiliser (after adjusting for stock changes), (peat) mineralisation and available 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 in the stock of synthetic fertiliser) + G)

1.4.6 Efficiency at (roughage) crop level

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

Ingested feed from home grown (unsold) and purchased roughage (hence, intake corrected for intake from 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 the stock of concentrates) - O_concentrates)) / ((C - adjusted for changes in the stock of roughage) + (R + T) + (L + S))

1.5 Limitations and improvements to the ANCA

The present version of the ANCA has several limitations. These are described in more detail in the discussion of the various components (also see the Reading Guide later in this chapter). In addition, during the regular validation of the ANCA, the calculation results are compared with measurement data from practical farms participating in the *Koeien & Kansen* project, which sheds light on the limits of the ANCA's scope of application.

Some of the limitations/points of concern in the use of the ANCA are as follows:

- The ANCA provides less reliable results for dairy farms with low milk production, large numbers of other ruminants and low numbers of dairy cows in relation to young stock. For this reason, the guide gives farm-specific excretion data that farms with these characteristics cannot use to determine fertiliser sales (RVO, 2020).
- For farms with non-ruminants (such as pigs, chickens, white veal calves), the manure N and P production in this category is not calculated by the ANCA, but is estimated externally on a farm-specific basis via the stock balance, which is subsequently entered in the ANCA. The stock balance

does not provide information on the distribution of N and P production per animal group. This is done in the ANCA, based on the average number of animals in each animal group and the standard N and P production of each animal group. In addition, because of the absence of information on imports and exports in the non-ruminant category (feed and animals), the N and P utilisation in the non-ruminant category and that of the total farm are not calculated.

- In the calculation of ammonia emissions per ton of produced milk, any emissions caused by non-ruminant and arable production are also included. Ammonia emissions from barns and the storage of non-ruminants are given separately in the ANCA export. With regard to ammonia emissions from manure application on arable land, no distinction is drawn between arable and dairy farm arable land crops.
- This version of the ANCA does not accurately calculate conservation losses for silage mixed with roughage and dry by-products.

In the 2020 version of the ANCA, various adjustments have been made compared to 2019, including:

- Milk not delivered
  In 2020 an input field was introduced in the ANCA in which farmers can enter how much milk was produced but not delivered to the milk processor. The number cannot be ‘0’, because every farm, some milk is produced that does not go into the tank. This might be milk from sick cows, milk fed to calves (e.g. colostrum) or milk used in the farmer’s own household. This quantity of milk clearly forms part of the farmer’s overall milk production, which in turn impacts feed intake and therefore excretions of nitrogen and phosphate. This is comparable to the standard excretion tables of the RVO (Netherlands Enterprise Agency).
- Calculation of methane emissions from rumen fermentation
  The ANCA calculates methane emissions from rumen fermentation based on the characteristics of the various feed ingredients. From 2020 onwards, the methane emissions from grass silage are calculated with the NDF content and the methane emissions from maize silage with the NDF and starch content. This makes the calculation more accurate than before, when it was based on energy (using the Dutch energy unit for lactation, ‘VEM’), crude protein (CP) and crude ash (CA) content (grass silage) and the VEM content (maize silage). In addition, all compound feed suppliers specifically determine the emission factors for methane for every compound feed. This depends on the raw materials in the compound feed.
- Type-specific compound feed footprint
  In 2019, a single, fixed value was used for the footprint of compound feed. From 2020 onwards, all compound feed suppliers supply a specific footprint (CO_2 emissions) for every type of compound feed. This varies depending on the origin, the processing and the cultivation of the raw materials of the compound feed, which enables dairy farmers to manage the footprint of their milk production more accurately.
- Reference values based on results of all dairy farms
  The ANCA has reference values for a large number of relevant indicators. These values can be compared with the results of the ANCA, such as crop yield per ha, nitrogen surplus in soil, ammonia emissions and greenhouse gas emissions. The indicators from a specific farm can then be compared with the averages for the group of farms matches it in terms of soil type and intensity. Until 2019, results from the *Bedrijveninformatienet* (BIN) were used for this purpose. The BIN is a group of around 300 dairy farms WUR keeps records for. As of 2020, the central ANCA database contains so much good quality data that information on comparison groups is derived from it.
- A new soil phosphate class (‘more than adequate’) has been added (manure policy component).
- The standard excretion values of other ruminants have been updated.
- Some RAV (Ammonia and Animal Husbandry Regulation) barns have been added, and the existing ones have been updated. These can now also be selected in the ANCA.
- For barns that have an air scrubber, blowdown lye is automatically created and included in the calculation.
- The digestion coefficients of crude protein (DCCP) in feed ingredients (including the method of calculating DCCP in compound feed) have been updated.
- The list of feed ingredients has been aligned with the NEVEDI list which gives the carbon footprint of raw materials.

- Energy consumption is obtained in a different way. The total amount supplied plus energy supplied for other categories (not ruminants and arable) are asked for. The ANCA assigns this to dairy cattle on the one hand and other ruminants/arable on the other.
- The net import and export of animals is no longer included in the CO_2 calculation. All imported animals are shown as an input item, and all live animals exported are included in the item 'meat export' for the purposes of the allocation.
- The coefficients for calculating the carbon footprint have been updated.
- The LU (livestock unit) calculation for the herd is now aligned with the LEI system and is based on RVO phosphate excretions.
- The ANCA reporting has been extended with some additional indicators. These include the proportions of nitrogen in the ration and TAN (urine N) in slurry, in the barn and just before application. The new report also provides a complete mineral balance.

1.6 Reading guide

The following types of excretion and emissions are explained in this report: farm-specific excretion ('BEX'), Chapter 2; farm-specific emissions of ammonia ('BEA'), Chapter 3; farm-specific emissions of nitrate and nitrous oxide ('BEN'), Chapter 4; farm-specific phosphate streams ('BEP'), Chapter 5; and farm-specific carbon currents and emissions of CO_2 equivalents ('BEC'), Chapter 6. Each chapter starts with an introduction, after which the calculation method for the indicators is explained. Comments are made at the end of each chapter, These discuss preconditions, limitations and elements that require further refinement or investigation. Since the flows of N, P and C are related, cross-referencing between chapters is unavoidable. In order not to confuse matters, Appendix 3 contains a thematic and an alphabetical list of abbreviations.

The words 'barn manure' and 'non-ruminants' appear several repeatedly in the report. 'Barn manure' refers to all manure excreted (collected, stored) indoors, as opposed to manure excreted on pasture. This does not necessarily mean barn manure is solid manure: 'barn manure' can be both slurry and solid manure. Simultaneously, it is untrue that the term 'non-ruminants' only concerns animals that are kept (partly) indoors. The term 'non-ruminants' does not refer to animals kept (partly) indoors, but to animals that are part of intensive livestock raising (pigs, chickens, veal calves). In this sense, a dairy herd with no access to pasture is not classified as 'non-ruminants', but as 'ruminants'.

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

2.1 Introduction

BEX, as most recently defined in the National Guidance for Farm-Specific Excretion of Dairy Cattle (2020), calculates the amount of nitrogen (N) and phosphorus (P) in the manure produced on an individual dairy farm. The calculation has been 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 and young cattle), the excretion of any other category of ruminants (breeding bulls, suckler cows, red meat bulls, rosé calves, sheep, goats, horses, ponies) is also calculated. However, the excretion of the dairy herd is calculated on a farm-specific basis, whereas the excretion of 'other ruminants' is calculated using standard excretion values (Anonymous, 2015a). BEX does not calculate N and P excretions in manure from non-ruminants, such as chickens 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 feed ingredients fed to the dairy herd. The net energy (VEM) requirement of the present animals, corrected for an assumed exceeding of the requirement by 2%, is the starting point for the assumed intake. This is why BEX requires participating farms to record the quantity of all feed ingredients, to analyse the VEM, N and P content and to analyse the total crude ash content for grassland maize silage products. For purchased feed ingredients, quantities are shown on the supplier's 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, has shown that this 'best practice' for estimating the amount of silage has large variation in results. The estimated amount of silage is therefore insufficiently accurate for determining feed intake from silage. In BEX, therefore, it has been decided to calculate the feed intake of fresh grass, grass silage and silage maize on the basis of the VEM requirement (see section 2.1.2.12). In this calculation, the required net energy is allocated to the various feed ingredients based on the ratio of the calculated fresh grass intake and the stocks of grassland products and maize silage products (as determined by an accredited laboratory). This calculation is explained in more detail in Oenema et al*.* (2017).

2.2 Excretion calculation method

2.2.1 General

BEX calculates the amounts of N and P in manure. 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 concerns excretions 'under the tail' and the net excretion is 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

Where:

> VEM intake = VEM requirement x 102%. This concerns the total VEM requirement of the dairy herd, based on the composition of the dairy herd and milk production.
>
> N (or P)/VEM: VEM, N and P are the weighted average of the analysed average VEM, N and P levels in each feed 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 mix of farm-specific information and standard values:

Farm-specific information is available for:
Amount of milk produced, N content in milk, P content in milk (if not available a standard value is used), numbers of animals in the categories of young stock younger than one year (calf), young stock older than one year (heifer), animals that have calved (dairy cows) and breed of dairy cattle.

Standard values are used for:
P content in milk (if not measured by an accredited institute), N and P retained in the foetus and adnexa, calf, heifer, first-lactation cow and second-lactation cow. In addition to this, constants are used for the percentage of pregnant animals (on an annual basis) in the herd in order to calculate N and P retained 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 BEA (see section 2.2).

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

The required information consists of a mix of farm-specific information and standard values:

Farm-specific information is available for:
Gross N excretion of the dairy herd and per animal category: young stock younger than one year, young stock older than one year, number of dairy cows including dry cows, share the slurry and housing type of the dairy cattle.

Standard values are used for the emission percentage for N from manure.
The emission percentage for N from manure is calculated using BEA. (see standard values in the description of BEA in section 2.2).

2.2.6 Age structure dairy herd

The dairy herd consists of several animal categories. Animal numbers are determined per category: dairy cows, dry cows, heads of young stock older than 1 year (heifer), heads of young stock younger than 1 year (calves). Animal categories and counting are laid down in Dutch law (*Uitvoeringsbesluit en Uitvoeringsregeling Meststoffenwet*). For all animal categories, the number is calculated by dividing the total number 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.

2.2.7 Milk production and milk composition

The milk production is equal to the total milk produced in kilograms per year as laid down in Dutch law (*Uitvoeringsbesluit Meststoffenwet*, Article 33; *Uitvoeringsregeling Meststoffenwet*, Article 42 (3) and Chapter 9 (Articles 73-75e); and *Regeling dierlijke producten*, clause 2 (Articles 2.10-2.59). This includes the totals of:

- the milk supplied to the processor,
- the milk used for processing on the farm,
- other milk production, such as colostrum, mastitis milk, milk fed to calves or milk for consumption on the farm.

The percentage of fat, protein and phosphorus in the milk is 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 net energy required for maintenance, including those of different weights and of the associated young stock. A so-called 'breed factor' is included for this in Table 2.1. This is based on the VEM maintenance requirement at adult weight.

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

	Dairy cow weight (kg)	Breed factor[1] VEM requirement	Young stock weights (kg)[2]			Breed WT factor[3]
Breed	Average		Birth	1 year	At calving	
Jersey	400	0.695	27	197	332	400/650
Cross: Jersey x other breed [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); 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 'Cross' can be calculated using the WT factor, based on the average weights of 'Other breeds' and are rounded.

[4] The 'Cross' is a cross of 'Jersey' x 'Other breed' or 'Other breed' x 'Jersey'.

2.2.9 Grazing

Unrestricted grazing refers to cows being grazed day and night (10-20 hours). Restricted grazing refers to dairy cows being grazed only during the daytime or only at night (2-10 hours). For dairy cows, the number of grazing days per year must be reported for these two systems and (if applicable) the average grazing hours per day for the relevant system.

When dairy cows receive fresh pasture grass in the barn, this is called 'summer stall feeding'. In this case too, the number of days of summer stall feeding and the number of times freshly cut grass is offered to the cows, day and night ('unrestricted') or only in the daytime or only at night ('restricted'), needs to be determined.

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 hours of grazing per day must be specified and it should be indicated whether only fresh grass is fed in the barn ('unrestricted') or, in addition to the fresh grass, roughage is also fed ('restricted').

For young stock, unrestricted grazing is assumed, with the number of grazing days being registered.

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

For grass intake, one should indicate what proportion comes from natural grassland. For cows, this should not exceed the share of natural grassland in the total area of grassland. 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 because it is assumed that the NEL use is 102%. This assumption is consistent with the calculation of standard values for excretion of dairy cattle (Tamminga et al., 2004).

The VEM requirement of cattle is calculated using calculation rules provided by the Dutch institute CVB. These calculation rules are also used to substantiate standard values for excretion in Dutch law (*Uitvoeringsregeling Meststoffenwet*). The calculation of the VEM requirement takes into account the age structure of the herd, the production level of the cows, the adult weight of the dairy cows and grazing activity of the dairy cows. The VEM requirement calculation for dairy cattle is based on cattle in tie-stalls. Cattle in freestall barns or grazing have higher VEM requirements due to the movement activity. In addition, extra energy is required for growth (young animals), pregnancy and compensation for the Negative Energy Balance (NEB) at the start of lactation. These additional energy needs are included in the total VEM requirement in the form of surplus 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. For maintenance, a distinction is made between lactating cows and dry cows. The calculation is based on an average of 315 lactation days per calendar year and a dry period of 50 days per calendar year per cow. In addition to energy requirements for maintenance and milk production, a cow also uses energy for movement, growth, gestation and mobilisation of body reserves (see Table 2.2). The VEM requirement of the total dairy herd (in kVEM/year) is the sum of the VEM requirement of dairy cows, heifers and calves.

Table 2.2 *Energy requirement and surpluses in kVEM per cow with an average weight of 650 kg* and per head of young stock (>/< 1 year) present on average.*

		Dairy cows and calves		Young stock	
				≥ 1 year	≤ 1 year
		kVEM/year	kVEM/day	kVEM/day	kVEM/day
Maintenance and milk		See page 18	See page 18	-	-
Maintenance and growth **		-		2259/365	1323/365
Surplus requirements					
Movement ***	No grazing	201			
	extra with Restricted grazing		0.419		
	extra with Combined grazing		0.419		
	extra with Unrestricted grazing		0.560	0.784	0.346
Youth ****		101			
Gestation and NEB *****		194	0.5315	0.2819	

* For a breed with a different adult weight, the surplus requirement in this table must be multiplied by the breed factor VEM requirement belonging to the relevant weight in Table 2.1.1.

** Only some of the calves stay on the farm all year (after birth). It is necessary to correct for this. The kVEM requirement is therefore not 1,380 but 1,324 kVEM per year. It is assumed that the replacement percentage is 28%, with 0.376 calves per average dairy cow present, according to the Dutch Dairy Farm Handbook (*Handboek Melkveehouderij*). Per average dairy cow present, the number of calves born alive is 1.14 and the number of calves to be sold at the age of half a month (i.e. 15.2 days) is 0.7653. Converted to the number of calves per year, this means 0.7653 x 15.2 / 365 = 0.0319 calf per average dairy cow present, i.e. 0.3760 + 0.0319 = 0.4079 calves younger than 1 year (category 101) are present per average dairy cow. The requirement in the first month is 54.4 kVEM. Calculated 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 times half a month). The adjusted requirement is 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 head of young stock younger than 1 year old.

*** The movement allowance for ‘No grazing’ applies to non-tethered animals (10% of maintenance requirement, set at 2010 kVEM/year (Tamminga et al., 2004)). The surplus requirement for extra movement in this table for dairy cows is 7.5% for ‘restricted grazing’ and 10% for ‘unrestricted grazing’ and for young stock, these are based on the principles in BEX young stock, which are shown in kVEM per animal per day of grazing. For calves the kVEM surplus is specified per average calf present: 0.375 kVEM per day per calf and 0.3760 / 0.4079 = 0.9218 calf of this animal category present all year round, the grazing surplus is 0.375 x 0.3760 / 0.4079 = 0.346 kVEM per day.

**** The youth supplement per cow is calculated for first and second lactation cows and is based on 660 VEM per day in the first lactation and 330 EN in the second lactation. Assuming a replacement percentage of 28%, the total surplus amounts to: (660 + 330) x 365 x 0.28 = 101. For the calculation of the youth surplus for dairy cows, ‘other breeds’ are based on 540 kg at two years of age, 595 kg at the age of three and 650 kg at the age of four.

***** The gestation surplus for a dairy cow amounts to (rounded) 144.7 kVEM per year; the surplus for a heifer (1st lactation 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 6 on page 24), the gestation surplus is 144.7 x 0.70 = 101.3 kVEM per year. The VEM requirement for the Negative Energy Balance (NEB) is the energy required on average to rebuild body reserves mobilised during the first months of lactation; this amounts to 93 kVEM. The total pregnancy and NEB is therefore 194.3: rounded 194. For a heifer, the gestation surplus is an average of 0.79 calf per heifer (see Table 6 on page 24), so 144.7 x 0.9 x 0.79 = 102.9 kVEM per year (that is 0.2819 kVEM per day).

Overview of calculation rules for VEM requirement

kVEM requirement for young stock 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).

In the VEM requirement, it has been taken into account that not all calves stay on the farm in the year after birth. Many calves leave the farm at an age of (on average) 15 days and therefore contribute with a much lower VEM than the calves that stay on the farm all 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 0.79 + 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%)) / 315 (days).
VEM milk production = (442 x FPCM / day x (1 + (FPCM / day -15) x 0.00165)) x 315 (days).
kVEM milk production = VEM milk production / 1,000
.

kVEM requirement for dairy cows per year: maintenance
WT (kg) = live weight depending on the type of cow (see table 2.1.1).
VEM maint during lactation = (42.4 x $WT^{0.75}$ x (1 + (FPCM / day - 15) x 0.00165)) x 315 (days).
VEM maint during dry period = 42.4 x $WT^{0.75}$ x (1 + (-15 x 0.00165)) x 50 (days).
VEM maintenance dairy cattle = VEM maint during lactation + VEM maint during dry period.
kVEM maintenance = VEM maintenance dairy cattle / 1,000.

Surplus VEM requirement for dairy cows per year
kVEM surplus per cow = (surplus energy required for movement 'No grazing' from Table 2.1.2 + (number of months of grazing x surplus for extra exercise for 'restricted grazing' or 'unrestricted grazing' from Table 2.1.2) * 315/365) + surplus for 'youth' from Table 2.1.2 + surplus for pregnancy and NEB from Table 2.1.2.

kVEM requirement of the dairy herd per year
kVEM requirement of dairy herd = ((kVEM milk production + kVEM maintenance + kVEM surplus) x number of dairy cows) + (kVEM young stock <1 year x number of young stock < 1 year) + (kVEM young stock > 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 per feed ingredient by the analysed N/VEM and P/VEM respectively (see section 2.2.3). The total VEM intake is then calculated by adding up results of all feed ingredients. However, on practical farms the VEM intake is often not known for all feed ingredients. For purchased feed ingredients, intake is calculated as the amount purchased minus a change in stock, but homegrown roughage in particular lacks reliable data on the share of pasture grass in the roughage supply. The total energy from homegrown roughage - maize silage, grass silage and fresh (pasture) grass - is estimated as follows:

VEM intake from maize 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 maize silage, grass silage and fresh grass

Dividing the total calculated VEM intake from maize silage, grass silage and fresh (pasture) grass over these three individual products is done by calculating a ratio between a calculated VEM intake from fresh grass, a measured amount of grass silage fed and a measured amount of maize silage fed.
I. For fresh (pasture) grass, neither intake nor feeding values are available. 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 unrestricted grazing is 10 to 20 hours per day. This variation is limited to 2 to 10 hours per day for restricted grazing.
- In practice, grazing dairy cows are grazed at least 2 hours. During 2 hours of grazing, a dairy cow absorbs 2 kg of dry matter grass (type 'Other breeds' - see Tables 2.1 and 2.2 - and with a milk production of 9,500 kg FPCM/year). Additional grazing per hour adds 0.75 kg of dry matter, with a

maximum of 18 additional 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%.
- In summer stall feeding, it is assumed that the dry matter intake of a dairy cow with 'unrestricted' access amounts to 87% of the intake in unrestricted grazing for 20 hours per day. For a dairy cow with 'restricted' access to fresh grass in summer stall feeding, 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 is 70% and 85% of that of cows of 'other breeds', respectively. The same percentages apply to the reference level of the milk production to calculate dry matter intake (6650 and 8075 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) in pastures and in summer stall feeding is unknown. In BEX, a distinction is made between fresh grass from production grassland (production grass) and fresh grass from natural grassland (natural grass). The ratio of VEM, N and P in fresh 'production grass' is derived from the N/VEM and P/VEM in grass silage (based on research in practical farms; *Koeien & Kansen* project). In this case, the quality of the grass silage(s) should be representative of the quality of the fresh grass fed to dairy cows via grazing or summer stall feeding. Therefore, the ratio between VEM, N and P in grassland products (only grass silage, excl. purchased grass and not from natural pastures) is the starting point for the estimated composition of the fresh 'production grass'. If grass silage is not available on the farm, standard values are used (based on data from the *Koeien & Kansen* project). For fresh natural grass, standard values are derived from other research (Vellinga, 1994; Korevaar et al., 2006).

2.2.14 Correction for feed intake by other ruminants

If, in addition to dairy cows and associated young stock ('dairy cattle'), other ruminants are present on the farm and the feed for these ruminants is not clearly separated from the feed for dairy cattle, this amount will be deducted from the total intake, using standard values for feed intake by other ruminants (Table 2.3). This includes feed intake and feeding losses.

Furthermore, attention should be paid to the distribution of feed over animal categories in Table 6.3. In principle, the total kVEM intake per animal category is used. However, if one or more feed categories are not fed on a farm, the kVEM intake per animal category should be based on other feed categories, which are listed per animal category. This is done as follows, always in a specific order, as stated below:
- In case of no fresh (pasture) grass: grass products, maize silage, other products, concentrates, milk powder. This applies, for example, if cows that are normally grazed are not grazed because of a lack of pasture grass. In this case, it is assumed that the kVEM requirement of 1,792 kVEM from pasture grass comes from grass products, hence the intake still amounts to 3,187 kVEM;
- In case of no or insufficient artificial milk powder: concentrates, other products, maize silage, grass products, fresh pasture grass;
- In case of no or insufficient concentrates: other products, maize silage, grass products, fresh pasture grass, artificial milk powder;
- In case of no or insufficient other products: maize silage, grass products, fresh pasture grass, concentrates, milk powder;
- In case of no or insufficient maize silage: other products, grass products, fresh pasture grass, concentrates, milk powder;
- In case of no or insufficient grass products: other products, maize silage, fresh pasture grass, concentrates, milk powder.

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

Feed category: / Feed losses (%): / Animal category[1]	Synthetic milk powder 2	Concentrates[2] 2	Pasture grass (grazing) n/a	Grass products[3] 5	Maize silage, ensiled 5	Other products[4] 3	Total kVEM uptake
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	140	497	734	0	47	1,418
943 Horses (standing ≥ 1.56 m at the withers and incl. foals < 6 months)	0	441	909	1,452	0	49	2,851

1 For an exact description, see Appendix D of the Implementation Regulation of the Dutch Fertilisers Act (*Uitvoeringsregeling Meststoffenwet*).
2 Dry concentrates: compound feeds plus single dry concentrate feeds.
3 Grass hay, grass silage and/or grass pellets. This category should actually be called 'other grass products'; it has already been made clear in the foregoing what this feed category entails.
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 if grass silage is not available:
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 natural grass = 189/6.25 g/kg DS
P content of fresh natural grass = 4.0 g/kg DS

Calculation of the amount of intake from pasture grass

milk factor = 1 + (milk production - 9,500 * breed factor) / 500 x 0.02

In grazed herds:
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
the following applies: number of grazing hours/day $\leq$ 20

For summer stall feeding:
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

The following applies to this:
- Number of grazing hours/day = 20 with ‘unrestricted’ access to fresh grass in the barn.
- Number of grazing hours/day = 9 with ‘restricted’ access to 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 young cattle. No additional data are required; almost all calculations are done with standard values, except for N and P retained in milk and the numbers 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 age 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
N and P retention in dairy cows			
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	
Gestation			
Number of calves born per cow per calendar year	=	0.7	Ncalf Ncontcalf
Nitrogen (N) calf content (g/kg)	=	29.4	Pcontcalf
Phosphorus (P) calf content (g/kg)	=	8.0	
N and P contents of calves concern the composition at birth			
Growth of (lactating) first-lactating cow (replacement)			
Share of replacement per dairy cow	=	0.28	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
N and P content of first-lactation cows concern composition at first calving			
N and P retention in young stock			
Young stock less than one year old			
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 Ncontcalf			
Young stock more than one year old			
Number of calves born from young stock per calendar year	=	0.79	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 2.1.1. For ‘other breeds’ this is 650 kg.

** For ‘other breeds’ (Table 2.1.1), the average weight of a calf (at birth) is 44 kg, a heifer 320 kg (at 1 year of age) and a first-lactation cow 540 kg (at the age of approximately 26 months).

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

N and P retention in dairy cows		
During milk production		
Nmilk	=	(total milk delivered x (protein percentage x 10 / 6.38)) / 1,000
Pmilk	=	(total milk delivered x 0.97) / 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 (lactating) 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
N and P retention in young stock		
Younger than 1 year old		
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 old		
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. heads of young stock > 1yr
Pys> 1	=	(PcalfO + (P1lact1 – Pheif) x 12/14) x avg. heads of young stock > 1yr

* The starting points for the formulas can be found in Table 2.1.4.

** For Ncalf and Ncalf1 see Table 2.1.4; Ncalf = average number of calves born per year in cows; Ncalf1 = average number of calves born per year from young cattle.

*** For N and P contents of cow, first lactation cow, heifer and calf, see Table 2.1.4.

**** These correction factors for N and P retention are used because not all calves stay on the farm in their first year after birth. Many are removed at an age of (on average) 15 days so considerably less N and P is retained than in animals that remain on the farm a whole year. Therefore, corrections are made analogously to the corrections for the net energy (VEM) requirement.

2.2.16 Gaseous N losses

Part of the nitrogen excretion of the dairy herd is lost from barns and manure storages through volatilisation. As manure-N application standards are based on the quantity after deduction of gaseous losses, these gaseous N losses must be taken into account. These gaseous N losses are calculated in the BEA module of the ANCA (Chapter 3).

2.2.17 Manure production by 'other ruminants'

The quantities of manure-N and manure-P_2O_5 excreted by other ruminants are based on standard values in the ANCA (Table 2.6), with a distinction for manure-N between conventional and organic dairy farming systems. These standard values are based on net excretions, hence gaseous N losses are already deducted. These excretions are also first converted into gross excretions in the ANCA tool to calculate the soil N surplus by accounting for the gaseous N-losses using the BEA module.

Table 2.6 *Net excretion in the form of manure-N and manure-P_2O_5 per average animal present for 'other ruminants' (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

2.2.18 Manure production by non ruminants

For the calculation of some indicators the ANCA takes into account the presence of 'non-ruminants'. For this reason data are needed on the contribution of these non-ruminants to the production, export and possible use of N and P in animal manure from non-ruminants. These are not calculated by querying the ANCA data on quantities and composition of purchased feed and other input materials and quantities and composition of exported animals or products, but by directly obtaining data about the net farm balance(s) available in other monitoring systems. This is based on net production of manure N, that is after deduction of gaseous N losses from the barn and storage. These excretions are also first converted into gross excretions in the ANCA tool to calculate the soil N surplus by accounting for the gaseous N-losses using the BEA module. The environmentally harmful part of the emissions (ammonia-N, nitrous oxide-N, methane) from non-ruminants is added to the emissions of the rest of the farm. With regard to methane emissions, this applies both to the methane emitted from manure in barns and manure storage facilities and to the enteric methane emitted during digestion. Emissions are estimated using emissions coefficients and numbers of animals present (Mosquera & Hol, 2012; Anonymus, 2015b).

The calculation of manure N and P excretion by non-ruminants requires the following information:
- Total net excretion nitrogen and phosphate (fertilisation plan)
- Average number of animals present (AN)
- Type of manure (slurry or solid manure)
- Type of manure (slurry or solid manure)

- The total amounts of nitrogen and phosphate from the net stock balance is divided over the different animal groups via a weighted average of normative nitrogen and phosphate production calculated using manure production and manure contents in Table 2.7:
  - Normative production of nitrogen = AN * manure production per AN * N content of manure
  - Normative production of phosphate = AN * manure production per AN * P_2O_5 content of manure
- The amount of manure in tons is calculated using Table 2.7:
  - Normative manure production = AN * manure production per AN
- Two types of 'barn manure' are distinguished in the ANCA: slurry and solid manure. It is therefore necessary to indicate whether the relevant animal category produces slurry or solid manure. The total nitrogen and phosphate production in slurry and solid manure can be determined by adding up the net excretion among the animals.
- Finally, the N and P content is determined by dividing the amounts of nitrogen and phosphate by the amount of manure.

Table 2.7 *Normative net manure production and manure contents for different types of non-ruminants and housing systems.*

Animal species	RAV code barn	Manure production, slurry (tons per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/ton)	Nitrogen content solid manure (kg N/ton)	Phosphate content slurry (P_2O_5/ton)	Phosphate content solid manure (kg P_2O_5 / ton)
Laying hens	E 2.5.6	43.7	14.56	16.6	50.1	6.0	18.8
	E 2.7	43.7	15.6	9.3	26.3	6.0	24.2
	E 2.8	43.7	15.6	15.0	42.3	6.0	24.2
	E 2.9.1	43.7	15.6	14.7	41.5	6.0	24.2
	E 2.9.2	43.7	15.6	14.2	40.1	6.0	24.2
	E 2.9.3	43.7	15.6	14.2	40.1	6.0	24.2
	E 2.10	43.7	15.6	16.6	46.6	6.0	24.2
	E 2.11.1	43.7	18.72	15.4	36.2	6.0	24.2
	E 2.11.2	43.7	18.72	16.1	37.8	6.0	24.2
	E 2.11.3	43.7	18.72	16.7	39.2	6.0	24.2
	E 2.11.4	43.7	18.72	16.5	38.6	6.0	24.2
	E 2.12.1	43.7	15.6	15.9	44.6	6.0	24.2
	E 2.12.2	43.7	15.6	15.1	42.6	6.0	24.2
	E 2.13	43.7	15.6	15.3	43.2	6.0	24.2
	E 2.14	43.7	15.6	15.3	43.2	6.0	24.2
	E 2.15	43.7	15.6	15.3	43.2	6.0	24.2
	E 2.100	43.7	15.6	11.0	31.1	6.0	24.2
Broilers	E 5.1	19.2	11.4	21.9	37.1	6.0	16.6
	E 5.2	19.2	11.4	21.5	36.4	6.0	16.6
	E 5.3	19.2	11.4	21.9	37.1	6.0	16.6
	E 5.4	19.2	11.4	21.8	36.8	6.0	16.6
	E 5.5	19.2	11.4	20.1	34.1	6.0	16.6
	E 5.6	19.2	11.4	20.5	34.7	6.0	16.6
	E 5.7	19.2	11.4	21.1	35.7	6.0	16.6
	E 5.8	19.2	11.4	21.2	36.0	6.0	16.6
	E 5.9.1.2.2	19.2	11.4	20.7	35.0	6.0	16.6
	E 5.9.1.2.4	19.2	11.4	20.6	34.8	6.0	16.6
	E 5.10	19.2	11.4	20.3	34.4	6.0	16.6
	E 5.11	19.2	11.4	21.0	35.6	6.0	16.6
	E 5.12	19.2	11.4	21.1	35.7	6.0	16.6
	E 5.13	19.2	11.4	21.1	35.7	6.0	16.6
	E 5.14	19.2	11.4	20.3	34.4	6.0	16.6
	E 5.15	19.2	11.4	21.5	36.4	6.0	16.6
	E 5.100	19.2	11.4	18.6	31.5	6.0	16.6

Animal species	RAV code barn	Manure production, slurry (tons per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/ton)	Nitrogen content solid manure (kg N/ton)	Phosphate content slurry (P_2O_5/ton)	Phosphate content solid manure (kg P_2O_5 / ton)
Farrowing sows	D 1.2.1	5000	3200	4.4	6.9	2.5	13.6
	D 1.2.2	5000	3200	4.4	6.7	2.5	13.6
	D 1.2.3	5000	3200	4.3	6.7	2.5	13.6
	D 1.2.4	5000	3200	4.5	6.9	2.5	13.6
	D 1.2.5	5000	3200	4.5	6.9	2.5	13.6
	D 1.2.6	5000	3200	4.3	6.7	2.5	13.6
	D 1.2.7	5000	3200	4.1	6.4	2.5	13.6
	D 1.2.8	5000	3200	4.5	6.9	2.5	13.6
	D 1.2.9	5000	3200	4.6	7.1	2.5	13.6
	D 1.2.10	5000	3200	4.6	7.1	2.5	13.6
	D 1.2.11	5000	3200	4.6	7.1	2.5	13.6
	D 1.2.12	5000	3200	4.6	7.1	2.5	13.6
	D 1.2.13	5000	3200	4.5	7.0	2.5	13.6
	D 1.2.14	5000	3200	4.5	7.0	2.5	13.6
	D 1.2.15	5000	3200	5.0	7.7	2.5	13.6
	D 1.2.16	5000	3200	4.5	7.0	2.5	13.6
	D 1.2.17.1	5000	3200	4.8	7.4	2.5	13.6
	D 1.2.17.2	5000	3200	4.6	7.1	2.5	13.6
	D 1.2.17.3	5000	3200	4.8	7.4	2.5	13.6
	D 1.2.17.4	5000	3200	4.8	7.4	2.5	13.6
	D 1.2.17.5	5000	3200	4.8	7.4	2.5	13.6
	D 1.2.17.6	5000	3200	4.9	7.6	2.5	13.6
	D 1.2.18	5000	3200	4.8	7.4	2.5	13.6
	D 1.2.19	5000	3200	4.9	7.6	2.5	13.6
	D 1.2.20	5000	3200	4.8	7.4	2.5	13.6
	D 4.1	5000	3200	4.0	6.1	2.5	13.6
	D 1.2.100	5000	3200	3.5	5.4	2.5	13.6
Other sows	D 1.3.1	2800	1792	5.8	8.9	2.5	13.6
	D 1.3.2	2800	1792	6.0	9.2	2.5	13.6
	D 1.3.3	2800	1792	5.8	8.9	2.5	13.6
	D 1.3.4	2800	1792	6.0	9.2	2.5	13.6
	D 1.3.5	2800	1792	5.9	9.0	2.5	13.6
	D 1.3.6	2800	1792	6.1	9.5	2.5	13.6
	D 1.3.7	2800	1792	6.1	9.5	2.5	13.6
	D 1.3.8	2800	1792	5.9	9.0	2.5	13.6
	D 1.3.9.1	2800	1792	5.8	9.0	2.5	13.6
	D 1.3.9.2	2800	1792	5.8	8.9	2.5	13.6
	D 1.3.10	2800	1792	5.7	8.8	2.5	13.6
	D 1.3.11	2800	1792	6.5	10.0	2.5	13.6
	D 1.3.12.1	2800	1792	6.3	9.8	2.5	13.6
	D 1.3.12.2	2800	1792	6.1	9.5	2.5	13.6
	D 1.3.12.3	2800	1792	6.3	9.8	2.5	13.6
	D 1.3.12.4	2800	1792	6.3	9.8	2.5	13.6
	D 1.3.12.5	2800	1792	6.3	9.8	2.5	13.6
	D 1.3.12.6	2800	1792	6.4	9.9	2.5	13.6
	D 1.3.13	2800	1792	6.3	9.8	2.5	13.6
	D 1.3.14	2800	1792	6.4	9.9	2.5	13.6
	D 1.3.15	2800	1792	5.9	9.0	2.5	13.6
	D 1.3.16	2800	1792	6.1	9.4	2.5	13.6
	D 4.1	2800	1792	5.6	8.7	2.5	13.6
	D 1.3.100	2800	1792	5.2	8.1	2.5	13.6
Weaned piglets	D 1.1.1	535	343	3.7	5.7	3.9	13.6

Animal species	RAV code barn	Manure production, slurry (tons per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/ton)	Nitrogen content solid manure (kg N/ton)	Phosphate content slurry (P_2O_5/ton)	Phosphate content solid manure (kg P_2O_5 / ton)
	D 1.1.2	535	343	3.6	5.6	3.9	13.6
	D 1.1.3	535	343	3.8	5.8	3.9	13.6
	D 1.1.4.1	535	343	3.6	5.5	3.9	13.6
	D 1.1.4.2	535	343	3.5	5.3	3.9	13.6
	D 1.1.5	535	343	3.4	5.2	3.9	13.6
	D 1.1.6	535	343	3.7	5.7	3.9	13.6
	D 1.1.7	535	343	3.6	5.5	3.9	13.6
	D 1.1.8	535	343	3.6	5.6	3.9	13.6
	D 1.1.9	535	343	3.7	5.6	3.9	13.6
	D 1.1.10	535	343	3.7	5.6	3.9	13.6
	D 1.1.11	535	343	3.7	5.7	3.9	13.6
	D 1.1.12.1	535	343	3.7	5.7	3.9	13.6
	D 1.1.12.2	535	343	3.7	5.7	3.9	13.6
	D 1.1.12.3	535	343	3.7	5.6	3.9	13.6
	D 1.1.13	535	343	3.7	5.7	3.9	13.6
	D 1.1.14	535	343	3.7	5.7	3.9	13.6
	D 1.1.15.1	535	343	4.0	6.1	3.9	13.6
	D 1.1.15.2	535	343	3.8	5.9	3.9	13.6
	D 1.1.15.3	535	343	3.7	5.6	3.9	13.6
	D 1.1.15.4	535	343	3.8	5.9	3.9	13.6
	D 1.1.15.5	535	343	3.8	5.9	3.9	13.6
	D 1.1.15.6	535	343	3.8	5.9	3.9	13.6
	D 1.1.16	535	343	3.9	6.0	3.9	13.6
	D 1.1.17	535	343	3.8	5.9	3.9	13.6
	D 1.1.18	535	343	3.9	6.0	3.9	13.6
	D 4.1	535	343	3.7	5.6	3.9	13.6
	D 1.1.100	535	343	3.2	4.9	3.9	13.6
Fattening pigs	D 3.1	1337	974	5.6	7.6	3.9	13.6
	D 3.2.1	1337	974	5.6	7.6	3.9	13.6
	D 3.2.2	1337	974	7.5	10.1	3.9	13.6
	D 3.2.3	1337	974	7.4	10.0	3.9	13.6
	D 3.2.4	1337	974	7.8	10.6	3.9	13.6
	D 3.2.5	1337	974	7.6	10.4	3.9	13.6
	D 3.2.6	1337	974	7.5	10.2	3.9	13.6
	D 3.2.7.1	1337	974	7.8	10.6	3.9	13.6
	D 3.2.7.2	1337	974	7.6	10.3	3.9	13.6
	D 3.2.8	1337	974	7.9	10.7	3.9	13.6
	D 3.2.9	1337	974	7.9	10.7	3.9	13.6
	D 3.2.10	1337	974	7.6	10.3	3.9	13.6
	D 3.2.11	1337	974	7.4	10.0	3.9	13.6
	D 3.2.12	1337	974	7.7	10.5	3.9	13.6
	D 3.2.13	1337	974	7.4	10.0	3.9	13.6
	D 3.2.14	1337	974	8.4	11.4	3.9	13.6
	D 3.2.15.1	1337	974	8.2	11.1	3.9	13.6
	D 3.2.15.2	1337	974	7.9	10.7	3.9	13.6
	D 3.2.15.3	1337	974	8.2	11.1	3.9	13.6
	D 3.2.15.4	1337	974	8.2	11.1	3.9	13.6
	D 3.2.15.5	1337	974	8.2	11.1	3.9	13.6
	D 3.2.15.6	1337	974	8.3	11.2	3.9	13.6
	D 3.2.16	1337	974	7.8	10.5	3.9	13.6
	D 3.2.17	1337	974	8.2	11.1	3.9	13.6
	D 3.2.18	1337	974	8.3	11.2	3.9	13.6
	D 3.2.19	1337	974	8.0	10.8	3.9	13.6
	D 4.1	1337	974	7.1	9.6	3.9	13.6

Animal species	RAV code barn	Manure production, slurry (tons per AN) (kg/AN)	Manure production, solid manure (kg/AN)	Nitrogen content slurry (kg N/ton)	Nitrogen content solid manure (kg N/ton)	Phosphate content slurry (P_2O_5/ton)	Phosphat e content solid manure (kg P_2O_5 / ton)
	D 3.100	1337	974	6.6	8.9	3.9	13.6
White meat calves	A 4.1	2743	2469	5.0	5.5	1.4	4.3
	A 4.2	2743	2469	4.7	5.2	1.4	4.3
	A 4.3	2743	2469	4.7	5.2	1.4	4.3
	A 4.4	2743	2469	5.0	5.5	1.4	4.3
	A 4.5.1	2743	2469	4.9	5.4	1.4	4.3
	A 4.5.2	2743	2469	4.7	5.2	1.4	4.3
	A 4.5.3	2743	2469	4.9	5.4	1.4	4.3
	A 4.5.4	2743	2469	4.9	5.4	1.4	4.3
	A 4.5.5	2743	2469	4.9	5.4	1.4	4.3
	A 4.5.6	2743	2469	5.0	5.5	1.4	4.3
	A 4.6	2743	2469	4.9	5.4	1.4	4.3
	A 4.7	2743	2469	4.3	4.7	1.4	4.3
	A 4.8	2743	2469	4.5	4.9	1.4	4.3
	A 4.100	2743	2469	4.0	4.3	1.4	4.3

2.3 Manure separation

To calculate the composition of animal manure separated into a liquid and solid fraction, the principles and assumptions 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 and ammonium N (NH_4-N, Nmin) with water. The ‘separation efficiency’ determines the extent to which an element in the incoming manure eventually ends up in the solid fraction. Based on this principle, the separation efficiency consists of indicators:

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 in simple methods from 30 to 60% (Schröder et al., 2009). A separation efficiency of P of 60% means that 60% of the P (as assumed part of the DM) goes to the solid fraction and that 40% remains in the liquid fraction (indicator 1). The solid fraction usually contains no more than 200-350 kg DS/ton (indicator 2).

The N/P ratio in the farm’s own manure is determined on the basis of the N/P ratio in the net excretion according to BEX, that is after deduction of the gaseous losses. The amount and composition of the (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 exported removed in terms of N and P, 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 forms the basis for the incoming manure for manure separation, based on the two indicators, and an estimate can then be made of the contents of TAN, organic N (N-total – TAN) and P in the liquid and solid fractions. The N/P ratio in livestock manure is based on the net excretion (see section 2.1.4).

In practice, it appears to be difficult to properly enter the separation efficiency (indicator 1) based on available information. In manure separation, often only results of analysis of the solid fraction (delivery notes) is available. Therefore, an alternative method can be used to determine separation efficiency, based on the following data about the solid fraction:

1. Amount of solid fraction removed (tons)
2. N content solid fraction (kg/ton)
3. P_2O_5 content solid fraction (kg/ton)

The above data can be used to determine what the separation efficiency has been, but only if the quantities of N and P produced in 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, but sometimes just manure from a certain manure pit or animal group. In some cases, the incoming manure is also measured. That is why there is an option in ANCA to specify the composition of the incoming slurry. This alters the composition of the residual (not separated) slurry.

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

2.4 Manure digestion

During manure digestion, part of the organic matter is converted into energy (methane and carbon dioxide). The fermented 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. Amount of manure entering the digester (tons)
2. Supply of co-substrates (quantity in tons, kg N and kg P_2O_5)

2.5 Air scrubbers

Some RAV housing types use air scrubbers (chemical/biological/combinations) and capture a large proportion of the nitrogen from the NH_3 emissions in the scrubbing water. In the ANCA, this scrubbing water is treated as blowdown lye on application.

2.6 Critical notes on BEX and manure production of other ruminants and non-ruminants

Use of constants as input for BEX
Input parameters for BEX that can hardly be determined in practice are entered as a constant in the BEX calculation method (an average value for the Netherlands). The combined effect of all constants used as input for BEX influences the accuracy of BEX results. In a scientific evaluation by the Dutch Committee of Experts on the Fertilizers Act (CDM), it was concluded that BEX is sufficiently accurate to be used for legal purposes (Šebek, 2008). This means that the currently used constants jointly result in a good estimate of the N and P excretion. Adjustment of individual constant parameters without taking into account interrelations will affect BEX accuracy.

For example, there is discussion about the constant used for VEM coverage in BEX (102% of the requirement). The ANCA uses an VEM coverage percentage of 102%, which guarantees uniformity with other laws and regulations (‘Handreiking’). However, in trials, a wide range of VEM coverage percentages can be observed (roughly between 98% and 108%; and even above 110% in case of much illness (e.g. much mastitis) or poorly digestible rations). In practice, it is assumed that a VEM coverage of 105% better matches reality (especially with maize rations), but in practice it is seldom possible to determine VEM coverage. Due to cross-connections 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 these kinds of 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 315 days of lactation and 50 days of dry period (CRV, 2015; -, 2016; -, 2017)).
3. Live weight adult cow (Jersey, Jersey cross and Other; 400, 525 and 650 kg respectively).
4. VEM requirement for young stock younger and older than 1 year (see section 2.1.2.10).
5. Extra energy requirement (VEM) for movement and growth (see Table 2.1.2).
6. Weight, N and P content in animals (foetus + adnexa, calf, heifer, first lactation heifer, cow; see Table 2.1.4). With these assumed weights and contents, N and P retention in the herd is calculated.
7. Dairy herd replacement percentage (28%), to determine 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 heifer per calendar year (= 0.79), to calculate the retention in foetus + adnexa in young stock.
10. P content in milk = 0.97 g/kg of milk. In Dutch monitoring project (Koeien & Kansen) P content varied from approximately 0.86 to 1.12 g P/kg milk. This standard value is used only if the farm-specific 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

- It is not possible to determine the average composition (VEM, N and P content) of silages consisting of different feeds (mixed silage). Farms with mixed silages cannot participate in BEX. Three exceptions are made. These apply when:
  - The mixed silage is homegrown, or if one of the products is purchased maize silage, provided that the feeding value and quantity have been determined for the individual silages and the purchased maize silage. Silage losses due to adding a second-cut silage in the same pit must also be accounted for.
  - 90% of the DM in the silage consists of the same roughage and the rest consists of an *unknown* purchased (moist) roughage.
  - 80% of the DM in the silage consists of the same roughage and the rest consists of a *known* purchased (moist) roughage.
- At farms that apply manure separation to a high degree, it is possible that the volume of manure specified in the ANCA 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. Additives in the form of rinse water and rainwater play a role in this. Making different fertiliser flows and types more specific makes it more difficult to achieve a balanced fertiliser balance (in volume and contents), without revealing any implausible results. For this reason, it is preferable to specify the amount of manure separation on the farm as a percentage of the total manure production.
- Problems may arise not only in the separation of manure, but also in the ‘destination’ of the various types of manure (import and export, stocks, application). Accurate input data/administration is required. However, despite accurate input, it can still lead to situations in which the outcome of the calculation model deviates too much from reality. For example, the actual export of manure may deviate from the outcome of the calculation model. Particularly in the case of farmer-farmer export, which mainly uses standard values, in reality less manure is sometimes exported than calculated in the ANCA. Conversely, if the actual contents are larger than the standard values, less manure remains on the farm than calculated. Imports of manure stocks are also often a ‘weak link’. This can lead to unexpected results from the calculation model.

With regard to manure production by non-ruminants, the following should be noted. Since the most common non-ruminant livestock species kept on dairy farms are fattening pigs, sows, laying hens, broilers and white meat calves, only these ‘non-ruminant animal’ categories are included in the ANCA. This means not all types of non-ruminants are included in the ANCA. For a more complete ANCA, more species of non-ruminants should be included. This applies, for example, to pigs other than fattening pigs and breeding sows.

In order to limit the amount of data entry in the ANCA, the (net) manure production of non-ruminants (in N and P_2O_5) can be obtained from the stock balance and the (legal) Fertilisation Plan, together with the export and stock balance of manure of non-ruminants. In this way, the correct amounts of nitrogen and phosphate are used, with a limited number of input parameters. In this way, imports of nitrogen and phosphate with feed and animals and exports of nitrogen and phosphate with animals are not required. However, this does mean that the utilisation of nitrogen and phosphate by non-ruminants, and of these types of farms as a whole, cannot be calculated by the ANCA.

3 BEA

3.1 Introduction

BEA is a calculation tool for calculating 'Farm-specific Ammonia Emissions'. The calculated losses relate to the ammonia-N (NH_3-N) that is released from barns, from manure storages, from faeces and urine that are excreted during grazing, from machine-spread animal manure on grassland and arable land (arable roughage crops such as silage maize and exported arable crops) and from some types of synthetic fertilisers. In addition, there are a number of other NH_3 emission sources (standing, grazed and harvested crops) that are also discussed in this part of the ANCA calculation rules.
Besides the NH_3 losses, BEA also calculates the other gaseous N losses (N_2, N_2O and NO_x). The calculation rules it uses for this are discussed in the section on BEN (Chapter 4). The calculation of the TAN content in the manure takes these losses into account.

BEA uses the National Emission Model for Ammonia to calculate NH_3 emissions (NEMA, Van Bruggen et al., 2017; -, 2018). This method 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. The share of ammonia nitrogen in the total amount of nitrogen (% TAN) plays an important role in this.

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 legislation. For example, the EFs for the barn (floor and storage) are based on the NH_3 emissions measurements that are the basis of the Ammonia and Animal Husbandry Regulation (RAV, http://wetten.overheid.nl/BWBR0013629/geldigheidsdatum_09-12-2013). In principle, BEA therefore also corresponds with the RAV. The way in which the losses are calculated and expressed do differ. The RAV is based on the relationship between the emission of ammonia and the concentration of ammonium in manure and urine. NEMA and BEA, however, are based on the relationship between ammonia emissions and the amount of TAN excreted. The RAV expresses the emission in kg of ammonia per animal place per year, while BEA expresses the emission in kg of ammonia per farm.

BEA uses BEX to calculate the amount of N and TAN excreted by the dairy cattle (the source of ammonia emissions). However, there are additional calculation rules in BEA and these relate to the conversion from N excretion (= output BEX) to TAN excretion. This is a relatively minor addition to 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 livestock 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. With regard to the dairy herd, these factors are taken into account in the ANCA. With regard to the emissions from the housing of 'other ruminants' and 'non-ruminants', however, the ANCA 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 land. This part of the emission depends on the land use and how animal manure is spread. In addition, the type of synthetic fertiliser also plays a role. The calculation procedure for BEA for specialised dairy farms is shown schematically in Figure 3.1.

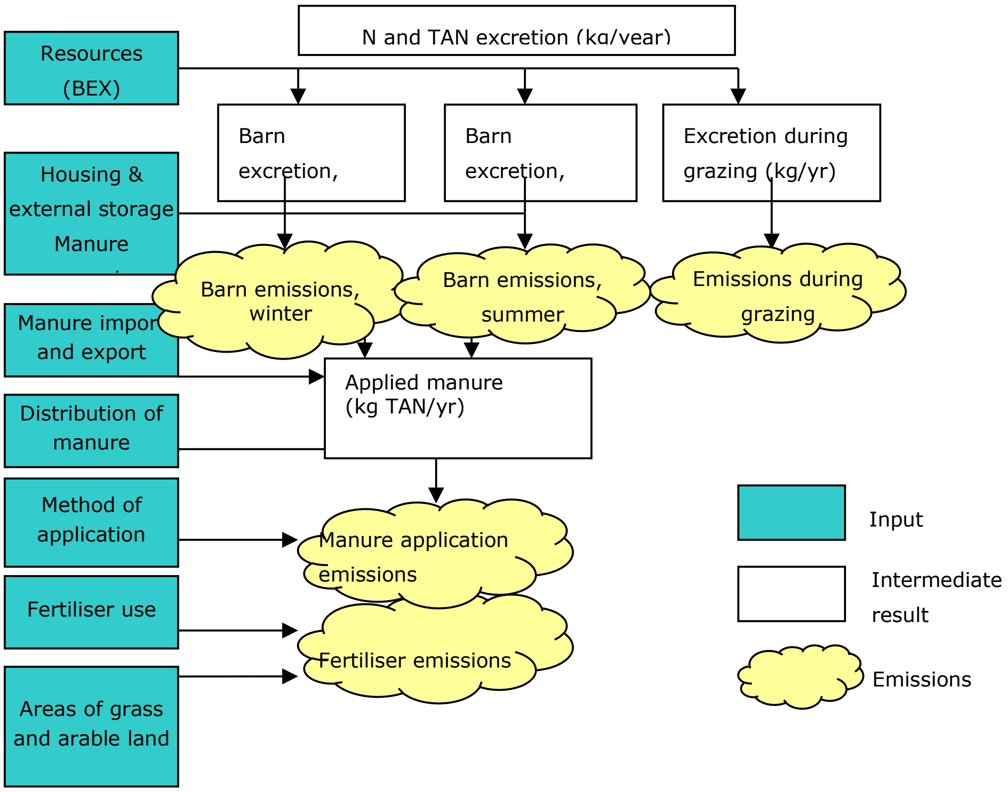

Figure 3.1 *Schematic representation of the calculation of the ammonia emissions (kg NH_3 per year) of a dairy farm.*

BEA requires information on:

With regard to 'dairy cattle' (dairy cows and associated young stock)

- Proportion of slurry in cows, heifers and calves.
- The amount of N and TAN produced by the livestock (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 ruminants'

- The numbers of animals present on average per animal category.
- The nature of the animal manure (proportion of slurry).

As for 'non-ruminants'

- The average number of animals present per animal category.
- The nature of the animal manure (proportion of slurry).
- House type (predefined types based on Dutch housing system categories and ammonia emission factors; RAV)
- Data that can be directly derived from the (legal) fertilisation plan with the net excretion of non ruminants.

With regard to 'dairy cattle', 'other ruminants' and 'non-ruminants' together
- The distribution of TAN for application on grass or arable land, including the application method.
- The amount of synthetic fertiliser applied on grass or arable land.

Emission factors (EF and mineralisation coefficient, 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 for application of manure for grass and arable land and for manure application method.
- EF for application of synthetic fertiliser, per type of fertiliser.

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 young stock

BEA is based on the gross N excretion from BEX, so 'under the tail' N excretion (for conversion to the final net BEX excretion). However, BEA calculates the ammonia emissions in the barn based on the amount of TAN (mineral N) in the manure, per animal group. Therefore, a correct estimate of the TAN excretion is necessary. This requires information about the feed ingredients used and the digestion coefficient of the crude protein (DCCP) in those feed ingredients per animal group. The DCCP is used to calculate which part of the N excretion is excreted in the urine. The urinary part of the N-excretion is in principle volatile (TAN). The other N is excreted in faeces and only becomes TAN when there is mineralisation (in the manure storage).

In order to determine the gaseous nitrogen losses from the manure (faeces and urine) of the dairy cattle, the different feed categories that have been fed to the dairy cattle (being dairy cows and associated young stock) must first be allocated to the different categories of young stock 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 of all, a certain allocation of feed categories applies for young stock. This allocation always concerns the amount of feed (in kVEM) intended for the dairy herd, if there are also other ruminants 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:
- Synthetic milk powder: all imported milk 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 silage maize silage fed (see section 2.1.2.12);
- Concentrate feed: the share of the VEM requirement from concentrates is 25% for the calves in the barn and 10% in the pasture, and for heifers, 5% in the barn and 0% in the pasture.
- Roughage: calves in the barn get 75% of their VEM requirement from grass silage and 25% from maize silage, while heifers get 90% from grass silage and 10% from maize 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.

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[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 above principle applies for allocation of feed categories to young stock. If a certain feed category appears to be missing or there is too little of it, the following is applied:

- Allocated first to calves and then to heifers;
- The amounts of milk powder and fresh grass are fixed; these are listed in the administration and have been calculated, respectively. However, the latter may increase as shown in the following: 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 from (in this order): other products, maize silage, grass products, fresh grass;
- Maize silage: with no or insufficient maize silage, the VEM requirement from maize silage is supplemented from (in this order): grass products, other products, concentrates, fresh grass;
- Grass products (grass silage): with no or insufficient grass products, the VEM requirement from grass products is supplemented from (in this order): silage maize 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

When feed categories (with various feed types) are allocated to young stock and dairy cattle, these quantities represent the feed intake of these animal categories in 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 in the year. Although this may not be entirely correct, it is expected to be a fairly accurate approach to 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 BEX, information about the DCCP of the feed ingredients used is required to calculate the distribution of the N-excretion between the faeces and the urine.

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

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

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

The calculated N-excretion_urine is equated with 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) in the barn and the manure storage in that barn is converted into TAN.

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 for solid manure, 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 digestibility of crude protein

The DCCP (digestibility coefficient of crude protein) of feed ingredients is not known to the dairy farmer, but is calculated using regression formulae from the Centraal Veevoederbureau (CVB, 2006, 2018). These formulae estimate the digestible protein based on its chemical composition (total crude protein (CP), crude ash (CA) and, in the case of whole-ear maize silage (WECS), crude fibre too). An average DCCP from the Animal Feed Table is used for products with little variation (CVB, 2011, 2019). The following categories of feed ingredients are distinguished in BEA:

1. Category ‘grass silage’ (contents per kg DM)

   DCCP grass silage = (0.931 x CP – 43.2) / CP

2. Category ‘grass hay’ (contents per kg ds)

   DCCP grass hay = (0.931 x CP – 43.2) / CP

3. Category ‘grass meal/grass pellets/grass bales’ (artificially dried) (contents per kg ds)

   DCCP grass pellets = (0.878 x CP – 38.4) / CP

4. Category ‘maize silage’ (contents per kg DM)

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

5. Category ‘grazed grass’ (contents per kg ds)
   The composition of fresh grass is not known for practical farms. In BEX, the N/VEM ratio in fresh grass is calculated based on existing grass silage (see section 2.1.2.15). CP fresh grass = N/VEM fresh grass * 960 * 6.25.

   DCCP meadow grass = (0.963 x CP -38.3) / CP

6. Category ‘compound feeds’
   For compound feeds, insufficient information is available on practical 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 = 63.26 + 0.0854 x CPcompound feed

7. Category ‘other feed’
   Formulas are not available for all products. When a formula is missing, a fixed DCCP is used (Appendix 4).

3.2.2.2 Other ruminants

TAN production for 'other ruminants' 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 * % TAN/100

Table 3.1 *Gross N excretion by 'other ruminants' and % TAN to convert these quantities into the amount of ammoniacal N (TAN).*

Category	Gross N excretion with manure[1] (kg N per animal)	% TAN in manure N-excretion[2]
Breeding bulls > 1 year (cat. 104)	82.6	63
Pasture and suckler cows (cat. 120)	79.4	63
Calves for rosé or red meat (cat. 115)	12.3	60
Rosé calves, 3 months – slaughter (cat. 116)	30.9	52
Rosé calves, 2 weeks – slaughter (cat. 117)	25.2	52
Red meat bulls, 3 months – slaughter (cat. 122)	31.97	52
Breeding sheep (cat. 550)	13.4	73
Meat sheep, < 4 months (cat. 551)	1.2	73
Other sheep, > 4 months (cat. 552)	9.8	73
Milk goats (cat. 600)	16	62
Rearing and meat goats, < 4 months (cat. 601)	1	62
Rearing and meat goats, > 4 months (cat. 602)	7.9	62
Ponies (cat. 941)	35.5	76
Horses (cat. 943)	76.4	74

1 Source: www.rvo.nl.

2 Van Bruggen et al. (2017), Appendix 1 (2017).

3.2.2.3 Non-ruminants

The ammonia emission of non-ruminants from housing and storage is not calculated as the product of the gross N excretion, TAN percentage and the emission factor, but as ammonia loss per animal place (Table 3.8).

3.2.3 TAN excretion in barn and pasture from livestock

3.2.3.1 Dairy herd

For the TAN excretion calculation, a distinction is made between the 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 hours animals spend on pasture. 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 is pastured 10 hours per day, 10/24 of the TAN is excreted on pasture and 14/24 in the barn. This approach differs from NEMA and RAV, in which only a distinction is made between zero-grazing, limited grazing and unlimited grazing.

3.2.3.2 Other ruminants

The distribution of the manure N and associated TAN excretion (Table 3.1) over the barn and pasture is based on the days the animals spend on pasture. The days on pasture are estimated based on the VEM intake from fresh grass in 'other ruminants', assuming animals graze all day.

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

3.2.4 Ammonia loss and other gaseous N losses from housing

3.2.4.1 Dairy herd

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

- TAN excretion of dairy herd in the barn in the winter period (= 100% of the TAN excretion in that period).
- TAN excretion of dairy herd in the barn in the summer period (% of the TAN excretion in that period depends on grazing time).
- Mineralisation of the organically bound slurry-N in the storage (= 10% of the N-excretion of the dairy herd in the barn during the housing period + the period on pasture).
- Immobilisation of mineral N in solid manure in storage of 25%.

Part of the TAN is lost through volatilisation as ammonia and part through volatilisation in other gaseous N losses. The latter concerns nitrogen oxides (N_2O and NO) or elemental nitrogen (N_2). The EF indicates which part of the TAN is lost, which depends on the barn or pasture period, the type of manure (solid manure or slurry) and the type of barn. NEMA (Van Bruggen et al., 2017) makes a distinction between housing with slatted floors and low-emission barns. The ANCA calculates the emissions for a standard barn (Tables 3.2 and 3.3) and any emission reduction is calculated via the selected RAV housing (see below in this section).

Table 3.2 *The gaseous emissions of NH_3-N and other N in a standard dairy cowshed according to NEMA (Van Bruggen et al., 2017).*

Season	Fertiliser type	EF NH_3-N (as % of TAN)		EF other N (as % of N total)	
		Dairy cow	Young stock	Dairy cow	Young stock
Barn period	Slurry	14.3	14.3	2.4	2.4
	Solid manure	14.3	14.3	3.5	3.5
Grazing period	Slurry	14.3-40.9 (see Table 2.2.3)		2.4	2.4
	Solid manure	14.3-40.9 (see Table 2.2.3)		3.5	3.5

Table 3.3 *Dairy cattle NH_3-N emissions from the barn during the summer period, depending on the number of hours of outdoor grazing.*

Hours of outdoor grazing per day	Emission factor (% NH_3-N per kg produced TAN)
0	14.3
1	14.5
2	14.8
3	15
4	15.3
5	15.7
6	16
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 in Tables 3.2 and 3.3 can be used for practical farms, but these housing types only apply in some cases in practice. In the Ammonia and Animal Husbandry Regulation (RAV), 30 housing types are distinguished for the dairy cattle category (Table 3.5), each with their own specific emission factors. RAV emissions are expressed as kg NH_3 per animal place per year and are therefore not readily applicable in BEA (see section 3.1), in which emission factors are expressed as a fraction of the ammoniacal N produced. This means that an emission factor per RAV house type is needed for the BEA calculations of barn emissions. These emission factors are not available and are therefore generated in BEA by relating the emission of each RAV housing type to the emission of the standard RAV housing type 'A 1.100 - other housing systems'. It is assumed that the emission according to RAV barn A 1.100 corresponds to the emission as calculated according to the NEMA method of the 'low-emission barn'. For the other RAV housing types, the calculated housing emissions are then multiplied by a housing type correction factor (see Table 3.5), which corresponds to the ratio between the RAV emissions per animal place in the housing type concerned and the RAV emissions per animal place in housing type 'A 1.100 - other housing systems'. Table 3.4 shows an example of this.

Table 3.4 *Example of comparison of RAV housing type A 1.5 with reference RAV housing type A 1.100.*

RAV-Barn	Emission factor (kg NH_3 per animal place per year)	Correction relative to A 1.100
A 1.100 (standard)	13	
A 1.5	11.8	11.8 / 13 = 0.91

BEA first calculates the NH_3 emissions from the barn and storage based on the standard RAV housing type A 1.100. If another housing type is chosen (e.g. A 1.5), the standard calculated NH_3 emission from the barn and storage is multiplied by the correction factor for the housing type (so for housing type A 1.5 by 0.91).

Table 3.5 *Correction factors for the calculated emissions of NH_3-N depending on the type of dairy barn (source of housing types: Kenniscentrum Infomil).*

Code	Category	NH_3[1)]	Factor[2)]
A 1	Animal category of cows older than 2 years		
A 1.100	Standard barn	13	1
A 1.1	Tiestall with slurry	5.7	0.44
A 1.2	Loose housing - slatted floor, flushing system or sloping floor, slurry gutter, flushing system	10.2	0.78
A 1.3	Loose housing - sloping floor, slurry gutter	10.2	0.78
A 1.4	Loose housing - sloping floor, flushing system	9.2	0.71
A 1.5	Loose housing - grooved floor, manure scraper	11.8	0.91
A 1.6	Free stall barn - solid sloping floor, profile, manure scraper	11	0.85
A 1.7	Free stall barn - solid sloping floor, rubber top layer, manure scraper	11	0.85
A 1.8	Free stall barn – grooved floor, studs, manure scraper	11.8	0.91
A 1.9	Free stall barn - slatted floor, convex rubber top layer, sealing flaps in slots	6	0.46
A 1.10	Free stall barn - slatted floor, convex rubber top layer	7	0.54
A 1.11	Free stall barn - flat floor, profile, sloping slots, finger scraper	11.8	0.91
A 1.12	Free stall barn - flat floor, profile, sloping slots, manure scraper	12.2	0.94
A 1.13	Free stall barn - slatted floor, cassettes in slots	6	0.46
A 1.14	Free stall barn - flat floor, profile, sloping slots, manure scraper, roof insulation	7	0.54
A 1.15	Free stall barn - flat floor, profile, sloping slots, finger scraper	10.3	0.79
A 1.16	Free stall barn - V-floor of mastic asphalt, slurry discharge pipe	11.7	0.9
A 1.17	Mechanically ventilated barn, chemical air scrubber	5.1	1[3)]
A 1.18	Free stall barn - V-floor, profile, slurry discharge pipe	8	0.62
A 1.19	Free stall barn - slatted floor, sloping slots, sealing flaps in slots	11	0.85
A 1.20	Free stall barn - floor, perforations and sloping profiling, manure scraper	10.1	0.78
A 1.21	Free stall barn - floor, sloping longitudinal grooves, V-shaped transverse grooves, manure scraper	7	0.54
A 1.22	Free stall barn - grooved floor, slatted floor, rubber top layer and sealing flaps in waiting area and passages	11	0.85
A 1.23	Free stall barn - floor slabs, profile, sloping longitudinal slots, transverse grooves, manure scraper	6	0.46
A 1.24	Free stall barn - floor, sloping longitudinal slots, perforations, manure scraper	9.1	0.7
A 1.25	Free stall barn - flat floor, rubber mats, sloping profile	10.3	0.79
A 1.26	Free stall barn - V-floor, rubber mats, profile, slurry gutter, manure scraper	8	0.62
A 1.27	Free stall barn - slatted floor, sealing flaps, sloping grooves, manure scraper, misting system	8	0.62
A 1.28	Free stall barn - slatted floor, rubber mats, composite lugs, sealing flaps in slots, manure scraper	6	0.46
A 1.29	Free stall barn - profiled sloping floor, cavities, manure scraper	9.9	0.76
A 1.30	Free stall barn - convex rubber mats, about 7% slope, concrete grids	8.0	0.62
A 1.31	Free stall barn - grooved floor, closed sloping floor with profiled rubber tiles, manure scraper	8.1	0.62
A 1.32	Free stall barn - flat concrete floor slabs, slots, profile, sloping grooves, slurry gutter with slurry holes, manure removal	9.1	0.7
A 1.33	Free stall barn - flat floor, rubber slots, sloping longitudinal slots, profiled rubber with grooves and studs, manure scraper	7.1	0.55
A 1.34	Free stall barn - solid grooved floor, rubber mats, sloping profile, composite cams, finger scraper	9	0.69
A 1.35	Free stall barn - flat floor, rubber slots, sloping longitudinal slots, profiled rubber with grooves and studs, finger scraper	8.3	0.64
A 1.100	Other housing systems	13	1
A 1.100 organic deep litter	Organic - deep litter system with solid manure	13	1

Code	Category	NH_3[1)]	Factor[2)]
A 1.100 organic tiestall	Organic - tiestall with solid manure	13	1
A 1.100 other organic	Organic - other housing systems for dairy cows	13	1

1) Emissions in kg NH_3 per animal place per year according to the RAV (Ammonia and Animal Husbandry Regulation).

2) Housing type correction factor for calculated emissions of NH_3-N compared to housing type A 1.100.

3) RAV housing type A 1.17 is a barn with an air scrubber. NH3 emission is reduced, but the reduced gaseous N-loss is no longer present in the animal manure, but is contained in the waste water of the air scrubber. The correction factor for this house is therefore 1.

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

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

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

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

If the young stock are housed in the same barn as the dairy cattle, the ammonia emissions from young cattle are reduced by the same factor as the dairy cattle.

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

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

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

3.2.4.2 Other ruminants

By combining the calculated TAN produced by ‘other ruminants’ (section 3.2.2.2) during the housing period and the emission factors for ammonia-N during the housing period (Table 3.6), 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-$other_{barn}$). Both types of losses are needed to calculate how much N on balance goes to an external manure storage or directly to the field. Calculation rules are:

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

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

Table 3.6 *Emission factors (EF) for ammonia-N and other gaseous losses per 'other ruminants' category per individual fertiliser (SL = slurry, SM = solid manure). Source: Van Bruggen et al. (2017).*

category	Fertiliser 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
Calves for rosé or 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
Milk goats (cat. 600)	SL	16.9	7
	SM	16.9	7
Rearing and meat goats, < 4 months (cat. 601)	SL	16.9	7
	SM	16.9	7
Rearing and meat goats, > 4 months (cat. 602)	SL	16.9	7
	SM	16.9	7
Ponies (cat. 941)	SL	29	3.5
	SM	29	3.5
Horses (cat. 943)	SL	19.5	3.5
	SM	19.5	3.5

3.2.4.3 Non-ruminants

Standard ammonia emissions are used for 'non-ruminants', 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:

GAD = average number of animals present (from the input data)
Stocking density = standard stock density (Table 3.7)
Ammonia = emission per animal place (Table 3.8)

Table 3.7 *Standard stocking densities for non-ruminants.*

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

Table 3.8 *Ammonia emissions per animal place for different types of non-ruminants and housing systems.*

Animal species	RAV code barn	Description barn	Ammonia (kg NH_3/place)
Laying hens	E 2.5.6	Colony housing - aeration via manure belt	0.030
	E 2.7	Floor system - approx. 1/3 litter floor + 2/3 slatted floor	0.402
	E 2.8	Floor system - aeration via Perfosystem	0.110
	E 2.9.1	Floor system - aeration under the slatted floor	0.125
	E 2.9.2	Floor system - aeration via tubes on both sides of nests	0.150
	E 2.9.3	Floor system - aeration via vertical ventilation shafts	0.150
	E 2.10	Housing – acid air scrubber, 90% NH_3 reduction	0.032
	E 2.11.1	Aviary housing - 50% slatted floor and manure removal by belt system once a week	0.090
	E 2.11.2	Aviary housing - 50% slatted floor and manure removal by belt system twice a week	0.055
	E 2.11.3	Aviary housing - 30-45% slatted floor and aeration via manure belt	0.025
	E 2.11.4	Aviary housing - 55-60% slatted floor and aeration via manure belt	0.037
	E 2.12.1	Free-range housing - 2 floors	0.068
	E 2.12.2	Free-range housing - frequent manure/litter removal	0.106
	E 2.13	Housing - organic air scrubber, 70% NH_3 reduction	0.095
	E 2.14	Housing - biofilter, 70% NH_3 reduction	0.095
	E 2.15	Housing – acid air scrubber, 70% NH_3 reduction	0.095
	E 2.100	Other housing systems	0.315
Broilers	E 5.1	Plenum floor	0.004
	E 5.2	Perforated floor	0.012
	E 5.3	Tiered system slatted floor	0.004
	E 5.4	Acid air scrubber - 90% NH_3 reduction	0.007
	E 5.5	Heated and cooled littered floor	0.038
	E 5.6	Mixed air ventilation	0.031
	E 5.7	Organic air scrubber - 70% NH_3 reduction	0.020
	E 5.8	Tiered system - manure belt	0.017
	E 5.9.1.2.2	Separate hatching and growing - mixed air ventilation	0.028
	E 5.9.1.2.4	Separate hatching and growing - hot water heaters and fans	0.030
	E 5.10	Heating based on heaters and fans	0.035
	E 5.11	Air mixing system in combination with heat exchanger	0.021
	E 5.12	Biofilter - 70% NH_3 reduction	0.020
	E 5.13	Acid air scrubber - 70% NH_3 reduction	0.020
	E 5.14	Heaters - air mixing system	0.035
	E 5.15	House with tube heating	0.012
	E 5.100	Other housing systems	0.068
Farrowing sows	D 1.2.1	Slurry flushing system in gutters	3.300
	D 1.2.2	Plastic collection floor on top of manure pit	3.700
	D 1.2.3	Coated underneath slats with manure scraper (e.g. rack and pinion)	4.000
	D 1.2.4	Manure scraper	3.100
	D 1.2.5	Manure gutter	3.200
	D 1.2.6	Manure channel and water channel	4.000
	D 1.2.7	Sloped floor underneath slats	5.000
	D 1.2.8	Manure collection in acidified liquid fraction	3.100
	D 1.2.9	Scraper in manure gutter	2.500
	D 1.2.10	Organic air scrubber - 70% NH_3 reduction	2.500
	D 1.2.11	Acid air scrubber - 70% NH_3 reduction	2.500
	D 1.2.12	Manure cooling system	2.400
	D 1.2.13	Manure tray	2.900
	D 1.2.14	Manure tray with water channel and manure channel	2.900
	D 1.2.15	Acid air scrubber - 95% NH_3 reduction	0.420
	D 1.2.16	Water channel	2.900
	D 1.2.17.1	Combi scrubber (acid) - 85% NH_3 reduction	1.300
	D 1.2.17.2	Combi scrubber (organic) - 70% NH_3 reduction	2.500
	D 1.2.17.3	Combi scrubber (acid) - 85% NH_3 reduction	1.300
	D 1.2.17.4	Combi scrubber (organic) - 85% NH_3 reduction	1.300

Animal species	RAV code barn	Description barn	Ammonia (kg NH_3/place)
	D 1.2.17.5	Combi scrubber (organic) - 85% NH_3 reduction	1.300
	D 1.2.17.6	Combi scrubber (organic) - 90% NH_3 reduction	0.830
	D 1.2.18	Organic air scrubber - 80% NH_3 reduction	1.300
	D 1.2.19	Acid air scrubber - 90% NH_3 reduction	0.830
	D 1.2.20	Manure tray with water channel and manure channel, cooling system	1.300
	D 4.1	Floating balls in the manure	5.893
	D 1.2.100	Other housing systems	8.300
Other sows	D 1.3.1	Triangular metal slats	2.400
	D 1.3.2	Manure gutter with combined slats	1.800
	D 1.3.3	Flushing gutters	2.500
	D 1.3.4	Manure collection in acidified liquid fraction	1.800
	D 1.3.5	Manure scraper	2.200
	D 1.3.6	Organic air scrubber - 70% NH_3 reduction	1.300
	D 1.3.7	Acid air scrubber - 70% NH_3 reduction	1.300
	D 1.3.8	Manure cooling system	2.200
	D 1.3.9.1	Feeding crates or automatic sow feeder with triangular metal slats	2.300
	D 1.3.9.2	Feeding crates or automatic sow feeder with slats other than metal triangular	2.500
	D 1.3.10	Walking house	2.600
	D 1.3.11	Acid air scrubber - 95% NH_3 reduction	0.210
	D 1.3.12.1	Combi scrubber (acid) - 85% NH_3 reduction	0.630
	D 1.3.12.2	Combi scrubber (organic) - 70% NH_3 reduction	1.300
	D 1.3.12.3	Combi scrubber (acid) - 85% NH_3 reduction	0.630
	D 1.3.12.4	Combi scrubber (organic) - 85% NH_3 reduction	0.630
	D 1.3.12.5	Combi scrubber (organic) - 85% NH_3 reduction	0.630
	D 1.3.12.6	Combi scrubber (organic) - 90% NH_3 reduction	0.420
	D 1.3.13	Organic air scrubber - 80% NH_3 reduction	0.630
	D 1.3.14	Acid air scrubber - 90% NH_3 reduction	0.420
	D 1.3.15	Separate discharge of manure and urine, V-shaped manure belt, metal triangular slats	2.200
	D 1.3.16	Water+manure channel, floor feeding, cooling system, water filling/flushing system in manure gutter	1.500
	D 4.1	Floating balls in the manure	2.982
	D 1.3.100	Other housing systems	4.200
Belt buckle. Piglets	D 1.1.1	Coated underneath slats with manure scraper (e.g. rack and pinion)	0.200
	D 1.1.2	Slurry flushing system in gutters	0.240
	D 1.1.3	Manure collection in water	0.150
	D 1.1.4.1	Water and manure channel 0.13 m^2 per piglet	0.260
	D 1.1.4.2	Water and manure channel 0.19 m^2 per piglet	0.330
	D 1.1.5	Partly slatted, max 60% slatted	0.390
	D 1.1.6	Manure collection in acidified liquid, fully slatted	0.180
	D 1.1.7	Manure collection in acidified liquid, partly slatted	0.250
	D 1.1.8	Sloping manure belt	0.230
	D 1.1.9	Organic air scrubber - 70% NH_3 reduction	0.210
	D 1.1.10	Acid air scrubber - 70% NH_3 reduction	0.210
	D 1.1.11	Manure cooling system, partly slatted	0.170
	D 1.1.11	Manure cooling system, fully slatted	0.170
	D 1.1.12.1	Sloping pit wall, regardless of group size	0.170
	D 1.1.12.2	Sloping pit wall, group size up to 30 piglets	0.210
	D 1.1.12.3	Sloping pit wall, group size> 30 piglets	0.180
	D 1.1.13	Fully slatted, water and manure channels	0.200
	D 1.1.14	Acid air scrubber - 95% NH_3 reduction	0.030
	D 1.1.15.1	Combi scrubber (acid) - 85% NH_3 reduction	0.100
	D 1.1.15.2	Combi scrubber (organic) - 70% NH_3 reduction	0.210
	D 1.1.15.3	Combi scrubber (acid) - 85% NH_3 reduction	0.100
	D 1.1.15.4	Combi scrubber (organic) - 85% NH_3 reduction	0.100
	D 1.1.15.5	Combi scrubber (organic) - 85% NH_3 reduction	0.100
	D 1.1.15.6	Combi scrubber (organic) - 90% NH_3 reduction	0.070

Animal species	RAV code barn	Description barn	Ammonia (kg NH_3/place)
	D 1.1.16	Organic air scrubber - 80% NH_3 reduction	0.100
	D 1.1.17	Acid air scrubber - 90% NH_3 reduction	0.070
	D 1.1.18	Temperature-controlled lying floor, daily manure export	0.210
	D 4.1	Floating balls in the manure	0.490
	D 1.1.100	Other housing systems	0.690
Fattening pigs	D 3.1	Fully slatted	4.500
	D 3.2.1	Partly slatted	4.500
	D 3.2.2	Manure collection and flushing	1.600
	D 3.2.3	Cooling system, 170%	1.700
	D 3.2.4	Manure collected in formaldehyde	1.000
	D 3.2.5	Manure collection in water	1.300
	D 3.2.6	Cooling system, 200%	1.500
	D 3.2.7.1	Manure pit, metal triangular slats	1.000
	D 3.2.7.2	Manure pit, other slats	1.400
	D 3.2.8	Organic air scrubber - 70% NH_3 reduction	0.900
	D 3.2.9	Acid air scrubber - 70% NH_3 reduction	0.900
	D 3.2.10	Convex floor	1.400
	D 3.2.11	Separated manure channels	1.700
	D 3.2.12	Flushing gutters, metal triangular slats	1.200
	D 3.2.13	Flushing gutters with slats	1.700
	D 3.2.14	Acid air scrubber - 95% NH_3 reduction	0.150
	D 3.2.15.1	Combi scrubber (acid) - 85% NH_3 reduction	0.450
	D 3.2.15.2	Combi scrubber (organic) - 70% NH_3 reduction	0.900
	D 3.2.15.3	Combi scrubber (acid) - 85% NH_3 reduction	0.450
	D 3.2.15.4	Combi scrubber (organic) - 85% NH_3 reduction	0.450
	D 3.2.15.5	Combi scrubber (organic) - 85% NH_3 reduction	0.450
	D 3.2.15.6	Combi scrubber (organic) - 90% NH_3 reduction	0.300
	D 3.2.16	V-shaped manure belt	1.100
	D 3.2.17	Organic air scrubber - 80% NH_3 reduction	0.450
	D 3.2.18	Acid air scrubber - 90% NH_3 reduction	0.300
	D 3.2.19	Feed and water provision above water channel, cooling system, water filling/flushing system	0.770
	D 4.1	Floating balls in the manure	2.130
	D 3.100	Other housing systems	3,000
White veal calves	A 4.1	Acid air scrubber - 90% NH_3 reduction	0.35
	A 4.2	Organic air scrubber - 70% NH_3 reduction	1.1
	A 4.3	Acid air scrubber - 70% NH_3 reduction	1.1
	A 4.4	Acid air scrubber - 95% NH_3 reduction	0.18
	A 4.5.1	Combi scrubber - 85% NH_3 reduction	0.53
	A 4.5.2	Combi scrubber - 70% NH_3 reduction	1.1
	A 4.5.3	Combi scrubber (water scrubber, acid) - 85% NH_3 reduction	0.53
	A 4.5.4	Combi scrubber (water curtain, organic) - 85% NH_3 reduction	0.53
	A 4.5.5	Combi scrubber (water curtain, organic) - 85% NH_3 reduction	0.53
	A 4.5.6	Combi scrubber (organic and acid) - 90% NH_3 reduction	0.35
	A 4.6	Organic air scrubber - 85% NH_3 reduction	0.53
	A 4.7	Sloping slatted floor in combination with sloping false floor under the slatted floor	2.5
	A 4.8	Slatted floor with convex rubber top layer, sealing flaps	1.9
	A 4.100	Other housing systems	3.5

Table 3.9 *Gross manure N excretion of non-ruminants and emission factor of other gaseous losses (other than NH_3 -N) in slurry or solid manure systems, where: Emission of N-other (kg N) = Gross N - excretion * EF N-other.*

Animal group	Gross N excretion (kg N per animal place)	EF N-other slurry (% of N)	EF N-other 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 meat calves	14.3	2.4	3.5

3.2.5 Ammonia loss from external storage

Part of the manure goes to the external manure storage. In the ANCA, it is assumed that 20% of the ruminant slurry produced in the barn, 19% of the non-ruminant slurry produced and 100% of the solid manure produced in the barn (values based on Van Bruggen et al. (2017) go to an external manure storage. Some NH_3 losses also occur in external manure storage, estimated at 1% of the stored manure for ruminant slurry, 2% for non-ruminant slurry and 2% for solid manure (percentages based on total N).

3.2.6 Gaseous N losses from slurry separation

When slurry is separated, gaseous N losses form. These losses occur both during the process and in storage of the liquid and solid fraction. For NH_3 losses, NEMA assumes 2.3% and 3.18% of the input N in manure for slurry from ruminants and non-ruminants respectively, and for the other N losses (N_2O, NO_x, N_2), 3.5% of the input N in manure for slurry from both ruminants and non-ruminants. The NEMA percentages for pig slurry are used as the basis for slurry from all non-ruminants.

Losses of ammonia, including losses during external storage of the slurry, take place before separation. The latter are calculated separately in the ANCA, namely at 1% and 2% of the externally stored N for slurry from ruminants and non-ruminants respectively (see section 3.2.5). To prevent duplicates, the NEMA percentages for manure separation need to be adjusted for this. For ruminant 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. This leaves 2.1% NH_3 loss for manure separation in the ANCA (Table 3.10). For non-ruminant 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. This leaves 2.8% for manure separation in the ANCA (Table 3.10).

For other gaseous N losses, the NEMA loss percentages for manure separation (3.5% of total N) include emissions in the barn. The ANCA already includes these separately. To prevent duplications in this case too, a correction has been made by deducting the barn losses (2.4%, see Table 3.2) from the NEMA percentage. This leaves a loss of 1.1% for manure separation in the ANCA (Table 3.10).

Table 3.10 *Additional gaseous N losses from the separation of slurry and storage of the liquid and solid fraction (derived from NEMA). Losses are given as % of input N slurry.*

Input slurry	NH_3-N (% of N)	N-other (% of N)
Ruminants	2.1	1.1
Non-ruminants	2.8	1.1

3.2.7 Gaseous N losses from slurry fermentation

Part of the slurry can be fermented. This can be specified in ANCA. Fermentation has consequences for gaseous N losses. The TAN content changes - which impacts NH_3 losses - and losses occur during storage of the digestate. Both are explained in the section below.

Changes in TAN content
When manure is fermented, part of the organic N is converted to TAN. This amounts to 25% of the organic N entering the digester. This percentage is based on fertilisation research in which the N effect of fermented manure was compared to unfermented 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 house, 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.

Then the amount of extra TAN from anaerobic digestion is calculated:

*TAN fermentation (kg) = Norg slurry (kg) x fraction of slurry fermented * 0.25*

From this point the fermented manure is considered as digestate in the ANCA.

Gaseous N losses during digestate storage
When slurry ferments, gaseous N losses form. These losses occur during storage of the output product digestate. NEMA only gives total losses, including losses during external storage of the slurry. NH_3 losses amount to 1.0% and 2.0% of the input N in manure for slurry from ruminants and non-ruminants 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 ruminant and non-ruminant slurry respectively. To prevent duplications, the NEMA percentages for manure fermentation need to be corrected for this. For ruminant slurry, it is assumed that 20% of the slurry is stored externally. This means that of the 1.0% NH_3 loss from fermentation (as per NEMA), 0.2% (= 1.0% * 0.2) is already included in the external manure storage in the ANCA. This leaves an NH_3 loss of 0.8% for manure fermentation (Table 3.11). For non-ruminant slurry, it is assumed that 19% of the slurry is stored externally. This means that of the 2.0% NH_3 loss from fermentation (as per NEMA), 0.38% (2% * 0.19) is already included in the external manure storage in the ANCA. This therefore leaves an NH_3 loss of 1.62% for manure fermentation (Table 3.11).

No additional other gaseous N losses occur during manure fermentation.

Table 3.11 *Additional gaseous N losses during digestate storage (NEMA). Losses are given as % of input N slurry.*

Input slurry	NH_3-N (% of N)	N-other (% of N)
Ruminants	0.80	0.0
Non-ruminants	1.62	0.0

3.2.8 Ammonia loss during grazing

During grazing, less N is lost through NH3 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%

3.2.9 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 export, if any. Manure import and export is expressed in kg N in BEA. The manure import and export is expressed in BEA in kg N. 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 as fertiliser is calculated as a percentage of the kg N applied:

TAN applied (kg) =% TAN manure x kg N 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) used in the form of manure from 'non-ruminants' ('intensive livestock') is calculated within BEA as:

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

Kg N applied = Total net excretion + N manure imported - N manure exported + N initial stock - N final stock, and

% TAN manure according to standard percentages as shown in Table 3.12

Table 3.12 *Standard TAN percentage (%) in manure of non-ruminants.*

Animal species	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

Next, the total TAN-applied from manure from dairy cattle (cattle with associated young stock), other ruminants and non-ruminants is divided over arable land and grassland. This is done according to the farm's indication of kg N applied on grassland and arable land in BEA. Finally, the method of application (see Table 3.13) is also specified and related to an EF for application. In the BEA module of the ANCA the percentage of manure per application method should be specified, with a distinction being drawn between three application methods for both grassland and arable land.

Table 3.13 *Average emission factors (kg NH_3-N per 100 kg TAN applied) per type of fertiliser and method of application for grassland and arable land (based on Velthof* et al.*, 2012; Van Bruggen et al., 2017).*

Land use	Method of administration	Fertiliser type				
		Solid manure & solid fraction	Slurry, liquid fraction, digestate	Slurry with half part of water[1]	Mineral concentrate and blowdown lye	Compost
Grassland	Surface application	71	71		71	69
	Trailing shoe	-	(31)	19 [3]	10	
	Slit coulter[2]	-	25		9	
	Shallow injection	-	19		8	
Arable land	Surface application	46	69		69	69
	Surface application with direct incorporation	-	22		22	
	Trailing shoe	-	36		12	
	Deep injection (> 10 cm)	-	2		3	
	Shallow injection (< 10 cm)		24		8	

1) Half part of water means: two parts manure with one part water (more water is allowed but does not lead to emissions lower than that of slurry injection).

2) For the emission factor of a slit coulter, the average of the emission factor of a trailing foot and slurry injection is used.

3) The emission factor for the application of diluted manure with a trailing foot on grassland is maintained at a similar level as for slurry injection. The minimum dilution is 2 parts manure and 1 part water.

The ammonia emissions are calculated from the combination of the kg TAN and EF used from Table 3.13:

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

Where 1 ... n = application methods from Table 3.13

3.2.10 Ammonia loss during synthetic fertiliser application

Ammonia can also volatilise from synthetic fertilisers. That is why BEA requires information about the amount of synthetic N fertiliser used. When estimating emissions, no distinction is made between soil types or land use. However, a differentiation is made according to the type of synthetic N fertiliser (Table 3.14).

Table 3.14 *Emission factors for synthetic fertiliser ($EF\_NH_3\text{-}N_{fertiliser}$, kg N per 100 kg N total applied (Van Bruggen et al., 2017; Vonk et al., 2018).*

Fertiliser type	Land use	Emission factor
N fertilisers, 100% ammonium	Grassland and arable land	11.3
N fertilisers, 100% nitrate	Grassland and arable land	0.0
N fertilisers, 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 by injection	Grassland and arable land	1.5

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

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

where 1 ... n = fertiliser type from Table 2.2.12

3.2.11 Ammonia loss from crops

In Figure 1.3, crops produced on own land are indicated as the 'harvestable and mowable amount of feed grown' (i.e. arable-managed roughages such as maize (whole plant maize silage 'WPCS', whole-ear maize silage 'WECS', or CCM), grass silage, fresh grass for indoor feeding; excluding roots, stubble and catch crops but including harvest losses), and the 'grown amount of pasture grass' (including the part that may be grazed by geese and grazing losses). On mixed crop-livestock farms with arable crop production, non-roughage crops are added to this. In the paragraph on BEN (section 2.3.2.1) these items are calculated with $Af1_{maize}$, $AF3_{maize}$, $Af1_{cut\ grass}$, $Af3_{cut\ grass}$, $Af1_{pasture\ grass}$, $AF3_{pasture\ grass}$, $Af1_{other\ roughage}$, $AF3_{other\ roughage}$, $Af1_{market\ arable}$ and $AF3_{market\ arable}$ (kg N per ha). Af1 items concern the net export (from field or mouth) in case of roughage (maize, 'cut grass', 'pasture grass', 'other roughage' and 'geese grazing'), and the export of primary products from marketable arable crops ('market arable'). Af3 items concern the harvesting, mowing and grazing losses of roughage (maize, cut grass, pasture grass and other roughage) and the (possibly exported) by-products of marketable arable crops ('market arable'), such as straw. Ammonia losses (kg N) from all these crops are estimated at 3% (Vertregt & Rutgers, 1987) of:

$(GO \times (Af1_{cut\ grass} + AF3_{cut\ grass} + Af1_{pasture\ grass} + AF3_{pasture\ grass} +$
$SO \times (Af1_{maize} + Af3_{maize}) +$
$ORO \times (Af1_{other\ roughage} + Af3_{other\ roughage}) +$
$AMO \times (Af1_{market\ arable} + Af3_{market\ arable}),$

with GO, SO, ORO and AMO being the areas (ha) of grassland, maize land, other roughage and marketable arable crops respectively.

The area-weighted average N exports are used for $Af1_{market\ arable}$ and $Af3_{market\ arable}$. In case the by-product of the latter crops ($Af3_{market\ arable}$) remains on the land, a default value is used for the N-yield of the by-product. Regardless of whether by-products are exported, it is assumed that primary and by-products lose ammonia before harvest.

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), will there be differences in emissions from the fouled floor surface. As a result (see Table 3.3), 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 the RAV type of barn A 1.100 is equal to the emission calculated by the NEMA method of the 'not low-emission housing' within BEA. This assumption is correct when it comes to comparing or deriving the EF for the other RAV barn types. However, this assumption is debatable for a quantitative comparison (based on kg of ammonia) of the emission calculated by BEA and RAV. Indeed, there are indications that the RAV emission factor for cattle is too low (Van Bruggen et al., 2017). Velthof et al. (2009) indicated that calculations by Smits et al. (2007) indicate that the RAV emission factor for dairy cattle may be up to approximately 20% higher.
- For manure separated on the farm and applied to the land, the EF of slurry will be used for the liquid fraction and that of solid manure for the solid fraction. Of the imported amount of 'synthetic fertiliser substitutes' (liquid fraction of separated manure, digestate, mineral concentrate, blowdown lye), it is assumed that these types of fertiliser are applied on land as soon as possible after purchasing. This means that no emissions from barn and storage are included for these fertilisers.
- Different emission factors are used for the application of mineral concentrate and blowdown lye (Table 3.13) than for slurry application. When applying mixtures of mineral concentrate (or blowdown lye) and slurry, ANCA uses the emission factors of the individual fertilisers.
- The amount of N applied is reported by the dairy farm in BEA by indicating how much N goes to the arable land. The other N is assumed to be applied to grassland. Here are potential errors:
  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 other temperatures, the assumed 10% extra mineralisation of organic N no longer applies.
- If young stock are housed in the same housing type as the dairy cows, BEA makes no distinction between dairy cattle and young stock with regard to emissions. The potential error is limited because the number of young stock and TAN excretion per unit of young stock 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 (related to the dry matter content in manure), deliberate dilution of manure with water, acidification, additives, soil type, weather conditions (precipitation , temperature, wind), crop type and height, fertiliser application, volume of manure, distribution of manure over a year.
- 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 on land. Ammonia losses from application of this manure are, naturally, taken into account. It is assumed that imported manure has the TAN percentage shown in Table 2.1. In reality, this is not the case.
- Unlike in dairy cattle, the contribution of 'non-ruminants' to ammonia emissions is not differentiated based on feed ration composition.
- The calculation of the indicator 'ammonia-N emission per ton of milk' is based on all ammonia, including the part that is caused by non-ruminants or arable production. In case of livestock

production other than dairy cattle or arable production, therefore, this indicator cannot yet be compared with that of a specialised dairy farm.

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. Environment impact is determined, among other things, 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 calculations is to identify these nitrogen losses.

4.2 Calculation methods

4.2.1 N soil surplus and N leaching

The calculation of N leaching is based on the N soil surplus. The N soil surplus can be used to calculate the quantity of leached N and the nitrate concentration in the leached water.

4.2.1.1 Calculation of N soil surplus

The N soil surplus is calculated based on the terms given in Table 4.1. This is in line with methods used in the LMM and in the approved Dutch Action Programs related to the European Nitrate Directive (Schröder et al., 2007). The soil surplus of all grassland, maize land, land on which other roughage is cultivated and land on which marketable arable crops are cultivated is initially calculated separately.

Table 4.1 Input and output terms for determining the N soil surplus (kg N/ha), with an indication ('X') of whether the data relate to the farm as a whole, to crops (grassland, arable land) or to crops with a distinction between the part in rotation and the part in continuous cropping.

Input/output	Code	Item	Scale		
			Farm	Crop	Crop & crop rotation or not
Supply	In0	Nmin spring, in year x	X		
	In1	Pasture manure		X	
	In2	'barn manure', incl. feed leftovers roughage			X
	In3	Synthetic fertiliser			X
	In4	clover		X	
	In5	deposition	X		
	In6	grazing, mowing and harvesting losses		X	
	In7	Crop residues		X	
	In8	Catch crops and green manures		X	
	In9	peat mineralisation		X	
	In10	from ploughing grassland			X
	In11	Geese excretion	X	X	
	To	SUBTOTAL			
Output	Out0	Nmin spring, year x + 1	X		
	Out1	harvested from own land, including geese grazing	X	X	(X)**
	Out2	ammonia losses during grazing, (synthetic) fertiliser application and from standing crop*		X	
	Out3	grazing, mowing and harvesting losses		X	
	Out4	Crop residues		X	
	Out5	Catch crops and green manures		X	
	Out6	Formation artificial pasture			X
	Out	SUBTOTAL			
Soil surplus	In-Out	TOTAL			X

* N loss with maturing or during pre-drying.

** For the most accurate estimate of N surpluses in crop rotation and continuous cultivation, the quantity of N output should also be specified for these two situations.

Input items

At the moment, users of the ANCA are not asked to differentiate in input between the part of the grassland and the arable land in crop rotation and the part with continuous cropping. Table 4.1, however, does specify this. The idea is that, if desired in future, the N concentrations estimated by BEN can be validated against observations of the participating farms, and these observations could be influenced by rotation. This concerns the input items In2, In3 and In10 and the output item Out6. This kind of distinction, focusing on validation, makes sense only if, besides a distinction in the input items, a distinction is made in the exported amount of N (Out1). After all, the yields (and N and P removal) of crops in rotation can differ from those in continuous cropping. Accordingly, soil surpluses can differ between rotation and continuous cropping not only due to differences in input, but also due to differences in output.

The items In0 (mineral soil N at the start of the year) and Out0 (mineral soil N twelve months later) are assigned a default value of 30 kg N per ha. These items have been included in accordance with preferences of the European Commission, but they are only relevant for accounting records and cancel out each other. Users of the ANCA are therefore not asked for a farm-specific value.

The item In1 (pasture manure) is expressed as kg total N per ha of total grassland, initially without correction for the NH_3-N losses occurring during grazing. The items In2 ('barn manure', i.e. manure excreted and stored indoors, usually slurry) and In3 (synthetic fertiliser) 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 ANCA users. In2 is derived from the data on gross N excretion in the context of BEX (Chapter 2), where this takes place indoors, after accounting for all gaseous losses from the barn and storage according to BEA (Chapter 3), plus the net manure production of non-ruminants (if any), after accounting for imported and exported manure, plus feed leftovers, but not yet corrected for the NH_3-N losses that occur when barn manure is applied on land. 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 In2; if more manure is in stock at the end of the year than at the start, the difference is deducted from the total of manure-N in 'barn manure' applied on land:

> Manure applied-N = excreted manure + feed leftovers-N - (NH_3 -$N_{barn\ +\ storage}$ + exported manure) ± stock change.

Feed leftovers-N (kg N/ha) is estimated at 2 to 5%, depending on the type of feed (Table 1.1), 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 maize 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 users then specify what amount of 'barn manure' is applied (kg N/ha) on grassland ($In2_{grassland}$), on maize land ($In2_{maize}$), on land with other roughage ($In2_{other\ roughage}$), and on the arable land with marketable arable crops ($In2_{market\ arable}$), as follows:

> Manure applied-N (kg) = ((GO x $In2_{grassland}$) + (SO x $In2_{maize}$) + (ORO x $In2_{other\ roughage}$) + (AMO x $In2_{market\ arable}$)) where,

GO = total area of grassland (ha), SO = total area of maize land, ORO = total area of other roughage and AMO = total area of marketable arable crops. Instead of specific entries for all of the aforementioned four destinations ('area x amount per ha'), the amount of manure-N in the fourth destination can also be calculated from the amount applied in the other three destinations. By dividing that fourth amount by the corresponding area, the amount per ha at that fourth destination can also be calculated.

For the calculation of the N-soil surplus, the current version of ANCA does not distinguish between the part of the grassland and the arable land in continuous cropping and the part in rotation. If this is integrated in a future version, additional data entry will be required:

- The difference in amount of 'barn manure' (kg N/ha grassland) applied on grassland in rotation and permanent grassland (ESG, positive if amount applied on crops in rotation > amount applied on continuous cropping system),
- The difference in amount of 'barn manure' (kg N/ha arable land) applied on arable land in rotation and continuous cropping (ESB, positive if amount applied on crops in rotation > amount applied on continuous cropping system),
- The difference in amount of synthetic fertiliser (kg N/ha of grassland) applied on grassland in rotation and permanent grassland (EKG, positive if amount applied on crops in rotation > amount applied on continuous cropping system),
- The difference in amount of synthetic fertiliser (kg N/ha arable land) applied on arable land in rotation and continuous cropping (EKB, positive if amount applied on crops in rotation > amount applied on continuous cropping system),
- Total farm area (TO, ha), the total area of grassland (GO, ha), the area of grassland in rotation (WHO, ha) and the area of arable land in rotation (WBO, ha), the total area of arable land (BO, ha)

and the ‘barn manure’ and synthetic fertiliser application are calculated for permanent grassland, permanent arable cropping, grassland in rotation and arable land in rotation, as follows:

In2 on grass in rotation = ((GO x $In2_{grassland}$) + ((GO-WHO) x ESG))/GO
In2 on permanent grassland = In2 on grass in rotation - ESG

In2 on arable land in rotation = ((BO x $In2_{arable\ land}$) - ((BO - WBO) x ESB))/BO
In2 on permanent arable cropping = In2 on arable land in rotation + ESB,

where BO = TO - GO and
$In2_{arable\ land}$ = ((SO x $In2_{maize}$) + (ORO x $In2_{other\ roughage}$) + (AMO x $Inn2_{market\ arable}$)) / (SO + ORO + AMO),

Furthermore, the following applies:
In3 on grass in rotation = ((GO x $In3_{grassland}$) + ((GO-WHO) x EKG))/GO
In3 on permanent grassland = In3 on grass in rotation - EKG
In3 on arable land in rotation = ((BO x $In3_{arable\ land}$) - ((BO - WBO) x EKB))/BO
In3 on permanent arable land = In3 on arable land in rotation + EKB

where BO = TO –GO and

$In3_{arable\ land}$ = ((SO x $In3_{maize}$) + (ORO x $In3_{other\ roughage}$) + (AMO x $In3_{market\ arable}$)) / (SO + ORO + AMO)

In the above, it seems to be assumed that, within arable land, there are no more than three ‘types’ of use (maize, other roughage and marketable arable crops) and that the ANCA therefore only requires data about the area and organic and synthetic fertiliser application of these three uses. In reality, however, the current version of the ANCA allows for the aforementioned data to be entered for three types of maize (WPMS, WEMS, CCM), three types of other roughage crops (grain WPS, lucerne, field beans, WPS) and more than ten types of marketable arable crops (see Table 4.2). An area-weighted average is calculated based on this information.

As regards the contribution of clover in grassland, the item In4 (N fixing by leguminous plants, kg N per ha) is calculated 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 ton of dry matter in the form of clover (Elgersma & Hassink, 1997; Schils, 2002). The amount of grown dry matter in the form of 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: ton DM/kg N x ($Af1_{cut\ grass}$ + $Af1_{pasture\ grass}$ + $Af3_{cut\ grass}$ + $Af3_{pasture\ grass}$). It should also be noted that the aforementioned ‘clover percentage’ is not equal to the visually estimated ‘clover density’ in grass clovers. The relationship between the two is roughly: clover percentage/clover density = 0.82 (Schils et al., 2001).

With regard to field beans and lucerne, the contribution to N-fixation is estimated at 100 and 300 kg N per hectare per year, respectively. A fixed contribution of 60 kg N per hectare per year is assumed for leguminous green manures, assuming that leguminous plants fix 20 kg N per ton dry matter and leguminous green manures produce 3 tons dry matter per hectare (Schröder et al., 1997; Schröder et al., 2003).

The item In5 (N deposition) averages about 30 kg N per ha per year (Anonymus, 2009) but varies from less than 20 (parts of the north and northwest Netherlands) to more than 50 (parts of the east and south of the Netherlands) kg N per ha per year. Regional specification takes place on the basis of area-specific data on N-deposition (Anonymous, 2013).

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 maize land ($In6_{maize\ land}$, 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 lucerne mowing losses (‘mowing, teddering, swathing, loading') at 5% of the N yield of cuts. Harvest losses from maize 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, lucerne and maize, and for marketable arable crops.

Elsewhere in this section it is explained how the above N-yields are derived. Formally, the principle described above, namely that In6 equals the harvest, mowing and grazing losses, is not right because under the BEA plus (section 3.2.11) it is assumed that some of these losses occur in the form of ammonia. In theory, these ammonia losses should be deducted from In6. Since it concerns a cross post and the term is not part of the numerator and denominator of calculations, the effect on ANCA results is nil.

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 maize land (WPCS, WECS and CCM) ($In7_{maize\ land}$), the value of this annual supply post, as far as roots and stubble are concerned, is set at 15 kg N/ha (Schröder et al., 2016). Irrespective of the value, this input item is also offset by an equally large output item (Out4) for maize in continuous cropping. In case of residual effects from grazing, mowing and harvesting losses (In6) and crop residues (In7), it is assumed that these N input items benefit the crops from which they originate in grassland and maize land (WPCS, WECS and CCM). The fact that in a rotation system this is not true for each phase of rotation is currently ignored.

If the residual plant material from WECS or CCM is not removed from the field, crop residues consist of more than just roots and stubble. For this, default values are assumed as shown in Table 4.3. The crop residues of the non-maize roughage and marketable arable crops (which, as previously indicated, are assumed to have no harvest losses and only crop residues in the form of roots and stubble and any by-products left behind) are calculated as shown in Table 4.2. Also, for these crops, it is assumed that the output is equal to the input. In the ANCA, rather than the amount of input (In7), it is the amount of output (Out4) that is calculated on a crop-specific basis in the first instance, because the output can be made crop-specific while the input is not determined by the crop itself but by the preceding crop(s). Since the crop rotation is not exactly known, an area-weighted average value of Out4 is calculated. After this the value of In7 for all non-maize roughage crops and marketable arable crops together is equated to that average value of Out4.

Table 4.2 *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			By-product			Crop residue		
							By-product	Roots and stubble*	
	DS	N	P_2O_5	DS	N	P_2O_5		Min, Max	Factor
WPS grains	550	8.9	3.8	-	-	-	-	10, 30	0.25
Lucerne	160	5.8	1.4	-	-	-	-	10, 225	0.55
Red clover	160	5.8	1.4	-	-	-	-	10, 225	0.55
Beets	260	1.8	0.9	160	3.4	0.7	34.5	10, 30	1.06
Maize	750	13.5	5.2	400	2.8	0.7	18.8	15, 15	n/a
Grains, coarse grain	750	13.5	5.2	400	2.8	0.7	18.8	10, 70	0.62
Grains, small grain	840	17.8	7.9	840	5.6	1.9	4	10, 30	0.25
Grass seed	830	21	10.1	830	7.2	3.7	3	10, 40	1.27
Legumes	840	34.6	9.4	840	21	4.6	3	10, 30	0.17
Potatoes	200	3.3	1.1	-	-	-	-	10, 60	0.36
Seed potatoes	200	3	1.1	-	-	-	-	10, 100	1.6
Onions and bulbs	100	2.2	0.7	-	-	-	-	10, 20	0.17
Leafy vegetables	75	2.5	0.7	-	-	-	-	10, 50	0.81
Non-leafy vegetables	85	2.6	1.1	85	3	0.9	10	10, 30	0.22
Other	1000	5	1.0	-	-	-	-	10, 20	0.3
Unfertilised catch crop							40		
Non-leguminous green manure							50		
Leguminous green manure							60		

* Where: N in roots and stubble = MIN(Max, (MAX(Min, (factor x N in main product)))).

The value assigned to the item In8 (catch crops and green manures) is 40 kg N/ha for (fertilised) catch crops (mainly cultivated after maize), 50 kg N/ha for non-leguminous (fertilised) green manures and 60 kg N/ha for (fertilised) leguminous green manures.

The value assigned to the item In9 (peat mineralisation) is 235 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 item In10 refers to the input of N to arable land from ploughed grassland. This means that In10 = 0 for permanent grassland, grassland in rotation and permanent arable land. In arable land in rotation, In10 is equated with the product of the duration of the previous grassland phase and an annual sod build-up of 75 kg N per ha (Velthof & Oenema, 2001) with a maximum of 300 kg N per ha, divided by the duration of the arable land phase:

In10 with arable land in rotation = (MIN (300, (75 x duration grassland phase)) / (duration arable land phase)

The term In11 refers to the import 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. The last feed ingested is still excreted after digestion in that resting area. A rule of thumb for grazing time per day and excretion is 10 hours. Since excretion starts 2 hours after grazing, excretion on the grazed plots is assumed to be 8 hours per day, and equal to 80% of the total excretion. 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. 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 it 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 fertiliser, from crops in the field) is derived from the section on BEA (Chapter 3). The term Out3 (grazing, mowing and harvesting losses) is a cross post equal to the term In6, in the sense that the value of In6 is based on the calculated value of Out3. The reasoning behind this is that the input can only be maintained by a comparable (annual) investment in the soil stock, comparable to the cross posts In0 and Out0. From the same line of thought, the item Out4 (crop residues) is equal to In7. The item Out5 (catch crops), as elaborated above, is set at 40-60 kg N per ha and is only applicable to arable land.

The item Out6 (formation artificial pasture) refers to the formation of a new sod under grassland in rotation (a so-called artificial pasture), which is sown after a period of arable land. This item contributes 75 kg N per ha per year for the entire duration of the grassland phase with a maximum of 300 kg N per ha. This means that if the grassland phase lasts longer than 4 years, it is assumed that the same amount of N will be released annually from roots and stubble and added annually to roots and stubble.

Harvested from own land
The item Out1 (harvested from own land via 'mouth' 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 quantity of 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 ($NOP_{maize\ silage}$, 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 ($Out3_{pasture}$):

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

with GO (ha) = total grassland area.

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 stocking of roughage must be settled.

For the amount of cut grass (barn feeding and silage) (kg N) from own land ($NOP_{cut\ grass\_ownland}$) taken up:

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

where $NOP_{cut\ grass}$ is the total amount of freshly fed and ensiled grass ingested from both purchased grass and home-grown grass, and $NOP_{cut\ grass\_purchased}$ from the grass (barn feeding and silage) ingested in the relevant year (after correction for stock changes and feeding losses of that purchased grass):

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

The conservation loss (expressed as a percentage according to Table 1.1) takes into account that also purchased grass silage is exposed to loss. The term ∆N grass silage indicates changes in stock of grass silage (positive values indicate an increase) in the past 12 months. The settlement calculation of the feeding loss (in percentages according to Table 1.1) shows 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-conservation loss) / 100), whereby one must take into account that not all grass that is cut is conserved (i.e. in the case of summer stall feeding).

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

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

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:

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

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

Similarly, for the maize silage:

For the amount of maize (kg N) taken from the home country ($NOP_{maize\_ownland}$):

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

where NOP_{maize} is the total amount of ingested maize from both purchased and home-grown maize (WPCS, WECS and CCM), and $NOP_{maize\ purchased}$ is maize purchased in the concerning year (after adjustment for stock changes and feeding losses of the purchased maize):

$NOP_{maize\_purchased}$ = (((purchased maize N x (100 conservation loss)/100) - ∆Nmaize silage) x (100 feeding loss)/100)

The settlement calculation of the conservation loss (in percentages according to Table 1.1) shows that purchased maize silage is also exposed to conservation losses. The term ∆Nmaize silage refers to changes in the stock of maize silage (positive values indicate increase) in the past 12 months. The feeding loss (in percentages according to Table 1.1) settles that feeding losses also occur with purchased maize.

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

$NAAN_{maize\_ownland} = NOP_{maize\_ownland} / (100 – feeding loss)/100$

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

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

From this $Out1_{maize}$ can be derived if:

$Out1_{maize} = NDAM_{maize} / SO$,

with SO = total area (ha) of maize land (WPCS, WECS and CCM). Finally, the (above ground, excluding stubble) grown amount of maize (kg N / ha) of own land ($Out1_{maize} + Out3_{maize}$), is equal to:

$Out1_{maize} + Out3_{maize} = Out1_{maize}$ x (100 / (100-Harvesting Loss)) with harvesting loss (%) according to Table 1.1.

Similarly, for other roughage:

For the ingested 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 ingested from both purchased and home-grown roughage, and $NOP_{other\ roughage\_purchased}$ is purchased - the ingested 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 in purchased other roughage x (100-conservation loss)/100) - ∆Nother roughage silage) x (100-feeding loss)/100)

The settlement calculation of the conservation loss (in percentages according to Table 1.1) also shows that purchased other roughage is exposed 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) settles that feed losses also occur with purchased roughage.

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

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

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 can also deal with dairy farms with arable production, 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 by 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 figure is based on the average lump sum of a rotation plan consisting of 25% winter wheat, 25% ware potatoes, 25% sugar beet and five times 5% of summer barley, summer wheat, grass seed, grain maize 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:

$$Out1_{market\ arable}\ (kg\ N/ha) = (\sum_{1}^{n} BOn \times ((YHn \times CNHn) + (YBn \times CNBn)))/AMO,$$

With BOn = arable land area with crop n (ha), YHn = yield of main product of crop n (tons of fresh/ha), YBn = yield of removed by-product of crop n (tons of fresh/ha), CNHn = N content of main product (kg N/ton fresh), CNBn = N content of by-product (kg N/ton fresh) and AMO = total area (ha) of area 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, maize 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.

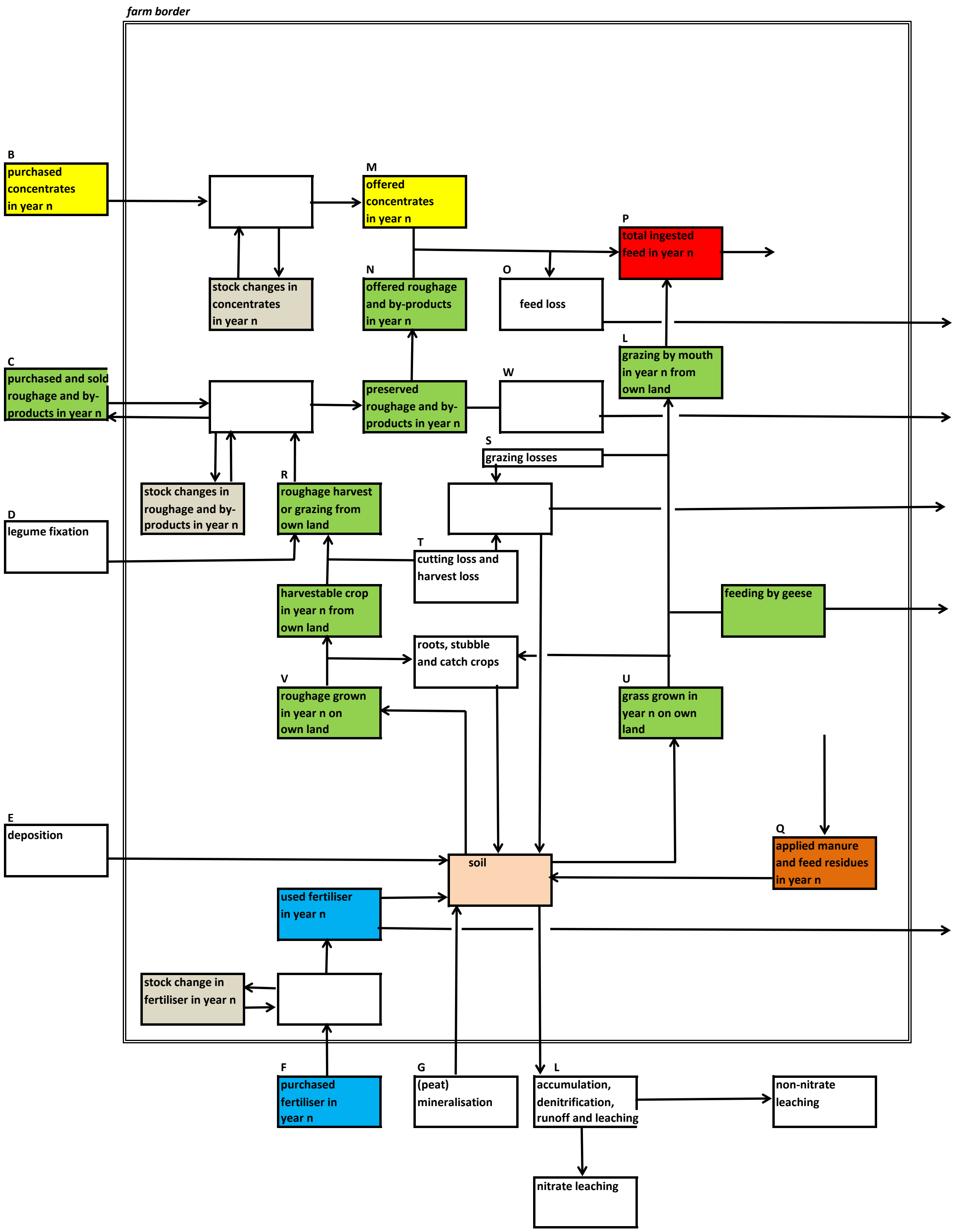

Figure 4.1 *Nutrient flows involved in the calculation of the soil-N surplus (and possibly nitrate concentration in receiving water) based on the estimated feed-N intake for specialised dairy farms without arable crops.*

Nitrogen Use Efficiency (NUE)

The previous paragraphs described the (un) balance of N input and N output of the soil balance. The N use efficiency in this part of the cycle (N-efficiency$_{soil}$) is equal to the fraction of the N input (after deduction of ammonia losses from grazing and application of (synthetic) fertiliser) that leads to usable N-output (output 'via mouth, field, and/or yard', including feeding by geese). Choices must be made with regard to whether or not to include cross posts (Nmin spring, grazing, mowing and harvesting losses, crop residues, catch crops, fixation of N ín and the release of N from grassland in rotation) in numerator and denominator. This also applies to the way in which the items In5 (N-deposition) and Out2 (ammonia losses) must be handled: these are also cross posts at a higher scale level because ammonia deposition cannot exist without ammonia emissions.

On the other hand, N input via deposition is not influenced by an individual ANCA user, and this does not only take place within the company boundaries. This also applies indirectly to In9 (peat mineralisation). Although this item is not influenced by an individual ANCA user, just like deposition, it is to some extent a consequence of jointly taken agricultural decisions. Considering all this, ANCA defines the N use efficiency in the soil compartment as:

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

4.2.1.2 Calculation of N leaching

The quantity of leached N is calculated via the N soil surplus. The factor linking the N soil surplus (kg N / ha) to the N concentration (mg N / l) consists of a so-called leaching fraction (LF (kg N / kg N); i.e. the part of the N soil surplus that actually leaches and is not converted into gaseous compounds such as N_2, N_2O en NO_x) and the precipitation surplus (PS (mm = 10000 x litre/ha), i.e. the amount of water in which the leached N is dissolved), as follows:

$$\text{N concentration (mg N/l)} = \text{N soil surplus (kg N/ha)} \times \text{LF (kg N/kg N)} / (100 \times \text{PS (mm)})$$

The LMM shows that LF and PS depend on the land use (grassland, arable land) and on the type of soil (Table 4.3). The relevant table also indicates that there are significant differences in the values of the leaching fraction and the precipitation surplus between years. The values for LF and PS are derived from the relationships between the N soil surplus and the measured nitrate concentration, using associations found at sites of the Dutch National Monitoring Network on Effects of Manure Policy (LMM), RIVM and WEcR-Wageningen UR (http://www.rivm.nl/Topics/L/National_Meetnet_effects_Fertilisers).

The quantity of leached N (N soil surplus * LF) is also used to calculate the indirect N_2O emissions (see section 4.2.2.1).

For BEN, the N soil surpluses of all grassland, maize land, the land on which other roughage is cultivated and the land on which marketable arable crops are cultivated are initially calculated separately. The weighted average soil type-specific LF and the PS of grassland and arable land are calculated separately, and subsequently the corresponding N concentration based on the percentage distribution of the grassland and arable land (maize land, other roughage, marketable arable crops) over the various soil types. Finally, the weighted average N concentration of the farm as a whole is calculated.

Table 4.3 *Leaching fraction LF and precipitation surplus PS (Fraters et al., 2012).*

Ground type	Leaching fraction (95% CI)		Precipitation surplus (10% and 90% percentile)	
	Pasture	Arable land	Pasture	Arable land**
Peat	0.05 (0.04-0.06)	0.12 (0.09-0.14)*	320 (264-379)	381 (314 - 432)*
Clay	0.11 (0.09-0.13)	0.34 (0.25-0.43)	311 (247-375)	353 (294-420)
Moist sand (Gt IV)	0.19 (0.16-0.22)	0.39 (0.35-0.42)	274 (221-319)	358 (304-405)
Moderately dry sand (Gt VI)	0.29 (0.25-0.33)	0.59 (0.53-0.64)	280 (226-346)	332 (297-387)
Dry sand (Gt VII)	0.37 (0.32-0.42)	0.75 (0.68-0.81)	298 (245-362)	332 (295-392)

* Not specified in Fraters et al. (2012), but estimated from the ratio of arable land and grass values for the other soil types.

** According to Schröder et al. (2007), the precipitation surplus of silage maize land, depending on the soil type, is, at most, 5% greater or smaller than that of the other arable land; this distinction is no longer made in the ANCA.

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 make the largest contribution (approximately 80%) to total N_2O emissions from a dairy farm (based on unpublished results from Dutch farms in the 'Dairyman' project). The other sources of farm N_2O emissions, namely those from manure storages, are discussed in section 4.2.3.

The generally accepted 'Tier 1' calculation rules of the IPCC (2006) 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 specified for land use and soil type by Velthof & Mosquera (2011) based on the most recent field research in the Netherlands (see Table 4.4). In addition, the calculations are also tailored to the specific farming situation as indicated by ANCA user (farm-specific N-flows).

The calculated N_2O emissions relate to the emissions caused by humans ('human-derived'). Together with the so-called 'background emission', they form the total N_2O soil emissions from a farm.

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 Indirect N_2O emissions

As previously indicated, the so-called indirect N_2O emissions are the result of volatilisation ('vol'), runoff and leaching ('lea') of N and are calculated according to equations 4.1 and 4.2 (see Table 4.4 for an explanation of the terms/codes and the values of emission factors):

$$N_2Oem(vol) = EF(vol) * Nloss(vol) \quad \text{(Eq 4.1)}$$

with Nloss (vol) = total NH_3-N loss according to BEA (including ammonia losses from standing crops and swaths) in kg NH_3 -N, hence Out2 x BO.

$$N_2Oem(lea) = EF(lea) * Nloss(lea) \quad \text{(Eq 4.2)}$$

with Nloss (lea) = N soil surplus x LF (according to BEN).

As soil conditions outside the farm are (relatively) unknown, the equations Eq 4.1 and Eq 4.2 use emission factors drawn up by the IPCC (Tier 1) in combination with the farm-specific (total) loss of N via volatilisation and leaching. The relevant N flows are determined in BEA and BEN.

4.2.2.2 Direct soil emissions

For the calculation of direct N_2O soil emissions from the farm, the following N flows are distinguished: synthetic fertiliser ('cf', Eq 4.3), organic fertiliser ('of', Eq 4.4), N-excretion in urine and dung by animals on pasture ('an', Eq 4.5), net N-input in the soil from N-fixation by leguminous plants, e.g. clovers ('cl', Eq 4.6), N input by crop residues ('cr', Eq 4.7), organic matter depletion in mineral soils ('om', Eq 4.8) and organic matter depletion due to dewatering of peat soils ('pt', Eq 4.9). With regard to the item 'N-excretion on pasture', this consists of pasture manure excreted by the livestock (In1) plus the N added in the form of goose manure (In11). Each flow (except in Eq 4.9) must be quantified separately for the grassland and the arable part of the farmland and for the fraction of the farm that consists of mineral or peat soil because the emission factors are different (maximum 4 categories in total, see Table 2.3.4). If the distribution of both land use types (grassland and arable land) between mineral and peat soil is unknown, the dominant soil type of the farm is chosen. An N_2O emission is calculated for each N flow, each land use type and, within that, continuous cropping or crops in rotation (see also Table 4.4):

The N flows associated with fertilisation (Eq 4.3 and 4.4) and total N excretion on pasture (manure and urine; Eq 4.5) are based on information previously used to calculate the N concentration in water in BEN.

$N_2Oem(cf) = EF(cf) * Ninp(cf)$ (Eq 4.3)

where:

$Ninp\ (cf)$ on grass = $In3_{grassland}$ x GO

$Ninp\ (cf)$ on grass = $In3_{grassland}$ x GO

with $In3_{arable\ land}$ = area-weighted average of $In3_{maize\ land}$, $In3_{other\ roughage}$ and $In3_{market\ arable}$ and

EF(cf) according to Table 4.4.

$N_2Oem(of) = EF(of) * Ninp(of)$ (Eq 4.4)

where:

$Ninp\ (or)$ on grass = $In2_{grassland}$ x GO

$Ninp\ (or)$ on arable land = $In2_{arable\ land}$ x BO,

with $In2_{arable\ land}$ = area weighted average of $In2_{maize\ land}$, $In2_{other\ roughage}$ and $In2_{market\ arable}$ and

EF(of) according to Table 4.4.

$N_2Oem(an) = EF(an) * Ninp(an)$ (Eq 4.5)

where:

Ninp(an) = (In1 + In11) x GO, and

EF(an) according to Table 4.4.

The N-flow associated with N-fixation by leguminous plants (Eq 4.6) does not relate to the total N-fixation but to the part that ends up in the soil via crop residues of leguminous plants. IPCC assumes that no N_2O is produced during the fixation process, so that no direct N_2O emission takes place from the part that is harvested. In BEN, an estimate is made of the total N fixation on the farm based on the area of grassland and the proportion of white clover in it and the area of lucerne and field beans. The N content of the crop residue of white clover is estimated as $In4_{clover}$ x 0.33. The N-content of the crop residues of lucerne and field bean are estimated as $Out4_{lucerne}$ and $Out4_{field\ bean}$ according to Table 2.3.3. For the N_2O emissions, a distinction must be made between mineral soil and peat soil (Table 4.4). The calculation is as follows:

$$N_2Oem(cl) = EF(cl) * Ninp(cl) \quad \text{(Eq 4.6)}$$

where:

Ninp(cl) = (In4 x GO x 0.33) + ($Out4_{lucerne}$ x LO) + ($Out4_{field\ bean}$ x VO) where GO, LO and VO refer to the areas (ha) of grassland, lucerne and field bean, respectively,

and EF (cl) according to Table 2.3.4 with weighted values based on mineral soil and peat soil shares.

In the IPCC ‘Tier 1’ calculation methodology, the N that ends up in the soil via crop residues on the field also forms a source of N_2O emission (Eq 4.7). IPCC uses an adapted definition of crop residues; in addition to the root and stubble residues from the arable land (Out4), crop residues also include grazing, mowing and harvesting losses from grassland and arable land (Out3), as well as crops cultivated after the main arable crop (i.e. catch crops after maize and green manures). IPCC (2006) uses a different calculation method for the N_2O emission that is linked to crop residues in the form of the root and stubble residues of grassland. IPCC (2006) 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 that is renewed annually must be available. This concerns both reseeding grassland on former grassland and reseeding grassland on former arable land. For grass in rotation with arable crops, an N fixation is assumed of 75 kg N per ha per year (with a maximum of 300 kg N per ha), which is released during the arable phase. This amount includes an increase in soil N during the grassland phase. For grass that is re-sown on ploughed grassland, the amount of N in the sod (only the N in the grass, i.e. the roots and stubble, during grassland renewal) is estimated at an average of 190 kg N per ha (Van Dijk et al., 1996; Conijn & Taube, 2004; Conijn 2004).

Based on the above, the N_2O emissions from crop residues are estimated as follows:

$N_2Oem(cr) = EF(cr) * Ninp(cr)$ (Eq 4.7)

where:

$Ninp\ (cr) = GO \times In6_{grassland} + SO \times Out3_{maize\ land} + ORO \times Out3_{other\ roughage}$

$+ BO \times Out4_{arable\ land} + SO \times Out5_{maize\ land} + (BO\text{-}SO) \times Out5_{non\text{-}maize\ land}$

+ (fraction of (GO-WHO) / GO that is re-sown annually on average on ploughed grassland x 190)
+ $WHO_{<5} \times 75$

Where:

GO, BO, SO, ORO, WHO, WHO < 4 = areas of, respectively, all grassland, all arable land, maize land (WPCS, CCM, WECS), other arable-managed roughage, grassland in rotation and grassland in rotation with a maximum age of 4 years, and
$In6_{grassland} = Out3_{cut\ grass} + Out3_{pasture}$, and

$Out4_{arable\ land}$ = area-weighted average of the crop-specific crop residues according to Table 2.3.3, and

$Out5_{non\text{-}maize\ land}$ = area -weighted average of the N-content of green manure on arable land excluding maize land in the form of fallow (Out5 = 0), non-leguminous green manure (Out5 = 50) and leguminous green manure (Out5 = 60), and

EF(cr) according to Table 4.4 with weighted values based on mineral soil and peat soil shares.

The last two sources of direct N_2O emission from the soil are related to a decrease in the stock of organically bound N in the soil (Eq 4.8). The following situations may occur with mineral soils: (a) in permanent grassland (with/without grassland renewal) and in permanent arable land, there may be a gradual decrease per year and (b) during the arable land phase after tillage of grassland in rotation systems, a decrease will occur. Decreases as referred to under a) are not yet quantified in BEN. Decreases as referred to under b) have already been estimated using Eq 4.7 due to the annual accumulation in grass and soil of 75 kg N per hectare of grassland in rotation. This N is released again with the total additional mineralisation (kg N per ha per cycle) that occurs during the arable land phase due to degradation of the grass sod and soil organic matter (see section 4.2.1.1).

In the Netherlands, dewatering of peat soils for dairy farms results in a gradual decline of the soil and additional degradation of the soil organic matter. Dutch data are used for the quantification of the additional N input (see Table 4.4), including an annual peat mineralisation of 235 kg N/ha. The N_2O emission associated with the peat mineralisation is estimated as follows:

$N_2Oem(pt) = EF(pt) * Ninp(pt)$ (Eq 4.8)

where:

Ninp (pt) = TO x fraction peat soil in total land area x 235,

and EF(pt) = 0.02 (see Table 4.4).

To calculate the total N_2O emission at farm level, emissions of equations 4.1 to 4.8 are totalled (in kg N_2O-N per year), after which the soil emissions under unfertilised conditions are added. The IPCC (2006) reports on this: '*Natural N_2O emissions on managed land are assumed to be equal to emissions on unmanaged land. The latter emissions are very low. Therefore, nearly all emissions on managed land are considered anthropogenic. Estimates using the IPCC methodology are of the same magnitude* *as total measured emissions from managed land. The so-called 'background' emissions estimated by Bouwman (1996) (i.e., approx. 1 kg N_2O–N/ha/yr under zero fertiliser N addition) are not 'natural' emissions but are mostly due to contributions of N from crop residue. These emissions are anthropogenic and accounted for in the IPCC methodology'*.

For arable land, the IPCC has included the annual input of crop residues (Eq 4.7), which includes emissions from the aforementioned unfertilised arable land, but this has not yet been done for grassland. As a result, emissions from unfertilised grassland have not been included yet. Two situations are distinguished:

a. The emission of unfertilised grassland on mineral soils (N_2Oem (backgr_grassl_m)) is estimated at an average of 1 kg N_2O-N per ha per year (Velthof et al., 1996) and is multiplied by the number of hectares of grassland on the farm:

   N_2Oem (backgr_grassl_m) = GO x (1 - peat soil fraction within TO) x 1 (Eq 4.9)

b. The emission of unfertilised grassland on peat soils (N_2Oem (backgr_grassl_p)) is estimated at an average of 5.3 kg N_2O-N per ha per year (Velthof et al., 1996). However, account has already been taken of 235 x 0.02 = 4.7 kg N_2O-N emissions per ha peat soil as a result of additional mineralisation on dehydrated peat soils (see Eq 4.8 and Table 4.4). Correcting for this implies:

   N_2Oem (backgr_grassl_p) = GO x (peat soil fraction within GO) x (5.3 - 4.7) (Eq 4.10)

These 'additional' N_2O emissions are added to the emissions in Eq 4.1 to 4.8. By multiplying by 44/28 the total N_2O farm emission is obtained in kg N_2O per year.

Table 4.4 *Soil-related N inputs and N_2O emission factors. Values belonging to Cf and Of are based on Velthof & Mosquera (2011), values belonging to An are from Velthof et al. (1996), other values are assumed to be the same as those from Cf and Of or are from other literature sources.*

Inputs (kg N y^{-1})[a)]	Code	Description	Emission factors (EF)[b)] (g N_2O-N (g N input)$^{-1}$	
			IPCC (2006)	Values in BEN[k)]
Volatilisation ('off-farm')	Vol	Total N loss due to volatilisation	0.01	0.01 (IPCC)
Leaching ('off-farm')	Lea	Total N loss due to leaching	0.0075	0.0075 (IPCC)
Synthetic fertiliser	Cf	Applied synthetic fertiliser-N	0.01	Grassland: 0.008 - 0.03[c)] Cropland: 0.008 - 0.03[c,d)]
Organic fertiliser	Or	Organic fertilisation applied[e)]	0.01	Grassland: 0.003 - 0.01[c)] Cropland: 0.013 - 0.02[c)]
Excretion in the field	An	Excretion in the field (manure plus urine)	0.02	Grassland: 0.024 - 0.061[c)]
Net organically fixed N	Cl	N fixed in crop residues of leguminous plants	0.01	Mix Culture[f]: 0.003 - 0.01[c,g)] Monoculture: 0.013 - 0.02[c,g)]
Crop/grass residues	Cr	Total input via crop/grass residues	0.01	Grassland: 0.003 - 0.01[c,g)] Cropland: 0.013 - 0.02[c,g)]
Input via soil organic matter decrease	Om	Net decrease in soil organic N on mineral soils	0.01	Grass-grass[h)]: 0.003[g)] Perm. arab.,: 0.013[g)] Grass-arable: 0.008[i)]
Extra mineralisation in peat soils	Pt	Decrease of soil organic N on peat soils	8 kg N_2O-N ha^{-1} y^{-1}	4.7 kg of N_2O-N ha^{-1} j^{-1} [j)]

a) Inputs are determined per land use type (grassland or arable land) and, if possible, per soil type.

b) EFs are based on total inputs including any ammonia volatilisation in the field.

c) The first value applies to mineral soils, the second to organic soils.

d) Value is assumed to be equal to that of grassland.

e) Value applies to low-emission application (with respect to ammonia volatilisation).

f) Mixed culture applies to grass-clover mixtures; monoculture applies to arable cultivation of leguminous plants.

g) Values are assumed to be equal to those of organic fertiliser application on grassland or arable land.

h) Grass-grass refers to permanent grassland or re-sowing of grassland; perm. arab. refers to permanent arable cropping; and grass-arable refers to arable farming and grassland in rotation.

i) Values are estimated by averaging the values for organic fertiliser application on grassland and arable land.

j) Value is based on a net decrease of 235 kg N ha^{-1} y^{-1} due to oxidation of soil organic matter and an emission factor of 0.02 (source: NL protocol for reporting N_2O emissions (NIR, 2014), based on Kuikman et al. (2005).

k) The values fall within the uncertainty range as published by the IPCC: 0.007 - 0.06 for excretion in the field, 0.003 - 0.03 for other inputs and 2-24 for N_2ON emissions from cultivated organic soils in the temperate climate zone.

4.2.3 Emission of N_2O from 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) and in an outdoor storage facility (manure heap).

The method of calculation in the context of BEN is largely based on national monitoring protocols. These protocols describe the methods and processes for the determination of the emissions, including activity data and emission factors. These have been published by the Ministry of Infrastructure and the Environment (IenM). This protocol falls under IPCC categories 4B11 and 4B12: N_2O manure management (www.agentschapnl.nl/ programs-regulations / monitoring protocols). This protocol is limited to N_2O emissions from manure produced in the barn, temporarily stored and/or treated/processed and then removed. Nitrous oxide emissions from manure excreted on pasture are discussed in the previous section 4.2.2.2.

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:

$$N_2O_{(Dmm)} = \left[\sum_S \left[\sum_T \left(Nexcretion_T * MS_{(T,S)}\right)\right] * \ EF_{(S)}\right] * \frac{44}{28}$$

$N_2O_{(Dmm)}$: N_2O emission from manure management systems in kg.

$Nexcretion_{(T)}$: Total N excretion per animal category *T* in kg (where *T* = dairy cattle, young stock or (total) other ruminants). This N excretion is derived from BEX (Chapter 2), but without deduction of gaseous N losses from the barn and storage and without correction for manure import and export. According to IPCC conventions, the N_2O emissions from manure storages only relate to manure produced on the farm itself.

$MS_{(T,S)}$: fraction of total N excretion per animal category T in manure management system S.

EF (S): emission factor for the defined manure management system S in kg N_2O-N / kg N excreted manure.

44/28: conversion factor from kg N_2O-N to kg N_2O

S: manure management systems: liquid manure system and solid manure system.

The amount of N in manure refers to the gross amount of N in manure, i.e. not reduced by gaseous N losses from the barn and storage. This methodology corresponds to the IPCC method (IPCC, 2006). This means that the total amount of manure N produced is multiplied by the emission factor without deducting ammonia and other gaseous N losses.

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., 2017). In addition to NH_3, the NEMA model estimates emissions of N_2O, NO and N_2 from barns and storages (Tables 3.2 and 3.3).

The emission factors use the default values of IPCC (2006) (Table 4.5).

Table 4.5 *Emission factors (EF_S) per manure management system in kg N_2O-N/kg N excreted manure.*

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

Source: IPCC, 2006.

4.2.3.2 Other ruminants

For ‘other ruminants’, the fixed net manure-N production (Table 3.6) 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 4.6).

Table 4.6 *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

4.2.3.3 Non-ruminants

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

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

where:

GAD = average number of animals present (from the input data)
Nitrous oxide = emission in kg N per animal (Table 4.7)

Table 4.7 *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 (DM) and for solid manure (VM).*

Animal category_oms	Gross N excretion (kg N per animal place)	EF_{notNH3}, DM	EF_{notNH3}, VM	EF_{N2O}, DM	EF_{N2O}, VM
Farrowing sows	36.6	2.4	3.5	0.2	0.5
Dry and pregnant sows	17.85	2.4	3.5	0.2	0.5
Weaned piglets	3.4	2.4	3.5	0.2	0.5
Fattening pigs	10.9	2.4	3.5	0.2	0.5
Laying hens	0.726	1.2	0.7	0.1	0.1
Broilers	0.498	1.2	0.7	0.1	0.1
White meat calves	10.58	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 these emissions is already included in the ANCA manure storage calculation, namely 0.2% of the N in slurry (Table 4.5). To prevent duplications, 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 4.8 *Additional N_2O losses during slurry separation and storage of the liquid and solid fractions (based on NEMA) in kg N_2O-N/kg N.*

Input slurry	Emission factors in kg N_2O-N / kg N in input slurry
Ruminants	0.003
Non-ruminants	0.003

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

In the previous paragraphs, 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 fertiliser/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, maize (WPMS, WEMS and CCM) and additional roughage including wet by-products, respectively (Table 1.1).

The remaining gaseous N losses from housing and storage are calculated as the difference between other gaseous N losses according to Tables 3.6 (other ruminants) and Table 3.9 (non-ruminants, for the purpose of calculating non-ammonia losses) and the nitrous oxide losses according to Table 4.6 (other ruminants) and Table 4.7 (non-ruminants), with losses always being based on the sum of the gross amount of ‘barn manure’, the manure exported and the manure imported (corrected for stock changes).

4.3 Comments on BEN

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

- Accurately evaluating the crop-specific N efficiencies in the grassland and arable land phase of rotation systems because the N yields do not distinguish between rotation and continuous cropping, and the output items of grazing, mowing and harvesting losses do not yet exactly match with input items assigned to the subsequent crops in rotation,
- In the ANCA, 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 spread is due to the fact that the items 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, as is the issue of whether 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 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 VEM intake is 2% higher than the calculated VEM requirement because it is assumed that the VEM use is 102%. 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 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 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 BEN. Obviously, this does increase the data requirements in BEN.
  - Grassland renewal.
    Tests have shown that grassland renewal also changes the emission factors of the fertiliser applied compared to the situation without renewal. Through additional literature review adjusted emission factors can be determined.
  - Changes in organic matter content.
    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 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 is used to calculate how much P (P_2O_5) is ingested by ruminants ('through the mouth'), harvested by machines ('leaving the field') and, possibly, eaten by geese. This indicator provides insight into how much P must be added in the form of manure and / or fertiliser to ensure that input and output are in balance.

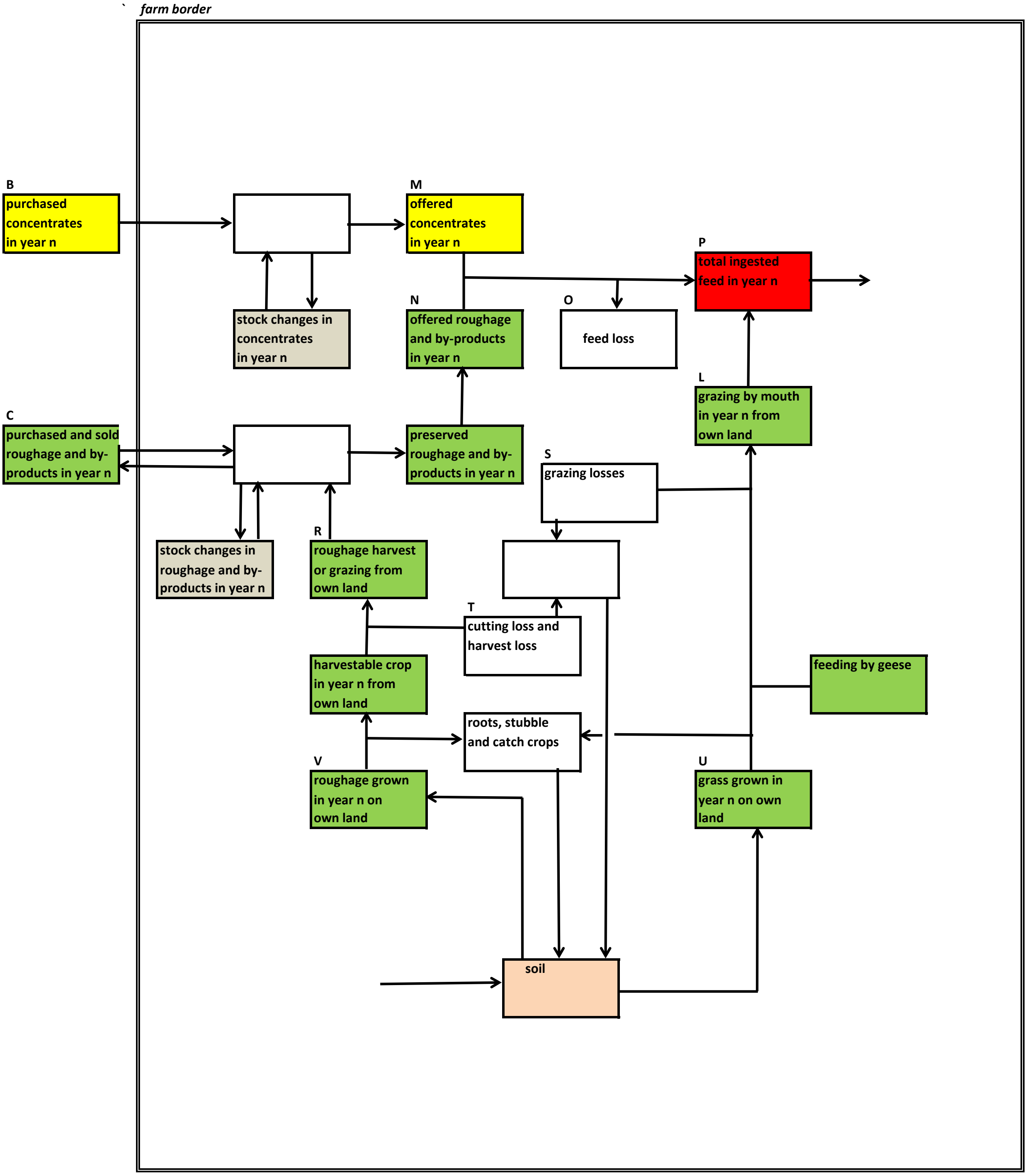

Figure 5.1 *Nutrient flows involved in calculating the amount of P harvested by machines and animals from a dairy farm's own land without arable production.*

5.2 Calculation method

In the context of 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 (WPCS, WECS and CCM), lucerne, field bean, GPS). By multiplying each of these feeds by their farm-specific P/VEM ratio, it is calculated how much P (kg P_2O_5) has been ingested from own feed and how much has been harvested by grazing ('mouth') or machines. 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 mouth or machine - P feed $\text{leftovers}_{own\_feed}$, (Eq 5.2)
↔ P harvested in roughage by mouth or machine = P intake from own feed + P feed $\text{leftovers}_{ownfeed}$

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 from conserved grass and silage maize / (1- 0.05)) + 0.03 x (P intake from other self-cultivated roughage and wet by-products/(1 - 0.03)) + 0.02 x (P intake from 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 mouth or machines and P in purchased feed ends up in either stocks, or in the manure of the dairy cattle, or in feed leftovers, or in milk and meat of dairy cattle:

P in roughage harvested by mouth or machine + 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 by mouth or machine is corrected for indicated stock changes and 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 maize silage according to the BEX module, and the P intake from own grass silage and maize silage according to data entry. This entry is equal to P stock changes in grass silage and maize silage plus the existing stock of grass silage and maize silage. The consequence of this correction is also that the amount of P in roughage harvested by mouth or machine (only the proportions of grass silage and maize silage) changes. The consequence of this correction is also that the amount of P in roughage harvested by mouth or machine (only the proportions of grass silage and maize silage) changes.

factor_purchase_mutation = (BEX_Popn_gksm_mlk + BEX_Popn_gksm_ovg) / (Stock_Pverbr_gksm * (1-PcFeedlossRoughage/100))

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

BEX_Popn_gksm_mlk = P intake of dairy cattle from grass silage and silage maize

BEX_Popn_gksm_ovg = P intake of other ruminants from grass silage and silage maize

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

PcFeedlossRoughage = Percentage of feed leftovers in forage

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

P in fertiliser 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 fertiliser applied to land for
roughage cultivation. (Eq 5.6)

Substitution of Eq 5.6 in Eq 5.5 gives:

P in roughage harvested by mouth or machine + (P in milk and meat of dairy cattle) - P in synthetic fertiliser 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 fertiliser applied to
land for roughage cultivation = P in roughage harvested by mouth or machine (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) fertiliser applied to land for roughage cultivation is the same as the amount of P in roughage harvested by mouth or machine.

Based on the ratio of the amount of stock increase from own grass (production grassland and natural grassland separately) and maize (grass products, intake of pasture grass, maize silage (WPCS, WECS and CCM), other silage (lucerne, field beans, GPS); see BEX), a derived P yield from grassland (production grassland and natural grassland separately), maize land and other roughage is determined. For the amount P from grassland ($P_{grassland}$) the following applies:

$P_{grassland}$ harvested by mouth or machine = P in roughage harvested by mouth or machine /
$(P_{cut\_grass} + P_{pasture} + P_{maize\_silage} + P_{other\_silage}) * (P_{cut\_grass} + P_{pasture})$ (Eq 5.8)

where:

$P_{cut\ grass}$ = the amount of P in own grass silage or fresh grass,

$P_{pasture}$ = the amount of P in grazed grass including feeding by geese (see section BEN),

$P_{maize\ silage}$ = the amount of P in own maize silage, and

$P_{other\ roughage}$ = the amount of P in silage pits with other own roughage.

For the amount P from maize land the following applies ($P_{maize\ land}$):

$P_{maize\ land}$ harvested by machine = P in roughage harvested by mouth or machine /
$(P_{cut\_grass} + P_{pasture} + P_{maize\_silage} + P_{other\_roughage}) * (P_{maize\_silage})$ (Eq 5.9)

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

$P_{other\ roughage}$ harvested by machines = P in roughage harvested by mouth or machine /
$(P_{cut\_grass} + P_{pasture} + P_{maize\_silage} + P_{other\_silage}) * (P_{other\_silage})$ (Eq 5.10)

To determine on dairy farms with arable and/or non-ruminant categories whether the import of manure-P and synthetic fertiliser-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 BEX (pasture manure, barn manure) should be added to the net amount of manure-P derived from the 'non-ruminant' category, and the P output in marketable arable crops should be calculated. The latter is done by entering the number of hectares of the arable crops listed in Table 4.3 and the average yield of those crops in the relevant year. Then the P output is calculated by multiplying the yields by crop-specific default values in Table 4.3. For arable crops not included in the table, it is assumed that they have a standard output of 60 kg P_2O_5/ha. This figure is based on the average lump sum of a rotation plan consisting of 25% winter wheat, 25% ware potatoes, 25% sugar beet and five times 5% of summer barley, summer wheat, grass seed, grain maize 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:

$$P_2O_5 \text{ output from the arable category (kg } P_2O_5\text{)} = \sum_1^n (\text{BOn x ((YHn x CPHn) + (YBn x CPBn)))},$$

Where BOn = arable land area with crop n (ha), YHn = yield of main product of crop n (tons fresh/ha), YBn = yield of exported by-product of crop n (tons fresh/ha), CPHn = P_2O_5 content of main product (kg N/ton fresh) and CPBn = P_2O_5 content of by-product (kg P_2O_5/ton fresh).

5.3 Comments on BEP

Previous research (Oenema et al., 2011) indicates that there is a strong association between the P harvest calculated in this way, based on the estimated P intake from roughage from own land and the actual amount of P harvested. The strength of association between these two parameters increases when the calculated amount of P harvested according to BEP is based on more years.

The figures used for field losses (grazing loss, mowing loss, harvest loss), conservation losses and feeding losses come from past research. It is advised to update these figures. The accuracy of the estimate of the amount of P harvested according to BEP also requires a more accurate estimation of silage pit densities. This research is currently executed.

The reliability of the BEP is lower when dairy farms also have arable production. This is because P output in the form of marketable arable crops is based on average standard values for manure production and contents. Actual values will deviate from this.

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 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 greenhouse gases. N_2O emissions are described in 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 fertiliser 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. This additional storage should in principle be able to be deducted from the calculated greenhouse gas emissions. Conversely, if there is a negative balance, the organic matter content of the soil will drop and extra CO_2 will be released. However, the ANCA 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 Sources of emissions

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

CH_4 is released during digestion of feed in ruminants in particular and from manure. Also methane can be emitted during the cultivation or processing of purchased feed ingredients. This is the case, for example, with rice products and palm kernel meal.

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. Gas can be 'made' on the farm itself or imported to the farm and, when imported, be based on fossil or renewable sources. With regard to milk production, in addition to energy used on the farm itself, raw materials are often brought onto the farm which were produced outside the farm using energy (fossil or renewable), such as purchased fertilisers, concentrate and other feed. In addition, the production and transport of somewhat smaller farm inputs such as water use, purchased animals, litter, pesticides and plastic are taken into account.

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

Non-ruminants (e.g. pigs, chickens) are not included in the greenhouse gas emission calculation because only part of the data is available. Nothing is known about the supply of, for example, feed for this category in the ANCA.

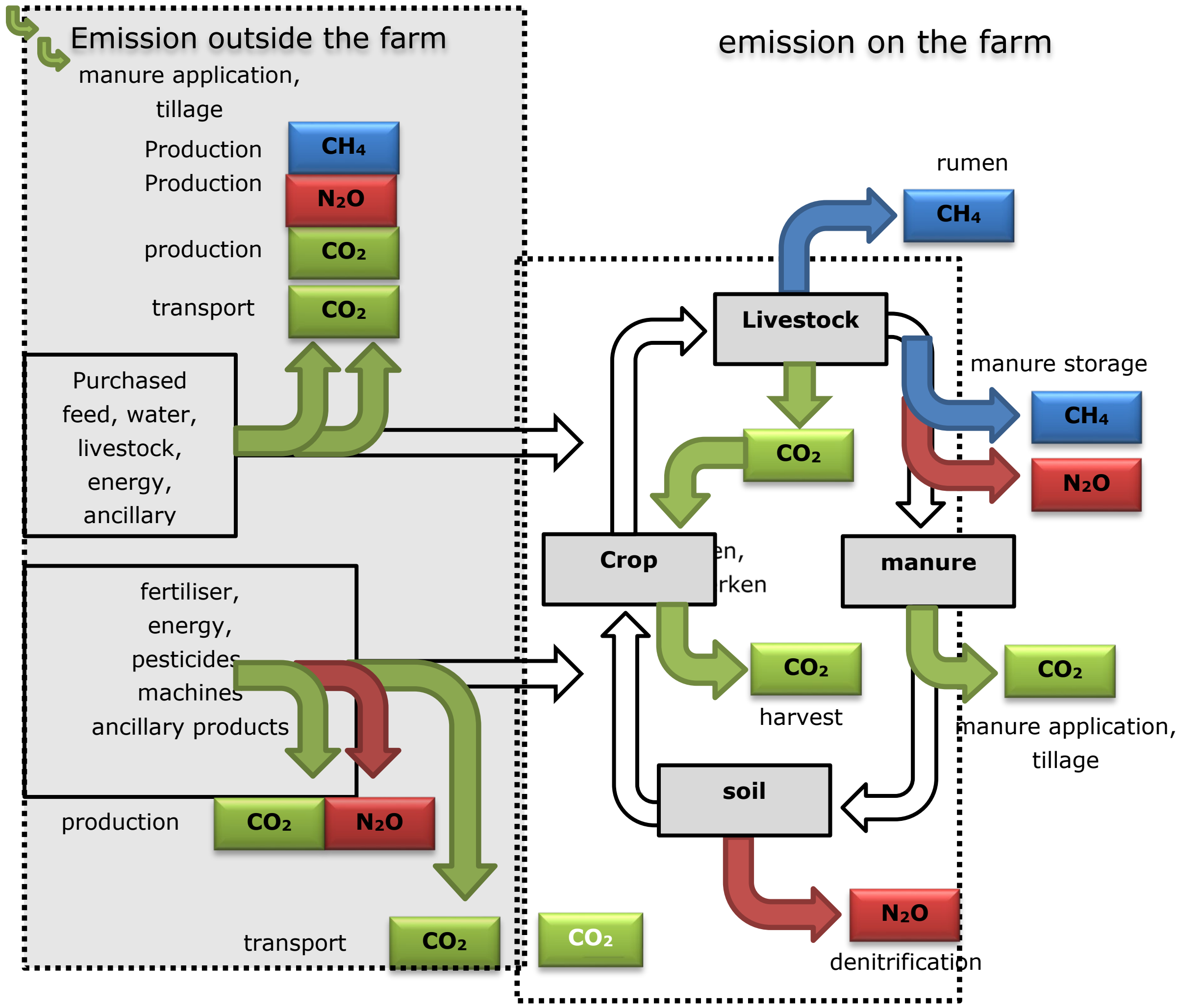

Figure 6.1 *Simplified diagram of greenhouse gas emissions on a dairy farm.*

6.2 Guidelines for calculating emissions

In 2018, the European Commission adopted important rules for calculating greenhouse gas emissions from imported products. The rules are based on the Life Cycle Analysis (LCA). They are about the emissions associated with all inputs and processes required throughout the production chain to make a product. This means that the BEC calculation differs from the other calculations because BEX, BEA, BEN and BEP are limited to what happens on the primary farm.

The chain approach of the BEC 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 fertiliser, crop protection products, ancillary products (e.g. litter, plastic covers), mechanisation 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; b) emissions from biogenic sources and c) land use and land use change. The ANCA does not make this subdivision yet.

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

6.2.1 Expressing methane and nitrous oxide in CO_2 equivalents

To be able to sum different gases, the greenhouse effect of CH_4 and N_2O is expressed in CO_2 equivalents: 1 kg CH_4 from biological processes (biogenic methane) corresponds to 34 kg CO_2, 1 kg CH_4 from fossil fuel (fossil methane) corresponds to 36.75 kg CO_2 and 1 kg N_2O corresponds to 298 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 (Blonk, 2019) is included in a tool that is part of FeedPrint/Agrifootprint (Vellinga et al., 2013).
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 takes place in two steps:

Step 1
In this step, only the emissions for dairy cattle are included. The emissions that can be clearly calculated and/or measured separately are split into dairy cattle (including young stock) and other ruminants. 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 maize silage is exported, only half of the emissions associated with the cultivation of maize silage is included for dairy cattle.

Step 2
In this step, the remaining emissions from the dairy cattle must be allocated to the production of milk and the live weight of culled animals. A formula is used for this:

Milk allocation factor = 1 - 6.04 * Production_Live weight / Production_FPCM, where:

Production_Live weight = export of kg animals (live animals only) and
Production_FPCM = production of kg fat and protein corrected milk [kg milk * (0.2534 + 0.1226 * Fat% + 0.0776 * Protein%)],

and

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 cattle / 1000 * Allocation factor milk / Production FPCM

6.3 Calculation method for CH_4 emissions

6.3.1 Emissions from rumen fermentation (enteric methane)

With regard to enteric methane emissions, the ANCA is currently limited to ruminants ('ruminants'). 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. In the calculation, a distinction is made between dairy cattle (including young stock) and other ruminants.

6.3.1.1 Dairy cattle (including young stock)

The CH_4 emission from rumen enteric fermentation in dairy cattle is calculated according to the most accurate level permitted by the IPCC: the Tier 3 level. This Tier 3 method offers both the most accurate estimate of enteric CH_4 emissions and most management options to reduce (mitigate) methane emissions. The Tier 3 method is based on the fact that the methane emission 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). The nutrient composition and the degree of acidity in the rumen influences the composition (ratio) of fermentation products produced in the rumen: acetic acid, propionic acid, butyric acid and other volatile fatty acids. With shifts in the ratio of these fermentation products also the amount of hydrogen 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 applied in the ANCA 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 maize silage in the roughage part (= fresh grass, grass products and maize 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 maize silage in the roughage part of the ration, EF lists have been derived for rations with different shares of silage maize (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 silage maize between 0% and 80% can be done by interpolation with the three EF lists for the rations with 0%, 40% and 80% maize silage in the roughage. This approach is also appropriate for older young stock feeding on roughage. It is therefore in line with the ANCA approach to calculate rations at the herd level.

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

SUM kg DM from roughage = total amount of dry matter from roughage
% silage maize in roughage = 100 * (kg DM maize silage/SUM of kg DM from roughage)

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

Subsequently, for three levels of the share of maize 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 maize silage products, it is calculated based on the specified feed values (NDF, starch or energy (VEM), CP and 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 maize silage in the roughage part of the ration:

- If the calculated % of maize silage is between 0% and 40%, then interpolate with the EF lists 0% and 40%
- If the calculated % of maize 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 net energy 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 young stock aged 0-3 months must be calculated. The methane emission from young stock 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 kg DM.

The methane emission factor of the ration (CH_4 _EF ration) 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, silage maize and compound feeds
As indicated above, for conserved grass products and conserved maize 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 + 0.05 * (NDF - 465)
EF40% = 19.5 + 0.05 * (NDF - 465)
EF80% = 21.0 + 0.05 * (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 WPMS, if NDF and starch known (g CH_4 / kg DM):
EF0%_NDF = 18.4 - 0.083 * (NDF - 374)
EF40%_NDF = 17.5 - 0.083 * (NDF - 374)
EF80%_NDF = 16.2 - 0.083 * (NDF - 374)
EF0%_STA = 18.4 - 0.049 * (starch - 385)
EF40%_STA = 17.5 - 0.049 * (starch - 385)
EF80%_STA = 16.2 - 0.049 * (starch - 385)
EF0% = (EF0%_NDF + EF0%_STA) / 2
EF40% = (EF40%_NDF + EF40%_STA) / 2
EF80% = (EF80%_NDF + EF80%_STA) / 2

Conserved WPMS, if NDF and/or starch unknown (g CH_4/kg DM):
EF0% = 67.51 - 0.04978 * VEM
EF40% = 66.61 - 0.04978 * VEM
EF80% = 65.31 - 0.04978 * VEM
Minimum: VEM = 807, EF0 = 0.9 * 13.57, EF40 = 0.9 * 12.67, EF80 = 0.9 * 11.37
Maximum: VEM = 1063, EF0 = 1.1 * 26.83, EF40 = 1.1 * 25.93, EF80 = 1.1 * 24.63

The calculation rules for conserved grass products and maize 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 maize 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 (without NDF and/or starch values) 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.

From 2020 onwards, the 3 EF values for methane for compound feed will in principle be supplied by the compound feed supplier. If these 3 EF values are not supplied, 3 fixed EF values are used for compound feed. These values are based on three compositions and the use of average compound feed types in 2018/2019.
Compound feeds (g CH_4/kg DM):
EF0% = 20.21
EF40% = 19.83
EF80% = 20.52

6.3.1.2 Other ruminants

Tier 2 is used for ruminants other than dairy cows and associated young stock. 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 6.5% 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, 2006).

GE herd intake* = DM herd intake •18.45

CH_4 emission (in kg CH_4) $= \frac{BEintake \bullet \boldsymbol{Ym}}{55.65} \bullet 100$

* Note: if concentrate feed intake is shown per kg of product, first convert to kg DM (rule of thumb: kg DM = kg product x 0.88).

Where:

BE = Gross energy, in MJ

DM = Dry matter intake of livestock, in kg

Y_M = Methane conversion factor, in the ANCA 6.5% is used

18.45 MJ/kg = average gross energy content of a kg of DM cattle ration

6.5% = methane conversion factor for young stock in North West Europe (IPCC 2006)

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 6.5% of the gross energy for the different categories of cattle, sheep and goats, standard values for the other ruminants on the dairy farm have been calculated (in kg CH_4 per animal per year, Table 6.1).

For horses and ponies, only IPCC Tier 1 emissions are available (IPCC, 2006) (Table 6.1). There is no separate animal group for ponies in Tier 1. This is 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.

Table 6.1 *Methane emissions from other ruminants.*

Category	Kg DM/yr	Y_M	CH_4 (kg/yr)	CH_4 (kg CO_2-eq/yr)
Breeding bulls, > 1 year (cat. 104)	3049	6.5%	65.7	2234
Pasture and suckler cows (cat. 120)	3433	6.5%	74	2516
Calves for rosé or red meat (cat. 115)	659	6.5%	14.2	483
Rosé calves, 3 months – slaughter (cat. 116)	2050	6.5%	44.2	1503
Rosé calves, 2 weeks – slaughter (cat. 117)	1561	6.5%	33.6	1142
Red meat bulls, 3 months – slaughter (cat. 122)	2656	6.5%	57.2	1945
Breeding sheep, incl. Lambs (cat. 550)	469	6.5%	10.1	343
Meat sheep, < 4 months (cat. 551)	62	6.5%	1.3	44
Other sheep, > 4 months (cat. 552)	312	6.5%	6.7	228
Milk goats (cat. 600)	833	6.5%	17.9	609
Rearing and meat goats, < 4 months (cat. 601)	193	6.5%	4.2	143
Rearing and meat goats, > 4 months (cat. 602)	496	6.5%	10.7	364
Ponies (cat. 941)	1523	-	12.8	435
Horses (cat. 943)	3053	-	18	612

6.3.2 Emissions of methane from manure

6.3.2.1 Basic Principles

For CH_4 emissions from manure in barn and storage and in pasture the following two source categories are distinguished:

- Dairy cattle and associated young stock
- Other ruminants

The description of this protocol is based on the 'Tier 2' approach of IPCC (2006) and deviates from the methods and work processes for determining emissions described in national monitoring protocols, These have been published by the Ministry of Infrastructure and the Environment (IenM). The national protocol falls under IPCC categories 4B1 to 4B9 and 4B13: 12-029 manure CH_4 (www.agentschapnl.nl/programmas-regelingen/monitoring-protocollen).

The methodology used here for the calculation of national CH_{44} emissions differs from IPCC in that it assumes emission factors (EF) per kg of manure per animal category and per manure management system instead of the annual absolute amounts of CH_4 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 house. 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 (also barn manure in the strict sense) and pasture manure. Because part of the dairy cows in the Netherlands is (partly) 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 other ruminants housed only in the lambing period. Solid manure is produced during this housing period. For horses and ponies a housing and grazing period is distinguished, producing solid manure in 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 can 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 anaerobic conditions, the formation of CH_4 in manure also depends on other storage conditions, 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 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).

The CH_4 emission from manure also depends on the (chemical) composition of the manure. For example, CH_4 emissions mainly depend on the organic content matter of the manure.

6.3.2.2 Calculation method

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

$$CH_{4Mest} = \sum_{S} \left[EF_{(T)} * N_{(T)} \right]$$

$CH_{4\ Manure}$: 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 cattle, young stock and (total) other ruminants)

The emission factor per animal is calculated as follows:

$$EF_{(T)} = \left(VS_{(T)} * 365\right) * \left[B_{0(T)} * 0.67 * \sum_{T} \frac{MCF_S}{100} * MS_{(T,S)}\right]$$

$EF_{(T)}$: 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

B_0 : maximum methane production potential per animal category T in m3 CH4 per kg excreted VS

0.67 : methane density (kg/m^3)

$MCF_{(S)}$: methane conversion factor per manure management system in percentages of B_0

$MS_{(T,\ S)}$: fraction of total N excretion of each animal category T in manure management system S.

B_0

The maximum CH_4 formation is determined by the degradability of the organic components in the manure. B_0 is expressed in m^3. CH_4/kg VS and the (default) values are derived from NIR (2014) (Table 6.2).

MCF $_{(S)}$

The MCF indicates the degree to which the amount of degradable substance is actually converted into CH_4 under certain conditions. 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 litter that end up in the manure.
The amount of VS excreted depends on the ration. The calculation is as follows (Zom & Groenestein, 2015):

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 ($CH4N_2O$). 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-N / 0.466 (= (14 * 2) / (12 + 4 * 1 + 14 * 2 + 16))

Urinary N excretion (kg N/year, TAN nitrogen) is determined in 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,%).
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 IV).
The data for the types of feed and grass products/maize silage products of the CA content come from entries in the ANCA. The other CA contents and the DCOM values are values from the CVB tables (Appendix IV). In this way, a dry matter intake, CA content and DCOM value are obtained per feed ingredient.
For compound feed it is assumed that the DCOM is 84% and the CA content is 65 g/kg. These estimates are based on an average composition and the shares of main raw materials in compound feeds.

The net organic matter intake of each feed ingredient i is calculated as:

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

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

The tot-OM_{intake} (kg) = Σ $OM_{intake-1}$ (kg) + $OM_{intake-2}$ (kg) + …… + $OM_{intake-i}$ (kg) (i = 1… n)

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

$DOM_{intake-i}$ (kg) = $OM_{intake-i}$ × $DCOM_{-i}$/100

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

The tot- DOM_{intake} (kg) = Σ $DOM_{intake-1}$ (kg) + $DOM_{intake-2}$ (kg) + …… + $DOM_{intake-i}$ (kg) (i = 1… n)

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

VS-excr = tot-OM_{intake} (kg) - tot-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 'messed'. 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-$IFL_{intake-i}$) is calculated as:

OM-$IFL_{intake-i}$ (kg) = DM-$IFL_{intake-i}$ (kg) × (1000-CA_i (g/kg DM))

The total net organic matter intake including feed loss (tot-OM-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 feed ingredients:

The tot-OM-IFL_{intake} (kg) = Σ OM-$IFL_{intake-1}$ (kg) + OM-$IFL_{intake-2}$ (kg) + …… + OM-$IFL_{intake-i}$ (kg) (i = 1… n)

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

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

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

VS_{litter} = 0% * kg DM lime + 0.9 * kg DM other litter

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

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

The above method for calculating the VS in manure is used for dairy cows and associated young stock.
The following method was used for the other ruminants.

$VS = \sum(Nexcretie_T * \text{Factor})$, where:

$Nexcretion_{(T)}$: total N excretion per animal category in kg per day (dairy cattle, young stock and (total) other ruminants). This N excretion is derived from BEX (Chapter 2) without deduction of the gaseous N losses from barns and storage.

Factor: Conversion factor from N to VS (OM/N ratio in manure, Table 6.2)

Table 6.2 *Parameter values for determining the methane emission factors of manure management systems. For explanation of the parameters, see text above.*

Animal category	B_0	OM/N factor*		MCF		
		Liquid manure	Solid manure	Liquid manure	Solid manure	Pasture manure
Dairy cattle	0.22			17 or 3**	2.0	1
Young stock	0.22			17 or 3**	2.0	1
Other ruminants***	0.20	15.6	25.8		1	

Source: Lagerwerf et al., 2019.

* OM/N is only used for VS calculation of other ruminants.

** Undigested/digested.

*** IPCC distinguishes several animal categories, which differ in parameter B_0 (e.g. goats 0.18; sheep 0.19; horses 0.3). In the ANCA these have been provisionally placed under one category with a B_0 value of 0.2.

6.3.2.3 Manure digestion

In the ANCA, you can specify how much slurry is anaerobically digested externally and/or on the farm. In the ANCA, we assume that this manure has been in storage for less than 30 days before it goes into the digester, so for this amount of manure an MCF (see Table 6.2) of 3 is used instead of 17. Methane production during the anaerobic digestion process is assumed to be 95% of the maximum methane production (B_0), of which 4.3% (Hjort-Gregersen, 2014) escapes through leakage.

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 production of imported products and livestock, maintenance and transport of imported products and livestock (section 6.4.2).

For the production of own roughage, some farm-specific data about inputs are used, which are requested in the ANCA. This concerns the production and application of animal manure and synthetic fertiliser.

Appendix 5 provides an overview of all emission coefficients of carbon dioxide (directly and indirectly) 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 fertilisers (lime and urea)

There are a number of C-containing products that are used in the cultivation of crops. This concerns (Source: IPCC Guidelines (2006); Fifth Assessment Report, 2014):

Urea: kg Nureum * NURE_URE * EF_CO_2 _Nure / 1000 * 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: (kgKalk_Dolo * EF_CO_2 _Dolo / 1000 + kgKalk_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, 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 'Ruminants and fodder crops' is reported. The ANCA then calculates the proportion of the consumption to be attributed to milk production using the normative 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 normative 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 6.3 shows which activities occur on each type of grassland and how often they occur.

Table 6.3 *Frequency of activities per grassland cut for grazing, summer stall feeding, harvesting for grass silage, harvesting for hay and harvesting for grass drying (FeedPrint, 2018).*

Activity	Cut Grazing	Cut fresh grass (summer stall feeding)	Cut grass silage	Cut hay	Cut fresh grass (external drying)	Cut pre-dried grass (external drying)
Synthetic fertiliser	1	1	1	1	1	1

Pasture topping	0.5					
Mowing		1	1	1	1	1
Grass loading		1	1		1	1
Teddering			2	3		2
Swathing			1	1		1
Packing silage			1			
Large square baler				1		

The following tables indicate which general activities (Table 6.4) and which sowing-related activities (Table 6.5) occur in grassland.

Table 6.4 *Frequency of general activities per hectare of grassland.*

Activity	grassland, field work
Liming	0.25
harrowing	0.5
Roles	0.5

Table 6.5 *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 in the ANCA, 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 stall fed grass = 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 6.6),
- the products of the number of hectares and the frequencies per hectare for lime spreading, rolling and harrowing and the diesel consumption per operation (Table 6.6),
- 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) is multiplied by the diesel consumption of the operations carried out during sowing (Table 6.6).

Table 6.6 *Diesel consumption per unit, grassland operations.*

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	tons	1.3

Applying synthetic fertiliser	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
Loading	Ha	5.3
Small square bales	Ha	5.7
Large square bales	Ha	11.3
Packing silage	Ha	2.5
Rolling	Ha	4.2
Harrowing	Ha	4.2

Arable land activities (standard calculation)

For all arable crops, activities have been distinguished, which basically boil down to preparing the land (ploughing, seedbed preparation, sowing, crop management (fertilisers, pest and disease control), harvesting and post-harvest activities. For these crops, the normative values for energy consumption (diesel and electricity) are used, as calculated by FeedPrint/Agrifootprint (Table 6.7).

Table 6.7 *Diesel and electricity consumption per hectare of arable crop in the ANCA.*

Crop	Diesel (kg)	Electricity (kWh)
Maize silage	95.9	0
WPS grains	95.9	0
Lucerne	128.1	0
Red clover	128.0	0
Beets	192.9	0.3
Maize (CCM, WECS)	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 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)

When all products are on the farm, they must still 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 6.8 shows the direct energy consumption per ton of product fed. Feeding compound feed takes so little energy that no separate energy consumption is calculated for it.

Table 6.8 *Diesel consumption for feeding, per ton of product of the various feed ingredients. The DM contents belonging to the different feed ingredients are listed in Appendix 4.*

Feeding	Diesel (kg)
Roughage[1] (tons of product)	2.5
Other roughage[1] (tons of product)	3.9

By-products[1] (tons of product)	2.4
Fresh grass[1] (tons of product)	0.4

[1] The products belonging to the different feed ingredients 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 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 also calculates the normative consumption and maps out the magnitude of the associated CO_2 losses. To this end, the ANCA 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 fermentation

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:

Cooling milk (electricity): Depending on pre-cooler and heat recovery installation (y/n):
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 * 29.9644 (KWh)
Heat source is gas: Consumption gas = hot water * 5.7631 (m^3)
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 (m^3)
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 ruminant slurry is separated using an electrically powered screw press filter and non-ruminant slurry using a diesel-powered mobile separator.
Ruminant manure: Consumption = 1.0 kWh electricity per ton of input manure
Non-ruminant manure: Consumption = 0.8 litres diesel per ton of input manure

Manure fermentation:
For slurry fermentation it is assumed that the fermentation process takes place in a mono fermenter. This uses electricity for agitating, pumping, crushing etc. and heat to keep the digester at the desired temperature.
Consumption is estimated at 12 kWh per ton of input manure.

Other ruminants (electricity and gas):
For other ruminants, standard consumption is used (see Table 6.9).

Table 6.9 *Standard consumption of electricity and gas for other ruminants (Anonymous, 2019).*

	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
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

On-farm electricity generation

On-farm production of energy also generates CO_2. The average EF depends on the form of generation. These EF values can be found in Appendix 5.

At data entry, one ‘other’ form of energy generation can be specified, so that the average EF per MJ becomes equal to:

The average EF per MJ becomes:

EFelek_prod = fraction Bio * 12.78 + fraction Wind * 3.79 + fraction Sun * 22.77 + fraction Other * emission coefficient ‘other’, where

emission coefficient ‘other’ = weighted average of the well-known renewable sources:

(fraction Bio * 12.78 + fraction Wind * 3.79 + fraction Sun * 22.77) /
(fraction BIO + fraction WIND + fraction SUN)

If own energy is produced and possibly supplied back to the electricity grid, the energy supply must first be calculated:

OwnElek = production of electricity - supply of electricity back to grid
Supply = Electricity consumption - OwnElek

To calculate the CO_2 per energy carrier, the energy quantities must be multiplied by the EF values (see Appendix 5).

The above emissions do not include transport to the farm.

CO_2 electricity: Supply in kWh * 3.6 * (EFelek_grey * share of grey electricity + _
EFelek_green * share of green electricity)
+ OwnElek in kWh * 3.6 * (EFelek_prod * (1 - PcGVO/100) + _
EFelek_grey * PcGVO/100
CO_2 gas: Consumption of gas in m3 * proportion of normal gas * 31.65 * EFgas_norm
+ Consumption of gas in m3 * share of biogas * 21.80 * EFgas_bio

CO_2 prop: Consumption of propane in ltr * 0.51 * 45.2 * EF propane
CO_2 oil: Fuel oil consumption in ltr * 0.84 * 41.0 * EF fuel oil

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 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 maize silage (dried from 355 g/DM to 910 g/DM), artificially dried lucerne and clover (dried from 300 g/DM to 910 g/DM).

CO_2 emissions are taken into account for drying and baling or pelleting according to Table 6.10.

Table 6.10 *Emissions of CO_2 during the drying of various products, emission factor (EF) in g CO_2-eq/ton of incoming product, excluding transport to the drying location and back to the farm.*

Drying of	emission coefficient	Unit	Source
Grass bale, fresh grass	399	kg CO_2-eq/ton input	FeedPrint, 2020
Grass pellets, fresh grass	413	kg CO_2-eq/ton input	FeedPrint, 2020
Grass bale, pre-dried grass	263	kg CO_2-eq/ton input	FeedPrint, 2020
Grass pellets, pre-dried grass	295	kg CO_2-eq/ton input	FeedPrint, 2020
Maize silage	351	kg CO_2-eq/ton input	FeedPrint, 2020
other roughage	379	kg CO_2-eq/ton input	FeedPrint, 2020

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 6.11.

Table 6.11 *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 fertiliser	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
Packing silage	Ha	1.5	1.1	1.1	0.2
Rolling	Ha	2.9	1.9	3.1	0.3
Harrowing	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 6.12.

Table 6.12 *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)
Maize silage	124.2	82.4	133.8	14.1
WPS grains	124.2	82.4	133.8	14.1
Lucerne	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
Maize (CCM, WECS)	197.4	130.1	215.6	22.2
Grains, coarse grain	176.9	116.7	193.2	19.9
Grains, small grain	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 6.13.

Table 6.13 *Indirect energy consumption for feeding, per ton of product of the various feed ingredients. The DM contents of the different feed ingredients are listed in Appendix 4.*

	Electricity, indirect (MJ)	Gas, indirect (MJ)	Kerosene, indirect (MJ)	Coal, indirect (MJ)
Roughage[1] (tons of product)	2.0496	1.3976	2.0665	0.2386
Other roughage[1] (tons of product)	4.2212	2.8162	4.488	0.4808
by-products[1] (tons of product)	8.2959	5.222	9.9837	0.8916
fresh grass[1] (tons of product)	0.2626	0.1816	0.2553	0.031

1 The products belonging to the different feed ingredients are listed in Appendix 4.

6.4.2.3 Imported feed ingredients

As the ANCA primarily focuses on the utilisation and losses of N, P and C within the boundaries of the farm, the CO_2 emissions resulting from the production of feed (fertilisers, field work, transport, storage and processing) would not be included when this feed is not grown on the farm but elsewhere. These indirect emissions from purchased feed ingredients are calculated using standard values for emissions per kg of product taken from FeedPrint/Agrifootprint (FeedPrint, 2018) (also see Appendix 4).

An exception to the above is compound feed. From 2020 onwards, CO_2 emissions for the production of compound feed will in principle be supplied by the feed supplier based on the composition. If this value is not provided, the CO_2 emissions for production of compound feed will be based on the CP content.

Three values are available for this, for three different CP contents in compound feed based on compositions of average compound feed types in 2018/2019. The following is interpolated between these three values based on the CP content per feed batch:

- 141 g CP/kg = 816 g CO_2-eq/kg (standard compound feed)

- 222 g CP/kg = 1499 g CO_2-eq/kg (high-protein compound feed)
- 272 g CP/kg = 2136 g CO_2-eq/kg (extra high-protein compound feed)

The CO_2 emissions in Appendix 4 and compound feed include land use change and transport to the supplier. Emissions from transport to the farm are included separately.

If feed is sold from the initial stock, the corresponding CO_2 is deducted from this exported purchased quantity (= net purchase).

Feed sold in the reference year itself is already included in feed production (separation of processes).

Emissions related to feeding products are calculated separately, depending on the type of product.

6.4.2.4 Imported synthetic fertiliser

Synthetic fertiliser use must be multiplied by the EF value of the different types of synthetic fertiliser (Appendix 5). The emissions associated with synthetic fertiliser production are derived from Agrifootprint.

For organic manure only transport emissions are taken into account .

6.4.2.5 Imported pesticides

The use of pesticides in kg active substance (AS) is included as standard in accordance with Table 6.14.

Table 6.14 *Standard consumption of pesticides (kg AS/ha), source: www.agrimatie.nl.*

Kind	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 litter

The use of litter must be multiplied by the EF value of the various litter types (Appendix 5).

6.4.2.7 Imported water

The ANCA assumes 0.411 g CO_2 -eq per litre and 1.707 m^3 water per ton of milk (Agrimatie, 2018). For other ruminants, standard consumption is calculated per animal and is assumed to be tap water. Values are shown in Table 6.15. Greenhouse gas emissions for other ruminants are less relevant to greenhouse gas emissions for dairy operations because emissions for other ruminants are not included in dairy operations.

Table 6.15 *Standard consumption of water for other ruminants (Anonymous, 2019).*

Other ruminants	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

6.4.2.8 Imported livestock

The calculations in the ANCA are based on imported livestock in kg. The weight of the imported animals depends on the breed and their average age on arrival. A quantity of CO_2 is subsequently included per kg of animal (for EF values, see Appendix 5).

6.4.2.9 Imported silage covering material

The use of covering material is calculated based on the amount of grass products and maize silage products per ton DM according to Table 6.16.

Table 6.16 *Use of plastic as a covering material for grass silage and maize silage (kg / ton DM), source: Hospers et al., 2019.*

Roughage type	Use
Grass silage	0.95
Maize silage	1.49

The use of covering material must be multiplied by the EF value of covering material. The EF value of plastic is 3053 g of CO_2 equivalents per kg of plastic, excluding transport to the farm.

6.4.2.10 Transport

All products have a carbon footprint calculated up to a regional delivery point, i.e. a trader in fuels or fertilisers, etc. All these products still have to be transported by truck to the primary farm. In the calculations, the ANCA 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 6.17). The CO_2 emissions associated with this transport are estimated at 101 g CO_2 per ton per km.

Table 6.17 *Fixed transport distances (km) for various products.*

Product	Standard distance
Fresh grass, grass products and maize 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 fertiliser	100
Oil	100
Organic fertiliser	100
Straw	50
Cattle	250

6.5 Organic matter balance

Crop residues and organic manure are the main input items supplying organic matter (OM) to the soil. The ANCA calculates the OM imported via crop residues from grass and maize (WPMS, WEMS, CCM) by closely matching terms that are also used in the BEN module. With regard to imports via crop residues from other crops, crop-specific effective organic matter contributions from the literature have been used.

For grass and maize (excluding any residual plants in case of WEMS and CCM), BEN assumes a crop residue (stubble and root) of 75 and 15 kg N per ha respectively. In an equilibrium situation (continuous cropping), it is assumed that the same quantity is broken down every year. When both crops are rotated, it is assumed that an additional 75 kg N per ha will be sequestered annually under new grassland, with a maximum of 300 kg N per ha, but this amount will be completely broken down in the following arable period, regardless of its duration. Like BEN, BEC does not yet make a visible distinction between the organic matter balances of the grassland and the arable land. To calculate the organic matter contributions of the roots and stubble of grass and maize, the ANCA converts the N content into effective organic matter. To calculate the effective organic matter, the imported organic matter must be corrected for the part that has already been exhaled during the first 12 months, as per convention; only the organic matter that remains after that period is referred to as effective organic matter. Table 6.18 shows the conversion factors (‘HC values’) used in the ANCA.

Table 6.18 *Humification coefficients ('HC values') of fresh plant material, crop residues and organic fertilisers, the amount of organic matter per kg N-total in manure, and the fixed effective organic matter contribution of various fertilisers (http://www.kennisakker.nl/kenniscentrum/handleidingen/adviesasis-voor-de-bemesting-van-akkerbouwgewassen-organische-stof).*

Source	HC[1] (kg OM per kg OM applied)	OS/N	E.O.M.[1] contribution (per m³) [2]	(per kg N-total[2])
Fresh plant material[3]	0.25			
Crop residues[4]	0.30			
Ruminants slurry, manure code 14	0.70	17.8[5]	50	12
Ruminants solid manure, manure code 10	0.70	20.1[5]	98	14
Pasture manure ruminants[6]	0.70	17.8[5]	50	12
Non-ruminant slurry, manure code 50	0.33	11.3[5]	27	4
Ruminants solid manure, manure code 39	0.70	12.3[5]	84	4
Compost[7]	0.90	30.1[5]	152	27
Ruminants liquid fraction, manure code 11	0.70	11.7[5]	29	8
Ruminants solid fraction, manure code 13	0.70	24.1[5]	118	17
Fertiliser substitutes (blowdown lye, mineral concentrate)	0.33	2,9[8]	7	1
Digestate[9]	0.90 [10]	6.0[5]	30	5
Other[6]	0.70	17.8[5]	50	12

1 HC: the humification coefficient is the fraction that is still effectively present one year after application: 'EOM'.
2 Based on Table 1.2.
3 Grazing, mowing and harvesting losses, feed leftovers.
4 Roots, stubble, grass sod, WPMS, WEMS and CCM.
5 Den Boer et al., 2012.
6 Same as ruminant slurry.
7 Average biodegradable waste and green compost.
8 Velthof, 2011.
9 Average of cattle and fattening pigs and degradation of Norg of 25-50%.
10 Same as compost, due to prior mineralisation.

The input items for the effective organic balance are shown in Table 6.19. The organic matter balance 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 (WPMS, WEMS, CCM, lucerne, field bean) and marketable arable crops (grain maize, cereals, root crops, etc.). For the organic material balance, the weighted average of the individual types of land use is only calculated at the second stage. 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) applies to grassland hectares only, as follows:

EOMIn1 = In1 x OM / Nmanure x HCmanure, where:

OM / N_{manure} and HC_{manure} : see Table 2.5.20 for manure from grazing animals

The term OMIn2 (effective organic matter from 'barn manure') cannot simply be derived from the crop- and rotation-specific terms from BEN calculation if In2 includes manure from grazing animals. This is because in that case manure (In2) is defined as the sum of excreted manure and urine 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, with a distinction between continuous and rotational cropping, is equal to:

$EOMIn2_{pure\_manure}$ on grassland = Fraction 'real' manure x In2 on grassland x OM/N_{manure} x HC_{manure}

$EOMIn2_{pure\_ manure}$ on arable land = Fraction 'real' manure x In2 on arable land x OM/N_{manure} x HC_{manure}

where Fraction of 'real' manure = ((In2 at average farm level, kg N/ha - weighted average feed leftovers of all feed ingredients used, kg N/ha) / (In2 at average farm level, kg N/ha))

In2 at average farm level is the sum of the total N supply (kg N/ha) from manure from ruminants and non-ruminants, and compost. OM/N_{manure} and HC_{manure} are based on the N-supply weighted average values of the three types of manure used (Table 6.19). It is assumed that there is no difference in inputs of effective organic matter between unfermented and fermented manure. With fermented manure the OM/N ratio (becomes lower) and the HC (becomes higher) changes in such a way that the supply of EOM is equal to that of unfermented manure.

The effective organic matter applied via feed leftovers on the land ($OMIn2_{feed\ leftover}$) is equal to:

$EOMIn2_{feed\_leftover}$ on grassland = (1 – Fraction of 'real' manure) x In2 on grassland x $OM/N_{feed\_leftover}$ x HC_{fresh_crop}

$EOMIn2_{feed\_leftover}$ on arable land = (1 – Fraction of 'real' manure) x In2 on arable land x $OM/N_{feed\_leftover}$ x HC_{fresh_crop}

HC_{fresh_crop} = 0.25 and $OM/N_{feed\_leftover}$ based on the average N content of the ensiled roughage

The organic matter contributions from grazing, mowing and harvesting losses are based on the same HC's as those for fresh crops. This is a simplification of reality because the different crops will actually differ in degradability.

The effective organic matter that ends up on the grassland as grazing and mowing losses ($EOMIn6_{grass}$) is equal to:

$EOMIn6_{grassland}$ = ($In6_{grassland}$) x $OM/N_{cultivated\_grass}$ x $HC_{fresh\_crop,}$ where:

$In6_{grassland}$ = 5% to 20% of the N yield (kg N/ha) of the grassland (depending on the grassland use, see Table 1.1), $OM/N_{cultivation\ grass}$ = (kg OM/kg DM)/(kg N/kg DM in home-grown grass) = (90/100)/(kg N/kg DM in home-grown grass), and $HC_{fresh\ crop}$ = 0.25.

The effective organic matter that ends up on the arable land through harvesting losses is limited to that on maize land ($EOM_{maizelandharvestloss}$) because it is assumed that no other crop losses occur for the other arable forage crops and marketable arable crops, at least not in addition to the EOM contribution that are already attributed to these crops (see later in this section).

$EOM_{maize\_land\_harvest\_loss}$ (kg per ha arable land) = SO/BO x ($In6_{maize\_land}$) x $OM/N_{cultivated\_maize}$ x HC_{fresh_crop}, where:

SO = maize land area, BO = arable land area, $In6_{maize\_land}$ = 2% (Table 1.1) of the N yield (kg N/ha) of maize (WPMS, WEMS and CCM) from own land, $OM/N_{cultivated\_maize}$ = (kg OM/kg DM)/(kg N/kg DM in home-grown maize) = (90/100)/(kg N/kg DM in home-grown maize) and HC_{fresh_crop} = 0.25.

With regard to organic matter contributions from the crop residues, a slightly lower HC than the HC of fresh crops is assumed (Table 2.5.26), but with OM/N ratios that are assumed to be the same as those of the fresh crop. This is a simplification of reality because the crop residues will actually have a different N content (protein content). The effective organic matter that ends up on the grassland as crop residues ($EOMIn7_{grassland}$) is equal to:

> $EOMIn7_{grassland} = (In7_{grassland}) \times OM/N_{cultivation\ grass} \times HC_{crop\ residue}$, where: $In7_{grassland} = 75$, $OS/N_{cultivation\ grass}$ = kg OM per kg grass-N, and $HC_{crop\ residue} = 0.30$.

The effective organic matter that ends up on the grassland as crop residues ($EOS_{crop\_residue\_arable\_land}$) is equal to:

> $EOS_{crop\_residue\_arable\_land} = ((SO \times (In7_{maize\_land}) \times OM/N_{cultivated\_maize} \times HC_{crop\_residue}) + ((BO-SO) \times EOM_{crop\_residue\_non\_maize\_land}))/BO$, where:

SO = maize land area, $In7_{maize\_land} = 15$, $OM/N_{cultivated\_maize}$ = kg OM per kg maize N, $HC_{crop\_residue} = 0.30$, BO = arable land area, and $EOM_{crop\_residue\_non\_maize\_land}$ = the area-weighted EOM contributions of the non-maize arable crops and their by-products left behind (if any) (Table 6.20).

The contribution of effective organic matter in the form of grazing and mowing losses on grassland ($EOMIn6_{grassland}$), harvesting losses on maize land ($EOM_{maize\_land\_harvest\_loss}$), crop residues on grassland ($EOMIn7_{grassland}$) and crop residues on arable land ($EOM_{crop\_residue\_arable\_land}$) are assumed to benefit the crops from which they originate. That this is not the reality in every phase of a crop rotation is ignored here.

The term EOMIn8 (effective organic matter in the form of catch crops and green manures) only relates to the organic matter balance of arable land, as follows:

> $EOMIn8 = ((SO \times FV \times In8_{maize\_land} \times OM/N_{catch\_crop} \times HC_{fresh\_crop}) + ((BO-SO) \times FG \times EOM_{green\_manure}))/BO$, where:
>
> SO = maize land area, FV = fraction of maize land sown with a catch crop, $In8_{maize\_land}$ = 40 kg N per ha, $OM/N_{catch\_crop} = 45$, $HC_{fresh\_crop} = 0.25$, BO = arable land area, FG = fraction of the non-maize arable land sown with a green manure crop, $EOM_{green\_manure\_crop}$ = 1000 kg per ha (Table 6.20).

Table 6.19 *Input terms for determining the input of effective organic matter (kg/ha), indicating ('X') whether the data relate to the farm as a whole, to crops (grassland, arable land) or to crops with a distinction between the part with crops in rotation and continuous cropping.*

Code	Item	Scale	
		Farm	Grassland, Arable land
EOMIn1	Pasture manure		X
EOMIn2	'Barn manure', excluding feed leftovers roughage		X
$EOMIn2_{feed\ leftover}$	Feed leftovers		X
EOMIn6	Grazing, mowing and harvesting losses		X
EOMIn7	Crop residues		X
EOMIn8	Catch crops and green manures		X

Table 6.20 *Effective organic matter contribution (EOM, kg per hectare per year) of some arable crops and green manures (source: after Timmer et al., 2004).*

Crop	Crop residue	By-product
WPS grains	1650	-
Lucerne	1350	-
Red clover	1350	-
Beets	400	1000
Maize	700*	1350****
Grains, coarse grain	700	1350
Grains, small grain	1650	850
Grass seed	2500**	500
Legumes	500	500
Potatoes	900***	-
Seed potatoes	900	-
Onions and bulbs	300	-
Leafy vegetables	450	-
Non-leafy vegetables	600	150
Other	1700	-
Green manure	1000	-

* In practice, the contribution of the 'by-product' (straw) of 1350 kg per hectare will be added.

** Average of various grass seed types and including straw.

*** Including 100 kg per hectare of baby potatoes.

**** Estimated as a product of 6000 kg dry matter per hectare, of which 90% organic matter and a humidification coefficient of 25%.

The compounds that make up this organic matter also contain N, P and C. 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. Since organic matter in the soil consists of approximately 58% C (Anonymus, 2014), 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 580 kg C (2127 CO_2), 48 kg N and 6 kg P (14 kg P_2O_5).

6.6 Comments on BEC

- The CO_2 released as a result of fossil fuel use by 'non-ruminants' (pigs, chickens, veal calves) on-farm or 'upstream' (via purchased feed), is not yet included in ANCA. This means that the total emission of CO_2 equivalents is underestimated when 'non-ruminants' are present.

- With regard to N and P, ANCA 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 fertilisers, purchased feed ingredients, energy) are also included in the ANCA.
- With regard to the (effective) organic matter balance, the following should be noted. As a rule of thumb, it is assumed that the balance should be 1250-2500 kg of effective organic matter per hectare per year. This is based on the idea that a litre of soil weighs approximately 1300 grams, the topsoil is 25-30 cm thick, a soil contains 2-3% more or less stable organic matter and degrades approximately 2% of this annually (Kortleven, 1963). Since this rule of thumb is based on many assumptions, this also means that a balance of less than 1250-2500 kg per ha does not necessarily indicate a decrease in the organic matter content of the soil. Likewise, a balance of more than 1250-2500 kg per ha does not necessarily indicate an increase in organic matter content. Ideally, the supplementation required to maintain the organic matter content at a certain level should not be determined based on the rule of thumb, but farm-specifically as a function of the desired content. The required supplementation can then be compared with the result achieved, from which it can be deduced whether the organic matter content tends to decrease or increase. The outcome of this may be a reason to (re)sample the soil. Even then, vigilance is required because correct sampling is difficult due to changes in the density of the soil, sampling depth in relation to changed tillage methods, and contamination of deeper soil layers with soil material from higher layers during sampling. Conclusions about the fate of N and P linked to the organic matter can be drawn only if repeated, multi-year analyses show a systematic pattern.
- 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 ruminants and non-ruminants, 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 currently underestimates the organic matter supply when solid manure is used.

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Appendix 1 References of indicators to relevant sections in this report

Department	Indicator	Description in calculation rules report
BEX and BEP	Benefit of farm-specific excretion: nitrogen	See Appendix 2
	Benefit of farm-specific excretion: phosphate	See Appendix 2
	Benefits of farm's own usage standard: phosphate	See Appendix 2
	BEX excretion per ton of milk: nitrogen (kg N)	Excretion calculation for nitrogen in section 2.1.2. Divide by quantity of produced milk[1]
	BEX excretion per ton of milk: phosphate (kg P_2O_5)	Excretion calculation for phosphate in section 2.1.2 Divide by quantity of produced milk[1]
	Milk per kg of BEX excretion: phosphate (kg milk)	Quantity of produced milk[1] divided by phosphate excretion [see section 2.1.2]
Farm surplus	Surplus per ha: nitrogen (kg N)	Section 2.3.2.1
	Surplus per ha: phosphate (kg P_2O_5)	Section 2.4.1
Efficient feeding	Use efficiency: nitrogen (%)	Section 1.4.3
	Use efficiency: phosphate (%)	Section 1.4.3
Grassland yield	Gross yield per ha: DM (kg DM)	See footnote 3
	Net yield per ha: DM (kg DM)	DM grass intake [section 2.1.2] + (P-yield grassland per ha [section 2.4.1] – P grass intake per ha [section 2.1.2])/average P content of grass silage on own land[1] / (1-(percentage feed loss/100))/(1-(percentage conservation loss/100))
	Net yield per ha: KVEM (kvem)	VEM grass intake [section 2.1.2] + ((P yield grassland per ha [section 2.4.1] – P grass intake per ha [section 2.1.2]) / average P content of grass silage on own land[1] x average kVEM content of grass silage on own land[1] / (1-(percentage feed loss/100)) / (1-(percentage conservation loss/100))
	Net yield per ha: nitrogen (kg N)	N grass intake [section 2.1.2] + (P yield grassland per ha [section 2.4.1] – P grass intake per ha [section 2.1.2]) / average P content of grass silage on own land[1] x average N content of grass silage on 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 2.4.1] x (1-(percentage feed loss/100)) x (1-(percentage conservation loss/100))
Maize silage yield	Gross yield per ha: DM (kg DM)	Net DM yield of maize silage [section 2.1.2] / (1-(percentage field loss [Table 1]/100))
	Net yield per ha: DM (kg DM)	(P yield maize silage per ha [section 2.4.1] / average P content of grass silage[1] on own land x (1-(percentage feed loss) x (1-percentage conservation loss)
	Net yield per ha: KVEM (kvem)	(P yield maize silage per ha [section 2.4.1] / average P content of grass silage[1] on own land x average kVEM content of grass silage on own land[1] x (1-(percentage feed loss/100)) * (1-(percentage conservation loss/100))
	Net yield per ha: nitrogen (kg N)	(P yield maize silage per ha [section 2.4.1] / average P content of grass silage[1] on own land x average N content of grass silage on own land[1] x (1-(percentage feed loss/100)) * (1-(percentage conservation loss/100))

Department	Indicator	Description in calculation rules report
	Net yield per ha: phosphate (kg P_2O_5)	(P yield maize silage land per ha [section 2.4.1] x (1-(percentage feed loss/100)) x (1-(percentage conservation loss/100))
Soil surplus	Surplus per ha: nitrogen (kg N)	Section 2.3.2.1
	Surplus per ha: phosphate (kg P_2O_5)	Section 2.4.1
	Imported effective org. matter per ha (kg EOM)	Section 2.5.6.13
Soil efficiency	Use efficiency: nitrogen (%)	Section 1.4.5
	Use efficiency: phosphate (%)	Section 1.4.5
Ammonia	Emissions per farm: total (kg NH_3)	Section 2.2.2.1
	Emissions per ton of milk: total (kg NH_3)	Divide total emissions (2.2.2.1) 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 2.2.2.3-2.2.2.5) by number of LU on farm[2]
	Emissions per ha: fertilisation and harvest (kg NH_3)	Divide total fertilisation and harvest emissions (sections 2.2.2.6-2.2.2.9) by number of hectares[1]
Farm greenhouse gas emissions	Emissions per ton of FPCM: on-farm methane (kg CH_4)	Divide methane emissions (sections 2.5.6.1, 2.5.6.2) by supplied FPCM[1] x 1000
	Emissions per ton of FPCM: on-farm nitrous oxide (kg N_2O)	Divide nitrous oxide emissions (sections 2.3.2.2, 2.3.2.3) by supplied FPCM[1] x 1000
	Emissions per ton of FPCM: on-farm other (kg CO_2-eq)	Divide other CO_2 emissions (sections 2.5.6.3, 2.5.6.4, 2.5.6.7, 2.5.6.9-2.5.6.11) by supplied FPCM[1] x 1000
	Emissions per ton of FPCM: total on-farm (kg CO_2-eq)	(Multiplication of CH_4 at farm level x 34 + multiplication of N_2O x 298 + on-farm emissions with CO_2) / supplied FPCM[1] x 1000
	Emissions per ton of FPCM: off-farm total (kg CO_2-eq)	Divide farm emissions (sections 2.5.6.5, 2.5.6.8, 2.5.6.12) by supplied FPCM[1] x 1000
	Emissions per ton of FPCM: farm total (kg CO_2-eq)	(Multiplication of CH_4 at farm level x 34 + multiplication of N_2O x 298 + sum of (on-farm emissions with CO_2 and off-farm emissions with CO_2) / supplied FPCM[1] x 1000

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]/100)) +
- dividing net grass silage yield (DM) by (1-(field losses [Table 1]/100))

Appendix 2 Definition and calculation of additional indicators

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, this is described as 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):

https://www.rvo.nl/sites/default/files/2019/01/Tabel-4-Diergebonden-forfaitaire-gehalten%202019-2021.pdf
https://www.rvo.nl/sites/default/files/2019/01/Tabel-6-Stikstof-en-fosfaatproductiegetallen-per-melkkoe.pdf

BEP advantage ('P equilibrium fertilisation')
A calculation of the amount of on-farm phosphate harvested is provided in section 4.2. This harvested quantity can in principle also be applied on the land with phosphate fertilisers in order to achieve equilibrium fertilisation. But just as in the generic manure policy, the BEP also takes account of the phosphate status of the soil; see also:

https://www.rvo.nl/onderwerpen/agrarisch-ondernemen/mest/gebruiken-en-uitrijden/hoeveel-fosfaat-landbouwgrond/fosfaatdifferentiatie

Grasland 2020 [1]

Klasse	PAL-waarde	Hoeveel fosfaat (per ha)	Protocol voor bemonsteren
Hoog	> 50	75 kg	Geen
Ruim	41 t/m 50	90 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Neutraal	27 t/m 40	95 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Laag	16 t/m 26	105 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Arm	< 16	120 kg	Fosfaatarm en Fosfaatfixerend

Bouwland 2020 [1]

Klasse	Pw-waarde	Hoeveel fosfaat (per ha)	Protocol voor bemonsteren
Hoog	> 55	40 kg	Geen
Ruim	46 t/m 55	60 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Neutraal	36 t/m 45	70 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Laag	25 t/m 35	80 kg	Fosfaatdifferentiatie en Derogatie, of Fosfaatarm en Fosfaatfixerend
Arm	< 25	120 kg	Fosfaatarm en Fosfaatfixerend

[1] Wilt u de normen van 2019 weten? Deze staan in Tabel 2 Fosfaatgebruiksnormen in het archief.

For a phosphate status of 'amply sufficient' and 'high', the farm-specific phosphate standard (BEP standard) is reduced by the difference in the usage standard classed as 'neutral'. For a phosphate status of ‘low’ and ‘poor’, the farm-specific phosphate standard (BEP standard) is increased by the difference in the usage standard classed as ‘neutral’. For example, for a ‘high’ status on grassland, the BEP standard is reduced by 20 kg P_2O_5 per ha, and for a ‘low’ status, it is increased by 10 kg P_2O_5 per ha.

By establishing the surface area of grassland and arable land classed as ‘high’, ‘amply sufficient’, ‘neutral’, ‘low’ and ‘poor’, a BEP standard for a specific year can be established for each category. The BEP crop yield for each crop is then corrected by the difference between the phosphate status in the ‘neutral’ category and the category of the corresponding plot. Then, depending on the proportion of the various categories with a specific phosphate status, a BEP standard per hectare for a specific year is determined for each crop. Averaging this specific BEP standard over three years produces the BEP standard used by the ANCA as the fertilisation standard for the coming year.

The surface area with the various categories of phosphate status also provides input for the ANCA.

The BEP advantage is the difference between the BEP standard as an average over the three previous years and the generic usage standard for phosphate (taken from the ANCA input of the ‘fertilisation plan’) divided by the generic usage standard for phosphate (generic) * 100%.

BEP advantage (%) = 100 * (generic - BEP)/generic

Therefore, if the BEP standard is greater than the generic usage standard, this is described as a BEP advantage.

On-farm protein
On-farm protein = 100 * (crop_g + crop_m + crop_o) / consumption

where:

crop_g	= N yield from grassland (after conservation)
crop_m	= N yield from maize silage (after conservation)
crop_o	= N yield from other fodder (after conservation)

This means that all fodder crops used on the farm are included in the calculation of ‘on-farm protein’. Arable crops grown for the market are not included in the calculation of ‘on-farm protein’.

consumption = N herd consumption (= intake + feed loss)

Sample calculation

<u>Calculation of cultivation of own nitrogen:</u>
In the ANCA output, go to the ‘Soil’ section. In ‘Crop yield’, go to the line ‘Nitrogen, net (kg/ha)’. Take the values for natural grassland, production grassland, maize silage and, if applicable, arable land. See also the circled values in the screenshot below (242, 157 and 97), Figure B1.1. This is the nitrogen yield of the crop after deduction of field losses.

Gewasopbrengst	Natuurgras	Productiegras	Snijmais	Akkerbouw
Opbrengst gewas:				
- Droge stof, bruto (kg ds/ha)	243	7638	12599	
- Droge stof, netto (kg ds/ha)	212	7058	12347	
- KVEM, netto (kvem/ha)	182	6705	12675	
- Stikstof, netto (kg/ha)	6	181	142	48
- Fosfaat, netto (kg/ha)	2	48	46	24
Voederwaarden gewas:				
- VEM, netto (/kg ds)	860	950	1027	
- RE, netto (g/kg ds)	189	160	72	
- P, netto (g/kg ds)	4.00	2.99	1.64	

Figure B1.1 *Explanation of the nitrogen yield of the crops in the ANCA output.*

The areas of grassland, natural grass, maize land and arable crops are 36.87 ha, 1.2 ha, 16.9 ha and 3 ha respectively. This can be seen in the 'Soil and crops' section in the farm profile. See also the screenshot below (Figure B1.2).

Bedrijfsportret van uw bedrijf	
Grond en gewassen	**2020**
Areaal gewassen totaal (ha)	57.97
- productiegras (ha)	36.87
- natuurgras (ha)	1.20
- snijmais (ha)	16.90
- akkerbouw (ha)	3.00
Gemiddeld aandeel klaver in grasland (%)	0.3
Grondsoort aandelen (%):	
- gras: veen / klei / nat zand / ov zand / drg zand	0/0/3/22/76
- bouw: veen / klei / nat zand / ov zand / drg zand	0/0/0/57/43

Figure B1.2 *Explanation of the surface area of the various crops in the ANCA output.*

From this, it can be calculated that 36.87 * 181 = 6673 kg nitrogen has been harvested from production grassland (after field losses) and 1.2 * 6 = 7.2 kg nitrogen from natural land. Together this comes to 6687.7 kg nitrogen. But part of this is fresh grass. This can be seen under 'livestock – ration result' (in the report). See also Figure B1.3, 83395 kg DM.

Rantsoen melkvee	Opname	Aandeel	VEM	RE	Aandeel	P	RE/kVEM	P/kVEM
	(kg ds)	(% van ds)	(/kg ds)	(g/kg ds)	(% van re)	(g/kg ds)	(g/kvem)	(g/kvem)
Vers gras	83395	11.7	960	188	13.9	3.30	196	3.4
Grasland producten	203649	28.5	901	174	31.3	3.49	193	3.9
Snijmais producten	191963	26.9	1022	73	12.4	1.74	71	1.7
Ov. ruwvoer, bijprod.	58118	8.1	922	129	6.6	1.60	140	1.7
Krachtvoeders *	173795	24.4	1085	230	35.3	4.41	212	4.1
Melkproducten *	2441	0.3	1576	231	0.5	7.67	147	4.9
Rantsoen	713361	100.0	989	158	100.0	3.08	160	3.1

*** Gehalten voer per kg product:**

Krachtvoeders : DS-gehalte = 880 g/kg (VEM=955 vem, RE=202 g, P=3.88 g)

Melkproducten : DS-gehalte = 962 g/kg (VEM=1516 vem, RE=222 g, P=7.38 g)

Figure B1.3 *Explanation of the feed intake of the dairy herd in DM and the CP content of the various feed ingredients.*

It can therefore be calculated that the intake of nitrogen with fresh grass is as follows: 83395 kg DM * 188 (g CP/kg DM) / 6.25/1000 = 2509 kg nitrogen intake from fresh grass (also see Table B1.1.). This means that the quantity of harvested nitrogen with grass silage can be determined as follows. The total nitrogen harvest from grassland (production grassland + natural grassland) – intake of nitrogen with fresh grass = (6673 + 7.2) – 2509 = 4172 kg nitrogen harvest before conservation. Conservation losses still need to be deducted from this. For grass silage this amounts to 3% of the nitrogen (Schröder et al., 2019; Table 1.1). This means that the quantity of nitrogen in the grass silage after conservation is 4047 kg.

Table B1.1 *Calculation of quantity of nitrogen absorbed with fresh grass.*

	kg DM	CP content (g/kg DM)	absorbed N
Fresh grass intake	83395	188	2509

For maize silage and other fodder crops, the post-conservation harvest is easier to calculate. The harvested quantity of nitrogen (before conservation losses) is a multiplication of the surface area with the quantity of harvested nitrogen per ha (see the values of maize silage and arable crops in Figures B1.1 and B1.2). The conservation losses of nitrogen for maize silage and other fodder crops are 1% and 1.5% of the harvested nitrogen respectively (Schröder et al., 2019; Table 1.1). This results in conserved nitrogen yields per hectare of 1545 kg N/ha for maize land and 577 kg N for other fodder crops (see also Table B1.2).

Table B1.2 *Calculation of the quantity of harvested nitrogen (kg N, after conservation) of fodder crops for the example farm.*

	Surface area, ha	Net, pre-conservation, kg N/ha	Total pre-conservation, kg	Conservation losses N (%)	Total N post-conservation, kg
Production grassland, total	36.56	242	8848		
Natural grassland, total	1.2	6	7		
Fresh grass intake			2509	0	2509
Grass silage (= total - fresh grass intake)			4172	3	4047
Maize land	16.9	142	2400	1	2376
Arable crops*	3	48	144	1.5	142
TOTAL					9073

* marked crops

<u>Correction for export of arable crops</u>
Some dairy farmers also grow arable crops. These are marketed and exported from the farm. They are not fodder crops and therefore do not have to be included in the level of on-farm protein self-sufficiency, i.e. not in the cultivation of on-farm protein. However, the quantity of nitrogen cultivated with arable crops is shown in the soil section (see Figure B1.1).

The quantity exported as marketable and not as fodder crop is stated in the part of the export report entitled FEED AND CROP – IMPORT export feed and crop. Also see Figure B1.4.

Overig veevoer	(kg ds)	(g N/kg ds)	(g P/kg ds)
Afvoer uit aangelegde voorraad	0		
Overige producten	**(kg)**	**(g N/kg)**	**(g P/kg)**
Afvoer akkerbouw hoofdproducten	80000	1.80	0.39
Afvoer akkerbouw bijproducten	0		

Figure B1.4 Explanation of export of arable products in the export report.

If a proportion of the arable crop in this example is marketed, it is important to eliminate the nitrogen production before sale of the arable crop. This is 80000 * 1.8 / 1000 = 144 kg nitrogen. This means that all 144 kg N from the arable crops grown is marketed and exported (see Table B1.2). The conservation losses from the other fodder crops amount to 1.5% (Schröder et al., 2019; Table 1.1). This means that 144 * 0.985 = 142 kg nitrogen from the arable crop still remains after conservation.

Therefore, none of the quantity of arable crop shown in Table B1.2 should be included in 'own cultivation'.

<u>Calculation of total nitrogen fed</u>
In the ANCA output, go to the 'Ration' section. Find the dry matter intake per feed ingredient and the associated CP contents of the various feed ingredients (see also the red circles in Figure B1.3). Multiplying the intakes by the CP contents gives the net intake of crude protein from the various feed ingredients.

In addition, the crude protein content must be converted to nitrogen. This means that the quantity of crude protein must be divided by 6.25, except for milk powder, which must be divided by 6.38. Grams have now been calculated via the content of g/kg. Dividing by 1000 gives kilograms of nitrogen that are taken up net by the herd. To make an effective comparison with the harvested quantity after conservation, the feed losses must be added to the net intake quantities. For grass and maize silage, the feed losses are 5% of the nitrogen. The feed losses in by-products are 3% and in concentrate and minerals 2% (Schröder et al., 2019; Table 1.1). The reason why the fed quantity of harvested grassland products (Table B1.3: 5968 adjusted for feed losses) is not the same as the quantity of harvested grassland products (Table B1.2: 4047) is because not everything fed during the course of a year is actually harvested on the farm in that year and vice versa.

Table B1.3 shows the total nitrogen fed on the example farm calculated before feed losses and after conservation.

Table B1.3 *Calculation of total fed nitrogen on the example farm (kg).*

Ration:	kg DM	CP (g/kg)	N (g/kg)	N intake per product (kg)	Feed loss (%)	Fed N per product (kg)
Fresh grass	83395	188	30.08	2509	0	2509
Grassland products harvested	203649	174	27.84	5670	5	5968
WPMS products harvested	191963	73	11.68	2242	5	2360
Other roughage and by-products	58118	129	20.64	1200	3	1237
Concentrates and minerals	173795	230	36.8	6396	2	6526
Milk products	2441	231	36.2	88	2	90
TOTAL						18690

The total fed N is 18690 kg, and the cultivated quantity of N (feed and other) is 8931 kg[2]. The percentage of own cultivated N compared with fed N is therefore 100 * 8931 / 18690 = 48%. This indicator is described as on-farm protein in the 'Environment & Climate' section.

Nitrogen soil surplus per hectare

The N soil surplus of the grassland, maize land and the land where marketable arable crops are grown is calculated. 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) + % maize land * N soil surplus (maize 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 fertiliser and with mineralisation, deposition and legumes are circled. See also Figure B1.5 with the circled values. This comes to a total of 281 kg per ha in this example. Nitrogen export per hectare with crops amounts to 159 kg (see arrow). The nitrogen soil surplus is then 122 kg per ha.

Milieu & Klimaat

Stikstofbodemoverschot	2020	2019	2018
Overschot bodem totaal (kg N per ha)	122		
Aanvoer kunstmest (kg N per ha)	53		
Aanvoer organische mest, weidemest (kg N per ha)	194		
Aanvoer mineralisatie, depositie, vl.bloemigen (kg N per ha)	34		
Afvoer van geoogste producten (kg N per ha)	159		

Figure B1.5 *Explanation of nitrogen import on the soil and nitrogen export from the soil resulting in a nitrogen soil surplus, 'Environment & Climate' section in the ANCA export report.*

Ammonia emissions per hectare

Ammonia emissions per ha = (ruminant NH_3 emissions from barn and manure storage/ha + NH_3 emissions during grazing/ha + NH_3 emissions during manure application/ha + NH_3 emissions from use of synthetic fertiliser/ha + NH_3 emissions from crop residues from grazing and harvesting losses/ha)

[2] This is the total amount cultivated minus the marketed arable crop.

See also ‘FARM RESULT Ammonia’ in the ANCA export report for the various components of the ammonia emissions per ha and per LU (Figure B1.6).

Emissie ammoniak	NH3 (kg/bedrijf)	NH3 (kg/ha)	NH3 (kg/ton melk)	NH3 (kg/GVE)
Emissie totaal	2794	48.2	3.60	27.4
- emissie uit stal+mestopslag, graasdieren	1292	22.3	1.66	12.7
- emissie uit stal+mestopslag, staldieren	0	0.0	0.00	0.0
- emissie uit org. mest op grasland	1119	19.3	1.44	11.0
- emissie uit org. mest op bouwland	250	4.3	0.32	2.5
- emissie uit kunstmest op grasland	76	1.3	0.10	0.7
- emissie uit kunstmest op bouwland	0	0.0	0.00	0.0
- emissie uit mest tijdens beweiding	33	0.6	0.04	0.3
- emissie uit gewasrest: weideverliezen	13	0.2	0.02	0.1
- emissie uit gewasrest: oogstverliezen	10	0.2	0.01	0.1

Figure B1.6 *Explanation of the ammonia emissions in various parts of the dairy farm, ‘FARM RESULT Ammonia’ in the ANCA export report.*

Ammonia emissions per LU

Ammonia emissions per LU = (ruminant NH_3 emissions from barn and manure storage / LU + NH_3 emissions during grazing / LU + NH_3 emissions during manure application / LU + NH_3 emissions from use of synthetic fertiliser / LU + NH_3 emissions from crop residues from grazing and harvesting losses / LU)

See also ‘FARM RESULT Ammonia’ and Figure B1.5 of the ANCA export 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 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, the livestock farmer can also have natural grassland (permanent or otherwise) with nature as the main function, which does not come 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% * total area with code (265, 331, 333, 334) : (total farm area - total area with code (332, 335))

Appendix 3 List of acronyms

By subject

General farm aspects

N:	Nitrogen
P:	Phosphorus
NO_3:	Nitrate
N_2O:	Nitrous oxide
PO_4:	Phosphate
NO_x:	Nitrogen oxides
CO_2:	Carbon dioxide
CH_4:	Methane
NH_3:	Ammonia
NH_4:	Ammonium
EF:	Emission factor, %
TO:	Total farm area, ha
GO:	Total area of grassland, ha
BO:	Total area of arable land including maize silage, ha
SO:	Area of maize silage, ha
ORO:	Area of other arable roughages
AMO:	Area of arable crops for market, 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 fertiliser application (kg N/ha grassland) between grassland in continuous cultivation and grassland in rotation
EKB:	Difference in synthetic fertiliser application (kg N/ha arable land) between arable land in continuous cultivation and arable land in rotation
Purchase_change_factor:	Ratio between BEX-based P intake and P intake as reported
BEX_Popn_gksm_mlk:	P intake by dairy cattle from grass silage and maize silage
BEX_Popn_gksm_ovg:	P intake by other ruminants from grass silage and maize silage
Voorraad_Pverbr_gksm:	P consumption calculated from reported stocks (initial + added – end)
PcVoerververliesRuwvoer:	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
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 manures, 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_{maure}:	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
$OM/N_{cultivated\_maize}$:	OM/N in maize harvest losses
FV:	Fraction of maize land (SO) sown with a catch crop (ha)
FG:	Fraction of non-maize land (BO – SO) sown with green manure (ha)

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
$Out1_{maize}$:	Net exported N in the form of maize, kg N per ha maize 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
$Out3_{maize}$:	Harvest losses from maize, kg N per ha maize land
$Out3_{other\_roughage}$:	Harvest losses from other roughage (lucerne), 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_{maize_silage}: N absorbed by animal in the form of maize 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
$NOP_{maize\_own\_land}$: N absorbed by animal in the form of maize silage from own land, kg N
$NOP_{maize\_purchased}$: N absorbed by animal in the form of purchased maize silage, kg N
$NAAN_{maize\_own\_land}$: N offered to animal in barn in the form of maize silage from own land, kg N
$NDAM_{maize}$: N removed by machine in the form of maize 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
$Outn_{maize}$: Export term n on the N balance of surface area with maize 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_{maize}: Import term n on the N balance of the area with maize 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

YHn: Yield of main product of marketable arable crop n, ton fresh per ha
YBn: Yield of by-product of marketable arable crop n, ton fresh per ha
CNHn: N content of main product of marketable arable crop n, kg N per ton fresh
CNBn: N content of by-product of marketable arable crop n, kg N per ton fresh
CPHn: N content of main product of marketable arable crop n, kg N per ton fresh
CPBn: P content of by-product of marketable arable crop n, kg N per ton 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 fertiliser 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
$EF_{(S)}$:	Emission factor for nitrous oxide from manure storage according to storage system S, 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 fertiliser 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 fertiliser 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
RAV:	Ammonia and Animal Husbandry Regulation

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
$B0_{(T)}$:	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
$CH_{4Fertiliser}$:	Totalled methane emissions from manure storages according to system S for animal category T, 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 S, -
BE:	Gross energy, MJ
Y_m:	Methane conversion factor, MJ / 100 MJ

Alphabetical classification

$Inn_{grassland}$:	Import term n on the N balance of grassland, kg N per ha
Inn_{maize}:	Import term n on the N balance of the area with maize land, 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
$Inn_{other\_roughage}$:	Import term n on the N balance of the area with other roughage crops, kg N per ha
$Out1_{cut\_grass}$:	Net exported N in the form of grass silage or fresh stall-fed grass, kg N per ha grassland
$Out1_{maize}$:	Net exported N in the form of maize, kg N per ha maize land
$Out1_{market\_arable}$:	Net exported N in the form of marketable arable crops, kg N per ha marketable arable crops
$Out1_{other\_roughage}$:	Net exported N in the form of other roughage, kg N per ha other roughage
$Out1_{pasture}$:	Net absorbed N in the form of pasture grass ingested by animal, kg N per ha grassland
$Out3_{cut\_grass}$:	Mowing losses from collection of grass silage or fresh stall-fed grass, kg N per ha grassland
$Out3_{maize}$:	Harvest losses from maize, kg N per ha maize land
$Out3_{market\_arable}$:	Harvest losses from marketable arable crops, kg N per ha marketable arable crops
$Out3_{other\_roughage}$:	Harvest losses from other roughage (lucerne), kg N per ha other roughage
$Out3_{pasture}$:	Grazing losses in grazed grass, kg N per ha grassland
$Outn_{grassland}$:	Export term n on the N balance of grassland, kg N per ha
$Outn_{maize}$:	Export term n on the N balance of surface area with maize land, 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
$Outn_{other\_roughage}$:	Export term n on the N balance of surface area with other roughage crops, kg N per ha

Ammonia

AMO:	Area of arable crops for market, not roughage, ha
$B0_{(T)}$:	Potential methane production from animal category T, m^3 CH_4 per kg excreted VS
BE:	Gross energy, MJ
BEX_Popn_gksm_mlk:	P intake by dairy cattle from grass silage and maize silage
BEX_Popn_gksm_ovg:	P intake by other ruminants from grass silage and maize silage
BO:	Total area of arable land including maize silage, ha

Soil nitrogen

CH_4:	Methane
CH_4:	Methane
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_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_EFration:	basic methane emissions (CH_4_EFbasis) corrected for share of calves in total dairy LU sum
CH_4_feed:	kg methane emissions totalled for the various ration components
$CH_{4Fertiliser}$:	Totalled methane emissions from manure storages according to system S for animal category T, kg CH_4
CNBn:	N content of by-product of marketable arable crop n, kg N per ton fresh

CNHn:	N content of main product of marketable arable crop n, kg N per ton fresh
CO_2:	Carbon dioxide
CPBn:	P content of by-product of marketable arable crop n, kg N per ton fresh
CPHn:	N content of main product of marketable arable crop n, kg N per ton fresh

Animal

DM:	Dry matter
EF(an):	Emission factor for nitrous oxide resulting from use of pasture manure, kg/kg
EF(cf):	Emission factor for nitrous oxide resulting from use of fertiliser N, 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(lea):	Emission factor for nitrous oxide resulting from leached N, kg/kg
EF(of):	Emission factor for nitrous oxide resulting from use of barn manure, kg/kg
EF(pt):	Emission factor for nitrous oxide resulting from presence of peat soil, kg/kg
$EF_{(S)}$:	Emission factor for nitrous oxide from manure storage according to storage system S, kg/kg
$EF_{(T)}$:	Emission factor for methane from manure storage for animal category T, kg CH_4 per animal
EF(vol):	Emission factor for nitrous oxide resulting from volatilised N deposited elsewhere, kg/kg
EF:	Emission factor, %
EKB:	Difference in synthetic fertiliser application (kg N/ha arable land) between arable land in continuous cultivation and arable land in rotation
EKG:	Difference in synthetic fertiliser application (kg N/ha grassland) between grassland in continuous cultivation and grassland in rotation
EOM:	kg effective organic matter (OM), the organic matter that remains in the soil 12 months after application, kg (E)OM per ha
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
$EOMIn2_{pure\_manure}$:	Effective organic matter in the form of manure without feed leftovers
$EOMIn2_{feed\_leftovers}$:	Effective organic matter in the form of feed leftovers
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 manures, kg OM/ha
ESB:	Difference in barn manure application (kg N/ha arable land) between arable land in continuous cultivation and arable land in rotation
ESG:	Difference in barn manure application (kg N/ha grassland) between grassland in continuous cultivation and grassland in rotation
Purchase_change_factor:	Ratio between BEX-based P intake and P intake as reported
FG:	Fraction of non-maize land (BO – SO) sown with green manure (ha)
FJK:	LU share of calves (0-3 mths) in total dairy LU sum
FPCM:	Fat and protein corrected milk production
FV:	Fraction of maize land (SO) sown with a catch crop (ha)
WT:	Live weight
GO:	Total area of grassland, ha
Gt:	Groundwater trap, -
HC:	Humification coefficient, fraction of organic matter (OM) remaining in the soil 12 months after application, kg OM per kg OM
$HC_{crop\_residues}$:	HC of crop residues

HC_{manure}:	HC of manure
HC_{fresh_crop}:	HC of fresh crop including feed leftovers

Nitrous oxide

MCF_S:	Methane conversion factor for manure management system S, kg per 100 kg

Methane

$MS_{(T,S)}$:	Fraction of NexcretionT according to manure management system S, -
$N_{(T)}$:	Number of animals in category T
N:	Nitrogen
N:	Nitrogen
N_2O:	Nitrous oxide
N_2O:	Nitrous oxide
$N_2O_{(D,mm)}$:	Emissions of nitrous oxide from storage of manure, kg N_2O (!)
$N_2Oem(an)$	Emissions of nitrous oxide resulting from manure N in the form of pasture manure, 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
$N_2Oem(cf)$:	Emissions of nitrous oxide resulting from fertiliser N, 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
$N_2Oem(lea)$:	Emissions of nitrous oxide resulting from leached N, kg N
$N_2Oem(of)$:	Emissions of nitrous oxide resulting from manure N in the form of barn manure, kg N
$N_2Oem(pt)$:	Emissions of nitrous oxide resulting from presence of peat soil, kg N
$N_2Oem(vol)$:	Emissions of nitrous oxide resulting from volatilised N deposited elsewhere, 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
$NAAN_{maize\_own\_land}$:	N offered to animal in barn in the form of maize 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
$NDAM_{maize}$:	N removed by machine in the form of maize silage from own land, kg N
$NDAM_{other\_roughage}$:	N removed by machine in the form of other roughage from own land, kg N
NEB:	Negative Energy Balance
NEMA:	National Emission Model for Ammonia
NexcretionT:	N excretion before deduction of gaseous losses from barn and storage in animal category T, kg
NH_3:	Ammonia
NH_4:	Ammonium
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
Ninp(of):	Total manure usage in the form of barn manure, kg
Ninp(pt):	Product of the hectares of peat soil on the farm and standard peat mineralisation, kg
Nipf(cf):	Total fertiliser N usage, kg

Nipn(cr):	Crop residues, crops cultivated after the main crop and ploughed in, mowing, grazing and harvest losses and new grass sods, kg
Nloss(lea):	Nitrate N leaving the farm as nitrate according to BEN, kg
Nloss(vol):	Ammonia N leaving the farm according to BEA incl. N from swaths, kg
PS:	Precipitation surplus, mm
NO_3:	Nitrate
NO_3:	Nitrate
NOP_{cut_grass}:	N absorbed by animal in the form of fresh grass or grass silage, kg N
$NOP_{cut\_grass\_purchased}$:	N absorbed by animal in the form of purchased fresh grass or grass 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
$NOP_{maize\_purchased}$:	N absorbed by animal in the form of purchased maize silage, kg N
$NOP_{maize\_own\_land}$:	N absorbed by animal in the form of maize silage from own land, kg N
NOP_{maize_silage}:	N absorbed by animal in the form of maize silage, kg N
$NOP_{other\_roughage\_purchased}$:	N absorbed by animal in the form of purchased other roughage, kg N
$NOP_{other\_roughage\_own\_land}$:	N absorbed by animal in the form of other roughage from own land, kg N
$NOP_{pasture}$:	N absorbed by animal via grazing, kg N
NOx:	Nitrogen oxides

Organic matter

ORO:	Area of other arable roughages
OM/N:	kg N per kg OM
OM/N_{maure}:	OM/N from manure
$OM/N_{cultivated\_grass}$:	OM/N in grazing and mowing losses
$OM/N_{cultivated\_maize}$:	OM/N in maize harvest losses
$OM/N_{feed\_leftovers}$:	OM/N from feed leftovers (including roughage, by-products and concentrate)
P:	Phosphorus
P:	Phosphorus
PcVoerververliesRuwvoer:	Percentage of feed loss from roughage
PO_4:	Phosphate
CA:	Crude ash
RAV:	Ammonia and Animal Husbandry Regulation
CP:	Crude protein
SO:	Area of maize silage, ha
TAN:	Total Ammoniacal Nitrogen
CI:	Calving interval
TO:	Total farm area, ha
LF:	Leaching fraction, kg N/kg N
DC:	Digestion coefficient, g/g
VEM:	Dutch energy unit for lactation
Voorraad_Pverbr_gksm:	P consumption calculated from reported stocks (initial + added - end)
DCP:	Digestible crude protein
$VS_{(T)}$:	Faeces production from animal category T, kg DM per animal per day
WBO:	Area of arable land in rotation (= rotated between arable land and grassland), ha
WGO:	Area of grassland in rotation (= rotated between arable land and grassland), ha
YBn:	Yield of by-product of marketable arable crop n, ton fresh per ha
YHn:	Yield of main product of marketable arable crop n, ton fresh per ha
Y_m:	Methane conversion factor, MJ / 100 MJ

Appendix 4 Indicators for feed ingredients

Dry matter content per feed ingredient (DM), crude ash content (CA), digestibility of crude protein (DCCP) (see section 2.2.2.2), 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 maize silage in ration (%) (see section 2.5.6.1) and emissions (CO_2 equivalents per kg product) from imported feed ingredients (excluding transport) (see section 2.5.6.8) for the various feed ingredients, subdivided into feed types and subgroups.

Name	Feed type[1]	DS (g/kg)	CA (g/kg)	DCCP[2]	DCOM	g CO_2-eq/kg[3]	EF CH_4 at 0% ms (g/kg dm)	EF CH_4 at 40% ms (g/kg dm)	EF CH_4 at 80% ms (g/kg dm)
Fresh grass: grazing	FG	160	17	0.82	0.84	76	19.2	19.2	19.2
Fresh grass: summer stall feeding	FG	160	17	0.82	0.84	76	23.3	23.3	23.3
Grass silage	GK	472	55	-[4]	0.76	241	-[4]	-[4]	-[4]
Grass hay	GK	845	84	-[4]	0.68	409	19.53	19.48	20.99
Dried fresh grass (bales)	GK	889	93	-[4]	0.76	2282	19.53	19.48	20.99
Dried fresh grass (pellets)	GK	926	119	-[4]	0.74	2349	20.12	19.94	20.66
Dried pre-dried grass (bales)	GK	889	93	-[4]	0.76	952	19.53	19.48	20.99
Dried pre-dried grass (pellets)	GK	926	119	-[4]	0.74	1018	20.12	19.94	20.66
Other grass product	GK	825	94	-[4]	0.74	1320	19.63	19.55	20.86
Maize silage, ensiled	MS	365	13	-[4]	0.75	66	-[4]	-[4]	-[4]
Maize silage, dried	MS	909	49	-[4]	0.73	1049	-[4]	-[4]	-[4]
Other maize silage	MS	637	31	-[4]	0.74	758	-[4]	-[4]	-[4]
Compound feed	KV	876	65	-[4]	0.84	-[5]	-[5]	-[5]	-[5]
Potato chips	KV	962	35	0.2	0.86	467	12.07	12.26	11.38
Potato protein	KV	906	12	0.89	0.88	1310	16.43	14.76	14.04
Potatoes dried	KV	897	42	0.39	0.85	467	22.74	21.51	20.49
Potato pulp	KV	878	58	0.32	0.82	528	21.65	21.22	20.45
Potato starch dried	KV	863	5	0.99	0.94	659	23.98	22.33	20.16
Sweet potatoes dried	KV	878	38	-0.01	0.85	1514	24.55	23.57	22.13
Bone meal	KV	948	463	0	0	310	20.00	20.00	20.00
Brewer's grains, dried	KV	915	46	0.75	0.65	434	16.74	16.43	16.27
Brewer's yeast dried	KV	924	65	0.82	0.79	450	19.75	18.63	18.60
Beet pulp	KV	903	70	0.62	0.87	356	25.76	25.80	28.31
Blood meal	KV	919	17	0	0	1119	18.27	16.67	16.77
Buckwheat	KV	865	24	0.74	0.69	1316	20.00	20.00	20.00
Beans (Phas) heated	KV	862	51	0.78	0.89	1631	21.29	20.87	21.38
Bread meal	KV	897	27	0.77	0.89	118	22.97	23.54	23.20
Casein	KV	916	32	0.95	0.95	6397	18.27	16.67	16.77
Citrus pulp	KV	912	66	0.49	0.86	701	26.98	26.43	28.00
DDGS	KV	916	46	0.84	0.83	285	21.00	21.00	21.00
Peas dry	KV	866	29	0.82	0.9	420	22.84	21.99	22.13
Phytase	KV	1000	0	0	0.83	2000	0.00	0.00	0.00
Barley	KV	873	21	0.74	0.85	432	22.80	22.07	20.74
Barley feed meal	KV	884	55	0.78	0.73	320	19.66	19.19	18.72
Barley mill by-product	KV	886	64	0.73	0.67	320	19.11	18.64	18.08
Millet	KV	897	28	0.71	0.8	1138	20.89	18.74	17.26
Grass meal	KV	926	119	0.66	0.74	2344	20.12	19.94	20.66
Grass seed	KV	863	47	0.63	0.61	1404	22.29	21.50	19.92
Groundnut with shell	KV	942	28	0.85	0.79	2149	8.42	9.13	11.51
Groundnut without shell	KV	932	22	0.87	0.93	4559	3.59	4.02	5.60
Groundnut expeller partly shell	KV	920	51	0.9	0.84	1434	17.63	17.72	20.03

Name	Feed type[1]	DS (g/kg)	CA (g/kg)	DCCP[2]	DCOM	g CO_2-eq/kg[3]	EF CH_4 at 0% ms (g/kg dm)	EF CH_4 at 40% ms (g/kg dm)	EF CH_4 at 80% ms (g/kg dm)
Groundnut expeller with shell	KV	933	41	0.89	0.78	1300	14.06	14.70	17.20
Groundnut expeller without shell	KV	932	64	0.91	0.87	1434	18.05	17.96	20.11
Groundnut meal partly shell	KV	926	56	0.92	0.82	1181	17.80	17.96	20.33
Groundnut meal with shell	KV	911	55	0.89	0.78	1090	17.80	17.96	20.33
Groundnut meal with shell	KV	913	60	0.91	0.85	1181	21.00	20.85	23.26
Oat	KV	879	24	0.74	0.76	492	19.66	19.78	19.76
Oats peeled	KV	888	20	0.79	0.9	668	21.08	20.80	20.42
Oats husk meal	KV	910	42	0.43	0.53	227	17.26	17.81	18.05
Oats mill feed	KV	886	24	0.71	0.75	447	18.92	19.22	19.35
Hemp seed	KV	913	48	0.75	0.62	6713	9.88	9.96	11.33
Carob	KV	897	30	0.02	0.73	593	27.20	26.05	26.35
Chalk grit	KV	990	980	0	0.83	513	0.00	0.00	0.00
Cottonseed with husk	KV	911	40	0.73	0.68	990	17.78	16.84	16.91
Cottonseed without husk	KV	935	44	0.8	0.84	1404	10.38	10.09	11.31
Cotton seed meal expeller partly with husk	KV	933	60	0.79	0.7	807	15.89	15.94	17.40
Cotton seed meal expeller with husk	KV	921	51	0.77	0.66	664	15.81	16.03	17.58
Cotton seed meal expeller without husk	KV	932	63	0.8	0.74	1015	13.94	13.96	15.36
Cotton seed meal extracted partly with husk	KV	896	63	0.79	0.69	727	17.51	17.69	19.87
Cotton seed meal extracted with husk	KV	945	50	0.77	0.66	593	17.95	18.18	20.35
Cotton seed meal extracted without husk	KV	898	65	0.8	0.72	921	17.36	17.40	19.51
Coconut copra cake	KV	907	61	0.72	0.82	952	18.71	19.08	20.92
Coconut copra meal	KV	910	69	0.74	0.8	952	20.80	21.18	23.22
Chalk (finely milled)	KV	990	980	0	0.83	1219	0.00	0.00	0.00
Linseed	KV	922	39	0.8	0.81	1407	8.56	9.00	10.72
Linseed expeller	KV	922	58	0.85	0.78	829	18.44	18.58	21.03
Linseed meal	KV	872	55	0.85	0.77	754	20.63	20.65	23.16
Lentils	KV	873	30	0.84	0.88	1418	22.26	20.90	19.81
Lupins	KV	887	33	0.9	0.91	1164	21.35	20.97	22.69
Lucerne meal	KV	913	104	0.68	0.65	1560	20.04	20.23	21.65
Magnesium Oxide	KV	1000	0	0	0.83	1058	0.00	0.00	0.00
Maize kernels, dry	KV	863	12	0.59	0.89	594	21.16	19.69	17.83
Maize chemical/heat treated	KV	876	13	0.6	0.9	600	22.65	22.91	21.17
Maize gluten meal	KV	899	17	0.95	0.94	1257	16.64	15.22	13.34
Maize gluten feed	KV	889	57	0.77	0.82	1582	20.34	19.76	19.37
Maize germ meal	KV	876	25	0.78	0.81	206	21.07	21.53	23.70
Maize germ bran expeller	KV	896	44	0.69	0.85	439	20.17	19.83	20.06
Maize germ bran meal	KV	875	39	0.7	0.84	264	21.20	21.54	23.47
Maize distillers solubles, dried	KV	894	50	0.76	0.82	285	19.43	20.05	22.87
Maize middlings	KV	877	14	0.61	0.89	559	21.90	20.55	18.69
Maize feed meal	KV	867	13	0.63	0.89	559	22.39	21.43	20.54
Maize bran	KV	894	23	0.65	0.79	1089	22.14	21.43	20.54
Maize starch	KV	892	1	0	0.96	932	23.92	21.99	22.72
Monocalcium Phosphate	KV	980	960	0	0.83	569	0.00	0.00	0.00
Malt culms	KV	916	50	0.76	0.71	6	21.58	20.74	21.47
Sodium bicarbonate	KV	1000	0	0	0.83	485	0.00	0.00	0.00
Niger seed	KV	916	47	0.79	0.76	3052	7.59	7.26	7.65
Horse beans, col.	KV	869	33	0.84	0.9	541	21.99	21.60	22.89
Horse beans white	KV	867	33	0.85	0.9	396	21.92	21.44	22.58
Palm kernel expeller	KV	923	43	0.75	0.76	648	16.86	17.38	18.58
Palm kernel solvent extracted	KV	893	39	0.76	0.76	648	19.72	20.85	23.51
Palm kernels	KV	938	20	0.62	0.86	2805	2.67	3.57	4.40

Name	Feed type[1]	DS (g/kg)	CA (g/kg)	DCCP[2]	DCOM	g CO_2-eq/kg[3]	EF CH_4 at 0% ms (g/kg dm)	EF CH_4 at 40% ms (g/kg dm)	EF CH_4 at 80% ms (g/kg dm)
Premix	KV	1000	0	0.75	0.83	1176	0.00	0.00	0.00
Rape seed extruded	KV	890	74	0.85	0.78	800	18.88	19.36	22.70
Rape seed	KV	925	38	0.78	0.83	2402	4.88	5.68	7.91
Rape seed expeller	KV	902	62	0.83	0.79	896	17.48	17.90	20.94
Rape seed meal	KV	877	67	0.84	0.75	1055	17.94	17.86	18.61
Rice with hulls	KV	886	44	0.47	0.75	1888	18.77	18.10	16.97
Rice without hulls	KV	885	7	0.49	0.91	2717	22.73	21.29	19.68
Rice husk	KV	912	153	0.43	0.42	281	11.99	12.41	12.18
Rice bran meal, solvent extracted	KV	901	108	0.64	0.7	471	15.95	15.64	15.05
Rice feed meal	KV	907	98	0.64	0.78	467	13.32	12.95	12.25
Rye	KV	870	16	0.72	0.87	447	23.72	23.32	22.90
Rye feed	KV	872	50	0.77	0.78	407	20.05	20.44	22.07
Safflower seed	KV	907	28	0.68	0.45	1627	7.71	8.91	11.64
Sesame seed	KV	942	75	0.83	0.85	1915	6.61	6.68	7.85
Sesame seed expeller	KV	943	132	0.9	0.85	715	15.43	14.99	16.20
Sesame seed meal solvent extracted	KV	893	60	0.9	0.82	599	21.54	20.67	21.88
Soya protein concentrate	KV	920	6	0.9	0.9	7023	0.00	0.00	0.00
Soya bean not heat treated	KV	899	50	0.9	0.88	3611	15.31	15.26	17.50
Soya bean hulls	KV	885	46	0.58	0.84	2426	23.34	22.95	23.56
Soya bean heat treated	KV	899	50	0.9	0.88	3615	15.07	15.03	17.33
Soya bean expeller	KV	916	64	0.91	0.91	4588	18.43	18.15	20.32
Soya bean meal, rumen bypass	KV	873	62	0.89	0.9	4475	20.40	19.25	18.86
Soya bean meal, dehulled	KV	879	65	0.91	0.91	4424	21.11	20.50	22.36
Sorghum	KV	872	15	0.49	0.85	1020	21.24	19.76	17.86
Sorghum gluten meal	KV	900	32	0.89	0.89	818	18.30	17.29	16.17
Sugar	KV	1000	0	0	1	527	34.09	31.06	28.52
Tapioca dried	KV	878	56	-0.5	0.84	840	23.90	23.14	21.96
Tapioca starch	KV	880	1	1	0.94	1033	24.92	23.43	20.86
Wheat	KV	867	15	0.74	0.89	454	23.35	22.97	22.52
Wheat gluten meal	KV	911	9	0.96	0.96	2953	17.00	15.74	16.21
Wheat gluten feed	KV	901	48	0.7	0.73	615	20.76	20.35	19.75
Wheat middlings	KV	871	47	0.77	0.73	275	20.41	20.58	22.01
Wheat germ feed	KV	869	40	0.86	0.84	823	19.94	19.91	21.10
Wheat feed flour	KV	869	26	0.81	0.87	275	21.93	21.79	22.10
Wheat feed meal	KV	870	43	0.79	0.77	275	20.86	20.92	22.08
Wheat bran	KV	869	53	0.76	0.68	448	20.23	20.30	21.74
Triticale	KV	867	17	0.72	0.89	497	23.65	23.29	23.09
Urea	KV	1000	0	1	1	1336	0.00	0.00	0.00
Fat from animals	KV	996	1	0	0.90	1,259	-11.73	-10.94	-11.19
Fat/oil vegetable	KV	995	0	0	0.95	6566	-11.75	-10.95	-11.21
Feather meal	KV	938	24	0	0	397	0.00	0.00	0.00
Fish meal	KV	913	165	0	0	1280	16.64	15.22	13.34
Meat-and-bone meal	KV	941	374	0	0	310	16.64	15.22	13.34
Chicory pulp dried	KV	897	74	0.56	0.84	206	25.01	25.19	27.86
Sea sand dried	KV	1000	0	0	0	2	0.00	0.00	0.00
Sunflower seed partly dehulled	KV	938	32	0.79	0.71	872	7.14	7.99	10.14
Sunflower seed not dehulled	KV	940	29	0.76	0.58	1121	4.62	5.57	7.02
Sunflower seed dehulled	KV	915	37	0.82	0.84	1106	6.47	6.66	8.26
Sunflower seed expeller partly dehulled	KV	923	58	0.86	0.66	482	14.01	14.61	17.13
Sunflower seed expeller not dehulled	KV	913	56	0.81	0.44	444	9.78	10.68	12.61
Sunflower seed expeller dehulled	KV	926	63	0.87	0.72	526	16.71	17.10	19.88
Sunflower seed meal	KV	892	65	0.88	0.68	447	17.94	18.40	21.22
Salt	KV	998	996	0	0	174	0.00	0.00	0.00

Name	Feed type[1]	DS (g/kg)	CA (g/kg)	DCCP[2]	DCOM	g CO_2-eq/kg[3]	EF CH_4 at 0% ms (g/kg dm)	EF CH_4 at 40% ms (g/kg dm)	EF CH_4 at 80% ms (g/kg dm)
Other grain	KV	885	23	0.75	0.8	568	17.84	17.84	17.99
Other legume	KV	886	34	0.86	0.88	839	22.07	21.38	22.02
Other dry by-product	KV	899	53	0.75	0.8	1183	17.94	17.69	18.34
Other minerals	KV	990	282	0.75	0.83	1176	0.00	0.00	0.00
Artificial milk	MP	964	48	0.89	0.93	6633	26.67	26.47	26.98
Milk powder skimmed	MP	951	79	0.92	0.95	15252	25.63	28.84	30.11
Milk powder whole	MP	949	59	0.89	0.95	13622	16.52	15.24	14.53
Whey powder	MP	982	81	0.77	0.94	1563	29.64	27.83	27.95
Whey powder (wet 60%)	MP	600	50	0.77	0.94	950	29.64	27.83	27.95
Whey powder (wet 30%)	MP	300	25	0.77	0.94	428	29.64	27.83	27.95
Whey powder (wet 6%)	MP	60	5	0.77	0.94	23	29.64	27.83	27.95
Whey powder delac (dry)	MP	959	203	0.88	0.93	987	22.77	21.77	22.77
Whey powder delac (wet 60%)	MP	600	111	0.89	0.94	950	29.64	27.83	27.95
Whey powder delac (wet 30%)	MP	300	55	0.89	0.94	428	29.64	27.83	27.95
Whey powder delac (wet 6%)	MP	60	11	0.89	0.94	23	29.64	27.83	27.95
Cheese whey	MP	38	4	0.86	0.94	1698	26.63	26.56	30.01
Other milk product	MP	564	61	0.85	0.94	3008	27.15	26.14	26.67
Potato juice concentrated	OV	548	159	0.91	0.93	66	20.06	21.72	26.74
Potato pulp pressed	OV	161	7	0.41	0.84	24	24.04	24.31	26.04
Potato peelings ensiled	OV	220	18	0.53	0.85	0	19.43	19.43	19.43
Potato cuttings/chips raw	OV	212	7	0.4	0.88	0	22.22	21.17	20.50
Potato peelings steamed	OV	140	9	0.63	0.88	0	23.24	24.90	28.06
Potato starch wet	OV	266	9	0.58	0.9	0	22.60	21.33	19.85
Potato starch, puffed	OV	451	8	0.99	0.93	0	22.93	21.36	19.18
Endive	OV	52	9	0.85	0.86	0	20.00	20.00	20.00
Apples	OV	157	4	-0.2	0.88	0	20.00	20.00	20.00
Gherkin	OV	49	4	0.63	0.79	0	20.00	20.00	20.00
Brewer’s grains	OV	242	11	0.8	0.64	0	15.68	15.50	15.50
Beet leaf	OV	182	57	0.6	0.73	0	20.00	20.00	20.00
Beet leaf and top	OV	160	32	0.79	0.82	0	20.00	20.00	20.00
Sugarbeet pulp pressed ensiled	OV	248	19	0.61	0.88	1	24.62	24.53	26.17
Sugarbeet rests ensiled	OV	135	25	0.55	0.78	63	20.00	20.00	20.00
Bean straw (Vicia)	OV	840	61	0.46	0.52	73	17.00	17.00	17.00
Bean straw (phas)	OV	863	98	0.62	0.61	146	17.00	17.00	17.00
CCM part core	OV	632	11	0.57	0.86	235	20.45	19.14	17.29
CCM with core	OV	525	11	0.58	0.84	206	20.55	19.36	17.52
CCM without core	OV	662	11	0.58	0.87	251	20.54	19.17	17.29
Pea straw	OV	710	75	0.58	0.5	135	17.00	17.00	17.00
Barley straw	OV	884	63	0.17	0.48	208	17.00	17.00	17.00
WPS grains	OV	325	26	0.63	0.68	124	20.00	20.00	20.00
Distillers’ grains (DDG)	OV	73	4	0.84	0.83	0	17.62	17.62	17.62
Grass seed straw	OV	844	64	0.36	0.54	57	17.00	17.00	17.00
Oats straw	OV	840	59	0.19	0.5	245	17.00	17.00	17.00
Clover red hay	OV	830	83	0.61	0.59	206	19.53	19.48	20.99
Clover red ensiled	OV	364	56	0.73	0.64	99	19.53	19.48	20.99
Clover red dried	OV	899	104	0.62	0.68	1400	19.53	19.48	20.99
Clover red straw	OV	830	56	0.44	0.42	206	19.53	19.48	20.99
Cucumber	OV	58	6	0.57	0.8	0	20.00	20.00	20.00
Cabbage (winterrape)	OV	100	15	0.87	0.83	0	20.00	20.00	20.00
Cabbage (cauliflower)	OV	72	10	0.91	0.9	0	20.00	20.00	20.00
Cabbage (marrowstem)	OV	120	16	0.84	0.83	0	20.00	20.00	20.00
Cabbage (red/white/Sav.)	OV	105	12	0.85	0.85	0	20.00	20.00	20.00
Cabbage (brussels sprouts)	OV	162	14	0.87	0.88	0	20.00	20.00	20.00
Turnips	OV	110	14	0.67	0.88	0	20.00	20.00	20.00
Beetroot	OV	136	11	0.58	0.89	0	20.00	20.00	20.00
Lucerne hay	OV	872	88	0.67	0.62	211	19.53	19.48	20.99
Lucerne ensiled	OV	403	57	0.73	0.65	100	19.53	19.48	20.99

Name	Feed type[1]	DS (g/kg)	CA (g/kg)	DCCP[2]	DCOM	g CO_2-eq/kg[3]	EF CH_4 at 0% ms (g/kg dm)	EF CH_4 at 40% ms (g/kg dm)	EF CH_4 at 80% ms (g/kg dm)
Lucerne dried	OV	903	106	0.67	0.63	1449	19.53	19.48	20.99
Maize gluten feed silage	OV	418	16	0.71	0.83	232	20.97	20.16	19.09
Whole ear maize silage	OV	553	9	0.58	0.86	227	20.51	20.51	20.51
Maize straw	OV	840	86	0.27	0.57	0	17.00	17.00	17.00
Maize solubles	OV	476	84	0.87	0.91	919	21.99	23.32	28.47
Molasses sugar beet	OV	787	90	0.73	0.9	114	30.01	28.71	30.70
Molasses sugarcane	OV	723	101	0.17	0.8	316	29.80	22.07	21.16
Sweet pepper	OV	125	8	0.56	0.72	0	20.00	20.00	20.00
Pears	OV	165	4	-0.93	0.87	0	20.00	20.00	20.00
Leeks	OV	100	10	0.8	0.83	0	20.00	20.00	20.00
Rye straw	OV	840	59	0.14	0.46	189	17.00	17.00	17.00
Lettuce	OV	61	11	0.82	0.85	0	20.00	20.00	20.00
Green cereals silage	OV	250	20	0.62	0.78	82	19.53	19.48	20.99
Spinach	OV	94	17	0.84	0.85	0	20.00	20.00	20.00
Brussels sprouts leaf & stalk	OV	180	20	0.85	0.84	0	20.00	20.00	20.00
Sugar beets fresh	OV	260	49	0.27	0.9	41	25.00	25.00	25.00
Wheat straw	OV	878	73	0.23	0.42	245	17.00	17.00	17.00
Tomatoes	OV	63	6	0.76	0.81	0	20.00	20.00	20.00
Onions/bulbs	OV	118	16	0.75	0.9	0	20.00	20.00	20.00
Field beans ensiled	OV	326	28	0.7	0.64	370	21.40	21.40	21.40
Vinasse sugar beet	OV	655	137	0.86	0.9	388	21.76	22.80	27.02
Fodder beet	OV	129	21	0.6	0.9	44	25.00	25.00	25.00
Fodder beet cleaned	OV	139	13	0.62	0.9	50	25.00	25.00	25.00
Potatoes	OV	322	24	0.33	0.88	188	19.95	19.95	19.95
Chicory foliage	OV	175	60	0.34	0.58	0	20.00	20.00	20.00
Pressed chicory pulp, ensiled	OV	232	22	0.53	0.84	0	24.79	24.49	25.73
Chicory root, forced, clean	OV	149	12	0.61	0.85	0	20.00	20.00	20.00
Chicory root, forced, dirty	OV	122	21	0.61	0.85	0	20.00	20.00	20.00
Chicory root, unforced	OV	200	20	0.49	0.92	0	20.00	20.00	20.00
Carrots	OV	112	10	0.59	0.9	0	20.00	20.00	20.00
Carrot peelings steamed	OV	52	7	0.64	0.9	0	24.67	23.93	24.65
Other grain straw	OV	861	71	0.18	0.46	222	17.00	17.00	17.00
Other leafy vegetables	OV	110	14	0.67	0.88	0	20.00	20.00	20.00
Other vegetables	OV	144	36	0.46	0.74	0	20.00	20.00	20.00
Other roughage	OV	499	47	0.52	0.68	123	19.43	19.31	19.41
Other wet by-product	OV	217	25	0.68	0.83	75	21.35	21.11	21.60

1 GK = grass silage; VG = fresh grass; SM = maize silage; KV = concentrates; MP = milk powder; OV = Other roughage and by-products

2 CVB, 2004; CVB, 200; CVB, 2011 and http://www.cvbdiervoeding.nl/pagina/10081/downloads.aspx.

3 per kg of product; FeedPrint version March 2020 (Vellinga et al., 2013) and Nevedi list 2019, excluding transport to the farm and grinding for other single products.

4 Being calculated, see main text.

5 Supplied by supplier or calculated if not supplied.

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	Agri-footprint 4.0	Transport, truck >20t, EURO5, 50%LF, default/GLO Economic
Supply	Synthetic fertiliser	Ammonium	Agri-footprint 4.0	Ammonium sulphate, as 100% $(NH_4)^2SO_4$ (NPK 21-0-0), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	nitrate	Agri-footprint 4.0	Liquid urea-ammonium nitrate solution (NPK 30-0-0), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	urea	Agri-footprint 4.0	Urea, as 100% $CO(NH_2)^2$ (NPK 46.6-0-0), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	nitrogen combinations	Agri-footprint 4.0	Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	phosphate	Agri-footprint 4.0	Triple superphosphate, as 80% Ca(H2PO4)2 (NPK 0-48-0), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	potassium	Agri-footprint 4.0	Potassium chloride (NPK 0-0-60), at regional storehouse/RER Economic
Supply	Synthetic fertiliser	lime, limestone	Agri-footprint 4.0	Limestone fertiliser, at regional storehouse/RER Economic
Supply	Synthetic fertiliser	lime, dolomite	Agri-footprint 4.0	Dolomite fertiliser, at regional storehouse/RER Economic
Supply	Litter	straw	Agri-footprint 4.0	Wheat straw, at farm/NL Economic
Supply	Litter	sawdust	Ecoinvent 3	Sawdust, wet, measured as dry mass {RoW}| suction, sawdust | Cut-off, S
Supply	Litter	lime	Agri-footprint 4.0	Limestone, including application
Supply	Litter	other		Average
Supply	Cattle	cows	Agri-footprint 4.0	Cows for slaughter, at dairy farm, PEF compliant/NL IDF/Economic
Supply	Cattle	heifers	Agri-footprint 4.0	Cows for slaughter, at dairy farm, PEF compliant/NL IDF/Economic
Supply	Cattle	calves	Agri-footprint 4.0	Calves, at dairy farm, PEF compliant/NL IDF/Economic
Supply	Cattle	Nursing calf	Agri-footprint 4.0	Calves, at dairy farm, PEF compliant/NL IDF/Economic
Supply	Pesticide	nematicide	Ecoinvent 3	Pesticide, unspecified {GLO}| market for | Cut-off, S
Supply	Pesticide	herbicide	Ecoinvent 3	Glyphosate {GLO}| market for | Cut-off, S
Supply	Pesticide	fungicide	Ecoinvent 3	Mancozeb {GLO}| market for | Cut-off, S
Supply	Pesticide	others	Ecoinvent 3	Pesticide, unspecified {RER}| production | Cut-off, S
Supply	Cover material	plastic	Ecoinvent 3	Packaging film, low density polyethylene {GLO}| market for | Cut-off, S
Energy use	drying	grass bale	FeedPrint 2020	
Energy use	drying	grass pellet	FeedPrint 2020	
Energy use	drying	maize silage	FeedPrint 2020	
Energy use	drying	Other roughage	FeedPrint 2020	

Process	Product	Specification	Source	Description
Energy use	burning	diesel	Zijlema 2020	
Energy use	burning	natural gas	Zijlema 2020	
Energy use	burning	biogas	Zijlema 2020	
Energy use	burning	propane	Zijlema 2020	
Energy use	burning	fuel oil	Zijlema 2020	
Energy use	production	electric normal	Ecoinvent 3, CBS	
Energy use	production	electric green	Ecoinvent 3, CBS	
Energy use	production	diesel	Ecoinvent 3	Diesel {RER}| market group for | Cut-off, S
Energy use	production	natural gas	Ecoinvent 3	Natural gas, low pressure {CH}| market for | Cut-off, S
Energy use	production	biogas	Ecoinvent 3	Biogas {CH}| market for biogas | Cut-off, S
Energy use	production	propane	Ecoinvent 3	Propane {GLO}| market for | Cut-off, S
Energy use	production	oil	Ecoinvent 3	Heavy fuel oil {RER}| market group for | Cut-off, S
Energy use	indirect	electricity	ELCD	Electricity mix, AC, consumption mix, at consumer, < 1kV EU-27 S
Energy use	indirect	gas	Agri-footprint 4.0	Combustion of natural gas, consumption mix, at plant/NL Economic
Energy use	indirect	kerosene	Agri-footprint 4.0	Energy, from diesel burned in machinery/RER Economic
Energy use	indirect	coal	Ecoinvent 3	Heat, district or industrial, other than natural gas {RoW}| heat production, at hard coal industrial furnace 1-10MW | Cut-off, S
Energy use	supply	water	Ecoinvent 3	ELCD Agri-footprint 4.0 Agri-footprint 4.0 Ecoinvent 3
Energy use	Electricity production	biomass	USLCI	Electricity, biomass, at power plant/US
Energy use	Electricity production	wind	Ecoinvent 3	Electricity, high voltage {NL}| electricity production, wind, 1-3MW turbine, onshore | Cut-off, S
Energy use	Electricity production	sun	Ecoinvent 3	Electricity, production mix photovoltaic, at plant/NL S
Application	lime	lime, dolomite	IPCC 2006	
Application	lime	lime, limestone	IPCC 2006	
Application	urea	-	IPCC 2006	

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 ruminants (RVO)	Breeding bulls, > 1 year (cat. 104)	0.627
	Pasture and suckler cows (cat. 120)	0.651
	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
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

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

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