National Institute for Public Health
and the Environment
*Ministry of Health, Welfare and Sport*

# Methodology for the **calculation of emissions** from **agriculture**

## Calculations for methane, ammonia, nitrous oxide, nitrogen oxides, non-methane volatile organic compounds, fine particles and carbon dioxide emissions using the National Emission Model for Agriculture (NEMA).

RIVM report 2026-0020
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# Colophon



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PBL advises the task force for agriculture emissions of the PRTR to ensure future implications of policies to be incorporated in the emission calculations. PBL is also involved in the quality control of the emission data. PBL is not ultimately responsible for the calculation method used and the quality of the emission data, and the underlying data. However, PBL commits itself to use the emission data.

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# Synopsis


**Methodology for the calculation of emissions from agriculture**

Calculations for methane, ammonia, nitrous oxide, nitrogen oxides, non-methane volatile organic compounds, fine particles and carbon dioxide emissions using the National Emission Model for Agriculture (NEMA).

Each year, the Netherlands reports both nationally and internationally on the amount of substances emitted into the air by the agricultural sector. This includes all substances listed in the Netherlands' Emission Registration that require reporting for this sector, such as greenhouse gases and substances contributing to air pollution, including ammonia and particulate matter. The emissions are calculated in compliance with international guidelines.

This is done using the National Emission Model for Agriculture (NEMA), which was developed in the Netherlands. For example, the NEMA calculates emissions of substances from stables and from manure storage and use.

The model is updated annually to reflect the latest scientific insights. This report describes the methods used for different substances, as well as the changes made to the model.

Emission data can be found at www.emissieregistratie.nl. The data are used for reports mandated by international agreements and EU legislation, such as the reporting obligations stemming from the United Nations Framework Convention on Climate Change (UNFCCC); the Paris Agreement (PA); the Convention on Long-Range Transboundary Air Pollution (CLRTAP), which includes the Gothenburg Protocol; the EU National Emission reduction Commitments Directive (NEC Directive); and Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action and its implementing regulations. Furthermore, these reports serve as the basis for (international) review teams who conduct reviews on the Dutch reporting documents.


Keywords: air pollution, ammonia, greenhouse gases, nitrogen, livestock, crops, stables, manure, enteric fermentation, National Inventory Document, Informative Inventory Report, Nomenclature for Reporting

# Publiekssamenvatting


## Methodiek om landbouwemissies naar lucht te berekenen

Berekeningen voor methaan, ammoniak, lachgas, stikstofoxiden, niet-methaan vluchtige organische stoffen, fijnstof en koolstofdioxide met NEMA.

Nederland rapporteert elk jaar nationaal en internationaal hoeveel stoffen de landbouw uitstoot naar de lucht. Het gaat om alle stoffen die in de Emissieregistratie voorkomen en voor deze sector moeten worden gerapporteerd. Denk aan broeikasgassen en stoffen die luchtverontreiniging veroorzaken, zoals ammoniak en fijnstof. De emissieberekeningen worden uitgevoerd op basis van internationale richtlijnen.

De uitstoot wordt berekend met het National Emission Model for Agriculture (NEMA), dat in Nederland is ontwikkeld. NEMA berekent de uitstoot van stoffen voor bijvoorbeeld stallen, de opslag van mest, en het gebruik van mest.

Het model wordt elk jaar aangepast aan de nieuwste wetenschappelijke inzichten. Dit rapport beschrijft de methoden die voor verschillende stoffen worden gebruikt, plus de wijzigingen die in het model zijn doorgevoerd.

De emissiegegevens zijn te vinden op www.emissieregistratie.nl. De gegevens worden gebruikt voor de rapportages die vanwege internationale overeenkomsten en EU-wetgeving verplicht zijn. Zoals de rapportageverplichtingen in het kader van het Raamverdrag van de Verenigde Naties over klimaatverandering (UNFCCC), het Akkoord van Parijs (PA), het Verdrag over grensoverschrijdende luchtverontreiniging over lange afstand (CLRTAP), waaronder het Gothenburg-protocol, de EU-richtlijn over nationale emissiereductieverplichtingen (NEC-richtlijn) en de Governanceverordening van de Energie-unie (EU 2018/1999) met de bijbehorende uitvoeringsverordeningen. De rapportage is ook de basis voor de (internationale) reviewers die de Nederlandse rapportages moeten controleren.


Kernwoorden: luchtverontreiniging, ammoniak, broeikasgassen, stikstof, vee, gewassen, stallen, mest, enterische fermentatie, National Inventory Document, Informative Inventory Report, Nomenclature for Reporting

# Contents

# Summary


Emissions to air from agricultural activities in the Netherlands are estimated using the National Emission Model for Agriculture (NEMA). Calculations include the emission of ammonia ($NH_3$), nitrogen oxides ($NO_x$), nitrous oxide ($N_2O$), non-methane volatile organic compounds (NMVOC), methane ($CH_4$), particulate matter ($PM_{10}$ and $PM_{2.5}$) and carbon dioxide ($CO_2$). These emissions originate from various processes within the agricultural production chain, grouped in the main categories enteric fermentation ($CH_4$), manure management ($CH_4$, $NH_3$, $NO_x$, $N_2O$, NMVOC and PM), crop production and agricultural soils ($NH_3$, $NO_x$, $N_2O$, NMVOC and PM), and lime application and urea application ($CO_2$). The calculations for greenhouse gas emissions are based on the 2006 IPCC guidelines and the 2019 refinement to the 2006 IPCC Guidelines. The figures for air pollutants are based on the EMEP Guidebook 2023.

Emissions from fuel combustion (agricultural machinery and heating of greenhouses and animal housing) and $CO_2$ emissions from agricultural land use are not part of the agricultural emissions. These emissions are included in the sectors Energy and Land Use, Land use Change and Forestry.

**Enteric fermentation**

Ruminal and/or intestinal fermentation processes take place during the digestion of feed. Particularly large amounts of $CH_4$ are formed in ruminants. For this reason, and in accordance with the key-source analysis, a country-specific (IPCC Tier 3) method that models enteric fermentation processes is used for dairy cattle. For other cattle categories, emissions are calculated using an IPCC Tier 2 approach based on feed rations per year. The emissions from small ruminants and intestinal fermentation by monogastric animals are calculated using IPCC 2019 default emission factors in kg $CH_4$ per head per year (Tier 1).

**Manure management**

This category includes emissions from manure stored in animal housing, manure treatment and/or manure in outside storage facilities.

The emission of $CH_4$ results from the fermentation of organic matter in treated or stored livestock manure. The rate of emission depends on the chemical composition of the manure, as well as on environmental factors (e.g. temperature and the availability of oxygen). Cattle, pigs and poultry are considered key sources, and they are therefore assessed using an IPPC Tier 2 approach. The excretion of volatile solids is calculated from rations fed. The emission of $CH_4$ is calculated by multiplying volatile solids by the maximum methane production potential ($B_o$) and the methane-conversion factor (MCF). Slurry and solid manure are distinguished from manure excreted on pasture land. Emissions from other livestock categories are calculated using the IPCC 2006 defaults in kg $CH_4$ per head per year (Tier 1). The addition of bedding material to the manure does not need to be taken into account for the Tier 2 calculation.

Ammonia ($NH_3$) is produced from urinary nitrogen (N) and mineralised organic N in the faeces, the sum of which is referred to as Total Ammoniacal Nitrogen (TAN). Following bacterial conversion to ammonium, gaseous $NH_3$ emits to the air, depending on physical and chemical conditions. The TAN content in the manure of the major livestock categories is calculated from annual feed composition. The $NH_3$ emissions are calculated using $NH_3$-N emission factors, expressed as percentage of TAN. These emission factors are derived from measurements of $NH_3$ emissions from animal housing, relative to the TAN excretion. If no results from $NH_3$ measurements are available, emission factors are deduced from measured emissions of other categories, using ratios of TAN excretion as a scale factor. Research has shown that the emission factors of some housing systems are higher in practice. Therefore, emission factors have been estimated based on the N/P ratio during storage of manure. Information on housing systems in agricultural practice is derived from the Agricultural Census, supplemented by provincial records on environmental permits. The amount of N and the resulting TAN that is added to the manure in the form of bedding material (straw) is also taken into account. After manure has been stored in animal housing, some of it is treated. The amount of manure that is separated, dried, incinerated or digested is based on registered manure transports. Separate calculations are performed for $NH_3$ emissions from manure storage outside animal housing. Because N emissions are calculated using the TAN-flow principle, the amount of TAN in storage is corrected for the total N losses in the housing system.

Emissions of N in the form of $NO_x$, $N_2O$ and $N_2$ are also part of the TAN-flow, and they originate from nitrification (or denitrification) processes occurring in manure during housing, manure treatment and in outside storage facilities. The $NO_x$ and $N_2O$ emissions are treated as equal in terms of N losses and based on the IPCC default emission factors for $N_2O$. $N_2$ emissions have their own default emission factors from the IPCC. When applied in the TAN-flow model, these emissions are converted into a percentage of TAN.

The Non-Methane Volatile Organic Compounds (NMVOC) emissions from manure management depend primarily on feed composition, as emissions in animal housing are primarily caused by the feeding of silage. In addition, NMVOC is emitted from manure in animal housing, as well as in outside manure storage. The NMVOC emissions from cattle manure in animal housing and outside storage are calculated based on feed intake. For other animal categories, emissions are calculated using the values for volatile solid excretion. Because NMVOC emissions from manure management are a key source, a Tier 2 method is applied. The emission factors are EMEP default emission factors.

Emissions of particulate matter ($PM_{10}$ and $PM_{2.5}$) from manure management depend primarily on the housing systems. Emission factors are derived from measurements of PM. If no measurement results are available, emission factors are deduced from emission factors measured in other systems, taking ratios of phosphorus (P) excretion as a scale factor or using defaults.

## Crop production and agricultural soils

As part of the TAN flow, available N in manure intended for application is calculated by subtracting N losses from animal housing, manure treatment and outside manure storage from the total N excreted by the animals and the N added in the form of bedding material. The N losses include $NH_3$-N, $N_2O$-N, $NO_x$-N, plus dinitrogen-N ($N_2$), as well as the net export of manure N. The N available for application to agricultural soils is divided over grassland and cropland (cropped and uncropped) and soil type (organic and mineral). This is done because of differences between the manure application techniques used on grasslands and those used on arable land, with $NH_3$ emission factors differing between application techniques. These emission factors are derived for manure application on grassland based on an analysis of measured field emission data. For $NH_3$ from grazed grasslands, $NH_3$ emission factors based on TAN excreted during grazing are used. The $NH_3$ emissions from the application of inorganic N fertilizer, sewage sludge and compost, crop ripening and crop residues left on the field are calculated using country-specific emission factors based on literature and measurements for these sources. The distribution of the different forms of N inputs over grassland and arable land and organic and mineral soils is based on calculations using the INITIATOR model.

Emissions of $NO_x$ and $N_2O$ occur when N is applied to agricultural soils. For $N_2O$, a distinction is made between surface spreading and low-ammonia emission application, as the incorporation of animal manure into the soil increases $N_2O$ emissions. The emission factors are country-specific (IPCC Tier 2), as are those for inorganic N fertilizer, sewage sludge, compost, pasture manure, crop residues and the cultivation of organic soils. Emissions of $NO_x$ are calculated using the EMEP default emission factor for N supply to soil.

After the application of manure, NMVOC emissions occur, and a Tier 2 calculation method using the EMEP default emission factors is applied to calculate these emissions. Although no direct emission factors for NMVOC emissions are available for manure application, a correlation has been found between the volume of $NH_3$ emissions and the volume of NMVOC emissions. It is therefore assumed that the ratio of NMVOC from application to NMVOC from animal housing is equal to the ratio of $NH_3$ from application to $NH_3$ from animal housing (EEA, 2023). To measure NMVOC emissions from manure on pasture, the storage of silage and the cultivation of crops, the EMEP default emission factors are used.

Particulate matter (PM) is emitted during the storage, handling and transport of agricultural products, as well as during the cultivation of agricultural soils and crop harvesting. A Tier 2 approach is used for $PM_{10}$ and $PM_{2.5}$ emissions from the tillage of crops. Fixed estimates are used for other sources of PM emissions (concentrates, inorganic fertilizers and pesticides).

## Liming

The application of lime to reduce soil acidity results in $CO_2$ emissions, due to the decomposition of carbonate. Emissions of $CO_2$ from lime are calculated from annual statistics and the IPCC default emission factors (Tier 1).

### Urea application

The application of urea, an inorganic N-fertilizer, results in $CO_2$ emissions. $CO_2$ is entrapped during the production of urea. During the application the $CO_2$ is released. Emissions of $CO_2$ from urea application are calculated from annual statistics and the IPCC default emission factors (Tier 1).

### Overview of methods and emission factors used

For the reporting of air pollutants within the Nomenclature For Reporting and Informative Inventory Report (NFR; IIR) format, the level of methods and emission factors used by NEMA are summarised in Table S.1.

*Table S.1 Methods and emission factors (EF) used in NEMA for air pollutants, by level as distinguished by the EMEP Guidebook 2023 (used in the Informative Inventory Report; IIR and Nomenclature For Reporting; NFR)*

| NFR source categories | $NH_3$ | | $NO_x$ | | NMVOC | | $PM_{10}/PM_{2.5}$ | |
|---|---|---|---|---|---|---|---|---|
| | **Method** | **EF** | **Method** | **EF** | **Method** | **EF** | **Method** | **EF** |
| 3. Agriculture | | | | | | | | |
| B. Manure management | T3 | CS | T3 | CS | T2 | D | T2 | CS |
| D. Agricultural soils | T3 | CS | T3 | D | T1, T2 | D | T2 | CS, D |
| F. Field burning of agricultural residues | N/A | N/A | NO | NO | NO | NO | NO | NO |
| I. Other | NO | NO | NO | NO | NO | NO | NO | NO |

Method: T2 = EMEP Tier 2; T3 = EMEP Tier 3; NO = not occurring; N/A = not applicable.
EF: D = EMEP default; CS = country-specific; NO = not occurring; N/A = not applicable.

The methods and emission factors used are in full compliance with the requirements set by the EMEP guidebook 2019.

For the reporting of greenhouse gases within the Common Reporting Format and the National Inventory Report (CRT; NIR), the level of methods and emission factors used by the NEMA are summarised in Table S.2.

*Table S.2 Methods and emission factors (EF) used in NEMA for greenhouse gases, by level as distinguished by the IPCC 2006 Guidelines (used in the National Inventory Report; NIR and Common Reporting Format; CRT)*

| **CRT source categories** | **$CO_2$** | | **$CH_4$** | | **$N_2O$** | |
|---|---|---|---|---|---|---|
| | **Method** | **EF** | **Method** | **EF** | **Method** | **EF** |
| 3. Agriculture | | | | | | |
| A. Enteric fermentation | N/A | N/A | T1, T2, T3 | CS, D | N/A | N/A |
| B. Manure management | N/A | N/A | T1, T2 | CS, D | T2 | D |
| C. Rice cultivation | N/A | N/A | NO | NO | N/A | N/A |
| D. Agricultural soils | N/A | N/A | N/A | N/A | T1, T2 | CS, D |
| E. Prescribed burning of savannahs | N/A | N/A | NO | NO | NO | NO |
| F. Field burning of agricultural residues | N/A | N/A | NO | NO | NO | NO |
| G. Liming | T1 | D | N/A | N/A | N/A | N/A |
| H. Urea application | T1 | D | N/A | N/A | N/A | N/A |
| I. Other carbon-containing fertilizers | NO | NO | N/A | N/A | N/A | N/A |
| J. Other | N/A | N/A | NO | NO | NO | NO |

Method: T1 = IPCC Tier 1; T2 = IPCC Tier 2; T3 = IPCC Tier 3;
NO = not occurring; N/A = not applicable.
EF: D = IPCC default; CS = country-specific; NO = not occurring; N/A = not applicable.

The methods and emission factors used follow the requirements set by the 2019 refinement to the 2006 IPCC Guidelines.

Key words: air pollutants, greenhouse gases, livestock, crops, animal housing, manure storage, manure treatment, manure application, inorganic N fertilizer, enteric fermentation, manure management, agricultural soils, liming, NIR, CRT, IIR, NFR

# Samenvatting


## Methoderapport voor het schatten van emissies uit de Nederlandse landbouw

Berekeningen voor $CH_4$, $NH_3$, $N_2O$, $NO_x$, NMVOS, $PM_{10}$, $PM_{2.5}$ en $CO_2$ met het National Emission Model for Agriculture (NEMA) – Update 2026

Om emissies naar de lucht uit landbouwkundige activiteiten in Nederland te schatten, wordt het National Emission Model for Agriculture (NEMA) gebruikt. De berekeningen omvatten emissies van ammoniak ($NH_3$), stikstofoxiden ($NO_x$), lachgas ($N_2O$), niet-methaan vluchtige organische stoffen (NMVOS), methaan ($CH_4$), fijnstof ($PM_{10}$, $PM_{2,5}$) en koolstofdioxide ($CO_2$). Deze emissies zijn afkomstig van diverse processen in de landbouwproductieketen, gegroepeerd in de hoofdcategorieën enterische fermentatie ($CH_4$), mestmanagement ($CH_4$, $NH_3$, $NO_x$, $N_2O$, NMVOS en PM), gewasproductie en landbouwbodems ($NH_3$, $NO_x$, $N_2O$, NMVOS en PM), bekalking en de aanwending van ureum ($CO_2$). De berekeningen voor broeikasgassen zijn gebaseerd op de 2006 IPCC Guidelines en de 2019 refinement to the 2006 IPCC Guidelines. Getallen voor luchtverontreinigende stoffen zijn op basis van het EMEP Guidebook 2023.

Emissies door het gebruik van brandstoffen (tractoren, verwarming van kassen en stallen) en de $CO_2$ emissies door het gebruik van land voor landbouw maken geen onderdeel uit van de landbouwemissies. Deze emissies maken deel uit van de sectoren Energie en Landgebruik en landgebruiksverandering.

### Enterische fermentatie

Tijdens de vertering van voer vinden pens- en darmfermentatieprocessen plaats (enterische fermentatie). Voornamelijk door herkauwers worden aanzienlijke hoeveelheden $CH_4$ gevormd. Daarom wordt in lijn met de key source (belangrijkste bronnen) analyse, een landspecifieke (IPCC Tier 3) methode toegepast voor melkkoeien waarin de enterische fermentatieprocessen gemodelleerd worden. Voor de andere rundveecategorieën worden emissies jaarlijks berekend op basis van de rantsoenen volgens een IPCC Tier 2-benadering. De emissies van kleine herkauwers en darmfermentatie door eenmagige dieren worden berekend met IPCC 2019 default emissiefactoren in kg $CH_4$ per dier per jaar (Tier 1).

### Mestmanagement

Deze categorie omvat emissies van mest opgeslagen in de stal, mest be- of verwerking en/of mestopslag in buitenopslagfaciliteiten.

Uit de fermentatie van organische stof in opgeslagen of be- of verwerkte mest van landbouwhuisdieren komen emissies van $CH_4$ voort. De omvang van de emissie hangt af van de chemische samenstelling van de mest en omgevingsfactoren zoals temperatuur en de beschikbaarheid van zuurstof. Rundvee, varkens en pluimvee worden beschouwd als key source, en worden daarom geschat met een IPCC Tier 2-benadering. De excretie van organische stof wordt berekend uit de gevoerde rantsoenen. De organische stof vermenigvuldigd met het biochemisch methaanpotentieel ($B_o$) en

methaanconversiefactor (MCF) geeft de $CH_4$-emissies. Er wordt onderscheid gemaakt tussen drijf- en vaste mest, en mestexcretie tijdens beweiden. Emissies van andere diercategorieën worden berekend met IPCC 2019 default (Tier 1) emissiefactoren in kg $CH_4$ per dier. De organische stof uit het strooiselmateriaal hoeft voor de Tier 2 berekening niet te worden meegenomen.

$NH_3$ wordt gevormd uit de stikstof (N) in de urine en gemineraliseerde organische N in de faeces, waarvan de som Totaal Ammoniakaal N (TAN) genoemd wordt. Na de bacteriologische conversie van urine en organische N naar ammonium kan gasvormig $NH_3$ naar de lucht emitteren, afhankelijk van fysische en chemische condities. TAN in de mest wordt jaarlijks afgeleid uit de voedersamenstelling. De $NH_3$-emissie wordt berekend met $NH_3$-N emissiefactoren uitgedrukt als percentage van TAN. Deze emissiefactoren zijn afkomstig van metingen aan $NH_3$-emissies uit stallen, gerelateerd aan de TAN-excretie. Als er geen meetresultaten beschikbaar zijn, dan worden de emissiefactoren afgeleid van bestaande emissiefactoren van andere stalsystemen gebruikmakend van de verhouding in TAN-excretie als schaalfactor. Onderzoek heeft aangetoond dat de emissiefactoren in de praktijk te laag zijn. Hierop is een inschatting gemaakt van de emissiefactoren gebruikmakend van de N/P verhouding in de mest. Informatie over stalsystemen in de landbouwpraktijk is afgeleid uit de Landbouwtelling, In de beginjaren waar nodig verfijnd met provinciale gegevens over omgevingsvergunningen. Naast de TAN uit mest wordt er ook rekening gehouden met de TAN die via het strooisel in de stal en opslag terechtkomt. Na mestopslag in de stal kan een deel van de mest worden be- of verwerkt. De hoeveelheid mest die wordt gescheiden, gedroogd, verbrand of vergist is gebaseerd op Vervoersbewijzen dierlijke mest (VDMs). $NH_3$-emissies uit mestopslagen buiten de stal worden apart berekend. Omdat N-emissies worden berekend volgens het TAN-stroomprincipe, wordt de hoeveelheid TAN in buitenopslag gecorrigeerd voor alle N-verliezen in de stal. Emissies van N in de vorm van $NO_x$, $N_2O$ en $N_2$ zijn ook deel van de TAN-stroom en ontstaan door (de-) nitrificatie in de mest gedurende opslag in de stal en buitenopslagen en mest be- of verwerking. De $NO_x$ en $N_2O$ emissies worden verondersteld van gelijke omvang te zijn in termen van N-verlies, $N_2$ heeft eigen emissiefactoren. Voor al deze N-verliezen geldt dat ze zijn gebaseerd op de IPCC default emissiefactoren. Deze emissies worden geconverteerd in percentage van TAN voor gebruik in het TAN-stroommodel. In de mestopslag wordt ook rekening gehouden met het strooiselmateriaal dat samen met de mest in de opslag terechtkomt en extra N toevoegt.

De NMVOS-emissies vanuit mestmanagement zijn voor een groot deel afhankelijk van het voer, omdat de meeste emissies uit het gevoerde kuilvoer komen. Daarnaast komen er nog NMVOS-emissies uit de stal en de mestopslag buiten de stal. De NMVOS-emissies voor melkvee worden berekend aan de hand van voeropnamen, terwijl voor de andere diercategorieën deze met de hulp van excretie van organische stof worden berekend. Aangezien de NMVOS-emissies uit mest een key source zijn worden deze emissies via een Tier 2 benadering berekend. De gebruikte emissiefactoren zijn de EMEP 2023 default emissiefactoren.

Fijnstof ($PM_{10}$ en $PM_{2,5}$)-emissies van mestmanagement hangen voornamelijk af van het stalsysteem. Emissiefactoren zijn afgeleid van metingen. Indien niet gemeten, zijn emissiefactoren afgeleid van bestaande emissiefactoren van andere stalsystemen, gebruikmakend van ratio's van de fosfaat (P)-excretie als schaalfactor, of zijn default emissiefactoren gebruikt.

### Gewasproductie en landbouwbodems

Beschikbare N in mest voor aanwending wordt berekend door de N-verliezen in de stal en buitenopslagen af te trekken van de totale N-excretie van de dieren. De totale N-verliezen omvatten $NH_3$-N, $N_2O$-N, $NO_x$-N en distikstof-N ($N_2$). Daarnaast wordt gecorrigeerd voor de (netto) export van mest N en voor N-verliezen bij mestbehandeling. De N die als mest wordt toegediend aan landbouwgronden wordt dan verdeeld over gras- en bouwland (beteeld en onbeteeld) en bodemtypes (mineraal en veen), met een onderscheid in mestaanwendingstechnieken met specifieke $NH_3$-emissiefactoren. Voor beweiding wordt gebruik gemaakt van $NH_3$-emissiefactoren gebaseerd op TAN-excretie tijdens beweiding. De $NH_3$-emissies door aanwending van minerale N-meststoffen, zuiveringsslib en compost, gewasafrijping en gewasresten die zijn achtergebleven op het veld worden berekend met landspecifieke emissiefactoren. De verdeling van de verschillende aangewende mestsoorten over gras- en bouwland en minerale gronden en veengronden wordt gedaan op basis van berekeningen met het INITIATOR model.

Na toediening van N aan landbouwgronden emitteert er ook $NO_x$ en $N_2O$. Voor $N_2O$ wordt onderscheid gemaakt tussen bovengrondse en emissiearme aanwending, omdat inwerken van dierlijke mest leidt tot een verhoogde $N_2O$-emissie. De emissiefactoren zijn landspecifiek (Tier 2), net als die voor minerale N-meststoffen, zuiveringsslib, compost, weidemest, gewasresten en het landbouwkundig gebruik van organische bodems. Emissies van $NO_x$ worden berekend op basis van de EMEP default emissiefactor voor N-toevoer naar de bodem.

Bij het toedienen van mest emitteert ook NMVOS. Op het moment zijn er nog geen emissiefactoren voor deze emissies. Er is er wel een correlatie gevonden tussen de $NH_3$- en NMVOS-emissies (EMEP Guidebook). De verhouding NMVOS uit mesttoediening tot NMVOS uit stal wordt gelijkgesteld aan de verhouding $NH_3$ uit mesttoediening tot $NH_3$ uit stal (EEA, 2023). Voor de NMVOS-emissies van weidegang, opslag van kuilvoer en de teelt van landbouwgewassen worden de EMEP 2023 default emissiefactoren gebruikt. Al deze bronnen worden geschat met een Tier 2-benadering, behalve de NMVOS-emissies van de teelt van landbouwgewassen, deze wordt met een Tier 1-methode berekend.

Tijdens de opslag, verwerking en transport van agrarische producten, het gebruik van landbouwbodems en oogsten vinden emissies van fijnstof (PM) plaats. Een Tier 2-benadering wordt gebruikt voor $PM_{10}$- en $PM_{2,5}$- emissies door het verbouwen van gewassen. Voor andere bronnen van PM-emissies (krachtvoer, anorganische meststoffen en pesticidengebruik) worden vaste schattingen per jaar gebruikt.

### Bekalking

Aanwending van kalk om de zuurtegraad van de bodem te verhogen, resulteert in $CO_2$-emissies vanwege de afbraak van carbonaat. Emissies van $CO_2$ door bekalking worden berekend aan de hand van jaarlijkse statistieken voor het gebruik van meststoffen en de IPCC default emissiefactoren (Tier 1).

### Aanwending ureum

De aanwending van ureum, een kunstmestsoort, resulteert in $CO_2$-emissies. Deze $CO_2$ is tijdens het productieproces opgeslagen om bij de aanwending weer vrij te komen. Emissies van $CO_2$ door aanwending ureum worden berekend aan de hand van jaarlijkse statistieken voor het gebruik van meststoffen en de IPCC default emissiefactoren (Tier 1).

### Overzicht van gebruikte methoden en emissiefactoren

Om luchtvervuilende stoffen in de Nomenclature For Reporting en Informative Inventory Report (NFR, IIR) indeling te rapporteren, wordt het niveau van methoden en emissiefactoren gebruikt in NEMA samengevat in Tabel S.1.

*Tabel S.1 Methoden en emissiefactoren (EF) gebruikt in NEMA voor luchtvervuilende stoffen, naar niveau zoals onderscheiden in het EMEP guidebook 2023 (gebruikt in het Informative Inventory Report; IIR en de Nomenclature For Reporting; NFR)*

| NFR broncategorie | | $NH_3$ | | $NO_x$ | | NMVOC | | $PM_{10}/PM_{2,5}$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Methode** | **EF** | **Methode** | **EF** | **Methode** | **EF** | **Methode** | **EF** |
| 3. Landbouw | | | | | | | | | |
| B. | Mest-management | T3 | CS | T3 | CS | T2 | D | T2 | CS |
| D. | Landbouw-bodems | T3 | CS | T3 | D | T1, T2 | D | T2 | CS, D |
| F. | Verbranden gewasresten op het veld | N/A | N/A | NO | NO | NO | NO | NO | NO |
| I. | Overig | NO | NO | NO | NO | NO | NO | NO | NO |

Methode: T2 = EMEP Tier 2; T3 = EMEP Tier 3; NO = not occurring (komt niet voor); N/A = not applicable (niet van toepassing).
EF: D = EMEP default; CS = country-specific (landspecifiek); NO = not occurring (komt niet voor); N/A = not applicable (niet van toepassing).

De gebruikte methoden en emissiefactoren zijn volledig in lijn met de vereisten uit het EMEP Guidebook 2023.

Om broeikasgassen in de Common Reporting Tables en het National Inventory Report (CRT, NIR) te rapporteren, wordt het niveau van methoden en emissiefactoren gebruikt in NEMA samengevat in Tabel S.2.

*Tabel S.2 Methoden en emissiefactoren (EF) gebruikt in NEMA voor broeikasgassen, naar niveau zoals onderscheiden in de 2019 refinement to the IPCC 2006 Guidelines (gebruikt in het National Inventory Report; NIR en de Common Reporting Tables; CRT)*

| **CRT broncategorie** | **$CO_2$** | | **$CH_4$** | | **$N_2O$** | |
|---|---|---|---|---|---|---|
| | **Methode** | **EF** | **Methode** | **EF** | **Methode** | **EF** |
| 3. Landbouw | | | | | | |
| A. Enterische fermentatie | N/A | N/A | T1, T2, T3 | CS, D | N/A | N/A |
| B. Mestmanagement | N/A | N/A | T1, T2 | CS, D | T2 | D |
| C. Rijstbouw | N/A | N/A | NO | NO | N/A | N/A |
| D. Landbouwbodems | N/A | N/A | N/A | N/A | T1, T2 | CS, D |
| E. Voorgeschreven verbranding van savannes | N/A | N/A | NO | NO | NO | NO |
| F. Verbranden gewasresten op het veld | N/A | N/A | NO | NO | NO | NO |
| G. Bekalking | T1 | D | N/A | N/A | N/A | N/A |
| H. Aanwending Ureum | T1 | D | N/A | N/A | N/A | N/A |
| I. Overige koolstof bevattende meststoffen | NO | NO | N/A | N/A | N/A | N/A |
| J. Overig | N/A | N/A | NO | NO | NO | NO |

Methode: T1 = IPCC Tier 1; T2 = IPCC Tier 2; T3 = IPCC Tier 3;
NO = not occurring (komt niet voor); N/A = not applicable (niet van toepassing).
EF: D = IPCC default; CS = country-specific (landspecifiek); NO = not occurring (komt niet voor); N/A = not applicable (niet van toepassing).

De gebruikte methoden en emissiefactoren zijn volledig in lijn met de 2019 refinement to the 2006 IPCC Guidelines.

Kernwoorden: luchtverontreiniging, broeikasgassen, vee, gewassen, stallen, mestbe- of verwerking, mestopslag, bemesting, kunstmest, enterische fermentatie, mest management, landbouwbodems, bekalking, NIR, CRT, IIR, NFR

# 1 Introduction

In 2024, the agricultural sector was responsible for 90% of all ammonia ($NH_3$) emissions in the Netherlands. Agriculture is also a significant contributor to the emission of nitrogen oxides ($NO_x$). The deposition of $NH_3$ and $NO_x$ can have adverse effects in the form of eutrophication and acidification. Both $NO_x$ and Non-Methane Volatile Organic Compounds (NMVOC) have an effect on the formation of ozone, which, in turn, can have a negative effect on human health and plant growth. Agricultural activities constitute a considerable source of particulate matter (PM) emissions as well, especially in the coarse fraction of up to 10 µm in size ($PM_{10}$). Particulate matter, both 10 µm and 2.5 µm ($PM_{2.5}$) can have detrimental health effects, and it constitutes an uncertain factor in climate change.

With regard to the greenhouse gases methane ($CH_4$) and nitrous oxide ($N_2O$), agriculture is the largest contributor to total national emissions. In 2024, the two gases combined and expressed as carbon dioxide equivalents ($CO_2$-eq.), amount to about 12% of all Dutch greenhouse gas emissions. Stationary combustion (mainly from heating in horticulture) and the use of mobile equipment are not allocated to agriculture, as they are included in the energy sector. The only $CO_2$ emissions reported in the agricultural sector originate from calcareous fertilizers (liming) and the application of urea.

Air-polluting emissions and greenhouse gas emissions are subject to differing reporting requirements, which are explained further in the following sections.

**Reporting requirements and institutional arrangements**

Under the Paris Agreement and under EU legislation, the Netherlands is required to set up and maintain a national system for monitoring its greenhouse gas emissions. One element of this system is a transparent and verifiable description of the methods and processes used within this monitoring system. These methods must meet international guideline criteria, which are defined by the United Nations (UN) and the European Union (EU), as described in the *2019 Refinement to the 2006 IPCC Guidelines*.

The Netherlands also reports emissions of other air pollutants. These reports are used to assess whether the Netherlands meets the National Emission Ceilings (NEC) and, as a party to the Convention on Long Range Transboundary Air Pollution (CLRTAP), the Gothenburg Protocol. In this case as well, the methods must meet the criteria of international guidelines, as defined by the European Monitoring and Evaluation Programme (EMEP) of the European Environment Agency (EEA), and described in the *EMEP Guidebook 2023*.

The Pollutant Release and Transfer Register (PRTR; in Dutch, '*Emissieregistratie*' [ER]) collects and formally establishes annual emissions of pollutants to air, water and soil. The PRTR is a collaborative group that includes the following and other entities: Statistics

Netherlands (CBS), Wageningen University & Research (WUR), the National Institute for Public Health and the Environment (RIVM) and PBL Netherlands Environmental Assessment Agency. It is coordinated by RIVM, under the supervision of the Netherlands Enterprise Agency (RVO), which acts as the National Inventory Entity (NIE) for greenhouse gas reporting. The PRTR is commissioned by the Ministry of Climate Policy and Green Growth (KGG), the Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN) and the Ministry of Infrastructure and Water Management (I&W).

Within the PRTR, several teams work on specific sectors defined by the guideline criteria, including the task force on Agriculture. Emissions from land use, land use change and forestry (LULUCF) are reported according to an unrelated calculation method. However, activity data that are used to calculate agricultural emission as well as LULUCF emissions are checked for consistency. The LULUCF calculation methods can be found in Van Baren et al., (2026). This report concerns emissions to air originating from agricultural activities, based on the National Emission Model for Agriculture (NEMA). The current report provides an overview of the methods applied in NEMA to estimate emissions of $CH_4$, $NH_3$, $N_2O$, $NO_x$, NMVOC, $PM_{10}$, $PM_{2.5}$ and $CO_2$ from the agricultural sector.

Emissions data are available through the website www.emissieregistratie.nl, as well as in annual reports on greenhouse-gas emissions (National Inventory Report, NIR) and other pollutants (Informative Inventory Report, IIR). Data from the PRTR are also used for the evaluation of national environmental policy and in many other environmental reports. For this reason, annual reports are also published in Dutch with updated NEMA results (Van der Most *et al.*, 2026; in prep.).

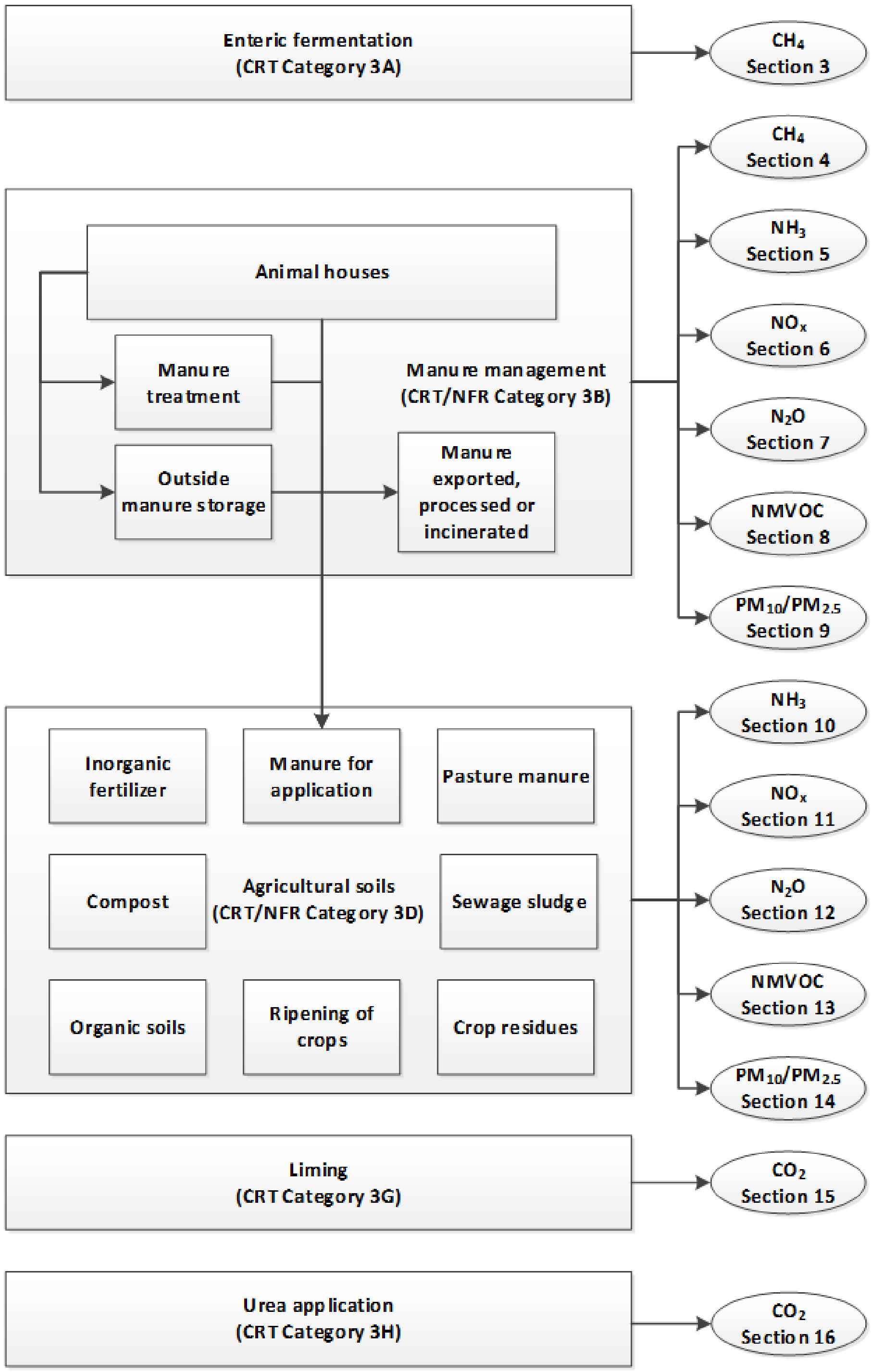
**Outline of the report**

Following this introductory section covering general aspects of emission and uncertainty calculations, subsequent sections describe the scope, definition, calculation method, emission factors, activity data, uncertainty and quality for each combination of compound and source category distinguished. The categorisation of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the EMEP Guidebook 2023 has been followed in this regard (IPCC, 2019; EEA, 2023). The Common Reporting Tables (CRT, to accompany the NIR) and the Nomenclature For Reporting (NFR, accompanying the IIR) are used for reporting purposes.

Emissions from agriculture occur in the following sectors: Enteric fermentation (3A), Manure management (3B), Agricultural soils (3D), Liming (3G) and Urea application (3H). Because of climatological conditions, activities relating to Sectors 3C (Rice cultivation) and 3E (Prescribed burning of savannahs) do not occur in the Netherlands. In addition, no emissions are produced from Sector 3F (Field burning of agricultural residues), as these activities were prohibited by law for the entire time series (Article 10.2 of the Environmental Management Act (in Dutch, '*Wet Milieubeheer*').

An overview of processes and emissions is presented in Figure 1.1, indicating the sections in which they are discussed in detail. The sections are arranged consecutively, starting at the animal level and proceeding to manure management (animal housing and outside manure storage), agricultural soils, liming and urea application, thereby providing a full overview of emission calculations. Repetition of information was kept to a minimum. However, some repetition was inevitable, as the sections are also intended to be read independently. Readers who are interested in specific compounds should therefore be able to skip the other sections.

*Figure 1.1 Processes and emissions in agriculture, with allocations to CRT and NFR reporting categories and the corresponding sections in this report.*

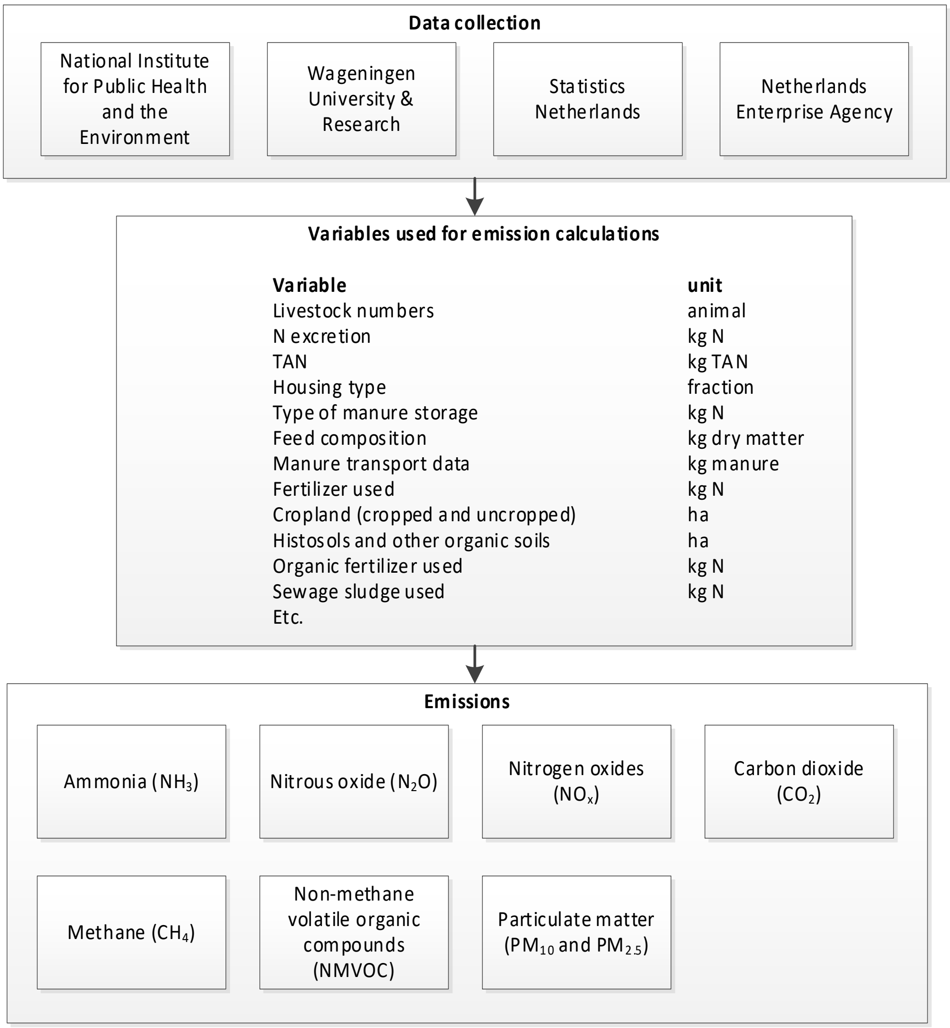


# 2 General aspects

## 2.1 Data collection

Several institutes work together to collect the data necessary to calculate the volume of emissions from agricultural activities in the Netherlands (Figure 2.1): Statistics Netherlands (CBS), the National Institute for Public Health and the Environment (RIVM), the Netherlands Enterprise Agency (RVO) and Wageningen University & Research (Wageningen Social & Economic Research, Wageningen Environmental Research, Wageningen Plant Research and Wageningen Livestock Research).

*Figure 2.1 Overview of the institutes collaborating to gather the data used to calculate the emissions from agriculture, with the most important variables for the calculations and all ensuing emissions calculated by NEMA and reported in the National Inventory Report and the Informative Inventory report.*



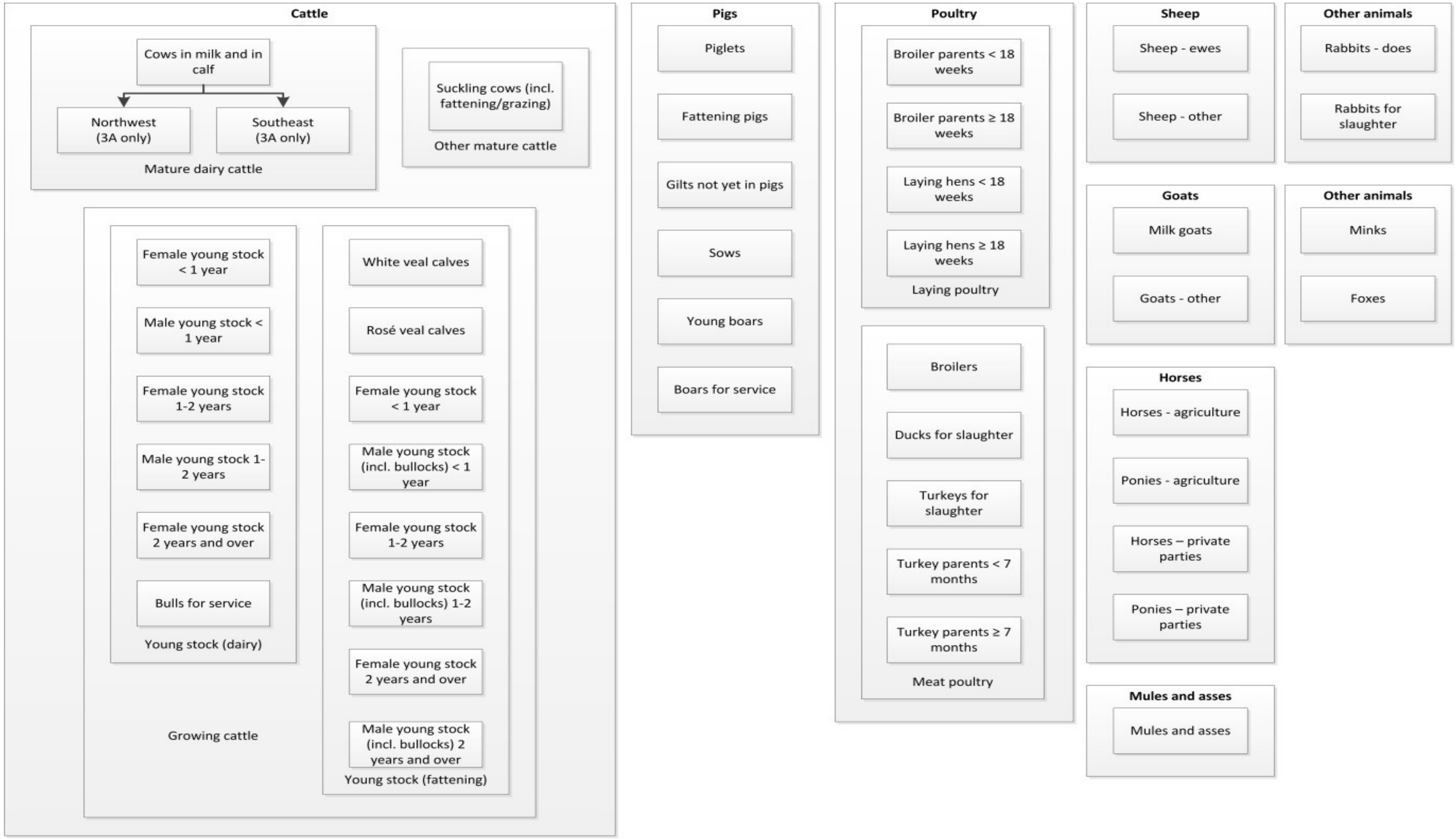
## 2.2 Activity data

In the Netherlands, livestock numbers, N excretion rates, bedding material usage and manure management types are used in the calculation of many different emissions for the purpose of calculating emissions from agricultural activities. The origin and calculation of livestock numbers and N excretions are described here, in order to minimise repetition in following sub-sections.

### *2.2.1 Livestock numbers*

Activity data on livestock numbers originate from the annual Agricultural Census. Until 2016, the census included all businesses with agricultural activities larger than three 'size units' (in Dutch, *grootte-eenheden*; until 2009) or 3,000 Standard Outputs in Euros (from 2010 onwards). Beginning in 2016, the Agricultural Census includes all agricultural businesses registered with agricultural activity codes in the Commercial Register of the Dutch Chamber of Commerce with more than 3,000 Euro Standard Outputs. Additional details on population statistics are available from CBS (www.cbs.nl) and Van der Most *et al.* (2026). The livestock categories are presented in Figure 2.2, as included in the Agricultural Census.

*Figure 2.2 Livestock categories in the Agricultural Census*



The Agricultural census distinguishes a considerable number of livestock categories and subcategories (Figure 2.2). This categorisation is also used in the NEMA calculations, with the results grouped into reporting categories, as indicated as the Average Animal Population (AAP) in the IIR/NFR and the NIR/CRT.
A small number of buffalo is kept in the Netherlands (less than 5000 in 2023). Since 2016 farmers register their buffalo in the agricultural census and state the purpose of the buffalo (beef or dairy). For the emission calculations the buffalo are included with the dairy cattle and other cattle accordingly. Emissions from buffalo are included in the emissions from cattle for two reasons. Firstly, the small number of buffalo (compared to the number of cattle) has no significant effect on the total emissions from cattle. Secondly, farmers were not asked about keeping buffalo before 2016. Farmers thus registered them as cattle (beef or dairy) in the agricultural census. From 2016 onwards, farmers have to register the number of buffalo separately and state the purpose of the buffalo (beef or dairy). In the calculations the buffalo are then treated accordingly as dairy cattle, growing cattle or other mature cattle. This procedure results in the most consistent timeseries.

The Agricultural Census states the number of animals as of 1 April. This number is assumed to be representative of the number of animals throughout the year, except in cases of outbreaks of animal diseases or other events that could cause fluctuations in the number of animals. In such cases, Statistics Netherlands/Working Group on Uniformity of Calculations for Manure and Mineral Data (WUM) modifies the number of animals, and the modified numbers are used in the emission calculations. To create a more consistent approach and prevent the need to modify the animal numbers it was decided to use the Identification and Registration (I&R) system from RVO. The I&R is a system of the Netherlands Enterprise Agency in which farmers have to register animals that are born, arrive on the farm and leave the farm (CBS, 2020 and RVO, 2020). The I&R is used from 2017 for cows and from 2018 for poultry, sheep and goats. The use of I&R for poultry resulted in lower poultry numbers, especially broilers, as farmers tended to report a full animal house in the Agricultural Census when their housing was empty on the reference date (1st of April) and did not take mortality into account when reporting their poultry, leading to a systematic overestimation of poultry numbers. The use of data from the agricultural census till 2017 and the use of I&R-data from 2017 resulted in an inconsistent time series for broilers and ducks. The relative difference between broiler and duck numbers from the agricultural census and the I&R of 2017 has been used to correct the time series by linearly extrapolating the number of broilers and ducks between 1990 and 2016. The number of ducks was decreased by 12.5% and the number of broilers by 7.5% using this correction of the time series. Unfortunately, 2017 was the only year with overlap as the agricultural census had no legal grounds to include questions on poultry numbers after the I&R had proved to be sufficient. For turkeys, it was not possible to implement a correction to the time series, because comparison of the difference between the agricultural census and the I&R in 2017, shows that turkey numbers had been underestimated. No explanation can be given for this underestimation. It should also be noted that the number of turkeys is low compared to broilers (566.206 turkeys vs. 44 million broilers in

2020) and that the number of turkeys varies strongly per year (Van Bruggen *et al.,* 2025).

Between 1990 and 2009, no figures were available on the number of mules and asses in the Netherlands. Based on expert judgement, the number of mules and asses has been set at a 1000 heads between 1990-2009. From 2010 onwards, the number of mules and asses has been included in the agricultural census. The number of privately-owned horses, ponies, mules and asses and sheep was not registered in the Agricultural Census. The former Product Boards for Livestock, Meat and Eggs estimated the number of privately owned horses and ponies at 300,000 (PVE, 2005). This number has been applied between 1990 and 2015. From 2016 onwards more detailed information became available on the number of privately held animals.

### 2.2.2 *N excretions*

The N excretions in animal houses (taking into account excretions on grassland during grazing) are calculated using the annually updated data of the WUM. The calculation methodology assumes a certain nutrient balance per animal, for which the nutrient excretion is calculated from the difference between nutrient uptake from feed and nutrient fixation in animal products. These data have been published by CBS (CBS, 2019-2025; in Dutch).
The starting points for calculating N emissions are the N excretion figures derived by the WUM. For emission calculations, the age category ≥ 1 year for cattle is divided into the age categories of 1-2 and > 2 years, with the same N excretions per animal. For the calculation of uncertainty values, they are not assessed separately, but combined. The manure production and nutrient excretion of piglets is included in the sow's figures, and a similar process is used for sheep, goats, rabbits and fur-bearing animals, for which the manure production and nutrient excretion of their young stock are also included in the figures for the mother animal. From 2022 onwards the N-excretion of weaned piglets is separately available (CBS, 2023).

### 2.2.3 *Manure management*

Animal manure can be either slurry or solid, depending on the livestock category and housing system (e.g. the use of straw). It is called slurry (or liquid manure) if it flows under gravity and is pumpable, while solid manure is stackable and can be packed in heaps (RAMIRAN, 2011).

- *Cattle* manure in the Netherlands is mainly stored as slurry. The majority of female young stock, dairy and suckling cows are kept on pastureland during the grazing period (May-October). This results in a share of the urine and faeces being excreted on the pastures. All dairy cows spend part of the day inside animal housing during the grazing period, depending on the grazing system applied, particularly at night and during milking times. Around 30% of the Dutch dairy cattle are kept at farms that practice no grazing.
- *Pig* manure in the Netherlands is predominantly slurry. All pigs are kept indoors year-round. A minor proportion of pig manure is solid, produced when bedding material is used (e.g. straw).

- *Poultry* includes laying hens, broilers, ducks and turkeys. Because of the high dry matter content of poultry excreta and the housing systems used, all poultry manure is currently considered solid. Battery cage systems with slurry were used in the earlier years of the time series. In recent years, poultry systems with free ranging have become more prevalent.
- *Goats* in the Netherlands are kept inside animal housing throughout the year and produce solid manure.
- *Sheep* are grazing animals kept outside except during the lambing season. During this housing period, they produce solid manure.
- *Horses, mules and asses* produce manure in animal housing and during grazing. Solid manure is produced in the period inside animal housing.
- *Rabbit*s are kept indoors year-round and produce solid manure.
- *Fur-bearing animals (minks and foxes*) are kept indoors year-round and produce liquid manure. Foxes have been banned in the Netherlands since 2008, minks since 2021.

### *2.2.4 Bedding material*

Bedding material provided to livestock in the form of e.g. straw is a nitrogen input into the manure and contributes to N-emissions from manure during storage, treatment and application. The IPCC guidelines and EMEP guidebook both provide methods to include bedding material and all related emissions in the inventory. The Tier 1 method assumes only straw is used as bedding material. As no information is available on the usage of other forms of bedding material in the Netherlands only straw is taken into account for the calculations in NEMA and INITIATOR. The Tier 1 methods assume a certain amount of straw to be provided per animal place per year. For grazing livestock, it is assumed that no straw is provided on days with grazing. The Dutch consumption of straw, per animal place and in the case of grazing livestock per animal place per day indoors, can mainly be based on information provided by the BedrijvenInformatieNetwerk (BIN).
Not all animal categories could be based on the BIN due to some lack of data. For these animal categories EMEP default values, or values from the German and Danish IIR were used, according to expert judgement. The applied bedding material usage per animal category can be found in Annex 11.

The immobilisation properties of the bedding material in the manure storage are not taken into account as the emission factors from storage are based on measurements from manure that already had bedding incorporated.

### *2.2.5 Manure application and grazing*

The amount of animal manure applied in the Netherlands is calculated as the TAN excretions, plus the TAN added to the manure in the form of bedding material, minus N emissions in animal houses, minus N emissions during manure treatment and during manure storage, and minus exported N. The amount of exported manure is reported by RVO, based on the transportation documents that are mandatory for exported and imported manure (amount and N content). The remaining manure is subsequently distributed over the different land types (grassland,

cropland uncropped, cropland cropped) and soil types (mineral soil and organic soil) using the INITIATOR model (Kros *et al.,* 2019 and De Vries *et al.,* 2023). The application methods are provided by the annual agricultural census.
The amount of N that is excreted during grazing is based on the amount of time animals spent grazing. The amount of time cattle spend grazing is provided by the annual agricultural census. Fixed values are applied for horses, ponies, mules and asses and sheep (Van Bruggen, 2008).

## 2.3 Emission calculations

In the Netherlands, agriculture is a major source of $NH_3$, $NO_x$, $N_2O$, NMVOC, $CH_4$, $PM_{10}$ and $PM_{2.5}$ emissions. Both $NH_3$ and $NO_x$ contribute to the eutrophication and acidification of soils, while $N_2O$ and $CH_4$ are greenhouse gases, and $N_2O$ and NMVOC damage the ozone layer. Particulate matter affects human health, and N emissions reduce the efficiency of nitrogen use in agriculture.
Commissioned by the Ministry of Climate Policy and Green Growth, the NEMA working group of the CDM developed a method to calculate $NH_3$ emissions in 2009 (Velthof *et al.*, 2009). The method includes emissions from animal housing, manure treatment and manure storage for livestock categories in the Dutch Agricultural Census, as well as from livestock grazing in pastures and applications of animal manure and fertilizers to the soil. At the request of the PRTR, modules for the calculation of $NO_x$, $N_2O$, $CH_4$, $PM_{10}$ and $PM_{2.5}$ have been included in the model since the emission calculations of 1990-2012 (Van Bruggen *et al.*, 2014). The name of the model was therefore changed from the National Emission Model for Ammonia to the National Emission Model for Agriculture (NEMA). With the implementation of the 2006 IPCC Guidelines in 2013, a module for the calculation of $CO_2$ from calcareous fertilizers (liming) was added as well. The 2016 update to the EMEP Guidebook led to the addition of NMVOC emission calculations in 2018. In 2021 the $CO_2$ emissions from the application of urea were added. This is in line with the approach in the 2006 IPCC Guidelines to allocate emissions of urea during use (and not in the production).

The results are used in reports to the EU and to assess whether the Netherlands is in compliance with the NEC directive and the UNECE (Gothenburg Protocol). The results are also reported to the UNFCCC within the context of the Paris Agreement.

**Reporting at higher levels**
The NEMA model calculates emissions using more subcategories than are reported internationally. In addition, there can be more emission factors than are actually reported. These subcategories are aggregated for purposes of reporting activity data and emissions. The resulting average emission factors are calculated by dividing emissions by the activity data. This calculated emission factor is referred to as the 'implied emission factor'.

## 2.4 Uncertainty calculations

### *2.4.1 General*

Models are not an exact representation of reality, and their estimates are therefore uncertain to some extent. In activity data, the availability and representativeness of data constitute the main source of uncertainty. When applying emission factors, uncertainties emerge from possible measurement errors, statistical random-sampling errors or missing data. Other causes of uncertainty include lack of completeness due to unrecognised emission sources or lack of measurement methods. These aspects are not taken into account in the current uncertainty analysis. For more details on causes of uncertainty, see Chapter 3 of the 2019 IPCC Guidelines (IPCC, 2019).

According to the guidance documents, uncertainty estimates are essential to a complete emission inventory. The Netherlands is obliged to estimate uncertainties for the national level and for trends in emissions, as well as for separate components: activity data, emission factors and other parameters used in estimating emissions. Uncertainty estimates for separate components and for the calculation methods should be used to prioritise efforts to make further improvements to the calculation of emissions. Additional attention should be paid to emissions sources listed in NEMA that have relatively high uncertainty and that are responsible for relatively large emissions.

An Approach 1 uncertainty analysis (propagation-of-error) as well as an Approach 2 analysis (Monte Carlo) are implemented each year before the NIR is submitted by the PRTR, based on the greenhouse gas inventory and in compliance with IPCC Guidelines. The assumptions used and their results are described in an annex to the NIR.

Based on the 2022 inventory (1990-2020 time series), new uncertainty estimates for the agricultural sector were calculated using the propagation-of-error approach for the most recent reference year (2020). Uncertainty values were estimated based on literature and expert judgements. Previous estimates were reconsidered and revised as needed, based on new insights or changed methods. Data from this uncertainty analysis were also used as input for the Monte Carlo analysis of uncertainties conducted on the 2022 inventory of emissions in the Netherlands. A more in-depth methodology of the uncertainty analysis is provided in the following subsections. A detailed overview of quality assurance and quality control is provided in Annex 11, which also contains outlines for the verification of data.

Methods for estimating emissions are periodically improved in response to the availability of new data or new scientific insights. This should be reflected in any new estimate of uncertainty for the relevant emission sources. An updated method does not automatically mean a reduction in uncertainty, as it is also possible that uncertainty was underestimated in the past.

### 2.4.2 *Calculation method*

For each emission source reported in the NIR and the IIR, uncertainty values are estimated according to the propagation-of-error method. The uncertainty value for each emission source is calculated as the square root of the sum of squared uncertainty values for the activity data and the emission factor (actual or implied), including their interaction (see Formula 2.1). The extent of total uncertainty is determined primarily by the largest uncertainty value, which is usually that of the actual or implied emission factor.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{(\text{U AD}^2 + \text{U IEF}^2 + (\text{U AD} \times \text{U IEF})^2)} \quad (2.1)$$

Where

| | | |
|---|---|---|
| Uncertainty $\text{estimate}_{\text{total}}$ | : | Total uncertainty estimate for an emission source |
| U AD | : | Relative uncertainty value for the activity data of the emission source |
| U IEF | : | Relative uncertainty value of the implied emission factor of the emission source |

Uncertainty over all emission sources (not limited to agriculture) is calculated by aggregating the subcategories, with the propagation-of-error method and the Monte Carlo method to simulate uncertainty at the national scale.

**Activity data**
For most emission sources within the agricultural sector, the activity data consist of livestock numbers. This can either be a total number of animals in a category (e.g. dairy cows, ducks, goats) or an aggregate of subcategories within a livestock category (e.g. the category 'young stock for milk production' consists of five subcategories divided by age and gender; 'laying hens' consists of four subcategories divided by age and production goal [eggs or broiler breeder]). A few emission sources are not directly related to livestock numbers. Activity data for emissions from crop production, grassland renewal and agricultural soils are expressed in acreage. Emissions from the application of fertilizer, compost and sewage sludge are based on input in kilograms N.

The composition of activity data for an emission source may differ between pollutants. A distinction between subcategories of livestock can be relevant for one pollutant, but irrelevant for another pollutant. Distinctions between subcategories are made when scientifically important and omitted when scientifically irrelevant, in order to simplify the calculations.

**Emission factor**
For emission sources calling for the use of Tier 1 methods, the default uncertainty from the IPCC Guidelines or EMEP Guidebook is used. When a range of uncertainties is given, the uncertainty value to be used is determined according to the expert judgement of the task force agricultural emissions.

To achieve a better approximation of the emissions, Tier 2 or Tier 3 methods can be used to estimate emissions. The uncertainty values associated with these calculations are derived based on literature and expert judgement. The list of experts consulted is provided in Annex 11. Higher-tier methods generally use more parameters for emission calculations, which increases the uncertainty. Less-complicated methods could yield lower uncertainty, while higher-tier methods (with possibly higher uncertainties) provide a better approximation of the complexity of the model, the availability of scientific data and the possibility of gaining insight into mitigation measures.

When the emission factor is calculated using several parameters, the uncertainty value for the implied emission factor is calculated using the propagation-of-error method.

**Levels of calculation and reporting**
Emission calculations are performed using livestock categories that are more detailed than those used in the reporting of emissions. For this reason, uncertainty values have been aggregated using the propagation-of-error method. With independent categories, the aggregation of uncertainty values leads to lower combined uncertainty. The propagation-of-error method can be used to calculate uncertainty values with dependencies, although simplified formulas are available only for fully dependent or independent uncertainties. Dependencies between 0% and 100% can be aggregated during the calculation of overall uncertainty. This method is used to reduce the likelihood of underestimating uncertainty values.

### 2.4.3 *Uncertainties of general activity data*

**Uncertainty of livestock numbers**
Uncertainty estimates for livestock numbers have been described by Statistics Netherlands (CBS, 2012). It was necessary to include additional uncertainty values according to expert judgement, as they are not part of the methodology of the WUM. In most cases, this applies to young animals, for which N excretions are included in the excretions of the mother animal. The uncertainty value for the number of piglets is assumed to be 10%, with the values in the total number of sheep being 10% and in the total number of goats being 10%, based on expert judgement. The uncertainty of poultry numbers have been reduced by half as the I&R system is more accurate than the agricultural census. The uncertainty of the number of privately-owned horses and ponies, mules and asses and sheep is assumed to be 50%.

The combined uncertainty values of the aggregated categories are calculated using the following formula:

Combined uncertainty = $\sqrt{(\Sigma\ (\text{U for livestock category}_i \times \text{AAP}_i)^2)} / \Sigma\ \text{AAP}_i$
(2.2)

Where:

| | | |
|---|---|---|
| Combined uncertainty | : | Relative uncertainty of the reported livestock category |
| U livestock category$_i$ | : | Relative uncertainty of the livestock subcategory (i) |
| AAP$_i$ | : | Average animal population for livestock category (i) |

This formula assumes 100% independence of categories. Uncertainty values for the livestock subcategories are presented in Table 2.1.

The same formula can also be used to disaggregate uncertainty values. An assumption must be made concerning whether absolute or relative uncertainty values are the same for the underlying categories. This is sometimes necessary when higher-level uncertainty values are reported in literature.

*Table 2.1 Uncertainty values for livestock numbers (CBS, 2012) updated in 2022 based on expert judgement*

| Livestock category | Uncertainty |
|---|---|
| *Cattle for breeding* | |
| Female young stock < 1 year | 2% |
| Male young stock < 1 year | 2% |
| Female young stock ≥ 1 year | 2% |
| Male young stock ≥ 1 year | 2% |
| Dairy cows | 2% |
| *Cattle for fattening* | |
| Veal calves, for white veal production | 2% |
| Veal calves, for rosé veal production | 2% |
| Female young stock < 1 year | 2% |
| Male young stock (incl. young bullocks) < 1 year | 2% |
| Female young stock ≥ 1 year | 2% |
| Male young stock (incl. young bullocks) ≥ 1 year | 2% |
| Suckling cows | 2% |
| *Other grazing animals* | |
| Sheep (ewes) | 5% |
| Sheep (all) | 10%[1)] |
| Dairy goats (≥ 1 year) | 5% |
| Goats (all) | 10%[1)] |
| Horses (agriculture) | 5% |
| Ponies (agriculture) | 5% |
| Mules and asses (agriculture) | 5%[1)] |
| Sheep (ewes not agriculture) | 50%[3)] |
| Horses and ponies (not agriculture) | 50%[1)] |
| Mules and asses (not agriculture) | 50%[3)] |
| *Pigs* | |
| Piglets | 10%[2)] |
| Fattening pigs | 10% |
| Sows | 5% |
| Breeding pigs | 5% |
| Boars | 5% |
| *Poultry* | |
| Broiler breeders < 18 weeks | 5%[3)] |
| Broiler breeders ≥ 18 weeks | 3%[3)] |
| Laying hens < 18 weeks | 5%[3)] |
| Laying hens ≥ 18 weeks | 3%[3)] |
| Broilers | 5%[3)] |
| Ducks | 5%[3)] |
| Turkeys | 5%[3)] |
| *Other animals* | |
| Rabbits (does) | 5% |
| Other rabbits | 10%[1)] |
| Mink | 5% |

1) Expert judgement.
2) Expert judgement: the 10% uncertainty value for piglets was estimated according to the following calculation. In 2012, there were 2.37 litters per sow (Agrovision). The number of full-grown piglets was 27.8 per sow. Assuming that piglets die primarily in the beginning, there would be 11.7 (27.8/2.37) piglets per litter. After 78 days, piglets become fatteners, while the next litter comes after 154 days (365/2.37). The average number of piglets per

sow during a year is thus 78/154x11.7 = 5.93. With 938,000 sows in 2012, there were 5.93 x 938,000 = 5.6 million piglets. The Agricultural Census counted 5.2 million piglets.
3) Expert judgement, updated in 2022.

**Uncertainty of N excretions**

The uncertainty values for N excretions have been estimated previously (CBS, 2012) and are summarised in Table 2.2 below. Although WUM reports the division of excretions over the housing and grazing periods, an uncertainty value is reported only for total excretions. In order to perform a propagation-of-error analysis on both animal housing and grazing emissions, uncertainty values were calculated for the shares:

$$U\ animal\ housing_i = \sqrt{((N\ excretion_i \times U\ N\ excretion_i)^2/(2 \times N\ excretion_{i,\ animal\ housing}^2))} \quad (2.3a)$$

$$U\ pasture_i = \sqrt{((N\ excretion_i \times U\ N\ excretion_i)^2/(2 \times N\ excretion_{i,\ pasture}^2))} \quad (2.3b)$$

Where:

| | | |
|---|---|---|
| U animal housing$_i$ | : | Relative uncertainty of N excretions in animal housing for livestock category (i) |
| U pasture$_i$ | : | Relative uncertainty of N excretions on pasture for livestock category (i) |
| N excretion$_i$ | : | Total N excretions for livestock category (i) |
| U N excretion$_i$ | : | Relative uncertainty of total N excretions for livestock category (i) |
| N excretion$_{i\ animal\ housing}$ | : | N excretions in animal housing for livestock category (i) |
| N excretion$_{i\ pasture}$ | : | N excretion on pasture for livestock category (i) |

The model assumes that only female cattle graze along with sheep, horses, ponies, mules and asses. Male cattle and dairy goats are generally kept indoors in the Netherlands, as are pigs and poultry (although some free-ranging of poultry does occur, it is accounted for in the emission factor for animal housing).

*Table 2.2 Uncertainty values (U, %) for total N excretion (CBS, 2012) and N excretions in animal housing and on pasture updated in 2022 based on excretions in 2020*

| Livestock category | U total N excretion per head | U animal house N excretion per head | U pasture N excretion per head |
|---|---|---|---|
| *Cattle for breeding* | | | |
| Female young stock < 1 year | 4.9% | 3.9% | 30.2% |
| Male young stock < 1 year | 5.5% | - | - |
| Female young stock ≥ 1 year | 4.1% | 3.8% | 12.7% |
| Male young stock ≥ 1 year | 5.3% | - | - |
| Dairy cows | 5.8% | 4.7% | 33.5% |
| *Cattle for fattening* | | | |

| Livestock category | U total N excretion per head | U animal house N excretion per head | U pasture N excretion per head |
|---|---|---|---|
| Veal calves, for white veal production | 14.8% | - | - |
| Veal calves, for rosé veal production | 9.5% | - | - |
| Female young stock < 1 year | 4.9% | 3.9% | 31.2% |
| Male young stock < 1 year (incl. young bullocks) | 11.3% | - | - |
| Female young stock ≥ 1 year | 4.1% | 3.7% | 12.9% |
| Male young stock ≥ 1 year (incl. young bullocks) | 8.9% | - | - |
| Suckling cows | 5.3% | 7.9% | 7.1% |
| *Other grazing animals* | | | |
| Sheep (ewes, including young animals and males) | 6.0% | 44.1% | 4.7% |
| Dairy goats ≥ 1 year (including young animals and males) | 14.5% | - | - |
| Horses (agriculture) | 21.4% | 28.4% | 32.4% |
| Ponies (agriculture) | 21.4% | 33.5% | 27.6% |
| Mules and asses[1)] | 21.4% | 33.5% | 27.6% |
| *Pigs* | | | |
| Fattening pigs | 9.9% | | |
| Sows (including piglets) | 11.4% | | |
| Breeding pigs | 9.8% | | |
| Boars | 7.9% | | |
| *Poultry* | | | |
| Broiler breeders < 18 weeks | 10.7% | | |
| Broiler breeders ≥ 18 weeks | 6.8% | | |
| Laying hens <18 weeks | 10.8% | | |
| Laying hens ≥ 18 weeks | 8.3% | | |
| Broilers | 21.6% | | |
| Ducks | 14.6% | | |
| Turkeys | 13.1% | | |
| *Other animals* | | | |
| Rabbits (does, including young animals and males) | 9.4% | | |
| Mink (females, including young animals and males) | 11.8% | | |

1) Mules and asses are not part of the calculations performed by WUM, and they have been set equal to ponies.

**Uncertainty of manure management systems**
The uncertainty value for the division between the solid and slurry fractions (summarised in Table 2.3) is estimated by experts at 10% for the smallest fraction. The uncertainty value for the larger fraction is derived by multiplying by the ratio between the manure management systems. If all of the manure is in a single manure management system (either all solid or all slurry), the uncertainty value is assumed to be 0%.

*Table 2.3 Uncertainty values (U, %) for manure management systems (expert judgment)*

| Livestock category | Manure management system | U fraction solid/slurry |
|---|---|---|
| *Cattle for breeding* | | |
| Cows in milk and in calf | Slurry | 10 |
| | Solid | 0.20 |
| Female young stock < 1 year | Slurry | 1.24 |
| | Solid | 10 |
| Male young stock < 1 year | Slurry | 7.24 |
| | Solid | 10 |
| Female young stock ≥ 1 year | Slurry | 1.24 |
| | Solid | 10 |
| Male young stock ≥ 1 year | Slurry | 7.24 |
| | Solid | 10 |
| *Cattle for fattening* | | |
| Veal calves, for white veal production | Slurry | 0 |
| Veal calves, for rosé veal production | Slurry | 0 |
| Female young stock < 1 year | Slurry | 10 |
| | Solid | 10 |
| Male young stock (incl. young bullocks) < 1 year | Slurry | 10 |
| | Solid | 10 |
| Female young stock ≥ 1 year | Slurry | 10 |
| | Solid | 10 |
| Male young stock (incl. young bullocks) ≥ 1 year | Slurry | 10 |
| | Solid | 10 |
| Suckling cows (incl. fattening/grazing) ≥ 2 years | Slurry | 10 |
| | Solid | 10 |
| *Pigs* | | |
| Fattening pigs | Slurry | 0 |
| Rearing pigs | Slurry | 0 |
| Sows | Slurry | 0.42 |
| | Solid | 10 |
| Boars for service | Slurry | 4.08 |
| | Solid | 10 |
| *Poultry* | | |
| Broilers | Solid | 0 |
| Ducks | Solid | 0 |
| Turkeys | Solid | 0 |
| Broiler breeders < 18 weeks | Solid | 0 |
| Broiler breeders ≥ 18 weeks | Solid | 0 |
| Laying hens < 18 weeks | Solid | 0 |
| Laying hens ≥ 18 weeks | Solid | 0 |

## 2.5 Quality assurance and quality control

### *2.5.1 General*

The Following sections provide an overview of the different steps that are taken every year for quality assurance and quality control purposes.

### *2.5.2 Quality assurance*

During the process of compiling the activity data and emission factors necessary to calculate the emissions multiple checks take place:

- The task force for agriculture emissions, which consists of experts from different institutes, with backgrounds in animal husbandry, crop production, and emissions meets several times during the year to discuss possible methodological changes based on new scientific insights, points brought up by reviewers, changes to the EMEP Guidebook or IPCC Guidelines and changes made by neighbouring countries. Members of this committee are:
  - G. Velthof (Wageningen Environmental Research)
  - M. Ros (Wageningen Environmental Research)
  - H. Kros (Wageningen Environmental Research)
  - H.J.C. van Dooren (Wageningen Livestock Research)
  - J. Mosquera (Wageningen Livestock Research)
  - J. Huijsmans (Wageningen Plant Research)
  - K. Oltmer (Wageningen Social & Economic Research)
  - M. van der Most (Centraal Bureau voor de Statistiek)
  - S. Weijers (Centraal Bureau voor de Statistiek)
  - A. Bleeker (Rijksinstituut voor Volksgezondheid en Milieu)
  - T. van der Zee (Rijksinstituut voor Volksgezondheid en Milieu)
  - W. Bussink (Nutriënten Management Instituut)
  - L. Schulte-Uebbing (Planbureau voor de Leefomgeving)
- A logbook is used to record when activity data and emission factors are sent to Statistics Netherlands and when they are implemented in NEMA. The logbook also contains a schedule of the expected period when the activity data and emission factors are sent to Statistics Netherlands.
- After every methodological change the model is run and the new emission totals are saved, allowing to assess the magnitude of the individual changes.

### *2.5.3 Quality control*

After compiling the activity data and emission factors multiple checks take place to ensure no mistakes were made after running the model:

- After all changes are implemented the model is sent from Statistics Netherlands to the RIVM which performs an additional check focussing on the implementation of the methodological changes and the consistency of the new year in the time series with the previous years.
- A file is sent to the members of the task force for agriculture emissions which shows the differences in emissions between the new time series and the previous time series, and the change in emissions between the newest year and the previous year. The file also gives an explanation for the changes in terms of activity data and emission factors. The members of the task force for agriculture emissions check the changes.
- In 2020, a review was performed by the NIE during which the methodology report was discussed with Statistics Netherlands and the RIVM.

- In 2023 CLM performed a review of the agriculture chapter of the NIR and the methodology report.
- A meeting is organised during which all sectors (Agriculture, LULUCF, Industrial processes and product use, Transport, Energy, Waste and Other) present their new time series and methodological changes. During this meeting members from the different contributing organisations are present as well as people not involved with compiling the emissions.
- A file with the time series is sent to the NIE for approval.
- The methodology report is sent to the NIE for approval.
- After the submission of the NIR and the IIR, reviews take place performed by reviewers from other countries.

# 3 $CH_4$ emissions from enteric fermentation (CRT sector 3A)

## 3.1 Scope and definition

This section provides a description of the methods and working processes used to determine the emission of $CH_4$ from ruminal and intestinal (enteric) fermentation. The following source categories are distinguished in the CRT:

- 3A1a Mature dairy cattle (ruminal and intestinal fermentation)
- 3A1b Other mature cattle (ruminal and intestinal fermentation)
- 3A1c Growing cattle (ruminal and intestinal fermentation)
- 3A2 Sheep (ruminal and intestinal fermentation)
- 3A3 Swine (intestinal fermentation only)
- 3A4 Other livestock
  a) Goats (ruminal and intestinal fermentation)
  b) Horses (intestinal fermentation only)
  c) Mules and asses (intestinal fermentation only)
  d) Poultry
  e) Other

In category 3A4d (Poultry), emissions are reported as ‘not estimated’ (NE), given that the anatomy of the gastro-intestinal tract of poultry (i.e. the high passage rate of feed) and the composition of poultry feed (relatively high energy value) result in a negligible contribution of fermentation processes to feed digestion. The 2019 refinement to the 2006 IPCC Guidelines also do not provide a default emission factor for poultry. No emissions are reported in category 3A4e (Other), either because the same applies to the livestock categories of fur-bearing animals and rabbits or because the respective species (lamas, alpacas and deer) are not kept commercially in the Netherlands.

The feed consumed by an animal is digested in the gastro-intestinal tract in order to provide the energy and nutrients needed for maintenance and production. Part of the nearly anaerobic gastro-intestinal tract accommodates a particularly large microbial population, fermenting the feed and forming methane as a by-product. In monogastric animals (e.g. pigs, horses, mules and asses), this involves only hindgut fermentation in the large intestine, which results in a relatively low $CH_4$ production compared to ruminants. The gastro-intestinal tracts of polygastric ruminants (e.g. cattle, sheep and goats) are adapted to digest fibrous material, especially in the rumen. In the process of intensive microbial fermentation, the rumen generates substantial amounts of $CH_4$.

In addition to the microbial matter synthesised through the fermentation of organic matter, volatile fatty acids and hydrogen gas are produced as end-products. Only a fraction of the hydrogen that is produced is utilised for microbial growth or the production of propionic acid and branched-chain volatile fatty acids. The remainder or surplus of the produced hydrogen is released into the rumen environment, either in the rumen fluid or in the gaseous head space. Together with $CO_2$, which is available in excess within the rumen environment, the surplus hydrogen gas is almost completely converted into $CH_4$ and water by methanogens. Under

Dutch feeding conditions for cattle (>80% of dry matter intake from roughages), less than 0.5% of the calculated enteric production of hydrogen was observed to be exhaled by dairy cattle, indicating that almost all surplus hydrogen is eventually converted into $CH_4$ (Van Zijderveld *et al.*, 2011). This relatively complete conversion of surplus hydrogen into $CH_4$ keeps the partial gas pressure of hydrogen in the rumen environment very low.

The amount of $CH_4$ produced by ruminants depends on the amount of feed consumed by the animal and the characteristics and composition of this feed (Veen, 2000; Smink *et al.*, 2003; Tamminga *et al.*, 2007). The amount of feed ingested strongly determines the amount of organic matter that will be fermented and, consequently, the amount of hydrogen gas that will be converted into $CH_4$. The characteristics of the feed (e.g. degradability, rate of degradation and outflow to the intestine) determine the fraction of individual feed components that will ferment in the rumen and the fraction that will escape rumen fermentation and flow out into the small intestine (Dijkstra *et al.*, 1992). The chemical composition of the fermented part of the feed determines the amount and type of volatile fatty acids that will be produced (Bannink *et al.*, 2008; Kebreab *et al.*, 2009), and it is thereby an important determinant of the amount of surplus hydrogen that will be converted into $CH_4$ (Mills *et al.*, 2001; Ellis *et al.*, 2008; Bannink *et al.*, 2011).

In conclusion, the amount and type of feed ingested determines the emission factor for $CH_4$ (i.e. the amount of $CH_4$ in kg $CH_4$/year that is produced by an animal), partly through its effect on the digestibility and 'methane-conversion factor' (i.e. the fraction of gross energy ingested with feed that is converted into $CH_4$).

## 3.2 Source-specific aspects

### *3.2.1 Calculation method*

The emission of $CH_4$ that is produced by enteric fermentation in cattle is calculated by multiplying the number of animals in each livestock category by a country-specific emission factor for that livestock category. For the other livestock categories, default emission factors are used, in accordance with the 2019 refinement to the 2006 IPCC Guidelines. The total $CH_4$ emission from all animals is calculated by summing the emissions of each livestock category.

$CH_4$ emissions enteric fermentation = $\Sigma_i$ $AAP_i$ x EF $CH_4$ enteric fermentation$_i$ (3.1)

Where:

| | | |
|---|---|---|
| $CH_4$ emissions enteric Fermentation | : | Methane emissions (kg $CH_4$/year) for all defined livestock categories (i) within the CFR source category 3A (Enteric fermentation) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| EF CH4 enteric Fermentation$_i$ | : | Emission factor (kg CH4/animal/year) for enteric fermentation of livestock category (i) |

### 3.2.2 *Comparison to IPCC methodology*

For non-cattle livestock categories, Tier 1 default IPCC emission factors are applied. For cattle, excluding mature dairy cattle, the Tier 2 approach is applied, with intake of gross energy being calculated according to a country-specific method. In this method, the emission factor is calculated using the methane-conversion factor and the gross energy intake from feed (MJ/animal/day). The default IPCC value of 0.065 is used as methane-conversion factor, except for white veal calves, as they are fed mainly milk products during early life and therefore do not yet have a fully developed rumen (Gerrits *et al.*, 2014). For mature dairy cattle, a country-specific Tier 3 approach is applied by using a dynamic simulation model that describes the mechanisms of the fermentation processes in the gastrointestinal tract (Bannink *et al.*, 2011; Bannink *et al.,* 2018). The model predicts the consequences of nutrition on microbial fermentation and the accompanying production of $CH_4$ in the rumen and the large intestine. The simulation model predicts the gross energy intake from feed and the production of $CH_4$ in the rumen and large intestine from feed intake and dietary characteristics (e.g. dry-matter intake, chemical composition and rumen degradation characteristics of chemical fractions in dry feed matter). The model subsequently calculates the methane-conversion factor from predicted $CH_4$ emissions and gross energy intake. It therefore predicts the methane-conversion factor as a model output, instead of assuming a constant methane-conversion factor value as a model input, as is the case with the Tier 2 approach.

### 3.2.3 *Activity data*

The activity data for this emission source consist of livestock numbers. These numbers and their uncertainty estimates are described in Section 2.2.1 and 2.4.3 respectively.

### 3.2.4 *Emission factors*

Emission factors used for the calculation of enteric fermentation are detailed in following sections dealing with mature dairy cattle (Tier 3), cattle excluding mature dairy cattle (Tier 2) and all livestock categories, excluding cattle (Tier 1).

#### 3.2.4.1 *Mature dairy cattle*

**Emission factors for mature dairy cattle**

A Tier 3 approach is applied for mature dairy cattle, in order to calculate country-specific emission factors using a dynamic simulation model. Depending on production conditions, the North-western part of the Netherlands (Provinces of Groningen, Friesland, Utrecht, North Holland and South Holland) and the South-eastern part of the Netherlands (Provinces of Drenthe, Overijssel, Flevoland, Gelderland, Zeeland, North Brabant and Limburg) are separated as a region with a different dietary composition and level of milk production (The average dietary composition and milk yield of both regions can be found in the reports: Dierlijke mest en mineralen (2019-2025)). The most important difference from the Tier 2 approach, which is used for other cattle, is that the simulation model predicts the emission factor from feed intake and dietary characteristics as model inputs, instead of using the values for gross energy intake and the methane-conversion factor. Another important difference is that the simulation model takes several dietary characteristics into account in order to predict the fermentation processes in the rumen and large intestine, instead of using only the net energy value for milk production and maintenance as a dietary characteristic. A final difference from the Tier 2 approach is that the simulation model calculates gross energy intake from dry-matter intake and dietary composition instead of adopting a gross-energy intake value for dry feed matter. The emission factor, gross energy intake and methane-conversion factor of mature dairy cattle are calculated annually (Bannink, 2011 & 2018 and Van der Most *et al.,* 2026). The Tier 3 approach does not account for the effects of feed additives that could demonstrably mitigate enteric $CH_4$ emissions.

The simulation model describes $CH_4$ production as a result of microbial fermentation processes in the gastro-intestinal tracts of mature dairy cattle (Dijkstra *et al.*, 1992; Mills *et al.*, 2001; Bannink *et al.*, 2005; Bannink *et al.*, 2008; Bannink *et al.*, 2011). Mills *et al.* (2001) extended the model with a representation of $CH_4$ production to the model of rumen fermentation processes developed by Dijkstra *et al.* (1992), including a representation of the fermentation processes taking place in the large intestine. This model extension calculates the production and utilisation of hydrogen using the production of volatile fatty acids, following Bannink *et al.* (2006), and the conversion of hydrogen into $CH_4$. More recently, an improved representation of the production of volatile fatty acids and hydrogen was included by making this value dependent on the acidity of rumen contents (Bannink *et al.*, 2005; Bannink *et al.*, 2008; Bannink *et al.*, 2011). Since 2005, this version of the simulation model has been applied as a Tier 3 approach for calculating $CH_4$ emissions in mature dairy cattle. Although the model can also be used for other cattle categories, it is currently not applied for this purpose, due to budget constraints and the lack of model-evaluation results for these categories. Most recently, Bannink *et al.* (2018) adapted the model description to improve its application to the prediction of apparent faecal nitrogen digestibility according to the national ammonia emissions registration. The consequences of this adaptation for calculated $CH_4$ predictions were negligible and methane emissions factors did not have to be updated.

Based on predicted values for the emission factor and gross energy intake, the simulation model also calculates the apparent methane-conversion factor. For this reason, the methane-conversion factor is not part of the assumptions made in the model representation, but instead constitutes a predicted outcome of the model in the same unit that is used for the methane-conversion factor in other categories. From the predicted values of the emission factor and the gross energy intake per year, the methane-conversion factor is calculated as follows:

$$Y_m = EF\ CH_4\ \text{enteric fermentation}_{\text{dairy cattle}} \times 55.65\ /\ (GE \times 365) \quad (3.2)$$

Where

| | | |
|---|---|---|
| $Y_m$ | : | Methane conversion factor (fraction of GE intake converted into $CH_4$) |
| EF $CH_4$ enteric fermentation$_{\text{dairy cattle}}$ | : | Emission factor (kg $CH_4$/animal/year) calculated with the simulation model |
| GE | : | Gross energy intake (MJ/animal/day) calculated with the simulation model |
| 55.65 | : | Standard energy content of 1 kg $CH_4$ (MJ/kg $CH_4$). The methane emission factor EF and the methane conversion factor Ym depend on the following input data for the simulation model: 1) the level of feed intake, 2) the chemical composition of ingested feed and 3) the degradation characteristics in the rumen. The origin of these data is described in the next section. |

**Feed intake and feed characteristics for mature dairy cattle**
Important input data for the simulation model include the following:

1. The chemical composition of dry-matter intake in the various dietary components (e.g. grass herbage, grass silage, maize silage, low-protein concentrates, protein-rich concentrates and wet by-products). A distinction is made between soluble carbohydrates (including sugars), starch, cell walls (hemi-cellulose, cellulose and lignin), crude protein (including a distinction of the ammonia fraction), crude fat and crude ash. Data on the composition is derived from information provided by the laboratory of Eurofins Agro (formerly Blgg and AgroXpertus) (eurofins-agro.com), which analyses the majority of roughages in the Netherlands, as well as from producers of compound feed. The data used for these calculations have been described previously by Smink *et al.* (2005). Between 1990 and 2008, CBS (2019) revised the WUM rations, including new calculations and data on chemical composition developed by Bannink (2011). Part of the ensiled roughage is not fed to dairy cattle in the same year in which the roughage analysis was performed. A correction for ensiled roughage has therefore been made in the annual ration calculations (CBS, 2025);
2. Rumen intrinsic degradation characteristics of starch, crude protein and fibre. The assumptions made concerning the degradation characteristics for starch, crude protein and fibre (i.e. the soluble/washable fraction, the fraction that is potentially

degradable, the fraction that is undegradable and the fractional degradation rate of the fraction that is potentially degradable) are stated in the report by Bannink (2011);

3. Feed intake levels and dry-matter intake, as calculated by WUM (CBS, 2025) for the North-western and South-eastern regions. Dry-matter intake (kg dry matter/animal/day) is derived from calculations prepared by the WUM. The intake of various components in the rations (grass, grass silage, maize silage, standard concentrates, protein-rich concentrates and wet by-products) is calculated annually based on national statistics concerning the amounts of these products that have been traded or produced. These statistics on dietary components cover part of the total energy requirement that is calculated annually according to a country-specific method. It is subsequently assumed that the remainder of the energy requirement for the recorded production level is covered by the intake of grass from grazing. Since 1990, the WUM has calculated dry-matter intake and rations annually, and these figures have been used as input for the method for calculating manure production and mineral excretion by livestock (CBS, 2019 through 2025). The first release was published in 1994 (WUM, 1994), and a revised calculation of the rations (from 1990 to 2018) was published in 2019 (CBS, 2019).

The input data vary according to annual changes in the proportion of individual dietary components (grass herbage, grass silage, maize silage, low-protein concentrates, protein-rich concentrates, wet by-products), as well as with changes in the chemical composition. The fractional passage rate of fermentable matter and fluid, the fluid volume and the acidity of contents in the rumen and large intestine are also important model parameters that have a considerable influence on predicted $CH_4$ production. Because they are internal model parameters, they do not have to be provided as input to the model. In the current method, the simulation model adopts empirical equations to predict the fractional passage rates and fluid volume as a function of dry-matter intake, and acidity is calculated as a function of the predicted concentration of volatile fatty acids according to Mills *et al.* (2001). The sensitivity of model predictions for these parameter values and their effect on uncertainty have been described previously (Bannink, 2011).

**Uncertainty values for emission factors for mature dairy cattle**
Bannink (2011) reports uncertainty values of 15% and 13% for the methane emission factor and the methane conversion factor, respectively, based on an analysis of the effect of input uncertainty on model predictions.

#### 3.2.4.2 *Cattle, excluding mature dairy cattle*

**Emission factors for cattle, excluding mature dairy cattle**
Growing cattle is considered a key source (Van der Net *et al.*, 2026) and therefore, for all cattle categories excluding mature dairy cattle, a country specific Tier 2 approach is used to calculate country-specific and year-specific emission factors for this group.

The general emission-factor calculation is expressed by the following equation:

$$EF\ CH_4\ enteric\ fermentation_i = (Y_{mi} \times GE_i) / 55.65 \qquad (3.5)$$

Where

| | | |
|---|---|---|
| EF $CH_4$ enteric fermentation$_i$ | : | Emission factor (kg $CH_4$/animal/year) for enteric fermentation of livestock category (i) |
| $Y_{mi}$ | : | Methane-conversion factor for livestock category (i) (fraction of gross energy intake ($GE_i$) that is converted into $CH_4$) |
| $GE_i$ | : | Gross energy intake (MJ/animal/year) for livestock category (i) |
| 55.65 | : | Standard energy content of 1 kg $CH_4$ (MJ/kg $CH_4$) |

A default value of 0.065 is used for the methane-conversion factor ($Y_m$) as described in the Guidelines (IPCC, 2006), with the exception of white veal calves (see Emission factors for white veal calves).

Gross energy intake is calculated according to the following equation:

$$GE_i = DM_i \times 18.45 \qquad (3.6)$$

Where

| | |
|---|---|
| $GE_i$ | : Gross energy intake (MJ/animal/year) for livestock category (i) |
| $DM_i$ | : Dry-matter intake (kg dry matter/animal/year) for livestock category (i) |
| 18.45 | : Gross energy content of 1 kg dietary dry matter (MJ/kg dry matter) |

It is assumed that 1 kg dietary dry matter has a gross energy content of 18.45 MJ/kg dry matter (IPCC, 2006), with the exception of milk products fed to white veal calves (21.00 MJ/kg DM; Gerrits *et al.*, 2014).

**Feed intake and rations of cattle, excluding mature dairy cattle**
Feed intake levels and dry-matter intake were calculated by WUM (CBS, 2019-2025) according to the same method as described above for mature dairy cattle. The intake of various components in the rations (milk/milk products, grass, grass silage, maize silage, standard concentrates, protein-rich concentrates and wet by-products) is calculated annually for each cattle category, based on national statistics on the amounts of these products that have been traded or produced. These statistics on dietary components cover part of the total energy requirement that is calculated annually according to a country-specific method for the various cattle categories.

It is subsequently assumed that the remainder of the energy requirement of the female cattle for the recorded production level is covered by the intake of grass from grazing. Male cattle are assumed to stay indoors year-round. Since 1990, the WUM has calculated dry-matter intake and rations annually, and these figures have been used as input for the method used to calculate manure production and mineral excretion by livestock (CBS, 2019 through2025). The first release was published in 1994 (WUM, 1994), and a revised calculation of the rations (from 1990 to 2018) was published in 2019 (CBS, 2019). The dry-matter intake of cattle, excluding mature dairy cattle, is stated in the report written by Smink (2005) and in Van der Most *et al.* (2026).

**Emission factors for white veal calves**
The production of white veal constitutes a considerable sector in the Netherlands. Rations consist largely or entirely of milk products, with low associated methane-conversion factors, as milk products are not fermented in the rumen. Over time, in order to improve animal welfare, rations have been supplemented with increasing amounts of concentrates and roughage. As the rumen is still not fully developed in white veal calves, the methane-conversion factors for these ration components were observed to be lower than the default value of 0.065. Specific methane-conversion factor values of 0.003 for milk products and 0.055 for other ration components are assumed, and a gross energy intake of 21.00 MJ/kg of dry matter for milk products is used (Gerrits *et al.*, 2014) to calculate the emission factor:

$$EF\ CH_4\ enteric\ fermentation_{white\ veal} = (Y_{m,\ milk\ products} \times GE_{milk\ products} + Y_{m,\ other\ ration\ components} \times GE_{other\ ration\ components}) / 55.65 \qquad (3.7)$$

Where

| | | |
|---|---|---|
| $EF\ CH_4$ enteric fermentation$_{white\ veal}$ | : | Emission factor (kg $CH_4$/animal/year) from enteric fermentation of white veal calves |
| $Y_{m,\ milk\ products}$ | : | Methane conversion factor for milk products |
| $GE_{milk\ products}$ | : | Gross energy intake (MJ/animal/year) with milk products |
| $Y_{m,\ other\ ration\ components}$ | : | Methane conversion factor for other ration components |
| $GE_{other\ ration\ components}$ | : | Gross energy intake (MJ/animal/year) with other ration components |
| 55.65 | : | Standard energy content of 1 kg $CH_4$ (MJ/kg $CH_4$) |

**Uncertainty values for emission factors cattle, excluding mature dairy cattle**
Feed intake depends on the total energy requirement and the variety of rations fed to fulfil this requirement. The uncertainty value for the total energy requirement is assumed to be 2%. Given the additional uncertainty concerning how to meet this requirement, the uncertainty value for dry-matter feed intake is assumed to be 5% for female young stock and 10% for male young stock categories. A value of 2% is used for veal calves, as their rations can be predicted more accurately. Given the mutual dependency of the various feed components, only the uncertainty factor for total dry-matter intake is considered.

The energy content of the feed is estimated to have an uncertainty value of 2.5%. The uncertainty depends on the uncertainties of fat, crude protein and carbohydrates. Although fat has a particularly large influence on energy content, it is also the smallest fraction in total dry feed matter, and its uncertainty therefore remains low. The fraction of crude protein and carbohydrates are more important determinants of uncertainty for energy content and estimated dry-matter intake.

The uncertainty value for the methane conversion factor is set to 20% for cattle, excluding white veal calves and mature dairy cattle. Because the diets of veal calves contain less or no roughage, the uncertainty value for the methane-conversion factor is set to 10% instead of 20%. As a physical quantity, the energy content of $CH_4$ is assumed to bear no uncertainty. For mature dairy cattle the uncertainty is determined based on model simulations and estimated to be 15% (Bannink *et al*., 2011; Bannink, 2011).

The starting points for the uncertainty calculations for the enteric fermentation emissions of cattle, excluding mature dairy cattle are summarised in Table 3.1.

*Table 3.1 Starting points for calculating the uncertainty (U) of methane emissions from enteric fermentation for cattle excluding mature dairy cattle, as calculated by a Tier 2 approach*

| **Livestock category** | **U DM intake** | **U feed energy content** | **U $Y_m$** | **U energy content $CH_4$** |
|---|---|---|---|---|
| *Young cattle* | | | | |
| Female young stock for breeding < 1 year | 5% | 2.5% | 20% | 0% |
| Male young stock for breeding < 1 year | 10% | 2.5% | 20% | 0% |
| Female young stock for breeding ≥ 1 year | 5% | 2.5% | 20% | 0% |
| Male young stock for breeding ≥ 1 year | 10% | 2.5% | 20% | 0% |
| Veal calves, for white veal production | 2% | 2.5% | 10% | 0% |
| Veal calves, for rosé veal production | 2% | 2.5% | 10% | 0% |
| Female young stock for fattening < 1 year | 5% | 2.5% | 20% | 0% |
| Male young stock (incl. young bullocks) for fattening < 1 year | 10% | 2.5% | 20% | 0% |
| Female young stock for fattening ≥ 1 year | 5% | 2.5% | 20% | 0% |
| Male young stock (incl. young bullocks) for fattening ≥ 1 year | 10% | 2.5% | 20% | 0% |
| *Other mature cattle* | | | | |
| Suckling cows (incl. fattening/grazing) ≥ 2 years | 5% | 2.5% | 20% | 0% |

#### 3.2.4.3 *All other livestock categories*

For all livestock categories, excluding cattle, a Tier 1 approach is applied, using default emission factors as described in the IPCC

Guidelines (IPCC, 2006). The emission factor of goats and sheep has been updated based on the 2019 refinement to the IPCC guidelines (IPCC, 2019). An overview of the emission factors used is provided in Table 3.2.

*Table 3.2 Emission factors (EF) for all livestock categories, excluding cattle*

| Livestock category | EF in kg $CH_4$/animal/year |
|---|---|
| Sheep | 9.00 |
| Goats | 9.00 |
| Horses | 18.00 |
| Mules and asses | 10.00 |
| Pigs | 1.50 |

Source: IPCC (2019)

The IPCC Guidelines provide default uncertainty values ranging from 30% to 50%. Based on expert judgement, an uncertainty value of 40% is used in the calculations.

## 3.3 Uncertainty estimates

The uncertainty estimates for the data sources and emission factors used are listed in Table 3.3, along with the total uncertainty estimate for $CH_4$ from enteric fermentation.

*Table 3.3 Uncertainty estimates (% of value) for $CH_4$ emissions, activity data (AD) and implied emission factors (IEF) from CRT Sector 3A Enteric fermentation*

| IPCC | Livestock category | U AD | U IEF | U emission |
|---|---|---|---|---|
| 3A1a | Mature dairy cattle | 2% | 15% | 15% |
| 3A1b | Other mature cattle | 2% | 23% | 23% |
| 3A1c | Growing cattle | 1% | 12% | 12% |
| 3A2 | Sheep | 10% | 40% | 41% |
| 3A3 | Swine | 6% | 40% | 41% |
| 3A4a | Goats | 10% | 40% | 41% |
| 3A4b | Horses | 39% | 40% | 58% |
| 3A4c | Mules and Asses | 5% | 40% | 41% |
| | Total | | | 11% |

# 4 $CH_4$ emissions from manure management (CRT sector 3B)

## 4.1 Scope and definition

This section provides a description of the methodology and working processes for determining $CH_4$ emissions from manure in animal housing, outside storage and manure treatment. The following source categories are distinguished in the CRT:

- 3B1a Mature dairy cattle
- 3B1b Other mature cattle
- 3B1c Growing cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4 Other livestock
- 5B2 Biological treatment of waste – anaerobic digestion at biogas facilities

Source category 3B4 (Other livestock) consists of poultry, goats, horses, mules and asses, fur-bearing animals and rabbits. Source category 5B2 includes emissions from the manure used in digestion-based manure treatment systems. Emissions from other types of manure treatment are included in the manure management source categories (3B1 through 3B4).

Methane emissions from animal manure are caused by the fermentation of organic matter in an anaerobic environment. It takes some time for methanogenic bacteria to develop and produce methane. This implies that, when manure is stored for less than a month, methane production will remain very low. The extent to which organic matter is converted into methane also depends on the composition of the manure, as well as on environmental factors (e.g. temperature). An overview of key factors affecting methane emissions from manure is presented in Webb *et al.* (2012).

Slurry from pigs and cattle is often stored in slurry pits underneath the slatted floors of the animal house, as well as in manure storage facilities outside the animal house. Solid manure is stored in animal housing and stacked outdoors, in most cases with a roof to avoid rainwater. In both cases, anaerobic conditions can occur, resulting in the production and emission of $CH_4$.

The slurry pit is an ‘accumulation system’, involving a constant input of manure and a volume that increases until the pit is emptied. In such systems, $CH_4$ emissions increase as the manure temperature rises and as the manure is stored for longer periods (Zeeman, 1994). These emissions also increase if older manure with high methanogenic activity is already present (inoculation).

Several different types of manure treatment are used in the Netherlands: separation, incineration, drying and/or digestion of manure.

Methane emissions from manure excreted during grazing is low, due to aerobic conditions and the rapid drying of manure on the field.

## 4.2 Source-specific aspects for CH4 emissions from manure storage

### *4.2.1 Calculation method*

Because cattle, pigs and poultry are regarded as key sources (Van der Net *et al.*, 2026), emission factors are calculated according to a Tier 2 approach.

**Tier 2**

In the Tier 2 approach, a distinction is made between slurry manure management systems, solid manure management systems and pasture manure.

$CH_4$ emissions manure management = $\Sigma$ $AAP_i$ x $FRAC_{j,\ manure\ management}$ x EF $CH_4$ manure $management_{ij}$ (4.1)

Where:

| | |
|---|---|
| $CH_4$ emissions manure Management | : Methane emission (kg $CH_4$/year) for all defined livestock categories (i) within the CFR source category 3B (Manure management) |
| $AAP_i$ | : Average animal population for livestock category (i) |
| $FRAC_{j,\ manure\ management}$ | : Fraction of manure in the various management systems (j) |
| EF $CH_4$ manure $management_{ij}$ | : Emission factor (kg $CH_4$/animal) for the manure management of livestock category (i) and manure management system (j) |

**Tier 1**

With respect to the other livestock categories, default Tier 1 emission factors are used (IPCC, 2006).

$CH_4$ emissions manure management = $\Sigma$ $AAP_i$ x EF $CH_4$ manure $management_i$ (4.2)

Where:

| | |
|---|---|
| $CH_4$ emissions manure management | : Methane emissions (kg $CH_4$/year) for all defined livestock categories (i) within the CRT source category 3B (Manure management) |
| $AAP_i$ | : Average animal population for livestock category (i) |
| EF $CH_4$ manure $management_i$ | : Emission factor (kg $CH_4$/animal) for the manure management of livestock category (i) |

### *4.2.2 Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**Volatile solids (VS)**
The amount of VS excreted is calculated for the key categories of cattle, pigs and poultry (Zom and Groenestein, 2015). Since 2018, this has been calculated annually. The amount of VS excreted by livestock depends on the digestibility of the organic matter and protein in the feed components. The excretion of VS in urine is calculated as the amount of urea ($CH_4N_2O$) or uric acid ($C_5H_4O_3N_4$) from the digestibility of crude protein, which is also used in the calculation of TAN. In faeces, VS depends on dry-matter intake, the ash content therein and the digestibility of the VS (Zom and Groenestein, 2015).

**Distribution between manure management systems**
The proportions of slurry and solid manure depend on how manure is managed in the housing systems. Data on these are derived from the Agricultural Census. The length of the grazing period in days per year and hours per day indicate the fraction of manure excreted on pasture land, as indicated by the WUM.

**Fraction of treated manure**
The amount of manure that has been treated can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO).

### 4.2.3 *Emission factors*
For sheep, goats, horses, mules and asses, rabbits and fur-bearing animals, the Tier 1 default emission factors from Table 4.1 are used (IPCC, 2006).

*Table 4.1 Emission factors (EF) for all livestock categories (excluding cattle, pigs and poultry), IPCC (2006)*

| Livestock category | EF in kg $CH_4$/animal/year |
|---|---|
| Sheep | 0.19 |
| Goats | 0.13 |
| Horses | 1.56 |
| Mules and asses | 0.76 |
| Rabbits | 0.08 |
| Fur-bearing animals (minks and foxes) | 0.68 |

For the key livestock categories of cattle, pigs and poultry, a country-specific emission factor is calculated annually for each manure management system using the following formula:

$$\text{EF for } CH_4 \text{ manure management}_{ij} = VS_i \times (1 - (f_i \times FRAC_{manure\ treatment})) \times B_{oi} \times MCF_{ij} \times 0.67 \quad (4.3)$$

Where:

EF for $CH_4$ manure management$_{ij}$ : Emission factor (kg $CH_4$/animal) for the manure management of livestock category (i) and manure management system (j)

$VS_i$ : Volatile solids (kg VS/year) excreted by the livestock category (i)

| | | |
|---|---|---|
| $f_i$ | : | Factor that corrects for storage time dependant on species, poultry = 1 and other species = 0.5 |
| $FRAC_{manure\ treatment}$ | : | Fraction of the manure that is treated, assumption this manure has a shorter storage time |
| $B_{oi}$ | : | Maximum methane production potential ($m^3$ $CH_4$/kg VS) for the manure produced by the livestock category (i) |
| $MCF_{ij}$ | : | Methane-conversion factor for the livestock category (i) and manure management system (j) |
| 0.67 | : | Density of methane (kg/$m^3$) |

**Correction factor storage time ($f_i$)**
The value of the correction factor storage time depends on the livestock category. For Poultry the $f_i$ is 1 as it is assumed that poultry manure that is treated is only stored for two weeks instead of 6 months when it is applied. This results in emissions that amount to 10% of normal storage emissions. These emissions are attributed to the manure treatment. For the other livestock categories (cattle and swine) it is assumed that shorter storage prior to treatment results in half the normal storage emissions, $f_i$ is 0.5.

**Maximum methane production potential ($B_o$)**
The value of $B_o$ depends on the degradability of the organic components in the manure. This value is expressed in $m^3$ $CH_4$/kg VS and is 0.22 for cattle manure, 0.31 for pig manure (Groenestein *et al.,* 2016), and 0.39 for manure from laying hens and 0.36 for all other poultry types (IPCC, 2006).

**Methane-conversion factor (MCF)**
The MCF indicates the share of $B_o$ that will actually be converted into methane, depending on the environmental conditions. The most important factors are storage time, inoculation, temperature, the availability of oxygen, dry-matter content and manure coverage (hard cover, floating, crust or otherwise). In the Netherlands, farmers are required to store the manure for six or seven months, as it is forbidden to apply manure from September to February (obligation related to implementation of the Nitrates Directive). For this reason, long-term measurements are needed in order to estimate the annual $CH_4$ emissions from which the MCF can be deduced, while environmental factors must be representative of the Dutch situation. Additionally, in analysing the measurements from housing systems, correction for enteric methane production is necessary to obtain emissions from manure. In light of the aforementioned considerations and based on literature, Groenestein *et al.* (2016) prepared estimates of the mean MCF for cattle and pig slurry (Table 4.2). Although solid manure is currently produced in poultry housing in the Netherlands, not enough data were available for solid poultry manure. The IPCC defaults have therefore been used. In the previous years of the time series, slurry manure from poultry was considered as well, with the MCF set equal to pig slurry. For solid manure from cattle and pigs and for manure on pasture land, the default IPCC MCF values of respectively 0.02 and 0.01 have been used.

*Table 4.2 MCF values used for each livestock category (Groenestein et al., 2016)*

| Livestock category | MCF |
|---|---|
| *Slurry* | |
| Cattle | 0.17 |
| Pigs | 0.36 |
| Laying hens | 0.36 |
| *Solid manure* | |
| Cattle | 0.02[1] |
| Pigs | 0.02[1] |
| Poultry | 0.015[1] |
| *Pasture manure* | |
| Cattle | 0.01[1] |

[1]) Default IPCC MCF values

### 4.2.4 *Uncertainty*

The IPCC specifies an uncertainty value of 30% for the Tier 1 emission factor. Based on the data from Groenestein *et al.* (2016), an uncertainty value (defined as 2 x (stdev/$\sqrt{n}$)) of 35.3% could be calculated for the estimation of MCF for slurry pig manure. For cattle and poultry, it is assumed that MCF uncertainty values will be the same. For solid manure, the uncertainty value is assumed to be twice that of slurry (Table 4.3). The uncertainty values for the estimation of the mean $B_o$ (defined as 2 x (stdev/$\sqrt{(n-1)}$)) depend on the livestock category (Table 4.3). Based on the data in Groenestein *et al.* (2016), these values have been set to 11.1% for cattle and 13.6% for pigs. The uncertainty value for poultry manure is assumed to be the same as for pig manure. The uncertainty values for the estimations of the excretion of VS are assumed to be 10% under housing conditions and 20% under grazing conditions. For the density of $CH_4$, an uncertainty value of 0% is assumed, given that it is a physical property.

*Table 4.3 Uncertainty estimates (U) in activity data for the calculation of methane emissions from manure management systems (MMS)*

| Livestock category | MMS | U MCF (%) | U $B_o$ (%) | U VS (%) |
|---|---|---|---|---|
| Cows in milk and in calf | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |
| | Pasture | 35.3 | 11.1 | 20 |
| Female young stock for breeding | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |
| | Pasture | 35.3 | 11.1 | 20 |
| Male young stock for breeding | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |
| Veal calves, for white veal production | Slurry | 35.3 | 11.1 | 10 |
| Veal calves, for rosé veal production | Slurry | 35.3 | 11.1 | 10 |
| Female young stock for fattening | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |
| | Pasture | 35.3 | 11.1 | 20 |
| Male young stock (incl. young bullocks) for fattening | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |
| Suckling cows (incl. fattening/grazing) ≥ 2 years | Slurry | 35.3 | 11.1 | 10 |
| | Solid | 70.5 | 11.1 | 10 |

| Livestock category | MMS | U MCF (%) | U $B_o$ (%) | U VS (%) |
|---|---|---|---|---|
| | Pasture | 35.3 | 11.1 | 20 |
| Pigs | Slurry | 35.3 | 13.6 | 10 |
| | Solid | 70.5 | 13.6 | 10 |
| Poultry | Solid | 70.5 | 13.6 | 10 |
| | Slurry | 35.3 | 13.6 | 10 |

## 4.3 Source-specific aspects for CH4 emissions from manure treatment

### *4.3.1 Calculation method*

The $CH_4$ emissions from manure treatment are calculated based on the amount of VS in the treated manure. The following six types of manure treatment are distinguished: separation, nitrification/denitrification, production of mineral concentrates, incineration, pelleting/drying and manure digestion. It is assumed that half of the regular $CH_4$ emissions from manure storage has taken place before the manure is treated, these emissions are reported under manure storage. For poultry the assumption is that storage times are much shorter and therefore emissions are set at 10% of the normal storage emissions (Melse and Groenestein, 2016). For all techniques except for digestion, these values are replaced by emissions from the storage of manure treatment products. Emissions are assumed to occur in the digestion-only process. For purposes of simplification, storage emissions during and after processing are combined and expressed as a single emission factor for ingoing VS manure.

The combined emissions from the $CH_4$ process (if relevant) and subsequent storage from manure treatment for livestock category (i) and process (o) are calculated as follows:

$$CH_4 \text{ emissions manure treatment}_{io} = \Sigma\ VS_i \times FRAC_{io,\ manure\ treatment} \times EF\ CH_4 \text{ manure treatment}_{io} \quad (4.4)$$

Where:

| | | |
|---|---|---|
| $CH_4$ emissions manure treatment$_{io}$ | : | Methane emissions (kg $CH_4$/year) for the livestock category (i) within the manure treatment system (o) |
| $VS_i$ | : | Volatile solids (kg VS/year) excreted by the livestock category (i) |
| $FRAC_{io,\ manure\ treatment}$ | : | Fraction of the manure that is treated for the livestock category (i) within the manure treatment system (o) |
| EF $CH_4$ manure treatment$_{io}$ | : | Emission factor (kg $CH_4$/kg VS) for the manure treatment system by livestock category (i) and manure treatment system (o) |

### 4.3.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Section 2.2.1 and 2.4.3 respectively.

**Volatile solids (VS)**

The amount of VS excreted is calculated for the key categories of cattle, pigs and poultry (Zom and Groenestein, 2015). The amount of VS excreted by livestock depends on the digestibility of the organic matter and protein in the feed components. The excretion of VS in urine is calculated as the amount of urea ($CH_4N_2O$) or uric acid ($C_5H_4O_3N_4$) from the digestibility of crude protein, which is also used in the calculation of TAN. In faeces, VS depends on dry-matter intake, the ash content therein and the digestibility of the VS (Zom and Groenestein, 2015).

**Fraction of treated manure**

The amount of manure that has been treated can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO). For the years 2010-2024 the N content of the treated manure is based on the mandatory transport certificates instead of the default used for all previous years. For all livestock categories fixed TAN contents are used for the treated manure. Only the TAN content of treated veal manure is based on the yearly calculated TAN excretion of the WUM.

### 4.3.3 *Emission factors*

A literature survey was conducted by Melse and Groenestein (2016) in order to compile the most suitable emission factors for the various types of manure treatment used in and under conditions in the Netherlands. These emission factors were subsequently updated and published in Van der Most et al. (2026), they are summarised in Table 4.4.

*Table 4.4 Emission factors (EF; kg CH4/kg VS in manure) for all livestock categories, by manure treatment system (Van der Most et al., 2026).*

| Livestock category | Manure treatment | EF |
|---|---|---|
| Cattle (excl. veal calves) | Separation | 0.0125 |
| | Digestion | 0.0055 |
| Veal calves | Separation | 0.0039 |
| Pigs | Separation | 0.0374 |
| | Digestion | 0.0069 |
| Poultry | Incineration | 0.0003 |
| | Pelleting/drying | 0.0003 |

### 4.3.4 *Uncertainty*

The amounts of manure treated (with the exception of poultry manure) are assumed to be 50% uncertain, based on expert judgement. Poultry manure is processed either by pelleting/drying or incineration, both of which are industrial processes with lower expected uncertainty values of 25%. The uncertainty values for the implied emission factor are assumed equal to those for regular manure management (Table 4.5).

*Table 4.5 Uncertainty values (% of value) for activity data (AD) and implied emission factors (IEF) for $CH_4$ emissions from manure treatment*

| Livestock category | Manure treatment | U AD | U IEF |
|---|---|---|---|
| Mature dairy cattle | Separation | 50% | 30% |
| Young cattle | Separation | 50% | 30% |
| Veal calves | Separation | 50% | 30% |
| Fattening pigs | Separation | 50% | 30% |
| | Mineral concentrates | 50% | 30% |
| Breeding pigs | Separation | 50% | 30% |
| | Mineral concentrates | 50% | 30% |
| Laying hens | Pelleting/drying | 25% | 30% |
| | Incineration | 25% | 30% |
| Broilers | Pelleting/drying | 25% | 30% |
| | Incineration | 25% | 30% |
| Turkeys | Pelleting/drying | 25% | 30% |
| | Incineration | 25% | 30% |
| Mature dairy cattle | Digestion | 50% | 30% |
| Young cattle | Digestion | 50% | 30% |
| Fattening pigs | Digestion | 50% | 30% |
| Breeding pigs | Digestion | 50% | 30% |

## 4.4 Uncertainty estimates

In NEMA uncertainty values for manure management and manure treatment are calculated separately, in order to account for differences in circumstances and thus in the associated emissions. The output of the model is at the level of detail shown in Table 4.3, Table 4.5 and Annex 11.

**Aggregation of emissions for reporting**
For the respective livestock categories distinguished in the CRT, emissions from manure management and manure treatment are summed to arrive at total $CH_4$ emission from manure management.

**Aggregation of uncertainties for $CH_4$ manure management and manure treatment**
Uncertainty values for emissions from manure management and manure treatment are aggregated to the CRT categories, as shown in Table 4.6.

*Table 4.6 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and $CH_4$ emissions from manure management*

| IPCC | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3A1a | Mature dairy cattle | 2% | 38% | 38% |
| 3A1b | Other mature cattle | 2% | 33% | 33% |
| 3A1c | Growing cattle | 1% | 18% | 18% |
| 3A2 | Sheep | 10% | 44% | 45% |
| 3A3 | Swine | 8% | 30% | 31% |
| 3A4a | Goats | 10% | 30% | 32% |
| 3A4b | Horses | 39% | 60% | 72% |
| 3A4c | Mules and asses | 15% | 46% | 42% |
| 3A4d | Poultry | 3% | 42% | 42% |
| 3A4e | Other | 5% | 28% | 28% |
| | Total | | | 21% |

# 5 $NH_3$ emissions from manure management (NFR category 3B)

## 5.1 Scope and definition

This section provides a description of the methods and working processes for determining $NH_3$ emissions from manure management, using the following NFR categories:

- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Laying hens
- 3B4gii Broilers
- 3B4giii Turkeys
- 3B4giv Other poultry
- 3B4h Other animals
- 5B2 Biological treatment of waste – anaerobic digestion at biogas facilities

Buffalo (3B4a) are reported as 'included elsewhere' (IE), as these animals are included with dairy cattle (3B1a) and non-dairy cattle (3B1b) according to their purpose as specified in the annual agricultural census. The category 'Other animals' (3B4h) consists of fur-bearing animals and rabbits. Source Category 5B2 includes the emissions from the manure used in digestion-based manure treatment systems. Emissions from other types of manure treatment are included in the manure management source categories (3B1 through 3B4).

Emissions of $NH_3$ from manure management are the sum of emissions from animal housing (including inside manure storage), outside manure storage and manure treatment (Figure 5.1). These emissions originate mainly from nitrogen excreted in the urine and to a small extent from mineralised organically bound N in faeces. In mammals, this N is excreted as urea ($CH_4N_2O$) and, in birds, as uric acid ($C_5H_4O_3N_4$). Both urea and uric acid are converted by bacterial enzymes (urease and uricase) into ammonium ($NH_4^+$). For urea, this process usually takes less than 24 hours (Elzing and Monteny, 1997), while uric acid breaks down more slowly (Groot Koerkamp, 1998). At high pH levels, the chemical equilibrium $NH_4^+$/ $NH_3$(l) shifts towards (dissolved) $NH_3$, which in its turn is in equilibrium with gaseous $NH_3$ in the boundary layer above the fluid surface. This process is affected by various factors, both physical (e.g. air speed, area and temperature) and chemical (e.g. $NH_4^+$ concentration, pH and ion strength).

The sum of the amount of $NH_3$ and $NH_4^+$ is referred to as total ammoniacal N (TAN). The N-flow method described in this methodology report and its predecessors (Velthof *et al.*, 2009; Vonk *et al.*, 2016; Vonk *et al.*, 2018, Lagerwerf *et al.,* 2019, Van der Zee *et al,* 2021, Van der Zee *et al*., 2022, Van der Zee *et al.,* 2023, Van der Zee *et al*., 2024, Van der Zee *et al*., 2025) calculates gaseous N emissions based on TAN. This represents a change with respect to methodologies that were used previously in the Netherlands, which used emission factors based on total N excretions (Oenema *et al.*, 2000; Van der Hoek, 2002). The excretion of TAN is calculated as the sum of all excretions of N in urine and the net mineralised organically bound N in faeces. The net mineralised organically bound N is used, given that TAN can also be immobilised and become organic N.

International consensus exists concerning the advantages of a methodology for calculating $NH_3$ emissions based on TAN instead of on total N:

- Gaseous N components are formed from $NH_4^+$ in manure. Research under controlled conditions has demonstrated that $NH_3$ emissions are more closely related to $NH_4^+$ content than to the content of total N in manure (e.g. Velthof *et al.*, 2005).
- A measure that does not change the total amount of N in the manure, but that does change the amount of TAN affects $NH_3$ emissions as well. This effect cannot be calculated with an emission factor based on total N. In addition to having an effect on total N excretions, rations have an effect on the share of TAN in the excretions (Annex 1, Annex 2 and Annex 3). The effects of ration composition on $NH_3$ emissions is better quantified with a methodology based on TAN.
- The emission factor for the application of manure is based on TAN (Section 10.3). In the methodology that was previously used in the Netherlands, emissions after application were calculated based on standard TAN contents in the manure, as derived from literature. These data are not influenced by changes in rations or housing systems. The calculation of $NH_3$ emissions after the application of manure according to the calculated TAN content of the manure also reveals the effects of rations and housing systems on TAN in emissions after application.
- The TAN-based methodology draws connections to internationally accepted concepts of $NH_3$ calculation methods (Reidy *et al.*, 2008; Reidy *et al.*, 2009), as well as to the Emission Inventory Guidebook of EMEP/EEA that is used in European and UNECE contexts (EEA, 2023).

The methodology assumes that the relationship between TAN content and $NH_3$ emissions progresses in a linear pattern. For this reason, a linear emission factor is applied as a percentage of the TAN excreted in manure. This assumption was also made in the former methodology based on total N (Oenema *et al.*, 2000), and it has been used in experimental research as well (Velthof *et al.*, 2005).

The method for calculating $NH_3$ emissions based on TAN excretion rates also takes into account the net mineralisation of organic N that occurs in the manure (Annex 4). Methods for calculating the animal-excretion rate of TAN are based on ration data and animal productivity, as drafted in Annex 1, Annex 2 and Annex 3. These calculations are performed annually by the WUM to quantify dietary effects in estimates of TAN excretion and $NH_3$ emissions (e.g. changes in roughage production and composition, and the consequent changes in the composition and feeding quality of rations). The actual ration compositions and N-digestibility of the separate components are taken as the starting point for the TAN calculations, instead of fixed TAN values or empirically averaged digestion values (Velthof et al., 2012). The method for calculating the TAN excretions of dairy cattle is consistent with the Tier 3 approach for estimating enteric $CH_4$ emissions (Bannink *et al.,* 2011 and Bannink *et al.,* 2018; see Section 3.2).

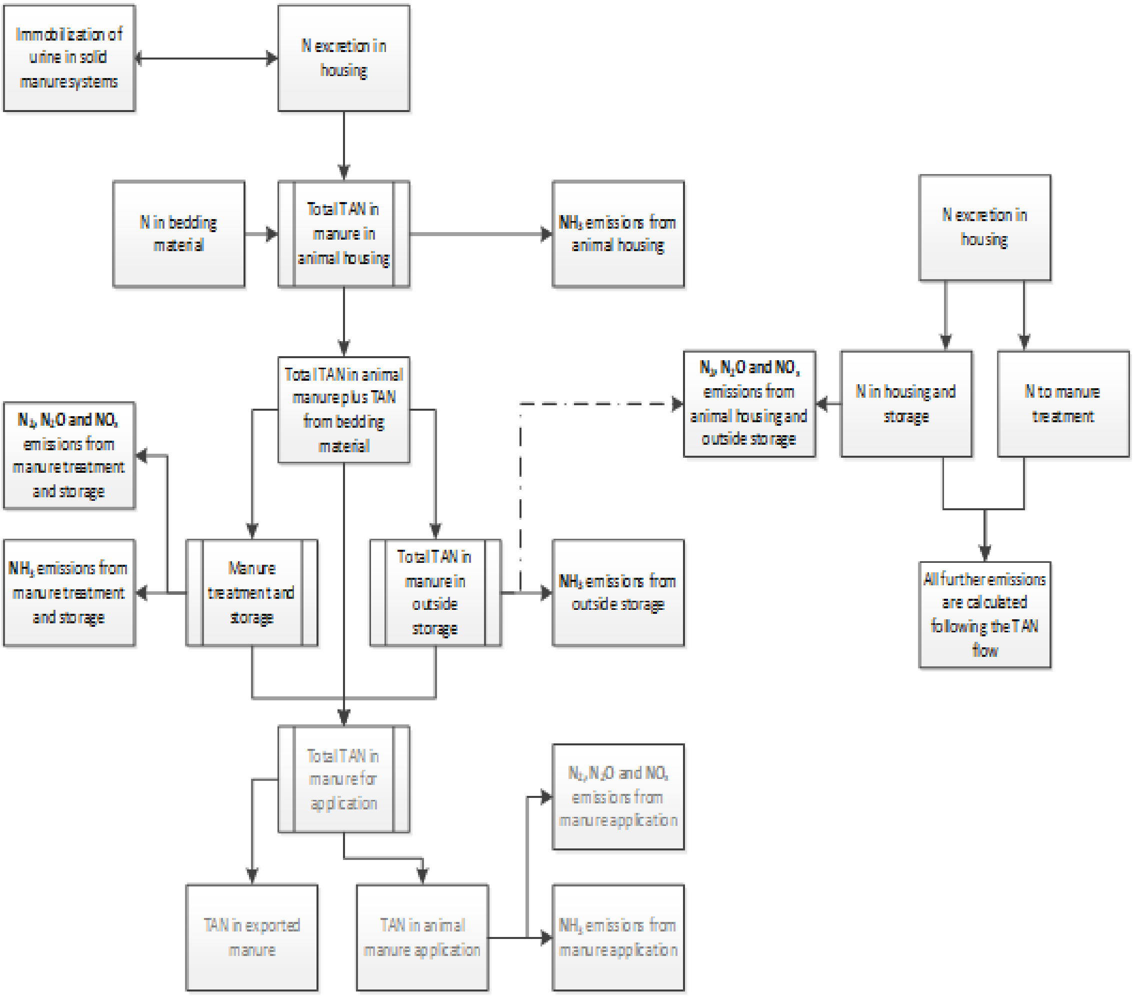
In poultry, TAN is composed mainly of uric acid instead of urea. As is commonly known, however, part of the uric acid in animal housing and in outside manure-storage facilities may not have been converted to $NH_4^+$, especially in dried manure. The amount of $NH_4^+$/uric acid in the applied manure is uncertain. For this reason, no correction has been made. In subsequent sections, uniform calculation rules are provided, based on TAN values for all livestock categories.

Over time, and for all livestock categories, part of the TAN in manure is lost in the form of gaseous N compounds (Figure 5.1). It is assumed that net mineralisation takes place directly after excretion in animal housing. The calculations are performed as follows:

1. The TAN excreted by the animal is calculated as the excretion of N in urine.
2. The amount of TAN produced by net mineralisation is calculated from the excretion of organic N in faeces. In slurry, mobilisation exceeds immobilisation, while the reverse occurs in solid manure (for poultry manure, it is assumed that no mobilisation or immobilisation occurs).
3. The amount of TAN in bedding material is calculated.
4. The total amount of TAN in manure is equal to the sum of TAN from Steps 1, 2 and 3.
5. The emissions of $NH_3$ are calculated relative to the total amount of TAN in the manure. Emissions of other N compounds ($N_2$, $N_2O$ and $NO_x$) are based on N excreted in housing.
6. After deducting N losses in animal housing from the total TAN in manure, part of the manure is treated (separated, incinerated, dried and/or digested) and stored, while another part of the manure is stored in outside storage facilities without treatment. In this case as well, N losses occur.
7. The amount of TAN remaining after the deduction of N losses in animal housing, outside storage and/or manure treatment is applied to land (Sections 10, 11 and 12).

The calculation steps are described in greater detail in the next section.

*Figure 5.1 The flow of TAN throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to manure management. Emissions of $N_2$, $N_2O$ and $NO_x$ from manure management are calculated based on N excreted in housing. These emissions are subtracted from the TAN available for application.*




## 5.2 Source-specific aspects for NH3 emissions from animal housing

### *5.2.1 Calculation method*

The total $NH_3$ emissions from animal housing are calculated based on the following activity data:

- Number of animals for each livestock category
- Total N excretions in animal housing for each livestock category and manure management system (slurry or solid manure)
- Share of TAN in excretions (urine N) for each livestock category (slurry or solid manure)
- Net mineralisation of organically bound N in manure stored in animal housing (slurry or solid manure)
- TAN added through bedding material
- Average emission factors for $NH_3$ from animal housing for each livestock category. This emission factor is weighted for the shares of the various housing systems (Section 5.2.3).

The $NH_3$ emissions from animal housing for livestock category (i) are calculated as follows:

$$NH_3 \text{ emissions animal housing}_i = \Sigma\, TAN_{ij,\ \text{animal housing}} \times EF\ NH_3\text{-}N_{TAN}\ \text{animal housing}_{ij} \times 17/14 \quad (5.1)$$

Where:

| | | |
|---|---|---|
| $NH_3$ emissions animal housing$_i$ | : | Total $NH_3$ emissions (kg $NH_3$/year) from animal housing for livestock category (i) |
| TANij, animal housing | : | Sum of urine excretion, net N mineralisation and bedding material in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) |
| EF NH3-NTAN animal housing$_{ij}$ | : | $NH_3$ emission factor (% of TAN) of animal housings for livestock category (i) and manure management system (j) |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ based on molecular weight |

The input of TAN is calculated differently, depending on the type of manure management. For slurry, a part of the fraction of organically bound N mineralises, while a part of the urine N immobilises in solid manure. In poultry manure, no mineralisation or immobilisation takes place.

### 5.2.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3 respectively.

**N excretion for each livestock category in a given year**

N excretions and uncertainty estimates are described in Sections 2.2.3 and 2.4.3.

**Fraction of TAN in total N excretions**

The excretion of urine N (TAN) is calculated annually, based on data concerning rations, the composition of the rations, the N digestibility of the feed components in the rations and the production parameters (Tamminga *et al.*, 2000; Tamminga *et al.*, 2004; Bannink *et al.*, 2016; Bannink *et al.*, 2018). Descriptions for historic years (before 2009) based on the calculation method using urine N excretions for cattle, pigs and poultry are provided in Annex 1, Annex 2 and Annex 3, respectively. For other grazing animals (horses, ponies, sheep and goats), the same methodology is used as for cattle. For rabbits and fur-bearing animals, no data were available for calculating the TAN fraction in N excretions. The share of total $NH_3$ emissions produced by these animals is limited, and data on ration composition are difficult to obtain. The TAN fractions for these livestock categories are therefore estimated to be 70% of the excreted N (based on expert judgement).

**Mineralisation/immobilisation of organic N**
It is assumed that the N mineralisation occurring during the storage of slurry in animal housing amounts to 10% of all organic N, based on research by Beline *et al.* (1998); see also Annex 4. For solid manure, an N immobilisation of 25% (or mineralisation of -25%) is assumed. For poultry and for slurry manure from fur-bearing animals, no mineralisation/immobilisation is assumed.

***Bedding material***
The amount of bedding material provided depends on the housing system used for poultry and for grazing livestock on the number of days housed indoors. Annex 12 provides a full overview of bedding material.

***Manure management system***
The proportion of slurry and solid manure depends on the housing systems used. Data on these systems are derived from the Agricultural Census. The length of the grazing period in days per year and hours per day indicate the fraction of manure excreted on pastureland, as indicated by the WUM.

**TAN in animal housing**
The input of TAN from animal housing for a given livestock category (i) with manure management system (j) is calculated as follows:

$$TAN_{i,\ slurry\ from\ animal\ housing} = AAP_i \times FRAC_{i,\ slurry\ manure\ management} \times (N\ excretion_i \times FRAC_{i,\ TAN\ in\ urine} + N\ excretion_i \times (1 - FRAC_{i,\ TAN\ in\ urine}) \times N\ mineralisation_j + Bedding_{TAN}) \quad (5.2a)$$

$$TAN_{i,\ solid\ from\ animal\ housing} = AAP_i \times FRAC_{i,\ solid\ manure\ management} \times (N\ excretion_i \times FRAC_{i,\ TAN\ in\ urine} + N\ excretion_i \times FRAC_{i,\ TAN\ in\ urine} \times N\ mineralisation_j + Bedding_{TAN}) \quad (5.2b)$$

Where

| | | |
|---|---|---|
| $TAN_{i,\ slurry\ from\ animal\ housing}$ | : | Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) |
| $TAN_{i,\ solid\ from\ animal\ housing}$ | : | Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $FRAC_{i,\ slurry\ manure\ management}$ | : | Fraction of slurry manure for livestock category (i) |
| $FRAC_{i,\ solid\ manure\ management}$ | : | Fraction of solid manure for livestock category (i) |
| $N\ excretions_i$ | : | N excretions (kg N/animal) in animalhousing for livestock category (i) |
| $FRAC_{i,\ TAN\ in\ urine}$ | : | Fraction of urine N in total N excretions in animal housing for livestock category (i) |

| | | |
|---|---|---|
| N mineralisation$_j$ | : | Net N mineralisation (% of organic N excretion) for manure management system (j) |
| Bedding$_{TAN}$ | : | Amount of TAN added in the form of bedding material. |

For slurry manure, the net N mineralisation refers to the mineralisation of faeces into TAN. For solid manure, the net N mineralisation refers to the immobilisation of TAN into organically bound N.

### 5.2.3 *Emission factors*

**$NH_3$ emission factor for each livestock category and housing system**

Although different housing systems may have the same manure management system, this does not necessarily mean that their emission factors will be the same. For this reason, a different emission factor is used for each type of housing system. The shares of housing systems for each livestock category are based on the Agricultural Census. If insufficient information on the shares of housing systems was available, other sources were used (e.g. environmental permit files for housing systems issued by the local authorities).

The $NH_3$ emission factors for housing systems are often derived from measurements resulting from the measurement protocol for emission factors specified in the legislative regulations for ammonia and animal husbandry (in Dutch, '*Regeling ammoniak en veehouderij'* or Rav). Where possible, data from the most recent $NH_3$ emission factors in the Rav have been used. If new information about a certain livestock category or housing system is available, however, the emission factor can override the factor reported in the Rav. The $NH_3$ emission factors derived from the measurements are expressed in kg for each animal place. These factors in kg $NH_3$ per animal place are then converted into an emission factor as a percentage of TAN, taking into account the TAN excretions of the housed animals in the year for which the emission factors were determined, as well as the housing occupancy (Velthof *et al.*, 2009).

To calculate the emission factor for all animal housing for livestock category (i) and manure management system (slurry or solid manure; j), the following equation is used:

$$EF\ NH_3\text{-}N_{TAN}\ \text{animal housing}_{ij} = \Sigma\ (EF\ NH_{3,}\ \text{animal housing}_{ik} \times (14/17)\ /\ (FRAC_{k,\ \text{occupancy, Rav year}}))\ /\ TAN_{i,\ \text{animal housing, Rav year}} \times FRAC_{ik,\ \text{animal housing}} \qquad (5.3)$$

Where:

| | | |
|---|---|---|
| EF $NH_3$–$N_{TAN}$ animal housing$_{ij}$ | : | $NH_3$ emission factor (% of TAN excretions) for livestock category (i) and manure management system (j) |
| EF $NH_{3,}$ animal housing$_{ik}$ | : | $NH_3$ emission factor (kg $NH_3$/animal place/year) for livestock category (i) and housing system (k) |

| | | |
|---|---|---|
| $FRAC_{k, \text{occupancy}, \text{Rav year}}$ | : | Fraction of occupancy for each animal place for livestock category (i) and housing system (k), for the year in which the EF $NH_3$ for animal housing$_{ik}$ was determined |
| $TAN_{i, \text{animal housing}, \text{Rav year}}$ | : | Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) for the year in which the emission factor for animal housing$_{ij}$ was determined |
| $FRAC_{ik, \text{animal housing}}$ | : | Fraction of housing system (k) for livestock category (i) |
| 14/17 | : | Conversion factor from $NH_3$ to $NH_3$-N, based on molecular weight |

Additional details on the emission factor calculations are provided in Annex 5, Annex 6 and Annex 7.

Research conducted by an enforcement agency revealed that many air scrubbers were not being used properly (Handhavingsamenwerking Noord-Brabant, 2013; 2015). For this reason, implementation grades were corrected. For the years up to and including 2009, it was assumed that 40% of the scrubbers did not function, decreasing by 8 percentage point per year up to 16% in 2012. From then on, a decrease of 4 percentage point per year was assumed until 2016, when all scrubbers were assumed to operate properly, given that electronic monitoring was compulsory on all equipment from that time.

Melse *et al.* (2018) demonstrate that combined air scrubbers (in most cases, a biological air scrubber with a water curtain) do not achieve an efficiency level of 85% $NH_3$ reduction, but only a reduction of 59%. The emission factors for animal housing take this into account.

Since 2010, reports on Dutch emissions from agriculture mention that nitrogen emissions from animal housing and manure storages are likely to be underestimated (Hoogeveen *et al.,* 2010 and Luesink *et al.,* 2011) A study performed by Statistics Netherlands suggests that the emission reduction in the RAV which is based on measurements in pilot housing systems is not always achieved in practice (Van Bruggen et al., 2019). The study determined the apparent N loss from manure from the change in the nitrogen to phosphorus ratio (N/P) of both excreted manure on the farm and of manure exported from the farm (this is measured in the Netherlands). This study indicates that nitrogen losses in low-emission livestock housing systems with modified floor types are higher than could be expected based on the emission factor of the low-emission housing. A group of experts judge these results as plausible (CDM, 2020). Therefore it was decided to adjust the emission factors of part of the low-emission housing systems, using the following equations:

$(Nrest)_{low}$ = (Nloss calculated from change in N/P-ratio)$_{low}$ – [($NH_3$ calculated with emission factor)$_{low}$ + (Nother calculated with emission factor)] (5.4)

Where:

| | | |
|---|---|---|
| $(Nrest)_{low}$ | : | The difference between the nitrogen loss from low emission housing based on the change in N/P ratio and the calculated emissions with emission factors for $NH_3$ and for other N compounds such as $N_2O$, NO and $N_2$. |
| (Nloss calculated from change in N/P-ratio)$_{low}$ | : | Amount of nitrogen lost based in difference in N/P ratio |
| ($NH_3$ calculated with emission factor)$_{low}$ | : | Amount of N lost in the form of $NH_3$ based on the emission factor of low emission housing. |
| (Nother calculated with emission factor) | : | Amount of N lost in the form of $N_2O$, NO and $N_2$ based on the emission factor, which is a standard percentage from the N excretion. |

$Nrest_{regular}$ = (Nloss calculated from change in N/P-ratio)$_{regular}$ – [($NH_3$ calculated using an emission factor)$_{regular}$ + (Nother calculated with emission factor) (5.5)

Where:

| | | |
|---|---|---|
| $(Nrest)_{regular}$ | : | The difference between the nitrogen loss from regular emission housing based on the change in N/P ratio and the calculated emissions with emission factors for $NH_3$ and for other N compounds such as $N_2O$, NO and $N_2$. |
| (Nloss calculated from change in N/P-ratio)$_{regular}$ | : | Amount of nitrogen lost based in difference in N/P ratio |
| ($NH_3$ calculated with emission factor)$_{regular}$ | : | Amount of N lost in the form of $NH_3$ based on the emission factor of regular emission housing. |
| (Nother calculated with emission factor) | : | Amount of N lost in the form of $N_2O$, NO and $N_2$ based on the emission factor, which is a standard percentage from the N excretion. |

($NH_3$ low emission housing) = ($NH_3$ calculated with emission factor)low + (Nrest)low – (Nrest)regular (5.6)

Where:

| | | |
|---|---|---|
| ($NH_3$ low emission housing) | : | Amount of $NH_3$ lost from low emission housing |
| ($NH_3$ calculated with emission factor)low | : | Amount of $NH_3$ lost from low emission housing based on the emission factor of low emission housing |
| (Nrest)low | : | The difference between the nitrogen loss from low emission housing based on the change in N/P ratio and the calculated emissions with emission factors for $NH_3$ and for other N compounds such as $N_2O$, NO and $N_2$. |
| (Nrest)regular | : | The difference between the nitrogen loss from regular emission housing based on the change in N/P ratio and the calculated emissions with emission factors for $NH_3$ and for other N compounds such as $N_2O$, NO and $N_2$. |

- The emission factor of low-emission housing of dairy was set equal to the emission factor of traditional housing, with the exception of the tie stall with liquid manure. Few farms still use this housing system and the study performed by statistics Netherlands could not ensure that their study was representative for the entire time series. Therefore it was decided to keep the current emission factor of this housing system.
- The emission factor of low-emission housing of all pig categories with floor or manure storage adaptations was adjusted. This was based on the change in N/P ratio of manure in housing systems for fattening pigs. When both the emission factors and the N/P ratios of traditional and low emission housing were compared, more nitrogen from low emission housing was lost between the moment of excretion and export from the farm. The difference is assumed to be in the form of $NH_3$. The result is a higher emission factor for $NH_3$. The effect of housing systems with air scrubbers could not be assessed in the study of Statistics Netherlands because information about the removal of nitrogen in the flushing water of air scrubbers is lacking. Housing systems with air scrubbers therefore keep their low emission factor.
- The emission factor of low-emission housing of poultry was adjusted depending on the housing system. Aviary systems without aeration of manure were not changed as these systems cannot be compared to the traditional housing system. The emission factor of aviary systems with manure aeration were set to the emission factor of the traditional aviary system. For the other laying hen housing systems correction factors were calculated based on the N/P ratio. Both the emission factors and the N/P ratios of traditional and low emission housing systems were compared analogues to the method applied for pig housing systems. For broilers a correction factor was calculated for the

systems using heated and cooled flooring and ventilation. Other systems (drying of litter and multiple storeys) appear to be effective and their share is small, therefore no correction factor was calculated (Van Bruggen *et al.,* 2021).

- The emission factor of goats has been updated based on new research from Mosquera *et al.* (2025). The original RAV emission factor for the reference year was applied to the years 1990-1998. The newly measured emission levels were combined with the TAN excretion of 2018 (the year of the measurements) to calculate a new emission factor which has been applied from 2018 onwards. To create a consistent timeseries, linear interpolation was applied to the years in-between (1999-2017).

**Occupancy**

The occupancy fraction of the different housing systems is presented in Annex 9, based on Van der Most *et al.* (2026). Occupancy refers to the number of animal places that are actually occupied by animals during the year. There are several reasons to explain why an animal housing unit might not be filled to capacity. In most cases, the reason is related to a period in which the animal housing unit is unoccupied between production rounds. Loss of animals, earlier selection of animals or other reasons for vacancies during a period of growth and rearing (as described in Stichting Groen Label, 1996) and in Ogink *et al.*, 2008) are not considered.

### 5.2.4 *Uncertainty*

Calculation of the overall uncertainty of $NH_3$ emissions from animal housing begins by estimating the uncertainty value for TAN excretions for each aggregated livestock category over a given manure type. These uncertainty estimates are subsequently multiplied by the uncertainty value for the $NH_3$ emission factor for animal housing. This method was selected because the emission factors of housing systems for the various livestock subcategories can originate from the same activity data, and they are therefore dependent on each other.

The uncertainty estimates for animal numbers, N excretions and fractions of manure types are the inputs for calculating the uncertainty of $NH_3$ from animal housing (see Section 2.4.3). In addition, the uncertainty of the fractions of TAN (10%), mineralisation (150%) and the emission factor (40%) are needed. The uncertainty value for the emission factor is an estimate of an emission factor for a given housing system, expressed in kg $NH_3$ per animal. This estimate is used for the average emission factor over all housing systems based on TAN. This method of aggregation is used to include dependencies, as described in Section 2.4. Some of the emission factors for housing systems are based on the same emission measurements. Results for manure management as a whole (animal housing, manure treatment and outside storage) are presented in Table 5.2. Outcomes for each subsector are reported in Annex 11.

## 5.3 Source-specific aspects for $NH_3$ emissions from manure treatment

### *5.3.1 Calculation method*

The $NH_3$ emissions from manure treatment are calculated based on the amount of N in the manure used in manure treatment. The following six types of manure treatment are distinguished: manure separation, nitrification/denitrification, production of mineral concentrates, incineration, pelleting/drying and manure digestion. For manure separation and pelleting/drying, $NH_3$ is emitted during both the treatment process and the storage of manure treatment products. For manure incineration and digestion, only additional storage emissions occur. In the interest of simplicity, emissions during processing and subsequent storage are combined and expressed as a single emission factor based on the N that is treated.

The combined $NH_3$ emissions from the manure treatment (o) for livestock category (i) are calculated as follows:

$$NH_3 \text{ emissions manure treatment} = \sum N_{io,\ manure\ treatment} \times EF\ NH_3\text{-}N\ \text{manure treatment}_{io} \quad (5.7)$$

Where:

| | | |
|---|---|---|
| $NH_3$ emissions manure Treatment | : | $NH_3$ emissions from manure treated (kg $NH_3$/year) |
| $N_{io,\ manure\ treatment}$ | : | Amount of N in treated manure (kg N/year) of livestock category (i) and manure treatment (o) |
| EF $NH_3$-N manure treatment$_{io}$ | : | Emission factor (% of N) for manure treatment of livestock category (i) and manure treatment (o) |

### *5.3.2 Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**Treated manure N**

The amount of manure that has been treated and its N content can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO). For the years 2010-2024 the N content of the treated manure is based on the mandatory transport certificates instead of the default used for all previous years. For all livestock categories fixed TAN contents are used for the treated manure. Only the TAN content of treated veal manure is based on the yearly calculated TAN excretion of the WUM.

**Manure management system**

The proportion of slurry and solid manure depends on the housing system. Data on these systems are derived from the Agricultural Census. The length of the grazing period in days per year and hours per day indicate the fraction of manure excreted on pasture land, as indicated by the WUM.

### 5.3.3 *Emission factors*

A literature study has been carried out by Melse and Groenestein (2016) to compile the most suitable emission factors for the different manure treatments used in and under conditions in the Netherlands. The following emission factors were calculated based on these findings (Table 5.1).

*Table 5.1 Emission factors for $NH_3$ (EF; kg/kg N) for all livestock categories and manure treatment techniques (Melse and Groenestein., 2016).*

| Livestock category | Manure treatment process including afterward storage | EF (%) |
|---|---|---|
| Cattle (excl. veal calves) | Separation | 2.3 |
| | Digestion | 1.0 |
| Veal calves | Separation | 1.6 |
| Pigs | Separation | 3.2 |
| | Digestion | 2.0 |
| Poultry | Incineration | 0.1 |
| | Pelleting/drying | 1.4 |

### 5.3.4 *Uncertainty*

The amounts of manure treated (with the exception of poultry manure) are assumed to have an uncertainty of 50%, based on expert judgement. Poultry manure is processed either by pelleting/drying or incineration, both of which are industrial processes with lower expected uncertainty values of 25%. The uncertainty values for the emission factor are assumed equal to those for regular manure management (40%). Results for manure management as a whole (animal housing, manure treatment and outside storage) are presented in Table 5.2, and outcomes for each subsector are provided in Annex 11.

## 5.4 Source-specific aspects for $NH_3$ emissions from outside manure storage facilities

### 5.4.1 *Calculation method*

Part of the manure is stored in manure storage facilities outside the animal housing. From the initial TAN excreted by livestock (including mineralisation), total gaseous N losses in animal housing are subtracted when calculating the emission factor (Figure 5.1). These losses occur in the form of $NH_3$, $NO_x$, $N_2O$ and $N_2$. The input of TAN into outside storage facilities is established by multiplying the result by the fraction of manure stored.

The $NH_3$ emissions from outside manure storage facilities for livestock category (i) are calculated as follows:

$$NH_3 \text{ emissions outside storage}_i = \Sigma\ TAN_{ij,\ \text{animal housing}} \times EF\ NH_3\text{-}NT_{TAN}\ \text{outside storage}_{ij} \times 17/14 \quad (5.8)$$

Where

| | | |
|---|---|---|
| $NH_3$ emissions outside storage$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from outside manure storage facilities for livestock category (i) |

| | | |
|---|---|---|
| $TAN_{ij,\ animal\ housing}$ | : | Sum of urine excretions, net N mineralisation and TAN from bedding material in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) |
| EF $NH_3$-$N_{TAN}$ outside storage$_{ij}$ | : | $NH_3$ emission factor (% of TAN) for outside storage facilities for livestock category (i) and manure management system (j) |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ based on molecular weight |

### 5.4.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**TAN in animal housing**

The calculation method for TAN input in animal housing is described in Section 5.2.2.

**Activity data for outside manure storage**

The amount of manure in storage is calculated based on the amount of manure produced in housing, available storage capacity and registered manure transports. The available storage capacity is provided by the Agricultural Census, information on manure transports are collected by RVO.

### 5.4.3 *Emission factors*

**$NH_3$ emission factor for outside manure storage**

The emission factor is expressed as a percentage of the amount of TAN excreted and mineralised in animal housing. To calculate the emission factors for $NH_3$ from manure storage, the following calculations are performed for all livestock categories (i) and manure management systems (slurry or solid; j):

$$EF\ NH_3\text{-}N_{TAN}\ outside\ storage_{ij} = \Sigma\ FRAC_{ij,\ outside\ storage} \times EF\ NH_3\text{-}N\ outside\ storage_{ijk} \times (N\ excretion_{ik} - (NH_3\text{-}N\ animal\ housing_{ik,\ Rav\ year} + N_2O\text{-}N\ emissions\ manure\ management\ direct_{ij} + NO_x\text{-}N\ emissions\ manure\ management_{ij} + N_2\ emissions\ manure\ management_{ij})) / TAN_{ij,\ animal\ housing} \times FRAC_{ik,\ animal\ housing} \quad (5.9)$$

| | | |
|---|---|---|
| EF $NH_3$-$N_{TAN}$ outside storage$_{ij}$ | : | $NH_3$-N emission factor (% of TAN) for animal housing for livestock category (i) and manure management system (j) |
| $FRAC_{ij,\ outside\ storage}$ | : | Fraction of manure stored outside for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined |

| | | |
|---|---|---|
| EF $NH_3$-N outside storage$_{ijk}$ | : | $NH_3$-N emission factor (kg N) for manure storage for livestock category (i), manure management system (j) and housing system (k) |
| N excretions$_{ik}$ | : | N excretions (kg N/animal) in animal housing for livestock category (i) and housing system (k) for the year in which the emission factor for outside storage was determined |
| $NH_3$-N emissions animal housing$_{ik,\ Rav\ year}$ | : | $NH_3$-N emissions (kg N) for animal housing for livestock category (i) and housing system (k) for the year in which the emission factor for animal housing was determined |
| $N_2O$-N emissions manure management direct$_{ij}$ | : | $N_2O$-N emissions (kg N) for animal housing for livestock category (i) and manure management system (j) for the year in which the emission factor for animal housing was determined |
| $NO_x$-N emissions manure management$_{ij}$ | : | $NO_x$-N emissions (kg N) for animal housing for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined |
| $N_2$ emissions manure management$_{ij}$ | : | $N_2$ emissions (kg N) for animal housing for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined |
| FRAC$_{ik,\ animal\ housing}$ | : | Fraction of housing system (k) within animal category (i) |
| TAN$_{ij,\ animal\ housing}$ | : | Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined |

**$N_2O$, $NO_x$ and $N_2$ emissions**
The calculation methods for emissions of $NO_x$ and $N_2O$ are described in Sections 6 and 7, respectively. The $N_2$-N emissions are 10 times greater than the $N_2O$-N emissions for slurry manure and 5 times greater than for solid manure (Oenema *et al.*, 2000).

**Fraction of manure stored outside**
Information on the fractions of manure stored outside animal housing, are taken from the Agricultural Census and complemented with data taken from literature. An overview of the percentages and sources is provided in annex 13 of van der Most *et al.,* (2026).

### *5.4.4 Uncertainty*
Uncertainty values for total emissions of $N_2O$, $NO_x$ and $N_2$ are estimated at 100% (based on expert judgement). The total uncertainty is estimated, as uncertainty estimates are calculated only for $N_2O$, $NO_x$ and $NH_3$ emissions from animal housing, and not for $N_2$ emissions.

The outside storage of slurry depends on storage capacity in relation to manure production. Storage capacity is queried in the Agricultural Census. Uncertainty values for storage fractions depend on manure production, the responses of farmers to the question in the Agricultural Census and the use of such outside storage. Uncertainty values are estimated at 25% for slurry and 50% for solid manure (based on expert judgement).

The uncertainty value for the emission factor for outside storage facilities is estimated at 200%. The emission factor is based on a limited amount of old data (and expert judgement). From data in Groot Koerkamp and Kroodsma (2000), the uncertainty value for the outside storage of solid manure from broilers can be calculated at 35%. It is assumed that other solid poultry manure has the same uncertainty value (based on expert judgement).

## 5.5 Uncertainty estimates
In NEMA the uncertainty values for emissions from animal housing and outside manure storage facilities are calculated separately, in order to account for differences in circumstances and thus in the associated emissions. The output of the model is at the level of detail shown in Table 5.1 and Annex 11 (available through www.prtr.nl).

**Aggregation of uncertainty estimates for $NH_3$ from animal housing, manure treatment and outside manure storage**
Uncertainty estimates calculated for emissions from animal housing, manure treatment and outside manure storage facilities are aggregated to the NFR categories, as shown in Table 5.2.

*Table 5.2 Uncertainty values for activity data (U AD; livestock numbers), implied emission factors (U IEF) and $NH_3$ emissions (U emissions) from manure management*

| EMEP | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3B1a | Dairy cattle | 2% | 44% | 44% |
| 3B1b | Non-dairy cattle | 1% | 29% | 29% |
| 3B2 | Sheep | 6% | 102% | 102% |
| 3B3 | Swine | 8% | 36% | 37% |
| 3B4d | Goats | 5% | 89% | 89% |
| 3B4gi | Laying hens | 2% | 45% | 45% |
| 3B4gii | Broilers | 5% | 48% | 48% |
| 3B4giii | Turkeys | 5% | 44% | 44% |
| 3B4giv | Other poultry | 5% | 46% | 46% |
| 3B4h | Other animals | 5% | 46% | 46% |
| 3B | Total | | | 21% |

# 6 $NO_x$ emissions from manure management (NFR category 3B)

## 6.1 Scope and definition

This section provides a description of the methods and working processes for determining $NO_x$ emissions from manure management, using the following NFR categories:

- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Laying hens
- 3B4gii Broilers
- 3B4giii Turkeys
- 3B4giv Other poultry
- 3B4h Other animals

Category 3B4a (Buffalo) is reported as ‘included elsewhere’ (IE), as these animals are included with dairy cattle (3B1a) and non-dairy cattle (3B1b) according to their purpose as specified in the annual agricultural census. Category 3B4h (Other animals) consists of fur-bearing animals and rabbits. Emissions reported under category 3B concern only the $NO_x$ emissions from manure produced in animal housing and then stored temporarily and/or treated before being transported elsewhere. The $NO_x$ emissions resulting from manure production on pastureland are reported under category 3D ($NO_x$ emissions from soil). Although emissions are reported as NO (nitrogen monoxide) in NEMA, they are referred to as $NO_x$ in this report, in order to prevent confusion with the notation key NO (‘Not Occurring’).

Nitrous oxide emissions from livestock manure management depend on the nitrogen and carbon content of the manure, the manure treatment method used and the amount of time the manure is stored. During storage, the manure often becomes low in oxygen, thereby slowing the nitrification process and maintaining a low level of denitrification.

Nitrification is the process whereby ammonia ($NH_4^+$) is converted into nitrate by bacteria under conditions of high oxygen. In this process, nitrous oxide can be formed as a by-product, particularly if the nitrification is limited through lack of oxygen. Nitrification does not require the presence of any organic substances (volatile solids). Straw-rich solid manure and poultry manure can possess a relatively open and loose structure, allowing $O_2$ to diffuse far more easily than it does in slurry, thus enabling nitrification.

Denitrification is the process of bacteria converting nitrate ($NO_3^-$) into the gaseous nitrogen compound $N_2$ under conditions of low oxygen, with $NO_x$ as a by-product. Organic substances (volatile solids) are used as an energy source. Denitrification in animal housing and manure storage facilities depends entirely on the nitrification process, which must supply the oxidised nitrogen compounds.

## 6.2 Source-specific aspects for NOx emissions from manure storage

### *6.2.1 Calculation method*

In contrast to the emissions of $NH_3$ from animal housing and outside manure storage, emissions of $NO_x$ are calculated for animal housings and outside manure storages combined. The calculation is also based on N-excreted instead of TAN and contrary to the $NH_3$ emission calculations the addition of bedding material does not constitute an additional source of emissions. The following formula is used to calculate $NO_x$ emissions from animal manure:

$$NO_x \text{ emissions manure management} = \Sigma\ AAP_i \times N\ excretions_i \times (1 - FRAC_{i,\ manure\ treatment}) \times FRAC_{j,\ manure\ management} \times EF\ NO_x\ manure\ management_{ij} \times 30/14 \quad (6.1)$$

Where:

| | | |
|---|---|---|
| $NO_x$ emissions manure Management | : | $NO_x$ emissions (kg $NO_x$, expressed as nitrogen monoxide) for all livestock categories (i) within NFR Category 3B (Manure management) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $FRAC_{j,\ manure\ management}$ | : | Fraction of manure in the various Management systems (j) |
| N $excretion_i$ | : | N excretions (kg N/animal) for livestock category (i) |
| $FRAC_{i,\ manure\ treatment}$ | : | Fraction of manure treated for livestock category (i) |
| EF $NO_x$ manure $management_{ij}$ | : | Emission factor (kg $NO_x$-N/kg N excreted in animal housing) for livestock category (i) and manure management system (j) |
| 30/14 | : | Conversion factor from kg $NO_x$-N to kg $NO_x$, expressed as nitrogen monoxide |

### *6.2.2 Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**N excretions per animal and manure management system**

N excretions and uncertainty estimates are described in Section 2.2.3 and 2.4.3.

### *6.2.3 Emission factors*

NEMA uses the emission factors displayed in Table 6.1, with $NO_x$ emission factors set to the same value as for $N_2O$ emission factors (Oenema *et al.*, 2000).

*Table 6.1 Emission factors (EF) for $NO_x$ from manure management (Oenema et al. (2000), based on the $N_2O$ emission factors specified by IPCC (2006))*

| Manure management system | EF in kg $NO_x$-N/kg N manure excreted in animal housing |
|---|---|
| Slurry (except poultry) | 0.002 |
| Solid manure (except poultry) | 0.005 |
| Poultry | 0.001 |
| Goats, deep bedding | 0.01 |

### 6.2.4 *Uncertainty*

Uncertainty values for animal numbers, N excretions and manure management systems are discussed in Section 2.4.3. Uncertainty values for emission factors are estimated at 100%.

## 6.3 Source-specific aspects for NOx emissions from manure treatment

### 6.3.1 *Calculation method*

The $NO_x$ emissions from manure treatment are calculated based on the amount of N in the manure used in manure treatment. It is assumed that four of the six different manure treatments distinguished emit $NO_x$: manure separation, nitrification/denitrification, production of mineral concentrates and pelleting/drying of manure. In the interest of simplicity, emissions during the processing and subsequent storage of manure treatment products are combined and expressed as a single emission factor, based on the N that is treated.

The combined $NO_x$ emissions from processing and subsequent storage in manure treatment (o) for livestock category (i) are calculated as follows:

$$NO_x \text{ emissions manure treatment} = \Sigma N_{io,\ manure\ treatment} \times EF\ NO_x \text{ from manure treatment}_{io} \quad (6.2)$$

Where:

| | | |
|---|---|---|
| $NO_x$ emissions manure Treatment | : | $NO_x$ emissions from manure treated (kg $NO_x$/year) |
| $N_{io,\ manure\ treatment\ input}$ | : | Amount of N in treated manure (kg N/year) for livestock category (i) and manure treatment (o) |
| EF $NO_x$ manure $treatment_{io}$ | : | Emission factor (% of N) for manure treatment for livestock category (i) and manure treatment (o) |

### 6.3.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**N excretions for each livestock category in a given year**
N excretions and uncertainties are described in Sections 2.2.3 and 2.4.3.3.

**Treated manure N**
The amount of manure that has been treated and its N content can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO). For the years 2010-2024 the N content of the treated manure is based on the mandatory transport certificates instead of the default used for all previous years. For all livestock categories fixed TAN contents are used for the treated manure. Only the TAN content of treated veal manure is based on the yearly calculated TAN excretion of the WUM.

**$NH_3$, $N_2O$ and $N_2$ emissions**
The calculation methods for emissions of $NH_3$ and $N_2O$ are described in Sections 5 and 7. The $N_2$ emissions are set at a value 10 times greater than $N_2O$-N emissions for slurry manure and 5 times greater than for solid manure (Oenema *et al.*, 2000).

### 6.3.3 *Emission factors*

A literature study has been carried out by Melse and Groenestein (2016) to compile the most suitable emission factors for the different manure treatments used in and under conditions in the Netherlands. The following emission factors were calculated based on these findings (Table 6.2).

*Table 6.2 Emission factors (EF; % of TAN input/animal/year) for all livestock categories and manure treatment systems (Melse and Groenestein, 2016).*

| Livestock category | Manure treatment | EF |
|---|---|---|
| Cattle (excl. veal calves) | Separation | 0.5 |
| | Digestion | 0.0 |
| Veal calves | Separation | 5.5 |
| Pigs | Separation | 0.5 |
| | Mineral concentrates | 0.5 |
| | Digestion | 0.0 |
| Poultry | Incineration | 0.0 |
| | Pelleting/drying | 0.0 |

### 6.3.4 *Uncertainty*

The amounts of manure treated (with the exception of poultry manure) are assumed to be 50% uncertain, based on expert judgement. Poultry manure is processed either by pelleting/drying or incineration, both of which are industrial processes with lower expected uncertainties of 25%. The uncertainty values for the emission factor are assumed equal to those for regular manure management (100%). Results for manure management as a whole (animal housing, manure treatment and outside storage) are presented in Table 6.3. Outcomes for each subsector are provided in Annex 11.

## 6.4 Uncertainty estimates

In NEMA uncertainty values for manure management and manure treatment are calculated separately, in order to account for differences in circumstances and thus in the associated emissions. The output of the model is at the level of detail shown in Table 6.2 and Annex 11.

### Aggregation of uncertainty values for $NO_x$ manure management and manure treatment

Uncertainty values calculated for emissions from manure management and manure treatment are aggregated to the NFR categories, as shown in Table 6.3.

*Table 6.3 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and $NO_x$ emissions from manure management*

| IPCC | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3B1a | Dairy cattle | 2% | 68% | 68% |
| 3B1b | Non-dairy cattle | 1% | 76% | 76% |
| 3B2 | Sheep | 6% | 110% | 110% |
| 3B3 | Swine | 5% | 72% | 73% |
| 3B4d | Goats | 5% | 102% | 102% |
| 3B4e | Horses | 39% | 82% | 91% |
| 3B4f | Mules and asses | 12% | 89% | 89% |
| 3B4gi | Laying hens | 2% | 75% | 75% |
| 3B4gii | Broilers | 5% | 105% | 105% |
| 3B4giii | Turkeys | 5% | 102% | 102% |
| 3B4giv | Other poultry | 5% | 102% | 102% |
| 3B4h | Other animals | 5% | 72% | 72% |
| 3B | Total | | | 38% |

# 7 $N_2O$ emissions from manure management (CRT sector 3B)

## 7.1 Scope and definition

This section provides a description of the methods and working processes for determining $N_2O$ emissions from manure management. The following source categories are distinguished in the CRT:

- Direct emissions
  - 3B1a Mature dairy cattle
  - 3B1b Other mature cattle
  - 3B1c Growing cattle
  - 3B2 Sheep
  - 3B3 Swine
  - 3B4 Other livestock
- Indirect emissions
  - 3B5 Indirect $N_2O$ emissions

Source category 3B4 (Other livestock) consists of poultry, goats, horses, mules and asses, fur-bearing animals and rabbits.

Emissions reported under category 3B concern only the $N_2O$ emissions from manure produced in animal housing and then stored temporarily and/or treated before being transported elsewhere. The nitrous oxide resulting from manure production on pastureland is reported under category 3D (Section 12; $N_2O$ emissions from crop production and agricultural soils).

Nitrous oxide emissions from livestock manure management depend on the nitrogen and carbon content of the manure, the amount of time the manure is stored and the treatment method used. During storage, the manure often becomes low in oxygen, thereby slowing the nitrification process and maintaining a low level of denitrification.

Nitrification is the process whereby ammonia ($NH_4^+$) is converted into nitrate by bacteria under conditions of high oxygen. In this process, nitrous oxide can be formed as a by-product, particularly if the nitrification is limited through lack of oxygen. Nitrification does not require the presence of any organic substances (volatile solids). Straw-rich solid manure and poultry manure can possess a relatively open and loose structure, allowing $O_2$ to diffuse far more easily than it does in slurry, thus enabling nitrification.

Denitrification is the process whereby bacteria can convert nitrate ($NO_3^-$) into the gaseous nitrogen compound $N_2$ under conditions of low oxygen, with nitrous oxide as a by-product. Organic substances (volatile solids) are used as an energy source. Denitrification in animal housing and manure storage facilities depends entirely on the nitrification process, which must supply the oxidised nitrogen compounds.

$N_2O$ emissions from solid manure are higher than those from slurry, as very little nitrification occurs in the latter, due to the lack of oxygen.

## 7.2 Source-specific aspects for direct $N_2O$ emissions from manure storage

### 7.2.1 *Calculation method*

In contrast to the emissions of $NH_3$ from animal housing and outside manure storage, emissions of $N_2O$ are calculated for animal housings and outside manure storages combined. The calculation is also based on N-excreted instead of TAN and contrary to the $NH_3$ emission calculations the addition of bedding material does not constitute an additional source of emissions. Direct $N_2O$ emissions from animal manure are calculated as follows:

$$N_2O \text{ emissions manure management direct} = \Sigma\ AAP_i \times N\ excretions_i \times (1 - FRAC_{i,\ manure\ treatment}) \times FRAC_{j,\ manure\ management} \times EF\ N_2O\ manure\ management\ direct_{ij} \times 44/28 \quad (7.1)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions manure management direct | : | $N_2O$ emissions for all livestock categories (i) within NFR category 3B (Manure management) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| N $excretions_i$ | : | N excretions (kg N/animal) for livestock category (i) |
| $FRAC_{i,\ manure\ treatment}$ | : | Fraction of manure that is treated for livestock category (i) |
| $FRAC_{j,\ manure\ management}$ | : | Fraction of manure in the various management systems (j) |
| EF $N_2O$ manure management $direct_{ij}$ | : | Emission factor (kg $N_2O$-N/kg N excreted manure) for livestock category (i) and manure management system (j) |
| 44/28 | : | Conversion factor from kg $N_2O$-N to kg $N_2O$ |

**Comparison to IPCC methodology**

The aforementioned method is consistent with that described by the IPCC (IPCC (2006); p. 10.52). The total amount of manure produced is therefore multiplied by an emission factor without subtracting $NH_3$ and $NO_x$ emissions. Default (Tier 1) values are used for the emission factors.

### 7.2.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**N excretions for each animal and manure management system**

N excretions and uncertainty values are described in Sections 2.2.3 and 2.4.3.

### 7.2.3 *Emission factors for direct $N_2O$ emissions from manure management*

The NEMA model uses the default IPCC 2006 emission factors, as presented in Table 7.1. The researchers involved in NEMA have investigated whether better emission factors for $N_2O$ from manure management are available in the Netherlands. The available data suggest that emissions of $N_2O$ from animal housing and outside manure storage facilities could be lower than the defaults. Due to the limited data available, however, it was decided to maintain the current methodology based on the IPCC Guidelines and Oenema *et al.* (2000), thus resulting in a conservative estimate of emissions.

*Table 7.1 Emission factors (EF) for N2O from manure management IPCC (2006)*

| Livestock category | EF in kg $N_2O$-N/kg N manure excreted in animal housing |
|---|---|
| *Slurry* | |
| Cattle | 0.002 |
| Pigs | 0.002 |
| Laying hens | 0.001 |
| Fur-bearing animals | 0.002 |
| *Solid manure* | |
| Cattle | 0.005 |
| Pigs | 0.005 |
| Poultry | 0.001 |
| Sheep | 0.005 |
| Goats, deep bedding | 0.010 |
| Horses, mules and asses | 0.005 |
| Rabbits | 0.005 |

### *7.2.4 Uncertainty*

Uncertainty values for animal numbers, and N excretions and manure management systems are discussed in Section 2.4.3. Uncertainty values for manure -management systems are described in Section 4. Uncertainty values for emission factors are estimated at 100% (IPCC, 2006).

## 7.3 Source-specific aspects for direct $N_2O$ emissions from manure treatment

### *7.3.1 Calculation method*

The $N_2O$ emissions from manure treatment are calculated based on the amount of N in the manure used in manure treatment. Of the six different manure treatments distinguished, it is assumed that $N_2O$ is emitted only in manure separation, nitrification/denitrification, production of mineral concentrates and pelleting/drying of manure. In the interest of simplicity, emissions during processing and subsequent storage are combined and expressed as a single emission factor, based on the N that is treated.

The combined $N_2O$ emissions from processing and subsequent storage in manure treatment (o) for livestock category (i) are calculated as follows:

$$N_2O \text{ emissions manure treatment} = \Sigma N_{io,\text{ manure treatment}} \times EF\ N_2O \text{ manure treatment}_{io} \quad (7.2)$$

Where:

$N_2O$ emissions manure

| | | |
|---|---|---|
| Treatment | : | $N_2O$ emissions from manure treated (kg $N_2O$/year) |
| $N_{io,\ manure\ treatment}$ | : | Amount of N in treated manure (kg N/year) for livestock category (i) and manure treatment (o) |
| EF $NO_x$ manure $treatment_{io}$ | : | $N_2O$ emission factor (% of N) for manure treatment for livestock category (i) and manure treatment (o) |

### 7.3.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**N excretions for each livestock category in a given year**

N excretions and uncertainty values are described in Sections 2.2.3 and 2.4.3.

**Treated manure N**

The amount of manure that has been treated and its N content can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO). For the years 2010-2024 the N content of the treated manure is based on the mandatory transport certificates instead of the default used for all previous years. For all livestock categories fixed TAN contents are used for the treated manure. Only the TAN content of treated veal manure is based on the yearly calculated TAN excretion of the WUM.

**$NH_3$, $NO_x$ and $N_2$ emissions**

The calculation methods for emissions of $NH_3$ and $NO_x$ are described in Sections 5 and 6, respectively. The $N_2$-N emissions are set at values 10 times greater than $N_2O$-N emissions for slurry manure and 5 times greater than for solid manure (Oenema *et al.*, 2000).

### 7.3.3 *Emission factors*

A literature study has been carried out by Melse and Groenestein (2016) to compile the most suitable emission factors for the different manure treatments used in and under conditions in the Netherlands. The following emission factors were calculated based on these findings (Table 7.2).

*Table 7.2 Emission factors (EF; % of TAN input/animal/year) for all livestock categories and manure treatment processes (Melse and Groenestein, 2016).*

| Livestock category | Manure treatment | EF |
|---|---|---|
| Cattle (excl. veal calves) | Separation | 0.5 |
| | Digestion | 0.0 |
| Veal calves | Separation | 5.5 |
| Pigs | Separation | 0.5 |
| | Mineral concentrates | 0.5 |
| | Digestion | 0.0 |
| Poultry | Incineration | 0.0 |
| | Pelleting/drying | 0.0 |

### 7.3.4 *Uncertainty*

The amounts of manure treated (with the exception of poultry manure) are assumed to be 50% uncertain, based on expert judgement. Poultry manure is processed either by pelleting/drying or incineration, both of which are industrial processes with lower expected uncertainties of 25%. The uncertainty values for the emission factor are assumed equal to those for regular manure management (100%). Results for manure management as a whole (animal housing, manure treatment and outside storage) are presented in Table 7.3. Outcomes for each subsector are provided in Annex 11.

## 7.4 Source-specific aspects for indirect $N_2O$ emissions from manure management

### 7.4.1 *Calculation method*

Indirect $N_2O$ emissions from manure management are calculated by multiplying the total emissions of $NH_3$ and $NO_x$ from animal housing, manure treatment and $NH_3$ from manure storage by an emission factor:

$N_2O$ emissions manure management indirect = ($NH_3$ emissions manure management x 14/17 + $NO_x$ emissions manure management direct x 14/30) x EF $N_2O$ manure management indirect x 44/28 (7.3)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions manure management indirect | : | Indirect nitrous oxide emissions (kg $N_2O$-N/year) following atmospheric deposition of $NH_3$ and $NO_x$ from manure management |
| $NH_3$ emissions manure Management | : | $NH_3$ emissions (kg $NH_3$/year) for all defined livestock categories (i) within NFR category 3B (Manure management) |
| 14/17 | : | Conversion factor from $NH_3$ to $NH_3$-N |
| $NO_x$ emissions manure management direct | : | $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) for all defined livestock categories (i) within NFR category 3B (Manure management) |
| 14/30 | : | Conversion factor from $NO_x$ (expressed as nitrogen monoxide) to $NO_x$-N |
| EF $N_2O$ manure management indirect | : | Nitrous oxide emission factor for indirect emission following atmospheric deposition of $NH_3$ and $NO_x$ |
| 44/28 | : | Conversion factor from kg $N_2O$-N to kg $N_2O$ |

**Comparison to IPCC methodology**

For indirect emissions from manure management, only atmospheric deposition is calculated for the Netherlands. The IPCC Guidelines also calculate leaching and runoff from manure storage. In the Netherlands, all slurry manure is stored underneath animal houses or in fully closed outside storage tanks (this is an obligation of the EU Nitrates Directive). Solid manure must be stored on concrete plates, with runoff directed into a slurry pit or separate tank.

### 7.4.2 *Activity data*

The calculations for $NH_3$ and $NO_x$ emissions are described in Sections 5 and 6.

### 7.4.3 *Emission factors*

The IPCC 2006 default emission factor of 0.01 kg $N_2O$-N/kg N emitted as $NH_3$ and $NO_x$ from animal housing and outside manure storage facilities is used.

### 7.4.4 *Uncertainty*

The uncertainty value for total $NH_3$ and $NO_x$ emissions from manure management is 17%. This is based on the uncertainty values calculated in Sections 5 and 6. The uncertainty value for this emission factor is set to 400% (IPCC, 2006).

## 7.5 Uncertainty estimates

In NEMA, uncertainty values for direct $N_2O$ emissions from manure management, manure treatment and indirect emissions from manure management are calculated separately, in order to account for the differences in circumstances, and thus in the associated emissions. The output of the model is at the level of detail shown in Table 7.2 and Annex 11.

**Aggregation of uncertainty values for $N_2O$ direct manure management, manure treatment and indirect manure management**

Uncertainty values calculated for emissions from direct manure management, manure treatment and indirect manure management are aggregated to the CRT categories, as shown in Table 7.3.

*Table 7.3 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and $N_2O$ emissions from manure management*

| IPCC | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3A1a | Mature dairy cattle | 2% | 68% | 68% |
| 3A1b | Other mature cattle | 2% | 78% | 78% |
| 3A1c | Growing cattle | 1% | 64% | 64% |
| 3A2 | Sheep | 6% | 117% | 117% |
| 3A3 | Swine | 4% | 52% | 52% |
| 3A4a | Goats | 5% | 102% | 102% |
| 3A4b | Horses | 39% | 83% | 91% |
| 3A4c | Mules and asses | 12% | 90% | 91% |
| 3A4d | Poultry | 8% | 59% | 60% |
| 3A4e | Other | 5% | 72% | 72% |
| 3B5 | Atmospheric deposition from manure management | 17% | 400% | 406% |
| 3B | Total | | | 127% |

# 8 NMVOC emissions from manure management (NFR category 3B)

## 8.1 Scope and definition

This section provides a description of the methods and working processes for determining NMVOC emissions from manure management, using the following NFR categories:

- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Laying hens
- 3B4gii Broilers
- 3B4giii Turkeys
- 3B4giv Other poultry
- 3B4h Other animals

Category 3B4a (Buffalo) is reported as ‘included elsewhere’ (IE), as these animals are included with dairy cattle (3B1a) and non-dairy cattle (3B1b) according to their purpose as specified in the annual agricultural census. Category 3B4h (Other animals) consists of fur-bearing animals and rabbits.

Emissions reported under Category 3B include the NMVOC emissions from manure produced in animal housing and then stored temporarily before being transported elsewhere, as well as the NMVOC emissions occurring during the feeding of silage in animal housing. No NMVOC emissions from manure treatment are reported, as no method is available for calculating these emissions. The NMVOC emissions resulting from manure application, manure production on pasture land during grazing, silage storage and crop cultivation are reported under category 3D (Crop production and agricultural soils).

In manure, NMVOC are produced by the degradation of fat, carbohydrates and protein (VS) present in the manure. For all animal categories except cattle, the volume of NMVOC is based on the amount of VS in the manure. For cattle, the volume of NMVOC depends on the energy content of the feed. Because of a correlation between emissions of $NH_3$ and NMVOC from manure, the ratio between $NH_3$ emissions from animal housing and manure application is a measure of the NMVOC emissions from housing and after application, as described in the EMEP Guidebook (EEA, 2023).

The NMVOC emissions are calculated with the Tier 2 method, as described in the EMEP Guidebook (EEA, 2023).

## 8.2 Source-specific aspects for NMVOC emissions from animal housing

### *8.2.1 Calculation method*

**Dairy and non-dairy cattle**

The NMVOC emissions from cattle manure in animal housing are calculated as follows:

$$\text{NMVOC emissions animal housing}_{cattle} = \Sigma\ AAP_i \times GE_i \times FRAC_{i,\ time\ spent\ inside} \times \text{EF NMVOC animal housing}_i \qquad (8.1)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions animal housing$_{cattle}$ | : | NMVOC emissions (kg NMVOC/year) from manure in animal housing for cattle within NFR category 3B (Manure management) |
| $AAP_i$ | : | Average animal population for cattle category (i) |
| $GE_i$ | : | Gross energy intake in megajoules (MJ/animal/year) for cattle category (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Fraction of time spent inside animal housing for cattle category (i) |
| EF NMVOC animal housing$_i$ | : | Emission factor (kg NMVOC/MJ) of NMVOC in animal housing for cattle category (i) |

**Other livestock**

For livestock categories other than cattle, NMVOC emissions from manure in animal housing are calculated as follows:

$$\text{NMVOC emissions animal housing}_{other} = \Sigma\ AAP_i \times VS_i \times FRAC_{i,\ time\ spent\ inside} \times \text{EF NMVOC animal housing}_i \qquad (8.2)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions animal housing$_{other}$ | : | NMVOC emissions (kg NMVOC/year) from manure in animal housing for other livestock within NFR category 3B (Manure management) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $VS_i$ | : | Volatile solids excretion (kg/animal/year) for livestock category (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Fraction of time spent inside animal housing for livestock category (i) |
| EF NMVOC animal housing$_i$ | : | Emission factor (kg NMVOC/kg VS excreted) of NMVOC in animal housing for livestock category (i) |

### 8.2.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**Feed intake**

The gross energy intake of cattle, the VS excretion of pigs and poultry, and the time spent inside animal housing are calculated by the WUM (CBS, 2019 through 2025). The IPCC default values are used for the VS excretions of sheep, goats, horses, ponies, mules and asses and other animals, as shown in Table 8.1 (IPCC, 2006).

*Table 8.1 Default VS excretion values, as provided by IPCC (2006)*

| Livestock category | Default VS excretions (kg/animal/day) |
|---|---|
| Sheep | 0.40 |
| Goats | 0.30 |
| Horses | 2.13 |
| Ponies | 0.94 |
| Mules and asses | 0.94 |
| Fur-bearing animals | 0.14 |
| Rabbits | 0.10 |

### 8.2.3 *Emission factors*

The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2023). The emission factors are listed in Table 8.2.

*Table 8.2 NMVOC emission factors (EF) of NMVOC from manure in animal housing, by livestock category (EEA, 2023)*

| Livestock category | EF for manure in housing | Unit |
|---|---|---|
| Cattle | 0.0000353 | kg NMVOC/MJ |
| Sheep | 0.001614 | kg NMVOC/kg VS excreted |
| Rearing and fattening pigs | 0.001703 | kg NMVOC/kg VS excreted |
| Sows | 0.007042 | kg NMVOC/kg VS excreted |
| Goats | 0.001614 | kg NMVOC/kg VS excreted |
| Horses | 0.001614 | kg NMVOC/kg VS excreted |
| Ponies | 0.001614 | kg NMVOC/kg VS excreted |
| Mules and asses | 0.001614 | kg NMVOC/kg VS excreted |
| Laying hens | 0.005684 | kg NMVOC/kg VS excreted |
| Broilers | 0.009147 | kg NMVOC/kg VS excreted |
| Turkeys | 0.005684 | kg NMVOC/kg VS excreted |
| Other poultry | 0.005684 | kg NMVOC/kg VS excreted |
| Other animals (fur-bearing animals) | 0.005684 | kg NMVOC/kg VS excreted |
| Other animals (rabbits) | 0.001614 | kg NMVOC/kg VS excreted |

### 8.2.4 *Uncertainty*

Uncertainty values for animal numbers and manure management systems are discussed in Section 2.4.3. Feed uptake and energy content are described in Section 3 (Table 3.1). The proportion of time spent inside animal housing is assumed to be 20% uncertain, and uncertainty values for emission factors are estimated at 300% (based on expert judgement).

## 8.3 Source-specific aspects for NMVOC emissions from silage feeding in animal housing

### 8.3.1 *Calculation method*

**Dairy and non-dairy cattle**

The NMVOC emissions from silage feeding in animal housing if silage is used for feeding cattle are calculated as follows:

$$\text{NMVOC emissions silage feeding}_{cattle} = \sum AAP_i \times GE_i \times FRAC_{i,\ time\ spent\ inside} \times (\text{EF NMVOC silage feeding}_i \times FRAC_{i,\ silage}) \qquad (8.3)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions silage feeding$_{cattle}$ | : | NMVOC emissions (kg NMVOC/year) from the feeding of silage for all cattle categories (i) within NFR Category 3B (Manure management) |
| $AAP_i$ | : | Average animal population for cattle category (i) |
| $GE_i$ | : | Gross energy intake in megajoules (MJ/animal) for cattle category (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Fraction of time spent inside animal housing (i) |
| EF NMVOC silage feeding$_i$ | : | Emission factor (kg NMVOC/MJ) of NMVOC from the feeding of silage for cattle category (i) |
| $FRAC_{i,\ silage}$ | : | Fraction of the feed given consisting of silage for cattle category (i) |

If the fraction of feed consisting of silage is greater than 0.5 of all dry-matter consumption, it is assumed that silage feeding is dominant, and the fraction of feed consisting of silage is set to 1.0.

**Other livestock**

NMVOC emissions from silage feeding in animal housing when silage is used for feeding livestock categories other than cattle that are fed silage are calculated as follows:

$$\text{NMVOC emissions silage feeding}_{other} = \sum AAP_i \times VS_i \times FRAC_{i,\ time\ spent\ inside} \times (\text{EF NMVOC silage feeding}_i \times FRAC_{i,\ silage}) \qquad (8.4)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions silage feeding$_{other}$ | : | NMVOC emissions (kg NMVOC/year) from the feeding of silage for all other livestock categories (i) within NFR category 3B (Manure management) |

| | | |
|---|---|---|
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $VS_i$ | : | Excreted volatile solids (kg/animal/year) for livestock category (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Proportion of time spent inside animal housing for livestock category (i) |
| EF NMVOC silage $feeding_i$ | : | Emission factor (kg NMVOC/animal) of NMVOC from the feeding of silage for livestock category (i) |
| $FRAC_{i,\ silage}$ | : | The fraction of the feed given consisting of silage for livestock category (i) |

If the fraction of feed consisting of silage is greater than 0.5 of total dry-matter consumption, it is assumed that silage feeding is dominant, and the fraction of feed consisting of silage is set to 1.0.

### 8.3.2 *Activity data*

**Livestock numbers**

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**Feed intake**

The gross energy intake of cattle, the VS excretion of pigs and poultry, and the time spent inside the animal housing are calculated by the WUM (CBS, 2019 through 2025). In the Netherlands, silage includes both grass and maize silage. The IPCC default values are used for the VS excretion of sheep, goats, horses, ponies, mules and asses and other animals, as shown in Table 8.1 (IPCC, 2006).

### 8.3.3 *Emission factors*

The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2023), as listed in Table 8.3.

*Table 8.3 NMVOC emission factors (EF) of NMVOC from silage feeding, by livestock category (EEA, 2023)*

| Livestock category | EF for silage feeding | Unit |
|---|---|---|
| Cattle | 0.000202 | kg NMVOC/MJ |
| Sheep | 0.01076 | kg NMVOC/kg VS excreted |
| Goats | 0.01076 | kg NMVOC/kg VS excreted |
| Horses | 0.01076 | kg NMVOC/kg VS excreted |
| Ponies | 0.01076 | kg NMVOC/kg VS excreted |
| Mules and asses | 0.01076 | kg NMVOC/kg VS excreted |

### 8.3.4 *Uncertainty*

Uncertainty values for animal numbers and manure management systems are discussed in Section 2.4.3. Feed uptake and energy content are described in Section 3 (Table 3.1). The proportion of time spent inside animal housing is assumed to be 20% uncertain, and uncertainty values for emission factors are estimated at 300% (based on expert judgement).

## 8.4 Source-specific aspects for NMVOC emissions from outside manure storage

### 8.4.1 *Calculation method*

**Dairy and non-dairy cattle**

The NMVOC emissions from outside cattle manure storage are calculated as follows:

$$\text{NMVOC emissions manure storage}_{cattle} = \sum \text{AAP}_i \times \text{NMVOC emissions animal housing}_{cattle} \times (\text{NH}_3 \text{ emissions manure storage}_i \,/\, \text{NH}_3 \text{ emissions animal housing}_i) \quad (8.5)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions manure storage$_{cattle}$ | : | NMVOC emissions (kg NMVOC) for all cattle categories (i) within NFR category 3B (Manure management) |
| AAP$_i$ | : | Average animal population for cattle category (i) |
| NMVOC emissions animal housing$_{cattle}$ | : | NMVOC emissions (kg NMVOC/animal/year) from manure in animal housing for cattle category (i) |
| $NH_3$ emissions manure storage$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from manure storage facilities outside animal housing for cattle category (i) |
| $NH_3$ emissions animal housing$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from animal housing for cattle category (i) |

**Other livestock**

NMVOC emissions from outside manure storage for livestock categories other than cattle are calculated as follows:

$$\text{NMVOC emissions manure storage}_{other} = \sum \text{AAP}_i \times \text{NMVOC emissions animal housing}_i \times (\text{NH}_3 \text{ emissions outside storage}_i \,/\, \text{NH}_3 \text{ emissions animal housing}_i) \quad (8.6)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions manure storage$_{other}$ | : | NMVOC emissions (kg NMVOC) for all other livestock categories (i) within NFR category 3B (Manure management) |
| NMVOC emissions animal housing$_i$ | : | NMVOC emissions (kg |

| | | |
|---|---|---|
| | | NMVOC/animal/year) from manure in animal housing for livestock category (i) |
| $NH_3$ emissions outside storage$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from outside manure storage facilities for livestock category (i) $NH_3$ emissions |
| animal housing$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from animal housing for livestock category (i) |

### 8.4.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively. The emissions of $NH_3$ from animal housing and outside storage are described in Sections 5.2 and 5.4, respectively.

### 8.4.3 *Emission factors*

The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2023).

### 8.4.4 *Uncertainty*

Uncertainty values for animal numbers and manure management sytems are discussed in Section 2.4.3. Feed uptake and energy content are described in Section 3 (Table 3.1). The proportion of time spent inside animal housing is assumed to be 20% uncertain, and the uncertainty values for emission factors are estimated at 300% (based on expert judgement).

## 8.5 Uncertainty estimates

In NEMA uncertainty values for emissions from animal housing, silage feeding in animal housing and outside manure storage are calculated separately, in order to account for differences in circumstances, and thus in the associated emissions.

**Aggregation of uncertainties for NMVOC from animal housing, silage feeding in animal housing and outside manure storage**

Uncertainty values calculated for emissions from animal housing, silage feeding in animal housing and outside manure storage are aggregated to the NFR categories, as shown in Table 8.4.

*Table 8.4 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and NMVOC emissions from manure management*

| EMEP | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3B1a | Dairy cattle | 2% | 220% | 220% |
| 3B1b | Non-dairy cattle | 1% | 131% | 131% |
| 3B2 | Sheep | 6% | 283% | 283% |
| 3B3 | Swine | 8% | 221% | 221% |
| 3B4d | Goats | 5% | 302% | 302% |
| 3B4e | Horses | 42% | 256% | 260% |
| 3B4f | Mules and asses | 12% | 252% | 252% |
| 3B4gi | Laying hens | 2% | 209% | 209% |

| EMEP | Livestock category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3B4gii | Broilers | 5% | 302% | 302% |
| 3B4giii | Turkeys | 5% | 302% | 302% |
| 3B4giv | Other poultry | 5% | 302% | 302% |
| 3B4h | Other animals | 5% | 297% | 297% |
| 3B | Total | | | 152% |

# 9 $PM_{10}$ and $PM_{2.5}$ emissions from animal housing (NFR category 3B)

## 9.1 Scope and definition

This section provides a description of the methods and working processes for determining emissions of $PM_{10}$ and $PM_{2.5}$ (particulate matter smaller than 10 µm and smaller than 2.5 µm respectively) from animal housing, using the following NFR categories:

- 3B1a Dairy cattle
- 3B1b Non-dairy cattle
- 3B2 Sheep
- 3B3 Swine
- 3B4d Goats
- 3B4e Horses
- 3B4f Mules and asses
- 3B4gi Laying hens
- 3B4gii Broilers
- 3B4giii Turkeys
- 3B4giv Other poultry
- 3B4h Other animals

Category 3B4a (Buffalo) is reported as 'included elsewhere' (IE), as these animals are included with dairy cattle (3B1a) and non-dairy cattle (3B1b) according to their purpose as specified in the annual agricultural census. Category 3B4h (Other animals) consists of fur-bearing animals and rabbits.

Particulate matter emissions from agriculture originate mainly from animal housing and consist of skin, manure, feed and bedding particles. Poultry is the main source category of $PM_{10}$ and $PM_{2.5}$ emissions in Dutch agriculture. Over time, slurry-based housing systems for laying hens have been replaced by systems that produce solid manure, leading to higher emissions of PM. Pigs and cattle contribute to the production of PM as well, albeit to a lesser extent. The increasing use of air scrubbers in housing systems for pigs is decreasing the emission of PM (Melse *et al.*, 2018).

## 9.2 Source-specific aspects

### *9.2.1 Calculation method*

Emissions are calculated as the product of the number of animals in each housing system and the corresponding emission factors for $PM_{10}$ and $PM_{2.5}$ in grams per animal per year.

$$\text{PM emissions animal housing} = \sum AAP_i \times FRAC_{ik,\text{ housing system}} \times \text{EF PM animal housing}_{ik} / 1{,}000 \quad (9.1)$$

Where:

| | | |
|---|---|---|
| PM emissions animal Housing | : | PM emissions (kg $PM_{10}$ or $PM_{2.5}$/year) for all livestock categories (i) and housing systems (k) within NFR category 3B (Manure management) |

| | | |
|---|---|---|
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $FRAC_{ik, \text{housing system}}$ | : | Fraction of animals in the various animal-housing systems (k) |
| EF PM animal $\text{housing}_{ik}$ | : | Emission factor (g $PM_{10}$ or $PM_{2.5}$/year) for livestock category (i) and animal-housing system (k) |
| 1,000 | : | Conversion factor from grams to kilograms |

### 9.2.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

The shares of housing systems for each livestock category are based on the Agricultural Census. If insufficient information is available for certain livestock categories, other sources can be used (e.g. the permit files of local authorities).

Research by an enforcement agency revealed that many air scrubbers were not being used properly (Handhavingsamenwerking Noord-Brabant, 2013; 2015). For this reason, implementation grades were corrected. For the years up to and including 2009, it was assumed that 40% of the scrubbers did not function, decreasing by 8% a year up to 16% in 2012. From then on, a decrease of 4% per year was assumed until 2016, when all scrubbers were assumed to operate properly, given that electronic monitoring was compulsory on all equipment from that point in time.

New information has become available on the implementation of additional measures taken by poultry farmers to reduce particulate matter emissions. From 2015 onwards these measures have been taken into account. For years prior to 2015, no information on additional measures are available and their usage is assumed to have been negligible.

### 9.2.3 *Emission factors*

The emission factors are based on a measurement programme conducted by WUR Livestock Research between 2007 and 2009 (publication series 'Particulate matter emission from animal houses', in Dutch; (Mosquera *et al.*, 2009a; Mosquera *et al.*, 2009b; Mosquera *et al.*, 2009c; Winkel *et al.*, 2009a; Winkel *et al.*, 2009b; Winkel *et al.*, 2009c; Mosquera *et al.*, 2010a; Mosquera *et al.*, 2010b; Mosquera *et al.*, 2010c; Huis in 't Veld *et al.*, 2011; Mosquera *et al.*, 2011; Winkel *et al.*, 2011). The emission factor of goats in traditional housing in 1990 is based on Mosquera and Hol, 2012 (19 g $PM_{10}$ per goat). Recent research (Mosquera *et al.,* 2025) shows that $PM_{10}$ emissions from goat housing have drastically increased to 170 g $PM_{10}$ per goat over the years as ventilation rates have been increased to improve animal welfare (Mosquera *et al.,* 2025). Therefore it has been decided to apply the low emission factor to 1990 and the recently measured (during the period 2018-2023) higher emission factor from 2018 onwards. The emission factor has been linearly interpolated for the years in between (1991-2017) to create a consistent timeseries.

Measurements of PM emissions from housing were not conducted for all livestock categories. For categories that were not measured, emission factors were deduced from factors measured for similar livestock categories, using ratios of fixed P excretions (Chardon and Van der Hoek, 2002) as a scale factor. An overview of housing systems and emission factors for $PM_{10}$ and $PM_{2.5}$ is provided in Table 9.1.

Several techniques have been developed for reducing PM emissions, with air scrubbers being the most common. Air scrubbers generate the following reductions in emissions of $PM_{10}$, as well as in $PM_{2.5}$ based on measurements (Mosquera *et al.*, 2011). If air scrubbers are used in animal housing for a given animal category, the emission factor is reduced by the following percentages, depending on the type of air scrubber.

- Chemical air scrubber: 35%
- Biological air scrubber with short retention time: 60%
- Biological air scrubber with long retention time: 75%
- Combined air scrubber: 80%

*Table 9.1 Emission factors (EF) for PM10 and PM2.5 from animal housing (g/animal/year; traditional systems do not have PM emission reduction, but can have emission reductions for other substances. Calculated emission factors for air scrubbers for each livestock category are not mentioned)*

| **Livestock category** | **Housing system** | **EF $PM_{10}$** | **EF $PM_{2.5}$** |
|---|---|---|---|
| *Dairy cattle* | | | |
| Female young stock < 1 year | Traditional | 37.7 | 10.4 |
| Male young stock < 1 year | Traditional | 170.1 | 46.8 |
| Female young stock 1-2 years | Traditional | 37.7 | 10.4 |
| Male young stock 1-2 years | Traditional | 170.1 | 46.8 |
| Female young stock ≥ 2 years | Traditional | 117.8 | 32.5 |
| Cows in milk and in calf | Tie-stall system | 80.8 | 22.3 |
| | Cubicle system, grazing[1)] | 117.8 | 32.5 |
| | Cubicle system, no grazing[1)] | 147.5 | 40.6 |
| Bulls for service ≥ 2 years | Traditional | 170.1 | 46.8 |
| *Cattle for fattening* | | | |
| Veal calves, for white veal production | Traditional[2)] | 35.7 | 9.8 |
| Veal calves, for rosé veal production | Traditional[2)] | 35.7 | 9.8 |
| Female young stock < 1 year | Traditional | 37.7 | 10.4 |

| Livestock category | Housing system | EF $PM_{10}$ | EF $PM_{2.5}$ |
|---|---|---|---|
| Male young stock < 1 year (incl. young bullocks) | Traditional | 170.1 | 46.8 |
| Female young stock 1-2 years | Traditional | 37.7 | 10.4 |
| Male young stock 1-2 years (incl. young bullocks) | Traditional | 170.1 | 46.8 |
| Female young stock ≥ 2 years | Traditional | 86.2 | 23.8 |
| Male young stock ≥ 2 years (incl. young bullocks) | Traditional | 170.1 | 46.8 |
| Suckling cows ≥ 2 years (incl. fattening/grazing) | Traditional | 86.2 | 23.8 |
| *Pigs* | | | |
| Piglets | Traditional partially raster[1), 2)] | 81.2 | 2.0 |
| | Traditional fully raster[1), 2)] | 62.0 | 2.1 |
| Fattening pigs and growing pigs | Traditional[1), 2)] | 157.3 | 7.4 |
| Sows, pregnant and open | Traditional, individual[1), 2)] | 186.3 | 16.0 |
| | Traditional, group[1), 2)] | 173.7 | 12.1 |
| Sows with piglets | Traditional[2)] | 164.9 | 14.2 |
| Boars for service | Traditional[2)] | 185.6 | 15.9 |
| *Poultry* | | | |
| Broilers | Traditional[1), 2), 4)] | 26.8 | 2.0 |
| Broiler breeders < 18 weeks | Floor housing[3)] | 17.0 | 1.3 |
| Broiler breeders ≥ 18 weeks | Cage housing | 8.7 | 1.8 |
| | Floor housing + aviary[1), 2), 4)] | 49.1 | 3.8 |
| Laying hens < 18 weeks | Battery[3), 5)] | 2.2 | 0.4 |
| | Colony housing | 9.6 | 0.9 |
| | Floor housing[2), 4)] | 34.8 | 1.7 |
| | Aviary housing | 26.9 | 1.6 |
| Laying hens ≥ 18 weeks | Battery[3), 5)] | 5.4 | 1.1 |
| | Enriched cage/colony housing | 24.0 | 2.3 |
| | Floor housing[1), 2), 4)] | 87.1 | 4.2 |
| | Aviary housing[1)] | 67.3 | 4.0 |
| Ducks | Traditional | 104.5 | 5.0 |
| Turkeys | Traditional[1)] | 95.1 | 44.6 |
| Turkey breeders < 7 months | Traditional | 177.0 | 83.0 |

| Livestock category | Housing system | EF $PM_{10}$ | EF $PM_{2.5}$ |
|---|---|---|---|
| Turkey breeders ≥ 7 months | Traditional | 240.8 | 112.9 |
| Rabbits (mother animals) | Traditional | 10.7 | 2.1 |
| Minks (mother animals) | Traditional[1)] | 8.1 | 4.2 |
| Foxes (mother animals) | Traditional | 8.1 | 4.2 |
| Sheep | Traditional | 19.0 | 5.7 |
| Goats (1990) | Traditional | 19.0 | 5.7 |
| Goats (2018 onwards) | Traditional[2), 3), 7)] | 170.0 | 51 |
| Horses[6)] | Traditional | 220.0 | 140.0 |
| Ponies[6)] | Traditional | 220.0 | 140.0 |
| Mules and asses[6)] | Traditional | 160.0 | 100.0 |

1) Source: Wageningen UR Livestock Research measurements.
2) Air scrubbers available.
3) Chemical air scrubbers available.
4) Additional emission reducing techniques available see Table 8.2.
5) Prohibited since 2013.
6) Default emission factors from the EMEP Guidebook (EEA, 2023).
7) the emission factor has been linearly interpolated for the years 1991-2017
*Source:* Wageningen UR Livestock Research.

### 9.2.4 *Uncertainty*

The uncertainty values for livestock numbers, including the aggregation and disaggregation of subcategories, are provided in Section 2.4.3. Uncertainty values in the shares of housing systems are estimated at 10%. Uncertainty values for the measured emission factors are also published in publication series 'Particulate matter emission from animal houses' and displayed in Table 9.2.
An uncertainty value of 40% is assumed for the EMEP default emission factors used (horses, ponies, mules and asses), based on expert judgement.

*Table 9.2 Uncertainty values for emission factors for $PM_{10}$ and $PM_{2.5}$ from manure management*

| Livestock category | Uncertainty $PM_{10}$ | Uncertainty $PM_{2.5}$ | Source |
|---|---|---|---|
| Dairy cows | 32% | 35% | Greatest uncertainty[1)] in particulate-matter emissions from animal housing: dairy cows (Mosquera *et al.*, 2010a) (47.4 x 100% / 147.5 = 32%) |
| Other cattle | 32% | 35% | Equal to dairy cows |
| Goats | 32% | 35% | Equal to dairy cows |
| Fattening pigs | 45% | 55% | Greatest uncertainty in particulate-matter emissions from animal housing: fattening pigs (Mosquera *et al.*, 2010b) (65.4 x 100% / 144.0 = 45%) |

| Livestock category | Uncertainty $PM_{10}$ | Uncertainty $PM_{2.5}$ | Source |
|---|---|---|---|
| Sows | 48% | 52% | Greatest uncertainty in particulate-matter emissions from animal housing: gestating sows (Winkel *et al.*, 2009b; Mosquera *et al.*, 2010c) (82.6 x 100% / 173.7 = 48%) |
| Laying hens | 44% | 100% | Greatest uncertainty in particulate-matter emissions from animal housing: laying hens in animal housing with a drying tunnel (Mosquera *et al.*, 2009a; Mosquera *et al.*, 2009b; Winkel *et al.*, 2009a; Winkel *et al.*, 2011) (1.7 x 100% / 3.9 = 44%) |
| Broilers | 33% | 45% | Greatest uncertainty of particulate-matter emissions from animal housing: broilers (Winkel *et al.*, 2009c) (8.8 x 100% / 26.8 = 33%) |
| Ducks | 33% | 45% | Equal to broilers |
| Turkeys | 33% | 45% | Equal to broilers |
| Rabbits | 49% | 100% | Greatest uncertainty in gaseous emissions and particulate matter from rabbit animal housing with manure storage under the welfare cages (Huis in ’t Veld *et al*., 2011) and report minks (Mosquera *et al*., 2011) (5.21 x 100% / 10.7 = 49%) |
| Fur-bearing animals | 49% | 100% | Uncertainty value for rabbits used |

In line with the EMEP Guidebook (2023), the greatest uncertainty value is selected.

## 9.3 Uncertainty estimates

Emission calculations use more livestock categories than are listed in Table 9.3, along with several housing systems (Table 9.1). These livestock categories (e.g. young female cattle < 1 year and 1-2 years) have been aggregated in the uncertainty analysis, so that the associated uncertainty value is considered only once. The same applies to the uncertainty values for the emission factors of housing systems. The emission factors of air scrubbers are dependent on the traditional system. Uncertainty values are calculated using only one category, instead of two.

The uncertainty value for shares of housing system is included in the implied emission factor. Implied emission factors are calculated by multiplying these uncertainty estimates by the selected aggregation (based on expert judgement), as shown in Table 9.3.

*Table 9.3 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and $PM_{10}$ and $PM_{2.5}$ emissions from animal housing*

| NFR | Livestock category | U AD | U IEF $PM_{10}$ | U emissions $PM_{10}$ | U IEF $PM_{2.5}$ | U emissions $PM_{2.5}$ |
|---|---|---|---|---|---|---|
| 3B1a | Dairy cattle | 2% | 25% | 25% | 27% | 28% |
| 3B1b | Non-dairy cattle | 1% | 15% | 15% | 16% | 16% |
| 3B2 | Sheep | 10% | 37% | 39% | 37% | 39% |
| 3B3 | Swine | 6% | 22% | 23% | 26% | 27% |
| 3B4d | Goats | 5% | 32% | 32% | 35% | 35% |
| 3B4e | Horses | 39% | 36% | 53% | 36% | 53% |
| 3B4f | Mules and asses | 12% | 29% | 31% | 33% | 35% |
| 3B4gi | Laying hens | 4% | 36% | 36% | 77% | 77% |
| 3B4gii | Broilers | 10% | 28% | 28% | 37% | 38% |
| 3B4giii | Turkeys | 10% | 32% | 32% | 43% | 43% |
| 3B4giv | Other poultry | 10% | 35% | 35% | 46% | 47% |
| 3B4h | Other animals | 5% | 44% | 44% | 96% | 96% |
| 3B | Total | | | 19% | | 30% |

# 10 $NH_3$ emissions from crop production and agricultural soils (NFR category 3D)

## 10.1 Scope and definition

This section provides a description of the method and working processes for determining $NH_3$ emissions from crop production and agricultural soils, using the following NFR categories:

- 3Da1 Inorganic N fertilizers (including urea application)
- 3Da2a Livestock manure applied to soils
- 3Da2b Sewage sludge applied to soils
- 3Da2c Other organic fertilizers applied to soils (including compost)
- 3Da3 Urine and dung deposited by grazing animals
- 3Da4 Crop residues left behind on soils
- 3De Cultivated crops

$NH_3$ emissions occur in all subcategories describing N inputs to the soil (i.e. 3Da1 up to 3Da4; Figure 10.2) and during crop cultivation (3De). In this report, category 3Da2a (Livestock manure applied to soils) is referred to as 'Animal manure applied to soil', as the IPCC Guidelines use the term 'animal manure', and the choice was made to use one term consistently. Category 3F (Field burning of agricultural residues) is reported as 'not occurring' (NO), as field burning was prohibited in the Netherlands throughout the entire time series (Article 10.2 of the Environmental Management Act; in Dutch, '*Wet Milieubeheer*'). Categories 3Df (Use of pesticides) and 3I (Agriculture other) also generate no $NH_3$ emissions.

*Figure 10.1 TAN flow throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to crop production and agricultural soils.*

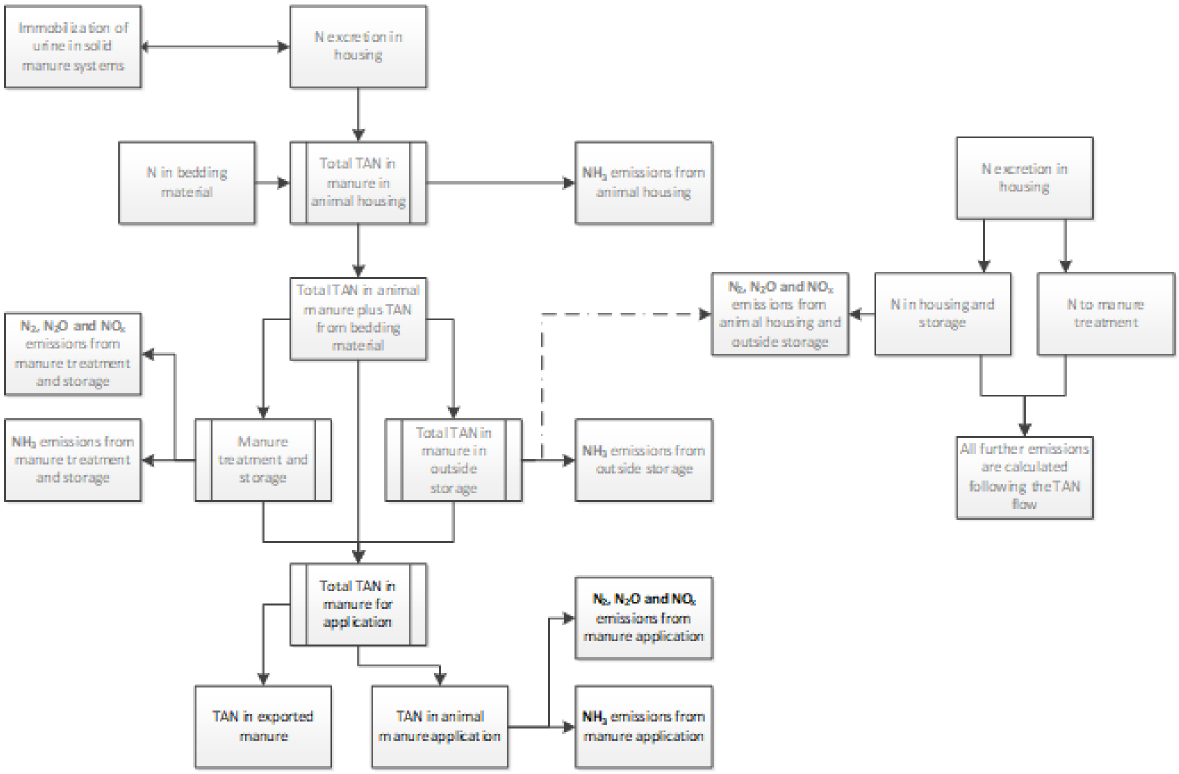
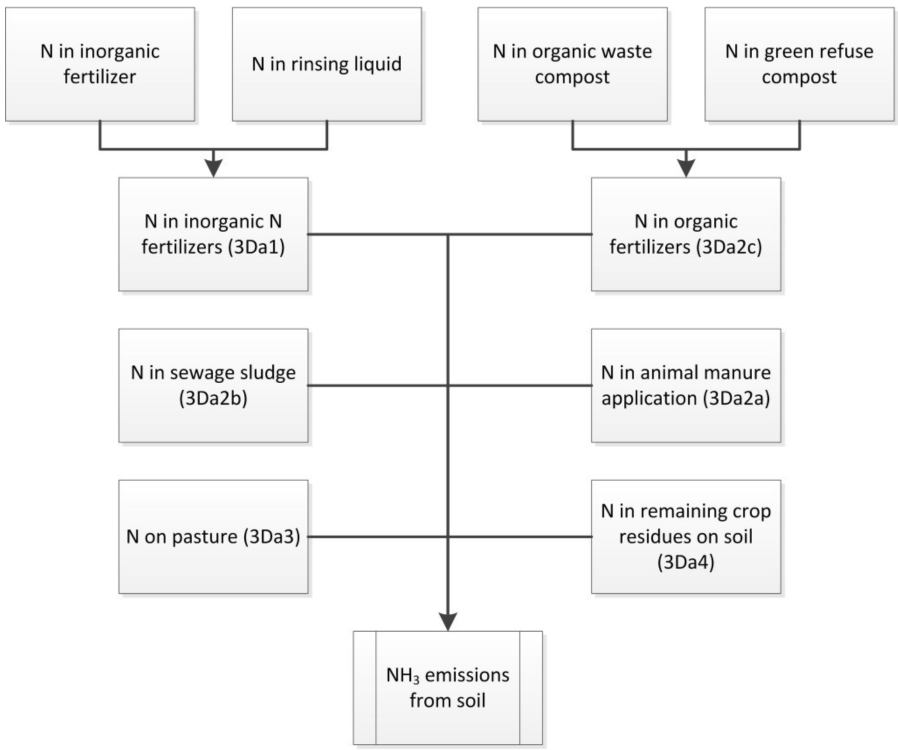



*Figure 10.2 Source categories contributing to $NH_3$ emissions from agricultural soils*



NEMA includes calculation methods for all source categories that have been distinguished. The amount of TAN in animal manure available for application is derived from TAN excretions minus N emissions in animal houses, manure treatment and during manure storage, and minus exported N, using a balance method to model N flows in agriculture (Figure 10.1).

In addition to the application of N in animal manure, the following additional supply sources of N have been included in the model: inorganic N fertilizer, sewage sludge, compost and crop residues, and TAN excreted on pasture land during grazing (Figure 10.2).

## 10.2 Source-specific aspects for NH3 emissions from the application of inorganic N fertilizer

### *10.2.1 Calculation method*

Inorganic N fertilizer includes synthetic fertilizer and rinsing liquid from air scrubbers (Figure 10.2). The $NH_3$ emission from inorganic N fertilizer is calculated with the following activity data:

- Amount of N applied per type of inorganic N fertilizer
- Amount of N applied from rinsing liquid
- Emission factor per type and application technique of inorganic N fertilizer (Section 10.3.2)
- Emission factor for rinsing liquid.

The $NH_3$ emissions from inorganic N fertilizer application are calculated as follows.

$$NH_3 \text{ emissions inorganic fertilizer} = \sum N_{l,\ \text{inorganic fertilizer}} \times EF\ NH_3 \text{ inorganic fertilizer}_l \times 17/14 \quad (10.1)$$

Where:

| | | |
|---|---|---|
| $NH_3$ emissions inorganic fertilizer | : | $NH_3$ emissions (kg $NH_3$/year) from inorganic N fertilizers applied to agricultural soils |
| $N_{l,\ \text{inorganic fertilizer}}$ | : | Total amount of inorganic N fertilizer (kg N) applied for type of inorganic fertilizer (l) |
| EF $NH_3$ inorganic fertilizer$_l$ | : | $NH_3$ emission factor for inorganic N fertilizer (% of applied N) for type of inorganic fertilizer (l) |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

### *10.2.2 Activity data*

The usage of the various types of inorganic N fertilizers is taken from the synthetic fertilizer statistics of Wageningen Social & Economic Research. This statistic was based on a voluntary yearly census amongst manufacturers and wholesale of inorganic fertilizers. From 2016 onwards, the usage of the various types of inorganic N fertilizers is taken from the inorganic fertilizer statistics from the Farm Accountancy Data Network (FADN; in Dutch, BIN) of Wageningen Social & Economic Research. Consistency between the two data sources has been verified and confirmed (Van Bruggen *et al.,* 2019). The amount of rinsing liquid produced by air scrubbers, as calculated by NEMA, is also considered.

It is assumed that all inorganic N fertilizers are surface-applied, with the exception of liquid-injected urea and fertilizer applied in greenhouse horticulture.

### 10.2.3 *Emission factors*

The $NH_3$ emission factors for inorganic N fertilizer are based on a review paper by Bouwman *et al.* (2002), which uses results from 148 studies (1,667 $NH_3$ measurements) from all over the world to quantify the effect of fertilizer type, crop, N addition, application method, temperature, soil characteristics (cation exchange capacity [CEC], pH, organic matter content) and location on $NH_3$ emission. A calculation method was developed based on the results of regression analysis ($R^2$ = 28%). The following data are used in the Netherlands.

**Crop**

In the calculation model, a distinction is made between grassland and upland crops. The areas of grassland, cropland and maize are determined based on soil-use maps. The factor-class value for grassland is -0.045. Cropland and maize are regarded as upland crops, with a factor-class value of 0.158.

**Fertilizer type**

Calculations have been performed for the fertilizer types addressed in Bouwman *et al.* (2002), but the paper does not mention all inorganic types of N fertilizer that are in use. The emission factors have been calculated as follows:

- Ammonium sulphate nitrate: This fertilizer type contains both ammonium nitrate and ammonium sulphate. The emission factor is equal to the average emission factor for ammonium nitrate and ammonium sulphate.
- Nitrogen magnesium: This type of fertilizer resembles calcium ammonium nitrate, but contains $MgCO_3$ besides $CaCO_3$. This difference does not require a different emission factor.
- Chilean nitrate, calcium nitrate and potassium nitrate: These types of fertilizer contain only nitrate N and no ammonium. Their use therefore does not result in $NH_3$ emissions from the soil, and the emission factor is set to 0%.
- Fertilizer blends: This category can include all types of fertilizer. The emission factor is set equal to that of the fertilizer type that is most commonly used in the Netherlands.
- Nitrogen phosphate potassium magnesium fertilizers: These types of fertilizer are comparable to nitrogen phosphate potassium fertilizer, and the emission factor is set to 2%.
- Ammonia water: This type of fertilizer is comparable to liquid ammonia.
- Sulphur-coated urea: The coating on this type of fertilizer type leads to lower emissions than those generated by uncoated urea (Oenema and Velthof, 1993). The emission factor is set to half that of urea.

**Emission factors**
The emission calculations for 2015 included an additional subdivision of urea fertilizers (see Annex 5 in Van Bruggen *et al.,* 2017). The resulting emission factors used to calculate $NH_3$ emissions from inorganic N fertilizers are presented in Table 10.1.

*Table 10.1 Emission factors (EF; in % of N) for inorganic N fertilizer (Velthof et al., 2012), derived from Bouwman et al. (2002)*

| Fertilizer type | EF used (% of N) |
|---|---|
| Ammonium nitrate | 5.2 |
| Ammonium sulphate | 11.3 |
| Ammonium sulphate nitrate | 8.2 |
| Chilean nitrate | 0.0 |
| Diammonium phosphate | 7.4 |
| Mixed nitrogen fertilizer | 2.5 |
| Potassium nitrate | 0.0 |
| Calcium ammonium nitrate | 2.5 |
| Calcium nitrate | 0.0 |
| Monoammonium phosphate | 7.4 |
| Other nitrogen, phosphate and potassium fertilizers[1)] | 4.5 |
| Nitrogen phosphate potassium magnesium fertilizers | 2.5 |
| Nitrogen magnesium | 2.5 |
| Urea – granular incl. urea with nitrification inhibiter | 14.3 |
| Urea – granular with urease inhibitor | 5.9[2)] |
| Urea – liquid, surface-applied | 7.5[2)] |
| Urea – liquid, injected | 1.5[2)] |
| Urea – liquid with urease inhibitor or acid, surface-applied | 3.1[2)] |
| Urea – greenhouse horticulture | 0.0[2)] |
| Liquid ammonia | 2.3 |
| Sulphur-coated urea | 7.1 |

1) Including nitrogen phosphate and nitrogen potassium fertilizers.
2) See Annex 5 in Van Bruggen *et al.* (2017)

**Rinsing liquid**
No ammonia emission factors are available for the application of rinsing liquid to soil. Given that rinsing liquid is a solution of ammonium sulphate, the emission factor was derived for granular (or other) ammonium sulphate fertilizer. The study by Velthof *et al.* (2009) is taken as the starting point for determining the emission factors of rinsing liquid. On non-calcareous soils, the application of ammonium sulphate does not result in ammonia emissions, as the pH is too low. On calcareous soils, the emission factor is therefore 15%, assuming that the emission of rinsing liquid is half of that of granular ammonium sulphate, as it will penetrate into the soil and is applied in part using low-ammonia-emission techniques. Taking into account that 76% of agricultural soils in the Netherlands are non-calcareous (Velthof *et al.*, 2009), and assuming a homogeneous distribution of rinsing liquid over soil types, the emission factor becomes 0.76 x 0 + 0.24 x 7.5 = 1.8%.

### 10.2.4 *Uncertainty*
The uncertainty analyses are based solely on the total amount of fertilizer. Uncertainty estimates at higher levels of aggregation are more robust, while providing the same overall uncertainty values as those

produced when estimating for each category separately. Only rinsing liquid is estimated separately. Uncertainty values for the total amount of inorganic fertilizer applied are estimated at 25%, excluding rinsing liquid. A small proportion of fertilizers is used outside agriculture. If the uncertainty values for the use of inorganic fertilizer for agriculture and private purposes are disaggregated, the uncertainty value for the use of inorganic fertilizer in agriculture is 27%. The uncertainty value for the use of rinsing liquid is 40%.

## 10.3 Source-specific aspects for $NH_3$ emissions from animal manure applied to soils

The amount of TAN and organic N that remains in manure from animal housing after outside storage, manure treatment and export is applied to the soil. It is assumed that manure stocks in storage remain equal, such that no correction is made for manure stored longer than one year. The amount of TAN in manure applied to soil is calculated according to the following activity data:

- Total N (urine N and faecal N) excretions in animal housing
- Mineralisation/immobilisation of organic N in storage
- Addition of TAN through bedding material
- Losses of $NH_3$, $N_2O$, $NO_x$ and $N_2$ inside animal housing and during outside storage and manure treatment
- Amount of manure that is exported or treated and subsequently used outside Dutch agriculture
- Manure can also be applied to soils directly through grazing animals. Emissions occurring during grazing are calculated directly from TAN. In addition to manure application and grazing, the application of inorganic N fertilizer (including the rinsing liquid from air scrubbers) to agricultural soils is a source of $NH_3$ emissions. Emissions of $NH_3$ occur only if the fertilizer contains urea or when ammonium ($NH_4^+$) is applied to calcareous soils.

### *10.3.1 Calculation method*

The total amounts of slurry and solid manure are divided over grassland, uncropped land and cropped land (see Section 10.3.2). The level of $NH_3$ emissions is calculated based on the application of manure to grassland, uncropped land and cropped land.

The level of $NH_3$ emissions from manure application is calculated as follows:

$NH_3$ emissions manure application = $\Sigma$ (($TAN_{ijm,\ applied\ on\ grassland}$ x $FRAC_{j,\ application\ technique\ grassland}$ x EF $NH_3$ application technique on $grassland_{jm}$) + ($TAN_{ijm,\ applied\ on\ uncropped\ land}$ x $FRAC_{j,\ application\ technique\ uncropped\ land}$ x EF $NH_3$ application technique on uncropped $land_{jm}$) + ($TAN_{ijm,\ applied\ on\ cropped\ land}$ x $FRAC_{j,\ application\ technique\ cropped\ land}$ x EF $NH_3$ application technique on cropped $land_{jm}$)) x 17/14 (10.2)

Where:

| | | |
|---|---|---|
| $NH_3$ emissions manure application | : | $NH_3$ emissions from manure applied to agricultural soils (kg $NH_3$/year) |
| $TAN_{ijm,\ applied\ on\ grassland}$ | : | Amount of TAN in manure (kg N/year) for livestock category (i) and manure |

| | | |
|---|---|---|
| | | management system (j) applied to grassland for manure application technique (m) |
| $FRAC_{j,\ application\ technique\ grassland}$ | : | Fractions of manure application techniques (m) for manure management system (j) used on grassland |
| EF $NH_3$ application technique on $grassland_{jm}$ | : | $NH_3$-N emission factor (% of TAN) for manure application technique (m) for manure management system (j) used on grassland |
| $TAN_{ijm,\ applied\ on\ uncropped\ land}$ | : | Amount of TAN in manure (kg N/year) for livestock category (i) and manure management system (j) applied to uncropped land for manure application technique (m) |
| $FRAC_{j,\ application\ technique\ uncropped\ land}$ | : | Fractions of manure application techniques (m) for manure management system (j) used on uncropped land |
| EF $NH_3$ application technique on uncropped $land_{jm}$ | : | $NH_3$-N emission factor (% of TAN) for manure application technique (m) for manure management system (j) used on uncropped land |
| $TAN_{ij,\ applied\ on\ cropped\ land}$ | : | Amount of TAN in manure (kg N/year) for livestock category (i) and manure management system (j) applied to cropped land for manure application technique (m) |
| $FRAC_{j,\ application\ technique\ cropped\ land}$ | : | Fractions of manure application techniques (m) for manure management system (j) used on cropped land |
| EF $NH_3$ application technique on cropped $land_{jm}$ | : | $NH_3$-N emission factor (% of TAN) for manure application technique (m) for manure management system (j) used on cropped land |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

The level of $NH_3$ emissions is measured or derived for specific manure application techniques. The following application techniques are distinguished for grassland: surface spreading, shallow injection, trailing shoe and slit coulter application. For uncropped land: surface spreading, injection/full coverage, shallow injection, trailing shoe, incorporation in one track and incorporation in two tracks. For cropped land: shallow injection and trailing shoe.

The amount of TAN available for each livestock category/manure type is calculated by subtracting N emissions in animal housing, during manure storage and during manure treatment from the TAN excretion in animal housing and the TAN added in the form of bedding material. Part of the manure can be used outside agriculture, treated or exported. The amount of manure for livestock category (i) and manure management system (j) that is available for application is found by subtracting these amounts from initial TAN excretions:

$$\text{TAN for application}_{ij} = \text{TAN}_i \times \text{FRAC}_{j,\ \text{manure management}} + \text{TAN}_{i,\ \text{bedding}} - \text{N losses in animal housing}_{ij} - \text{NH}_3 \text{ emissions storage}_{ij} - \text{NH}_3 \text{ emissions treatment}_{ij} - \text{N used outside agriculture}_{ij} - \text{N exported}_{ij} \quad (10.3)$$

Where:

| | | |
|---|---|---|
| TAN for application$_{ij}$ | : | Amount of manure (kg N) applied to agricultural soils, for livestock category (i) and manure management system (j) |
| TAN$_i$ | : | TAN excretions (kg N) in animal housing for livestock category (i) |
| FRAC$_{j,\ manure\ management}$ | : | Fraction of manure in the various management systems (j) |
| TAN$_{i,\ bedding}$ | : | TAN added in the form of bedding material for livestock category (i) |
| N losses in animal housing$_{ij}$ | : | Sum of $NH_3$, $N_2O$, $NO_x$ and $N_2$ losses (kg N) from animal housing for livestock category (i) and manure management system (j) |
| $NH_3$ emissions storage$_{ij}$ | : | $NH_3$ emissions from outside manure storage facilities (kg N) for livestock category (i) and manure management system (j) |
| $NH_3$ emissions treatment$_{ij}$ | : | $NH_3$ emissions from manure treatment (kg N) for livestock category (i) and manure management system (j) |
| N used outside agriculture$_{ij}$ | : | Amount of manure (kg N) processed and marketed outside agriculture, for livestock category (i) and manure management system (j) |
| N export$_{ij}$ | : | Amount of manure (kg N) exported, for livestock category (i) and manure management system (j), with import denoted as negative export |

It is assumed that the amount of manure imported for each kind of manure accounts for the same TAN fraction of total N as does Dutch manure coming from animal housing and storage.

### 10.3.2 *Activity data*

**TAN in manure applied to soil**

The amount of TAN in manure applied to the soil is calculated from N excretions in urine, the mineralisation and immobilisation of organic N in animal housing and the losses of gaseous N occurring in animal housing and during manure storage (as described in Sections 5, 6 and 7). Based on statistics from Statistics Netherlands, data from the Netherlands Enterprise Agency and calculations of the manure market, the amount of TAN has been corrected for the treatment, export and import of manure.

**Fractions of manure applied to land type**
The amounts of manure applied to grassland, uncropped arable land and cropped arable land for the years 1990-1999 are based on the results of the calculations performed for purposes of monitoring the manure market. The data are supplied by the FADN of Wageningen Social & Economic Research, and data on manure transports from the Netherlands Enterprise Agency have been used (Luesink *et al.*, 2008; De Koeijer *et al.*, 2012; De Koeijer *et al.*, 2014). For the years 2000-2024, the distributions of manure to grassland and arable have been derived with calculations using the INITIATOR model (Kros *et al.,* 2019 and De Vries *et al.,* 2023). These distributions are the same as for the calculations of $N_2O$ emissions from manure application (section 12.3.2).

The implementation grades of manure application techniques are based on the results of the Agricultural Census. The 2022 Agricultural Census was the most recent to include questions concerning the type of manure application techniques used on grassland, uncropped land and cropped land. Figures for cropped land are based on data from Huijsmans and Verwijs (2008).

### 10.3.3 *Emission factors*
The emission factors are derived from experimental emission measurements. The emission factors for manure application on cropland are based on the Ryden & McNeill model. This model is used to derive the measured emissions of 58 different experiments to calculate the emission factors of the different application techniques for uncropped cropland and for measured emissions on cropped cropland (Huismans and Schils, 2009 and Huijsmans & Hol, 2012).

The emission factors for manure application on grassland are based upon the exponential concentration profile model. This model fits the measured emissions of 160 different experiments to calculate the emission factors of the different application techniques for grassland. Emission factors for grassland were calculated using the Ryden & McNeill model. However, new research has shown that a better fit was achieved using an exponential concentration profile model. The new model leads to emission factors that are on average 10% lower than the previous emission factors. The updated emission factors are given in table 10.2. From 2019 onwards, manure applied on grassland using the trailing-shoe or the slit coulter has to be diluted with water resulting in the same emission factor as shallow injection (Goedhart *et al.,* 2020).

The emission factors for both grassland and cropland and all application methods are all based on measurements, with the exception of the 'slit coulter' (in Dutch, '*sleufkouter*'). As the slit coulter technique results in levels of manure placements falling between shallow-injection and narrow-band application, the average of these two techniques has been applied to the slit coulter.

Depending on the method of manure incorporation, a certain reduction of $NH_3$ volatilisation can be achieved on arable land. However, the reduction achieved by incorporation in a second pass is highly dependent on the time-lag between surface spreading and incorporation (Huijsmans and De Mol, 1999). The incorporation of the manure in a second pass always leads to a certain time lag. For this reason, the emission factors for surface incorporation in two passes and ploughing in were estimated as 46% and 35%, respectively, which are the average emission values for surface spreading and direct incorporation. The application and incorporation of slurry in two passes has been banned in the Netherlands since 2008, although is still the prescribed technique for the application of solid manure on arable land. The emission factors for arable land (as shown in Table 10.2) are therefore representative of current application methods (i.e. spreading and incorporation in a single operation).

*Table 10.2 Emission factors (EF) for $NH_3$ (% of TAN applied) for each application technique on grassland and on cropland between 1990 and 2024*

| **Land type/ application technique** | **EF (% of TAN)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1990** | **1991** | **1992-1993** | **1994-1998** | **1999-2003** | **2004-2018** | **2019-2024** |
| *Grassland* | | | | | | | |
| Surface spreading[4)] | 64 | 68 | 68 | 68 | 68 | 68 | 68 |
| Narrow-band (trailing-shoe)[4)] | 26.4 | 26.4 | 26.4 | 26.4 | 26.4 | 26.4 | 17 |
| Slit-coulter[1)] | 21.7 | 21.7 | 21.7 | 21.7 | 21.7 | 21.7 | 17 |
| Shallow-injection[4)] | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17 |
| *Cropland (uncropped)* | | | | | | | |
| Surface spreading | 64 | 64 | 69 | 69 | 69 | 69 | 69 |
| Incorporation in two passes[2)] | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| Narrow-band (trailing-shoe)[3)] | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| Slit-coulter[1)] | 24.5 | 24.5 | 24.5 | 27.5 | 30 | 30 | 30 |
| Shallow-injection[3)] | 13 | 13 | 13 | 19 | 24 | 24 | 24 |
| Incorporation (direct) | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Full coverage | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *Cropland (cropped)* | | | | | | | |
| Narrow-band (trailing-shoe)[3)] | N/A | N/A | N/A | N/A | N/A | 36[3)] | 36[3)] |
| Shallow-injection[3)] | N/A | N/A | N/A | N/A | N/A | 24[3)] | 24[3)] |

1) The emission factor for the slit-coulter technique is based on the average of the emission factors for narrow-band and shallow-injection.
2) The emission factor for incorporation in two passes is based on the average of the emission factors for surface spreading and direct incorporation.
Source: Huijsmans and Schils (2009), with the exception of 3) Huijsmans and Hol (2012) and 4) Goedhart *et al.* (2020)

### 10.3.4 *Source-specific uncertainty*

The uncertainty value for the amount of manure exported out of Dutch agriculture is estimated at 20% for slurry and 30% for solid manure. The information is based primarily on registered manure transports, although several types of transport are not subject to mandatory registration, such as compost for mushroom growing and export of fertilizer pellets in packages up to 25 kg. The measurement of N and P in manure samples is also subject to error.
The uncertainty values for the share of manure applied to grassland, uncropped land or cropped land is estimated at 20% for slurry and 40% for solid manure. Although information gathered in the Agricultural Census is usually accompanied by low uncertainty values, an uncertainty value of 25% has been assumed for the application techniques. Census questions refer to the situation in the previous year, and it is assumed that, when in doubt, respondents are likely to enter the techniques with lower emissions. New research has been started to derive a better view on the use of manure application techniques. Uncertainty values of the emission factors for each application technique are taken from Huijsmans and Schils (2009).

## 10.4 Source-specific aspects for $NH_3$ emissions from sewage sludge applied to soils

### 10.4.1 *Calculation method*

In the calculation of $NH_3$ emissions from sewage-sludge application, a distinction is made between liquid and solid sludge, with a different TAN fraction for each type:

$NH_3$ emissions sewage sludge = $\Sigma$ ($N_{sewage\ sludge}$ x $FRAC_{liquid}$ x $TAN_{liquid\ sewage\ sludge}$ x EF $NH_3$ liquid sewage $sludge_m$ + $N_{sewage\ sludge}$ x $FRAC_{solid}$ x $TAN_{solid\ sewage\ sludge}$ x EF $NH_3$ solid sewage sludge) x 17/14 (10.4)

Where:

| | | |
|---|---|---|
| $NH_3$ emissions sewage sludge | : | $NH_3$ emissions (kg $NH_3$/year) sewage sludge applied to agricultural soils |
| $N_{sewage\ sludge}$ | : | Amount of sewage sludge (kg N) applied to agricultural soils |
| $FRAC_{liquid}$ | : | Fraction of sewage sludge in liquid form |
| $TAN_{liquid\ sewage\ sludge}$ | : | Fraction of TAN in liquid sewage sludge |
| EF $NH_3$ liquid sewage sludge | : | $NH_3$ emission factor (% of TAN applied) for liquid sewage sludge |
| $FRAC_{solid}$ | : | Fraction of sewage sludge in solid form |
| $TAN_{solid\ sewage\ sludge}$ | : | Fraction of TAN in solid sewage sludge |
| EF $NH_3$ solid sewage sludge | : | $NH_3$ emission factor (% of TAN applied) for solid sewage sludge |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

### 10.4.2 *Activity data*

Amounts of sewage sludge applied to agricultural soils were available from Statistics Netherlands until 2017. Beginning in 2017, the application of sewage sludge has been derived from registered transports to agricultural holdings.

### 10.4.3 *Emission factors*

The percentage of TAN in the sludge is calculated from German data on the N and TAN contents of liquid and solid sewage sludge (Landwirtschaftliches Wochenblatt, 2007). All sewage sludge is assumed to be applied to cropland, using shallow injection for the liquid part and incorporation in two passes for the solid part. The corresponding emission factors for manure application (Table 10.) are used.
An exception is made for the first two years of the time series (1990 and 1991), in which the emission factor for surface spreading was used for both liquid and solid sewage sludge. The reason is that, before 1992, there was no obligation to incorporate sewage sludge into the soil immediately, but within a few days of application. With the use of this technique, $NH_3$ emissions had already occurred before incorporation.

### 10.4.4 *Source-specific uncertainty*

The uncertainty value for the total usage of sewage sludge is estimated at 25%. Disaggregated uncertainty values are calculated for the liquid and solid fractions. Uncertainty values for the two emission factors combined is estimated at 100%. This figure differs from the uncertainty associated with the manure application emission factor, as emission factors are measured for manure and not for the application of sewage sludge.

## 10.5 Source-specific aspects for $NH_3$ emissions from other organic fertilizers applied to soils (including compost)

### 10.5.1 *Calculation method*

Although two sources of compost are considered (i.e. organic waste and green refuse; see Figure 10.2), it is assumed that the fraction of TAN in both sources is equal. All compost is surface-applied on uncropped land:

$NH_3$ emissions organic fertilizers = (N organic waste compost + N green refuse compost) x $TAN_{compost}$ x EF $NH_3$ compost x 17/14 (10.5)

Where:

| | | |
|---|---|---|
| $NH_3$ emissions organic fertilizers | : | $NH_3$ emissions (kg $NH_3$/year) from compost applied to agricultural soils |
| N organic waste compost | : | Amount of organic waste compost (kg N) applied to agricultural soils |
| N green refuse compost | : | Amount of green refuse compost (kg N) applied to agricultural soils |
| $TAN_{compost}$ | : | Fraction of TAN in compost |
| EF $NH_3$ organic fertilizers | : | $NH_3$ emission factor (% of TAN applied) for compost |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

### 10.5.2 *Activity data*

The amounts of N in organic (household) waste and green refuse compost are available from Statistics Netherlands.

### 10.5.3 *Emission factors*

The percentage of TAN is taken from the Arable Fertilisation Recommendations (De Haan and Van Geel (2013); *Bemestingsadvies akkerbouw*, http://www.kennisakker.nl). All compost is assumed to be applied to uncropped land, using surface spreading. The corresponding emission factor for solid manure application and incorporation in two passes is used (Table 10.).

### 10.5.4 *Uncertainty*

The uncertainty value for total compost use is estimated at 25%. Given that some compost is used outside agriculture, the uncertainty value for the share of compost used in agriculture is 23%. The uncertainty value for TAN is 25%. Uncertainty of the emission factor is estimated to be 100%. This differs from the uncertainty value for the emission factor for manure application, as emission factors are measured for manure and not for compost application.

## 10.6 Source-specific aspects for NH3 emissions from urine and dung deposited by grazing animals

### 10.6.1 *Calculation method*

The $NH_3$ emissions from urine and dung deposited by grazing animals is calculated from the following values:

- N excretions on pastureland for each grazing livestock category (in kg N), calculated annually by the WUM
- Share of TAN in N excretions during grazing, expressed as a percentage of total N excretions (Annex 1)
- Emission factors for grazing, expressed as a percentage of TAN on pastureland (Section 10.6.3).

Total $NH_3$ emissions from grazing for all livestock categories (i) is calculated as follows:

$$NH_3 \text{ emissions grazing} = \Sigma\, AAP_i \times (TAN_{i,\ grazing} - TAN_{i,\ excreted\ in\ nature\ areas}) \times EF\ NH_3 \text{ grazing} \times 17/14 \qquad (10.6)$$

Where:

| | | |
|---|---|---|
| $NH_3$ emissions grazing | : | $NH_3$ emissions (kg $NH_3$/year) from grazing |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $TAN_{i,\ grazing}$ | : | TAN excretions on pasture land (kg N/year) for livestock category (i) |
| $TAN_{i,\ excreted\ in\ nature\ areas}$ | : | TAN excretions from grazing animals in nature areas (kg N/year) for livestock category (i) |
| EF $NH_3$ grazing | : | Emission factor (% of TAN) for grazing |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

TAN excretions on pastureland are calculated as follows:

$$TAN_{i,\ grazing} = N \text{ excretions on pasture}_i \times FRAC_{i,\ TAN\ pasture} \qquad (10.7)$$

Where:

| | | |
|---|---|---|
| $TAN_{i,\ grazing}$ | : | TAN excretions (kg N/animal/year) on pastureland for livestock category (i) |
| N excretions on $pasture_i$ | : | Total N excretions (kg N/animal/year) on pastureland for livestock category (i) |
| $FRAC_{i,\ TAN\ pasture}$ | : | Fraction of TAN in total N excretions on pastureland for livestock category (i) |

The emission factor for grazing is calculated annually, based on grass composition (year-specific emission factor).

### 10.6.2 *Activity data*

**Livestock numbers**
Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

**N excretions on pastureland**
N excretions and uncertainty values are described in Sections 2.2.3 and 2.4.3.

**Percentage of TAN in pasture manure**
The percentage of the N excretions consisting of TAN is determined annually by the WUM for each category of grazing livestock.

**TAN excretions in nature areas**
Nature terrain is land for which the primary function is nature and that is not regarded to be agricultural land. In addition, when an agricultural company rents or owns nature terrain, it is not treated as part of the company in the manure legislation. Disposal on nature terrain must be reported in documents for the transport of animal manure (abbreviated in Dutch to VDM), including pasture manure. Agricultural firms with natural grassland are therefore required to submit a VDM declaring how much manure was applied to this land. Because the manure remains on the company’s own property, it is likely that some companies do not declare this form of disposal on a VDM.

In some cases, animals from agricultural companies are grazed on nature terrain owned by nature-protection organisations. As the owners of the land, these organisations are obliged to submit transportation documents accounting for the manure disposal on nature terrain. It is assumed that this is usually not done. The disposal of pasture manure on nature terrain owned by nature-protection organisations is estimated at 0.7 million kg $P_2O_5$ (Luesink *et al.*, 2011). This disposal of pasture manure is divided over the livestock categories based on the production of phosphate in pasture manure. The disposal of nitrogen is calculated from the disposal of phosphate and the $N/P_2O_5$ ratio of pasture manure. In addition to the production of pasture manure on nature terrain, the disposal of stored animal manure on nature terrain is subject to accounting through transport documents. The disposals registered through transport documents are counted as disposal on natural grassland, with the manure being applied above ground.

### 10.6.3 *Emission factors*

There are no recent measurements for $NH_3$ emissions during grazing. An emission factor (expressed as a percentage of total N excretions) was derived from a study by Bussink (1992; 1994). An emission factor based on TAN can also be derived from this work, as N excretions in urine are reported in addition to total N excretions. Several adjustments have been made to Bussink's (1992; 1994) dataset, and the emission factor for grazing (EFgrazN) has been corrected for:

- Inorganic N fertilizer applied during the study by Bussink (1992; 1994),
- Changes over time in grazing systems used,
- Soil type.

**Application of inorganic N fertilizer**
The emission factor for inorganic N fertilizer reported in the study by Bussink was 2% (calcium ammonium saltpetre on calcium rich clay). For several reasons, however, it could be assumed that the emissions examined in this specific study site would normally be lower, given that:

- $NH_3$ emissions from inorganic N fertilizer are inhibited by the higher $NH_3$ concentration in the air from grazing (application took place around three days after grazing),
- Emission factors for inorganic N fertilizers are derived from experiments in which grass height was lower than in the study by Bussink (1992; 1994),
- Emissions from inorganic N fertilizer are slow, and only a part of total $NH_3$ emissions would have occurred during the measuring days,
- Measured $NH_3$ emissions from calcium ammonium saltpetre at the same location in another year were 0.1% at 50 kg N/ha and 1% at 400 kg N/ha (Bussink, personal communication).

In addition, the application of inorganic N fertilizer also occurred during periods without grazing or $NH_3$ measurements. It is estimated that around 75% was applied when the measurements were performed (Bussink, personal communication). The correction for inorganic N fertilizer based on that amount and an emission factor of 1% yields a corrected $NH_3$ emission value between 6 and 38 kg N/ha for grazing.

**Grazing system**
In recent years, the grazing systems in the Netherlands have undergone a strong shift towards systems with limited grazing (Aarts *et al.*, 2008; Van Bruggen and Faqiri, 2015). Bussink derived an emission factor in a situation with unlimited grazing (both day and night). Higher temperatures, wind speeds and global radiation during the day can lead to higher average $NH_3$ emissions from fresh urine patches. Furthermore, during the night-time, the grass is wet from dew, and background concentrations of $NH_3$ are relatively high (little dilution). This effect is also clearly visible in Bussink's measurements. The average $NH_3$-N flux over 24 hours was 38 g $NH_3$-N per hour, with a flux of 46 g $NH_3$-N per hour in the period between 07:00 and 21:30h in case of restricted grazing (Bussink, 1992). Emissions during the daytime are therefore a factor of 1.20 higher, and this factor is used to derive the emission factor for systems with limited grazing based on the emissions reported by Bussink (1992; 1994).

**Soil type**
Emissions of $NH_3$ are also dependent on the cation exchange capacity (CEC) of the soil (Whitehead and Raistrick, 1993; Bussink, 1994). At higher CEC levels, the soil can bind $NH_4^+$ more strongly, thereby reducing the risk of $NH_3$ emissions. The CEC correction calculated by Bussink (1996) is used as follows:

CEC correction = (7.71 – 0.02793 x (CEC – 280)) / 7.71 (10.8)

The following average CEC values for each soil type were estimated based on data published by Blgg (currently Eurofins Agro in Wageningen, Netherlands) for 2007-2008 (Arjan Reijneveld [Blgg] personal communication): 70 $mmol_c\ kg^{-1}$ for sand, 180 $mmol_c\ kg^{-1}$ for clay and loess, and 300 $mmol_c\ kg^{-1}$ for peat and peat moss/cover-sand soils. The resulting correction factors for these soil types are 1.8, 1.4 and 0.9, respectively.

After correcting for the use of inorganic N fertilizer and grazing systems, emission factors based on TAN vary between 4.0 and 11.7, depending on soil type. According to the national soil-use map of the Netherlands (LGN), 15% of all grassland is on peat, with 47% on sand and 39% on clay and loess. These areas and the CEC correction were used to calculate a weighted emission factor, expressed as a percentage of TAN (Bussink, 1996):

EF $NH_3$ grazing = 4.0%, with $Nration_{WUM}$ < 28 g N per kg DM
EF $NH_3$ grazing = $1.98 \times 10^{-5} * (Nration_{WUM})^{3.664}$, with $Nration_{WUM} \geq 28$ g N per kg DM (10.9)

Where:

| | | |
|---|---|---|
| EF $NH_3$ grazing | : | Emission factor (% of TAN) for grazing |
| $Nration_{WUM}$ | : | Average N content of rations during the grazing season according to the WUM (g N/kg dry matter). |

High N rates in feed result in high levels of N excretions and high TAN values, which in turn lead to high $NH_3$ emissions. In the Netherlands, no measurement data are available for $NH_3$ emissions from grazing by other species of grazing animals (other cattle, horses, ponies and sheep). It is assumed that these values are equal to those of dairy cows. For this reason, the formula for dairy cattle is also used for other grazing animals.

### *10.6.4 Uncertainty*

The uncertainty values for livestock numbers, including the aggregation and disaggregation of subcategories, are provided in Section 2.4.3. Uncertainty values for TAN are estimated at 10%. The uncertainty value of TAN excretions in nature areas is estimated at 50%, and that of the grazing emission factor is 100%.

## 10.7 Source-specific aspects for $NH_3$ emissions from crop residues

### *10.7.1 Calculation method*

Calculation of emissions from crop residues is based on the methodology and calculations of De Ruijter and Huijsmans (2019):

$NH_3$ emissions crop residues = $\Sigma$ $area_n$ x N in above-ground $residue_n$ x $FRAC_{n,\ residues}$ x EF $NH_3$ crop $residue_n$ x 17/14 (10.10)

Where:

| | | |
|---|---|---|
| $NH_3$ emissions crop Residues | : | $NH_3$ emissions (kg $NH_3$/year) from crop residues |
| $Area_n$ | : | The area covered by crop (in ha) for crop type (n) |
| N in above-ground $residue_n$ | : | N contained within the crop residues (kg N/ha) for crop (n) |
| $FRAC_{n,\ residues}$ | : | Fraction of residues contributing to $NH_3$ |

| | | |
|---|---|---|
| | | emissions (i.e. not incorporated into the soil in the first days after harvest) for crop (n) |
| EF $NH_3$ crop $residue_n$ | : | Emission factor (% of N) for crop residues (n) |
| 17/14 | : | Conversion factor from $NH_3$-N to $NH_3$ |

The emission factor is based on the N content of the residues, and it assumes the full exposure of crop residues to air, both in amounts and over time (see Section 10.7.3). As a result, the factor considers only the N in above-ground residues. The share of residues that are not incorporated into the soil are accounted for in the fraction of contributing residue.

Crop residues are also produced through the cutting, drying and collection of grass for the production of silage or hay, with an assumed average amount of 1,000 kg dry matter/ha/year. Although pasture topping also generates crop residues, it is not considered separately, as it is accounted for in the emission factor for grazing (De Ruijter and Huijsmans, 2019). Emissions are calculated according the WUM formula based on the total area mown and the N content of fresh grass. Grassland renovation is calculated annually from the area of grassland remaining grassland, along with a ploughing factor.

### 10.7.2 *Activity data*

Areas of cultivated crops are derived from the Agricultural Census. Data on grassland renovation were obtained from Statistics Netherlands and Wageningen Social & Economic Research.

### 10.7.3 *Emission factors*

Data from the WUM were used to calculate the N contents of crop residues consisting of grass. Data available from De Ruijter *et al.* (2019) were used to calculate the N content of residues from other crops.
To calculate the percentage of N that is emitted as $NH_3$ from crop residues, a regression model was derived from literature describing the relationship between $NH_3$ emissions and the N content of residues (De Ruijter and Huijsmans, 2019):

$$\text{EF } NH_3 \text{ crop residue} = 0.41 \times \text{N content}_m - 5.42 \qquad (10.11)$$

Where:

| | | |
|---|---|---|
| EF $NH_3$ crop residue | : | Emission factor (% of N) for crop residues |
| N content | : | N contained in above-ground crop residues (g/kg dry matter) for crop (m) |

Based on the regression equation, no emission occurs if the N content is less than 13.2 g/kg. The model assumes complete exposure to air of all residues for a prolonged period of time, but is also used in case of incorporation of the crop residue by including a factor for limited exposure (FRAC in (10.10)).

### 10.7.4 *Uncertainty*

The uncertainty value for the area of cultivated crops is 5% per crop. The uncertainty value for the N contents of crops is estimated at 25%. The uncertainty value associated with the fraction of crop residue that contributes to the emissions is estimated at 15%, and the uncertainty value of the emission factor is estimated at 80%.

## 10.8 Source-specific aspects for $NH_3$ emissions during crop cultivation

### *10.8.1 Calculation method*

Emissions from standing crops in the Netherlands have been calculated using the DEPAC resistance model (Van Zanten *et al.*, 2010). In this model, the exchange of $NH_3$ between the stomata of the plants, the air layer directly above the crop and the atmosphere are modelled. Emission or deposition occurs, depending on the ambient $NH_3$ concentration and type of crop. These values were determined on an hourly basis and aggregated over the growing season.

For the Netherlands, this method yielded a total emission estimate of 1.5 Gg $NH_3$-N. This estimate has been adopted for the entire time series, instead of calculating the emissions for each year separately. This choice was made due to the high associated level of uncertainty (estimated at 300%), which originates primarily from the stomatal compensation points required for the calculation. It was deemed that using a calculation rule that takes cultivated areas into account, would represent a level of accuracy that cannot be attained at this point.

### *10.8.2 Activity data*

A fixed estimate of $NH_3$ emissions from standing crops is reported, based on Van Zanten *et al.* (2010), thereby eliminating the need for activity data.

### *10.8.3 Emission factors*

A fixed estimate of $NH_3$ emissions from standing crops is reported, based on Van Zanten *et al.* (2010), thereby eliminating the need for emission factors.

### *10.8.4 Uncertainty*

The uncertainty of estimated $NH_3$ emissions from standing crops is 300% (Van Zanten *et al.*, 2010).

## 10.9 Uncertainty estimates

An overview of all uncertainty values for the activity data, the implied emission factors and the emissions included in the category of $NH_3$ emissions from crop production and agricultural soils is provided in Table 10.2.

*Table 10.2 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and $NH_3$ emissions (U emissions) from crop production and agricultural soils*

| EMEP | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3Da1 | Inorganic N fertilizers | 26% | 26% | 36% |
| 3Da2a | Animal manure applied to soils | 2% | 30% | 31% |
| 3Da2b | Sewage sludge applied to soils | 25% | 85% | 88% |

| EMEP | Source category | U AD | U IEF | U emissions |
| --- | --- | --- | --- | --- |
| 3Da2c | Other organic fertilizers applied to soils | 23% | 106% | 111% |
| 3Da3 | Urine and dung deposited by grazing animals | 1% | 48% | 48% |
| 3Da4 | Crop residues applied to soils | 18% | 44% | 45% |
| 3De | Cultivated crops | | | 300% |
| | Total, agricultural soils | | | 25% |

# 11 NOx emissions from crop production and agricultural soils (NFR category 3D)

## 11.1 Scope and definition

The NFR source category 3D (Crop production and agricultural soils) consists of:

- 3Da1 Inorganic N fertilizers (including urea application)
- 3Da2a Livestock manure applied to soils
- 3Da2b Sewage sludge applied to soils
- 3Da2c Other organic fertilizers applied to soils (including compost)
- 3Da3 Urine and dung deposited by grazing animals
- 3Da4 Crop residues applied to soils
- 3Db Indirect emissions from managed soils

No emissions of $NO_x$ occur in source categories 3Db (Indirect emissions from managed soils), 3Dc (Farm-level agricultural operations including storage, handling and transport of agricultural products), 3Dd (Off-farm storage, handling and transport of bulk agricultural products), 3De (Cultivated crops) or 3Df (Use of pesticides). Given that field burning is prohibited by law in the Netherlands, no emissions occur in Category 3F (Field burning of agricultural residues). Finally, a choice was made to report emissions from the cultivation of organic soils under Category 3I (Agriculture other).

Although emissions are reported as NO (nitrogen monoxide) in NEMA, they are referred to as $NO_x$ in this report, in order to prevent confusion with the notation key NO.

## 11.2 Source-specific aspects for NOx emissions from the application of inorganic N fertilizer

### *11.2.1 Calculation method*

Total $NO_x$ emissions from inorganic N fertilizers are calculated as follows:

$NO_x$ emissions inorganic fertilizer = $N_{inorganic\ fertilizer}$ x EF $NO_x$ inorganic fertilizer x 30/14 (11.1)

Where:

| | | |
|---|---|---|
| $NO_x$ emissions fertilizer | : | $NO_x$ emission (kg $NO_x$/year, expressed as nitrogen monoxide) for inorganic N fertilizers |
| $N_{inorganic\ fertilizer}$ | : | Amount of N (kg N/year) from inorganic N fertilizers |
| EF $NO_x$ fertilizer | : | $NO_x$ emission factor for inorganic N fertilizer (kg $NO_x$-N/kg N applied) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

### *11.2.2 Activity data*

The usage of the different types of inorganic N fertilizers is taken from the statistics on synthetic fertilizer available from Wageningen Social &

Economic Research. As of 2016, the usage of the various types of inorganic N fertilizers is taken from the statistics on inorganic fertilizer statistics available from the FADN. Consistency between these two data sources has been verified and confirmed (Van Bruggen *et al.,* 2019).

#### *11.2.3 Emission factors*

The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

#### *11.2.4 Source-specific uncertainty*

The uncertainty value for usage is estimated at 27% for inorganic N fertilizer and 40% for rinsing liquid (Section 10.2.4). The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

### 11.3 Source-specific aspects for $NO_x$ emissions from animal manure applied to soils

#### *11.3.1 Calculation method*

Total $NO_x$ emissions from animal manure applied to soils are calculated as follows:

$$NO_x \text{ emissions manure application} = N_{\text{animal manure}} \times EF\ NO_x \text{ manure application} \times 30/14 \quad (11.2)$$

Where:

| | | |
|---|---|---|
| $NO_x$ emissions manure application | : | $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) from animal manure applied to soils |
| $N_{\text{animal manure}}$ | : | Amount of N (kg N/year) from animal manure applied to soils |
| EF $NO_x$ application | : | $NO_x$ emission factor for animal manure applied to soils (kg $NO_x$-N/kg N applied) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

#### *11.3.2 Activity data*

The amount of N that is applied with manure to the soil is calculated from N excretions, bedding material and the loss of gaseous N occurring in animal housing, manure storage facilities and manure treatment, as described in greater detail in Section 10.3. Based on statistics from Statistics Netherlands, data from RVO and calculations of the manure market, these figures have been corrected for the treatment, export and import of manure. Their calculation (including the underlying uncertainty values) is described in Section 10.3.

#### *11.3.3 Emission factors*

The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

### 11.3.4 *Uncertainty*

The calculated uncertainty value for the amount of N in animal manure applied to soils is 3%. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

## 11.4 Source-specific aspects for $NO_x$ emissions from sewage sludge applied to soils

### 11.4.1 *Calculation method*

Total $NO_x$ emissions from sewage sludge applied to soils are calculated as follows:

$NO_x$ emissions sewage sludge = $N_{sewage\ sludge}$ x EF $NO_x$ sewage sludge x 30/14 (11.3)

Where:

| | | |
|---|---|---|
| $NO_x$ emissions sewage sludge | : | $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) from sewage sludge applied to soils |
| $N_{sewage\ sludge}$ | : | Amount of N (kg N/year) from sewage sludge applied to soils |
| EF $NO_x$ sewage sludge | : | $NO_x$ emission factor for sewage sludge applied to soils (kg $NO_x$-N/kg N applied) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

### 11.4.2 *Activity data*

Amounts of sewage sludge applied to agricultural soils were available from Statistics Netherlands until 2017. From 2017 onwards, the application of sewage sludge has been derived from registered transports to agricultural holdings.

### 11.4.3 *Emission factors*

The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

### 11.4.4 *Uncertainty*

The uncertainty value for total usage of sewage sludge is estimated at 25%. Disaggregated uncertainty values have been calculated for the liquid and solid fractions. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

## 11.5 Source-specific aspects for $NO_x$ emissions from other organic fertilizers applied to soils (including compost)

### 11.5.1 *Calculation method*

Total $NO_x$ emissions from compost are calculated as follows:

$NO_x$ emissions organic fertilizers = Σ $N_{organic\ fertilizers}$ x EF $NO_x$ organic fertilizers x 30/14 (11.4)

Where:

| | | |
|---|---|---|
| $NO_x$ emissions organic fertilizers | : | $NO_x$ emissions (kg $NO_x$/year, |

| | | |
|---|---|---|
| | | expressed as nitrogen monoxide) from compost applied to agricultural soils |
| $N_{organic\ fertilizers}$ | : | Amount of N (kg N/year) in compost |
| EF $NO_x$ organic fertilizers | : | $NO_x$ emission factor for organic fertilizers applied to soils (kg $NO_x$-N/kg N applied) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

### *11.5.2 Activity data*
The amount of compost applied to agricultural soils is calculated by Statistics Netherlands.

### *11.5.3 Emission factors*
The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

### *11.5.4 Uncertainty*
The uncertainty value for total compost usage is estimated at 25%. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

## 11.6 Source-specific aspects for $NO_x$ emissions from urine and dung deposited by grazing animals

### *11.6.1 Calculation method*
Total $NO_x$ emissions from urine and dung deposited by grazing animals are calculated as follows:

$$NO_x \text{ emissions grazing} = N_{grazing} \times EF\ NO_x \text{ grazing} \times 30/14 \qquad (11.5)$$

Where:

| | | |
|---|---|---|
| $NO_x$ emissions grazing | : | $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) from urine and dung deposited by grazing animals |
| $N_{grazing}$ | : | Amount of N (kg N/year) in urine and dung deposited by grazing animals |
| EF $NO_x$ grazing | : | $NO_x$ emission factor for urine and dung deposited by grazing animals to soils (kg $NO_x$-N/kg N) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

### *11.6.2 Activity data*
Part of the animal manure is produced on pasture land during grazing. The amount of nitrogen per animal is calculated by the WUM and is available from Statistics Netherlands. Information on animal figures is provided in Sections 2.2.1 and 2.4.3, respectively.

### *11.6.3 Emission factors*
The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

### 11.6.4 *Uncertainty*

The uncertainty value for the amount of nitrogen deposited on pastureland is calculated to be 19%, as described in Section 10.6. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

## 11.7 Source-specific aspects for NOx emissions from crop residues

### 11.7.1 *Calculation method*

Total $NO_x$ emissions from crop residues applied to soils are calculated as follows:

$$NO_x \text{ emissions crop residues} = N_{crop\ residues} \times EF\ NO_x \text{ crop residues} \times 30/14 \qquad (11.6)$$

Where:

| | | |
|---|---|---|
| $NO_x$ emissions crop residues | : | $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) from crop residues left on agricultural soils |
| $N_{crop\ residues}$ | : | Amount of N (kg N/year) from crop residues left on agricultural soils |
| EF $NO_x$ crop residues | : | $NO_x$ emission factor for crop residues left on soils (kg $NO_x$-N/kg N) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, Expressed as nitrogen monoxide |

### 11.7.2 *Activity data*

In accordance with the IPCC calculation rules, the activity data include all arable and outdoor horticultural crops (e.g. but not greenhouse farming). All crops falling under both of these categories are included in the Agricultural Census (available from www.cbs.nl), and they are included in the calculations for $NO_x$ emissions. In addition, a fixed country-specific value in kg N per hectare per crop type is used for the nitrogen content of above-ground crop residues. Finally, the calculations consider the fact that, in some cases, part of the above-ground crop residues are removed from the field and thus do not contribute to $NO_x$ emissions. Country-specific values are used for these removals (Van der Hoek *et al.*, 2007). The areas used for these crops are taken from the annual Agricultural Census. Mowing losses and pasture renovation are also taken into account.

### 11.7.3 *Emission factors*

The $NO_x$ emissions from N input to the soil are calculated using the default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input.

### 11.7.4 *Uncertainty*

The uncertainty values for area and nitrogen content are described in Section 10. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2023).

## 11.8 Source-specific aspects for $NO_x$ emissions from the agricultural use of organic soils

### 11.8.1 *Calculation method*

The $NO_x$ emissions are determined by multiplying the area of peat and other organic soils by specific mineralisation values in the Netherlands and default EMEP emission factors. Total $NO_x$ emissions from organic soils are calculated as follows:

$NO_x$ emissions organic soils = $\Sigma$ $area_{p,\ soil\ type}$ x $mineralisation_p$ x EF $NO_x$ organic soils x 30/14 (11.7)

Where:

$NO_x$ emissions organic soils: $NO_x$ emissions (kg $NO_x$/year, expressed as nitrogen monoxide) for all defined soil types

| | | |
|---|---|---|
| $Area_{p,\ soil\ type}$ | : | Area of various soil types (ha) for soil type (p) |
| $Mineralisation_p$ | : | Amount of N mineralised (kg N/ha/year) for soil type (p) |
| EF $NO_x$ organic soils | : | $NO_x$ emission factor for the agricultural use of organic soils (kg $NO_x$-N/ha) |
| 30/14 | : | Conversion factor from $NO_x$-N to $NO_x$, expressed as nitrogen monoxide |

### 11.8.2 *Activity data*

The areas of organic soils cultivated are estimated from the land-use maps of the sector classified as 'Land Use, Land Use Change and Forestry' (LULUCF). Maps are available for the base years 1990, 2004, 2009, 2013, 2017, 2021 and 2025. Between these years, interpolation takes place. An overview of the areas is provided in Annex 22 of Van der Most *et al.* (2026).

### 11.8.3 *Emission factors*

The average mineralisation is 233.5 kg N per hectare for peat soil and 204.5 kg N per hectare for other organic soil (Kuikman *et al.*, 2005). The default EMEP emission factor of 0.012 kg $NO_x$-N/kg N input is used.

### 11.8.4 *Uncertainty*

The uncertainty value for the area of histosols is estimated at 20%. Kuikman *et al.* (2005) specifies an uncertainty value of 25% for mineralisation. The uncertainty value for the area of other organic soils is estimated at 35%. Because this category falls between sand and peat and is harder to detect, the uncertainty values are higher than those for the area of histosols. The EMEP Guidebook gives a default uncertainty value of 160% for the emission factor.

## 11.9 Uncertainty estimates

An overview of all uncertainty estimates for the activity data, the implied emission factors and the emissions included in the category of $NO_x$ emissions from crop production and agricultural soils is provided in Table 11.1.

*Table 11.1 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and $NO_x$ emissions (U emissions) from crop production and agricultural soils*

| EMEP | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3Da1 | Inorganic N fertilizers | 24% | 160% | 166% |
| 3Da2a | Animal manure applied to soils | 3% | 160% | 160% |
| 3Da2b | Sewage sludge applied to soils | 25% | 160% | 167% |
| 3Da2c | Other organic fertilizers applied to soils | 25% | 160% | 167% |
| 3Da3 | Urine and dung deposited by grazing animals | 19% | 160% | 164% |
| 3Da4 | Crop residues applied to soils | 2% | 153% | 153% |
| | Total, agricultural soils | | | 87% |

# 12 $N_2O$ emissions from crop production and agricultural soils (CRT sector 3D)

## 12.1 Scope and definition

This section provides a description of the methodology and working processes for determining direct and indirect emissions of $N_2O$ from the soil as a result of agricultural activities in the Netherlands. It refers to the CRT source categories 3Da (Direct $N_2O$ emissions from managed soils) and 3Db (Indirect $N_2O$ emissions from managed soils), subdivided into:

- 3Da1 Inorganic N fertilizers
- 3Da2 Organic N fertilizers (further subdivided into animal manure, sewage sludge and other organic fertilizers applied to soils)
- 3Da3 Urine and dung deposited by grazing animals
- 3Da4 Crop residues
- 3Da5 Mineralisation/immobilisation associated with loss/gain of soil organic matter
- 3Da6 Cultivation of organic soils (i.e. histosols)
- 3Db1 Indirect $N_2O$ emissions from atmospheric deposition
- 3Db2 Indirect $N_2O$ emissions from nitrogen leaching and runoff

Nitrous oxide is formed in the soil during the microbiological processes of nitrification and denitrification. Nitrification is the process whereby ammonia ($NH_4^+$) is converted into nitrate by bacteria under aerobic (i.e. oxygen-rich) conditions. In slurry, oxygen is the limiting factor for nitrification. Nitrous oxide can be formed as a by-product, particularly if the nitrification process is delayed through lack of oxygen. No organic substances are required for nitrification. Denitrification is the microbiological transformation of $NO_3^-$ into the gaseous nitrogen compound $N_2$ under anaerobic (low-oxygen) conditions, with $N_2O$ as a by-product. Organic substances are used as energy sources. Organic soils have higher emissions of nitrous oxide than do mineral soils.

The IPCC Guidelines give separate estimates for the direct and indirect emissions of nitrous oxide from the agricultural sector (IPCC, 2006). *Direct* emissions occur within the agricultural system, resulting primarily from the application of inorganic N fertilizers and animal manure. *Indirect* emissions of nitrous oxide have to do with the formation of $N_2O$ in soils and aquatic systems as a result of nitrogen losses from the soil to air and water. They are attributed to agriculture, regardless of whether emission occurs on agricultural land or whether agricultural activities form the initial source, even within the same country.

## 12.2 Source-specific aspects for direct $N_2O$ emissions from the application of inorganic N fertilizer

### *12.2.1 Calculation method*

For the years 2000 to 2024, direct $N_2O$ emissions from inorganic N fertilizers are calculated by multiplying the amount of nitrogen of inorganic N fertilizers by a country-specific emission factor which also takes the soil type and land use into account:

$N_2O$ emissions inorganic fertilizer = Σ N inorganic fertilizer$_{ij}$ x EF $N_2O$ inorganic fertilizer$_{i,j}$ x 44/28 (12.2)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions inorganic fertilizer | : | $N_2O$ emissions (kg $N_2O$) from inorganic N fertilizers applied to soil |
| N inorganic fertilizer$_{ij}$ | : | Application of N from inorganic N fertilizers (kg N) on soil type (i) and land use (j) |
| EF $N_2O$ inorganic fertilizer$_i$ | : | Emission factor (kg $N_2O$-N/kg N) for the application of N from inorganic N fertilizer for soil type (i*)* and land use (j) |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

Due to time constraints the method applied for the years 2000 to 2019 could not be extended to the years 1990-1999. For the years 1990-1999, direct $N_2O$ emissions from inorganic N fertilizers are calculated by multiplying the amount of nitrogen of inorganic N fertilizers by a country-specific emission factor:

$N_2O$ emissions inorganic fertilizer = Σ $N_{inorganic\ fertilizer}$ x EF $N_2O$ inorganic fertilizer x 44/28 (12.1)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions inorganic fertilizer | : | $N_2O$ emissions (kg $N_2O$) from inorganic N fertilizers applied to soil |
| $N_{inorganic\ fertilizer}$ | : | Application of N from inorganic N fertilizers (kg N) |
| EF $N_2O$ inorganic fertilizer | : | Emission factor (kg $N_2O$-N/kg N) for the application of N from inorganic N fertilizer for soil type (i*)* |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

To prevent a time series inconsistency between 1990-1999 and 2000-2024, it was decided to apply for the years 1990-1999 the splicing overlap technique from the IPCC (IPCC, 2006).

Recalculated $N_2O$ emission = $X_0$ x ((1/(n – m + 1) x $\sum_{i=m}^{n} y_{i/x_i}$) (12.3)

Where:

Recalculated $N_2O$ emission: The new $N_2O$ emission for a year between 1990-1999 in kg $N_2O$

| | | |
|---|---|---|
| $X_0$ | : | the estimate developed using the previously used method |
| $Y_i$ | : | estimated emission using the new method during the overlap period |
| $X_i$ | : | estimated emission using the old method during the overlap period |
| m | : | first year of the overlap period (2000) |
| n | : | last year of the overlap period (2007) |

**Comparison to IPCC methodology**
The methodology described above is consistent with the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.2.2 *Activity data*

**Amount of nitrogen in inorganic N fertilizer applied to soil**
Usage figures for the various types of inorganic N fertilizers are taken from the statistics on synthetic fertilizer available from Wageningen Social & Economic Research. Since 2016 usage figures for the various types of inorganic N fertilizers have been taken from the statistics on inorganic fertilizer available from the FADN. Consistency between the two data sources has been verified and confirmed (Van Bruggen *et al.,* 2019). The distribution of inorganic N fertilizers across grassland and cropland for the years 1990-1999 is based on calculations with the MAMBO model. The distribution across the different soil types and land uses for the years 2000-2024 is based on calculations with the INITIATOR model (Kros *et al.,* 2019 and De Vries *et al.,* 2023).

### 12.2.3 *Emission factors*

The average emission factor used for the years 1990-1999 is 0.013 $N_2O$-N per kg applied N This factor is the weighted mean of inorganic N fertilizers applied on mineral and peat soils (Velthof *et al.*, 2010; Velthof and Mosquera, 2011; Van Schijndel and Van der Sluis, 2011, see Annex 4). For the years 2000-2024, the emission factors for the application of inorganic N fertilizer are 0.008 $N_2O$-N per kg net applied N for grassland on mineral soil, 0,007 $N_2O$-N per kg applied N for arable land on mineral soil and 0,030 $N_2O$-N per kg applied N from grassland on both mineral and organic soils (Velthof and Mosquera, 2011).

### 12.2.4 *Uncertainty*

Uncertainty values are estimated at 27% for inorganic N fertilizer and 40% for rinsing liquid (Section 10.2.4). The uncertainty value for the emission factor is estimated at 34% (see Annex 11).

## 12.3 Source-specific aspects for direct $N_2O$ emissions from animal manure applied to soils

### 12.3.1 *Calculation method*

For the period 1990-1999, the direct $N_2O$ emissions from the application of N from animal manure are calculated by multiplying the amount of nitrogen application from animal manure by a country-specific emission factor.

$$N_2O \text{ emissions manure application} = \Sigma\, N_{animal\ manure} \times EF\ N_2O \text{ manure application}_i \times 44/28 \qquad (12.4)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions manure application | : | $N_2O$ emissions (kg $N_2O$) from the application of animal manure to agricultural soils |
| $N_{animal\ manure}$ | : | Amount of N (kg N/year) from animal manure applied to soils |
| EF $N_2O$ manure application$_i$ | : | Emission factor (kg $N_2O$-N/kg N) for the application of N from animal |

| | | |
|---|---|---|
| | | manure for application technique (i) |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

The use of animal manure is divided into two types of manure application techniques, above-ground application and incorporation into the soil. Each having its own country-specific emission factor, weighed for soil type (see Annex 10 and Velthof and Mosquera, 2011).

For the period 2000-2024, the direct $N_2O$ emissions from the application of N from animal manure are calculated by multiplying the amount of nitrogen application from animal manure by a country-specific emission factor which takes the soil type and the land use into account.

$$N_2O \text{ emissions manure application} = \Sigma N_{animal\ manure} \times EF\ N_2O\ \text{manure application}_{i,j,k} \times 44/28 \quad (12.5)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions inorganic fertilizer | : | $N_2O$ emissions (kg $N_2O$) from the application of animal manure to agricultural soils |
| $N_{animal\ manure}$ | : | Amount of N (kg N/year) from animal manure applied to soils |
| EF $N_2O$ manure application$_{ijk}$ | : | Emission factor (kg $N_2O$-N/kg N) for the application of N from animal manure for application technique (i), soil type (j) and land use (k) |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories, with the sources ‘animal manure’, ‘sewage sludge’ and ‘compost’ reported together under 3Da2 (Organic N fertilizers). The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.3.2 *Activity data*

**Amount of nitrogen in animal manure applied to soil**

The amount of nitrogen applied to soils is calculated using the N flow. The calculation of N excretions is described in Section 2. Emissions in animal housing and outside manure storage facilities are calculated using the method described in Sections 2 and 4. The amount of nitrogen applied to soils is determined by the amount of nitrogen in animal manure also taking the bedding material into account, after subtracting emissions from animal housing and outside storage and the N in net exported manure (i.e. export - import). The distribution across the different soil types and land uses is based on calculations with the INITIATOR model.

### 12.3.3 *Emission factors*

The average emission factors used for the years 1990-1999 are 0.004 kg $N_2O$-N per kg applied N for surface spreading and 0.009 for the application of low-emission manure (Van Schijndel and Van der Sluis, 2011). Both of these figures are weighted means for mineral and organic soils. The higher emission factor for low-emission manure application methods is caused by the larger amount of N that is available for nitrification/denitrification when this method is used (Velthof *et al.*, 2010; Velthof and Mosquera, 2011; see annex 10). For the years 2000-2024 the emission factors for surface spreading are: 0.005 kg $N_2O$-N per kg applied N on organic soils (both grassland and arable land), and 0.001 kg $N_2O$-N per kg applied N for grassland on mineral soil and 0.006 kg $N_2O$-N per kg applied N for arable land on mineral soil (Velthof and Mosquera, 2011). The emission factors of low-emission techniques are: 0.010 kg $N_2O$-N per kg applied N on organic soils (both grassland and arable land), and 0.003 kg $N_2O$-N per kg applied N for grassland on mineral soil and 0.013 kg $N_2O$-N per kg applied N for arable land on mineral soils. The amounts of manure applied using surface spreading and using low-emission techniques are taken from the Agricultural Census.

### *12.3.4 Uncertainty*

The uncertainty value for the amount of manure applied is calculated according to the N-flow calculation, with a corresponding uncertainty value of 3%. The uncertainty value for the fraction of low-emission techniques is estimated at 5%, with a value of 50% for the fraction of surface spreading (based on expert judgement). The uncertainty value for the low-emission application emission factor is 71%, with an uncertainty value of 82% for surface spreading. Source-specific aspects for direct $N_2O$ emissions from sewage sludge applied to soils.

## 12.4 Source-specific aspects for direct $N_2O$ emissions from sewage sludge applied to soils

### *12.4.1 Calculation method*

Direct emissions of nitrous oxide from sewage sludge are calculated by multiplying the amount of nitrogen from sewage sludge by a country-specific emission factor.

$$N_2O \text{ emissions sewage sludge} = N_{\text{sewage sludge}} \times EF\ N_2O \text{ sewage sludge} \times 44/28 \qquad (12.6)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions sewage sludge | : | $N_2O$ emissions (kg $N_2O$) from sewage sludge applied to agricultural soils |
| $N_{\text{sewage sludge}}$ | : | Amount of N (kg N) from sewage sludge |
| EF $N_2O$ sewage sludge | : | Emission factor (kg $N_2O$-N/kg N) for sewage sludge |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories, with the sources ‘Animal manure’, ‘Sewage sludge’ and ‘Compost’ reported together under Category 3Da2 (Organic N fertilizers).

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.4.2 *Activity data*

Amounts of sewage sludge applied to agricultural soils were available from Statistics Netherlands until 2017. As of 2017, the application of sewage sludge is derived from registered transports to agricultural holdings.

### 12.4.3 *Emission factors*

For sewage sludge, the emission factors and uncertainty values for manure application are used: 0.004 kg $N_2O$-N per kg N for surface application and 0.009 kg $N_2O$-N for low-ammonia emission application.

### 12.4.4 *Uncertainty*

The uncertainty value for total sewage sludge usage is estimated at 25%. Disaggregated uncertainty values are calculated for the liquid and solid fractions. The uncertainty value for the emission factor is estimated at 100%. This is higher than the uncertainty value for the same emission factors for manure application, as the measurements relate to application of animal manure.

## 12.5 Source-specific aspects for direct $N_2O$ emissions from other organic fertilizers applied to soils (including compost)

### 12.5.1 *Calculation method*

Direct $N_2O$ emissions from compost are calculated by multiplying the amount of nitrogen from compost by a country-specific emission factor.

$$N_2O \text{ emissions organic fertilizers} = N_{\text{organic fertilizers}} \times EF\ N_2O \text{ organic fertilizers} \times 44/28 \qquad (12.7)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions organic fertilizers | : | $N_2O$ emissions (kg $N_2O$) from organic fertilizers applied to agricultural soils |
| $N_{\text{organic fertilizers}}$ | : | Amount of N from compost in kg N |
| EF $N_2O$ organic fertilizers | : | Emission factor for compost (kg $N_2O$-N/kg N) |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories, with the sources ‘Animal manure’, ‘Sewage sludge’ and ‘Compost’ reported together under 3Da2 (Organic N fertilizers).

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2019).

### 12.5.2 *Activity data*

The amounts of organic waste and green refuse compost applied to agricultural soils or used outside the context of agriculture are calculated by Statistics Netherlands and published through Statline.

### 12.5.3 *Emission factors*

All compost is assumed to be surface-applied, with an emission factor of 0.004 kg $N_2O$-N per kg N applied (Section 12.3).

### 12.5.4 *Uncertainty*

The uncertainty value for total compost usage is estimated at 25%. The uncertainty value for the emission factor is 100%. This is higher than the uncertainty value calculated for the emission factor reported in Section 12.3, as no emission factor is available for the application of compost. The emission factor is therefore assumed to be the same as for the application of manure.

## 12.6 Source-specific aspects for direct N2O emissions from urine and dung deposited by grazing animals

### 12.6.1 *Calculation method*

For the period 1990-1999, the direct $N_2O$ emissions from the application of N from urine and dung deposited by grazing animals are calculated by multiplying the amount of nitrogen by a country-specific emission factor.

$$N_2O\ emissions\ grazing = N_{grazing} \times EF\ N_2O\ grazing \times 44/28 \qquad (12.8)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions grazing | : | $N_2O$ emissions (kg $N_2O$) from urine and dung deposited by grazing animals |
| $N_{grazing}$ | : | Amount of N for livestock category (kg N/year) in urine and dung deposited by grazing animals |
| EF $N_2O$ grazing | : | Emission factor (kg $N_2O$-N/kg N) for urine and dung deposited by grazing animals |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

For the period 2000-2024 the direct $N_2O$ emissions from the application of N from urine and dung deposited by grazing animals are calculated by multiplying the amount of nitrogen by a country-specific emission factor which also takes the soil type into account.

$$N_2O\ emissions\ grazing = \sum N_{grazing} \times EF\ N_2O\ grazing_i \times 44/28 \qquad (12.9)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions grazing | : | $N_2O$ emissions (kg $N_2O$) from urine and dung deposited by grazing animals |
| $N_{grazing}$ | : | Amount of N for livestock category (kg N/year) in urine and dung deposited by grazing animals |
| EF $N_2O$ $grazing_i$ | : | Emission factor (kg $N_2O$-N/kg N) for urine and dung deposited by grazing animals for soil type (i). |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories.

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.6.2 *Activity data*

Some animal manure is produced on pasture land. The amount of nitrogen per animal is calculated by the WUM and available from www.cbs.nl. Statistics concerning the livestock populations are also available on the CBS website.

### 12.6.3 *Emission factors*

An average emission factor of 0.033 kg $N_2O$-N per kg net applied N is used for grazing for the years 1990-1999. This factor is a weighted mean over soil types (see Annex 10). For the years 2000-2024 an emission factor of 0.025 kg $N_2O$-N per kg net applied N is used for mineral soils and 0.060 kg $N_2O$-N per kg net applied N for organic soils.

### 12.6.4 *Uncertainty*

The uncertainty value for nitrogen excretion is described in Section 2.4.3. The uncertainty for the emission factor is 64%. The uncertainty value is calculated using uncertainty values for the emission factors for each soil type and for the distribution of manure distribution over these soil types (Annex 11).

## 12.7 Source-specific aspects for direct $N_2O$ emissions from crop residues

### 12.7.1 *Calculation method*

Calculation of emissions from crop residues is based on the methodology and calculations of De Ruijter and Huijsmans (2019). Direct $N_2O$ emissions from crop residues are calculated by multiplying the amount of nitrogen from crop residues by a country-specific emission factor.

$$N_2O \text{ emissions crop residues} = N_{\text{crop residues}} \times EF\ N_2O \text{ crop residues} \times 44/28 \quad (12.10)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions crop Residues | : | $N_2O$ emissions (kg $N_2O$) from crop residues present on agricultural soils |
| $N_{\text{crop residues}}$ | : | Amount of N (kg N/year) from crop residues applied to agricultural soils |
| EF $N_2O$ crop residues | : | Emission factor (kg $N_2O$-N/kg N) for crop residues |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories.

Direct $N_2O$ emissions from grassland renewal are calculated by multiplying the amount of ha of grassland that is renewed by a country specific emission factor.

$$N_2O \text{ emissions grassland renewal} = \text{Area renewed} \times EF\ N_2O \text{ grassland renewal} \times 44/28 \quad (12.11)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions grassland renewal | : | $N_2O$ emissions (kg $N_2O$) from grass residues present on renewed grasslands |
| Area renewed | : | Number of ha of grassland renewed |
| EF $N_2O$ grassland renewal | : | Emission factor (kg $N_2O$-N) for grass residues |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

**Comparison to IPCC methodology**
The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.7.2 *Activity data*

**Amount of nitrogen in crop residues**
In accordance with the IPCC calculation rules, these values include all arable and outdoor horticultural crops (e.g. but not greenhouse farming). All crops falling under these two categories are included in the Agricultural Census (available at www.cbs.nl), and they are included in the calculations for nitrous oxide emissions. In addition, a fixed country-specific value in kg N per hectare per crop type is used for the nitrogen content of above-ground and below-ground crop residues. Data available from Annex I of De Ruijter and Huijsmans (2019) were used to calculate the N content of residues from crops. Finally, the calculations consider the fact that, in some cases, part of the above-ground crop residues are removed from the field and thus do not contribute to nitrous oxide emissions. Country-specific values are used for these removals, as reported in Van der Hoek *et al.* (2007).

**Grassland renewal**
The areas used for crops and grassland are taken from the annual Agricultural Census, which includes all agricultural companies that are headquartered in the Netherlands and that are larger than or equal to three Netherlands size units (nge, until 2009) or 3,000 Standard Outputs (SO, from 2010). This also includes natural grassland primarily used by farmers.

### 12.7.3 *Emission factors*

An emission factor of 0.01 kg $N_2O$-N per kg N is used for crop residues remaining on mineral soils. This value is estimated from Dutch research studies conducted in the first half of the 1990s (Kroeze, 1994). Arable farming and outdoor horticulture hardly ever occur in organic soils.
For grassland renewal an emission factor of 2.7 kg $N_2O$-N per ha grassland renewed is used. The emission factor of grassland renewal is based on the average of grassland renewal with and without ploughing up the land (Velthof et al., 2010b).

### 12.7.4 *Uncertainty*

Uncertainty values for areas of crops are described in Section 10. The uncertainty value for activity data for pasture renewal is estimated at 25%. The uncertainty value for the emission factor is estimated at 160%, based on Kroeze (1994). This value is dependent on the age and management of the grass.

## 12.8 Source-specific aspects for direct $N_2O$ emissions from the agricultural use of organic soils

### 12.8.1 *Calculation method*

Direct nitrous oxide emissions from agricultural use of organic soils are calculated by multiplying the amount of mineralised nitrogen in organic soils (peat soils and other organic soils) by a country-specific emission factor.

$N_2O$ emissions organic soils = Σ $area_{p,\ soil\ type}$ x $mineralisation_p$ x EF $N_2O$ organic soils x 44/28 (12.12)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions organic soils | : | $N_2O$ emissions (kg $N_2O$) for all defined soil types |
| $Mineralisation_p$ | : | Amount of N mineralised (kg N/ha/year) for soil type (p) |
| $Area_{p,\ soil\ type}$ | : | Area of various soil types (ha) for soil type (p) |
| EF $N_2O$ organic soils | : | Emission factor (kg $N_2O$-N/kg N) for mineralised nitrogen in organic soils |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories.

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).

### 12.8.2 *Activity data*

Nitrous oxide emissions are determined by multiplying the area of peat and other organic soils by specific Dutch mineralisation rates and emission factors. The extent of the areas of cultivated land are estimated from the land-use maps of the sector designated as ‘Land Use, Land Use Change and Forestry’ (LULUCF). Maps of land use are available for the years 1990, 2004, 2009, 2013, 2017, 2021 and 2025. Additionally two maps with geographically explicit information on soil types (1977 and 2014) plus a map with projected extent of peat and peaty soils in 2040 are used in the LULUCF sector to assess combined land-use change and soil information trajectories (see Van Baren *et al.* (2026) for details on the maps and methodologies). Overlays of the maps determine the annual extent of drained and cultivated peat and peaty soils with their respective land-uses over time.

The areas of organic soils reported in Table CRT Table 4.C under the LULUCF sector report total area of organic soils, which also includes nature grasslands, while for the N2O emissions reported in CRT Table 3.D in the Agriculture sector only the area of cultivated grassland is considered (see NIR Chapter 6.6.2). An overview of the resulting areas of cultivated grassland and cropland on peat and peaty soils is provided in Annex 24 of Van der Most *et al.* (2026).

### 12.8.3 *Emission factors*

The average mineralisation values are 233.5 kg N per hectare of peat soil and 204.5 kg N per hectare of other organic soil (Kuikman *et al.*, 2005). Using an emission factor of 0.02 (taken largely from Dutch research projects conducted in the first half of the 1990s and reported in Kroeze, 1994), the nitrous oxide emissions of histosols amount to 4.67 kg $N_2O$–N per hectare of peat soil and 4.09 kg $N_2O$-N per hectare of other organic soils.

### 12.8.4 *Uncertainty*

The uncertainty value for the area of histosols is estimated at 20%. The uncertainty value for the area of other organic soils is estimated at 35%. Because this area is a category between sand and peat, it is harder to detect, and the uncertainty values are therefore greater than those for the area of histosols. The uncertainty value for mineralisation is 25% (expert judgement based on Kuikman *et al.*, 2005). Kroeze (1994) provides emission factors ranging from 1.25% to 2.5%. The greater of these two values yields an uncertainty value of 37.5%. The emission factor used for the histosols is also used for other organic soils. The uncertainty value is greater (50%), given that measurements are conducted only for histosols.

## 12.9 Source specific aspects for direct $N_2O$ emissions from mineralisation/immobilisation associated with loss/gain of soil organic matter

### 12.9.1 *Calculation method*

Direct $N_2O$ emissions from mineralisation/immobilisation associated with loss/gain of soil organic matter are calculated by multiplying the amount of mineralised nitrogen due to losses in soil organic matter of mineral soils with the Tier 1 emission factor.

$N_2O$ emissions mineralisation = Σ loss soil C x C/N ratio x EF $N_2O$ emissions mineralisation x 44/28 (12.13)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions Mineralisation | : | $N_2O$ emissions (kg $N_2O$) due to losses of soil organic matter of mineral soils used for agriculture. |
| Σ loss soil C | : | Amount of C lost (kg C/year) |
| C/N ratio | : | carbon nitrogen ratio of mineral soils the Netherlands |
| EF $N_2O$ organic soils | : | Emission factor (kg $N_2O$-N/kg N) for mineralised nitrogen in organic soils |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

These emissions are reported under their respective CRT categories.

### 12.9.2 *Activity data*

The LULUCF sector calculates the losses of soil organic matter of mineral soils due to agricultural usage. The amount of mineralised nitrogen is calculated using a C/N ratio of 10.

### 12.9.3 *Emission factors*

The Tier 1 emission factor provided by the 2019 Refinement to the 2006 IPCC guidelines is used, 0.006 kg N-$N_2O$/ kg N mineralised.

### 12.9.4 *Uncertainty*

The uncertainty value for the losses of soil organic matter is estimated at 60% (Van Baren *et al.,* 2025). The uncertainty value for the emission factor is set at 200% (IPCC, 2019).

## 12.10 Source-specific aspects for indirect $N_2O$ emissions after atmospheric depositions of $NH_3$ and NOx

### *12.10.1 Calculation method*

Indirect $N_2O$ emissions occur after atmospheric depositions of nitrogen compounds that have evaporated in the form of $NH_3$ and $NO_x$ from animal housing, manure treatment and manure storage (attributed to manure management; see Sections 5 and 6), as well as from inorganic N fertilizer, the application of animal manure, grazing, sewage sludge and compost (attributed to agricultural soils; this section).

Indirect $N_2O$ emissions after atmospheric depositions of nitrogen compounds are calculated by multiplying the amount of nitrogen by the default 2006 IPCC emission factors.

$N_2O$ emissions indirect soil = $N_{atmospheric\ deposition}$ x EF $N_2O$ emissions indirect soil x 44/28 (12.14)

Where:

| | | |
|---|---|---|
| $N_2O$ emissions indirect soil | : | Indirect $N_2O$ emissions (kg $N_2O$) from the soil after atmospheric deposition of nitrogen compounds |
| $N_{atmospheric\ deposition}$ | : | Amount of N (kg N) from atmospheric deposition |
| EF $N_2O$ indirect soil | : | Default IPCC emission factor (kg $N_2O$-N/kg N supply) for atmospheric deposition |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006).The extent of the various supply sources is determined using country-specific data at the Tier 2 or Tier 3 level. The $N_2O$ emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

### *12.10.2 Activity data*

Although the term ‘deposition’ is used here, it does not refer to actual depositions of $NH_3$ and $NO_x$, but to the total $NH_3$ and $NO_x$ emissions produced by the agricultural sector in the Netherlands (as derived from the IPCC Guidelines). This refers primarily to the total depositions of all $NH_3$ and $NO_x$ emitted by the Dutch agricultural sector, regardless of their geographic location (thus also including those outside the country’s borders).

The extent of the $NH_3$ emissions from the application of inorganic N fertilizer and animal manure, as well as during grazing are calculated within the National Emission Model for Agriculture (NEMA) using country-specific emission factors (described in Section 10). For $NO_x$ emissions, EMEP default emission factors for the application of inorganic N fertilizer, for the application of animal manure and for grazing are applied (described in Section 11).

### 12.10.3 *Emission factors*

Due to the lack of measurement data in the Netherlands, IPCC default emission factors of 0.01 kg $N_2O$–N per kg N supply were used when calculating indirect emissions of nitrous oxide (Denier van der Gon *et al.*, 2004; Van der Hoek *et al.*, 2007).

### 12.10.4 *Uncertainty*

The uncertainty value for total emissions from agricultural soils in the form of $NH_3$ and $NO_x$ is calculated to be 27%. IPCC gives an uncertainty value of 400% for the emission factor.

## 12.11 Source-specific aspects for indirect $N_2O$ emissions from leaching and runoff of nitrogen added to the soil

### 12.11.1 *Calculation method*

Indirect nitrous oxide emissions from aquatic systems occur through leaching and runoff of nitrogen (especially nitrate) from agricultural soils. Nitrate undergoes de-nitrification in groundwater or surface water, thereby creating nitrous oxide.

The following calculation rule is used for calculating nitrous oxide emissions for this supply source:

$$N_2O \text{ emissions leaching} = N_{\text{applied to soil}} \times FRAC_{\text{leach}} \times EF\ N_2O \text{ leaching} \times 44/28 \quad (12.15)$$

Where:

| | | |
|---|---|---|
| $N_2O$ emissions leaching | : | $N_2O$ emissions (kg $N_2O$) from leaching and runoff of nitrogen added to the soil |
| $N_{\text{applied to soil}}$ | : | Amount of N (kg N) applied to the soil |
| $FRAC_{\text{leach}}$ | : | Fraction of nitrogen leaching and running off |
| EF $N_2O$ leaching | : | $N_2O$ leaching emission factor (kg $N_2O$-N/kg N supply) |
| 44/28 | : | Conversion factor from $N_2O$-N to $N_2O$ |

The amount of nitrogen ($N_{\text{applied to soil}}$) refers to the total amount of inorganic N fertilizer and animal manure applied to soils, together with pasture manure, crop residues, sewage sludge, compost and the mineralisation of organic soils. The emission factor used is the IPCC default, and the $FRAC_{\text{leach}}$ is country-specific. Further background information on the $FRAC_{\text{leach}}$ values is provided in Velthof and Mosquera (2011). Further information concerning the nitrous oxide emission factor of 0.0075 is provided in the 2006 IPCC Guidelines (IPCC, 2006, p. 11.24).

**Comparison to IPCC methodology**

The methodology described above conforms to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006). The nitrous oxide emissions caused by effluent discharged from sewage treatment plants into surface water are not included in the agricultural sector, but in CRT Category 5B.

The extent of the various supply sources is determined using country-specific data at the Tier 2 or Tier 3 level. The $N_2O$ emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

### 12.11.2 *Activity data*

Activity data include all nitrogen applied to soils directly, inorganic fertilizer (described in Section 12.2), animal manure (described in Section 12.3), sewage sludge (described in Section 12.4), compost (described in Section 12.5), urine and dung deposited by grazing animals (described in Section 12.6), crop residues (described in Section 12.7) and the mineralisation of organic soils (described in Section 12.8).

### 12.11.3 *Emission factors*

With respect to the *leaching and runoff* of nitrogen added to soil, the emission factor refers to the share of nitrogen that is leached and run off: the '$FRAC_{leach}$' (Table 12.1). A country-specific value between 15% to 13% is applied, due to the relatively high groundwater tables in the Netherlands (Velthof and Mosquera, 2011). The default emission factor of 0.0075 is used.

*Table 12.1 $FRAC_{leach}$ and nitrous oxide emission factors for indirect nitrous oxide emissions from leaching and runoff*

| Supply source | Factor |
|---|---|
| $FRAC_{leach}$ | 0.15 kg N per kg N to soil (1990-1991) |
| | 0.14 kg N per kg N to soil (1992-1997) |
| | 0.13 kg N per kg N to soil (1998-present) |
| Nitrous oxide emission factor | 0.0075 kg $N_2O$–N per kg N leached/runoff |

Source: Velthof and Mosquera (2011)

### 12.11.4 *Uncertainty*

The uncertainty value for the amount of N added to the soil is calculated at 10.0%. The uncertainty value for $FRAC_{leach}$ is estimated at 50%. The uncertainty value for the emission factor is 233% (largest range in the IPCC Guidelines: greatest value 0.025).

## 12.12 Uncertainty estimates

An overview of all uncertainty values for the activity data, the implied emission factors and the emissions included in the category of $N_2O$ emissions from crop production and agricultural soils is provided in Table 12.2.

*Table 12.2 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and $N_2O$ emissions (U emissions) from crop production and agricultural soils*

| IPCC | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3Da1 | Inorganic N fertilizers | 24% | 34% | 42% |
| 3Da2a | Animal manure applied to soils | 3% | 68% | 69% |
| 3Da2b | Sewage sludge applied to soils | 25% | 100% | 106% |
| 3Da2c | Other organic fertilizers applied to soils | 25% | 100% | 106% |
| 3Da3 | Urine and dung deposited by grazing animals | 19% | 64% | 68% |
| 3Da4 | Crop residues | 2% | 41% | 41% |
| 3Da6 | Cultivation of organic soils (i.e. histosols) | 18% | 37% | 41% |
| 3Db1 | Atmospheric deposition | 27% | 400% | 415% |
| 3Db2 | Nitrogen from leaching and runoff | 51% | 233% | 267% |
| | Total, agricultural soils | | | 37% |

# 13 NMVOC emissions from crop production and agricultural soils (NFR Sector 3D)

## 13.1 Scope and definition

This section provides a description of the methods and working processes for determining NMVOC emissions from silage storage, manure application, urine and dung deposited by grazing animals and crop production, according to the following NFR categories:

- 3Da2a Animal manure applied to soils
- 3Da3 Urine and dung deposited by grazing animals
- 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products
- 3De Cultivated crops

The emission of NMVOC occurs when manure is applied to the soil, during grazing (through the depositing of urine and manure) and during the storage of silage. No estimates are provided for NMVOC emissions during the application of organic/inorganic fertilizer or sewage sludge, as no emission factors are available for these sources.

The NMVOC from manure are produced during the degradation of fats, carbohydrates and proteins present in the manure. The composition of manure therefore influences the emission of NMVOC. Given the existence of a correlation between $NH_3$ and NMVOC emissions from manure management, the ratio of $NH_3$ emissions from animal housing to those from manure application is used to divide NMVOC emissions over these categories, as described in the EMEP Guidebook (EEA, 2023).

The calculation used for the application of cattle manure differs from that used for the other animal categories. The NMVOC calculations for cattle manure are based on the energy content of the cattle feed. For the other animal categories, the VS content of the manure is used.

## 13.2 Source-specific aspects for NMVOC emissions from animal manure applied to soils

### 13.2.1 *Calculation method*

The methods used are described in the EMEP Guidebook (EEA, 2023).

The NMVOC emissions from the application of manure are calculated as follows:

$$\text{NMVOC manure application} = \sum \text{AAP}_i \times \text{NMVOC animal housing}_i \times (\text{NH}_3\ \text{manure application}_i / \text{NH}_3\ \text{animal housing}_i) \qquad (13.1)$$

Where:

| | | |
|---|---|---|
| NMVOC manure application | : | NMVOC emissions (kg NMVOC) for manure application for livestock category (i) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| NMVOC animal $housing_i$ | : | NMVOC emissions (kg NMVOC/animal/year) from manure in |

| | | |
|---|---|---|
| | | livestock housing for animal category (i), as calculated in Section 8.2 |
| $NH_3$ manure application$_i$ | : | $NH_3$ emissions (kg $NH_3$/year) from manure application for livestock category (i), as calculated in Section 10.3 |
| $NH_3$ animal housing$_i$ | : | Total $NH_3$ emissions (kg $NH_3$/year) from animal housing for livestock category (i), as calculated in Section 5.2 |

### 13.2.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in sections 2.2.1 and 2.4.3, respectively. The NMVOC emissions from animal housing are described in Section 8.2. The emissions of $NH_3$ from manure application and $NH_3$ from animal housing are described in Sections 10.3 and 5.2, respectively.

### 13.2.3 *Emission factors*

The NMVOC emissions from animal manure applied to soils are based on the emissions of animal manure in housing (described in Section 8.2).

### 13.2.4 *Uncertainty*

The uncertainty value for livestock numbers, including the aggregation/disaggregation of subcategories, is given in Section 2.4.3. The uncertainty value for the emission factors is 300% (estimate based on expert judgement).

## 13.3 Source-specific aspects for NMVOC emissions from urine and dung deposited by grazing animals

### 13.3.1 *Calculation method*

The methods used are described in the EMEP Guidebook (EEA, 2023).

**Dairy and non-dairy cattle**

The NMVOC emissions from urine and dung deposited by grazing of cattle are calculated as follows:

$$\text{NMVOC emissions pasture}_{cattle} = \sum \text{AAP}_i \times \text{GE}_i \times (1 - \text{FRAC}_{i,\ \text{time spent inside}}) \times \text{EF NMVOC pasture}_i \quad (13.2)$$

Where:

| | | |
|---|---|---|
| NMVOC pasture$_{cattle}$ | : | NMVOC emissions (kg NMVOC/year) during grazing, for all cattle categories (i) |
| AAP$_i$ | : | Average animal population for cattle category (i) |
| GE$_i$ | : | Gross energy intake in megajoules (MJ/animal/year) for cattle category (i) |
| FRAC$_{i,\ \text{time spent inside}}$ | : | Fraction of time spent inside housing facilities for cattle category (i) |
| EF NMVOC pasture$_i$ | : | Emission factor (kg NMVOC/MJ) for grazing for cattle category (i) |

**Other livestock**
The NMVOC emissions from urine and dung deposited by grazing by livestock categories other than cattle are calculated as follows:

$$\text{NMVOC emissions pasture}_{other} = \sum_i AAP_i \times VS_i \times (1- FRAC_{i,\text{ time spent inside}}) \times \text{EF NMVOC pasture}_i \quad (13.3)$$

Where:

| | | |
|---|---|---|
| NMVOC $\text{pasture}_{other}$ | : | NMVOC emissions (kg NMVOC/year) during grazing for all other livestock categories (i) |
| $AAP_i$ | : | Average animal population for livestock category (i) |
| $VS_i$ | : | Volatile solids (kg VS/year) excreted by livestock category (i) |
| $FRAC_{i,\text{ time spent inside}}$ | : | Fraction of time spent inside housing facilities for other livestock category (i) |
| EF NMVOC $\text{pasture}_i$ | : | Emission factor (kg NMVOC/animal) for grazing of livestock category (i) |

### 13.3.2 *Activity data*
Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Sections 2.2.1 and 2.4.3, respectively.

The gross feed intake of cattle, the composition of feed and the time spent inside housing facilities are calculated by the WUM (CBS, 2019 through 2025). For the VS excretion of sheep, goats, horses, ponies and mules and asses, the IPCC default values (as listed in Table 8.1) are used (IPCC, 2006).

### 13.3.3 *Emission factors*
The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2023). All emission factors are listed in Table 13.1.

*Table 13.1 NMVOC emission factors (EF) of grazing used for each livestock category (EEA, 2023)*

| Livestock category | EF for grazing | Unit |
|---|---|---|
| Cattle | 0.0000069 | kg NMVOC/MJ |
| Sheep | 0.00002349 | kg NMVOC/kg VS excreted |
| Goats | 0.00002349 | kg NMVOC/kg VS excreted |
| Horses | 0.00002349 | kg NMVOC/kg VS excreted |
| Mules and asses | 0.00002349 | kg NMVOC/kg VS excreted |

### 13.3.4 *Uncertainty*
The uncertainty value for livestock numbers, including the aggregation/disaggregation of subcategories, is given in Section 2.4.3. The uncertainty value for the emission factors is 300% (estimate based on expert judgement).

## 13.4 Source-specific aspects for NMVOC emissions from farm-level agricultural operations, including the storage, handling and transport of agricultural products

### *13.4.1 Calculation method*

The methods used are described in the EMEP Guidebook (EEA, 2023). It is assumed that the NMVOC emissions from the storage of silage are a fraction of the NMVOC emissions from silage feeding in animal housing.

**Dairy and non-dairy cattle**

The NMVOC emissions from silage storage for cattle feeding are calculated as follows:

$$NMVOC\ emissions\ silage\ storage_{cattle} = \Sigma\ AAP_i \times GE_i \times FRAC_{i,\ time\ spent\ inside} \times (FRAC_{i,\ silage} \times EF\ NMVOC\ silage\ storage_i) \times 0.25 \quad (13.4)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions silage $storage_{cattle}$ | : | NMVOC emissions (kg NMVOC/year) from the storage of silage for all cattle categories (i) |
| $AAP_i$ | : | Average animal population for cattle category (i) |
| $GE_i$ | : | Gross energy intake in megajoules (MJ/animal) per year (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Fraction of time spent inside animal housing for cattle category (i) |
| $FRAC_{i,\ silage}$ | : | Fraction of gross energy uptake consisting of silage (i) |
| EF NMVOC silage $storage_i$ | : | Emission factor (kg NMVOC/MJ) for NMVOC from the storage of silage for cattle category (i) |
| 0.25 | : | Fraction of emissions from silage storage compared to emissions from silage feeding in animal housing |

**Other livestock**

The NMVOC emissions from silage storage for livestock categories other than cattle that are fed silage are calculated as follows:

$$NMVOC\ emissions\ silage\ storage_{other} = \Sigma_i\ AAP_i \times VS_i \times FRAC_{i,\ time\ spent\ inside} \times (FRAC_{i,\ silage} \times EF\ NMVOC\ silage\ storage_i) \times 0.25 \quad (13.5)$$

Where:

| | | |
|---|---|---|
| NMVOC emissions silage $storage_{other}$ | : | NMVOC emissions (kg NMVOC/year) from the storage of silage for all other livestock categories (i) |
| $VS_i$ | : | Volatile solids (kg VS/year) excreted by livestock category (i) |
| $FRAC_{i,\ time\ spent\ inside}$ | : | Fraction of time spent inside animal housing for other livestock category (i) |
| $FRAC_{i,\ silage}$ | : | Fraction of feed given consisting of silage (i) |

| | | |
|---|---|---|
| EF NMVOC silage storage$_i$ | : | Emission factor (kg NMVOC/animal) for NMVOC from the storage of silage for livestock category (i) |
| 0.25 | : | Fraction of emissions from silage storage compared to emissions from silage feeding in animal housing |

### 13.4.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Section 2.2.1 and 2.4.3. Gross energy intake and uncertainties are described in Section 3.2.

The gross feed intake of cattle, the VS excreted by pigs and poultry, the feed composition and the time spent inside animal housing are calculated by the WUM (CBS, 2019 through 2025). For the VS excretion of sheep, goats, horses and ponies, mules and asses and other animals, the IPCC default values (listed in Table 8.1) are used (IPCC, 2006).

### 13.4.3 *Emission factors*

The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2023). All categories of emission factors are listed in Table 13.2.

*Table 13.2 NMVOC emission factors (EF) for silage storage, by livestock category (EEA, 2023)*

| Livestock category | EF | Unit |
|---|---|---|
| Cattle | 0.0002002 | kg NMVOC/MJ |
| Sheep | 0.01076 | kg NMVOC/kg VS excreted |
| Goats | 0.01076 | kg NMVOC/kg VS excreted |
| Horses | 0.01076 | kg NMVOC/kg VS excreted |
| Mules and asses | 0.01076 | kg NMVOC/kg VS excreted |

### 13.4.4 *Uncertainty*

The uncertainty value for livestock numbers, including the aggregation/disaggregation of subcategories, is given in Section 2.3. The uncertainty value for the emission factors is 300% (estimate based on expert judgement).

## 13.5 Source-specific aspects for NMVOC emissions from crop cultivation

### 13.5.1 *Calculation method*

The methods used are described in the EMEP Guidebook (EEA, 2023) at the Tier 1 level. NMVOC emissions from cultivated crops are calculated as follows:

$$\text{NMVOC emissions crop cultivation} = \text{area} \times \text{EF NMVOC crop cultivation} \quad (13.6)$$

Where:

NMVOC emissions crop cultivation: NMVOC emissions (kg NMVOC/year) from cultivated crops

| | | |
|---|---|---|
| Area | : | The area covered by crops (in ha) |
| EF NMVOC crop cultivation | : | Emission factor (kg NMVOC/ha) for NMVOC from cultivated crops |

### 13.5.2 *Activity data*
Information on the areas used for crop production is taken from the Agricultural Census.

### 13.5.3 *Emission factors*
The Tier 1 default emission factor of 0.86 (kg NMVOC/ha) from the EMEP Guidebook is used (EEA, 2023).

### 13.5.4 *Uncertainty*
The uncertainty value for area per crop is 5%. The uncertainty value for the emission factor is 300% (estimate based on expert judgement).

## 13.6 Uncertainty estimates
An overview of all uncertainty estimates for the activity data, the implied emission factors and the emissions included within the category of NMVOC emissions from crop production and agricultural soils is provided in Table 13.3.

*Table 13.3 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and NMVOC emissions (U emissions) from crop production and agricultural soils*

| EMEP | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3Da2a | Animal manure applied to soils | 5% | 125% | 125% |
| 3Da3 | Urine and dung deposited by grazing animals | 5% | 159% | 159% |
| 3Dc | Farm-level agricultural operations | 1% | 176% | 176% |
| 3De | Cultivated crops | 12% | 218% | 218% |
| | Total, agricultural soils | | | 104% |

# 14 $PM_{10}$ and $PM_{2.5}$ emissions from crop production and agricultural soils (NFR category 3D)

## 14.1 Scope and definition

The NFR source category 3D (Crop production and agricultural soils) consists of the following:

- 3Dc Farm-level agricultural operations, including the storage, handling and transport of agricultural products
- 3De Cultivated crops
- 3Df Use of pesticides

Emissions of PM occurring during the use of inorganic N fertilizers, as well as during the loading of fertilizer application equipment. These values are therefore not reported under category 3Da1 (Inorganic N fertilizers, including urea application) but under category 3Dc (Farm-level agricultural operations, including the storage, handling and transport of agricultural products). No emissions of PM occur in source categories 3Da2a (Livestock manure applied to soils), 3Da2a (Sewage sludge applied to soils), 3Da2c (Other organic fertilizers applied to soils, including compost), 3Da3 (Urine and dung deposited by grazing animals), 3Da4 (Crop residues applied to soils) and 3Db (Indirect emissions from managed soils).

Activities falling under category 3Dd (Off-farm storage, handling and transport of bulk agricultural products) are covered by other sectors. Given that field burning is prohibited by law (Article 10.2 of the Environmental Management Act; in Dutch, *Wet Milieubeheer*), no emissions take place in category 3F (Field burning of agricultural residues). Finally, the Netherlands has opted not to report PM emissions under category 3I (Agriculture other).

Particulate matter emissions from crop production occur during soil cultivation or crop harvesting, and depend on crop sort, soil type, methods used and the weather. Particulate matter is also emitted during other agricultural activities (e.g. during haymaking and in the use of concentrates, inorganic N fertilizers and pesticides). These emissions are allocated to NFR categories 3De and 3Dc, respectively.

## 14.2 Source-specific aspects for PM emissions from farm-level operations

### *14.2.1 Calculation method*

Emissions of PM from farm-level operations consist of $PM_{10}$ and $PM_{2.5}$ from the use of feed, fertilizer and pesticides. Emissions of PM during the transport and handling of feed, fertilizer and pesticide have been calculated once, using a country-specific method (Chardon and Van der Hoek, 2002) and kept constant for the entire time series.

### *14.2.2 Activity data*

Activity data for the use of inorganic fertilizer are described in Section 10.2.2.

### 14.2.3 *Emission factor*

The emission estimates for farm-level operations are presented in Table 14.1.

*Table 14.1 Emission estimates for particulate matter from farm-level operations*

| Source category | $PM_{10}$ (ton/year) | $PM_{2.5}$(ton/year) |
|---|---|---|
| Inorganic fertilizers | 105.0 | 21.0 |
| Concentrates | 90.0 | 18.0 |
| Pesticides | 125.0 | 25.0 |

Source: Chardon and Van der Hoek (2002).

### 14.2.4 *Uncertainty*

Uncertainty values for the use of fertilizer, pesticide and feed are estimated at 25% (based on expert judgement). The use of rinsing liquid does not result in any emission of PM, as a liquid is involved. Uncertainty values for the emission estimates are estimated at 100% (based on expert judgement).

## 14.3 Source-specific aspects for PM emissions from crop cultivation

### 14.3.1 *Calculation method*

Emissions of PM from crop cultivation are calculated using a Tier 2 method. The area of each crop is multiplied by a specific emission factor. The total PM emissions from all crop sorts are then calculated by summing the PM emissions for each crop.

Crop cultivation is calculated using the following formula:

$$\text{PM emissions crop cultivation} = \Sigma \text{ area}_n \times \text{EF PM crop cultivation}_n \quad (14.1)$$

Where:

PM emissions crop cultivation: PM emissions (kg PM/year) from cultivated crops

$\text{Area}_n$ : Cropped area for the defined crop (n) (ha)

$\text{EF PM crop cultivation}_n$ : Emission factor (kg PM/ha) for the defined crop (n)

The emission factor in the aforementioned formula considers the following operations in wet climate conditions:

1. Soil cultivation
2. Harvesting
3. Cleaning
4. Drying

Emissions from haymaking have been calculated by multiplying production by an emission factor. Due to a high degree of uncertainty, however, the emissions are kept constant throughout the time series.

These emissions are reported under NFR category 3Dc (Farm-level agricultural operations, including the storage, handling and transport of agricultural products).

**Comparison to EMEP methodology**
The methodology described above conforms to the method of the EMEP Guidebook (EEA, 2023).

### *14.3.2 Activity data*
Information on the areas used for crop production is taken from the Agricultural Census. The production of haymaking is taken from Chardon and Van der Hoek (2002).

### *14.3.3 Emission factors*
For emissions arising during the tillage of crops, EMEP default emission factors are used (EEA, 2023). Haymaking has an additional estimate, as derived by Chardon and Van der Hoek (2002). An overview is presented in Table 14.2.

*Table 14.2 Emission factors (EF) for particulate matter (PM) from crops*

| Crop | EF $PM_{10}$ | EF $PM_{2.5}$ |
|---|---|---|
| Wheat | 3.7 | 0.212 |
| Barley | 3.14 | 0.168 |
| Rye | 2.78 | 0.149 |
| Oats | 4.56 | 0.251 |
| Other crops | 0.25 | 0.015 |
| | Added estimate (ton/year) | |
| Haymaking | 6.0 | 1.2 |

Source: Chardon and Van der Hoek (2002); EEA (2023).

### *14.3.4 Source-specific uncertainty*
The uncertainty values for areas are 5% per crop and 25% for haymaking (based on expert judgement). Uncertainty values for emission factors are 400% for crops (EEA, 2023) and 100% for haymaking (based on expert judgement).

## 14.4 Uncertainty estimates
An overview of all uncertainty values for the activity data, the implied emission factors and the emissions included in the categories of $PM_{10}$ and $PM_{2.5}$ emissions from crop production and agricultural soils is provided in Table 14.3.

*Table 14.3 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and $PM_{10}$ and $PM_{2.5}$ emissions (U emissions) from crop production and agricultural soils*

| EMEP | Source category | U AD | U IEF $PM_{10}$ | U emissions $PM_{10}$ | U IEF $PM_{2.5}$ | U emissions $PM_{2.5}$ |
|---|---|---|---|---|---|---|
| 3Da1 | Inorganic fertilizers | 25% | 100% | 106% | 100% | 106% |
| 3Dc | Farm-level agricultural operations | 25% | 100% | 106% | 100% | 106% |
| 3De | Cultivated crops | 2% | 225% | 225% | 222% | 222% |
| 3Df | Use of pesticides | 25% | 100% | 106% | 100% | 106% |

| EMEP | Source category | U AD | U IEF $PM_{10}$ | U emissions $PM_{10}$ | U IEF $PM_{2.5}$ | U emissions $PM_{2.5}$ |
|---|---|---|---|---|---|---|
| | Total, agricultural soils | | | 125% | | 94% |

# 15 $CO_2$ emissions from liming (CRT category 3G)

## 15.1 Scope and definition

Calcareous fertilizers (calcic limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) are used to reduce soil acidity. Emissions of $CO_2$ occur as carbonate lime dissolves and releases bicarbonate. Bicarbonate ($HCO_3^-$) dissolves into $H_2O$ and $CO_2$.

## 15.2 Source-specific aspects

### *15.2.1 Calculation method*

Emissions of $CO_2$ resulting from the use of lime on soils are determined for reporting in Table 3G of the CRF. The $CO_2$ emissions can be calculated according to the following Tier 1 method:

$$CO_2 \text{ emissions 3G} = (\text{limestone use} \times \text{EF } CO_2 \text{ limestone} + \text{dolomite use} \times \text{EF } CO_2 \text{ dolomite}) \times 44/12 \quad (15.1)$$

Where:

| | | |
|---|---|---|
| $CO_2$ emissions 3G | : | Carbon dioxide emissions (kg $CO_2$/year) from CRT Source Category 3G (Liming) |
| EF $CO_2$ limestone | : | Emission factor (kg $CO_2$-C/kg applied) for limestone |
| EF $CO_2$ dolomite | : | Emission factor (kg $CO_2$-C/kg applied) for dolomite |
| 44/12 | : | Conversion factor from $CO_2$-C to $CO_2$ |

### *15.2.2 Activity data*

Information on the amount of carbonate applied to soil originates from Wageningen Social & Economic Research. Input on the use of carbonate comes from industrial processing records and import/export data from retailers of lime fertilizers. As of 2016, the usage of the various types of inorganic N fertilizers is taken from the statistics on inorganic fertilizer statistics available from the FADN. The available figures are totals, and they do not specify application on grassland and cropland separately. Given that all C will eventually be emitted as $CO_2$, there is no need to derive separate emission factors. For this reason, totals are used.

### *15.2.3 Emission factors*

IPCC 2006 Tier 1 default values are used for the use of lime on soils (i.e. 0.12 kg $CO_2$-C/kg limestone and 0.13 kg $CO_2$-C/kg dolomite). These values translate to 440 kg $CO_2$/ton pure limestone and 477 kg $CO_2$/ton pure dolomite.

### *15.2.4 Uncertainty*

The uncertainty value for the use of limestone is 28%, and the uncertainty value for the use of dolomite is 49% (calculated from 25% in total use; based on expert judgement). The uncertainty value for both emission factors is 1% (based on expert judgement). This uncertainty is very low, as all C will ultimately be emitted as $CO_2$.

## 15.3 Uncertainty estimates

The uncertainty values for liming, implied emission factors and resulting $CO_2$ emissions are presented in Table 15.1.

*Table 15.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and $CO_2$ emissions (U emissions) from liming*

| IPCC | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| | Limestone | 28% | 1% | 28% |
| | Dolomite | 49% | 1% | 49% |
| 3G | Liming | | | 25% |

# 16 $CO_2$ emissions from urea application (CRT category 3H)

## 16.1 Scope and definition

Urea is applied to soils as an artificial nitrogen fertilizer. During and after the application, $CO_2$ is emitted as urea reacts with water and urease enzymes in the soil, breaking down into ammonium, hydroxyl ion and bicarbonate. The bicarbonate subsequently evolves into water and $CO_2$. The $CO_2$ emissions from this process were previously allocated to the production of urea, as the production of urea entails the removal of an equal amount of $CO_2$ from the atmosphere. However, the IPCC guidelines stipulate that the $CO_2$ emission should be allocated to the agriculture sector (IPCC, 2006).

## 16.2 Source-specific aspects

### *16.2.1 Calculation method*

Emissions of $CO_2$ resulting from the application of urea are determined for reporting in Table 3H of the CRT. The $CO_2$ emissions can be calculated according to the following Tier 1 method:

$$CO_2 \text{ emissions 3H} = M_{urea} \times EF\ CO_2\ urea \times 44/12 \qquad (16.1)$$

Where:

| | | |
|---|---|---|
| $CO_2$ emissions 3H | : | Carbon dioxide emissions (kg $CO_2$/year) from CRT source category 3H (Urea application) |
| $M_{urea}$ | : | Mass of urea (kg) |
| EF $CO_2$ urea | : | Emission factor (kg $CO_2$-C/kg applied) for urea |
| 44/12 | : | Conversion factor from $CO_2$-C to $CO_2$ |

### *16.2.2 Activity data*

Usage figures of urea are taken from the synthetic fertilizer statistics available from Wageningen Social & Economic Research. As of 2016 usage figures of urea application is derived from the statistics on inorganic fertilizer available from the FADN. Consistency between the two data sources has been verified and confirmed in terms of total nitrogen applied (Van Bruggen *et al.,* 2019). Urea fertilisers are often composed of urea and other nitrogen fertilisers. As there is no information on the composition of the urea fertilisers it is assumed that the entire solution is urea, this prevents an underestimation of emissions.

### *16.2.3 Emission factors*

IPCC 2006 Tier 1 default values are used for the application of urea (i.e. 0.2 kg $CO_2$-C/kg Urea). These values translate to 733 kg $CO_2$/ton Urea.

### *16.2.4 Uncertainty*

The uncertainty value for the use of inorganic fertilizer in agriculture is 25%. The uncertainty value for the emission factor is 1% (based on expert judgement). This uncertainty is very low, as all C will ultimately be emitted as $CO_2$.

## 16.3 Uncertainty estimates

The uncertainty values for urea application, implied emission factors and resulting $CO_2$ emissions are presented in Table 16.1.

*Table 16.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and $CO_2$ emissions (U emissions) from urea application*

| IPCC | Source category | U AD | U IEF | U emissions |
|---|---|---|---|---|
| 3H | Urea application | 25% | 1% | 25% |

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## Justification

This report is an account of the methods used for the calculation of emissions to air from agriculture in the Netherlands over the 1990-2024 period, as reported in the National Inventory Report 2026 (NIR; for greenhouse gases) and Informative Inventory Report 2026 (IIR; for air pollutants). With these annual reports, the Netherlands fulfils the reporting requirements of the Paris Agreement and Gothenburg protocols. Yearly, the results are published in Van Bruggen *et al.* (in Dutch).

Emissions are assessed with the National Emission Model for Agriculture (NEMA) which is approved by the independent Dutch Scientific Committee of the Manure Act (CDM). Statistics Netherlands (CBS) is the administrator of the NEMA model. The work is guided by the task force Agriculture and Land Use of the Pollutant Release and Transfer Register (PRTR, or 'Emissieregistratie' (ER) in Dutch). For greenhouse gas reporting, the Netherlands Enterprise Agency (RVO.nl) reviews proceedings acting as the National Inventory Entity (NIE).

The methodologies used follow or comply with the 2019 IPCC Guidelines (greenhouse gases) and the EMEP guidebook 2023 (air pollutants). The draft report was reviewed and approved by Natalie Bakker (RVO.nl) and Margreet van Zanten (PRTR).

# Annex 1 Calculation of TAN excretion for dairy cattle and young stock

Translation with adaptation of the annex from L. Šebek & A. Bannink (Division Animal Husbandry, Animal Sciences Group (ASG), WUR) in Velthof *et al.* (2009).

## A1.1 Introduction

Until 2009, the $NH_3$ emission is estimated by means of an emission percentage applied on total N excretion. It is however mainly the excretion of urine N that is responsible for the $NH_3$ emission. Therefore, the current aim is to estimate $NH_3$ emission based on excreted urine N. Excretion of urine N is comparable to that of total ammoniacal N (TAN). A description of the calculation method of TAN is given here.

## A1.2 Calculation method

The total N excretion is calculated in accordance with the method used by the WUM, also used by Tamminga et al. (2000; 2004), to derive the fixed excretion figures for various livestock categories. In this method the uptake of N with the separate ration components is calculated, and total N excretion as the difference between N uptake and N retained in animal products (milk, growth, offspring).
For the results reported in the present document, the same method was used but it was extended with an estimation of the digestion coefficient (DC) for crude protein (CP). Introduction of DC-CP is required to be able to calculate TAN. The calculation is performed for each feedstuff in the ration separately. With the DC-CP per feedstuff the percentage of crude protein uptake can be calculated that is absorbed by the intestine (= digested). The remainder (100% - DC-CP) of crude protein uptake leaves the body with the faeces. Protein absorbed by the intestine is either used for production (milk, growth and offspring) or excreted as urine N by the kidneys. By setting the TAN equal to the excretion of urine N, TAN is calculated by the following steps:

- Summation of the amount crude protein uptake that is absorbed in the intestine for all feedstuffs in the ration;
- Conversion of absorbed protein to absorbed N;
- Calculation of N retained with animal production;
- Calculation of excreted urine N as the difference between absorbed N and N retained with animal production.

### Calculation of the DC-CP

The CVB animal feed table (Centraal Veevoederbureau, 2005b) lists DC-CP values (as a % of crude protein content) for all common products. For roughages this is dependent on the quality of the roughage. Regression equations have been published to calculate the DC-CP based on chemical composition (crude protein content, crude ash content and crude crude fibre content; Centraal Veevoederbureau (2005a)). In Table A1.1 the DC-CP is given for the various ration components fed to young stock.

Faecal N digestibility of dairy is now calculated using the Tier 3 method because above method gives an overestimation. For young cattle above method is corrected using the difference calculated for dairy cattle.

## A1.3 Used data

The amounts of feed that has been provided yearly to the different livestock categories are according to the report of the Working group on Uniformity of Manure and mineral data (WUM). Also, data are available for milk production, and the composition of roughages (based on yearly statistics on analyses of silages by the laboratory Eurofins Agro (formerly Blgg and AgroXpertus), concentrates (based on reports of feed manufacturers) and by-products (based on amounts of products marketed). These figures are recently used and described by Smink *et al.* (2005) for the calculation of the methane emission of dairy cattle and the same data are used in the present study. For moisture-rich by-products it is assumed that these consisted of 25, 40 and 35% of brewers' grains, potato products and sugar beet pulp. This division compares well to the WUM report of the availability by-products for cattle (respectively 26, 35 and 26%; 30:40:30 ratio).

For young stock the WUM rations of 1990 have been used in accordance with the starting points in the available WUM excretion data. The composition of roughages and concentrates was assumed equal to that of dairy cattle in the year 2001.

*Table A1.1 The CP content, the ammonia content and the faecal CP digestibility for the various ration components in the ration of young stock*

| | **CP content[1)]** | **Ammonia content** | **DC-CP[2)]** |
|---|---|---|---|
| | **g CP/kg DM** | **% CP** | **%** |
| Fresh grass / grass herbage | 229 | 0 | 85 |
| Grass silage (+ hay) | 191 | 10 | 77 |
| Maize silage | 81 | 10 | 50 |
| Standard concentrate | 180 | 0 | 70 |
| Protein-rich concentrate | 330 | 0 | 82 |
| By-products[3)] | | | |
| Brewers' grains | 250 | 0 | 80 |
| Potato pulp | 85 | 0 | 36 |
| Pressed sugar beet pulp | 115 | 0 | 65 |
| Whole milk | 35 | 0 | 86 |

1) Including ammonia N.
2) Concerns an estimation of the real instead of apparent digestibility of crude protein.
3) Only most abundant product in the category mentioned here (brewers' grains for category protein-rich by-products, potato pulp for category of rest material potato processing industry, pressed sugar beet pulp for category of pulps and vegetables).

## A1.4 Other starting points/assumptions

*Correction CP content for ammonia fraction.* It was assumed that ammonia N (expressed as CP) accounted for 10% of the total CP content in both grass silage and maize silage.

*Correction feed uptake for so-called "feed losses".* For the time being no corrections have been made for feed losses because these also seem not to have been made in the calculation of the N excretions in WUM. If the corrections in the feeding of dairy cattle according to the current WUM methodology (0, 5, 3 and 2% feed losses for respectively fresh grass, grass silage, maize silage, moist by-products and concentrates) were to be made this would lead to much lower N excretions than the reported 131.0 kg N/dairy cow/year according to WUM.

*Composition urine N.* For the time being 100% of the urine N is considered as TAN and no differentiation is made between N holding components that do not (quickly) lead to ammonia formation (Reijs, 2007).

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# Annex 2 Calculation of TAN excretion for pigs

Translation with adaptation of the annex from Age Jongbloed (Animal Sciences Group (ASG), Wageningen UR, Lelystad) in Velthof *et al.*, 2009.

## A2.1 The excretion of nitrogen in pig farming

### *A2.1.1 Nitrogen content in pigs*

In Table A2.1 is indicated what the N contents (g per kg live weight) are in the livestock categories distinguished. Also, the sources are indicated.

*Table A2.1 N contents in livestock categories distinguished (Ref. = reference year)*

| Livestock category | Physiological status | Ref. | Weight Ref. (kg) | N content Ref. | Weigh t 2005 (kg) | N content 2005 (g/kg) | Source contents Ref. |
|---|---|---|---|---|---|---|---|
| Stillborn piglet | 0 days | 1994 | 1.3 | 19.2 | 1.3 | 18.73 | 1 |
| Lost piglet | 1-28 days | 1994 | 2.8 | 19.2 | 2.8 | 23.1 | 1 |
| Lost piglet | 29-42 days | 1994 | 9.0 | 24.0 | 9.0 | 24.3 | 1 |
| Weaned piglet | 6 weeks | 1994 | 11.0 | 24.0 | 11.0 | 24.4 | 1 |
| Lost piglet | 7 weeks | 1994 | 12.0 | 24.0 | 12.0 | 24.5 | 1 |
| Starter piglet | Ca. 10 weeks | 1991 | 25.7 | 24.0 | 25.6 | 24.8 | 1 |
| Fattening pig | Ca. 26 weeks | 1991 | 109 | 23.0 | 115.7 | 25.0 | 1 |
| Gilts | 7 months | 2001 | 125 | 24.9 | 125 | 24.9 | 2 |
| Gilts | First mating | 2001 | 140 | 24.9 | 140 | 24.9 | 2 |
| Young boar | 7 months | 2001 | 135 | 24.9 | 135 | 24.9 | 2 |
| Boar | 7 months | 1991 | 130 | 23.3 | - | - | 1 |
| Boar | 2 years | 1991 | 300 | 24.6 | 325 | 25.0 | 1 |
| Sow | At weaning | 1994 | 205 | 24.9 | 220 | 25.0 | 1 |
| Slaughter sow | 1 week after weaning piglets | 1994 | 205 | 24.9 | 220 | 25.0 | 1 |

1 = WUM, 1994; 2 = Jongbloed and Kemme, 2002.

### *A2.1.2 The N content and the N digestibility of pig feeds*

In Table A2.2 an overview is given of the N contents in the various pig feeds with which calculations have been made.

The N content in the various feeds in the reference year is for an important part derived from WUM (1994) for the year concerned and for the reference year 2001 from Jongbloed and Kemme (2005). The N content in the feeds for 2005 is for most feeds derived from Jongbloed and Van Bruggen (2008).

*Table A2.2 Overview of the N contents and the N digestibility (DC-N) in the various pig feeds for the reference year and 2005*

| | **Reference year** | | | **2005** | |
|---|---|---|---|---|---|
| | **Year** | **N (g/kg)** | **DC-N (%)** | **N (g/kg)** | **DC-N (%)** |
| Piglet rearing feed/weaning feed | 1994 | 29.0 | 83.0 | 28.8 | 83.0 |
| Piglet feed (12-26 kg) | 1994 | 29.0 | 83.0 | 28.8 | 83.0 |
| Starting feed (26-40 kg) | 1991 | 28.2 | 81.9 | 25.2 | 81.0 |
| Starting feed gilts/young boars (26-40 kg) | 2001 | 27.1 | 81.0 | 27.1 | 81.0 |
| Fattening pig feed (40-110 kg) | 1991 | 26.0 | 80.1 | 25.2 | 78.6 |
| Gilts/young boars feed (40-125 kg) | 2001 | 24.5 | 80.5 | 25.2 | 78.0 |
| Standard sow feed | 1991 | 25.7 | 79.0 | - | - |
| Standard sow feed | 1994 | 25.4 | 79.0 | - | - |
| Lactating sow feed | 1991 | 24.6 | 80.0 | 25.2 | 78.0 |
| Lactating sow feed | 1994 | - | - | 25.2 | 78.0 |
| Lactating sow feed | 2001 | 24.5 | 80.0 | 25.2 | 78.0 |
| Sow in pig feed | 1994 | - | - | 21.9 | 66.2 |

### *A2.1.3 Estimation of the N digestibility in the feeds*

The digestibility of N in the feeds is for the reference year based on some publications in which the resource composition of feeds was given. On enquiry with several composite feed companies no information on this was available as it is stored for only five or six years. The digestibility of N is estimated based on the given digestibilities for those according to the Animal feed table (CVB, 2007). Unfortunately, only sporadic information was available of the resource composition of the feeds that were produced in 2005. In the same way as above the N digestibility was estimated. There where data were missing based on consultation with some specialists within and outside ASG a best possible estimation of the N digestibility was made.

## A2.2 Breeding sows with piglets up to ca. 6 weeks of age (category 400)

### *A2.2.1 Starting points*

The start weight of the sows for 1994 and for 2005 is set to 140 kg and the end weight is for 1994 and 2005 set to 205 respectively 220 kg. Based on Agrovision (1994, 2005) for 1994 calculations can be made with a farm litter index of 2.25 and for 2005 of 2.31.

The replacement of sows amounted 47% in 1994 and in 2005 this was 45% (Agrovision, 1994; 2005). According to Agrovision (1994) a breeding sow of which the piglets are weaned at 4 weeks, takes up 1,079 kg of feed per year in 1994; in 2005 that is 1,145 kg, of which circa 65% as sow in pig feed and 35% as lactating sow feed.

The number of live born piglets per litter is according to Agrovision (1994) on average 10.9 and in 2005 the number of live born piglets per litter is 12.0. The number stillborn piglets per litter was in 1994 and 2005 0.7 respectively 1.0 (Agrovision, 1994; 2005).

The weight of piglets on 42 days is 11.0 kg in 1994 and 10.8 kg in 2005. The feed uptake of piglets up to day 42 after birth is set to 4.5 kg in 1994 (Backus *et al.*, 1997) and 4.48 kg in 2005. This amount is in vast majority weaning feed.

The N content of the weaning feed in 1994 was 29.0 g/kg and in 2005 28.8 g/kg. The N digestibility in the weaning pellet is derived from the feed composition according to Kloosterman and Huiskes (1992) and was 83.3%; for 2005 83.0% is taken. The sow feed in 1994 contained 25.4 g N/kg (WUM, 1994), while in 2005 the feed for sows with piglets and lactating sow feed contained 21.9 respectively 25.2 g N/kg (Jongbloed and Van Bruggen, 2008). The N digestibility of the sow feed in 1994 is estimated based on the feed composition according to Everts *et al.* (1991) and was 79.0%. The N digestibility of the feed for sows with piglets is derived from the feed composition of a composite feed manufacturer during the first half of 2006 and was 66.2%. According to another composite feed manufacturer in 2005 the N digestibility of lactating sow feed was 78.0%.

### *A2.2.2 Results breeding sows with piglets up to ca. 6 weeks of age*

In Table A2.3 is based on above mentioned starting points for breeding sows with piglets up to ca. 6 weeks of age an overview given of the nitrogen balance if a sow place would be occupied the whole year (no days lost).

*Table A2.3 Nitrogen balance (kg) in breeding sows with piglets up to ca. 6 weeks of age on yearly basis (category 400)*

| **Category 400** | **1994** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (kg)** | **g N/kg** | **DC-N** | **N uptake (kg)** |
| Weaning feed | 29.0 | 83.3 | 2.71 | 28.8 | 83.0 | 3.15 |
| Feed for sows with piglets | 25.4 | 78.9 | 17.81 | 21.9 | 66.2 | 16.15 |
| Lactating sow feed | 25.4 | 78.9 | 9.59 | 25.2 | 78.0 | 10.27 |
| Total uptake | | | 30.12 | | | 29.57 |
| Fixation | | | 7.13 | | | 7.71 |
| Excretion | | | 22.98 | | | 21.86 |
| In faeces | | | 6.2 | | | 8.3 |
| In urine | | | 16.8 | | | 13.6 |
| In urine (%) | | | 72.9 | | | 62.2 |

Table A2.3 shows that the N excretion per sow per year compared to 1994, in 2005 has decreased by over 1.0 kg and that there has been a large shift towards much more N in the faeces and much less in the urine. The percentage of the N excretion in the urine decreased from 72.9 to 62.2. This shift is mostly due to the introduction of a feed for sows with piglets that has to contain much raw fibre in the framework of the Pig decree (1994).

## A2.3 Breeding sows with piglets up to ca. 25 kg (category 401)

### *A2.3.1 Starting points*

For data of the breeding sows is referred to the previous section (the description for category 400). The weight of piglets by the start of fattening is according to Agrovision (1994; 2005) 25.7 kg in 1994 and 25.6 kg in 2005. The age at the start of fattening is on average 80 days. The amount of weaning feed taken up per piglet is 4.5 kg. Based on a feed conversion of 1.65 a piglet takes up 30.0 kg of feed before start of fattening in 1994 and in 2005 feed conversion is 1.59 so that per piglet 28.7 kg of feed is taken up (Agrovision, 1994; 2004).

The N contents of the piglet feed in 1994 and 2005 were 29.0 respectively 28.8 g/kg. The N digestibility of the piglet feed in 1994 is derived from the feed compositions according to Kloosterman and Huiskes (1992) and was 83.3%; for 2005 83.0% is taken.

## A2.4 Results breeding sows with piglets up to ca. 25 kg

In Table A2.4 is based on abovementioned assumptions for breeding sows with piglets up to ca. 25 kg an overview given of the nitrogen balance if a sow place would be occupied the whole year (no days lost).

*Table A2.4 N uptake and N excretion (kg) by breeding sows with piglets up to ca. 25 kg on yearly basis (category 401)*

| Category 401 | 1994 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N | N uptake (kg) | g N/kg | DC-N | N uptake (kg) |
| Weaning feed | 29.0 | 83.3 | 2.71 | 28.8 | 83.0 | 3.16 |
| Piglet feed | 29.0 | 83.3 | 15.38 | 28.8 | 83.0 | 16.71 |
| Feed for sows with piglets | 25.4 | 78.9 | 17.81 | 21.9 | 66.2 | 16.15 |
| Lactating sow feed | 25.4 | 78.9 | 9.59 | 25.2 | 78.0 | 10.27 |
| Total uptake | | | 45.49 | | | 46.30 |
| Retention | | | 14.11 | | | 16.53 |
| Excretion | | | 31.38 | | | 29.77 |
| In faeces | | | 8.8 | | | 11.1 |
| In urine | | | 22.6 | | | 18.7 |
| In urine (%) | | | 71.9 | | | 62.7 |

### A2.4.1 *Discussion breeding sows*

Table A2.3 shows that the N excretion per sow per year compared to 1994, decreased with over 1.5 kg in 2005 and that there has been a large shift towards much more N in the faeces and much less in the urine. The percentage of the N excretion in the urine has declined from 71.9 to 62.7. This shift is mainly due to the introduction of a sow in pig feed that has to contain much raw fibre in the framework of the Pig decree (1994).

It has been examined what the effect is on the excretion in faeces and urine if the N digestibility is 1% unit higher or lower. Table A2.5 gives the results of this.

*Table A2.5 N uptake and N excretion (kg) by breeding sows with piglets up to ca. 25 kg on yearly basis (category 401) with a higher or lower N digestibility*

| Category 401 | 1994 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher |
| Total uptake | 45.49 | 49.49 | 45.49 | 46.30 | 46.30 | 46.30 |
| Excretion | 31.38 | 31.38 | 31.38 | 29.77 | 29.77 | 29.77 |
| In faeces | 9.26 | 8.80 | 8.35 | 11.56 | 11.10 | 10.63 |
| In urine | 22.12 | 22.58 | 23.03 | 18.21 | 18.67 | 19.14 |
| In urine (%) | 70.5 | 71.9 | 73.4 | 61.2 | 62.7 | 64.3 |

From Table A2.5 follows that as a result of a difference in N digestibility of 2% units a shift of on average 3.0% units will occur.

## A2.5 Gilts not yet in pig of ca. 25 kg to ca. 7 months (category 402)

### *A2.5.1 Starting points*

The start and end weight of the gilts not yet in pig for both 2002 is set to 26 respectively 125 kg. This end weight is derived from Jongbloed and Kemme (2005). The average length of the period is calculated to be 133 days, such that the average growth is 744 g/day. In 2002 the ratio between the starting feed and rearing feed for gilts not yet in pig is set to 15:85 (Jongbloed and Kemme, 2005). The total amount of feed during the lay on period for this category of gilts not yet in pig is 287 kg for 2002. For 2005 the same starting points as for 2002 are taken. The N contents of the starting feed and rearing feed in 2002 were 27.1 respectively 24.5 g/kg. For 2005 these contents are 27.1 respectively 25.2 g/kg. The N digestibility of the starting feed is set to 81.0 and of the rearing feed to 78.0 which is equal to the N digestibility of the lactating sow feed.

### *A2.5.2 Results gilts not yet in pig of 25 kg to ca. 7 months*

In Table A2.6 is based on abovementioned starting points for gilts not yet in pig to ca. 7 months an overview given of the nitrogen balance if a pig place would be occupied the whole year (no lost days).

*Table A2.6 N uptake and excretion (kg) by gilts not yet in pig of 25 kg to ca. 7 months on yearly basis (category 402)*

| Category 402 | 2001 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N | N uptake (kg) | g N/kg | DC-N | N uptake (kg) |
| Starting feed | 27.1 | 81.0 | 4.27 | 27.1 | 81.0 | 4.27 |
| Lactating sow feed | 24.5 | 80.0 | 15.44 | 25.2 | 78.0 | 15.88 |
| Total uptake | | | 19.71 | | | 20.15 |
| Retention | | | 6.77 | | | 6.77 |
| Excretion | | | 12.93 | | | 13.38 |
| In faeces | | | 3.9 | | | 4.3 |
| In urine | | | 9.0 | | | 9.1 |
| In urine (%) | | | 69.9 | | | 67.8 |

Table A2.6 shows that the N excretion per gilt not yet in pig compared to 2001 decreased somewhat in 2005 and that there has been a shift to more N in the faeces. The percentage of the N excretion in the urine has decreased from 69.9 to 67.8.

## A2.6 Gilts not yet in pig of ca. 7 months to first mating (category 403)

### *A2.6.1 Starting points*

The start and end weight of these gilts not yet in pig for both 2002 and 2006 is set to 125 respectively 140 kg (Topigs, 2004). According to this reference it follows that the age at first insemination on average is 243 days, thus the average length of the period can be set to 30 days in 2001 and 2005. The average growth is 500 g/day.

The total amount of the lactating sow feed during the lay on period for this category gilts not yet in pig, is calculated to 72 kg for 2001 and 2005.

The N contents of the lactating sow feed in 2001 and 2005 are 24.5 respectively 25.2 g/kg. The N digestibility of the lactating sow feed is 80.0 respectively 78.0%.

### *A2.6.2 Results gilts not yet in pig of ca. 7 months to first mating*

In Table A2.7 is based on abovementioned starting points for this category gilts not yet in pig an overview given of the N excretion if a pig place would be occupied for the whole year (no loss of days).

*Table A2.7 N uptake and excretion (kg) by gilts not yet in pig of ca. 7 months to first mating on yearly basis (category 403)*

| **Category 403** | **2001** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (kg)** | **g N/kg** | **DC-N** | **N uptake (kg)** |
| Lactating sow feed | 24.5 | 80.0 | 21.46 | 25.2 | 78.0 | 22.08 |
| Fixation | | | 4.54 | | | 4.54 |
| Excretion | | | 16.92 | | | 17.53 |
| In faeces | | | 4.3 | | | 4.9 |
| In urine | | | 12.6 | | | 12.7 |
| In urine (%) | | | 74.6 | | | 72.3 |

Table A2.7 shows that the N excretion per gilt not yet in pig compared to 2001 increased somewhat in 2005 and that there has been a shift to more N in the faeces. The percentage of the N excretion in the urine decreased from 74.6 to 72.3%.

## A2.7 Gilts not yet in pig of ca. 25 kg to first mating (category 404)

### *A2.7.1 Starting points*

The begin and end weight of the gilts not yet in pig for both 2001 and 2005 is set to 26 respectively 140 kg (for more details see the description for categories 402 and 403). The average length of the period is calculated to 163 days, so that the average growth is 699 g/day. In 2002 the ratio between the starting feed, rearing feed and lactating sow feed for gilts not yet in pig during the lay on period is set to 16:64:20, and for 2006 to 4:76:20 (Jongbloed and Kemme, 2005). The total amount of feed during the lay on period for this category gilts not yet in pig for 2001 and 2005 is 359 kg. For 2005 further the same starting points as for 2001 are taken.

The N contents of the starting feed, gilts not yet in pig feed and lactating sow feed in 2001 were 27.1, 24.5 respectively 24.5 g/kg. For 2005 the contents in these feeds are 27.1, 25.2 respectively 25.2 g/kg. The N digestibility of the feeds in 2001 is set to 81.0, 80.5 respectively 80.0%, while those for 2005 were 81.0%, 79.0% respectively 79.0%.

*A2.7.2 Results gilts not yet in pig of 25 kg to first mating*

In Table A2.8 is based on abovementioned starting points for gilts not yet in pig an overview given of the nitrogen balance if a pig place were to be occupied the whole year (no loss of days).

*Table A2.8 N uptake and excretion (kg) by gilts not yet in pig of 25 kg to first mating on yearly basis (category 404)*

| **Category 404** | **2001** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (kg)** | **g N/kg** | **DC-N** | **N uptake (kg)** |
| Starting feed | 27.1 | 81.0 | 3.49 | 27.1 | 81.0 | 3.49 |
| Gilts not yet in pig feed | 24.5 | 80.5 | 12.61 | 25.2 | 78.0 | 15.40 |
| Lactating sow feed | 24.5 | 80.0 | 3.94 | 25.2 | 78.0 | 1.62 |
| Total uptake | | | 20.03 | | | 20.50 |
| Fixation | | | 6.36 | | | 6.36 |
| Excretion | | | 13.67 | | | 14.14 |
| In faeces | | | 3.9 | | | 4.4 |
| In urine | | | 9.8 | | | 9.7 |
| In urine (%) | | | 71.4 | | | 68.8 |

Table A2.8 shows that the N excretion per gilt not yet in pig per year compared to 2001 increased somewhat in 2005 and that a shift occurred to more N in the faeces. The percentage of the N excretion in the urine has decreased from 71.4 to 68.8%.

## A2.8 Young boars of ca. 25 kg to ca. 7 months (category 405)

*A2.8.1 Starting points*

The start and end weight of the young boars for both 2001 as 2005 is set to 26 respectively 135 kg. The average length of the period is 133 days in 2001 and 2005, so that the average growth per animal per day is 820 grams. In 2001 and 2005 the feed conversion of this category pigs is 2.66. In 2001 and also 2005 during the lay on period a ratio between starting feed, growth feed and finishing feed of 15:20:65 is taken (Jongbloed and Kemme, 2005). This ratio is applied on the total amount of feed (290 kg).

The N contents of the starting feed, growth feed and finishing feed in 2001 were 27.1, 24.5 respectively 25.7 g/kg. These contents in 2005 were 27.1, 25.2 respectively 25.2 g/kg.
The N digestibility of the feeds was in 2001 81.0%, 80.5% respectively 80.5% and in 2005 81.0%, 78.0% respectively 81.0%.

*A2.8.2 Results young boars*

In Table A2.9 is based on abovementioned starting points for young boars an overview given of the nitrogen balance if a pig place were to be occupied the whole year (no loss of days).

*Table A2.9 N uptake and excretion (kg) by young boars to ca. 7 months on yearly basis (category 405)*

| **Category 405** | **1991** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (kg)** | **g N/kg** | **DC-N** | **N uptake (kg)** |
| Starting feed | 27.1 | 81.0 | 3.24 | 27.1 | 81.0 | 3.24 |
| Lactating sow feed | 24.5 | 80.5 | 16.57 | 25.2 | 78.0 | 17.05 |
| Total uptake | | | 19.81 | | | 20.28 |
| Fixation | | | 7.46 | | | 7.45 |
| Excretion | | | 12.35 | | | 12.83 |
| In faeces | | | 3.8 | | | 4.4 |
| In urine | | | 8.5 | | | 8.5 |
| In urine (%) | | | 68.9 | | | 66.0 |

Table A2.9 shows that the N excretion per young boar per year compared to 2001 increased somewhat in 2005 and that a shift occurred toward more N in the faeces. The percentage of the N excretion in the urine decreased from 68.9 to 66.0%.

## A2.9 Breeding boars of ca. 7 months and older (category 406)

### *A2.9.1 Starting points*

The start and end weight of the breeding boars for 1991 is set to 130 kg respectively 300 kg, for 2005 these weights are 135 kg respectively 325 kg. The average length of the period that these breeding boars are present is 548 days (WUM, 1994) which is also taken for 2005. The average feed uptake in 1991 is set to 2.9 kg/day (WUM, 1994) and in 2005 3.0 kg/day (Jongbloed and Kemme, 2005).

The N content of the feed that is given to breeding boars (sow feed) was in 1991 25.7 g/kg and in 2005 the lactating sow feed contained 25.2 g/kg. The N digestibility in the sow feed was in 1991 and 2005 78.9% respectively 78.0%.

### *A2.9.2 Results breeding boars older than 7 months*

In Table A2.10 is based on abovementioned assumptions for breeding boars an overview given of the nitrogen balance if a pig place would be occupied the whole year (no loss of days).

*Table A2.10 N uptake and excretion (kg) by breeding boars of 7 months and older on yearly basis (category 406)*

| Category 406 | 1991 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N | N uptake (kg) | g N/kg | DC-N | N uptake (kg) |
| Lactating sow feed | 25.7 | 78.9 | 27.20 | 25.2 | 78.0 | 27.59 |
| Fixation | | | 2.90 | | | 3.18 |
| Excretion | | | 24.30 | | | 24.42 |
| In faeces | | | 5.7 | | | 6.1 |
| In urine | | | 18.6 | | | 18.3 |
| In urine (%) | | | 76.4 | | | 75.1 |

Table A2.10 shows that the N excretion per breeding boar compared to 1991 remained almost the same in 2005 and that a shift has occurred towards more N in the faeces. The percentage of the N excretion in the urine has decreased from 76.4 to 75.1%.

## A2.10 Piglets of ca. 6 weeks to ca. 25 kg (category 407)

### *A2.10.1 Starting points*

The start and end weight of the piglets for 1994 was 11.0 respectively 25.7 kg. For 2005 the weights are set to 10.8 respectively 25.6 kg. The average length of the period is 33 respectively 38 days. The average growth is for 1994 and 2005 445 respectively 389 g per animal per day. The feed conversion of this category piglets in 1994 was 1.74 and is 1.72 in 2005. The N content of the piglet feed is 1994 was 29.0 and in 2005 this content was 28.8 g/kg. The N digestibility of the piglet feed is in 1994 and 2005 83.0%.

### *A2.10.2 Results piglets of 6 weeks to 25 kg*

In Table A2.11 is based on abovementioned assumptions for piglets of 6 weeks to ca. 25 kg an overview given of the nitrogen balance as a pig place would be occupied the whole year (no loss of days).

*Table A2.11 N uptake and excretion (kg) by piglets of 6 weeks to ca. 25 kg on yearly basis (category 407)*

| Category 407 | 1994 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N | N uptake (kg) | g N/kg | DC-N | N uptake (kg) |
| Uptake piglet feed | 29.0 | 83.0 | 8.18 | 28.8 | 83.0 | 7.04 |
| Fixation | | | 3.92 | | | 3.56 |
| Excretion | | | 4.26 | | | 3.48 |
| In faeces | | | 1.4 | | | 1.2 |
| In urine | | | 2.9 | | | 2.3 |
| In urine (%) | | | 67.3 | | | 65.6 |

Table A2.11 shows that the N excretion per weaned piglet of 6 weeks to ca. 25 kg per year compared to 1994 decreased considerably in 2005 and that considerably less N is excreted through the urine. The percentage of the N excretion in the urine decreased from 67.3 to 65.6%.

## A2.11 Sows for slaughter (category 410)

### *A2.11.1 Starting points*

The start and end weight of the sows for slaughter in 1994 is 205 kg and for 2005 220 kg. The average length of the period kept is 7 days. It is assumed that in both years per day 3 kg lactating sow feed is taken up.

The N content of the sow feed in 1994 was 24.5 g/kg and of the lactating sow feed in 2005 25.2 g/kg. The N digestibility of these feeds was 78.9 respectively 78.0%.

### *A2.11.2 Results sows for slaughter*

In Table A2.12 is based on abovementioned assumptions for sows for slaughter an overview given of the nitrogen balance if a pig place would be occupied the whole year (no loss of days).

*Table A2.12 N uptake and excretion (kg) by sows for slaughter of 220 kg on yearly basis (category 410)*

| Category 410 | 1994 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N | N uptake (kg) | g N/kg | DC-N | N uptake (kg) |
| Uptake sow feed | 24.5 | 78.9 | 26.83 | 25.2 | 78.0 | 27.59 |
| Fixation | | | 0.0 | | | 0.0 |
| Excretion | | | 26.83 | | | 27.59 |
| In faeces | | | 5.7 | | | 6.1 |
| In urine | | | 21.2 | | | 21.5 |
| In urine (%) | | | 78.9 | | | 78.0 |

Table A2.12 shows that the N excretion per sow for slaughter per year compared to 1994 remained almost equal in 2005 and that the percentage of the N excretion in the urine decreased somewhat from 78.9 to 78.0%.

## A2.12 Fattening pigs of ca. 25 to ca. 110 kg (category 411)

### *A2.12.1 Starting points*

The start and end weight of the pigs in 1991 is set to 25 respectively 109 kg (WUM, 1994). In 2005 these weights are 25.6 respectively 115.7 kg (Agrovision, 2005). The average growth per animal per day was 712 g in 1991 (WUM, 1994) and in 2005 that was 773 g (Agrovision, 2005). The length of the growth period was therefore 118 respectively 117 days. The feed conversion of the fattening pigs was 2.87 in 1991 and in 2005 that was 2.67. In 1991 during the first part of the lay on period an average amount of 44 kg starting feed and 197 kg fattening pig feed was given (WUM, 1994). In 2005 45 kg starting feed per pig was taken up, 70 kg growth feed and 126 kg finishing feed (Agrovision, 2005). The N content of the starting feed and fattening pig feed in 1991 was 28.2 respectively 26.0 g/kg. For 2005 these contents in the feeds are on average 25.2 g/kg (Jongbloed and Van Bruggen, 2008). The N digestibility of the starting feed in 1991 is estimated based on the raw material composition according to Van der Peet-Schwering (1990) and Kloosterman and Huiskes (1992) and was on average 81.9%. The N digestibility of the fattening pig feed in 1991 is estimated based on the raw material composition according to Van der Peet-Schwering (1990), Kloosterman and Huiskes (1992) and Wahle and Huiskes (1992) and was on average 80.1%.

The N digestibility of the starting feed in 2005 is estimated based on the starting point that as result of the addition of amino acids and somewhat different raw materials, so that it is ca. 1% unit lower than in 1991 and thus 81.0% is assumed. The N digestibility of the fattening pig feed in 2005 is estimated based on the raw material composition of a composite feed manufacturer in the first half year of 2006 and was on average 78.6% of the feeds with an energy value of 1.05 and 1.10.

### *A2.12.2 Results fattening pigs*

In Table A2.13 is based on abovementioned starting points for fattening pigs an overview given of the nitrogen balance if a pig place would be occupied during the whole year (no lost days).

*Table A2.13 N uptake and excretion (kg) by fattening pigs of ca. 25 to 114 kg on yearly basis (category 411)*

| **Category 411** | **1991** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (kg)** | **g N/kg** | **DC-N** | **N uptake (kg)** |
| Starting feed | 28.2 | 81.9 | 3.83 | 25.2 | 81.0 | 3.55 |
| Fattening pig feed | 26.0 | 80.1 | 15.83 | 25.2 | 78.6 | 15.43 |
| Total uptake | | | 19.66 | | | 18.98 |
| Fixation | | | 5.97 | | | 7.07 |
| Excretion | | | 13.70 | | | 11.91 |
| In faeces | | | 3.8 | | | 4.0 |
| In urine | | | 9.8 | | | 7.9 |
| In urine (%) | | | 71.9 | | | 66.6 |

### *A2.12.3 Discussion fattening pigs*

Table A2.13 shows that the N excretion per fattening pig per year compared to 1991 decreased considerably in 2005. As result of the higher N retention the percentage of the N excretion in the urine decreased considerably from 71.9 to 66.6%.

For fattening pigs is examined what the effect is on the excretion in faeces and urine if the digestibility of N in the feeds for fattening pigs is 1% unit lower or higher than in the starting situation (Table A2.14).

*Table A2.14 N uptake and excretion (kg) by fattening pigs of ca. 25 to 114 kg on yearly basis (category 411) at a higher or lower N digestibility*

| **Category 411** | **1991** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **DC-N 1 unit lower** | **DC-N starting point** | **DC-N 1 unit higher** | **DC-N 1 unit lower** | **DC-N starting point** | **DC-N 1 unit higher** |
| Total uptake | 19.66 | 19.66 | 19.66 | 18.98 | 18.98 | 18.98 |
| Excretion | 13.70 | 13.70 | 13.70 | 11.91 | 11.91 | 11.91 |
| In faeces | 4.04 | 3.84 | 3.65 | 4.17 | 3.98 | 3.79 |
| In urine | 9.65 | 9.85 | 10.05 | 7.75 | 7.94 | 8.13 |
| In urine (%) | 70.5 | 71.9 | 73.4 | 65.0 | 66.6 | 68.2 |

From Table A2.14 it can be seen that in the dependability of the digestibility of N with a deviation of 2% units, no large shifts occur in the division of N over faeces and urine; this is a difference of 2.9% units in 1991 and 3.2% units in 2005.

## A2.13 General discussion

An important attention point is a good insight in the N contents of the various feeds. Also, because the use of a whole range of feeds for various categories pigs it is sometimes difficult to know how long those feeds are given. However, by means of data from Levies Office (Bureau Heffingen) that insight can be obtained for some important feeds but are lacking for small livestock categories. This needs to receive more attention.

Another point is the N digestibility. Also because of a storage period of five to six years, data on this are lacking in the compound feed industry particularly for the reference years (1991 to 2002). The N digestibility also is not of interest in the formation of the feeds: for protein this is based on ileal or faecal digestible amino acids. Also, for the year 2005 it was not possible to gain a reliable insight in the N digestibility. Besides there is such a large array of feeds that it is difficult to classify these correctly. It is hard for the compound feed industry to calculate these data, and possibly competition is a reason not to make these available after all. Ways should be found to obtain more reliable data on the N digestibility in the feeds.

## A.2.14 Summary pigs

In Table A2.15 a summary is given of the excretion of N and % TAN by various categories of pigs in the reference year and in 2005 in g/year.

*Table A2.15 Overview of the excretion of N and % TAN by the various categories of pigs in the reference year and 2005 (kg/year)*

| Category | Number | Ref. year | N in ref. year | % TAN in ref. year | N in 2005 | % TAN in 2005 |
|---|---|---|---|---|---|---|
| Breeding sows with piglets up to 6 weeks of age | 400 | 1994 | 23.0 | 72.9 | 21.9 | 62.2 |
| Breeding sows with piglets to ca. 25 kg | 401 | 1994 | 31.4 | 71.9 | 29.8 | 62.7 |
| Gilts not yet in pig of ca. 25 kg to ca. 7 months | 402 | 2001 | 12.9 | 69.9 | 13.4 | 67.8 |
| Gilts not yet in pig of ca. 7 months to first mating | 403 | 2001 | 16.9 | 74.6 | 17.5 | 72.3 |
| Gilts not yet in pig of ca. 25 kg to ca. 7 months | 404 | 2001 | 13.7 | 71.4 | 14.1 | 68.8 |
| Young boars of ca. 25 kg to ca. 7 months | 405 | 1991 | 12.4 | 68.9 | 12.8 | 66.0 |
| Breeding boars of ca. 7 months and older | 406 | 1991 | 24.3 | 76.4 | 24.4 | 75.1 |
| Piglets of ca. 6 weeks to ca. 25 kg | 407 | 1991 | 4.3 | 67.3 | 3.5 | 65.6 |
| Sows for slaughter | 410 | 1994 | 27.8 | 78.9 | 27.6 | 78.0 |
| Fattening pigs | 411 | 1991 | 13.7 | 71.9 | 11.9 | 66.6 |

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# Annex 3 Calculation of TAN excretion for poultry

Translation with adaptation of the annex from Age Jongbloed (Animal Sciences Group (ASG), WUR, Lelystad) in Velthof *et al.*, 2009.

## A3.1 The excretion of nitrogen in the poultry sector

For the approach followed reference can be made to section A2.1.2 and A2.1.3 (see Annex 2).

### *A.3.1.1 Contents of nitrogen in chickens and chicken eggs*

In Table A3.1 is indicated what are the N contents (g per kg live weight or per kg produce) for the livestock categories distinguished. Also the references are indicated. The start weight of day-old chickens for respectively the meat sector and the laying sector is set to 42 and 36 g in these calculations.

*Table A3.1 Weights and contents of N in various categories of chickens (Ref. = reference year)*

| Livestock category | Physiological status | Ref. | Weight Ref. (g) | N content Ref. (g/kg) | Weight 2005 (g) | N content 2005 (g/kg) | Literature contents |
|---|---|---|---|---|---|---|---|
| Egg meat sector | - | 1993 | 62 | 19.2 | 62 | 19.3 | 1 |
| Day-old chicken meat | 1 day | | 42 | 30.4 | 42 | 30.4 | 3 |
| Broiler | Delivery | 2002 | 2,100 | 27.8 | 2,200 | 27.8 | 2 |
| Broiler mother breeder | 19 weeks | 2000 | 2,000 | 33.4 | 2,000 | 33.4 | 1 |
| Broiler father breeder | 19 weeks | 2000 | 2,750 | 34.5 | 2,750 | 34.5 | 1 |
| Broiler mother breeder | ≥19 weeks | 1996 | 3,600 | 28.4 | 3,900 | 28.4 | 1 |
| Broiler father breeder | ≥19 weeks | 1996 | 4,800 | 35.4 | 5,000 | 35.4 | 1 |
| Egg laying sector | - | 1993 | 62.4 | 19.2 | 62.5 | 18.5 | 2 |
| Day-old chicken laying | 1 day | 1993 | 36 | 30.4 | 35 | 30.4 | 3 |
| Laying hens battery light | 17 weeks | 1991 | 1,215 | 28.0 | 1,285 | 28.0 | 2 |
| Laying hens battery heavy | 17 weeks | 1991 | 1,420 | 28.0 | 1,520 | 28.0 | 2 |
| Laying hens other heavy | 17 weeks | | 1,520 | 28.0 | 1,520 | 28.0 | 2 |
| Laying hens battery light | ≥18 weeks | 1993 | 1,750 | 28.0 | 1,600 | 28.0 | 2 |
| Laying hens battery heavy | ≥18 weeks | 1993 | 2,050 | 28.0 | 1,800 | 28.0 | 2 |
| Laying hens other heavy | ≥18 weeks | 1998 | 1,900 | 28.0 | 1,800 | 28.0 | 2 |

1 = Versteegh and Jongbloed, 2000; 2 = Jongbloed and Kemme, 2002; 3 = LNV, 2004.

### A3.1.2 *The N content and N digestibility in chicken feeds*

In Table A3.2 an overview is given of the N contents and the digestibility of N in the various chicken feeds with which calculations are made in this study. In the corresponding sections the basis for the N contents and the N digestibility in the feeds is described further.

*Table A3.2 Overview of the N contents and the N digestibility (DC-N) in the various chicken feeds for the reference year and in 2005*

| | Reference year | | | 2005 | |
|---|---|---|---|---|---|
| **Feed type** | **Year** | **g N/kg** | **DC-N (%)** | **g N/kg** | **DC-N (%)** |
| Laying hens feed 1 | 1993 | 29.1 | 83.1 | 24.9 | 84.5 |
| Laying hens feed 2 | 1993 | 29.1 | 82.8 | 24.9 | 84.5 |
| Laying hens feed 3 | 1993 | 29.1 | 82.2 | 24.9 | 84.0 |
| Rearing feed start laying varieties | 1991 | 31.3 | 80.7 | 27.0 | 79.1 |
| Laying hens feed 1 | 1998 | 26.4 | 83.1 | 24.9 | 84.5 |
| Laying hens feed 2 | 1998 | 26.4 | 82.8 | 24.9 | 84.5 |
| Laying hens feed 3 | 1998 | 26.4 | 82.2 | 24.9 | 84.0 |
| Rearing feed start laying varieties | 1998 | 28.6 | 79.1 | 27.0 | 79.1 |
| Rearing feed 1 (laying varieties) | 1991 | 31.3 | 80.7 | 26.1 | 80.7 |
| Rearing feed 2 (laying varieties) | 1991 | 31.3 | 79.1 | 26.1 | 79.1 |
| Rearing feed start meat varieties | - | - | - | 31.0 | 84.2 |
| Rearing feed 1 (meat varieties) | 2000 | 28.6 | 80.8 | 28.4 | 80.8 |
| Rearing feed 2 (meat varieties) | 2000 | 28.6 | 80.8 | 25.2 | 80.8 |
| Start feed (broiler breeders) | 1996 | 31.0 | 80.8 | 25.2 | 80.8 |
| Breeding brood feed 1 (broiler breeders) | 1996 | 27.8 | 83.2 | 24.3 | 83.2 |
| Breeding brood feed 2 (broiler breeders) | 1996 | 27.8 | 82.3 | 24.2 | 82.3 |
| Broiler feed 1 | 2002 | 34.6 | 85.1 | 36.0 | 85.4 |
| Broiler feed 2 | 2002 | 32.0 | 84.3 | 34.1 | 83.9 |
| Broiler feed 3 | 2002 | 30.9 | 84.3 | 33.1 | 83.4 |

## A3.2 Rearing hens and roosters of laying varieties younger than ca. 18 weeks in battery housing (category 300A)

### A3.2.1 *Starting points*

The start weight of the rearing laying hens for both 1993 and 2005 is set to 35 g (Reuvekamp, 2004). The end weight of this category in 1993 is for middle heavy and white laying hens 1,420 respectively 1,215 g (KWIN-V, 1991). For 2005 these weights are 1,520 respectively 1,285 g. The length of the rearing period is 122.5 respectively 119 days (KWIN-V, 1991; 2005). The division over middle heavy and white laying hens in battery housing was in 1991 56:44 (WUM, 1994) and for 2005 50:50 is taken (Cijferinfo Pluimveesector 99/11; PVE, 1999). Per rearing

period is for 1991 the feed uptake per delivered hen respectively 5.6 and 5.0 kg (KWIN-V, 1991) resulting in 5.5 and 4.9 kg feed per hen present for middle heavy and white laying hens (on average 5.2 kg) and a feed conversion of 4.04. The ratio between uptake of rearing feed 1 and 2 is in 1991 20:80. For 2005 the feed uptake per rearing period per delivered hen for middle heavy and white laying hens 5.6 respectively 5.2 kg (per hen present 5.4 respectively 5.2 kg), resulting in an average feed uptake of 5.3 kg per hen present and a feed conversion of 3.87. The ratio between uptake of start feed, rearing feed 1 and 2 in 2005 is 5.6:25.9:68.5 (KWIN-V, 2005).
The loss of animals amounts for 1991 to 4.5% for both middle heavy and white laying hens and for 2005 that is 3.0 respectively 5.0%. This percentage is only used for conversion of delivered hen to average present hen. In 1991 the rearing feeds contained on average 31.3 g N/kg, while these feeds in 2005 contained on average 26.1 g N/kg. The digestibility of the rearing feeds in 1991 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a and 1995b). For rearing feed 1 there were three observations just like as for rearing feed 2. For the start feed the digestibility of the rearing feed 1 is taken. Because of the lack of data about composition and N digestibility of rearing feeds in 2005 the same N digestibilities as for 1991 are taken.

### *A3.2.2 Results rearing hens and roosters of laying varieties younger than ca. 18 weeks in battery housing*

In Table A3.3a is based on abovementioned starting points an overview given of the N uptake and excretion for rearing hens and roosters of laying varieties younger than ca. 18 weeks housed in batteries. Also in Table A3.3b and A3.3c the results are presented if 100% rearing hens respectively middle heavy (brown) rearing hens are kept. The calculated excretion is expressed per animal year (1 animal present the whole year).

*Table A3.3a Nitrogen balance (g) in rearing hens and roosters (ca. 50% white) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)*

| **Category 300A** | **1991** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Start feed | - | - | - | 26.1 | 80.7 | 24 |
| Rearing feed 1 | 31.3 | 80.7 | 96 | 26.1 | 80.7 | 110 |
| Rearing feed 2 | 31.3 | 79.1 | 405 | 26.1 | 79.1 | 290 |
| Total uptake | | | 501 | | | 424 |
| Fixation | | | 112 | | | 117 |
| Excretion | | | 389 | | | 307 |
| In faeces | | | 103 | | | 86 |
| In urine | | | 286 | | | 220 |
| In urine (%) | | | 73.5 | | | 71.8 |

*Table A3.3b Nitrogen balance (g) in rearing hens and roosters (100% white) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)*

| Category 300A | 1991 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N (%) | N uptake (g) | g N/kg | DC-N (%) | N uptake (g) |
| Start feed | - | - | - | 26.1 | 80.7 | 23 |
| Rearing feed 1 | 31.3 | 80.7 | 96 | 26.1 | 80.7 | 105 |
| Rearing feed 2 | 31.3 | 79.1 | 360 | 26.1 | 79.1 | 281 |
| Total uptake | | | 456 | | | 410 |
| Fixation | | | 99 | | | 107 |
| Excretion | | | 357 | | | 303 |
| In faeces | | | 94 | | | 84 |
| In urine | | | 263 | | | 219 |
| In urine (%) | | | 73.7 | | | 72.4 |

*Table A3.3c Nitrogen balance (g) in rearing hens and roosters (100% brown) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)*

| Category 300A | 1991 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N (%) | N uptake (g) | g N/kg | DC-N (%) | N uptake (g) |
| Start feed | - | - | - | 26.1 | 80.7 | 24 |
| Rearing feed 1 | 31.3 | 80.7 | 109 | 26.1 | 80.7 | 117 |
| Rearing feed 2 | 31.3 | 79.1 | 402 | 26.1 | 79.1 | 308 |
| Total uptake | | | 510 | | | 450 |
| Fixation | | | 116 | | | 127 |
| Excretion | | | 394 | | | 322 |
| In faeces | | | 105 | | | 92 |
| In urine | | | 290 | | | 231 |
| In urine (%) | | | 73.4 | | | 71.6 |

Results in Tables A3.3a, A3.3b and A3.3c show that the N excretion in 2005 is much lower than in 1991, mainly because of the lower N content of the feeds. Since the N retention hardly differs between both years there is a much lower N excretion in the urine. The proportion of the percentage N in urine : N in faeces is on average 1.7% unit lower in 2005 compared to 1991.

## A3.3 Rearing hens and roosters of laying varieties younger than ca. 18 weeks in housing other than battery (category 300B)

In section A3.2 some general remarks are made which are also valid for this section. Also it needs to be mentioned that to make an estimation of the technical results in this housing systems research data of free range housing is used.

### *A3.3.1 Starting points*

In the alternative housing (free range) almost completely middle heavy hens are used (Cijferinfo Pluimveesector 99/11; PVE, 1999). Also the data from research concerns these hens. As a result it is chosen to take only middle heavy hens for this category, both for 2002 and 2006.

The start weight of the rearing hens for both 2000 and 2005 is set to 35 g (Reuvekamp, 2004). The end weight of this category is for both 2000 and 2005 1,520 g (Managementgids Isabrown, 2004; Vermeij, 2005; Hendrix-Poultry, 2005). The length of the rearing period is 119 days (KWIN-V, 2000; 2005). Per rearing period for 2000 the feed uptake per delivered hen is 5.9 kg (per middle heavy hen present 5.8 kg) (KWIN-V, 2000). This results in a feed conversion of 4.20. The ratio between uptake of rearing feed 1 and 2 is 20:80. For 2005 the feed conversion per rearing period per animal present for middle heavy laying hens is 6.0 kg and the feed conversion is 3.96. The ratio between uptake of start feed, rearing feed 1 and 2 in 2005 is 5:26:69. The loss of animals for 2000 is 4.0% and for 2005 also 4.0%. The percentage animals lost is only used for the conversion of delivered hen to average present hen.

In 2000 the rearing feeds contain on average 28.6 g N/kg, while these feeds in 2005 contain on average 26.1 g N/kg. The digestibility of the rearing feeds in 2000 is derived from the feed compo-sitions of Van Niekerk and Reuvekamp (1994; 1995a and 1995b). For rearing feed 1 there were three observations and for rearing feed 2 the same. For the start feed the digestibility of rearing feed 1 is taken. Because the lack of data on rearing feeds in 2005 the same digestibilities as in 2000 are used.

### *A3.3.2 Results rearing hens and roosters of laying varieties younger than ca. 18 weeks in housing other than battery*

In Table A3.4 is based on abovementioned starting points an overview given of the N uptake and excretion for rearing hens and roosters of laying varieties younger than ca. 18 weeks in non-battery housing systems. The calculated excretion is expressed per animal year (1 animal that is present the whole year). With this the figure differs from usual parameters within the sector.

*Table A3.4 Nitrogen balance (g) in rearing hens and roosters (100% brown) of laying varieties younger than ca. 18 weeks in non-battery housing in kg N per animal year (category 300B)*

| **Category 300B** | **2000** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Start feed | - | - | - | 26.1 | 80.7 | 24 |
| Rearing feed 1 | 28.6 | 80.7 | 99 | 26.1 | 80.7 | 121 |
| Rearing feed 2 | 28.6 | 79.1 | 408 | 26.1 | 79.1 | 326 |
| Total uptake | | | 507 | | | 471 |
| Fixation | | | 119 | | | 128 |
| Excretion | | | 388 | | | 343 |
| In faeces | | | 104 | | | 96 |
| In urine | | | 284 | | | 247 |
| In urine (%) | | | 73.1 | | | 72.0 |

Results in Table A3.4 show that the N excretion in 2005 is somewhat lower than in 2000, mostly due to the somewhat lower N content of the feeds. Since the N retention hardly differs between both years the N excretion in the urine is lower. The division of the percentage N in urine : N in faeces becomes 1.1% unit lower in 2005 compared to 2000.

### A.3.4 Hens and roosters of laying varieties ca. 18 weeks and older in battery housing (category 301A)

In this section the calculations for hens in battery systems are examined further. Here also the differences are calculated if only white leghorns or brown laying hens are kept in a battery system.

#### *A3.4.1 Starting points*

The start weight of the middle heavy and white laying hens for 1993 is 1,420 respectively 1,215 g (KWIN-V, 1993). For 2005 these weights are 1,520 respectively 1,285 g. The end weight of this category at the end of the laying period is in 1993 for middle heavy and white laying hens 2,050 respectively 1,750 g (KWIN-V, 1993). For 2005 these weights are 1,800 respectively 1,600 g. The length of the laying period is 417 days (399 days actual laying period, 18 days rearing) (KWIN-V, 1993). The division over middle heavy and white laying hens in battery housing is 56:44 (WUM, 1994) and for 2005 50:50 is taken (Cijferinfo Pluimveesector 99/11; PVE, 1999).
The feed uptake of the middle heavy and white laying hens amounts 90 respectively 85 g/day during rearing and 117.5 respectively 110 g/day during the actual laying period for 1993, and for 2005 110 respectively 109.5 g/day is taken (KWIN-V 1993 respectively 2005). Per round the feed uptake in 1993 is on average 42.6 kg per hen present. In 1993 per hen laid on 19.9 (middle heavy) or 20.4 kg (white laying hen) eggs are produced. In this is calculated with another 5 eggs produced during rearing with the same egg weight. The average feed conversion is 2.23 (KWIN-V, 1993), which is based on feed uptake from 20 weeks on and egg production from 17 weeks.

Per round the feed uptake in 2005 is on average 41.1 kg per hen present. In 2005 per hen laid on 20.5 (middle heavy) or 22.3 kg (white laying hen) eggs are produced. In this is calculated with another 5 eggs produced during rearing with the same egg weight. The average feed conversion is 2.02 (KWIN-V, 2005), which is based on feed uptake from 20 weeks on and egg production from 17 weeks.

The loss of animals amounts to 6.3 and 7.3% for middle heavy and white laying hens in 1993 and for 2005 the same values have been taken. The percentage of animals lost is only used for the conversion of delivered hen to average present hen.

The start and laying feeds contain in 1993 on average 29.1 g N/kg (WUM, 1994). For 2005 the average N content in the start and laying feeds was 24.9 g N/kg (Van Bruggen, 2007). The ratio between the laying feeds 1, 2 and 3 over the laying period is 40:40:20, both for 1993 and 2005. There are also businesses where laying feed 2 is used to the end of the laying period instead of switching to laying feed 3. In the calculations this is not taken into account.

The digestibility of the laying hen feeds in 1993 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a; 1995b; 1997) and Emous *et al.* (1999). For laying feed 1 there were six observations with an average N digestibility of 84.1%. Of laying feed 2 there were six observations too with an average N digestibility of

83.8%, while for laying feed 3 there were four observations with an average N digestibility of 83.2%. For 2005 we had the disposal of data on laying feed 1 of the first half year of 2006. The average N digestibility was 84.5%. For laying feed 2 the same N digestibility was taken and for laying feed 3 an N digestibility of 84.0% was taken. The N digestibility of the start feed is set equal to that of the laying feed 2.

### *A3.4.2 Results hens and roosters of laying varieties ca. 18 weeks and older in battery housing*

In Tables A3.5a, A3.5b and A3.5c is based on abovementioned starting points an overview given of the N excretion for hens and roosters of laying varieties of ca. 18 weeks and older in batteries.

*Table A3.5a Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (ca. 50% white) in kg N per animal year (category 301A)*

| **Category 301A** | **1993** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Rearing feed | 29.1 | 79.1 | 39 | 27.0 | 79.1 | 40 |
| Laying feed 1 | 29.1 | 84.1 | 464 | 24.9 | 84.5 | 380 |
| Laying feed 2 | 29.1 | 83.8 | 464 | 24.9 | 84.5 | 380 |
| Laying feed 3 | 29.1 | 83.2 | 232 | 24.9 | 84.0 | 190 |
| Total uptake | | | 1,200 | | | 990 |
| Fixation | | | 350 | | | 362 |
| Excretion | | | 850 | | | 628 |
| In faeces | | | 196 | | | 156 |
| In urine | | | 654 | | | 472 |
| In urine (%) | | | 76.9 | | | 75.1 |

*Table A3.5b Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (100% white) in kg N per animal year (category 301A)*

| **Category 301A** | **1993** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Rearing feed | 29.1 | 79.1 | 36 | 27.0 | 79.1 | 36 |
| Laying feed 1 | 29.1 | 84.1 | 448 | 24.9 | 84.5 | 380 |
| Laying feed 2 | 29.1 | 83.8 | 448 | 24.9 | 84.5 | 380 |
| Laying feed 3 | 29.1 | 83.2 | 224 | 24.9 | 84.0 | 190 |
| Total uptake | | | 1,155 | | | 986 |
| Fixation | | | 345 | | | 365 |
| Excretion | | | 810 | | | 620 |
| In faeces | | | 189 | | | 156 |
| In urine | | | 622 | | | 465 |
| In urine (%) | | | 76.7 | | | 74.9 |

The results in Table A3.5a are for businesses with a division of ca. 50% white and 50% middle heavy (brown) laying hens; those in Table A3.5b and A3.5c are for businesses with 100% white respectively 100% brown laying hens. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). As such this figure differs from the usual parameters in the sector.

### *A3.4.3 Discussion laying hens in battery housing*

Tables A3.5a, A3.5b and A3.5c show that differences in total N excretion between the various laying varieties do exist, but that there are hardly differences in the share TAN in the excreta. Compared to 1993 the share TAN in the excreta decreased somewhat with on average 1.8% unit. Examined is also what the effect on the excretion of N in faeces and urine is, if the N digestibility is 1% unit higher or lower. Table A3.6 gives the results of this.

*Table A3.5c Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (100% middle heavy; brown) in kg N per animal year (category 301A)*

| Category 301A | 1993 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | g N/kg | DC-N (%) | N uptake (g) | g N/kg | DC-N (%) | N uptake (g) |
| Rearing feed | 29.1 | 79.1 | 42 | 27.0 | 79.1 | 44 |
| Laying feed 1 | 29.1 | 84.1 | 477 | 24.9 | 84.5 | 380 |
| Laying feed 2 | 29.1 | 83.8 | 477 | 24.9 | 84.5 | 380 |
| Laying feed 3 | 29.1 | 83.2 | 239 | 24.9 | 84.0 | 190 |
| Total uptake | | | 1,235 | | | 994 |
| Fixation | | | 354 | | | 358 |
| Excretion | | | 881 | | | 636 |
| In faeces | | | 202 | | | 157 |
| In urine | | | 679 | | | 479 |
| In urine (%) | | | 77.1 | | | 75.2 |

*Table A3.6 N uptake and N excretion (g) by hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (ca. 50% white) in kg N per animal year (category 301A)*

| Category 301A | 1993 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher |
| Total uptake | 1,200 | 1,200 | 1,200 | 990 | 990 | 990 |
| Excretion | 850 | 850 | 850 | 628 | 628 | 628 |
| In faeces | 208 | 196 | 184 | 166 | 156 | 147 |
| In urine | 642 | 654 | 666 | 462 | 472 | 481 |
| In urine (%) | 75.5 | 76.9 | 78.3 | 73.5 | 75.1 | 76.7 |

From Table A3.6 follows that in the dependability of the differences in the N digestibility there are no large shifts in the relative N excretion through the faeces and urine; with a 2% unit difference in N digestibility the relative share in the urine increases with ca. 3% units.

## A3.5 Hens and roosters of laying varieties ca. 18 weeks and older in housing other than battery (category 301B)

In section A3.4 some general remarks have been described that also concern this section. Also needs to be mentioned that in estimating the technical results in this housing systems research data of free range housing has been used. In this two types occur, with and without outside access. According to Statistics Netherlands (CBS, 2004) the number of animals is divided equally over both systems and the technical results over both systems are averages (KWIN-V, 1998; 2005).

### *A3.5.1 Starting points for 1998 and 2005*

In the alternative housing (free range) almost completely middle heavy hens are used (Cijferinfo Pluimveesector 99/11; PVE, 1999). Also the data from research concern these hens. Therefore it has been chosen to take only the middle heavy hens for this category, both for 1998 as 2005.

The start weight of the middle heavy laying hens for 1998 and 2005 is 1,470 respectively 1,520 g (KWIN-V, 1998; 2005). The end weight of this category at the end of the laying period for 1998 and 2005 is 1,900 respectively 1,800 g (KWIN-V, 1998; 2005). In 1998 the length of the laying period is 401 days (380 days actually laying period, 21 days rearing) and in 2005 that is 406 (385 actual laying period, 21 days rearing (KWIN-V, 1998; 2005).

The feed uptake is 97.5 g/day during the rearing and 119 g/day during the actual laying period (KWIN-V, 1998), while in 2005 the uptakes are 100 respectively 121 g/day (KWIN-V, 2005). Per round the feed uptake for 1998 is on average 49.6 kg per hen present and 20.28 kg eggs are produced. This production takes place at an average feed conversion of 2.29. For 2005 the feed uptake is on average 48.7 kg per hen present and the egg production 20.19 kg, resulting in an average feed conversion of 2.25. The loss of animals amounts to 8.3% for 1998 and 9.3% for 2005. The percentage loss of animals is only used for the conversion of delivered hen to average hen present.

The start and laying feeds in 1998 contain on average 26.4 g N/kg (Tamminga *et al.*, 2000). For 2005 the average N content in the start and laying feeds was 24.9 g N/kg (Van Bruggen, 2007). The ratio between the laying feeds 1, 2 and 3 over the laying period is 40:40:20, both for 1993 and 2005. There are also businesses where laying feed 2 is given to the end of the laying period instead of switching to laying feed 3. In the calculations this is not considered.

The digestibility of the laying hen feeds in 1998 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a; 1995b; 1997) and Emous *et al.* (1999). For laying feed 1 there were six observations with an average N digestibility of 84.1%. Of laying feed 2 there were also six observations with an average N digestibility of 83.8%, while for laying feed 3 there were four observation with an average N digestibility of 83.2%. For 2005 we had the disposal of data on laying feed 1 of the first half year of 2006. The average N digestibility was 84.5%. For laying feed 2 the same N digestibility as of laying feed 1 is taken and for laying feed 3 84.0% is taken. The N digestibility of the start feed is set equal to that of the rearing feed 2.

#### *A3.5.2 Results hens and roosters of laying varieties ca. 18 weeks and older in housing other than battery*

In Table A3.7 is based on abovementioned starting points an overview given of the N excretion for hens and roosters of laying varieties of ca. 18 weeks and older in housing other than batteries. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

*Table A3.7 N uptake and excretion (g) by hens and roosters of brown laying varieties ca. 18 weeks and older in housing other than batteries in kg N per animal year (category 301B)*

| **Category 301B** | **1998** | | | | **2005** | | | |
|---|---|---|---|---|---|---|---|---|
| **Uptake** | **kg feed** | **g N/kg** | **DC-N (%)** | **kg N** | **kg feed** | **g N/kg** | **DC-N (%)** | **kg N** |
| Rearing feed | 1.8 | 28.6 | 79.1 | 51 | 1.9 | 27.0 | 79.1 | 51 |
| Laying feed 1 | 16.5 | 26.4 | 83.1 | 436 | 16.8 | 24.9 | 84.5 | 417 |
| Laying feed 2 | 16.5 | 26.4 | 82.8 | 436 | 16.8 | 24.9 | 84.5 | 417 |
| Laying feed 3 | 8.2 | 26.4 | 82.2 | 218 | 8.4 | 24.9 | 84.5 | 209 |
| Total | 43.0 | | | 1,140 | 43.8 | | | 1,094 |
| Fixation | | | | 348 | | | | 357 |
| Excretion | | | | 792 | | | | 736 |
| In faeces | | | | 187 | | | | 173 |
| In urine | | | | 605 | | | | 563 |
| In urine (%) | | | | 76.4 | | | | 76.5 |

From Table A3.7 follows that the N excretion form 1998 to 2005 decreased somewhat, but that there is no difference in the share TAN in the excreta.

## A3.6 Rearing hens and roosters of meat varieties 0 to 19 weeks (category 310)

Category 310 concerns the young breeder animals for the broiler sector. Different from the laying sector this is a clearly distinguished category. Differences between hens and roosters have been taken into account. Conversion of parameters took place because in the manure legislation both the hens and roosters are counted, while parameters in some cases are expressed per hen.

### *A.3.6.1 Starting points for 2000 and 2005*

The start weight of the rearing breeder animals (the chicks) is for both 2000 and 2005 set to 42 g (Van Middelkoop, 2000). The end weight of this category at ca. 19 weeks of age is for roosters and hens in 2000 2,750 respectively 2,000 g (Ross, 2004) and for 2005 the same weights are taken. The length of the rearing period is for 2000 and 2005 calculated to 126 days (KWIN-V, 2000; 2005). The number of roosters at lay on is 15%. On average there are 14.0% roosters per reared hen (KWIN-V, 2000; 2005). At the end of the rearing period selection of the roosters takes place. At lay on for the laying period 10% roosters are deployed. Per rearing period is for 2000 the feed uptake of rearing feed 1 and 2 per hen delivered 2.0 respectively 6.5 kg and per average hen present 1.68 respectively 5.47 kg, resulting in an average feed conversion of 3.49. For 2005 the same values are taken.

The loss of animals in 2000 amounts to 7.0 and 14.0% for hens and roosters and also for 2005. The percentage animals lost is only used for the conversion of delivered hen to average present animal.

The rearing feed contains in 2000 on average 28.3 g N/kg (Tamminga *et al.*, 2000) and in 2005 the average N content of the start and rearing feed is 26.1 g/kg (Van Bruggen, 2007). These contents are copied from those of rearing laying hens, since no data was available for the rearing of broiler breeders. The digestibility of the rearing feeds in 2000 is derived from the feed compositions of Van der Haar and Meijerhof (1996) and of a feed supplier. For rearing feed 1 there were two observations (average 80.8%) and for rearing feed 2 seven observations (average 80.7%). For the start feed is based on information from a feed supplier an N digestibility of 84.2% taken. For the rearing feeds 1 and 2 is an average N digestibility taken of 80.7%. Since data on rearing feeds in 2005 are lacking the same digestibilities as in 2000 are used.

#### *A3.6.2 Results rearing hens and roosters of meat varieties 0 to 19 weeks*

In Table A3.8 is based on abovementioned starting points an overview given of the N excretion for rearing hens and roosters of meat varieties 0 to 19 weeks. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

*Table A3.8 N uptake and excretion (g) by rearing hens and roosters of meat varieties 0 to 19 weeks in kg N per animal year (category 310)*

| **Category 310** | **2000** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Rearing feed start | - | - | - | 31.0 | 84.2 | 38 |
| Rearing feed 1 | 28.6 | 80.8 | 140 | 28.4 | 80.8 | 104 |
| Rearing feed 2 | 28.6 | 80.8 | 453 | 25.2 | 80.8 | 400 |
| Total uptake | | | 593 | | | 541 |
| Fixation | | | 200 | | | 200 |
| Excretion | | | 393 | | | 342 |
| In faeces | | | 114 | | | 99 |
| In urine | | | 280 | | | 242 |
| In urine (%) | | | 71.1 | | | 71.0 |

From Table A3.8 follows that the N excretion decreased somewhat from 2000 to 2005, but that there is no difference in the share TAN in the excreta.

### A3.7 Breeders of meat varieties ca. 19 weeks and older (category 311)

Category 311 concerns the breeder animals for the broiler sector. Different from the laying sector this is a clearly distinguished category. Differences between hens and roosters are taken into account. Conversion of parameters took place because in the manure legislation both the hens and the roosters are counted, while parameters in some cases are expressed per hen.

#### *A3.7.1 Starting points*

The start weight of the hens respectively roosters for 1996 is 1,900 respectively 2,600 g and for 2005 2,000 respectively 2,750 g (Ross, 2004). The end weight of this category at the end of the production period is for hens and roosters for 1996 3,600 respectively 4,800 g and for 2005 3,700 respectively 4,800 g (KWIN-V, 1996; 2005). The length of the production cycle is for 1998 and 2006 calculated to 346 respectively 343 days (KWIN-V, 1996; 2005).

Goal for both 1996 as for 2005 is to have 10% roosters at the start of the laying period. Over the whole period on average 95.51 hens and 8.44 roosters are present. Per laying round is for 1996 the feed uptake on average 3.0 kg pre laying feed and 45.0 kg breeding brood feed per laid on hen (2.9 kg respectively 43.3 kg per average animal present) and 148 brood eggs and 10 consumption eggs of on average 62 grams apiece are produced. This results in 9.27 kg eggs per average present animal. For 2005 the feed uptake per round is on average 3.30 kg pre laying feed and 44.7 kg breeding brood feed per laid on hen (3.20 kg respectively 43.0 kg per average animal present) and 150 brood eggs and 10 consumption eggs of on average 62 grams are produced. This results in 9.54 kg eggs per average animal present. The loss of animals amounts for 1996 to 1.0 respectively 3.5% for hens and roosters during rearing and 10.0 respectively 35.0% during the laying period. For 2005 the percentages loss of animals during rearing are 1.0 respectively 3.6 and 10.0 respectively 35.0% during the laying period. The percentage animals lost is only used for the conversion of delivered hen to average present animal.

The N content in the pre laying feed and the breeding brood feed for 1996 is calculated by taking the average content of 1992 (WUM, 1994) and that of Tamminga *et al.* (2000). The pre laying feed then contains 31.0 g N/kg and the breeding brood feed 27.8 g N/kg. In 2005 the pre laying feed, breeding brood feed 1 and 2 contained respectively 25.2, 24.3 and 24.2 g N/kg (Van Bruggen, 2007). Of the N digestibility of the feeds in 1996 no data are available. For 2005 for the pre laying feed the N digestibility of the rearing feed 2 (80.8%) was taken. Based on data of a composite feed manufacturer beginning 2008 an N digestibility of the breeding brood feed 1 and 2 of 83.2 respectively 82.3% was calculated. These digestibilities are also taken for the feeds of 1996.

### A3.7.2 *Results hens and roosters of meat varieties from ca. 19 weeks and older*

In Table A3.9 is based on abovementioned starting points an overview given of the N uptake and excretion for hens and roosters of meat varieties from ca. 19 weeks and older. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

*Table A3.9 Nitrogen balance (g) in hens and roosters of meat varieties ca. 19 weeks and older in kg N per animal year (category 311)*

| **Category 311** | **1996** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Start feed | 31.0 | 80.8 | 103 | 25.2 | 80.8 | 92 |
| Breeding brood feed 1 | 27.8 | 83.2 | 614 | 24.3 | 83.2 | 538 |
| Breeding brood feed 2 | 27.8 | 82.3 | 768 | 24.2 | 82.3 | 662 |
| Total uptake | | | 1,484 | | | 1,293 |
| Fixation | | | 258 | | | 262 |
| Excretion | | | 1,227 | | | 1,030 |
| In faeces | | | 259 | | | 225 |
| In urine | | | 968 | | | 805 |
| In urine (%) | | | 78.9 | | | 78.1 |

From Table A3.9 follows that the N excretion clearly decreases from 1998 to 2005 but that there is hardly difference in the share TAN in the excreta.

## A3.8 Broilers (category 312)

### *A3.8.1 Starting points*

The start weight of the broilers is for both 2002 and 2006 set to 42 g (Van Middelkoop, 2000). The end weight of broilers at 43 days of age is for 2002 and 2005 2,100 respectively 2,200 g (KWIN-V, 2003; 2007). Per production round is for 2002 the average feed conversion 1.76 (KWIN-V, 2002), resulting in a feed uptake of on average 3.70 kg. For 2005 the production period is 43 days, the feed conversion on average 1.79, resulting in a feed uptake of 3.94 kg (KWIN-V, 2005).

The broiler feed 1, 2 and 3 for 2002 contained 34.6, 32.0 respectively 30.9 g N/kg. The contents for 2005 are 36.0, 34.1 respectively 33.1 g/kg (Van Bruggen, 2007). Of the broiler feed 1 per production round 300 g is taken up, of broiler feed 2 1,500 g and the remainder is broiler feed 3. There are also businesses where besides compound feed also wheat or corn cob mix is fed additionally but in the calculations this is not taken into account.

The digestibility of the broilers is estimated based on various feed compositions of broiler feed 2 at a composite feed manufacturer in the first half of 2006. This was on average 83.9%. Based on discussions with experts it seems reasonable to raise the N digestibility of broiler feed 1 by 2.5% units, so that it becomes 85.4%. Also is assumed that the N digestibility of broiler feed 3 is 0.5% lower than of broiler feed 2, so that the N digestibility then becomes 83.4%. The digestibilities above are taken for 2005. For 2002 based on discussion with some experts an N digestibility for broiler feed 1, 2 and 3 of 85.1, 84.3 respectively 84.3 is taken.

### *A3.8.2 Results broilers*

In Table A3.10 based on abovementioned assumptions an overview is given of the N excretion for broilers. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

*Table A3.10 Nitrogen balance (g) in broilers in g N per animal year (category 312)*

| **Category 312** | **2002** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N** | **N uptake (g)** | **g N/kg** | **DC-N** | **N uptake (g)** |
| Broiler feed 1 | 34.6 | 85.1 | 87 | 36.0 | 85.4 | 92 |
| Broiler feed 2 | 32.0 | 84.3 | 403 | 34.1 | 83.9 | 434 |
| Broiler feed 3 | 30.9 | 84.3 | 492 | 33.1 | 83.4 | 601 |
| Total uptake | | | 981 | | | 1,127 |
| Fixation | | | 479 | | | 508 |
| Excretion | | | 502 | | | 618 |
| In faeces | | | 153 | | | 183 |
| In urine | | | 349 | | | 435 |
| In urine (%) | | | 69.5 | | | 70.4 |

### A3.8.3 Discussion broilers

From Table A3.10 follows that the N excretion from 2002 to 2005 increased clearly, but also that the share TAN in the excreta increased somewhat.

*Table A3.11 N uptake and N excretion (kg) by broilers in g N per animal year (category 312)*

| Category 312 | 2002 | | | 2005 | | |
|---|---|---|---|---|---|---|
| | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher | DC-N 1 unit lower | DC-N starting point | DC-N 1 unit higher |
| Total uptake | 981 | 981 | 981 | 1,127 | 1,127 | 1,127 |
| Excretion | 502 | 502 | 502 | 618 | 618 | 618 |
| In faeces | 163 | 153 | 144 | 194 | 183 | 172 |
| In urine | 339 | 349 | 359 | 424 | 435 | 446 |
| In urine (%) | 67.5 | 69.5 | 71.4 | 68.6 | 70.4 | 72.2 |

It has been examined what the effect of an N digestibility 1% unit higher or lower is on the excretion in faeces and urine. Table A3.11 gives the results of this.

From Table A3.11 follows that in the dependability of a difference in N digestibility of 2% units the amount N in urine as percentage of the total N excretion yields a difference of ca. 4% units.

## A3.9 General discussion poultry

### A3.9.1 Reliability contents of and digestibility of N in chicken feeds and effects on the N excretion

Not for all feeds there is a reliable picture of the correct content of N in feeds for chickens. Often these data are lacking in the various years. Also it is difficult or even not feasible to obtain these contents from compound feed manufacturers. In addition the raw material composition of the feeds is not released by most of the compound feed manufacturers. It is amply known that by whether or not taking up free amino acids in the feeds the N content in the feeds can be lowered, but at the same time it is also possible to take up protein containing raw materials of poorer quality in the feed. Depending on the strategy at the firm both the N content and the N digestibility can vary. It is desirable to collect better underpinned data hereof.

## A3.10 Summary poultry

In Table A3.12 a summary is given of the excretion of N by various chicken categories in the reference year and in 2005 in g/year.

*Table A3.12 Overview of the excretion of N and % TAN by various chicken categories in the reference year and 2005 (g/year)*

| Category | Number | Ref. year | N in ref. year | % TAN in ref. year | N in 2005 | % TAN in 2005 |
|---|---|---|---|---|---|---|
| Rearing laying hens (battery) | 300A | 1991 | 389 | 73.5 | 307 | 71.8 |
| Rearing laying hens (ground) | 300B | 2000 | 388 | 73.1 | 343 | 72.0 |
| Laying hens (battery) | 301A | 1993 | 850 | 76.9 | 628 | 75.1 |
| Laying hens (ground) | 301B | 1998 | 792 | 76.4 | 736 | 76.5 |
| Rearing broiler breeders | 310 | 2000 | 393 | 71.1 | 342 | 71.0 |
| Broiler breeders | 311 | 1996 | 1,227 | 78.9 | 1,030 | 78.1 |
| Broilers | 312 | 2002 | 502 | 69.5 | 618 | 70.4 |

## A3.11 Turkeys

### *A3.11.1 General*

In Table A3.13 data on the average content of N in the animal product and in Table A3.14 the contents of protein and N and the faecal digestibility of N in the various turkey feeds are shown. The contents in the various turkey feeds in 1998 are derived from Veldkamp (1996) and Veldkamp *et al.* (1999) and in 2005 from Jongbloed and Kemme (2005). Also information was obtained from dr. Veldkamp, turkey specialist of ASG (Veldkamp, 2008).

*Table A3.13 Weights and contents of N in various turkey categories and in turkey eggs*

| Livestock category | Weight (g) 1998 | Weight (g) 2005 | Physiological status | N content (g/kg) | Literature contents |
|---|---|---|---|---|---|
| Turkey egg | 89 | 89 | - | 19.4 | WUM, 1994 |
| One-day turkey chick | 57 | 57 | - | 30.0 | LNV, 2004 |
| Turkey for slaughter hen | 9,500 | 9,800 | Ca. 16.5 weeks | 33.0 | LNV, 2004 |
| Turkey for slaughter rooster | 18,500 | 19,500 | Ca. 21 weeks | 33.0 | LNV, 2004 |

*Table A3.14 Overview of the average N contents and digestibility of N in the various turkey feeds for 1998 and 2005*

| | Reference year | | | 2005 | |
|---|---|---|---|---|---|
| **Feed type** | **Year** | **g N/kg** | **DC-N (%)** | **g N/kg** | **DC-N (%)** |
| Start feed | 1998 | 45.8 | 85.0 | 44.7 | 85.0 |
| Turkey feed phase 2 | 1998 | 41.4 | 83.6 | 40.9 | 83.6 |
| Turkey feed phase 3 | 1998 | 37.4 | 83.4 | 35.8 | 83.4 |
| Turkey feed phase 4 | 1998 | 31.3 | 83.1 | 29.6 | 83.1 |
| Turkey feed phase 5 | 1998 | 31.3 | 83.1 | 26.1 | 83.1 |
| Turkey feed phase 6 | 1998 | 27.6 | 84.0 | 24.2 | 84.0 |

*A3.11.2 Turkeys for slaughter (category 210)*

To assess various technical results of turkeys for slaughter the data of KWIN are used. Furthermore, information given by dr. Veldkamp (2008) has been processed.

*A3.11.3 Starting points for 1998 and for 2005*

The start weight of turkeys for slaughter for both 1998 and 2005 is set to 57 g (Veldkamp, 2008). For 1998 the end weight of the roosters and hens on an age of 147 and 116 days (on average 132 days) is 18.50 respectively 9.50 kg (average 14.00 kg). For 2005 the end weight of the roosters respectively hens on an age of 145 respectively 112 days (on average 128 days) is 19.50 respectively 9.80 kg (average 14.60 kg). Per production period is for 1998 the average feed conversion per kg delivered weight 2.63, resulting in a feed uptake of 36.9 kg per round and 99.9 kg per year. For 2005 the average feed conversion is 2.63, resulting in a feed uptake of 38.7 kg per round and 105.7 kg per year. The division of the feed uptake over the various phases is derived from British United Turkeys (2006).

The N contents in the various feeds for turkeys for slaughter are shown in Table A3.15. The N contents in the feeds for the year 1998 are derived from Veldkamp (1996) and Veldkamp *et al.* (1999) and are averages for each phase. The N contents in the various turkey feeds for 2005 are the same as mentioned by Jongbloed and Kemme (2005). Based on the feed composition according to Veldkamp *et al.* (1999) the digestibility of N in the various feeds for turkeys for slaughter are estimated. The digestibility of N in the distinguished feeds is kept equal for both years (Table A3.15) based on Veldkamp (2008).

*A3.11.4 Results turkeys for slaughter*

In Table A3.15 is based on abovementioned starting points an overview given of the N excretion for turkeys for slaughter. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

From the results according to Table A3.15 follows that N excretion has decreased because of the lower N content in the feeds and a higher retention of N. As a result, less N is excreted through the urine and share N in urine as percentage of the total N excretion decreased from 72.6 to 70.5%.

*Table A3.15 Nitrogen balance (kg) in turkeys for slaughter in kg N per animal year (category 210)*

| **Category 210** | **1998** | | | **2005** | | |
|---|---|---|---|---|---|---|
| | **g N/kg** | **DC-N (%)** | **N uptake (g)** | **g N/kg** | **DC-N (%)** | **N uptake (g)** |
| Start feed | 45.8 | 85.0 | 53 | 44.7 | 85.0 | 54 |
| Turkey feed phase 2 | 41.4 | 83.6 | 134 | 40.9 | 83.6 | 141 |
| Turkey feed phase 3 | 37.4 | 83.4 | 553 | 35.8 | 83.4 | 561 |
| Turkey feed phase 4 | 31.3 | 83.1 | 767 | 29.6 | 83.1 | 768 |
| Turkey feed phase 5 | 31.3 | 83.1 | 992 | 26.1 | 83.1 | 876 |
| Turkey feed phase 6 | 27.6 | 84.0 | 676 | 24.2 | 84.0 | 625 |
| Total uptake | | | 3,175 | | | 3,025 |
| Fixation | | | 1,248 | | | 1,321 |
| Excretion | | | 1,927 | | | 1,704 |
| In faeces | | | 527 | | | 502 |
| In urine | | | 1,400 | | | 1,202 |
| In urine (%) | | | 72.6 | | | 70.5 |

## A3.12 References

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# Annex 4 Mineralisation and immobilisation of nitrogen in manure

## A4.1 Translation of the annex from G.L. Velthof in Velthof *et al.*, 2009.

Part of the organic matter in manure is easily degradable and will already be broken down in the animal house or storage. During this process, $CH_4$ and $CO_2$ and depending on the composition of the manure, also $NH_4^+$ are formed (mineralisation). In manure containing straw (high C/N ratio) part of the $NH_4^+$ will be fixed (immobilised) as organic N.

The method to calculate $NH_3$ emission described in this report is based on TAN. As a result, changes in TAN during the storage of manure have to be taken into account.

In the literature, only little data is available on mineralisation and immobilisation of ammonium in manure storages. This is mainly because these processes are hard to determine through a balance method in manure from which also $NH_3$ is emitted. Another possibility to determine mineralisation is the use of $^{15}N$ labelled N, that is added to the ration of the animal or the manure.

In an incubation study of Sommer *et al.* (2007) the N mineralisation was low at 10 °C, for both cattle and pig slurry. The manure has been collected fresh and was stored frozen, until the start of the incubation study. The mineralisation increased strongly at increasing temperature. About 80% of the organic N was mineralised at 15-20 °C for 100-200 days. Mineralisation was higher in pig manure than in cattle manure.

In an incubation study of Sørensen *et al.* (2003), mineralisation of 9-50% of the organic N in cattle slurry was found. The fresh manure was incubated at 8 °C for 16 weeks first, and then for 4 weeks at 15 °C.

Processing of data from an incubation study of Velthof *et al.* (2005) shows that the N mineralisation of organic N of pig slurry at high temperature (90 days at 35 °C) was on average 15%, with a variation of -11 to +30% (depending on the ration). The manure was collected fresh and stored frozen, until the start of the incubation study.

In an incubation study with pig manure to which $^{15}N$ labelled urea was added (Beline *et al.*, 1998) the N mineralisation was 19% of the organic N during 84 days at 20 °C. The manure was collected from a farm and had thus been stored for a while (it is not clear how long the storage period was).

In models used in England and Germany for calculation of ammonia emissions on the national scale the N mineralisation is set to 10% of the organic N (with reference to the research of Beline *et al.*, 1998). In the models used by Denmark and Switzerland, mineralisation is not (yet) taken into account.

In the methodology described in this report, it is assumed that 10% of the organic N in slurry stored in the animal house mineralizes. This might be a conservative assumption. Given the uncertainties only mineralisation in the animal houses is calculated and not in the outside storage. Also in the outside storage mineralisation can occur, but this is possibly lower since the easily degradable organic N will mineralize quickly after excretion in the animal house.

For solid manure except poultry manure, 25% immobilisation is assumed. In poultry manure, both solid and slurry, and slurry manure of other animals (rabbits and fur-bearing animals) no mineralisation or immobilisation takes place. It is recommended to conduct further research into (net) mineralisation in cattle and pig slurry, since this has an effect on calculated $NH_3$ emissions from the animal house, manure storage and manure application.

## A4.2 References

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# Annex 5 Emission factors for $NH_3$ from animal housing of cattle

In this annex the emission factors in kg $NH_3$ per animal place are given that form the basis for the calculation of emission factors with respect to the TAN excretion (Section 5.2)

## A5.1 Dairy cows

In the calculation model NEMA the N excretion is divided over the winter and grazing period. During the grazing period dairy cows spend part of their time in the animal house and another part on pastureland. Therefore, the N excretion of the grazing period is split into excretion in the animal house and during grazing. To connect to the N excretion the year-round emission factors are split into factors for the winter period and for time spent in the animal house in unlimited (day and night) and limited (daytime) grazing, see also Van Bruggen *et al.*, 2011 (Section 5.4.2).

In Ogink *et al.* (2014) a current emission factor of 13.0 kg $NH_3$ per animal place is calculated for dairy cattle kept continuously indoors in traditional housing systems. These are cubicle housings with slatted floors as walking area and manure storage below the grates (Rav-code A1.100). Decrease in emissions per hour of grazing is determined to be 2.61%. On a yearly basis the percentual emission reduction then is:

2.61% x (number of grazing hours per day) x (number of grazing days) / 365 (A5.1)

Based on the reference value of 13.0 kg $NH_3$ per animal place and above formula, in Table A5.1 emission factors are calculated for the winter period and for the time spent in the animal house during the grazing period for each grazing system. Ogink *et al.* (2014) do no split the year-round emission. The calculation of the emission reduction by grazing of the working group NEMA differs somewhat from the calculation in Ogink *et al.* (2014). The working group NEMA takes the average number of grazing days in the years emission measurements took place (2007-2012) as the starting point, where in Ogink *et al.* (2014) the length of the grazing period of 2012 and a weighted average number of hours grazing per day are used.

In the calculation of the $NH_3$ emission of dairy cattle housings an increase in emission per animal place from 11.0 kg $NH_3$ in 2001 to 13.0 kg in the measurement period 2007-2012 is assumed.

*Table A5.1 Emission factors for traditional dairy housing (kg $NH_3$/animal place), 2007-2015*

| Grazing system | Grazing period (days) A[1)] | Hours grazing per day B[2)] | Emission reduction (kg $NH_3$) C[3)] | Grazing period (kg $NH_3$) D[4)] | Winter period (kg $NH_3$) E[5)] | Year-round (kg $NH_3$) F[6)] |
|---|---|---|---|---|---|---|
| Continuously indoors | 169 | 0 | 0.00 | 6.02 | 6.98 | 13.00 |
| Limited grazing | 169 | 8 | 1.26 | 4.76 | 6.98 | 11.74 |
| Unlimited grazing | 169 | 20 | 3.14 | 2.88 | 6.98 | 9.86 |

1) Source WUM-Statistics Netherlands: average length of the grazing period in the measurement period 2007-2012.
2) Source: Statistics Netherlands-research Grassland use 2008.
3) 2.61% * B x (A/365) x (13.0 kg NH3).
4) (A/365) x (13.0 kg NH3) – C.
5) ((365-A)/365) x (13.0 kg NH3).
6) D + E.

For the emission years 2016-2018 the hours grazing per day were reconsidered, limited grazing was set to 7 hours and unlimited grazing to 19 hours leading to year-round emission factors of 11.90 and 10.01 kg $NH_3$/animal for limited and unlimited grazing respectively. For the years 2019-2020 the hours grazing per day for unlimited grazing were reconsidered and set to 18 hours, for 2021 they were set at 17 hours per day. These changes resulted in an emission factor of 10.17 kg $NH_3$/animal for unlimited grazing in 2019-2020 and 10.33 from 2021 onwards.

The emission factors for low-emission housing have been set to equal the emission factor of regular housing for the entire time series with the exception of the tie stall with liquid manure. Few farms still use this housing system and the study performed by statistics Netherlands could not ensure that their study was representative for the entire time series. Therefore, it was decided to keep the current emission factor of this housing system (Van Bruggen *et al.,* 2025).

## A5.2 Other cattle excluding veal calves

Ogink *et al.* (2014) propose to calculate $NH_3$ emission factors per animal place for other cattle categories with the formula:

(TAN excretion in the animal house of livestock category)/(TAN excretion in the animal house dairy cattle) x 13.0 (A5.2)

This therefore means that the emission factor for traditional housing compared to the TAN excretion for all cattle categories is equal. In NEMA emission factors are calculated compared to the TAN excretion including 10% mineralisation of organic N. Ogink *et al.* (2014) however do not consider the 10% mineralisation of organic N and as a result emission factors calculated with above formula differ somewhat because the percentage organic N differs between cattle categories. To prevent these differences the calculation in Ogink *et al.* (2014) is applied on TAN excretion including 10% mineralisation of organic N.

In the calculation of the $NH_3$ emission of dairy cattle housings an increase in emission per animal place from 11.0 kg $NH_3$ in 2001 to 13.0 kg in the measurement period 2007-2012 is assumed. By relating the emission factor for other cattle to that of dairy cows, the emission factor of other cattle increases as well.

Table A5.3 shows the applied emission factors.

*Table A5.3 Emission factors $NH_3$-N for other cattle categories in % of TAN excretion (including 10% net mineralisation)*

| | 1990-2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007-2024 |
|---|---|---|---|---|---|---|---|
| Emission factor compared to TAN excretion | 11.03 | 11.51 | 11.99 | 12.47 | 12.95 | 13.43 | 13.91 |

## A5.3 Meat calves

In Groenestein *et al.* (2014) emission factors for meat calves are reconsidered in which separate emission factors are proposed for white veal calves and rosé veal calves. The factor for both categories was 2.5 kg $NH_3$ per animal place in the reference year 1998 with an occupancy rate of 0.93. The husbandry of meat calves and management thereof have evolved such that the available older measurement series are no longer representative of current practice. The new emission factors are derived from the emission factor of dairy cows (13.0 kg $NH_3$/animal place) in which differences in TAN excretion, size of emitting surfaces (Groenestein *et al.*, 2014) and the contribution of the grates and slurry pit to the emission of the animal house are taken into account. This method therefore differs from the method used in determining the emission factors for other cattle in above text. The new reference year is 2012.

The new factors are 3.1 and 3.7 kg $NH_3$ per animal place respectively for white veal calves and rosé veal calves, at an occupancy rate of 0.93 for white veal calves and 0.96 for rosé veal calves.

The emission factor for $NH_3$-N compared to the TAN excretion of white veal calves, including 10% mineralisation of organic N, is 27.15% in the years 1990-1998. As a result of the higher TAN excretion in the new reference year 2012 the emission factor per animal place gradually increases from 1999-2012 to 27.47% through linear interpolation.

For rosé veal calves the emission factor compared to the TAN excretion, including 10% mineralisation of organic N, is 12.99% in the years 1990-1998. The revised emission of 3.7 kg $NH_3$ per animal place yields an emission factor of 22.53% compared to the TAN excretion in the reference year 2012. Between 1998 and 2012 the emission factor is gradually increased through interpolation. The occupancy rate is increased from 0.93 to 0.96.

Since between the reference years 1998 and 2012 a gradual change in management took place, the emission factor is being interpolated. For meat calves two different methods for interpolation between 1998 and 2012 are possible: interpolation of the proposed Rav factor or interpolation of the emission factor compared to the TAN excretion. Interpolation of the proposed Rav factor means for white veal calves a gradual increase from 2.5 kg $NH_3$ to 3.1 kg $NH_3$ and for rosé veal calves an increase from 2.5 to 3.7 kg $NH_3$ per animal place. In the second method of interpolation the emission factor compared to the TAN excretion is gradually adjusted. For white veal calves this means the emission factor increases from 27.15 to 27.47% and for rosé veal calves a gradual increase from 12.99 to 22.53%.

The choice was made to interpolate the emission factor on the basis of net TAN excretion. With interpolation of the proposed Rav factor yearly fluctuations in the emission factor compared to the TAN excretion would occur, because TAN excretion also have yearly fluctuations. The latter is not logical since one would expect the emission factor compared to the TAN excretion to be constant or gradually changing because of changing management, but not to fluctuate yearly.

The average emission reduction of low-emission housing with air scrubbers for the years 1990-2014 was established to be 76% compared to regular housing for both white and rose veal calves. From 2015 onwards average emission reduction percentages vary as more detailed information is available on housing systems. The average emission reduction peaked in 2016 at 89%. In 2024 the average emission reduction was 86% (Van der Most *et al*., 2026).

## A5.4 References

Bruggen, C. van, C.M. Groenestein, B.J. de Haan, M.W. Hoogeveen, J.F.M. Huijsmans. S.M. van der Sluis & G.L. Velthof, 2011. Ammoniakemissie uit dierlijke mest en kunstmest, 1990-2008. Berekeningen met het Nationaal Emissiemodel voor Ammoniak (NEMA) (in Dutch). WOt-Working Document 250. WOT Natuur & Milieu, Wageningen UR, Wageningen, the Netherlands.

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Groenestein, C.M., S. Bokma & N.W.M. Ogink, 2014. Actualisering ammoniakemissiefactoren vleeskalveren tot circa 8 maanden. Advies voor aanpassing in de Regeling ammoniak en veehouderij (in Dutch). Report 778. Wageningen UR Livestock Research, Lelystad, the Netherlands.

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# Annex 6 Emission factors for $NH_3$ from animal housing of pigs

In this annex the emission factors in kg $NH_3$ per animal place are given that form the basis for the calculation of emission factors relative to the TAN excretion (Section 5.2).

*Table A6.1 Emission factors for traditional pig housing (kg $NH_3$ per animal place)*

| | **kg $NH_3$ per animal place** |
|---|---|
| Sows with piglets | 8.3 |
| Open and sows in pig | 4.2 |
| Weaned piglets | |
| Pen surface ≤ 0.35 $m^2$/animal place | 0.60 |
| Pen surface > 0.35 $m^2$/animal place | 0.75 |
| Fattening and rearing pigs | |
| Slurry pit under complete animal place, pen surface 0.8 $m^2$/animal place | 5.0 |
| Slurry pit under complete animal place, pen surface 1.0 $m^2$/animal place | 6.1 |
| Slurry pit under part of the animal place, pen surface 0.8 $m^2$/animal place | 3.4 |
| Slurry pit under part of the animal place, pen surface 1.0 $m^2$/animal place | 4.0 |
| Boars for service | 5.5 |

*Table A6.2 Average emission factors for reduced emission housing of pigs (kg $NH_3$ per animal place)*

| | 2000 | 2005 | 2010 | 2015 | 2020 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|
| ***Sows with piglets*** | | | | | | | |
| Air scrubbers | - | 1.7 | 1.9 | 2.5 | 1.9 | 2.1 | 2.0 |
| Floor/ slurry pit adjustments | 7.6 | 6.0 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 |
| ***Open and sows in pig*** | | | | | | | |
| Air scrubbers | - | 0.90 | 1.0 | 1.2 | 1.0 | 1.1 | 1.3 |
| Floor/ slurry pit adjustments | 3.8 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 | 4.2 |
| ***Weaned piglets*** | | | | | | | |
| Air scrubbers | - | 0.12 | 0.13 | 0.18 | 0.15 | 0.16 | 0.16 |
| Floor/ slurry pit adjustments | 0.55 | 0.31 | 0.31 | 0.33 | 0.31 | 0.31 | 0.33 |
| ***fattening pigs and young breeding pigs*** | | | | | | | |
| Air scrubbers (0.8 $m^2$) | - | 0.70 | 0.70 | 0.96 | 0.75 | 0.78 | 0.78 |
| Air scrubbers (1 $m^2$) | - | 0.82 | 0.83 | 1.1 | 0.88 | 0.92 | 0.93 |
| Floor/ slurry pit adjustments (0.8 $m^2$) | 3.4 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| Floor/ slurry pit adjustments (1 $m^2$) | - | 3.5 | 3.3 | 3.3 | 3.5 | 3.5 | 3.5 |
| ***Boars*** | | | | | | | |
| Air scrubbers | 1.65 | 1.3 | 1.4 | 1.6 | 1.2 | 1.3 | 1.4 |
| Floor/ slurry pit adjustments | - | - | - | 5.5 | 5.5 | 5.5 | 5.5 |

## References

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# Annex 7 Emission factors for NH3 from animal housing of poultry

In this annex the emission factors in kg $NH_3$ per animal place are given that form the basis for the calculation of emission factors relative to the TAN excretion (section 5.2).

## A7.1 Laying hens younger than ca. 18 weeks

In Table A7.1 the housing systems are given according to the former classification of the Agricultural census.

It is not clear which systems have been filled in by businesses under 'other battery cage housing solid manure' in the Agricultural census of 2008. To the other battery cage systems with solid manure belong the channel animal house (E1.4) and the battery cage system with manure belt aeration and above laying drying tunnel (E1.6). Although it concerns over 7% of the animal places in the Agricultural census of 2008, systems mentioned hardly occur in the environmental permits. Possibly it concerns businesses with manure belt aeration with the aeration turned off but producing solid manure after all through after drying, and therefore have filled in battery cage housing with solid manure (Ellen, 2010). The emission factor of manure belt with forced manure drying 0.2 $m^3$ per hour is applied as minimal value.

*Table A7.1 (Derived) emission factors for laying hens under 18 weeks (kg $NH_3$ per animal place)*

| | 1990-2010[1)] | 2015 | 2020 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|
| | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place |
| **Battery cage with slurry** | | | | | | |
| Open storage | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 |
| Manure belt | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 |
| **Battery cage with solid manure** | | | | | | |
| Manure belt, forced manure drying 0.2 $m^3$/animal/hour | 0.025 | 0.020 | 0.020 | 0.020 | 0.020 | 0.020 |
| Manure belt, forced manure drying 0.4 $m^3$/animal/hour | 0.011 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| Manure belt, forced manure drying 0.4 $m^3$/animal/hour with air scrubber | 0.006 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Other battery cage solid manure | 0.020 | 0.016 | 0.020 | 0.021 | 0.021 | 0.016 |

| | 1990-2010[1)] | 2015 | 2020 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|
| | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place |
| **Ground housing without manure aeration** | 0.170 | 0.170 | 0.170 | 0.170 | 0.170 | 0.170 |
| **Ground housing with air scrubber** | - | 0.035 | 0.038 | 0.037 | 0.036 | 0.042 |
| **Aviary system** | | | | | | |
| Aviary housing without forced manure drying | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 |
| Aviary housing with forced manure drying | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 | 0.050 |
| Ground/aviary housing with air scrubber | 0.017 | - | - | - | - | - |
| **Aviary system with manure drying** | | | | | | |
| Aviary housing without forced manure drying | 0.055 | 0.062 | 0.062 | 0.061 | 0.064 | 0.051 |
| Aviary housing with forced manure drying | 0.055 | 0.062 | 0.066 | 0.064 | 0.066 | 0.054 |
| Ground/aviary housing with air scrubber | 0.022 | - | - | - | - | - |
| **Other housing** | 0.139 | 0.118 | 0.120 | 0.121 | 0.122 | 0.120 |

1) Source: environmental permits in province Noord-Brabant on 1-1-2009.
2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
3) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

## A7.2 Laying hens

In Table A7.2 the housing systems are given according to the former classification of the Agricultural census.

It is assumed that the enriched cages and colony housing, both with manure belt aeration, have been filled in with battery cage housing with forced manure drying (0.7 $m^3$/hour) by businesses.

The “other battery cage system with solid manure” consists of canals animal house (E2.4 and the battery cage system with manure belt aeration and above lying drying tunnel (E2.6). These systems hardly occur. In other battery cage housing with solid manure it concerns most likely businesses with manure belt drying that have switched off the aeration. Possibly part of these businesses have after drying so that they produce solid manure after all (Ellen, 2010). For the share animals with housing type other battery cage solid manure the emission factor of manure belt with forced manure drying 0.042 $m^3$ per hour is applied as minimal value.

*Table A7.2 (Derived) emission factors for laying hens (kg $NH_3$ per animal place)*

| | 1990 kg $NH_3$/ animal place | 2000 kg $NH_3$/ animal place | 2010 kg $NH_3$/ animal place | 2015 kg $NH_3$/ animal place | 2020 kg $NH_3$/ animal place | 2022 kg $NH_3$/ animal place | 2023 kg $NH_3$/ animal place | 2024 kg $NH_3$/ animal place |
|---|---|---|---|---|---|---|---|---|
| **Battery cage with slurry** | | | | | | | | |
| Open storage | 0.083 | 0.083 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 | 0.100 |
| Manure belt | 0.035 | 0.035 | 0.042 | 0.042 | 0.042 | 0.042 | 0.042 | 0.042 |
| **Battery cage with solid manure** | | | | | | | | |
| Manure belt, forced manure drying 0.5 $m^3$/animal/hour | 0.045 | 0.045 | 0.052 | 0.050 | 0.042 | 0.042 | 0.042 | 0.042 |
| Manure belt, forced manure drying 0.7 $m^3$/animal/hour | 0.020 | 0.020 | 0.022 | 0.020 | 0.012 | 0.012 | 0.012 | 0.012 |
| Manure belt, forced manure drying 0.7 $m^3$/animal/hour with air scrubber | 0.011 | 0.011 | 0.011 | 0.009 | 0.001 | 0.001 | 0.001 | 0.001 |
| Other battery cage solid manure | 0.035 | 0.035 | 0.042 | 0.031 | 0.037 | 0.036 | 0.035 | 0.031 |
| **Ground housing** | | | | | | | | |
| Ground housing without manure aeration (including 0.1% with air scrubber) | 0.315 | 0.342 | 0.402 | 0.402 | 0.402 | 0.402 | 0.402 | 0.402 |
| Perfo system | 0.110 | 0.119 | 0.140 | 0.140 | 0.140 | 0.140 | 0.140 | 0.140 |
| Manure aeration | 0.223 | 0.242 | 0.285 | 0.303 | 0.303 | 0.301 | 0.301 | 0.303 |
| Manure belts | 0.143 | 0.155 | 0.183 | 0.206 | 0.210 | 0.214 | 0.212 | 0.210 |
| Manure belts with drying | 0.153 | 0.165 | 0.193 | 0.216 | 0.240 | 0.237 | 0.241 | 0.219 |

| | 1990<br>kg $NH_3$/ animal place | 2000<br>kg $NH_3$/ animal place | 2010<br>kg $NH_3$/ animal place | 2015<br>kg $NH_3$/ animal place | 2020<br>kg $NH_3$/ animal place | 2022<br>kg $NH_3$/ animal place | 2023<br>kg $NH_3$/ animal place | 2024<br>kg $NH_3$/ animal place |
|---|---|---|---|---|---|---|---|---|
| **Aviary housing** | | | | | | | | |
| Aviary housing without forced manure drying | 0.090 | 0.090 | 0.090 | 0.090 | 0.086 | 0.086 | 0.086 | 0.086 |
| Aviary housing with forced manure drying | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.090 | 0.90 | 0.090 |
| Aviary housing with after drying | 0.100 | 0.100 | 0.100 | 0.109 | 0.107 | 0.107 | 0.106 | 0.089 |
| Aviary housing with forced manure drying and after drying | 0.100 | 0.100 | 0.100 | 0.103 | 0.111 | 0.112 | 0.111 | 0.093 |
| **Other housing** | 0.290 | 0.315 | 0.370 | - | - | - | - | - |

## A7.3 Broiler breeders to circa 19 weeks

In Table A7.3 the animal housing systems are given according to the former classification in the Agricultural census.

*Table A7.3 Emission factors for broiler breeders under 19 weeks (kg $NH_3$ per animal place)*

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place |
| Traditional housing | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 |
| Air scrubber/ biofilter | - | - | - | 0.016 | 0.017 | 0.017 | 0.017 | 0.017 |
| Other low-emission housing | - | - | - | 0.122 | 0.111 | 0.113 | 0.111 | 0.113 |

## A7.4 Broiler breeders

In Table A7.4 the housing systems are given according to the former classification of the Agricultural census.

*Table A7.4 Derived emission factors for broiler breeders (kg $NH_3$ per animal place)*

| | 1990<br>kg $NH_3$/ animal place | 2000<br>kg $NH_3$/ animal place | 2010<br>kg $NH_3$/ animal place | 2015<br>kg $NH_3$/ animal place | 2020<br>kg $NH_3$/ animal place | 2022<br>kg $NH_3$/ animal place | 2023<br>kg $NH_3$/ animal place | 2024<br>kg $NH_3$/ animal place |
|---|---|---|---|---|---|---|---|---|
| Traditional housing | 0.580 | 0.564 | 0.456 | 0.456 | 0.456 | 0.456 | 0.456 | 0.456 |
| Enriched cage/group cage | 0.080 | 0.078 | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 | 0.063 |
| Enriched cage/group cage with after drying | 0.090 | 0.088 | 0.073 | 0.063 | 0.065 | 0.065 | 0.065 | 0.063 |
| Aviary housing with forced manure drying | 0.170 | 0.165 | 0.134 | 0.127 | 0.115 | 0.115 | 0.114 | 0.130 |
| Aviary housing with forced manure drying with after drying | 0.180 | 0.175 | 0.144 | 0.127 | 0.146 | 0.149 | 0.149 | 0.130 |
| Ground housing with manure aeration from above | 0.395 | 0.395 | 0.310 | 0.310 | 0.310 | 0.310 | 0.310 | 0.310 |
| Ground housing with vertical hoses in the manure or through tubes underneath the bin | 0.580 | 0.580 | 0.456 | 0.456 | 0.456 | 0.456 | 0.456 | 0.456 |
| Perfo system | 0.363 | 0.363 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 |
| Air scrubber systems | 0.080 | 0.078 | 0.063 | 0.056 | 0.061 | 0.080 | 0.079 | 0.063 |
| Ground housing with manure belts without after drying | 0.387 | 0.387 | 0.303 | 0.303 | 0.303 | 0.303 | 0.303 | 0.303 |
| Ground housing with manure belts with after drying | 0.397 | 0.386 | 0.313 | 0.353 | 0.303 | 0.303 | 0.303 | 0.303 |

## A7.5 Broilers

In Table A7.5 the housing systems are depicted according to the former classification of the Agricultural census.

*Table A7.5 (Derived) emission factors for broilers (kg $NH_3$ per animal place)*

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place |
| Traditional housing | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 |
| Floor with litter drying | 0.008 | 0.008 | 0.008 | 0.005 | 0.005 | 0.006 | 0.004 | 0.004 |
| Storey systems | 0.011 | 0.011 | 0.011 | 0.029 | 0.016 | 0.016 | 0.017 | 0.015 |
| Air scrubber systems | 0.008 | 0.008 | 0.008 | 0.010 | 0.009 | 0.009 | 0.009 | 0.009 |
| Ground housing with floor heating and cooling | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 |
| Mixed air ventilation, warmth heaters and fans, air blending | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 | 0.068 |

## A7.6 Ducks for slaughter

Ducks for slaughter are mostly held in traditional housing with an emission factor of 0.210 kg $NH_3$ per animal place. However, since 2015, ducks for slaughter are also kept in housing with air scrubbers. The emission factor of these ducks is 0.021 kg $NH_3$ per animal place. In 2023 new housing systems were introduced leading to an increase in average emission factor of low emission housing to 0.03 kg $NH_3$ per animal place, in 2024 the average emission factor increased to 0.034 kg $NH_3$ per animal place.

## A7.7 Turkeys for slaughter

In Table A7.6 the housing systems are presented according to the former classification of the Agricultural census (traditional housing and low emission housing).

*Table A7.6 (Derived) emission factors for turkeys (kg $NH_3$ per animal place)*

| | 1990 | 2000 | 2010 | 2015 | 2020 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place | kg $NH_3$/ animal place |
| Traditional housing | 0.680 | 0.758 | 0.932 | 0.932 | 0.932 | 0.932 | 0.932 | 0.932 |
| Low-emission housing | 0.493 | 0.493 | 0.493 | 0.383 | 0.377 | 0.382 | 0.373 | 0.351 |

# Annex 8 Emission factors for NH3 from animal housing of other livestock

In this annex the emission factors in kg $NH_3$ per animal place are given that form the basis for the calculation of emission factors relative to the TAN excretion (section 5.2).

*Table A8.1 (Derived) emission factors for sheep, goats, horses, ponies, mules and asses rabbits, mink and foxes (kg $NH_3$ per animal place)*

| | **1990-1998[1)]** | **2000** | **2005** | **2010** | **2015** | **2018** | **2020** | **2023** | **2024** |
|---|---|---|---|---|---|---|---|---|---|
| | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** | **kg $NH_3$/ animal place** |
| **Sheep** | | | | | | | | | |
| Ewes (including young stock and rams | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 | 0.70 |
| **Goats** | | | | | | | | | |
| Traditional housing | | | | | | | | | |
| Milk goats and rams | 1.9 | 2.14 | 2.74 | 3.34 | 3.94 | 4.3 | 4.3 | 4.3 | 4.3 |
| Breeding stock (3-50 kg) | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Meat kids (3-10 kg) | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Low-emission housing | | | | | | | | | |
| Milk goats and rams | NO | NO | NO | NO | NO | NO | 1.08 | 1.10 | 1.25 |
| Breeding stock (3-50 kg) | NO | NO | NO | NO | NO | NO | 0.25 | 0.20 | 0.15 |
| Meat kids (3-10 kg) | NO | NO | NO | NO | NO | NO | NO | 0.07 | 0.04 |
| **Horses** | | | | | | | | | |
| Adult horses | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |

| | 1990-1998[1)] kg $NH_3$/ animal place | 2000 kg $NH_3$/ animal place | 2005 kg $NH_3$/ animal place | 2010 kg $NH_3$/ animal place | 2015 kg $NH_3$/ animal place | 2018 kg $NH_3$/ animal place | 2020 kg $NH_3$/ animal place | 2023 kg $NH_3$/ animal place | 2024 kg $NH_3$/ animal place |
|---|---|---|---|---|---|---|---|---|---|
| Young stock | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 |
| **Ponies** | | | | | | | | | |
| Adult ponies | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| Young stock | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| **Mules and asses** | | | | | | | | | |
| Adult mules and asses | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| Young stock | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| **Rabbits** | | | | | | | | | |
| Does | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Young stock | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| Meat rabbits | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Mink (per breeding female)** | 0.25 | 0.25 | 0.25 | NO | NO | NO | NO | NO | NO |
| **Foxes (per breeding female** | 2.5 | NO | NO | NO | NO | NO | NO | NO | NO |

# Annex 9 Animal house occupancy fractions

To convert emissions from animal housings in kg $NH_3$ per animal place to an emission factor in kg $NH_3$ per animal, the animal house occupancy fractions are needed. For instance, an emission of 10.0 kg $NH_3$ per animal place at an occupancy fraction of 0.9 yields an emission of 10.0 / 0.9 = 11.1 kg $NH_3$ per animal entered in the Agricultural census. Table A8.1 presents reference year, occupancy fraction and period to which these apply (reporting period).

*Table A8.1 Animal house occupancy (fraction) and reference year*

| | **Reporting period** | **Reference year[1)]** | **Animal house occupancy (fraction)** |
|---|---|---|---|
| Dairy cows | 1990-2001 | 2001 | 0.9 |
| | 2002-2024 | 2007-2012 | 1.0 |
| Other cattle excluding meat calves | 1990-2024 | 2007-2012 | 1.0 |
| Meat calves, for white veal production | 1990-2024 | 1998 | 0.93 |
| | 1999-2024 | 2012 | 0.93 |
| Meat calves, for rosé meat production | 1990-1998 | 1998 | 0.93 |
| | 1999-2024 | 2012 | 0.96 |
| Female sheep | 1990-2024 | 1991 | 1.0 |
| Milk goats | 1990-2024 | 1998 | 1.0 |
| Horses, ponies and mules | 1990-2024 | 1997 | 1.0 |
| Fattening pigs and rearing pigs | 1990-2024 | 2008-2009 | 0.97 |
| Sows | 1990-2024 | 1994 | [2)] |
| Boars for service | 1990-2024 | 1991 | 0.9 |
| Broiler breeders < 18 weeks | 1990-2024 | 2008 | 0.83 |
| Broiler breeders ≥ 18 weeks | 1990-2007 | 1996 | 0.87 |
| | 2008-2024 | 2008 | 0.87 |
| Laying hens < 18 weeks | | | |
| battery cage slurry, dry manure 0.2 $m^3/h$, other battery and other housing | 1990-2024 | 1991 | 0.9 |
| battery cage dry manure 0.4 $m^3/h$ | 1990-2024 | 1996 | 0.9 |
| free range housing without manure aeration and aviary with manure drying | 1990-2024 | 2000 | 0.9 |
| aviary without manure drying with air scrubber | 1990-2024 | 1998 | 0.9 |
| Laying hens ≥ 18 weeks | | | |
| battery slurry with open storage, battery dry manure 0.7 $m^3/h$ and deep pit | 1990-2024 | 1996 | 0.95 |
| battery slurry 2/week mucking, dry manure 0.5 $m^3/h$, other battery | 1990-2024 | 1991 | 0.95 |
| floor housing and other housing | 1990-2007 | 1996 | 0.95 |
| | 2008-2024 | 2008 | 0.95 |
| aviary without manure drying | 1990-2024 | 1996 | 0.95 |
| aviary manure drying | 1990-2024 | 2001 | 0.95 |

| | Reporting period | Reference year[1)] | Animal house occupancy (fraction) |
|---|---|---|---|
| Broilers | | | |
| traditional, litter drying, storey system with slatted floor and aeration, air scrubber | 1990-2024 | 2002 | 0.81 |
| ground housing with floor heating and - cooling | 1990-2024 | 1997-1998 | 0.81 |
| mixed air ventilation | 1990-2024 | 2005 | 0.81 |
| Ducks | 1990-2024 | 2000 | 0.84 |
| Turkeys | | | |
| traditional | 1990-2007 | 1998 | 0.95 |
| | 2008-2024 | 2008 | 0.95 |
| low emission | 1990-2024 | 2008 | 0.95 |
| Rabbits (mother animals) | 1990-2024 | 1998 | 1.0 |
| Rabbits for slaughter | 1990-2024 | 1998 | 0.85 |
| Fur-bearing animals (mother animals) | 1990-2024 | 1991 | 0.9 |

1) The reference year is the year or period that corresponds with the year or the period in which the emission factor in kg NH3 per animal place is taken up in the Rav respectively is measured.
2) Per breeding sow present: 0.25 sow with piglets; 0.83 open and sows in pig and 2.8 weaned piglet per breeding sow.

# Annex 10 Emission factors for calculation direct nitrous oxide emissions from agricultural soils (including grazing)

**Marian van Schijndel and Sietske van der Sluis (PBL), 2011**

For fertilisation with inorganic N fertilizers and animal manure and for grazing emission factors have been established and applied in the NIR 2011. For an overview see Table A10.1. This memorandum describes the derivation of the (weighted average) emission factors that are applied in the NIR 2011 for the period from 1990 to now in the ER-calculations of direct $N_2O$ emissions from agricultural soils (including grazing).

*Table A10.1 $N_2O$-N emission factors (% of the N supply) for calculation of direct $N_2O$ emissions from agricultural soils and of $N_2O$ emissions as a result of grazing (based on Velthof and Mosquera, 2011b and Van der Hoek et al., 2007). The marked emission factors are applied since the NIR 2011 (Van der Maas et al., 2011).*

| **$N_2O$-emission factor (%)** | | **Grass land** | **Arable land** | **Weighted average all land use and soils** | **Was previously (1)*** | **Remarks** |
|---|---|---|---|---|---|---|
| *Animal manure emission low* | All soils | | | 0.9 | 2 (1.7) | 1990: 1.5<br>2008: 1.9 |
| | Mineral soils | 0.3 | 1.3 | | Like all soils | |
| | Peat soils | 1 | N/A | | Like all soils | |
| *Animal manure surface application* | All soils | | | 0.4 | 1 (0.9) | |
| | Mineral soils | 0.1 | 0.6 | | 1 (0.8) | 1990: 0.8<br>1999: 0.9 |
| | Peat soils | 0.5 | N/A | | 2 (1.6) | 1990: 1.5<br>1995: 1.7 |
| *Inorganic N fertilizer* | All soils | | | 1.3 | 1 (1.04) | |
| | Mineral soils | 0.8 | 0.7 | | Nitrate containing 1 (0.97). Ammonium containing 0.5 (0.48) | varying over the years |
| | Peat soils | 3 | N/A | | Nitrate containing 2 (1.94). Ammonium containing 1 (0.97) | varying over the years |
| *Grazing* | All soils | | | 3.3 | 1.68 (1.56) | |

| $N_2O$-emission factor (%) | | Grass land | Arable land | Weighted average all land use and soils | Was previously (1)* | Remarks |
|---|---|---|---|---|---|---|
| | Mineral soils | 2.5 | N/A | | | |
| | Peat soils | 6.0 | N/A | | | |
| | | | | | 1 (0.93) | faeces |
| | | | | | 2 (1.86) | urine |
| *Histosols* | Peat soils | ** | N/A | ** | 2 | No adjustment |
| *Crop residues* | Mineral soils | N/A | ** | ** | 1 | No adjustment |
| Sewage sludge | ???? | | | | 1 | No adjustment |

(1) Van der Hoek *et al.*, 2007.
* Between brackets the emission factors related to total gross N supply to soil (without deducting NH3-N in fertilizing). In the old method the N2O-N was calculated based on net N supply to soil, i.e. after deduction of NH3-N. In the new method no NH3-N deduction is applied anymore. Reason is that this also not happens in the N2O measurements in field experiments.
** No (new) data available.

### A10.1 Reason revision $N_2O$-N emission factors

In 1994 based on laboratory scale experiments country-specific emission factors for the direct $N_2O$ emission from agricultural soils were derived (Kroeze, 1994) for the distinguished sources. The $N_2O$-N emission factor for low emission manure application and surface spreading were respectively 2 and 1% of the N supply to the soil. Thus the emission factor for low emission manure application was compared to surface spreading a factor 2 higher. In 1997 this was summarised in a methodology description (Spakman *et al.*, 1997). For surface spreading the country-specific $N_2O$-N emission factor was somewhat lower than the IPCC 1996 default (1% versus 1.25% of the N supply).

For the NIR 2005 (Klein Goldewijk *et al.*, 2005) the methodology was developed further and adjusted (Van der Hoek *et al.*, 2007). Amongst others the emission factor for inorganic N fertilizer is refined based on research of Velthof *et al.*, 1997. This refinement comprised that for a separate category inorganic N fertilizers (ammonium containing inorganic N fertilizers that do not contain nitrate) a 50% lower emission factor was applied than used before for all kinds of inorganic N fertilizer.

Based on field experiments in the Netherlands there seemed to be indications that the $N_2O$-N emission factor for low emission manure application was lower than the 2% of the N supply used (Velthof *et al.*, 2003 and Van Groeningen *et al.*, 2004). This led to the question whether low emission manure application in practice indeed had a higher $N_2O$-N emission factor than surface spreading. An overview of Dutch and international research results published after the publication of Kroeze in 1994 (Kuikman *et al.*, 2006) offered insufficient reason to adjust and/or further refine the emission factors for low emission manure application and surface spreading (Van der Hoek *et al.*, 2007). In the Netherlands only a very limited number of comparative experiments had been carried out between surface spreading and low emission manure application. These resulted in relatively low emission factors (< 0.1% of the N supply) for both application techniques (Velthof *et al.*, 1997). Results of international comparative field experiments showed that the nitrous oxide emissions for low emission manure application were mostly higher than for surface spreading. However it was not possible to derive long year average $N_2O$-N emission factors and adjust these for Dutch circumstances. It was concluded that more research was needed (see also the NIR 2006; Brandes *et al.*, 2006).

Between 2007 and 2010 in the Netherlands 2 to 3 year lasting comparative field experiments have been conducted to map the $N_2O$ emissions for surface spreading and low emission manure application, in which for comparison also the fertilisation with inorganic N fertilizer was researched (Velthof *et al.*, 2010 and Velthof and Mosquera, 2011a). It was found that low emission manure application has higher $N_2O$-N emission factors than surface spreading.

The emission factors derived based were lower than the emission factors used for both fertilisation techniques, and there were differences in the $N_2O$-N emission factors between grassland and arable land and between animal manure and inorganic N fertilizer. These findings were the incentive to follow-up research. Based on all available Dutch and other NW European measurements of $N_2O$ emission factors starting from the beginning of the nineties it was recommended to adjust the emission factors for manure application and inorganic N fertilizer use (Velthof and Mosquera, 2011b). PBL Netherlands Environmental Assessment Agency has reviewed the statistical analysis performed by Velthof and Mosquera on behalf of the Emission Registration (see annex 2 of this Annex).

## A10.2 Motivation for calculating weighted average emission factors

Table 1 distinguishes for animal manure low emission manure application and surface fertilisation. Further for animal manure, inorganic N fertilizer and grazing there are separate emission factors for mineral soils, peat soils, grassland and arable land (see data in italics) as determined by Velthof and Mosquera, 2011b.

### *A10.2.1 Data series N supply to soil*

Based on the historical data for N supply to grassland and arable land (part of the manure and $NH_3$ calculation for the Emission Registration, see for instance Hoogeveen *et al.*, 2010) for four soil types a yearly and multiannual weighted average emission factor can be calculated (Table A10.5 up to 7). For this the data series of 1990-2005 is used, because the data 2006-2008 show a trend break with the data of 1990-2005. Especially there is a factor 8 to 15 increase in the supply of respectively inorganic N fertilizer and animal manure to arable land on peat soil. Also there is almost a bisection in the supply of N in manure (through fertilisation and grazing) to grassland on peat.

This correlates to specific data becoming available on the cultivation of crops on several soil types through the Agricultural census since 2006.

Up to 2006 this information was not available and crops were allocated to soil types. Grassland was situated on peat soil as much as possible and only in case of too little grassland also arable land was situated on peat soil. The supply of manure to arable land on peat soil was as a result of this limited to << 1% and deemed negligible.

In the assumption that the supply of manure to arable land is negligible, use of the whole data series (1990-2008) leads to a weighted average emission factor that is circa 0.1% lower than in using the data series 1990-2005. For the current emission calculations the data series of 1990-2005 is used to prevent underestimation of the emissions.

From the new information that is available over the period 2006-2008 it turns out that the supply of manure on arable land on peat soil is circa 1 to 2% higher. At this moment it is unknown whether including the supply of manure to arable land on peat leads to significant higher $N_2O$ emission factors. There is no $N_2O$ emission factor available for fertilisation of arable land on peat with animal manure or inorganic N fertilizer.

A sensitivity analysis shows that including the supply of manure to arable land on peat does not lead to a higher weighted average emission factor.

Only with an emission factor that is a factor 6 to 8 higher for supply of animal manure to arable land on peat the weighted average emission factor becomes 0.1% point higher. For inorganic N fertilizer this is only the case when the emission factor is a factor 40 higher.

Experiments on grassland show that the emission factor for peat soils is often a factor 3 to 5 higher than the emission factor for mineral soils. Assuming this increase also applies to arable land it is assumed that the weighted average emission factor is correct.

#### *A10.2.2 Variation in N supply to soil*

The share of the N supply to arable land coming from animal manure is for the whole period of 1990 until now on average circa 48%, this share varies between 36 and 57%.

Deviation of the average is therefore at maximum around 25%. For grassland the average N supply from animal manure is circa 52%, this varies between 43 and 64%. Deviation of the average is therefore at maximum around 20%. For grassland on peat soils an average N supply of circa 11% (9-14%) applies.

The share of the N supply to arable land coming from inorganic N fertilizer is for 1990 until now on average 27%, in which this share varies between circa 23 to circa 41%. Deviation of the average is therefore at maximum around 50%. For grassland the average N supply coming from inorganic N fertilizer is circa 73%, in which this share varies between circa 59 to 77%. Deviation from the average is therefore at maximum around 20%.

The variation in the shares of the N supply to arable land versus grassland therefore is tens of per cents. Also for the emission factors derived for the various sources the uncertainty is tens of per cents (see standard deviations in Velthof and Mosquera, 2011b).
The uncertainties of the emission factors and in the yearly N supply to mineral versus organic soils with grassland and arable land do not make it necessary to conduct yearly calculation for the distinguished sources. Also for the supply of $N_2O$ emission figures in international reports disaggregated emission factors are not necessary. From 2011 on the disaggregated data on N supply possibly will not become available yearly[1]. For these reasons multiannual weighted average emission factors are derived for surface spreading, for low emission manure application, for application of inorganic N fertilizers and for grazing.

## A10.3 Weighted average emission factors

### *A10.3.1 Animal manure*

For animal manure the (multiannual weighted average) $N_2O$ emission factor for surface spreading and low emission manure application is respectively 0.4% and 0.9% of the N supply to soil. That is circa a factor 2 lower than the value applied up to now. This applies to surface spreading (decrease from circa 1 to 0.4% of the N supply) as well as low emission manure application (decrease from circa 2 to 0.9% of the N supply).

There is a significant difference in emission factors for low emission manure application and surface spreading. For low emission manure application the $N_2O$-N emission factor is a factor 2 higher than for surface spreading, namely 0.9% versus 0.4% of the N supply (Velthof *et al.*, 2010). The share of N in surface spreading decreases strongly between 1990 and 1995 (from 100 to 5%). This makes it necessary to calculate these sources separately in the yearly emission calculations and thus to differentiate separate emission factors for surface spreading and low emission manure application.

### *A10.3.2 Inorganic N fertilizer*

For inorganic N fertilizer the (multiannual weighted average) $N_2O$-N emission factor is circa 30% higher than the value applied up until now (from circa 1 to 1.3% of the N supply). Reason is that especially for grassland on peat soils the emission factor based on measurement turns out to be higher than assumed (3% instead of 2%).

Also no longer a lower emission factor for ammonium containing (nitrate free) inorganic N fertilizer is applied, because the available measurements do not provide sufficient basis for different factors. In the Netherlands very few measurement were done; only 3 comparative experiments with a duration of more than 8 months. In 1 of the 3 experiments there seems to be a lower emission factor for the ammonium containing (nitrate fee) inorganic N fertilizer. In the other 2 experiments there is no difference or the emission factor is even higher.

[1] This as result of the transition to a new calculation methodology for the yearly national $NH_3$ calculations (Velthof *et al.*, 2009 and Van Bruggen *et al.*, 2011). The previously yearly used MAMBO model for the $NH_3$ calculations will be applied by the ER possibly only for the purpose of regionalisation. This will likely be less frequent than yearly, for instance 3 yearly.

Also literature research into international measurements does not provide a definite answer (Velthof and Mosquera, 2011b).

*A10.3.3* *Grazing*
For grazing the (multiannual weighted average) emission factor is circa a factor 2 higher based on measurements (urine/dung data in Appendix 1 of Velthof and Mosquera, 2011b); it increases from circa 1.7 to 3.3% $N_2O$-N of the N supply.

*A10.3.4* *Other sources*
For the emission factor of the smaller sources crop residues, histosols and sewage sludge the 'old' values still apply because no new data is available. For histosols the emission factor is 2%. This is consistent with the average of the new emission factors that apply for grassland on peat soils for inorganic N fertilizer and low emission manure application (respectively 3 and 1%).
For crop residues the emission factor is 1%. This is consistent with the average of the emission factors that apply for arable land on mineral soils for inorganic N fertilizers and low emission manure application (respectively 1 and 1.3%).

*A10.3.5* *Comparison to IPCC defaults*
The new emission factor for low emission manure application of 0.9% is lower than the IPCC 1996 default of 1.25%, but is approximately around the new IPCC 2006 default of 1%. For surface spreading the emission factor is a factor 2 lower than the IPCC 2006 default.
The new emission factor for inorganic N fertilizer is somewhat higher than the IPCC 1996 default (1.3 versus 1.25%). In comparison to the new IPCC 2006 default of 1% of the N supply the country specific value is circa 30% higher.
The new emission factor for grazing is 3.3% of the N supply and with that circa 65% higher than the IPCC 1996 and IPCC 2006 defaults of 2%.

*A10.3.6* *Uncertainties of weighted average emission factors*
Velthof and Mosquera (2011b) give uncertainties for the emission factors for animal manure, inorganic N fertilizer and grazing. For the calculation of the uncertainty of the weighted average emission factors an expert judgement (Luesink) was made on the uncertainty if the amount of manure going to different soil types and land use.

*Table A9.2 Animal manure*

| Agricultural soil | Manure to soil | U manure to soil | EF (%) | U EF |
|---|---|---|---|---|
| Low emission (total x2) | | | | 70% |
| Organic grassland | 21.6 | 40% | 1.0 | 45%* |
| Mineral grassland | 106.5 | 40% | 0.3 | 33% |
| Mineral arable land | 108.7 | 40% | 1.3 | 23% |
| Surface spreading (total x2) | | | | 81% |
| Organic grassland | 1.1 | 40% | 0.5 | 45%* |
| Mineral grassland | 5.5 | 40% | 0.1 | 20% |
| Mineral arable land | 5.6 | 40% | 0.6 | 33% |

* Velthof and Mosquera (2011b) do not give an uncertainty. The highest uncertainty of the other emission factors in taken, rounded at 5%.

*Table A10.3 Inorganic N fertilizer*

| Agricultural soil | Inorganic fertilizer to soil | U inorganic fertilizer to soil | EF (%) | U EF |
|---|---|---|---|---|
| Organic grassland | 18.8 | 20% | 3.0 | 20% |
| Mineral grassland | 123.2 | 20% | 0.8 | 13% |
| Mineral arable land | 83.4 | 20% | 0.7 | 43% |
| Total (2x) | | | | 37% |

*Table A10.4 Grazing*

| Agricultural soil | Manure deposited in pastures | U manure deposited in pastures | EF (%) | U EF |
|---|---|---|---|---|
| Organic grassland | 12.0 | 20% | 3.0 | 38% |
| Mineral grassland | 64.3 | 20% | 0.8 | 31% |
| Total (2x) | | | | 64% |

*Table A10.5 Calculation weighted average $N_2O$-N emission factor for application animal manure based on N in animal manure to soil**

| | | N supply (kg N) to | N supply (kg N) to | share N supply to | share N supply to | | $N_2O$-N emission factor (% of N supply) |
|---|---|---|---|---|---|---|---|
| **year** | **soil** | **arable land** | **grassland** | **arable land**** | **grassland** | **low emission manure application** | **surface spreading** |
| 1980 | mineral | 124,056,517 | 131,190,515 | 43% | 46% | 0.8 | 0.4 |
| | peat | 12,025 | 31,254,013 | | 11% | | |
| 1984 | mineral | 149,064,760 | 121,560,842 | 50% | 40% | 0.9 | 0.4 |
| | peat | 39,840 | 29,774,908 | | 10% | | |
| 1985 | mineral | 163,478,854 | 118,770,657 | 52% | 38% | 0.9 | 0.4 |
| | peat | 48,463 | 29,830,481 | | 10% | | |
| 1987 | mineral | 177,840,312 | 109,262,083 | 56% | 35% | 0.9 | 0.4 |
| | peat | 65,403 | 29,254,982 | | 9% | | |
| 1988 | mineral | 164,940,815 | 131,212,093 | 51% | 40% | 0.9 | 0.4 |
| | peat | 135,656 | 29,503,622 | | 9% | | |
| 1989 | mineral | 175,935,382 | 120,319,586 | 54% | 37% | 0.9 | 0.4 |
| | peat | 190,745 | 28,275,924 | | 9% | | |
| 1990 | mineral | 186,513,236 | 113,568,424 | 57% | 35% | 0.9 | 0.4 |
| | peat | 227,961 | 28,102,535 | | 9% | | |
| 1991 | mineral | 160,111,819 | 149,104,352 | 46% | 43% | 0.8 | 0.4 |
| | peat | 212,422 | 36,882,599 | | 11% | | |
| 1992 | mineral | 190,789,097 | 148,340,643 | 51% | 40% | 0.9 | 0.4 |
| | peat | 272,982 | 35,694,657 | | 10% | | |
| 1993 | mineral | 168,860,398 | 172,584,027 | 44% | 45% | 0.8 | 0.4 |
| | peat | 290,342 | 42,588,332 | | 11% | | |
| 1994 | mineral | 161,482,717 | 172,727,227 | 43% | 46% | 0.8 | 0.4 |
| | peat | 312,744 | 39,521,343 | | 11% | | |
| 1995 | mineral | 127,921,589 | 175,486,807 | 36% | 50% | 0.8 | 0.3 |
| | peat | 416,212 | 47,621,425 | | 14% | | |
| 1996 | mineral | 183,453,286 | 157,935,264 | 48% | 41% | 0.9 | 0.4 |
| | peat | 1,599,323 | 42,963,547 | | 11% | | |
| 1997 | mineral | 161,978,074 | 133,007,449 | 49% | 40% | 0.9 | 0.4 |

| | | N supply (kg N) to | N supply (kg N) to | share N supply to | share N supply to | | $N_2O$-N emission factor (% of N supply) |
|---|---|---|---|---|---|---|---|
| **year** | **soil** | **arable land** | **grassland** | **arable land**** | **grassland** | **low emission manure application** | **surface spreading** |
| | peat | 1,193,763 | 37,554,142 | | 11% | | |
| 1998 | mineral | 126,756,610 | 145,544,393 | 41% | 47% | 0.8 | 0.4 |
| | peat | 447,910 | 37,769,955 | | 12% | | |
| 1999 | mineral | 163,289,415 | 129,991,784 | 50% | 40% | 0.9 | 0.4 |
| | peat | 215,418 | 35,090,459 | | 11% | | |
| 2000 | mineral | 143,240,045 | 114,417,747 | 49% | 39% | 0.9 | 0.4 |
| | peat | 341,562 | 32,961,633 | | 11% | | |
| 2001 | mineral | 131,772,857 | 124,241,918 | 45% | 43% | 0.8 | 0.4 |
| | peat | 230,807 | 36,298,625 | | 12% | | |
| 2002 | mineral | 122,698,262 | 119,650,533 | 44% | 43% | 0.8 | 0.4 |
| | peat | 209,634 | 35,621,517 | | 13% | | |
| 2003 | mineral | 126,006,911 | 117,602,005 | 45% | 42% | 0.8 | 0.4 |
| | peat | 164,073 | 35,520,456 | | 13% | | |
| 2004 | mineral | 124,227,089 | 105,717,392 | 47% | 40% | 0.9 | 0.4 |
| | peat | 212,829 | 35,597,614 | | 13% | | |
| 2005 | mineral | 117,023,028 | 104,205,390 | 46% | 41% | 0.9 | 0.4 |
| | peat | 251,242 | 35,832,769 | | 14% | | |
| 2006 | mineral | 101,398,282 | 114,285,064 | 42% | 48% | 0.8 | 0.4 |
| | peat | 3,243,483 | 23,273,421 | | 10% | | |
| 2007 | mineral | 111,809,202 | 117,300,043 | 44% | 46% | 0.8 | 0.4 |
| | peat | 3,634,559 | 23,164,601 | | 9% | | |
| 2008 | mineral | 114,272,963 | 112,003,903 | 45% | 45% | 0.8 | 0.4 |
| | peat | 4,184,001 | 22,771,321 | | 9% | | |
| avg 1980-2005*** | | | 48% | 41% | 0.9 | | 0.4 |
| | | | | | 11% | | |
| avg 1980-2008 | | | 47% | 42% | 0.8 | | 0.4 |
| | | | | | 11% | | |

*Table A10.6 Calculation weighted average $N_2O$ emission factor for application inorganic N fertilizer based on N in inorganic N fertilizer to soil**

| year | soil | N supply (kg N) to arable land | N supply (kg N) to grassland | share N supply to arable land** | share N supply to grassland | $N_2O$-N emission factor (% of N supply) |
|---|---|---|---|---|---|---|
| 1980 | mineral | 106,970,124 | 321,290,597 | 22% | 68% | 1.2 |
| | peat | 845,784 | 47,364,270 | | 10% | |
| 1984 | mineral | 115,242,899 | 306,592,441 | 25% | 65% | 1.2 |
| | peat | 669,448 | 46,453,094 | | 10% | |
| 1985 | mineral | 121,629,145 | 321,528,042 | 25% | 65% | 1.2 |
| | peat | 980,333 | 51,032,821 | | 10% | |
| 1987 | mineral | 117,364,458 | 321,205,471 | 24% | 65% | 1.2 |
| | peat | 1,176,447 | 54,196,495 | | 11% | |
| 1988 | mineral | 103,843,410 | 285,610,253 | 23% | 64% | 1.3 |
| | peat | 567,437 | 58,982,461 | | 13% | |
| 1989 | mineral | 109,035,951 | 271,123,012 | 25% | 62% | 1.2 |
| | peat | 628,476 | 53,700,679 | | 12% | |
| 1990 | mineral | 93,955,348 | 258,779,664 | 23% | 64% | 1.3 |
| | peat | 587,758 | 50,443,644 | | 13% | |
| 1991 | mineral | 95,188,438 | 247,537,905 | 24% | 63% | 1.2 |
| | peat | 558,547 | 48,700,413 | | 12% | |
| 1992 | mineral | 95,575,147 | 239,788,209 | 25% | 63% | 1.3 |
| | peat | 606,476 | 47,919,077 | | 13% | |
| 1993 | mineral | 90,046,707 | 242,183,075 | 24% | 64% | 1.3 |
| | peat | 572,620 | 49,155,969 | | 13% | |
| 1994 | mineral | 93,444,169 | 224,305,307 | 26% | 62% | 1.3 |
| | peat | 735,972 | 45,573,592 | | 13% | |
| 1995 | mineral | 105,665,020 | 252,386,044 | 27% | 64% | 1.2 |
| | peat | 719,180 | 38,860,446 | | 10% | |
| 1996 | mineral | 103,559,665 | 220,116,636 | 27% | 58% | 1.3 |
| | peat | 1,503,317 | 56,088,691 | | 15% | |
| 1997 | mineral | 92,783,862 | 236,991,849 | 25% | 63% | 1.2 |
| | peat | 1,235,110 | 46,040,338 | | 12% | |
| 1998 | mineral | 93,406,574 | 247,455,602 | 24% | 65% | 1.2 |
| | peat | 436,096 | 42,469,506 | | 11% | |
| 1999 | mineral | 91,272,134 | 239,316,122 | 24% | 64% | 1.2 |
| | peat | 414,525 | 42,111,274 | | 11% | |
| 2000 | mineral | 94,109,506 | 199,931,253 | 28% | 61% | 1.2 |
| | peat | 452,482 | 36,361,014 | | 11% | |
| 2001 | mineral | 99,873,727 | 141,112,710 | 36% | 51% | 1.3 |
| | peat | 426,707 | 37,024,246 | | 13% | |
| 2002 | mineral | 87,422,680 | 146,382,600 | 32% | 54% | 1.3 |
| | peat | 367,928 | 37,970,173 | | 14% | |
| 2003 | mineral | 86,331,855 | 148,396,464 | 32% | 55% | 1.3 |
| | peat | 380,570 | 35,186,448 | | 13% | |
| 2004 | mineral | 86,696,990 | 148,801,581 | 31% | 54% | 1.3 |
| | peat | 346,690 | 41,245,514 | | 15% | |
| 2005 | mineral | 87,869,786 | 129,741,007 | 34% | 51% | 1.3 |
| | peat | 353,314 | 38,008,391 | | 15% | |
| 2006 | mineral | 105,470,705 | 132,928,979 | 41% | 51% | 1.2 |
| | peat | 2,874,346 | 21,094,967 | | 8% | |
| 2007 | mineral | 83,018,237 | 128,571,402 | 36% | 56% | 1.2 |

| year | soil | N supply (kg N) to arable land | N supply (kg N) to grassland | share N supply to arable land** | share N supply to grassland | $N_2O$-N emission factor (% of N supply) |
|---|---|---|---|---|---|---|
| | peat | 2,165,854 | 18,554,082 | | 8% | |
| 2008 | mineral | 83,433,097 | 123,167,371 | 37% | 55% | 1.2 |
| | peat | 1,913,870 | 18,795,236 | | 8% | |
| avg 1990-2005*** | | | | 27% | 60% | 1.3 |
| | | | | | 13% | |
| avg 1990-2008 | | | | 28% | 60% | 1.2 |
| | | | | | 12% | |

*Table A10.7 Calculation weighted average $N_2O$ emission factor for grazing based on N in pasture manure to soil**

| year | N supply (kg N) to mineral | N supply (kg N) to peat | $N_2O$-N emission factor (% of N supply) |
|---|---|---|---|
| 1980 | 107,508,357 | 24,674,512 | 3.2 |
| 1984 | 119,347,758 | 27,232,572 | 3.2 |
| 1985 | 121,731,826 | 28,144,527 | 3.2 |
| 1987 | 123,537,968 | 28,990,668 | 3.2 |
| 1988 | 115,887,919 | 27,259,575 | 3.2 |
| 1989 | 115,780,711 | 27,211,678 | 3.2 |
| 1990 | 121,894,046 | 28,534,860 | 3.2 |
| 1991 | 124,259,557 | 29,059,000 | 3.2 |
| 1992 | 119,230,167 | 28,189,410 | 3.2 |
| 1993 | 119,802,693 | 28,642,606 | 3.2 |
| 1994 | 110,172,205 | 26,420,847 | 3.2 |
| 1995 | 110,190,780 | 26,542,838 | 3.2 |
| 1996 | 112,515,810 | 30,676,162 | 3.2 |
| 1997 | 105,550,182 | 32,090,792 | 3.3 |
| 1998 | 94,709,103 | 28,909,070 | 3.3 |
| 1999 | 81,121,551 | 25,597,115 | 3.3 |
| 2000 | 74,318,394 | 23,178,293 | 3.3 |
| 2001 | 75,716,792 | 23,705,551 | 3.3 |
| 2002 | 60,076,981 | 19,368,654 | 3.4 |
| 2003 | 61,799,968 | 19,573,558 | 3.3 |
| 2004 | 60,023,293 | 21,370,347 | 3.4 |
| 2005 | 59,810,261 | 21,389,229 | 3.4 |
| 2006 | 66,689,712 | 12,502,196 | 3.1 |
| 2007 | 60,286,513 | 11,358,872 | 3.1 |
| 2008 | 64,312,534 | 11,955,203 | 3.0 |
| | | | |
| avg 1990-2005*** | | | 3.3 |
| avg 1990-2008 | | | 3.2 |

* N to soil after subtraction of NH3-N during application because data without subtraction of NH3-N for N to peat respectively mineral soils are not available; in the emission calculations the weighted average emission factors however are related to the total gross N supply to soil (without subtraction of NH3-N during application). Assumption is that the differences in evaporation of NH3 in arable land and grassland are so small that these will not influence the division of the gross N supply over grassland and arable land.
1980-1997: MestAmm data LEI
1997-2005: MAM data LEI
2006-2008: MAMBO data LEI

** In calculation of the shares N to arable land and grassland the N supply to arable land on peat is neglected. The share is relatively small (< 0.2%) and for this source no emission factors are available.
*** The data 2006-2008 show a break in the trend with the data 1980-2005. Especially there is a factor 8 to 15 increase in the supply of respectively inorganic N fertilizer and animal manure to arable land on peat. Also there is almost a halving in the supply of N in manure (through fertilisation and grazing) to grassland on peat. This correlates to specific data becoming available on the cultivation of crops on several soil types through the Agricultural census from 2006 on.
In the assumption that the supply of manure to arable land is negligible, use of the whole data series (1990-2008) leads to a weighted average emission factor that is circa 0.1% point lower than in use of the data series 1990-2005. For the emission calculation the weighted average emission factor based on the data series 1990-2005 is used to prevent underestimation of the emissions. From a sensitivity analysis follows that there is a reasonable chance that weighing in the supply of manure to arable land on peat does not lead to an even higher weighted average emission factor.

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# Annex 11 Uncertainty, quality assurance and verification

## A11.1 Estimating uncertainties

For the PRTR dataset of 2020 uncertainties are calculated with the propagation of error method based on literature and expert judgements. Since calculation methods of activity data and emission factors do not change often, this dataset of uncertainties can be used for multiple years. When a calculation method is changed, the uncertainty of the considered activity data or emission factor is adjusted based on literature and expert judgements. This keeps the data set of uncertainties up to date.

**List of experts consulted**
Albert Bleeker
Cor van Bruggen
Karin Groenestein
Jan Huijsmans
Lotte Lagerwerf
Harry Luesink
Gerard Velthof

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*Table A11.1 Uncertainty analysis results at database level for the reference year 2020*

| Ammonia ($NH_3$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity data | Emission factor | Emission | kg $NH_3$/year |
| | **Animal houses** | | | | |
| **0446649** | Dairy cows | 2% | 41% | 41% | 22,810,646 |
| **0446626** | Young cattle for breeding | 1% | 37% | 37% | 4,491,893 |
| **0446671** | Meat calves | 1% | 42% | 43% | 3,600,688 |
| **0446631** | Young cattle for meat production | 1% | 31% | 31% | 703,826 |
| **0446683** | Suckling cows (incl, fattening/grazing) | 2% | 35% | 35% | 229,504 |
| **0446679** | Pigs for meat production | 10% | 43% | 45% | 8,816,144 |
| **0446679** | Pigs for breeding | 4% | 42% | 42% | 3,363,266 |

| Ammonia ($NH_3$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $NH_3$/year |
| | | Activity data | Emission factor | Emission | |
| **0446645** | Laying hens | 2% | 41% | 41% | 7,308,018 |
| **0446675** | Broilers | 5% | 48% | 48% | 2,400,391 |
| **0446610** | Ducks | 5% | 44% | 45% | 107,217 |
| **0446636** | Turkeys | 5% | 44% | 44% | 457,364 |
| **0446667 and 0446719** | Sheep (all ewes) | 6% | 84% | 84% | 109,282 |
| **0446621** | Goats | 5% | 59% | 60% | 823,058 |
| **0446640** | Other animals (rabbits) | 5% | 51% | 51% | 107,351 |
| **0446661** | Other animals (furbearing animals) | 5% | 43% | 44% | 59,260 |
| **Total, animal houses** | | | | 20% | **55,387,907** |
| | **Outside storage** | | | | |
| **0446648** | Dairy cows | 2% | 184% | 184% | 532,993 |
| **0446625** | Young cattle for breeding | 1% | 163% | 163% | 188,782 |
| **0446682** | Suckling cows (incl, fattening/grazing) | 2% | 210% | 210% | 28,012 |
| **0446630** | Young cattle for meat production | 1% | 213% | 213% | 93,062 |
| **0446678** | Pigs for meat production | 10% | 208% | 210% | 206,717 |
| **0446614** | Pigs for breeding | 4% | 179% | 179% | 115,902 |
| **0446644** | Laying hens | 2% | 66% | 66% | 1,103,148 |
| **0446674** | Broilers | 5% | 68% | 69% | 43,324 |
| **0446609** | Ducks | 5% | 66% | 67% | 8,763 |
| **0446635** | Turkeys | 5% | 5% | 0% | 0 |
| **0446666 and 0446718** | Sheep (all ewes) | 6% | 265% | 265% | 12,449 |
| **0446620** | Goats | 5% | 244% | 244% | 156,290 |
| **0446639** | Other animals (rabbits) | 5% | 238% | 238% | 5,122 |
| **0446660** | Other animals (furbearing animals) | 5% | 211% | 211% | 9,723 |
| **Total, outside storage** | | | | 57% | **2,504,287** |
| | **Manure treatment** | | | | |
| **0441404** | Dairy cows | 50% | 40% | 67% | 51,433 |
| **0441405** | Young cattle | 50% | 40% | 67% | 8,811 |
| **0441407** | Meat calves | 50% | 40% | 67% | 53,947 |
| **0441409** | Fattening pigs | 40% | 36% | 54% | 619,989 |
| **0441410** | Breeding pigs | 43% | 39% | 58% | 282,195 |
| **0441412** | Laying hens | 18% | 42% | 46% | 78,314 |
| **0441411** | Broilers | 24% | 25% | 34% | 15,289 |
| **0441413** | Turkeys | 25% | 41% | 48% | 614 |
| **0441400** | Dairy cows digestion | 50% | 40% | 67% | 36,378 |
| **0441401** | Young cattle digestion | 50% | 40% | 67% | 6,232 |
| **0441402** | Fattening pigs digestion | 50% | 40% | 67% | 130,901 |
| **0441403** | Breeding pigs digestion | 50% | 40% | 67% | 66,717 |
| **Total, manure treatment** | | | | 29% | 1,350,820 |

| Ammonia ($NH_3$) - 2020 | | | | | |
|---|---|---|---|---|---|
| **Emission source code** | **Description** | **Aggregated uncertainties** | | | **Emission kg $NH_3$/year** |
| | | **Activity data** | **Emission factor** | **Emission** | |
| | **Pasture land** | | | | |
| **0446651** | Dairy cows | 2% | 111% | 111% | 764,665 |
| **0446628** | Young cattle for breeding | 1% | 86% | 86% | 270,378 |
| **0446685** | Suckling cows (incl, fattening/grazing) | 2% | 101% | 101% | 76,798 |
| **0446633** | Young cattle for meat production | 1% | 91% | 91% | 28,603 |
| **0446669** | Sheep | 5% | 101% | 101% | 226,500 |
| **0446658** | Horses and ponies | 4% | 92% | 92% | 93,040 |
| **0446606** | Mules and asses | 5% | 108% | 108% | 595 |
| **0446715** | Horses and ponies private parties | 50% | 110% | 121% | 341,215 |
| **0446706** | mules and asses private parties | 50% | 121% | 131% | 182 |
| **0446724** | Ewes private parties | 50% | 113% | 124% | 16,472 |
| **0400530** | grazing nature areas | 29% | 64% | 70% | 83,443 |
| **Total, pasture land** | | | | 53% | 1,901,889 |
| | **Application** | | | | |
| **0446647** | Dairy cows | 2% | 57% | 57% | 18,231,745 |
| **0446624** | Young cattle for breeding | 1% | 50% | 50% | 4,226,420 |
| **0446629** | Young cattle for meat production | 1% | 33% | 33% | 997,111 |
| **0446681** | Suckling cows (incl, fattening/grazing) | 2% | 38% | 38% | 332,149 |
| **0446670** | Meat calves | 1% | 87% | 87% | 1,089,770 |
| **0446677** | Pigs for meat production | 10% | 76% | 76% | 2795223 |
| **0446613** | Pigs for breeding | 4% | 41% | 41% | 1,485,463 |
| **0446643** | Laying hens | 2% | 2% | 0% | 0 |
| **0446673** | Broilers | 5% | 54% | 55% | 268,394 |
| **0446608** | Ducks | 5% | 54% | 54% | 113,308 |
| **0446634** | Turkeys | 5% | 5% | 0% | 0 |
| **0446664** | Sheep | 5% | 71% | 71% | 118780 |
| **0446619** | Goats | 5% | 57% | 57% | 1,668,933 |
| **0446653** | Horses and ponies | 4% | 57% | 57% | 625,268 |
| **0446601** | Mules and asses | 5% | 57% | 57% | 2,988 |
| **0446638** | Other animals (rabbits) | 5% | 24% | 25% | 11,736 |
| **0446659** | Other animals (furbearing animals) | 5% | 43% | 44% | 62,566 |
| **0446716** | Ewes private parties | 50% | 82% | 96% | 10,489 |
| **0446710** | Horses and ponies private parties | 50% | 94% | 106% | 1,997,022 |
| **0446701** | Mules and asses private parties | 50% | 116% | 126% | 721 |
| **0400530** | application outside agriculture | 13% | 27% | 31% | 1,637,507 |
| **Total, application** | | | | 31% | 35,675,593 |
| | **Other sources** | | | | |
| **0400500 and 0446707** | Fertilizer application | 26% | 26% | 36% | 9,856,599 |
| **0506800** | Sewage sludge | 25% | 85% | 88% | 25,501 |

| Ammonia ($NH_3$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $NH_3$/year |
| | | Activity data | Emission factor | Emission | |
| **0400612 and 0446708** | Compost | 23% | 106% | 111% | 630,088 |
| **0444601** | Crop residues | 2% | 44% | 45% | 2,231,179 |
| **0400210** | Ripening crops | | | 300% | 1,821,429 |
| **Total, other sources** | | | | 46% | 14,564,796 |
| | **Outside agriculture** | | | | |
| **0446713** | Horses and ponies housing | 39% | 76% | 86% | 1,764,668 |
| **0446704** | Mules and asses housing | 15% | 62% | 64% | 3,407 |
| **0446712** | Horses and ponies outside storage | 39% | 268% | 271% | 263,022 |
| **0446703** | Mules and asses outside storage | 15% | 246% | 247% | 346 |
| **Total, outside agriculture** | | | | 82% | 2,031,443 |
| | | | | | |
| | | | | | |
| **Total agriculture** | | | | 23% | **111,385,292** |
| **Total outside agriculture** | | | | 82% | **2,031,443** |
| | | | | | |
| **Total of all sources** | | | | 23% | **113,416,735** |

| Nitrous oxide ($N_2O$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $N_2O$/year |
| | | Activity rate | Emission factor | Emission | |
| | **Manure management** | | | | |
| **0446650** | Cows in milk and in calf | 2% | 70% | 70% | 643,036 |
| **0446627** | Young stock for breeding | 1% | 48% | 48% | 147,746 |
| **0446672** | Meat calves | 1% | 72% | 72% | 51,808 |
| **0446632** | Young stock for fattening | 1% | 34% | 34% | 41,613 |
| **0446684** | Suckling cows | 2% | 78% | 78% | 12,603 |
| **0446680** | Fattening pigs | 10% | 101% | 102% | 89,793 |
| **0446617** | Breeding pigs | 4% | 78% | 78% | 55,005 |
| **0446646** | Laying hens | 4% | 75% | 75% | 55,187 |
| **0446676** | Broilers | 5% | 105% | 105% | 28,558 |
| **0446611** | Ducks | 5% | 102% | 102% | 750 |
| **0446637** | Turkeys | 5% | 102% | 102% | 1,415 |
| **0446668 and 0446720** | Sheep | 6% | 117% | 117% | 5,738 |
| **0446623** | Goats | 5% | 102% | 102% | 137,927 |
| **0446657 and 0446714** | Horses and ponies | 39% | 83% | 91% | 104,603 |

| Nitrous oxide ($N_2O$) - 2020 | | | | | |
|---|---|---|---|---|---|
| **Emission source code** | **Description** | **Aggregated uncertainties** | | | **Emission** |
| | | **Activity rate** | **Emission factor** | **Emission** | **kg $N_2O$/year** |
| **0446605 and 0446705** | Mules and asses | 12% | 90% | 91% | 147 |
| **0446641** | Rabbits | 5% | 101% | 101% | 2,437 |
| **0446662** | Furbearing animals | 5% | 102% | 102% | 2,736 |
| **0444701** | Atmospheric deposition manure management | 18% | 400% | 407% | 811,226 |
| **Total manure management** | | | | 152% | **2,192,326** |
| | **Manure treatment** | | | | |
| **0441404** | Cows in milk and in calf | 50% | 100% | 122% | 14,470 |
| **0441405** | Young stock for breeding | 50% | 100% | 122% | 2,479 |
| **0441407** | Meat calves | 50% | 100% | 122% | 244,348 |
| **0441409** | Fattening pigs | 40% | 89% | 98% | 126,352 |
| **0441410** | Breeding pigs | 43% | 97% | 106% | 57,511 |
| **Total Manure treatment** | | | | 74% | **445,160** |
| | **Agricultural soils** | | | | |
| **0400500 and 0446707** | Inorganic fertilizer application | 24% | 34% | 42% | 3,846,269 |
| **0400600 and 0400530** | Manure application | 3% | 68% | 69% | 3,945,615 |
| **0440000 and 0446709** | Pasture manure | 19% | 64% | 68% | 2,987,542 |
| **0444500** | Histosols | 20% | 46% | 51% | 1,499,094 |
| **0400310** | Other organic soils | 35% | 57% | 70% | 824,417 |
| **0444600** | Crop residues | 2% | 42% | 42% | 1,006,556 |
| **0400400** | Pasture renewal | 25% | 160% | 167% | 101,338 |
| **0400610 and 0446708** | Compost | 25% | 100% | 106% | 52,522 |
| **0506800** | Sewage sludge | 25% | 100% | 106% | 3,663 |
| **0444702** | Atmospheric deposition agricultural soils | 29% | 400% | 418% | 819,703 |
| **0444800** | Nitrogen leaching and run-off | 51% | 233% | 267% | 1,177,480 |
| **Total agricultural soils** | | | | 37% | **16,264,201** |
| **Total of all sources** | | | | 37% | **18,901,686** |

| Nitrogen oxide (NO) - 2020 | | | | | |
|---|---|---|---|---|---|
| **Emission source code** | **Description** | **Aggregated uncertainties** | | | **Emission** |
| | | **Activity rate** | **Emission factor** | **Emission** | **kg NO/year** |
| | **Manure management** | | | | |
| **0446650** | Cows in milk and in calf | 2% | 70% | 70% | 876,867 |
| **0446627** | Young stock for breeding | 1% | 48% | 48% | 201,472 |
| **0446672** | Meat calves | 1% | 72% | 72% | 70,647 |
| **0446632** | Young stock for fattening | 1% | 34% | 34% | 56,745 |

| Nitrogen oxide (NO) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity rate | Emission factor | Emission | kg NO/year |
| **0446684** | Suckling cows (incl. fattening/grazing) | 2% | 78% | 78% | 17,186 |
| **0446680** | Fattening pigs | 10% | 101% | 102% | 122,445 |
| **0446617** | Breeding pigs | 4% | 78% | 78% | 75,007 |
| **0446646** | Laying hens | 2% | 75% | 75% | 75,254 |
| **0446676** | Broilers | 5% | 105% | 105% | 38,942 |
| **0446611** | Ducks for slaughter | 5% | 102% | 102% | 1,022 |
| **0446637** | Turkeys | 5% | 102% | 102% | 1,929 |
| **0446668 and 0446720** | Ewes | 6% | 110% | 110% | 7,825 |
| **0446623** | Milk goats | 5% | 102% | 102% | 188,083 |
| **0446641** | Rabbits | 5% | 101% | 101% | 3,323 |
| **0446662** | Furbearing animals | 5% | 102% | 102% | 3,730 |
| **Total manure management** | | | | 39% | **1,740,478** |
| **Manure treatment** | | | | | |
| **0441404** | Cows in milk and in calf | 50% | 100% | 122% | 19,731 |
| **0441405** | Young stock for breeding | 50% | 100% | 122% | 3,380 |
| **0441407** | Meat calves | 50% | 100% | 122% | 333,202 |
| **0441409** | Fattening pigs | 40% | 89% | 98% | 172,299 |
| **0441410** | Breeding pigs | 43% | 97% | 106% | 78,424 |
| **Total Manure treatment** | | | | 74% | **607,036** |
| **Agricultural soils** | | | | | |
| **0400600 and 0400530** | Manure application | 3% | 160% | 160% | 8,071,608 |
| **0440000 and 0446709** | Pasture | 19% | 160% | 164% | 1,563,969 |
| **0400500 and 0446707** | Inorganic fertilizer | 24% | 160% | 166% | 6,284,299 |
| **0506800** | Sewage sludge | 25% | 160% | 167% | 6,661 |
| **0400610 and 0446708** | Compost | 25% | 160% | 167% | 214,864 |
| **0444600** | Crop residues | 2% | 160% | 160% | 1,647,092 |
| **0400400** | Pasture renewal | 25% | 160% | 167% | 72,361 |
| **0444500** | Histosols | 20% | 167% | 171% | 1,226,531 |
| **0400310** | Other organic soils | 35% | 167% | 180% | 674,523 |
| **Total agricultural soils** | | | | 87% | **19,761,908** |
| **outside agriculture** | | | | | |
| **0446657 and** | Horses and ponies | 39% | 82% | 91% | 142,640 |

| Nitrogen oxide (NO) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg NO/year |
| | | Activity rate | Emission factor | Emission | |
| **0446714** | | | | | |
| **0446605 and 0446705** | Mules and asses | 12% | 89% | 89% | 200 |
| **Total, outside agriculture** | | | | 91% | **142,840** |
| | | | | | |
| **Total agriculture** | | | | 78% | **22,109,421** |
| **Total outside agriculture** | | | | 91% | **142,840** |
| | | | | | |
| **Total of all sources** | | | | 77% | **22,252,261** |

| Methane ($CH_4$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $CH_4$/year |
| | | Activity rate | Emission factor | Emission | |
| | **Manure management, tier 1** | | | | |
| **0446668 and 0446720** | Sheep, manure management | 10% | 181% | 181% | 31,767 |
| **0443501 and 0446723** | Sheep, pasture | 10% | 37% | 39% | 149,570 |
| **0446623** | Goats, manure management | 10% | 30% | 32% | 82,240 |
| **0446657 and 0446714** | Horses, manure management | 39% | 67% | 77% | 418,850 |
| **0446658 and 0446715** | Horses, pasture | 39% | 141% | 147% | 220,805 |
| **0446605 and 0446705** | Mules and asses, manure management | 15% | 56% | 58% | 519 |
| **0446606 and 0446706** | Mules and asses, pasture | 15% | 81% | 83% | 363 |
| **0446641** | Rabbits, manure management | 10% | 30% | 32% | 26,797 |
| **0446662** | Fur bearing animals, manure management | 5% | 30% | 30% | 295,937 |
| **Total (tier 1)** | | | | 39% | **1,226,847** |
| | **Manure management, tier 2** | | | | |
| **0446650** | Dairy cows, manure management | 2% | 39% | 39% | 58,971,672 |
| **0446651** | Dairy cows, pasture | 2% | 43% | 43% | 465,822 |

| Methane ($CH_4$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $CH_4$/year |
| | | Activity rate | Emission factor | Emission | |
| **0446627** | Young cattle for breeding, manure management | 1% | 27% | 27% | 9,288,775 |
| **0446632** | Young cattle for meat production, manure management | 1% | 20% | 20% | 1,296,033 |
| **0446663** | Young cattle, pasture | 1% | 33% | 33% | 154,074 |
| **0446684** | Suckling cows (incl. fattening/grazing), manure management | 2% | 37% | 37% | 351,695 |
| **0446685** | Suckling cows (incl. fattening/grazing), pasture | 2% | 43% | 43% | 44,883 |
| **0446672** | Meat calves, manure management | 1% | 28% | 28% | 5,263,350 |
| **0441421** | Pigs for breeding, manure management | 4% | 36% | 36% | 18,166,847 |
| **0446680** | Pigs for meat production, manure management | 10% | 40% | 41% | 35,174,918 |
| **0446676** | Broilers, manure management | 5% | 74% | 74% | 1,160,161 |
| **0446646** | Laying hens, manure management | 2% | 53% | 53% | 1,378,633 |
| **0446611** | Ducks, manure management | 5% | 74% | 74% | 28,540 |
| **0446637** | Turkeys, manure management | 5% | 74% | 74% | 40,726 |
| **Total (tier 2)** | | | | 21% | **131,786,128** |
| | **Manure treatment** | | | | |
| **0441404** | Dairy cows | 50.00% | 30.00% | 60.21% | 409,170 |
| **0441405** | Young cattle | 50.00% | 30.00% | 60.21% | 63,744 |
| **0441407** | Meat calves | 50.00% | 30.00% | 60.21% | 142,808 |
| **0441409** | Fattening pigs | 39.43% | 26.45% | 47.48% | 9,532,457 |
| **0441410** | Breeding pigs | 42.58% | 28.56% | 51.27% | 4,266,216 |
| **0441412** | Laying hens | 17.69% | 21.89% | 28.15% | 53,404 |
| **0441411** | Broilers | 23.65% | 29.25% | 37.62% | 80,485 |
| **0441413** | Turkeys | 25.00% | 30.92% | 39.76% | 4,380 |
| **0441400** | Dairy cows digestion | 50.00% | 30.00% | 60.21% | 328,579 |
| **0441401** | Young cattle digestion | 50.00% | 30.00% | 60.21% | 51,188 |
| **0441402** | Fattening pigs digestion | 50.00% | 30.00% | 60.21% | 616,368 |
| **0441403** | Breeding pigs digestion | 50.00% | 30.00% | 60.21% | 308,569 |
| **Total, manure treatment** | | | | 32% | **15,857,368** |
| **Total (manure)** | | | | 19% | **148,870,343** |
| | **Fermentation, tier 1** | | | | |
| **0443500 and 0446717** | Sheep | 10% | 40% | 41% | 7,635,224 |

| Methane ($CH_4$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg $CH_4$/year |
| | | Activity rate | Emission factor | Emission | |
| **0444501** | Goats | 10% | 40% | 41% | 3,163,080 |
| **0446654 and 0446711** | Horses | 39% | 40% | 58% | 7,380,630 |
| **0446602 and 0446702** | Mules and asses | 15% | 40% | 41% | 11,600 |
| **0446500** | Pigs | 6% | 40% | 41% | 17,790,564 |
| **Total (tier 1)** | | | | 25% | **35,981,098** |
| | **Fermentation, tier 2 and 3** | | | | |
| **0441501** | Young cattle | 1% | 12% | 12% | 69,325,807 |
| **0442500** | Suckling cows (incl. fattening/grazing) | 2% | 23% | 23% | 4,540,097 |
| **0441600** | Dairy cows NW | 3% | 21% | 21% | 93,196,328 |
| **0441700** | Dairy cows SE | 2% | 21% | 21% | 124,804,681 |
| **Total (tier 2 and 3)** | | | | 12% | 291,866,913 |
| **Total (fermentation)** | | | | 11% | **327,848,011** |
| **Total of all sources** | | | | 9% | **476,718,354** |

| Non-methane volatile organic components (NMVOC) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission kg NMVOC/year |
| | | Activity rate | Emission factor | Emission | |
| | **Manure management** | | | | |
| **0446627** | Young stock for breeding | 1% | 187% | 187% | 6,995,797 |
| **0446650** | Cows in milk and in calf | 2% | 220% | 220% | 43,619,517 |
| **0446672** | Meat calves | 1% | 223% | 223% | 1,658,113 |
| **0446632** | Young stock for fattening | 1% | 136% | 136% | 1,594,376 |
| **0446684** | Suckling cows (incl. fattening/grazing) | 2% | 307% | 307% | 221,482 |
| **0446680** | Fattening pigs | 10% | 303% | 303% | 1,120,234 |
| **0446617** | Breeding pigs | 4% | 294% | 295% | 2,256,059 |
| **0446646** | Broilers | 5% | 302% | 302% | 3,161,698 |
| **0446676** | Layers | 2% | 209% | 209% | 2,943,581 |
| **0446611** | Ducks for slaughter | 5% | 302% | 302% | 51,356 |
| **0446637** | Turkeys | 5% | 302% | 302% | 67,746 |
| **0446668 and 0446720** | Sheep | 6% | 283% | 283% | 21,060 |
| **0446623** | Goats | 5% | 302% | 302% | 612,424 |
| **0446641** | Rabbits | 5% | 302% | 302% | 2,364 |
| **0446662** | Fur animals | 5% | 302% | 302% | 147,145 |

| Non-methane volatile organic components (NMVOC) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity rate | Emission factor | Emission | kg NMVOC/year |
| **Total, manure management** | | | | 152% | **64,472,951** |
| **Agricultural soils** | | | | | |
| **0400600 and 0400530** | Manure application | 5% | 125% | 125% | 9,734,323 |
| **0440000 and 0446709** | Pasture manure | 5% | 159% | 159% | 234,279 |
| **0441430** | Silage storage | 1% | 176% | 176% | 11,434,212 |
| **0400201** | Crops | 12% | 218% | 218% | 1,462,359 |
| **Total, crop production and agricultural soils** | | | | 104% | **22,865,172** |
| **Total, agriculture** | | | | 115% | **87,338,124** |
| | | | | | |
| **Outside agriculture** | | | | | |
| **0446657 and 0446714** | Horses and ponies | 42% | 256% | 260% | 243,411 |
| **0446605 and 0446705** | Mules and asses | 12% | 252% | 252% | 295 |
| **Total outside agriculture** | | | | 259% | **243,706** |
| **Total** | | | | 115% | **87,581,830** |

| Particulate matter < 10µm ($PM_{10}$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity rate | Emission factor | Emission | kg $PM_{10}$/year |
| **Manure management** | | | | | |
| **0446627** | Young stock for breeding | 1% | 22% | 22% | 48,689 |
| **0446650** | Cows in milk and in calf | 2% | 25% | 25% | 199,258 |
| **0446672** | Meat calves | 1% | 33% | 33% | 33,060 |
| **0446632** | Young stock for fattening | 1% | 25% | 25% | 19,581 |
| **0446684** | Suckling cows (incl. fattening/grazing) | 2% | 32% | 32% | 5,026 |
| **0446680** | Fattening pigs | 10% | 29% | 31% | 545,153 |
| **0446617** | Breeding pigs | 8% | 31% | 32% | 279,595 |
| **0446646** | Broilers | 5% | 28% | 28% | 1,079,923 |
| **0446676** | Layers | 2% | 36% | 36% | 2,290,180 |
| **0446611** | Ducks for slaughter | 5% | 35% | 35% | 71,276 |
| **0446637** | Turkeys | 5% | 32% | 32% | 53,258 |
| **0446641** | Rabbits | 5% | 49% | 49% | 410 |
| **0446662** | Fur-bearing animals | 5% | 49% | 49% | 3,525 |
| **0446668 and 0446720** | Sheep | 10% | 37% | 39% | 1,741 |
| **0446623** | Goats | 5% | 32% | 32% | 12,020 |

| Particulate matter < 10µm ($PM_{10}$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity rate | Emission factor | Emission | kg $PM_{10}$/year |
| **Total, animal houses** | | | | 19% | 4,642,695 |
| | **Outside agriculture** | | | | |
| **0446657 and 0446714** | Horses and ponies | 39% | 36% | 53% | 90,208 |
| **0446605 and 0446705** | Mules and asses | 12% | 29% | 31% | 186 |
| | **Agricultural soils** | | | | |
| **0449300** | Concentrates | 25% | 100% | 106% | 90,000 |
| **0449400** | Inorganic fertilizer | 25% | 100% | 106% | 105,000 |
| **0449500** | Pesticides | 25% | 100% | 106% | 125,000 |
| **0449600** | Harvesting | 2% | 225% | 225% | 374,990 |
| **Total, agricultural soils** | | | | 125% | **694,990** |
| **Total agriculture** | | | | 23% | **5,337,685** |
| **Total outside agriculture** | | | | 53% | **90,393** |
| **Total of all sources** | | | | 23% | **5,428,078** |

| Particulate matter < 2.5 µm ($PM_{2.5}$) - 2020 | | | | | |
|---|---|---|---|---|---|
| Emission source code | Description | Aggregated uncertainties | | | Emission |
| | | Activity rate | Emission factor | Emission | kg $PM_{2.5}$/year |
| | **Manure management** | | | | |
| **0446627** | Young stock for breeding | 1% | 24% | 24% | 13,425 |
| **0446650** | Cows in milk and in calf | 2% | 27% | 28% | 54,935 |
| **0446672** | Meat calves | 1% | 35% | 35% | 9,076 |
| **0446632** | Young stock for fattening | 1% | 28% | 28% | 5,391 |
| **0446684** | Suckling cows (incl. fattening/grazing) | 2% | 35% | 35% | 1,388 |
| **0446680** | Fattening pigs | 10% | 35% | 37% | 25,704 |
| **0446617** | Breeding pigs | 8% | 30% | 31% | 13,092 |
| **0446646** | Broilers | 5% | 37% | 38% | 80,937 |
| **0446676** | Layers | 2% | 77% | 77% | 139,759 |
| **0446611** | Ducks for slaughter | 5% | 46% | 47% | 3,409 |
| **0446637** | Turkeys | 5% | 43% | 43% | 24,977 |
| **0446641** | Rabbits | 5% | 100% | 100% | 80 |
| **0446662** | Fur-bearing animals | 5% | 100% | 100% | 1,828 |
| **0446668 and 0446720** | Sheep | 10% | 37% | 39% | 522 |
| **0446623** | Goats | 5% | 35% | 35% | 3,606 |
| **Total, animal houses** | | | | 30% | 378,129 |
| | **Outside agriculture** | | | | |
| **0446657** | Horses and ponies private | 39% | 36% | 53% | 57,401 |

| Emission source code | Description | Aggregated uncertainties: Activity rate | Aggregated uncertainties: Emission factor | Aggregated uncertainties: Emission | Emission kg $PM_{2.5}$/year |
|---|---|---|---|---|---|
| **Particulate matter < 2.5 µm ($PM_{2.5}$) - 2020** | | | | | |
| **and 0446714** | | | | | |
| **0446605 and 0446705** | Mules and asses | 12% | 33% | 35% | 116 |
| | **Agricultural soils** | | | | |
| **0449300** | Concentrates | 25% | 100% | 106% | 18,000 |
| **0449400** | Inorganic fertilizer | 25% | 100% | 106% | 21,000 |
| **0449500** | Pesticides | 25% | 100% | 106% | 25,000 |
| **0449600** | Harvesting | 2% | 222% | 222% | 40,756 |
| **Total, agricultural soils** | | | | 94% | 104,756 |
| **Total agriculture** | | | | 31% | 482,885 |
| **Total outside agriculture** | | | | 53% | 57,521 |
| **Total of all sources** | | | | 29% | 540,406 |

| CRT code | Description | Aggregated uncertainties: Activity rate | Aggregated uncertainties: Emission factor | Aggregated uncertainties: Emission | Emission kg $CO_2$/year |
|---|---|---|---|---|---|
| **Carbon dioxide ($CO_2$) - 2020** | | | | | |
| | **Liming** | | | | |
| **N320000** | Limestone | 28% | 1% | 28% | 19,267,521 |
| **N320001** | Dolomite | 49% | 1% | 49% | 11,767,290 |
| **Total liming** | | | | 25% | 31,034,811 |
| | **Urea Application** | | | | |
| **0400510** | Urea application | 25% | 1% | 25% | 47,171,958 |
| **Total all sources** | | | | 18% | **78,206,768** |

## A11.2 Quality assurance and quality control (QA/QC)

The PRTR task force leader on Agriculture is responsible for:

1. well documented and adopted data;
2. calculations having been implemented correctly;
3. assumptions are consistent, specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

A yearly check on the above mentioned responsibilities is performed. Any actions that result from these checks are noted on an '*action list*' by the ER secretary. The task force leader is responsible for improvements and communicates by e-mail regarding these QC checks, actions and results with the ER secretary.

While adding a new emission year the task force leader performs a *trend analysis*, in which data from the new year are compared with data from the previous years. The task force leader provides an explanation if the increase or decrease of emissions exceeds the minimum level of 5% at target group level or 0.5% at national level. These explanations are also sent by e-mail to the PRTR secretary by the task force leader.

The PRTR secretary keeps a logbook of all these QC checks and trend explanations and archives all concerned e-mails on the ER network. This shows explicitly that the required checks and corrections have been carried out. Based on the results of the trend analysis and the feedback on the control and correction process ('action list') the Working Group on Emissions Monitoring (WEM) gives advice to the institute representatives (Deltares on behalf of Rijkswaterstaat, Statistics Netherlands (CBS) and Netherlands Environmental Assessment Agency (PBL)) to approve the dataset. The PRTR project leader at RIVM defines the dataset, on receipt of an e-mail by the institute representatives, in which they give their approval.

Furthermore, all changes of emissions in the whole time series as a *result of recalculations* are documented in CRT table 8(b).

## A11.3 Verification

To check the quality of the calculated emissions for the sources named in this report, general QA/QC-procedures have been followed that are in line with the IPCC Guidelines. These are described further in the QA/QC-programme used by the National System, and the annual working plans published by the PRTR.

*Sector-specific QC*
No additional specific verification procedures are implemented for the sources defined in this sector.

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# Annex 12 Bedding material usage

## A12.1 Introduction

Bedding material provided to livestock in the form of e.g. straw is a nitrogen input into the manure and contributes to N-emissions from manure during storage, treatment and application. The IPCC guidelines and EMEP guidebook both provide methods to include bedding material and all related emissions in the inventory. The Tier 1 method assumes only straw is used as bedding material. As no information is available on the usage of other forms of bedding material in the Netherlands only straw is taken into account for the calculations in NEMA. The Tier 1 methods assume a certain amount of straw to be provided per animal place per year. For grazing livestock, it is assumed that no straw is provided on days with grazing. The Dutch consumption of straw, per animal place and in the case of grazing livestock per animal place per day indoors, can mainly be based on information provided by the BedrijvenInformatieNetwerk (BIN).

## A12.2 Overview of activity data and uptake in NEMA

The calculations assume the following constant properties of bedding material (BIN, unpublished).

| **Straw contents** | |
|---|---|
| Dry matter content (DM) | 0.86 |
| Kg N per kg DM | 0.0058 |
| TAN | 50% |
| Kg $P_2O_5$ per kg DM | 0.0025 |

The activity data from multiple sources have been assessed:

- BIN (unpublished)
- Danish standard figures for animal manure: DCArapport191.pdf (au.dk) (from page 259)
- Calculations of gaseous and particulate emissions from German agriculture 1990 – 2021: 4.2.1 N in bedding materials · Wiki · Cora Vos / EmissionsAgriculture2023 · GitLab (thuenen.de)
- French Informative Inventory Report: UNECE_France_mars2021_d.pdf (europa.eu)
- The EMEP guidebook: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/4-agriculture/3-b-manure-management/view

The following tables provide an overview of the amounts of bedding material the different sources provided per animal place or in the case of grazing livestock per day indoors. The overview shows that there is a large range of amounts used per animal place, both within countries for different housing systems and between countries. For the animal categories for which BIN had information, BIN values are used in NEMA. For the other animal categories expert judgement was used to either apply one of the other sources or derive the amount of bedding material from a different animal category of the BIN.

### A12.2.1 Cattle

*Table A12.1 Bedding material usage of cattle per animal per year (kg)*

| | BIN | Denmark[1] | Germany[1] | France[1] | EMEP[1] |
|---|---|---|---|---|---|
| Dairy cows | 218 | 0 - 12 | 5 - 8 | 0 - 9 | 8.3 |
| Suckler cows | - | 0 - 8 | 5 - 8 | 0 - 7 | 2.8 |
| Young stock | - | 0 - 5 | 2 - 6 | 0 - 5 | 2.8 |
| Veal calves | - | 0 - 4 | 2 - 6 | 0 - 2 | 2.8 |

1) kg per day housed indoors

Bedding material usage by dairy cows from the BIN is based on total purchases by dairy farms divided by Groot Vee Eenheden (large livestock units, GVE). BIN usage thus creates an overestimate per cow as the usage of young stock are also included in this value. The average herd on a dairy farm consists of 105 cows and 56 young stock. In terms of GVE: 105 GVE + 28 * 0.5 GVE + 28 * 0.25 GVE = 126 GVE (cbs.nl).
According to EMEP young stock use 2.8/8.3 = 0.34 times as much straw as dairy cows
The average number of days without grazing of dairy cows is 365-155 and young stock spends 365-73 days indoors per year.

$$\begin{cases} (365-155) * 105x + (365-73) * 21y = 218 * 126 \\ 0.34x = y \end{cases}$$

X = 1.138 kg per day indoors per dairy cow and y = 0.387 kg per day indoors per young stock.
The EMEP values for usage of bedding material of suckler cows and of young stock used for fattening are the same as of young stock used for breeding. Therefore, the bedding material usage derived from the BIN is also applied for suckler cows and young stock used for fattening.
Veal calves are mostly housed on slatted floors without bedding material. Therefore, the bedding material usage is set at 0 kg.

### A12.2.2 Poultry

*Table A12.2 Bedding material usage of poultry per animal place per year (kg)*

| | **BIN** | **Denmark** | **Germany** | **France** | **EMEP** |
|---|---|---|---|---|---|
| Pullets | - | 0.2* | 0.75 | - | - |
| Laying hens | 0.03 | 0 - 0.5 | 0.5 | - | - |
| Broilers | 0.2 | 0.18 | 1.4 | - | - |
| Turkeys | - | 1.2 | 10.3 | - | - |
| Ducks | - | 15 | 22 | - | - |

* kg bedding material per raised pullet

BIN values are used for laying hens and broilers. Bedding material usage of pullets is set to the usage of laying hens. Laying hens housed in cages do not receive bedding material. For the other poultry categories only Germany and Denmark apply bedding material. As the Danish values for laying hens and broilers closely match the values from the BIN, the Danish values are applied for the turkeys and ducks.

### A12.2.3 Swine

*Table A12.3 Bedding material usage of swine per animal place per year (kg)*

| | BIN | Denmark | Germany[1] | France[1] | EMEP |
|---|---|---|---|---|---|
| Fattening pigs | 0.8 | 0-70 | 0.3 - 1 | 0.3 - 1.9 | 200 |
| Breeding pigs | 0.8 | 0-70 | 0.3 - 1 | 0.3 - 1 | 200 |
| Sows | 1.262 | 0-900 | 0.5 | 2 | 600 |
| Piglets | 0.379 | | | | |

1) kg per day housed indoors

The BIN are used for bedding material usage of swine.

### A12.2.4 Goats

*Table A12.4 Bedding material usage of goats per animal place per year (kg)*

| | BIN | Denmark | Germany[1] | France[1] | EMEP[1] |
|---|---|---|---|---|---|
| Goats | 347 | 550 | 0.4 | 1.5 | 0.7 |
| Kids | - | - | 0.16 | 0.25 - 0.75 | 0.7 |
| Buck | - | 550 | 0.4 | 1.5 | 0.7 |

1) kg per day housed indoors

The BIN are used for bedding material usage of goats.

### A12.2.5 Sheep

*Table A12.5 Bedding material usage of sheep per animal place per year (kg)*

| | BIN | Denmark | Germany[1] | France[1] | EMEP[1] |
|---|---|---|---|---|---|
| Ewes | - | 550 | 0.4 | 1.6 | 0.7 |
| Lambs | - | - | 0.16 | 0.25 - 0.75 | 0.7 |
| Rams | - | 550 | 0.4 | 1.6 | 0.7 |

1) kg per day housed indoors

The German values appear to be most suited to the Dutch circumstances. Using the other sources would result in bedding material usage of sheep that are higher than those of cattle, which seems unlikely. For the calculation of bedding material usage the following housing periods are applied: 80 days housed indoors for the years 1990-2003, 75 days housed indoors for the years 2004-2008 and 35 days housed indoors for the years 2009-2023 (CBS, 2020).

### A12.2.6 Horses, Ponies and Donkeys

*Table A12.6 Bedding material usage of horses and ponies per animal place per year (kg)*

| | BIN | Denmark | Germany[1] | France | EMEP[1] |
|---|---|---|---|---|---|
| Horses | - | 1825 | 8 | 500 | 500 |
| Ponies | - | 1095 | 5 | 500 | 500 |
| Donkeys | - | 1095 | 5 | 500 | 500 |

1) kg per day housed indoors

EMEP default values are used for horses, ponies and donkeys.

### A12.2.7 Other animals

*Table A12.7 Bedding material usage of other animals per animal place per year (kg).*

| | BIN | Denmark | Germany | France | EMEP[1] |
|---|---|---|---|---|---|
| Rabbits | - | - | - | - | - |
| Fur animals | - | 0 – 10 | - | - | - |

As BIN and EMEP do not provide a default value for these animals, no bedding material is included in the inventory.

## A12.3 Summary

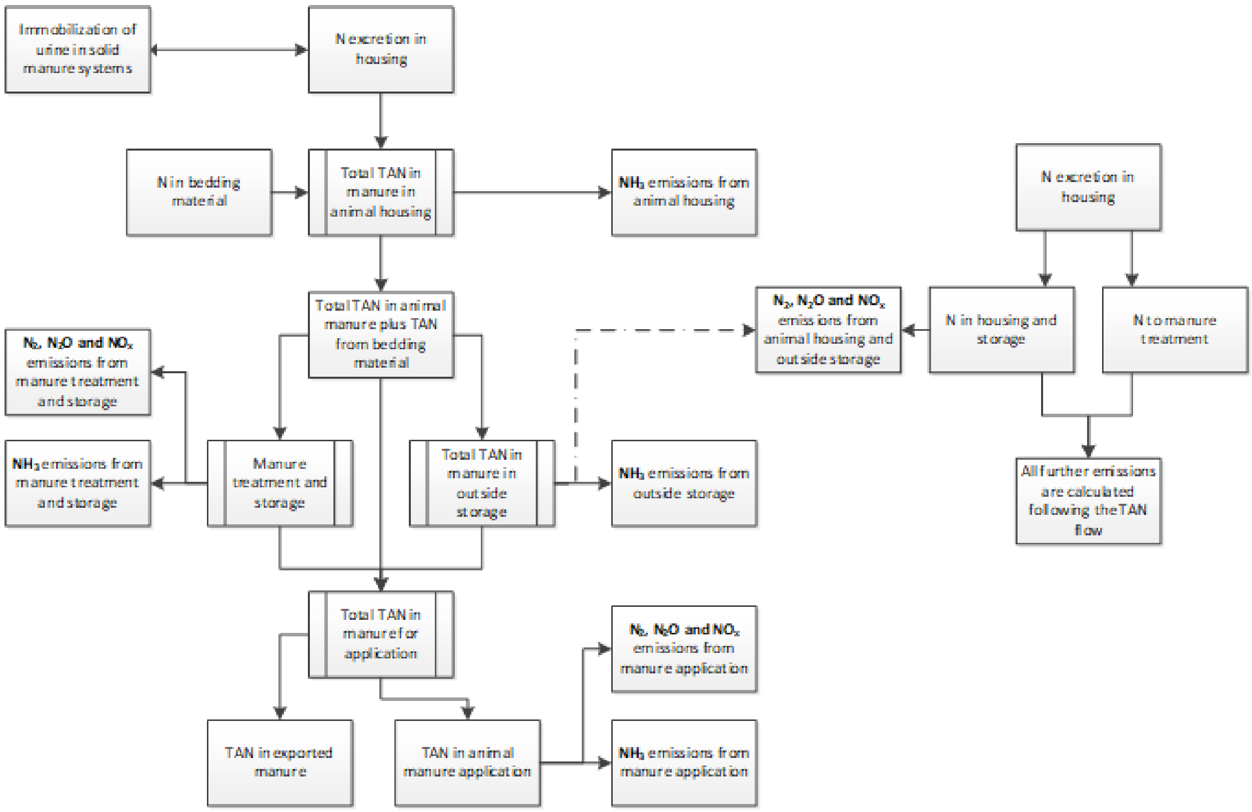
The values from table 8 are used for the calculations of NEMA.

*Table A12.8. Overview of bedding material usage in kg straw per animal per place.*

| **Animal category** | **Bedding material usage** |
|---|---|
| **Cattle** | |
| Dairy cows | 1.138[1] |
| Suckler cows | 0.387[1] |
| Young stock | 0.387[1] |
| Veal calves | 0 |
| **Poultry** | |
| Pullets | 0.03 |
| Laying hens | 0.03 |
| Laying hens housed in cages | 0 |
| Broilers | 0.2 |
| Turkeys | 1.2 |
| Ducks | 15 |
| **Swine** | |
| Fattening pigs | 0.8 |
| Breeding pigs | 0.8 |
| Sows | 13 |
| piglets | |
| **Goats** | |
| Goats | 347 |
| Kids | 0 (Included in goats) |
| Bucks | 0 (Included in goats) |
| **Sheep** | |
| Ewes | 0.4[1] |
| Lambs | 0.16[1] |
| Rams | 0.4[1] |
| **Horses** | |
| Horses | 500 |
| Ponies | 500 |
| Donkeys | 500 |
| **Other animals** | |
| Rabbits | 0 |
| Fur animals | 0 |

1. Kg straw per animal place per day housed indoors

*Figure A12.1 TAN flow in NEMA, including emissions from housing, manure storage, manure treatment and application. The N2O, NOx and N2 emissions from housing and storage are calculated based on N-excreted. The IPCC guidelines state that due to the slow mineralisation rate of N in bedding, volatilisation losses from bedding during housing and storage can be assumed to be zero.*




Bedding material has been added to the entire timeseries (1990-2023). Total $NH_3$, $NO_x$ and $N_2O$ emissions calculated by NEMA increased by less than 1%.

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# Annex 13 List of abbreviations

| | |
|---|---|
| $B_o$ | Maximum methane production potential |
| BIN | BedrijvenInformatieNetwerk |
| CBS | Statistics Netherlands |
| CDM | Scientific Committee on the Manure and Fertilisers Act |
| $CH_4$ | Methane |
| CLRTAP | Convention on Long Range Transboundary Air Pollution |
| $CO_2$ | Carbon dioxide |
| CRT | Common Reporting Tables |
| DMI | Dry-matter intake |
| EEA | European Environment Agency |
| EMEP | European Monitoring and Evaluation Programme |
| EU | European Union |
| KGG | Ministry of Climate Policy and Green Growth |
| GE | Gross energy intake |
| IenW | Ministry of Infrastructure and Water Management |
| IPCC | Intergovernmental Panel on Climate Change |
| LNV | Ministry of Agriculture, Nature and Food Quality |
| LULUCF | Land Use, Land Use Change and Forestry |
| MCF | Methane-conversion factor (for the calculation of $CH_4$ from manure management) |
| N | Nitrogen |
| $N_2$ | Dinitrogen |
| $N_2O$ | Nitrous oxide |
| NEC | National Emission Ceilings |
| NEMA | National Emission Model for Agriculture |
| NFR | Nomenclature For Reporting |
| $NH_3$ | Ammonia |
| NIE | National Inventory Entity |
| $NO_x$ | Nitrogen oxides |
| PBL | PBL Netherlands Environmental Assessment Agency |
| $PM_{10}$ | Particulate matter up to 10 μm in size |
| $PM_{2.5}$ | Particulate matter up to 2.5 μm in size |
| PRTR | Pollutant Release and Transfer Register |
| RIVM | National Institute for Public Health and the Environment |
| RVO | Netherlands Enterprise Agency |
| TAN | Total Ammoniacal Nitrogen |
| UN | United Nations |
| VS | Volatile Solids |
| WUR | Wageningen University & Research |
| WUM | Working Group on Uniformity of Calculations for Manure and Mineral Data |
| $Y_m$ | Methane-conversion factor (for the calculation of $CH_4$ from enteric fermentation) |

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