



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

Methodology for estimating emissions from agriculture in the Netherlands

Calculations for CH₄, NH₃, N₂O, NO_x,
NMVOC, PM₁₀, PM_{2.5} and CO₂ using
the National Emission Model for
Agriculture (NEMA) – Update 2021

RIVM report 2021-0008

T. van der Zee et al.



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Colophon

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Synopsis

Method for calculating agricultural emissions into the air

Calculations for methane, ammonia, nitrous oxide, nitrogen oxides, non-methane volatile organic compounds, fine particles and carbon dioxide using the model NEMA – update 2021

Every year, the Netherlands reports, both nationally and internationally, the quantities of substances that are emitted into the air by its agricultural sector. This entails all the substances originating from agricultural activities that are listed in the Pollutant Release and Transfer Register, e.g. greenhouse gases and substances that cause air pollution, such as ammonia and fine particles. The methods used to calculate the emissions are in accordance with international guidelines.

The emissions are calculated using the National Emission Model for Agriculture (NEMA), which is developed in the Netherlands. For example, the NEMA is used to calculate the emissions from stables, manure storages and the application of manure. It is also used to calculate emissions, such as methane, from various animals and manure.

The model is updated annually to reflect the latest scientific insights. This time around, the methods used for different substances as well as the implemented adjustments have been described. This time around, among other things, the so-called emission factors for certain low-emission stables have been modified. New insights show that more nitrogen is released from stables than was previously thought. The emission factor for emissions from the fertilisation of grassland, on the other hand, is lower.

The emission data is available to the public via the website emissieregistratie.nl. It is used for reports that are mandatory under international treaties such as the Kyoto Protocol, the EU Emission Ceilings (NEC Directive) and the Convention on Long-range Transboundary Air Pollution (CLRTAP). This report also forms the basis for the reviewers who validate the Dutch reports to the European Union and the United Nations.

Keywords: air pollution, greenhouse gases, livestock, crops, stables, manure, enteric fermentation, Nitrates Directive (NIR), Initial Inventory Report (IIR), Nomenclature for Reporting (NFR)

Publiekssamenvatting

Methode om landbouwemissies naar lucht te berekenen

Berekeningen voor methaan, ammoniak, lachgas, stikstofoxiden, niet-methaan vluchtige organische stoffen, fijnstof en koolstofdioxide met NEMA-update 2021

Nederland rapporteert elk jaar nationaal en internationaal hoeveel stoffen de landbouw uitstoot naar de lucht. Het gaat om alle stoffen uit de landbouw die in de Emissieregistratie voorkomen. 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. Het NEMA berekent de uitstoot van stoffen voor bijvoorbeeld stallen, mestopslag, en het gebruik van mest. Het NEMA wordt ook gebruikt om emissies zoals methaan uit verschillende dieren en mest te berekenen.

Dit model wordt elk jaar aangepast aan de nieuwste wetenschappelijke inzichten. Dit keer zijn de methoden beschreven die voor verschillende stoffen worden gebruikt, en de wijzigingen die zijn doorgevoerd. Dit keer zijn onder andere de zogeheten emissiefactoren voor bepaalde emissiearme stallen aangepast. Uit nieuwe inzichten blijkt dat er meer stikstof uit stallen vrijkomt dan eerder werd gedacht. De emissiefactor voor de uitstoot van de bemesting van grasland blijkt juist kleiner.

De gegevens over de uitstoot zijn openbaar via de website emissieregistratie.nl. Ze worden gebruikt voor rapportages die vanwege internationale verdragen verplicht zijn, zoals het Kyoto-protocol, de Europese Emissieplafonds (NEC-Directive) en de Convention on Long-range Transboundary Air Pollution (CLRTAP). Dit rapport is ook de basis voor de reviewers die de Nederlandse rapportages aan de Europese Unie en Verenigde Naties valideren.

Kernwoorden: luchtverontreiniging, broeikasgassen, vee, gewassen, stallen, mest, enterische fermentatie, NIR, IIR, NFR

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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 $\text{PM}_{2.5}$) 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. The figures for air pollutants are based on the EMEP Guidebook 2019.

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 2006 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 IPCC 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_0) 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).

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. Information on housing systems in agricultural practice is derived from the Agricultural Census, supplemented by provincial records on environmental permits. 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 are based on 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 $\text{PM}_{2.5}$) 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. The N losses include $\text{NH}_3\text{-N}$, $\text{N}_2\text{O-N}$, $\text{NO}_x\text{-N}$, plus dinitrogen-N (N_2). The net export of manure N is also taken into account. 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 newly derived for manure application on grassland based on a new analysing method of measured field emission data. For NH_3 from grazed

grasslands, NH₃ emission factors based on TAN excreted during grazing are used. The NH₃ 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 N₂O occur when N is applied to agricultural soils. For N₂O, a distinction is made between surface spreading and low-ammonia emission application, as the incorporation of animal manure into the soil increases N₂O 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 NH₃ 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 NH₃ from application to NH₃ from animal housing (EEA, 2019). 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 PM₁₀ 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 CO₂ emissions, due to the decomposition of carbonate. Emissions of CO₂ 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 CO₂ emissions. The CO₂ was entrapped during the production of urea. During the application the CO₂ is released. Emissions of CO₂ 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 2019 (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 (CRF; 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; CRF)

CRF source categories	CO ₂		CH ₄		N ₂ O	
	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, T1b, 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	T2	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; T1a, T1b, T1c = IPCC Tier 1a, Tier 1b and Tier 1c, respectively; 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 are in full compliance with the requirements set by 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, CRF, IIR, NFR

Samenvatting

Methoderapport voor het schatten van emissies uit de Nederlandse landbouw

Berekeningen voor CH₄, NH₃, N₂O, NO_x, NMVOS, PM₁₀, PM_{2.5} en CO₂ met het National Emission Model for Agriculture (NEMA) – Update 2021

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 (NH₃), stikstofoxiden (NO_x), lachgas (N₂O), niet-methaan vluchtige organische stoffen (NMVOS), methaan (CH₄), fijnstof (PM₁₀, PM_{2.5}) en koolstofdioxide (CO₂). Deze emissies zijn afkomstig van diverse processen in de landbouwproductieketen, gegroepeerd in de hoofdcategorieën enterische fermentatie (CH₄), mestmanagement (CH₄, NH₃, NO_x, N₂O, NMVOS en PM), gewasproductie en landbouwbodems (NH₃, NO_x, N₂O, NMVOS en PM), bekalking en de aanwending van ureum (CO₂). De berekeningen voor broeikasgassen zijn gebaseerd op de 2006 IPCC Guidelines. Getallen voor luchtverontreinigende stoffen zijn op basis van het EMEP Guidebook 2019.

Enterische fermentatie

Tijdens de vertering van voer vinden pens- en darmfermentatieprocessen plaats (enterische fermentatie). Voornamelijk door herkauwers worden aanzienlijke hoeveelheden CH₄ 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 2006 default emissiefactoren in kg CH₄ 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 CH₄ 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 (B₀) en methaanconversiefactor (MCF) geeft de CH₄-emissies. Er wordt onderscheid gemaakt tussen drijf- en vaste mest, en mestexcretie tijdens beweiden. Emissies van andere diercategorieën

worden berekend met IPCC 2006 default (Tier 1) emissiefactoren in kg CH₄ per dier.

NH₃ wordt gevormd uit de stikstof (N) in de urine en gemineraliseerde organische N in de faeces, waarvan de som Totaal Ammoniaktaal N (TAN) genoemd wordt. Na de bacteriologische conversie van urine en organische N naar ammonium kan gasvormig NH₃ naar de lucht emitteren, afhankelijk van fysische en chemische condities. TAN in de mest wordt jaarlijks afgeleid uit de voedersamenstelling. De NH₃-emissie wordt berekend met NH₃-N emissiefactoren uitgedrukt als percentage van TAN. Deze emissiefactoren zijn afkomstig van metingen aan NH₃-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. Nieuw onderzoek heeft aangetoond dat de emissiefactoren in de praktijk te laag zijn. Hierop is een nieuwe 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. 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). NH₃-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, N₂O en N₂ 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 N₂O emissies worden verondersteld van gelijke omvang te zijn in termen van N-verlies, N₂ 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.

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 organischestofexcretie 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 2019 default emissiefactoren.

Fijnstof (PM₁₀ 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 $\text{NH}_3\text{-N}$, $\text{N}_2\text{O-N}$, $\text{NO}_x\text{-N}$ 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, zuiveringslib 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, zuiveringslib, 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 gelijk gesteld aan de verhouding NH_3 uit mesttoediening tot NH_3 uit stal (EEA, 2019). Voor de NMVOS-emissies van weidegang, opslag van kuilvoer en de teelt van landbouwgewassen worden de EMEP 2019 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 $\text{PM}_{2,5}$ - 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 CO₂-emissies. Deze CO₂ is tijdens het productieproces opgeslagen om bij de aanwending weer vrij te komen. Emissies van CO₂ 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 2019 (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 2019.

Om broeikasgassen in het Common Reporting Format en National Inventory Report (CRF, 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 IPCC 2006 Guidelines (gebruikt in het National Inventory Report; NIR en het Common Reporting Format; CRF)

CRF broncategorie	CO ₂		CH ₄		N ₂ O	
	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	N/O	N/A	N/A
D. Landbouwbodems	N/A	N/A	N/A	N/A	T1, T1b, T2	CS, D
E. Voorgescreven verbranding van savannes	N/A	N/A	NO	N/O	NO	N/O
F. Verbranden gewasresten op het veld	N/A	N/A	NO	N/O	NO	N/O
G. Bekalking	T2	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	N/O	N/A	N/A	N/A	N/A
J. Overig	N/A	N/A	NO	N/O	NO	N/O

Methode: T1 = IPCC Tier 1; T1a, T1b, T1c = respectievelijk IPCC Tier 1a, Tier 1b en Tier 1c; 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 2006 IPCC Guidelines.

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

1 Introduction

In 2019, the agricultural sector was responsible for more than 85% of all ammonia (NH₃) emissions in the Netherlands. Agriculture is also a significant contributor to the emission of nitrogen oxides (NO_x). The deposition of NH₃ 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 (PM₁₀). 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 (CH₄) and nitrous oxide (N₂O), agriculture is the largest contributor to total national emissions. In 2019 the two gasses combined and expressed as carbon dioxide equivalents (CO₂-eq.), amount to about 10% 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 CO₂ 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 Kyoto Protocol 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 *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 2019*.

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 Economic Affairs and Climate Policy (EZK) 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 and Land Use. Emissions from land use, land use change and forestry (LULUCF) are reported according to an unrelated calculation method. They are therefore not discussed here, but they are available in Arets *et al.* (2021). This report concerns emissions to air originating from agricultural activities, based on the National Emission Model for Agriculture (NEMA) of the independent Dutch Scientific Committee of the Manure Act (CDM). The current report provides an overview of the methods applied in NEMA to estimate emissions of CH₄, NH₃, N₂O, NO_x, NMVOC, PM₁₀, PM_{2.5} and CO₂ from the agricultural sector. This methodology report has made five methodological changes from the previous methodology report (Lagerwerf *et al.*, 2019). The first change consists of the emission factor of N₂O from fertilizing soils. The EF has been split from a national average in two individual emission factors for organic soils and mineral soils (Section 12). The second change consists of the allocation of emissions from privately owned horses and ponies and the emissions resulting from applying manure on private land (greenhouse gasses were already allocated to the agriculture sector). These emissions have been allocated to the category agricultural emissions instead of the category other. The third change consists of the emission factor used to quantify the NH₃ emissions of animal manure applied to grassland. The Ryden and McNeill model was replaced by an exponential concentration profile, resulting in lower emission factors (Section 10.3.3). The fourth change is the manure distribution model used to distribute manure across different land types (mineral soil or organic soil and grassland or arable land). The MAMBO model has been replaced by the INIATOR model for NH₃ emissions from 2016 and for N₂O emissions from 2000. For NH₃ the change did not result in a time series inconsistency. However, for N₂O a recalculation had to be performed for the years 1990-1999 to prevent a time series inconsistency as the INIATOR model (Kros *et al.*, 2019) takes the soil type into account whereas the MAMBO model applied an average for the two soil types (Section 12). The fifth change concerns the NH₃ emissions from low-emission housing of cows, pigs and poultry. A study of Statistics Netherlands showed that low-emission housing did not reach the emission reduction levels in practice (Section 5.2.3).

Emissions data are available through the website www.prtr.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 Bruggen *et al.*, 2021; 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 Intergovernmental Panel on Climate Change (IPCC) Guidelines and the EMEP Guidebook 2019 has been followed in this regard (IPCC, 2019; EEA, 2019). The Common Reporting Format (CRF, 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.

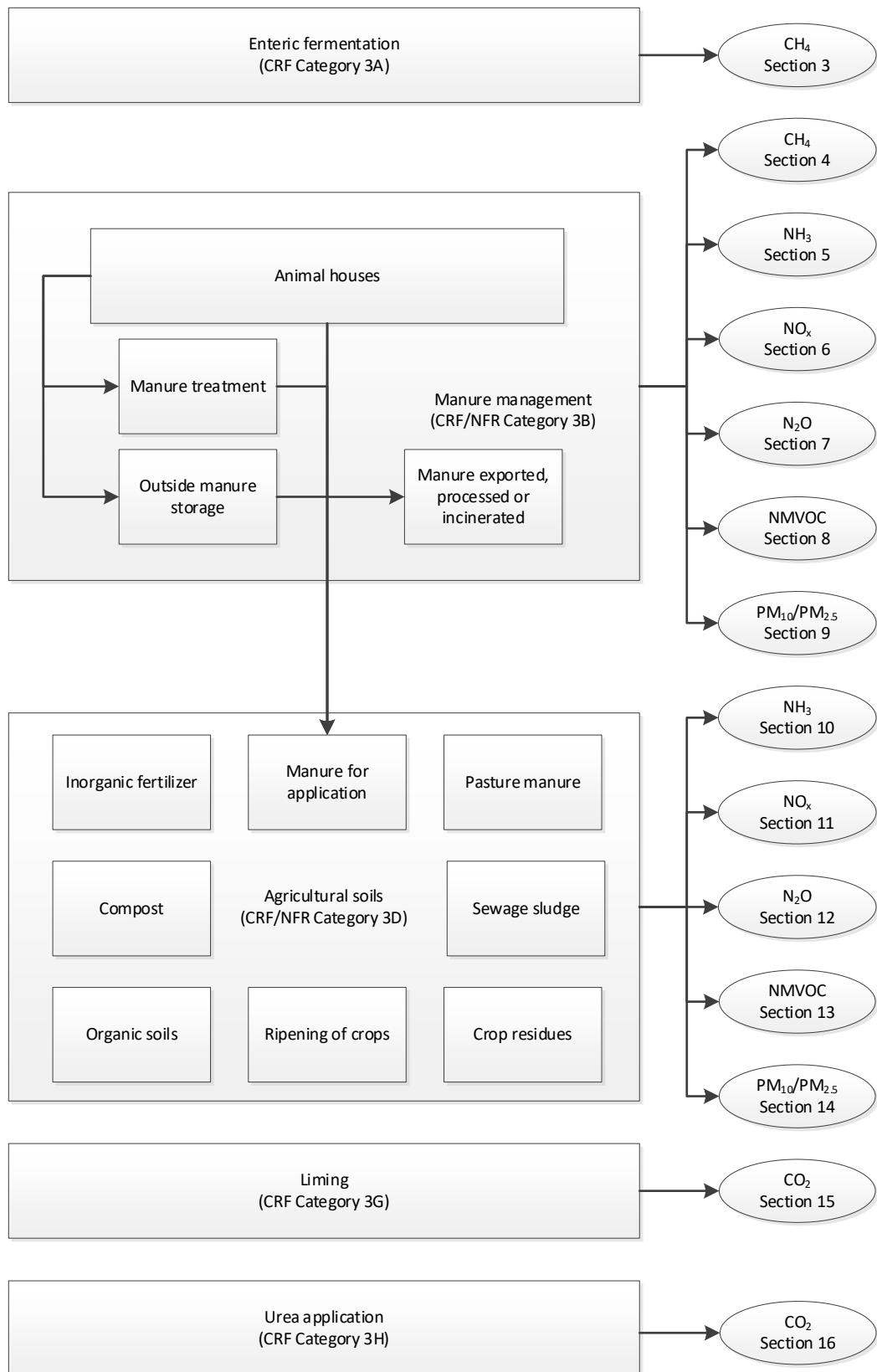


Figure 1.1 Processes and emissions in agriculture, with allocations to CRF and NFR reporting categories.

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 Economic Research, Wageningen Environmental Research, Wageningen Plant Research and Wageningen Livestock Research).

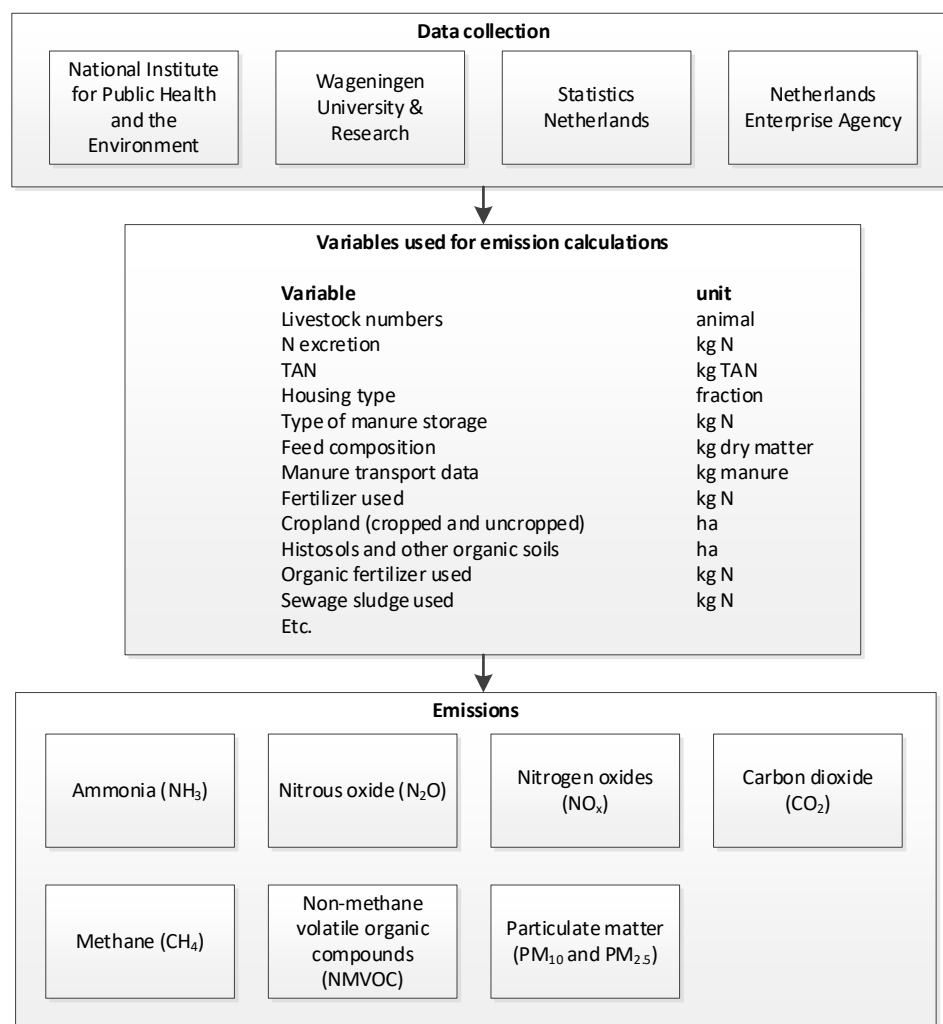


Figure 2.1 Institutes collaborating to gather the data necessary for calculating emissions

2.2 Activity data

In the Netherlands, livestock numbers, N excretion rates 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-section.

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 Bruggen *et al.* (2020). The livestock categories are presented in Figure 2.2, as included in the Agricultural Census.

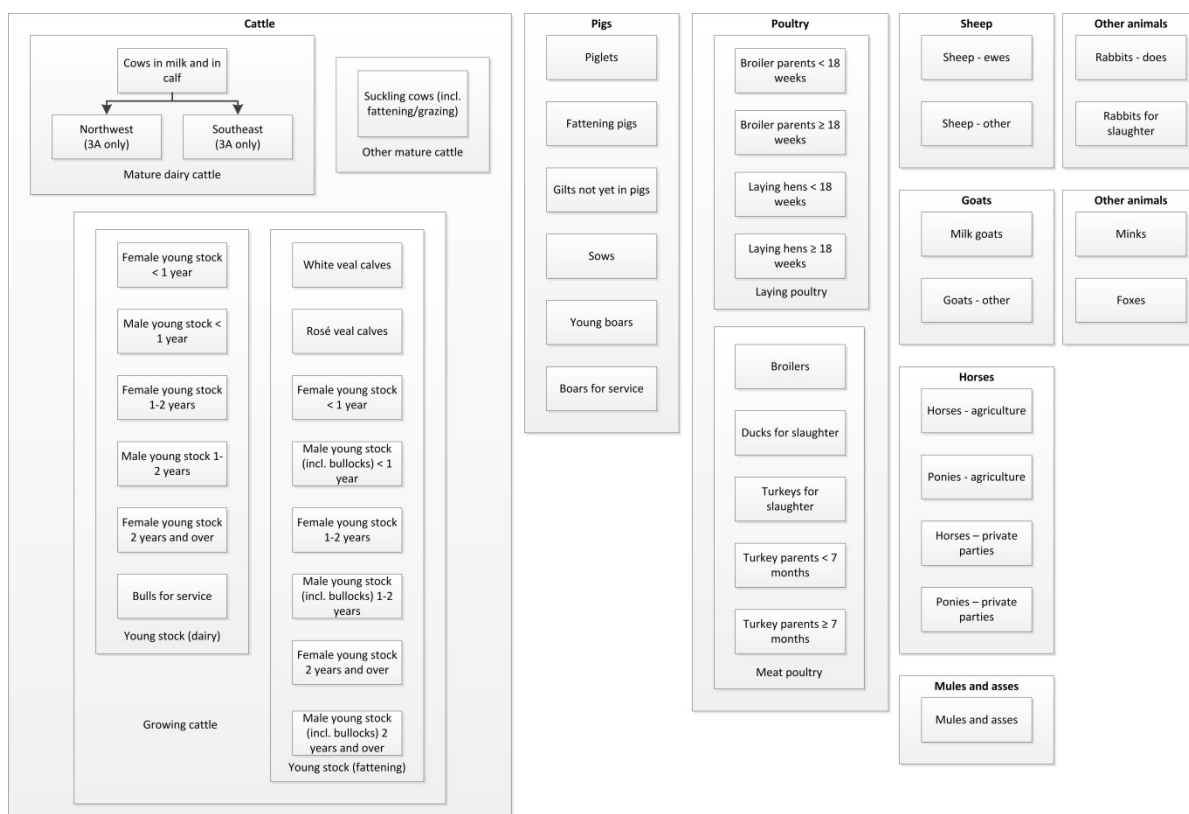


Figure 2.2 Livestock categories in the Agricultural Census

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/CRF.

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 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 change resulted in lower poultry numbers, especially broilers, as farmers tended to report a full animal house when their housing was empty on the reference date (1st of April) and did not take mortality into account when reporting their poultry. The time series inconsistency this caused will be addressed in the NIR and IIR 2022.

The number of privately-owned horses and ponies is 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). All emissions related to these animals have been allocated to the agricultural sector in both the NIR and the IIR.

2.2.2 *N excretions*

The N excretions in animal houses (taking into account excretions on pasture land 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 and CBS 2020; 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 (Cbs, 2019).

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 most commonly stored as slurry, with some solid storage also present. The majority of female young stock, dairy and suckling cows are kept on pasture land 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.
- *Rabbits* 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.

2.3 Emission calculations

In the Netherlands, agriculture is a major source of NH₃, NO_x, N₂O, NMVOC, CH₄, PM₁₀ and PM_{2.5} emissions. Both NH₃ and NO_x contribute to the eutrophication and acidification of soils, while N₂O and CH₄ are greenhouse gases, and N₂O 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 Economic Affairs and Climate Policy, the NEMA working group of the CDM developed a method to calculate NH₃ 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, N₂O, CH₄, PM₁₀ and PM_{2.5} have been included in the model since the emission calculations of 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 CO₂ 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 CO₂ 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 the 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 Kyoto Protocol.

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 unrecognized 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 2006 IPCC Guidelines (IPCC, 2006).

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) is 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. Where included in the QA/QC programme for the relevant period, additional analyses are implemented regularly in specific situations, which include any updating of the Approach 2 uncertainty analyses (Monte Carlo-analysis).

Based on the 2019 inventory (1990-2017 time series), new uncertainty estimates for the agricultural sector were calculated using the propagation-of-error approach for the most recent reference year (2015). 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 2019 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.

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

Where

Uncertainty estimate_{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 is calculated by aggregating the subcategories, with the Monte Carlo method used 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 NEMA working group.

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 the number of privately-owned horses and ponies is assumed to be 50%.

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

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

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)

Livestock category	Uncertainty
<i>Cattle for breeding</i>	
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%
<i>Cattle for fattening</i>	
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%
<i>Other grazing animals</i>	
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	5% ¹⁾
Horses and ponies (not agriculture)	50% ¹⁾
<i>Pigs</i>	
Piglets	10% ²⁾
Fattening pigs	10%
Sows	5%
Breeding pigs	5%
Boars	5%
<i>Poultry</i>	

Livestock category	Uncertainty
Broiler breeders < 18 weeks	10%
Broiler breeders ≥ 18 weeks	5%
Laying hens < 18 weeks	10%
Laying hens ≥ 18 weeks	5%
Broilers	10%
Ducks	10%
Turkeys	10%
<i>Other animals</i>	
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.

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:

$$U_{\text{animal housing}_i} = \sqrt{\left(\frac{N_{\text{excretion}_i} \times U_{N_{\text{excretion}_i}}}{2 \times N_{\text{excretion}_i}}\right)^2} \quad (2.3a)$$

$$U_{\text{pasture}_i} = \sqrt{\left(\frac{N_{\text{excretion}_i} \times U_{N_{\text{excretion}_i}}}{2 \times N_{\text{excretion}_{i, \text{pasture}}}}\right)^2} \quad (2.3b)$$

Where:

- $U_{\text{animal housing}_i}$: 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)
- $N_{\text{excretion}_i}$: Total N excretions for livestock category (i)
- $U_{N_{\text{excretion}_i}}$: Relative uncertainty of total N excretions for livestock category (i)
- $N_{\text{excretion}_{i, \text{animal housing}}}$: N excretions in animal housing for livestock category (i)
- $N_{\text{excretion}_{i, \text{pasture}}}$: 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

Livestock category	U total N excretion per head	U animal house N excretion per head	U pasture N excretion per head
<i>Cattle for breeding</i>			
Female young stock < 1 year	4.9%	4.0%	24.5%
Male young stock < 1 year	5.5%	-	-
Female young stock ≥ 1 year	4.1%	4.0%	10.3%
Male young stock ≥ 1 year	5.3%	-	-
Dairy cows	5.8%	4.7%	31.3%
<i>Cattle for fattening</i>			
Veal calves, for white veal production	14.8%	-	-
Veal calves, for rosé veal production	9.5%	-	-
Female young stock < 1 year	4.9%	4.0%	25.1%
Male young stock < 1 year (incl. young bullocks)	11.3%	-	-
Female young stock ≥ 1 year	4.1%	4.1%	10.2%
Male young stock ≥ 1 year (incl. young bullocks)	8.9%	-	-
Suckling cows	5.3%	7.7%	7.3%
<i>Other grazing animals</i>			
Sheep (ewes, including young animals and males)	6.0%	42.4%	4.7%
Dairy goats ≥ 1 year (including young animals and males)	14.5%	-	-
Horses (agriculture)	21.4%	29.2%	31.4%
Ponies (agriculture)	21.4%	36.8%	25.7%
Mules and asses ¹⁾	21.4%	36.8%	25.7%
Horses and Ponies (not agriculture)	21.4%	36.8%	25.7%
<i>Pigs</i>			
Fattening pigs	9.9%		
Sows (including piglets)	11.4%		
Breeding pigs	9.8%		
Boars	7.9%		
<i>Poultry</i>			
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%		
<i>Other animals</i>			

Livestock category	U total N excretion per head	U animal house N excretion per head	U pasture N excretion per head
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
<i>Cattle for breeding</i>		
Cows in milk and in calf	Slurry	0.31
	Solid	10
Female young stock < 1 year	Slurry	6.95
	Solid	10
Male young stock < 1 year	Slurry	6.95
	Solid	10
Female young stock ≥ 1 year	Slurry	0.42
	Solid	10
Male young stock ≥ 1 year	Slurry	2.05
<i>Cattle for fattening</i>		
	Solid	10
Veal calves, for white veal production	Slurry	0
Veal calves, for rosé veal production	Slurry	0
Female young stock < 1 year	Slurry	7.86
	Solid	10
Male young stock (incl. young bullocks) < 1 year	Slurry	8.18
	Solid	10
Female young stock ≥ 1 year	Slurry	7.86
	Solid	10
Male young stock (incl. young bullocks) ≥ 1 year	Slurry	9.61
	Solid	10
Suckling cows (incl. fattening/grazing) ≥ 2 years	Slurry	5.15
<i>Pigs</i>		
	Solid	10
Fattening pigs	Slurry	0
Rearing pigs	Slurry	0

Livestock category	Manure management system	U fraction solid/slurry
Sows	Slurry	0.31
	Solid	10
Boars for service	Slurry	2.35
<hr/>		
<i>Poultry</i>	Solid	10
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 NEMA-committee, 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. The members of the NEMA-committee are given in Annex 11.
- The methodological changes are approved by the task force agriculture. Members of the task force are given in Annex 11.
- 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 NEMA-committee 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 NEMA-committee 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.
- The task force agriculture reviews the new time series.
- 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 send to the NIE for approval.
- The methodology report is send to the NIE for approval.
- After the submission of the NIR and the IIR reviews take place performed by reviewers from other countries.

3 CH₄ emissions from enteric fermentation (CRF sector 3A)

3.1 Scope and definition

This section provides a description of the methods and working processes used to determine the emission of CH₄ from ruminal and intestinal (enteric) fermentation. The following source categories are distinguished in the CRF:

- 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 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 (llamas, 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 CH₄ 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 CH₄.

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 CO₂, which is available in excess within the rumen environment, the surplus hydrogen gas is almost completely converted into CH₄ 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 CH₄ (Van Zijderveld *et al.*, 2011). This relatively complete conversion of surplus hydrogen into CH₄ keeps the partial gas pressure of hydrogen in the rumen environment very low.

The amount of CH₄ 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 CH₄. 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 CH₄ (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 CH₄ (i.e. the amount of CH₄ in kg CH₄/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 CH₄).

3.2 Source-specific aspects

3.2.1

Calculation method

The emission of CH₄ 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 2006 IPCC Guidelines. The total CH₄ emission from all animals is calculated by summing the emissions of each livestock category.

$$\text{CH}_4 \text{ emissions enteric fermentation} = \sum_i \text{AAP}_i \times \text{EF CH}_4 \text{ enteric fermentation}_i \quad (3.1)$$

Where:

CH₄ emissions enteric fermentation: Methane emissions (kg CH₄/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)

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 CH₄ in the rumen and the large intestine. The simulation model predicts the gross energy intake from feed and the production of CH₄ 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 CH₄ 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.

3.2.2 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.

3.2.3 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).

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 and the South-eastern part of the Netherlands are separated as a region with a different dietary composition and level of milk production. 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 Bruggen *et al.*, 2021). The Tier 3 approach does not account for the effects of feed additives that could demonstrably mitigate enteric CH₄ emissions.

The simulation model describes CH₄ 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 CH₄ 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 CH₄. 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 CH₄ 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 CH₄ 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:

$$Y_m = \text{EF CH}_4 \text{ enteric fermentation}_{\text{dairy cattle}} \times 55.65 / (\text{GE} \times 365) \quad (3.2)$$

Where

- Y_m : Methane conversion factor (fraction of GE intake converted into CH₄)
- EF CH₄ enteric fermentation_{dairy cattle}: Emission factor (kg CH₄/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 CH₄ (MJ/kg CH₄)

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, 2019);
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, 2019) 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, 2008 through 2020). The first release was published in 1994 (WUM, 1994), and a revised calculation of the rations (from 1990 to 2008) was published in 2009 (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 CH₄ 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).

Should the results from the simulation model not be available in a particular year, a secondary (simplified) approach is used to calculate the emission factor, based on the methane-conversion factor and dry-matter intake from the three preceding years (as a back-up option). In such cases, the following equation is used to calculate the emission factor:

$$\text{EF CH}_4 \text{ enteric fermentation}_{\text{dairy cattle}} = (\text{DM} \times 365 \times \text{GE} / \text{DM}_{\text{average}} \times Y_{\text{m, average}}) / 55.6 \quad (3.3)$$

Where

EF CH ₄ enteric fermentation _{dairy cattle} :	Emission factor (kg CH ₄ /animal/year) for enteric fermentation of mature dairy cattle
DM	: Dry-matter intake (kg dry matter/animal/day)
GE	: Gross energy intake (MJ/animal/day)
DM _{average}	: Average dry-matter intake (kg dry matter/animal/day) of year n-1 to year n-3
Y _{m, average}	: Average methane conversion factor of year n-1 to year n-3
55.65	: Standard energy content of 1 kg CH ₄ (MJ/kg CH ₄)

The emission factor is calculated more accurately with Equation 3.3 compared with adoption of results from the preceding year, as estimates are based on dietary characteristics of three consecutive years, instead of for only a single year.

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.

Cattle, excluding mature dairy cattle

Emission factors for cattle, excluding mature dairy cattle

Growing cattle is considered a key source (Ruysenaars *et al.*, 2020) 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:

$$EF_{CH_4 \text{ enteric fermentation}_i} = (Y_{mi} \times GE_i) / 55.65 \quad (3.5)$$

Where

$EF_{CH_4 \text{ enteric fermentation}_i}$: 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:

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

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, 2020) 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, 2008 through 2018). The first release was published in 1994 (WUM, 1994), and a revised calculation of the rations (from 1990 to 2008) was published in 2009 (Cbs, 2019). The dry-matter intake of cattle, excluding mature dairy cattle, is stated in the report written by Smink (2005) and in Van Bruggen *et al.* (2020).

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 was 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:

$$\text{EF CH}_4 \text{ enteric fermentation}_{\text{white veal}} = \left(Y_{\text{m, milk products}} \times \text{GE}_{\text{milk products}} + Y_{\text{m, other ration components}} \times \text{GE}_{\text{other ration components}} \right) / 55.65 \quad (3.7)$$

Where

$\text{EF CH}_4 \text{ enteric fermentation}_{\text{white veal}}$: Emission factor (kg CH ₄ /animal/year) from enteric fermentation of white veal calves
$Y_{\text{m, milk products}}$: Methane conversion factor for milk products
$\text{GE}_{\text{milk products}}$: Gross energy intake (MJ/animal/year) with milk products
$Y_{\text{m, other ration components}}$: Methane conversion factor for other ration components
$\text{GE}_{\text{other ration components}}$: 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 CH₄ 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 CH₄
<i>Young cattle</i>				
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%
<i>Other mature cattle</i>				
Suckling cows (incl. fattening/grazing) ≥ 2 years	5%	2.5%	20%	0%

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). 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	8.00
Goats	5.00
Horses	18.00
Mules and asses	10.00
Pigs	1.50

Source: IPCC (2006)

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 CH₄ from enteric fermentation.

Table 3.3 Uncertainty estimates (% of value) for CH₄ emissions, activity data (AD) and implied emission factors (IEF) from CRF 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%	21%	21%
3A1c	Growing cattle	1%	11%	11%
3A2	Sheep	10%	40%	41%
3A3	Swine	6%	40%	41%
3A4a	Goats	10%	40%	41%
3A4b	Horses	36%	40%	56%
3A4c	Mules and Asses	5%	40%	40%
	Total			10%

4 CH₄ emissions from manure management (CRF sector 3B)

4.1 Scope and definition

This section provides a description of the methodology and working processes for determining CH₄ emissions from manure in animal housing, outside storage and manure treatment. The following source categories are distinguished in the CRF:

- 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 CH₄.

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, CH₄ 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 (Ruysenaars *et al.*, 2020), 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.

$$\text{CH}_4 \text{ emissions manure management} = \sum \text{AAP}_i \times \text{FRAC}_{j, \text{ manure management}} \times \text{EF CH}_4 \text{ manure management}_{ij} \quad (4.1)$$

Where:

CH₄ emissions manure management: Methane emission (kg CH₄/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 CH₄ manure management_{ij}: Emission factor (kg CH₄/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).

$$\text{CH}_4 \text{ emissions manure management} = \sum \text{AAP}_i \times \text{EF CH}_4 \text{ manure management}_i \quad (4.2)$$

Where:

CH₄ emissions manure management: Methane emissions (kg CH₄/year) for all defined livestock categories (i) within the CFR source category 3B (Manure management)

AAP_i: Average animal population for livestock category (i)

EF CH₄ manure management_i: Emission factor (kg CH₄/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 (CH₄N₂O) or uric acid (C₅H₄O₃N₄) 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 depends 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:

$$EF \text{ for CH}_4 \text{ manure management}_{ij} = VS_i \times (1 - \text{FRAC}_{\text{manure treatment}}) \times B_{oi} \times MCF_{ij} \times 0.67 \quad (4.3)$$

Where

EF for CH₄ manure management_{ij}: Emission factor (kg CH₄/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)

FRAC_{manure treatment}: Fraction of the manure that is treated B_{oi}: Maximum methane production potential (m³ CH₄/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/m³)

Maximum methane production potential (B₀)

The value of B₀ depends on the degradability of the organic components in the manure. This value is expressed in m³ CH₄/kg VS and is 0.22 for cattle manure, 0.31 for pig manure, and 0.34 for poultry manure (Groenestein *et al.*, 2016).

Methane-conversion factor (MCF)

The MCF indicates the share of B₀ 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 CH₄ 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 in order 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
<i>Slurry</i>	
Cattle	0.17
Pigs	0.36
Laying hens	0.36
<i>Solid manure</i>	
Cattle	0.02 ¹
Pigs	0.02 ¹
Poultry	0.015
<i>Pasture manure</i>	
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/√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_0 (defined as $2 \times (\text{stdev}/\sqrt{(n-1)})$) 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_0 (%)	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
	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
	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 CH_4 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. 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 CH₄ process (if relevant) and subsequent storage from manure treatment for livestock category (i) and process (o) are calculated as follows:

$$\text{CH}_4 \text{ emissions manure treatment}_{i_o} = \sum \text{VS}_i \times \text{FRAC}_{i_o, \text{ manure treatment}} \times \text{EF} \quad (4.4)$$

Where:

CH₄ emissions manure treatment_{i_o}: Methane emissions (kg CH₄/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_{i_o, manure treatment}: Fraction of the manure that is treated for the livestock category (i) within the manure treatment system (o)

EF CH₄ manure treatment_{i_o}: Emission factor (kg CH₄/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 (CH₄N₂O) or uric acid (C₅H₄O₃N₄) 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).

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, as summarised in Table 4.4.

Table 4.4 Emission factors (EF; g CH₄/kg VS in manure) for all livestock categories, by manure treatment system (Melse and Groenestein, 2016).

Livestock category	Manure treatment	EF
Cattle (excl. veal calves)	Separation	24.8
	Digestion	6.0
Veal calves	Separation	4.8
	Digestion	8.2
Pigs	Separation	64.0
	Digestion	8.2
Poultry	Incineration	0.6
	Pelleting/drying	0.6

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 CH₄ emissions from manure treatment

Livestock category	Manure treatment	U AD	U IEF
Mature dairy cattle	Separation	50%	38.7%
Young cattle	Separation	50%	38.9%
Veal calves	Separation	50%	38.7%
Fattening pigs	Separation	50%	39.6%
	Mineral concentrates	50%	39.6%
Breeding pigs	Separation	50%	39.6%
	Mineral concentrates	50%	39.6%
Laying hens	Pelleting/drying	25%	73.5%
	Incineration	25%	73.5%
Broilers	Pelleting/drying	25%	73.5%
	Incineration	25%	73.5%
Turkeys	Pelleting/drying	25%	73.5%
	Incineration	25%	73.5%
Mature dairy cattle	Digestion	50%	38.7%
Young cattle	Digestion	50%	38.9%
Fattening pigs	Digestion	50%	39.6%
Breeding pigs	Digestion	50%	39.6%

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 CRF, emissions from manure management and manure treatment are summed to arrive at total CH₄ emission from manure management.

Aggregation of uncertainties for CH₄ manure management and manure treatment

Uncertainty values for emissions from manure management and manure treatment are aggregated to the CRF categories, as shown in Table 4.6.

Table 4.6 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and CH₄ emissions from manure management

IPCC	Livestock category	U AD	U IEF	U emissions
3A1a	Mature dairy cattle	2%	39%	39%
3A1b	Other mature cattle	2%	34%	34%
3A1c	Growing cattle	1%	21%	21%
3A2	Sheep	10%	44%	45%
3A3	Swine	8%	29%	30%
3A4a	Goats	10%	30%	32%
3A4b	Horses	36%	58%	68%
3A4c	Mules and asses	5%	43%	43%
3A4d	Poultry	5%	44%	44%
3A4e	Other	5%	29%	29%
	Total			20%

5 NH₃ 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 NH₃ 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 ‘not occurring’ (NO), as these animals are not kept commercially in the Netherlands. 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 NH₃ 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 mineralized organically bound N in faeces. In mammals, this N is excreted as urea (CH₄N₂O) and, in birds, as uric acid (C₅H₄O₃N₄). Both urea and uric acid are converted by bacterial enzymes (urease and uricase) into ammonium (NH₄⁺). 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, NH₄⁺ is converted to NH₃, which is emitted in a process affected by various factors, both physical (e.g. air speed, area and temperature) and chemical (e.g. NH₄⁺ concentration, pH and ion strength).

The sum of the amount of NH₃ and NH₄⁺ 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) 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 NH₃ emissions based on TAN instead of on total N:

- Gaseous N components are formed from NH₄⁺ in manure. Research under controlled conditions has demonstrated that NH₃ emissions are more closely related to NH₄⁺ 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 NH₃ 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 NH₃ 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 NH₃ 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 NH₃ 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, 2019).

The methodology assumes that the relationship between TAN content and NH₃ 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 NH₃ 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 NH₃ 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 CH₄ 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 NH₄⁺, especially in dried manure. The amount of NH₄⁺/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 total amount of TAN in manure is equal to the sum of TAN excretions from Steps 1 and 2.
4. The emissions of NH₃ and other N compounds (N₂, N₂O and NO_x) are calculated relative to the total amount of TAN in the manure.
5. 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.
6. 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.

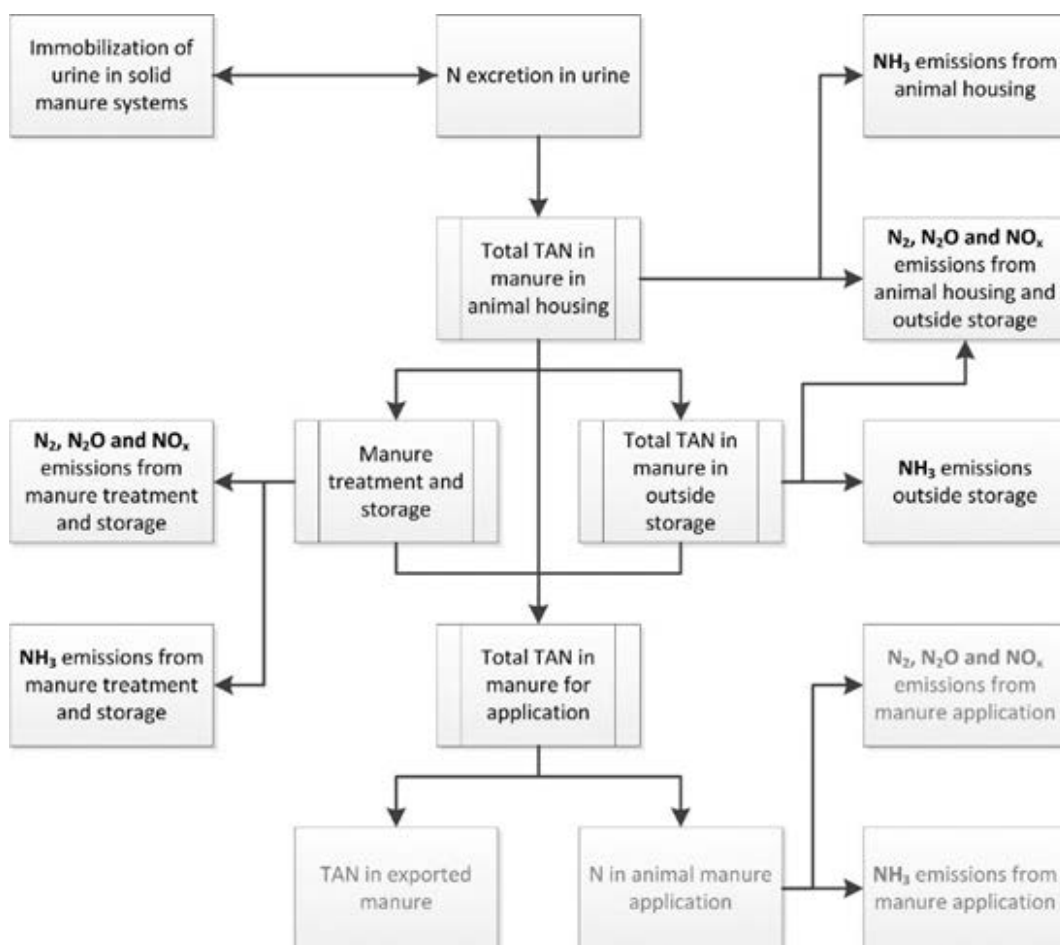


Figure 5.1 The flow of TAN throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to manure management

5.2

5.2.1

Source-specific aspects for NH₃ emissions from animal housing

Calculation method

The total NH₃ 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)
- Average emission factors for NH₃ 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 NH₃ emissions from animal housing for livestock category (i) are calculated as follows:

$$\text{NH}_3 \text{ emissions animal housing}_i = \sum \text{TAN}_{ij, \text{ animal housing}} \times \text{EF NH}_3\text{-N}_{\text{TAN}} \text{ animal housing}_{ij} \times 17/14 \quad (5.1)$$

Where:

NH_3 emissions animal housing _i	: Total NH_3 emissions (kg NH_3 /year) from animal housing for livestock category (i)
TAN_{ij} , animal housing	: Sum of urine excretion and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j)
$\text{EF NH}_3\text{-N}_{\text{TAN}}$ 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 $\text{NH}_3\text{-N}$ 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.

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 pasture land, 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:

$$\text{TAN}_{i, \text{ slurry from animal housing}} = \text{AAP}_i \times \text{FRAC}_{i, \text{ slurry manure management}} \times (\text{N excretion}_i \times \text{FRAC}_{i, \text{ TAN in urine}} + \text{N excretion}_i \times (1 - \text{FRAC}_{i, \text{ TAN in urine}}) \times \text{N mineralisation}_j) \quad (5.2a)$$

$$\text{TAN}_{i, \text{ solid from animal housing}} = \text{AAP}_i \times \text{FRAC}_{i, \text{ solid manure management}} \times (\text{N excretion}_i \times \text{FRAC}_{i, \text{ TAN in urine}} + \text{N excretion}_i \times \text{FRAC}_{i, \text{ TAN in urine}} \times \text{N mineralisation}_j) \quad (5.2b)$$

Where

$\text{TAN}_{i, \text{ slurry from animal housing}}$: Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j)

$\text{TAN}_{i, \text{ solid from animal housing}}$: 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)

$\text{FRAC}_{i, \text{ slurry manure management}}$: Fraction of slurry manure for livestock category (i)

$\text{FRAC}_{i, \text{ solid manure management}}$: Fraction of solid manure for livestock category (i)

N excretions_i : N excretions (kg N/animal) in animal housing for livestock category (i)

$\text{FRAC}_{i, \text{ TAN in urine}}$: Fraction of urine N in total N excretions in animal housing for livestock category (i)

$\text{N mineralisation}_j$: Net N mineralisation (% of organic N excretion) for manure management system (j)

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

NH₃ 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 NH₃ 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 NH₃ 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 NH₃ emission factors derived from the measurements are expressed in kg for each animal place. These factors in kg NH₃ 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:

$$EF_{NH_3-N_{TAN}, animal\ housing_{ij}} = \frac{\sum (EF_{NH_3, animal\ housing_{ik}} \times (14/17) / (FRAC_{k, occupancy, Rav\ year}))}{TAN_{i, animal\ housing, Rav\ year} \times FRAC_{ik, animal\ housing}} \quad (5.3)$$

Where:

$EF_{NH_3-N_{TAN}, animal\ housing_{ij}}$: NH₃ emission factor (% of TAN excretions) for livestock category (i) and manure management system (j)

$EF_{NH_3, animal\ housing_{ik}}$: NH₃ emission factor (kg NH₃/animal place/year) for livestock category (i) and housing system (k)

$FRAC_{k, occupancy, Rav\ year}$: 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

$TAN_{i, animal\ housing, Rav\ year}$: 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

$FRAC_{ik, animal\ housing}$: Fraction of housing system (k) for livestock category (i)

14/17: Conversion factor from NH₃ to NH₃-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% NH₃ reduction, but only a reduction of 59%. The emission factors for animal housing take this into account.

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 :

$$(N_{\text{rest}})_{\text{low}} = (N_{\text{loss calculated from change in N/P-ratio}})_{\text{low}} - [(NH_3 \text{ calculated with emission factor})_{\text{low}} + (N_{\text{other calculated with emission factor}})] \quad (5.4)$$

Where:

$(N_{\text{rest}})_{\text{low}}$: 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 NH₃ and for other N compounds such as N₂O, NO and N₂.

$(N_{\text{loss calculated from change in N/P-ratio}})_{\text{low}}$: Amount of nitrogen lost based in difference in N/P ratio

$(NH_3 \text{ calculated with emission factor})_{\text{low}}$: Amount of N lost in the form of NH₃ based on the emission factor of low emission housing.

$(N_{\text{other calculated with emission factor}})$: Amount of N lost in the form of N₂O, NO and N₂ based on the emission factor, which is a standard percentage from the N excretion.

$$N_{\text{rest regular}} = (N_{\text{loss calculated from change in N/P-ratio}})_{\text{regular}} - [(NH_3 \text{ calculated using an emission factor})_{\text{regular}} + (N_{\text{other calculated with emission factor}})] \quad (5.5)$$

Where:

$(N_{\text{rest}})_{\text{regular}}$: 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 NH₃ and for other N compounds such as N₂O, NO and N₂.

$(N_{\text{loss calculated from change in N/P-ratio}})_{\text{regular}}$: Amount of nitrogen lost based in difference in N/P ratio

$(\text{NH}_3 \text{ calculated with emission factor})_{\text{regular}}$: Amount of N lost in the form of NH_3 based on the emission factor of regular emission housing.

$(N_{\text{other calculated with emission factor}})$: 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.

$$(\text{NH}_3 \text{ low emission housing}) = (\text{NH}_3 \text{ calculated with emission factor})_{\text{low}} + (N_{\text{rest}})_{\text{low}} - (N_{\text{rest}})_{\text{regular}} \quad (5.6)$$

Where:

$(\text{NH}_3 \text{ low emission housing})$: Amount of NH_3 lost from low emission housing

$(\text{NH}_3 \text{ calculated with emission factor})_{\text{low}}$: Amount of NH_3 lost from low emission housing based on the emission factor of low emission housing

$(N_{\text{rest}})_{\text{low}}$: 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 .

$(N_{\text{rest}})_{\text{regular}}$: 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 a correction factor was 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).

Occupancy

The occupancy fraction of the different housing systems is presented in Annex 8, based on Van Bruggen *et al.* (2020). 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 NH₃ 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 NH₃ 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 NH₃ 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 NH₃ 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 NH₃ emissions from manure treatment

5.3.1 Calculation method

The NH₃ 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, NH₃ 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 NH₃ emissions from the manure treatment (o) for livestock category (i) are calculated as follows:

$$\text{NH}_3 \text{ emissions manure treatment} = \sum_{\text{manure treatment}_{i,o}} N_{i,o, \text{ manure treatment}} \times \text{EF NH}_3\text{-N} \quad (5.7)$$

Where:

NH₃ emissions manure treatment: NH₃ emissions from manure treated (kg NH₃/year)

$N_{i,o, \text{ manure treatment}}$: Amount of N in treated manure (kg N/year) of livestock category (i) and manure treatment (o)

EF NH₃-N manure treatment_{i,o}: 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).

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 NH₃ (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 NH₃ 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 NH₃, NO_x, N₂O and N₂. The input of TAN into outside storage facilities is established by multiplying the result by the fraction of manure stored.

The NH₃ emissions from outside manure storage facilities for livestock category (i) are calculated as follows:

$$\text{NH}_3 \text{ emissions outside storage}_i = \sum \text{TAN}_{ij, \text{ animal housing}} \times \text{EF NH}_3\text{-NT}_{\text{TAN}} \text{ outside storage}_{ij} \times 17/14 \quad (5.8)$$

Where

NH₃ emissions outside storage_i: NH₃ emissions (kg NH₃/year) from outside manure storage facilities for livestock 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)

EF NH₃-N_{TAN} outside storage_{ij}: NH₃ emission factor (% of TAN) for outside storage facilities for livestock category (i) and manure management system (j)

17/14 : Conversion factor from NH₃-N to NH₃ 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

Information on the use of outside manure storage facilities is taken from the Agricultural Census.

5.4.3 Emission factors

NH₃ 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 NH₃ from manure storage, the following calculations are performed for all livestock categories (i) and manure management systems (slurry or solid; j):

$$EF_{NH_3-N_{TAN} \text{ outside storage}}_{ij} = \sum \text{FRAC}_{ij, \text{ outside storage}} \times EF_{NH_3-N \text{ outside storage}}_{ijk} \times (N \text{ excretion}_{ik} - (NH_3-N \text{ animal housing}_{ijk, \text{ Rav year}} + N_2O-N \text{ emissions manure management direct}_{ij} + NO_x-N \text{ emissions manure management}_{ij} + N_2 \text{ emissions manure management}_{ij})) / \text{TAN}_{ij, \text{ animal housing}} \times \text{FRAC}_{ik, \text{ animal housing}} \quad (5.9)$$

$EF_{NH_3-N_{TAN} \text{ outside storage}}_{ij}$: NH₃-N emission factor (% of TAN) for animal housing for livestock category (i) and manure management system (j)

$\text{FRAC}_{ij, \text{ outside storage}}$: 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

$EF_{NH_3-N \text{ outside storage}}_{ijk}$: NH₃-N emission factor (kg N) for manure storage for livestock category (i), manure management system (j) and housing system (k)

$N \text{ excretions}_{S_{ik}}$: 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

$NH_3-N \text{ emissions animal housing}_{ijk, \text{ Rav year}}$: NH₃-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

$N_2O-N \text{ emissions manure management direct}_{ij}$: N₂O-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

$\text{NO}_x\text{-N}$ emissions manure management _{ij} :	$\text{NO}_x\text{-N}$ 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
$\text{FRAC}_{ik, \text{ animal housing}}$: Fraction of housing system (k) within animal category (i)
$\text{TAN}_{ij, \text{ animal housing}}$: 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 $\text{N}_2\text{-N}$ emissions are 10 times greater than the $\text{N}_2\text{O-N}$ 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 9.

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 NH₃ 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 NH₃ emissions (U emissions) from manure management

EMEP	Livestock category	U AD	U IEF	U emissions
3B1a	Dairy cattle	2%	45%	45%
3B1b	Non-dairy cattle	1%	29%	29%
3B2	Sheep	5%	106%	106%
3B3	Swine	8%	36%	37%
3B4d	Goats	5%	90%	90%
3B4e	Horses	4%	78%	78%
3B4f	Mules and asses	5%	88%	88%
3B4gi	Laying hens	4%	44%	44%
3B4gii	Broilers	10%	49%	50%
3B4giii	Turkeys	10%	44%	45%
3B4giv	Other poultry	10%	46%	47%
3B4h	Other animals	5%	47%	47%
	Total			20%

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 'not occurring' (NO), as these animals are not kept commercially in the Netherlands. 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 pasture land 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 (NH₄⁺) 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 O₂ to diffuse far more easily than it does in slurry, thus enabling nitrification.

Denitrification is the process of bacteria converting nitrate (NO₃⁻) into the gaseous nitrogen compound N₂ 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 NO_x emissions from manure storage

6.2.1 Calculation method

In contrast to the case of NH₃ from animal housing and outside manure storage, emissions of NO_x are calculated for animal housings and outside manure storages combined. The following formula is used to calculate NO_x emissions from animal manure:

$$\text{NO}_x \text{ emissions manure management} = \sum \text{AAP}_i \times \text{N excretions}_i \times (1 - \text{FRAC}_{i, \text{ manure treatment}}) \times \text{FRAC}_{j, \text{ manure management}} \times \text{EF NO}_x \text{ manure management}_{ij} \times 30/14 \quad (6.1)$$

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 N₂O 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 N₂O 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 200%.

6.3 Source-specific aspects for NO_x 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:

$$\text{NO}_x \text{ emissions manure treatment} = \sum N_{\text{io, manure treatment}} \times \text{EF NO}_x \text{ from manure treatment}_{\text{io}} \quad (6.2)$$

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).

NH₃, N₂O and N₂ emissions

The calculation methods for emissions of NH₃ and N₂O are described in Sections 5 and 7. The N₂ emissions are set at a value 10 times greater than N₂O-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 (200%). 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%	186%	186%
3B1b	Non-dairy cattle	1%	174%	174%
3B2	Sheep	5%	222%	222%
3B3	Swine	8%	146%	146%
3B4d	Goats	5%	203%	203%
3B4e	Horses	4%	208%	208%
3B4f	Mules and asses	5%	217%	217%
3B4gi	Laying hens	4%	201%	201%
3B4gii	Broilers	10%	207%	207%
3B4giii	Turkeys	10%	203%	203%
3B4giv	Other poultry	10%	204%	204%
3B4h	Other animals	5%	155%	155%
	Total			92%

7 N₂O emissions from manure management (CRF sector 3B)

7.1 Scope and definition

This section provides a description of the methods and working processes for determining N₂O emissions from manure management. The following source categories are distinguished in the CRF:

- Direct emissions
 - 3B1a Mature dairy cattle
 - 3B1b Other mature cattle
 - 3B1c Growing cattle
 - 3B2 Sheep
 - 3B3 Swine
 - 3B4 Other livestock
- Indirect emissions
 - 3B5 Indirect N₂O 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 N₂O 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 pasture land is reported under category 3D (Section 12; N₂O 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 (NH₄⁺) 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 O₂ to diffuse far more easily than it does in slurry, thus enabling nitrification.

Denitrification is the process whereby bacteria can convert nitrate (NO₃⁻) into the gaseous nitrogen compound N₂ 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.

N₂O 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 N₂O emissions from manure storage

7.2.1 Calculation method

Direct N₂O emissions from animal manure are calculated as follows:

$$\text{N}_2\text{O emissions manure management direct} = \sum \text{AAP}_i \times \text{N excretions}_i \times (1 - \text{FRAC}_{i, \text{ manure treatment}}) \times \text{FRAC}_{j, \text{ manure management}} \times \text{EF N}_2\text{O manure management direct}_{ij} \times 44/28 \quad (7.1)$$

Where:

N₂O emissions manure management direct: N₂O 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 N₂O manure management direct_{ij}: Emission factor (kg N₂O-N/kg N excreted manure) for livestock category (i) and manure management system (j)

44/28 : Conversion factor from kg N₂O-N to kg N₂O

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 NH₃ 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 N₂O 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 N₂O from manure management are available in the Netherlands. The available data suggest that emissions of N₂O 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 ₂ O-N/kg N manure excreted in animal housing
<i>Slurry</i>	
Cattle	0.002
Pigs	0.002
Laying hens	0.001
Fur-bearing animals	0.002
<i>Solid manure</i>	
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 200% (IPCC, 2006).

7.3 Source-specific aspects for direct N₂O emissions from manure treatment

7.3.1 Calculation method

The N₂O 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 N₂O 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 N₂O emissions from processing and subsequent storage in manure treatment (o) for livestock category (i) are calculated as follows:

$$\text{N}_2\text{O emissions manure treatment}_{i_o} = \sum N_{i_o, \text{ manure treatment}} \times \text{EF N}_2\text{O manure treatment}_{i_o} \quad (7.2)$$

Where:

N₂O emissions manure treatment: N₂O emissions from manure treated (kg N₂O/year)

N_{i_o, 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}: N₂O 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).

NH₃, NO_x and N₂ emissions

The calculation methods for emissions of NH₃ and NO_x are described in Sections 5 and 6, respectively. The N₂-N emissions are set at values 10 times greater than N₂O-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 (200%). 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 N₂O emissions from manure management

7.4.1 Calculation method

Indirect N₂O emissions from manure management are calculated by multiplying the total emissions of NH₃ and NO_x from animal housing, manure treatment and NH₃ from manure storage by an emission factor:

$$\text{N}_2\text{O emissions manure management indirect} = (\text{NH}_3 \text{ emissions manure management} \times 14/17 + \text{NO}_x \text{ emissions manure management direct} \times 14/30) \times \text{EF N}_2\text{O manure management indirect} \times 44/28 \quad (7.3)$$

Where:

N₂O emissions manure management indirect: Indirect nitrous oxide emissions (kg N₂O-N/year) following atmospheric deposition of NH₃ and NO_x from manure management

NH₃ emissions manure management: NH₃ emissions (kg NH₃/year) for all defined livestock categories (i) within NFR category 3B (Manure management)

14/17 : Conversion factor from NH₃ to NH₃-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 N₂O manure management indirect: Nitrous oxide emission factor for indirect emission following atmospheric deposition of NH₃ and NO_x

44/28 : Conversion factor from kg N₂O-N to kg N₂O

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 NH₃ 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 N₂O-N/kg N emitted as NH₃ and NO_x from animal housing and outside manure storage facilities is used.

7.4.4 Uncertainty

The uncertainty value for total NH₃ 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 N₂O 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 N₂O 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 CRF categories, as shown in Table 7.3.

Table 7.3 Uncertainty values (U) for activity data (AD; livestock numbers), implied emission factors (IEF) and N₂O emissions from manure management

IPCC	Livestock category	U AD	U IEF	U emissions
3A1a	Mature dairy cattle	2%	186%	186%
3A1b	Other mature cattle	2%	201%	201%
3A1c	Growing cattle	1%	126%	126%
3A2	Sheep	5%	222%	222%
3A3	Swine	8%	113%	113%
3A4a	Goats	5%	203%	203%
3A4b	Horses	36%	222%	225%
3A4c	Mules and asses	5%	217%	217%
3A4d	Poultry	5%	144%	144%
3A4e	Other	5%	155%	155%
3B5	Atmospheric deposition from manure management	17%	400%	406%
	Total			137%

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 'not occurring' (NO), as these animals are not kept commercially in the Netherlands. 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, 2019).

The NMVOC emissions are calculated with the Tier 2 method, as described in the EMEP Guidebook (EEA, 2019).

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:

$$\text{NMVOC emissions animal housing}_{\text{cattle}} = \sum \text{AAP}_i \times \text{GE}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times \text{EF NMVOC animal housing}_i \quad (8.1)$$

Where:

$\text{NMVOC emissions animal housing}_{\text{cattle}}$: 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)

$\text{FRAC}_{i, \text{ time spent inside}}$: Fraction of time spent inside animal housing for cattle category (i)

$\text{EF NMVOC animal housing}_i$: 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:

$$\text{NMVOC emissions animal housing}_{\text{other}} = \sum \text{AAP}_i \times \text{VS}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times \text{EF NMVOC animal housing}_i \quad (8.2)$$

Where:

$\text{NMVOC emissions animal housing}_{\text{other}}$: NMVOC emissions (kg NMVOC/year) from manure in animal housing for other livestock within NFR category 3B (Manure management)

AAP_i (i) : Average animal population for livestock category (i)

VS_i : Volatile solids excretion (kg/animal/year) for livestock category (i)

$\text{FRAC}_{i, \text{ time spent inside}}$: Fraction of time spent inside animal housing for livestock category (i)

$\text{EF NMVOC animal housing}_i$: 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, 2008 through 2018). 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, 2019). 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, 2019)

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:

$$\text{NMVOC emissions silage feeding}_{\text{cattle}} = \sum \text{AAP}_i \times \text{GE}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times (\text{EF NMVOC silage feeding}_i \times \text{FRAC}_{i, \text{ silage}}) \quad (8.3)$$

Where:

$\text{NMVOC emissions silage feeding}_{\text{cattle}}$: 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)

$\text{FRAC}_{i, \text{ time spent inside}}$: Fraction of time spent inside animal housing (i)

$\text{EF NMVOC silage feeding}_i$: Emission factor (kg NMVOC/MJ) of NMVOC from the feeding of silage for cattle category (i)

$\text{FRAC}_{i, \text{ silage}}$: 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:

$$\text{NMVOC emissions silage feeding}_{\text{other}} = \sum \text{AAP}_i \times \text{VS}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times (\text{EF NMVOC silage feeding}_i \times \text{FRAC}_{i, \text{ silage}}) \quad (8.4)$$

Where:

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

AAP_i (i) : Average animal population for livestock category (i)

VS_i : Excreted volatile solids (kg/animal/year) for livestock category (i)

$\text{FRAC}_{i, \text{ time spent inside}}$: 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, 2008 through 2018). 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, 2019), as listed in Table 8.3.

Table 8.3 NMVOC emission factors (EF) of NMVOC from silage feeding, by livestock category (EEA, 2019)

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:

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

Where:

$\text{NMVOC emissions manure storage}_{\text{cattle}}$: NMVOC emissions (kg NMVOC) for all cattle categories (i) within NFR category 3B (Manure management)

AAP_i : Average animal population for cattle category (i)

$\text{NMVOC emissions animal housing}_{\text{cattle}}$: NMVOC emissions (kg NMVOC/animal/year) from manure in animal housing for cattle category (i)

$\text{NH}_3 \text{ emissions manure storage}_i$: NH_3 emissions (kg NH_3 /year) from manure storage facilities outside animal housing for cattle category (i)

$\text{NH}_3 \text{ emissions animal housing}_i$: 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:

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

Where:

$\text{NMVOC emissions manure storage}_{\text{other}}$: NMVOC emissions (kg NMVOC) for all other livestock categories (i) within NFR category 3B (Manure management)

$\text{NMVOC emissions animal housing}_i$: NMVOC emissions (kg NMVOC/animal/year) from manure in animal housing for livestock category (i)

$\text{NH}_3 \text{ emissions outside storage}_i$: NH_3 emissions (kg NH_3 /year) from outside manure storage facilities for livestock category (i)

$\text{NH}_3 \text{ emissions animal housing}_i$: 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, 2019).

8.4.4 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 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%	221%	221%
3B1b	Non-dairy cattle	1%	146%	146%
3B2	Sheep	5%	309%	309%
3B3	Swine	8%	222%	223%
3B4d	Goats	5%	302%	302%
3B4e	Horses	4%	272%	272%
3B4f	Mules and asses	5%	309%	309%
3B4gi	Laying hens	4%	218%	218%
3B4gii	Broilers	10%	303%	303%
3B4giii	Turkeys	10%	303%	303%
3B4giv	Other poultry	10%	303%	303%
3B4h	Other animals	5%	299%	300%
	Total			143%

9 PM₁₀ 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 PM₁₀ 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 'not occurring' (NO), as these animals are not kept commercially in the Netherlands. 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 PM₁₀ 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 PM₁₀ and PM_{2.5} in grams per animal per year.

$$\text{PM emissions animal housing} = \sum \text{AAP}_i \times \text{FRAC}_{ik, \text{housing system}} \times \text{EF PM} \\ \text{animal housing}_{ik} / 1,00 \quad (9.1)$$

Where:

PM emissions animal housing: PM emissions (kg PM₁₀ 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, housing system} : Fraction of animals in the various animal-housing systems (k)

EF PM animal housing_{ijk} : Emission factor (g PM₁₀ 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 therefore 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 time.

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). 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 PM₁₀ 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 PM₁₀, 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}
<i>Dairy cattle</i>			
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
<i>Cattle for fattening</i>			
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
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
<i>Pigs</i>			
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
<i>Poultry</i>			
Broilers	Traditional ^{1), 2), 4)}	26.8	2.0
Broiler breeders < 18 weeks	Floor housing ³⁾	17.0	1.3

Livestock category	Housing system	EF PM ₁₀	EF PM _{2.5}
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
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	Traditional	19.0	5.7
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, 2019).

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 PM₁₀ 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 <i>et al.</i> , 2010a) ($47.4 \times 100\% / 147.5 = 32\%$)
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 <i>et al.</i> , 2010b) ($65.4 \times 100\% / 144.0 = 45\%$)
Sows	48%	52%	Greatest uncertainty in particulate-matter emissions from animal housing: gestating sows (Winkel <i>et al.</i> , 2009b; Mosquera <i>et al.</i> , 2010c) ($82.6 \times 100\% / 173.7 = 48\%$)
Laying hens	44%	100%	Greatest uncertainty in particulate-matter emissions from animal housing: laying hens in animal housing with a drying tunnel (Mosquera <i>et al.</i> , 2009a; Mosquera <i>et al.</i> , 2009b; Winkel <i>et al.</i> , 2009a; Winkel <i>et al.</i> , 2011) ($1.7 \times 100\% / 3.9 = 44\%$)
Broilers	33%	45%	Greatest uncertainty of particulate-matter emissions from animal housing: broilers (Winkel <i>et al.</i> , 2009c) ($8.8 \times 100\% / 26.8 = 33\%$)
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 <i>et al.</i> , 2011) and report minks (Mosquera <i>et al.</i> , 2011) ($5.21 \times 100\% / 10.7 = 49\%$)
Fur-bearing animals	49%	100%	Uncertainty value for rabbits used

¹⁾ In line with the EMEP Guidebook (2019), 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 PM₁₀ and PM_{2.5} emissions from animal housing

NFR	Livestock category	U AD	U IEF PM₁₀	U emissions PM₁₀	U IEF PM_{2.5}	U emissions PM_{2.5}
3B1a	Dairy cattle	2%	24%	24%	26%	26%
3B1b	Non-dairy cattle	1%	15%	15%	17%	17%
3B2	Sheep	10%	32%	34%	35%	37%
3B3	Swine	6%	26%	27%	31%	31%
3B4d	Goats	5%	32%	32%	35%	35%
3B4e	Horses	4%	40%	40%	40%	40%
3B4f	Mules and asses	5%	40%	40%	40%	40%
3B4gi	Laying hens	4%	36%	37%	79%	79%
3B4gii	Broilers	10%	32%	34%	43%	44%
3B4giii	Turkeys	10%	33%	35%	45%	46%
3B4giv	Other poultry	10%	35%	36%	47%	48%
3B4h	Other animals	5%	46%	47%	98%	98%
	Total			21%		31%

10 NH₃ 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 NH₃ 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

NH₃ emissions occur in all subcategories describing N inputs to the soil (i.e. 3Da1 up to 3Da4; Figure 10.1) 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 NH₃ emissions.

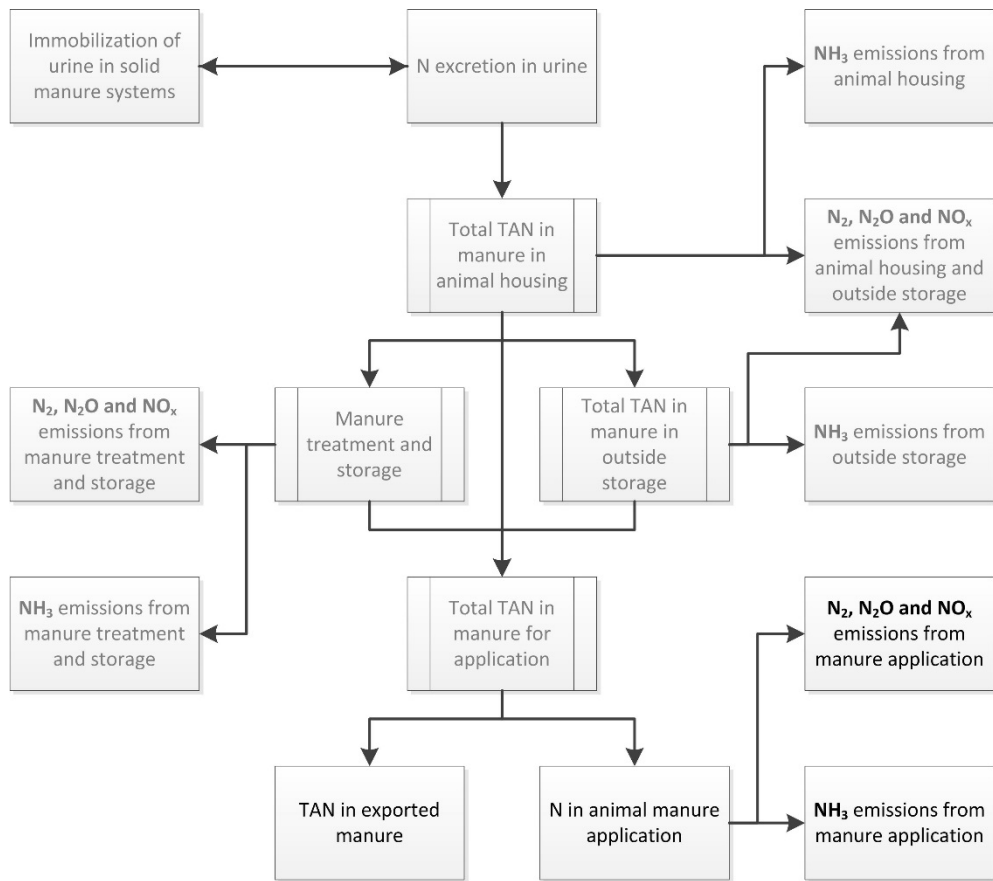


Figure 10.1 TAN flow throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to crop production and agricultural soils.

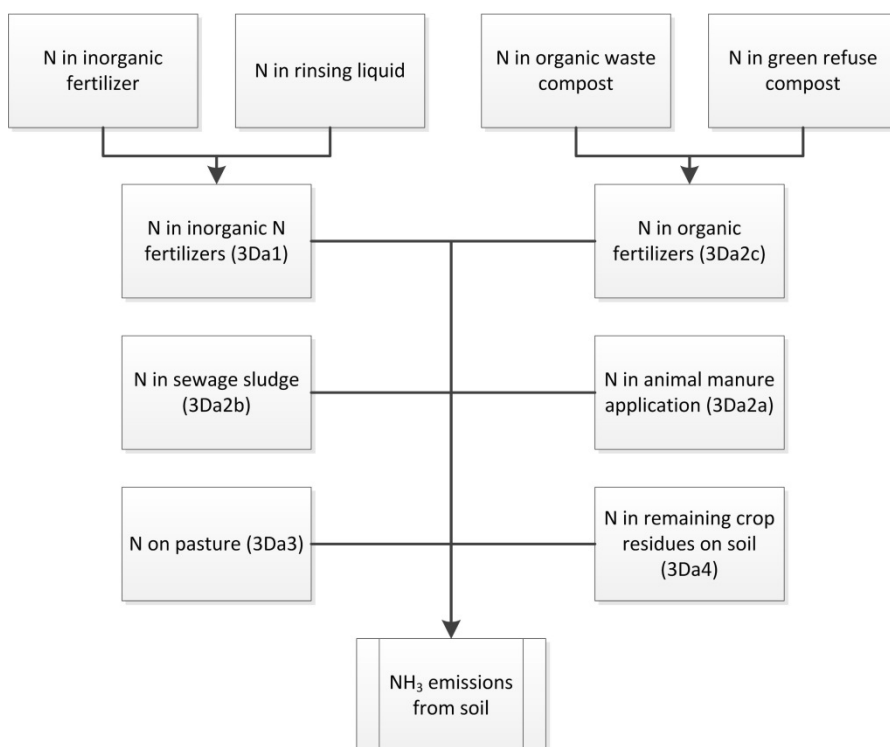


Figure 10.2 Source categories contributing to NH_3 emissions from agricultural soils

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 NH_3 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 10.1). 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.

$$\text{NH}_3 \text{ emissions inorganic fertilizer} = \sum N_{i, \text{ inorganic fertilizer}} \times \text{EF NH}_3 \text{ inorganic fertilizer}_i \times 17/14 \quad (10.1)$$

Where:

NH₃ emissions inorganic fertilizer: NH₃ emissions (kg NH₃/year) from inorganic N fertilizers applied to agricultural soils

N_{i, inorganic fertilizer} : Total amount of inorganic N fertilizer (kg N) applied for type of inorganic fertilizer (i)

EF NH₃ inorganic fertilizer_i : NH₃ emission factor for inorganic N fertilizer (% of applied N) for type of inorganic fertilizer (i)

17/14 : Conversion factor from NH₃-N to NH₃

10.2.2 Activity data

The usage of the various types of inorganic N fertilizers is taken from the synthetic fertilizer statistics of Wageningen 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 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 NH₃ 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 NH₃ 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 NH₃ emission. A calculation method was developed based on the results of regression analysis (R² = 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%.
- Mixed nitrogen fertilizer: 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 inhibitor	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 $0.76 \times 0 + 0.24 \times 7.5 = 1.8\%$.

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 26.6%. The uncertainty value for the use of rinsing liquid is 40%.

10.3 Source-specific aspects for NH₃ 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
- Losses of NH₃, N₂O, NO_x and N₂ 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 NH₃ emissions. Emissions of NH₃ occur only if the fertilizer contains urea or when ammonium (NH₄⁺) 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 NH₃

emissions is calculated based on the application of manure to grassland, uncropped land and cropped land.

The level of NH₃ emissions from manure application is calculated as follows:

$$\text{NH}_3 \text{ emissions manure application} = \sum ((\text{TAN}_{ijm, \text{ applied on grassland}} \times \text{FRAC}_{j, \text{ application technique grassland}} \times \text{EF NH}_3 \text{ application technique on grassland}_{jm}) + (\text{TAN}_{ijm, \text{ applied on uncropped land}} \times \text{FRAC}_{j, \text{ application technique uncropped land}} \times \text{EF NH}_3 \text{ application technique on uncropped land}_{jm}) + (\text{TAN}_{ijm, \text{ applied on cropped land}} \times \text{FRAC}_{j, \text{ application technique cropped land}} \times \text{EF NH}_3 \text{ application technique on cropped land}_{jm})) \times 17/14 \quad (10.2)$$

Where:

NH₃ emissions manure application: NH₃ emissions from manure applied to agricultural soils (kg NH₃/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 NH₃ application technique on grassland_{jm}: NH₃-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 NH₃ application technique on uncropped land_{jm}: NH₃-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 NH₃ application technique on cropped land_{jm}: NH₃-N emission factor (% of TAN) for manure application technique (m) for manure management system (j) used on cropped land

17/14: Conversion factor from NH₃-N to NH₃

The level of NH₃ 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. 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:

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

Where:

- $\text{TAN for application}_{ij}$: 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)
- $\text{FRAC}_{j, \text{ manure management}}$: Fraction of manure in the various management systems (j)
- $\text{N losses in animal housing}_{ij}$: 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)
- $\text{NH}_3 \text{ emissions storage}_{ij}$: NH_3 emissions from outside manure storage facilities (kg N) for livestock category (i) and manure management system (j)
- $\text{NH}_3 \text{ emissions treatment}_{ij}$: NH_3 emissions from manure treatment (kg N) for livestock category (i) and manure management system (j)
- $\text{N used outside agriculture}_{ij}$: 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

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 loss 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 land and cropped land 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 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).

The implementation grades of manure application techniques are based on the results of the Agricultural Census. The 2020 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 (Huisman 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 (Goedhart *et al.*, 2020). The updated emission factors are given in table 10.2.

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 NH₃ 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 is no longer allowed in the Netherlands, 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 NH₃ (% of TAN applied) for each application technique on grassland and on cropland

Land type/ application technique	EF (% of TAN)					
	1990	1991	1992- 1993	1994- 1998	1999- 2003	From 2004 on
<i>Grassland</i>						
Surface spreading ⁴⁾	64	68	68	68	68	68
Narrow-band (trailing-shoe) ⁴⁾	26.4	26.4	26.4	26.4	26.4	26.4
Slit-coulter ¹⁾	21.7	21.7	21.7	21.7	21.7	21.7
Shallow-injection ⁴⁾	17.0	17.0	17.0	17.0	17.0	17.0
<i>Cropland (uncropped)</i>						
Surface spreading	64	64	69	69	69	69
Incorporation in two passes ²⁾	46	46	46	46	46	46
Narrow-band (trailing-shoe) ³⁾	36	36	36	36	36	36
Slit-coulter ¹⁾	24.5	24.5	24.5	27.5	30	30
Shallow-injection ³⁾	13	13	13	19	24	24
Incorporation (direct)	22	22	22	22	22	22
Full coverage	2	2	2	2	2	2
<i>Cropland (cropped)</i>						
Narrow-band (trailing-shoe) ³⁾	N/A	N/A	N/A	N/A	N/A	36 ³⁾
Shallow-injection ³⁾	N/A	N/A	N/A	N/A	N/A	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. The measurement of N and P in manure samples is also subject to error. The mineral content of solid-manure exports is not based on the mineral content stated on the transport documents for animal manure (abbreviated in Dutch to VDM), as it has been concluded that the samples are not representative of the entire batch (Luesink *et al.*, 2011).

For solid poultry manure, Dutch averages calculated by the WUM/NEMA working groups have been used (Van Bruggen *et al.*, 2017). 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 NH₃ emissions from sewage sludge applied to soils

10.4.1 Calculation method

In the calculation of NH₃ emissions from sewage-sludge application, a distinction is made between liquid and solid sludge, with a different TAN fraction for each type:

$$\text{NH}_3 \text{ emissions sewage sludge} = \sum (\text{N}_{\text{sewage sludge}} \times \text{FRAC}_{\text{liquid}} \times \text{TAN}_{\text{liquid}} \times \text{EF NH}_3 \text{ liquid sewage sludge} + \text{N}_{\text{sewage sludge}} \times \text{FRAC}_{\text{solid}} \times \text{TAN}_{\text{solid sewage sludge}} \times \text{EF NH}_3 \text{ solid sewage sludge}) \times 17/14 \quad (10.4)$$

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 10.4) 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, NH₃ 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 NH₃ 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 10.1), it is assumed that the fraction of TAN in both sources is equal. All compost is surface-applied on uncropped land:

$$\text{NH}_3 \text{ emissions organic fertilizers} = (\text{N organic waste compost} + \text{N green refuse compost}) \times \text{TAN}_{\text{compost}} \times \text{EF NH}_3 \text{ compost} \times 17/14 \quad (10.5)$$

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.).

An exception is made for the first two years of the time series (1990 and 1991), in which the emission factor is kept equal to that of later years. The reason is that, in these years, there was an obligation to incorporate surface-spread manure into the soil on uncropped lands. The emission factor was thus set lower for 1990 and 1991, although this requirement did not apply to compost. Since 1992, the surface spreading of slurry

has not been allowed, and the obligation was lifted for other solid manures.

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 22.6%. 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 NH₃ emissions from urine and dung deposited by grazing animals is calculated from the following values:

- N excretions on pasture land 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 pasture land (Section 10.6.3).

Total NH₃ emissions from grazing for all livestock categories (i) is calculated as follows:

$$\text{NH}_3 \text{ emissions grazing} = \sum \text{AAP}_i \times (\text{TAN}_{i, \text{grazing}} - \text{TAN}_{i, \text{excreted in nature areas}}) \times \text{EF NH}_3 \text{ grazing} \times 17/14 \quad (10.6)$$

Where:

NH₃ emissions grazing : NH₃ emissions (kg NH₃/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 NH₃ grazing : Emission factor (% of TAN) for grazing
 17/14 : Conversion factor from NH₃-N to NH₃

TAN excretions on pasture land are calculated as follows:

$$\text{TAN}_{i, \text{grazing}} = \text{N excretions on pasture}_i \times \text{FRAC}_{i, \text{TAN pasture}} \quad (10.7)$$

Where:

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

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 P₂O₅ (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/P₂O₅ 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 NH₃ 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 (EF_{grazN}) 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:

- NH₃ emissions from inorganic N fertilizer are inhibited by the higher NH₃ 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 NH₃ emissions would have occurred during the measuring days,
- Measured NH₃ 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 NH₃ 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 NH₃ 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 NH₃ emissions from fresh urine patches. Furthermore, during the night-time, the grass is wet from dew, and background concentrations of NH₃ are relatively high (little dilution). This effect is also clearly visible in Bussink's measurements. The average NH₃-N flux over 24 hours was 38 g NH₃-N per hour, with a flux of 46 g NH₃-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 NH₃ 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 NH₄⁺ more strongly, thereby reducing the risk of NH₃ emissions. The CEC correction calculated by Bussink (1996) is used as follows:

$$\text{CEC correction} = (7.71 - 0.02793 \times (\text{CEC} - 280)) / 7.71 \quad (10.8)$$

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 $300 \text{ mmol}_c \text{ kg}^{-1}$ 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):

$$\begin{aligned} \text{EF NH}_3 \text{ grazing} &= 4.0\%, \text{ with } N_{\text{ration}_{\text{WUM}}} < 28 \text{ g N per kg DM} \\ \text{EF NH}_3 \text{ grazing} &= 1.98 \times 10^{-5} * (N_{\text{ration}_{\text{WUM}}})^{3.664}, \text{ with } N_{\text{ration}_{\text{WUM}}} \geq 28 \text{ g} \\ &\text{N per kg DM} \end{aligned} \quad (10.9)$$

Where:

EF NH₃ grazing : Emission factor (% of TAN) for grazing
 N_{ration_{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 NH₃ emissions. In the Netherlands, no measurement data are available for NH₃ 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 NH₃ 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):

$$\text{NH}_3 \text{ emissions crop residues} = \sum \text{area}_n \times \text{N in above-ground residue}_n \times \text{FRAC}_{n, \text{residues}} \times \text{EF NH}_3 \text{ crop residue}_n \times 17/14 \quad (10.10)$$

Where:

NH₃ emissions crop residues: NH₃ emissions (kg NH₃/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 NH₃ emissions (i.e. not incorporated into the soil in the first days after harvest) for crop (n)

EF NH₃ crop residue_n : Emission factor (% of N) for crop residues (n)
 17/14 : Conversion factor from NH₃-N to NH₃

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 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 NH₃ from crop residues, a regression model was derived from literature describing the relationship between NH₃ emissions and the N content of residues (De Ruijter and Huijsmans, 2019):

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

Where:

EF NH₃ 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 NH₃ 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 NH₃ 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 NH₃ 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 NH₃-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 NH₃ 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 NH₃ 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 NH₃ 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 NH₃ emissions from crop production and agricultural soils is provided in Table 10.4.

Table 10.2 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and NH₃ emissions (U emissions) from crop production and agricultural soils

EMEP	Source category	U AD	U IEF	U emissions
3Da1	Inorganic N fertilizers	26%	26%	37%
3Da2a	Animal manure applied to soils	4%	38%	38%
3Da2b	Sewage sludge applied to soils	25%	84%	88%
3Da2c	Other organic fertilizers applied to soils	23%	106%	111%
3Da3	Urine and dung deposited by grazing animals	1%	56%	56%
3Da4	Crop residues applied to soils	7%	59%	59%
3De	Cultivated crops			300%
	Total, agricultural soils			29%

11 NO_x 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

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 NO_x 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:

$$\text{NO}_x \text{ emissions inorganic fertilizer} = N_{\text{inorganic fertilizer}} \times \text{EF NO}_x \text{ inorganic fertilizer} \times 30/14 \quad (11.1)$$

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 Economic Research. For years from 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 25% 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, 2019).

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:

$$\text{NO}_x \text{ emissions manure application} = N_{\text{animal manure}} \times \text{EF NO}_x \text{ manure application} \times 30/14 \quad (11.2)$$

Where:

NO_x emissions manure application: NO_x emissions (kg NO_x/year, expressed as nitrogen monoxide) from animal manure applied to soils

N_{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 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, 2019).

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:

$$\text{NO}_x \text{ emissions sewage sludge} = N_{\text{sewage sludge}} \times \text{EF NO}_x \text{ sewage sludge} \times \frac{30}{14} \quad (11.3)$$

Where:

NO_x emissions sewage sludge: NO_x emissions (kg NO_x/year, expressed as nitrogen monoxide) from sewage sludge applied to soils

$N_{\text{sewage sludge}}$: 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, 2019).

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:

$$\text{NO}_x \text{ emissions organic fertilizers} = \sum N_{\text{organic fertilizers}} \times \text{EF NO}_x \text{ organic fertilizers} \times \frac{30}{14} \quad (11.4)$$

Where:

NO_x emissions organic fertilizers: NO_x emissions (kg NO_x/year, expressed as nitrogen monoxide) from compost applied to agricultural soils

$N_{\text{organic fertilizers}}$: 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, 2019).

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:

$$\text{NO}_x \text{ emissions grazing} = N_{\text{grazing}} \times \text{EF NO}_x \text{ grazing} \times 30/14 \quad (11.5)$$

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 pasture land is calculated to be 16%, as described in Section 10.6. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2019).

11.7 **Source-specific aspects for NO_x emissions from crop residues**

2.1.1 *Calculation method*

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

$$\text{NO}_x \text{ emissions crop residues} = N_{\text{crop residues}} \times \text{EF NO}_x \text{ crop residues} \times \frac{30}{14} \quad (11.6)$$

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

11.7.1 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.

11.7.2 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.

11.7.3 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, 2019).

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:

$$\text{NO}_x \text{ emissions organic soils} = \sum \text{area}_{\text{p, soil type}} \times \text{mineralisation}_{\text{p}} \times \text{EF NO}_x \text{ organic soils} \times \frac{30}{14} \quad (11.7)$$

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 and 2013. Between these years, interpolation takes place. An overview of the areas is provided in Annex 22 of Van Bruggen *et al.* (2020).

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 11.8.

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	27%	160%	168%
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	23%	160%	166%
3Da3	Urine and dung deposited by grazing animals	16%	160%	163%
3Da4	Crop residues applied to soils	6%	122%	122%
	Total, agricultural soils			87%

12 N₂O emissions from crop production and agricultural soils (CRF 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 N₂O from the soil as a result of agricultural activities in the Netherlands. It refers to the CRF source categories 3Da (Direct N₂O emissions from managed soils) and 3Db (Indirect N₂O 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
- 3Da6 Cultivation of organic soils (i.e. histosols)
- 3Db1 Indirect N₂O emissions from atmospheric deposition
- 3Db2 Indirect N₂O emissions from nitrogen leaching and runoff

In source category 3Da5 (Mineralisation/immobilisation associated with loss/gain of soil organic matter), only emissions from cropland that remains cropland are required to be reported. According to the methodology used for the sector designated as 'Land Use, Land Use Change and Forestry' (LULUCF) in the Netherlands, no emissions occur in this case (Arets *et al.*, 2019). Moreover, the Netherlands has not allocated emissions to source category 3Da7 (Other).

Nitrous oxide is formed in the soil during the microbiological processes of nitrification and denitrification. Nitrification is the process whereby ammonia (NH₄⁺) 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 NO₃⁻ into the gaseous nitrogen compound N₂ under anaerobic (low-oxygen) conditions, with N₂O 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 N₂O 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 N₂O emissions from the application of inorganic N fertilizer

12.2.1 Calculation method

For the years 2000 to 2019, direct N₂O 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:

$$\text{N}_2\text{O emissions inorganic fertilizer} = \sum \text{N inorganic fertilizer}_{ij} \times \text{EF N}_2\text{O inorganic fertilizer}_{i,j} \times 44/28 \quad (12.2)$$

Where:

N₂O emissions inorganic fertilizer: N₂O emissions (kg N₂O) 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 N₂O inorganic fertilizer_i: Emission factor (kg N₂O-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 N₂O-N to N₂O

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 N₂O emissions from inorganic N fertilizers are calculated by multiplying the amount of nitrogen of inorganic N fertilizers by a country-specific emission factor:

$$\text{N}_2\text{O emissions inorganic fertilizer} = \sum \text{N}_{\text{inorganic fertilizer}} \times \text{EF N}_2\text{O inorganic fertilizer} \times 44/28 \quad (12.1)$$

Where:

N₂O emissions inorganic fertilizer: N₂O emissions (kg N₂O) from inorganic N fertilizers applied to soil

N_{inorganic fertilizer} : Application of N from inorganic N fertilizers (kg N)

EF N₂O inorganic fertilizer: Emission factor (kg N₂O-N/kg N) for the application of N from inorganic N fertilizer for soil type (i)

44/28 : Conversion factor from N₂O-N to N₂O

To prevent a time series inconsistency between 1990-1999 and 2000-2019, it was decided to apply for the years 1990-1999 the splicing overlap technique from the IPCC (IPCC, 2006).

$$\text{Recalculated N}_2\text{O emission} = X_0 \times \left(\frac{1}{(n - m + 1)} \times \sum_{i=m}^n \frac{y_i}{x_i} \right) \quad (12.3)$$

Where:

Recalculated N₂O emission: The new N₂O emission for the a year between 1990-1999 in kg N₂O

X₀ : 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 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 2000-2019 is based on calculations with the INITIATOR model (Kros *et al.*, 2019).

12.2.3 Emission factors

The average emission factor used for the years 1990-1999 is 0.013 N₂O-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 10). For the years 2000-2019, the emission factors for the application of inorganic N fertilizer are 0.008 N₂O-N per kg net applied N for grassland on mineral soil, 0,007 N₂O-N per kg applied N for arable land on mineral soil and 0,030 N₂O-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 25% for inorganic N fertilizer and 40% for rinsing liquid (Section 10.2.4). The uncertainty value for the emission factor is estimated at 37% (see Annex 11).

12.3 Source-specific aspects for direct N₂O emissions from animal manure applied to soils

12.3.1 Calculation method

For the period 1990-1999, the direct N₂O 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.

$$\text{N}_2\text{O emissions manure application} = \sum \text{N}_{\text{animal manure}} \times \text{EF N}_2\text{O manure application}_i \times 44/28 \quad (12.4)$$

Where:

N_2O emissions manure application: N_2O emissions (kg N_2O) from the application of animal manure to agricultural soils
 $N_{\text{animal manure}}$: Amount of N (kg N/year) from animal manure applied to soils
 $EF_{N_2O \text{ manure application } i}$: 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 2000-2019, 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.

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

Where:

N_2O emissions inorganic fertilizer: N_2O emissions (kg N_2O) from the application of animal manure to agricultural soils
 $N_{\text{animal manure}}$: Amount of N (kg N/year) from animal manure applied to soils
 $EF_{N_2O \text{ manure application } i,j,k}$: 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 CRF 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, 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 2000-2019 the emission factors for surface spreading are: 0.005 kg N₂O-N per kg applied N on organic soils (both grassland and arable land), and 0.001 kg N₂O-N per kg applied N for grassland on mineral soil and 0.006 kg N₂O-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 N₂O-N per kg applied N on organic soils (both grassland and arable land), and 0,003 kg N₂O-N per kg applied N for grassland on mineral soil and 0.013 kg N₂O-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 70.4%, with an uncertainty value of 80.5% for surface spreading. Source-specific aspects for direct N₂O emissions from sewage sludge applied to soils

12.3.5 *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.

$$\frac{\text{N}_2\text{O emissions sewage sludge}}{44/28} = N_{\text{sewage sludge}} \times \text{EF N}_2\text{O sewage sludge} \times 44/28 \quad (12.6)$$

Where:

N₂O emissions sewage sludge: N₂O emissions (kg N₂O) from sewage sludge applied to agricultural soils

N_{sewage sludge} : Amount of N (kg N) from sewage sludge

EF N₂O sewage sludge : Emission factor (kg N₂O-N/kg N) for sewage sludge

44/28 : Conversion factor from N₂O-N to N₂O

These emissions are reported under their respective CRF 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).

12.3.6 *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 is derived from registered transports to agricultural holdings.

12.3.7 *Emission factors*

For sewage sludge, the emission factors and uncertainty values for manure application are used: 0.004 kg N₂O-N per kg N for surface application and 0.009 kg N₂O-N for low-ammonia emission application.

12.3.8 *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.

12.4 **Source-specific aspects for direct N₂O emissions from other organic fertilizers applied to soils (including compost)**

12.4.1 *Calculation method*

Direct N₂O emissions from compost are calculated by multiplying the amount of nitrogen from compost by a country-specific emission factor.

$$\text{N}_2\text{O emissions organic fertilizers} = \text{N}_{\text{organic fertilizers}} \times \text{EF N}_2\text{O organic fertilizers} \times 44/28 \quad (12.7)$$

Where:

N₂O emissions organic fertilizers: N₂O emissions (kg N₂O) from organic fertilizers applied to agricultural soils

N_{organic fertilizers} : Amount of N from compost in kg N

EF N₂O organic fertilizers: Emission factor for compost (kg N₂O-N/kg N)
44/28 : Conversion factor from N₂O-N to N₂O

These emissions are reported under their respective CRF 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, 2006).

12.4.2 *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.

12.4.3 *Emission factors*

All compost is assumed to be surface-applied, with an emission factor of 0.004 kg N₂O-N per kg N applied (Section 12.3).

12.4.4 *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.

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

12.5.1 Calculation method

For the period 1990-1999, the direct N₂O 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.

$$\text{N}_2\text{O emissions grazing} = N_{\text{grazing}} \times \text{EF N}_2\text{O grazing} \times 44/28 \quad (12.8)$$

Where:

N ₂ O emissions grazing	: N ₂ O emissions (kg N ₂ O) 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 ₂ O grazing	: Emission factor (kg N ₂ O-N/kg N) for urine and dung deposited by grazing animals
44/28	: Conversion factor from N ₂ O-N to N ₂ O

For the period 2000-2019 the direct N₂O 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.

$$\text{N}_2\text{O emissions grazing} = \sum N_{\text{grazing}} \times \text{EF N}_2\text{O grazing}_i \times 44/28 \quad (12.9)$$

Where:

N ₂ O emissions grazing	: N ₂ O emissions (kg N ₂ O) 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 ₂ O grazing _i	: Emission factor (kg N ₂ O-N/kg N) for urine and dung deposited by grazing animals for soil type (i).
44/28	: Conversion factor from N ₂ O-N to N ₂ O

These emissions are reported under their respective CRF categories.

Comparison to IPCC methodology

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

12.5.2 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.

12.5.3 Emission factors

An average emission factor of 0.033 kg N₂O-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 2000-2019 an

emission factor of 0.025 kg N₂O-N per kg net applied N is used for mineral soils and 0.060 kg N₂O-N per kg net applied N for organic soils.

12.5.4 *Uncertainty*

The uncertainty value for nitrogen excretion is described in Section 2.4.3. The uncertainty for the emission factor is 64.3%. 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 10).

12.6 **Source-specific aspects for direct N₂O emissions from crop residues**

12.6.1 *Calculation method*

Direct N₂O emissions from crop residues are calculated by multiplying the amount of nitrogen from crop residues by a country-specific emission factor.

$$\text{N}_2\text{O emissions crop residues} = N_{\text{crop residues}} \times \text{EF N}_2\text{O crop residues} \times \frac{44}{28} \quad (12.10)$$

Where:

N₂O emissions crop residues: N₂O emissions (kg N₂O) 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 N₂O crop residues: Emission factor (kg N₂O-N/kg N) for crop residues

44/28 : Conversion factor from N₂O-N to N₂O

These emissions are reported under their respective CRF categories.

Direct N₂O emissions from grassland renewal are calculated by multiplying the amount of ha of grassland that is renewed by a country specific emission factor.

$$\text{N}_2\text{O emissions grassland renewal} = \text{Area renewed} \times \text{EF N}_2\text{O grassland renewal} \times \frac{44}{28} \quad (12.11)$$

Where:

N₂O emissions grassland renewal: N₂O emissions (kg N₂O) from grass residues present on renewed grasslands

Area renewed : number of ha of grassland renewed

EF N₂O grassland renewal : Emission factor (kg N₂O-N) for grass residues

44/28 : Conversion factor from N₂O-N to N₂O

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*

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. 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).

12.6.3 Emission factors

An emission factor of 0.01 kg N₂O-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 N₂O-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).

12.6.4 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 80%, based on Kroeze (1994). This value is dependent on the age and management of the grass.

12.7 Source-specific aspects for direct N₂O emissions from the agricultural use of organic soils

12.7.1 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.

$$\text{N}_2\text{O emissions organic soils} = \sum \text{area}_{p, \text{ soil type}} \times \text{mineralisation}_p \times \text{EF N}_2\text{O organic soils} \times 44/28 \quad (12.12)$$

Where:

N₂O emissions organic soils: N₂O emissions (kg N₂O) 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 N₂O organic soils : Emission factor (kg N₂O-N/kg N) for mineralised nitrogen in organic soils

44/28 : Conversion factor from N₂O-N to N₂O

These emissions are reported under their respective CRF categories.

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

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 are available for the base years 1990, 2004, 2009 and 2013. Between these years, interpolation takes place. An overview of the resulting areas is provided in Annex 22 of Van Bruggen *et al.* (2020).

12.7.3 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 N₂O–N per hectare of peat soil and 4.09 kg N₂O–N per hectare of other organic soils.

12.7.4 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.

12.8 Source-specific aspects for indirect N₂O emissions after atmospheric depositions of NH₃ and NO_x

12.8.1 Calculation method

Indirect N₂O emissions occur after atmospheric depositions of nitrogen compounds that have evaporated in the form of NH₃ 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 N₂O emissions after atmospheric depositions of nitrogen compounds are calculated by multiplying the amount of nitrogen by the default 2006 IPCC emission factors.

$$\text{N}_2\text{O emissions indirect soil} = \text{N}_{\text{atmospheric deposition}} \times \text{EF N}_2\text{O emissions indirect soil} \times 44/28 \quad (12.13)$$

Where:

N₂O emissions indirect soil: Indirect N₂O emissions (kg N₂O) from the soil after atmospheric deposition of nitrogen compounds

N_{atmospheric deposition} : Amount of N (kg N) from atmospheric deposition

EF N₂O indirect soil : Default IPCC emission factor (kg N₂O-N/kg N supply) for atmospheric deposition

44/28 : Conversion factor from N₂O-N to N₂O

Comparison to IPCC methodology

The aforementioned method is similar to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006), although the IPCC also differentiates another supply source: N₂O formed in the atmosphere from NH₃ emissions. Because the IPCC provides no calculation method for this source, the nitrous oxide emissions created by NH₃ in the atmosphere are not included here. The extent of the various supply sources is determined using country-specific data at the Tier 2 or Tier 3 level. The N₂O emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

12.8.2 Activity data

Although the term 'deposition' is used here, it does not refer to actual depositions of NH₃ and NO_x, but to the total NH₃ 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 NH₃ 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 NH₃ 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).

12.8.3 Emission factors

Due to the lack of measurement data in the Netherlands, IPCC default emission factors of 0.01 kg N₂O-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).

12.8.4 Uncertainty

The uncertainty value for total emissions from agricultural soils in the form of NH₃ and NO_x is calculated to be 25.9%. IPCC gives an uncertainty value of 400% for the emission factor.

12.9 Source-specific aspects for indirect N₂O emissions from leaching and runoff of nitrogen added to the soil

12.9.1 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:

$$\text{N}_2\text{O emissions leaching} = \text{N}_{\text{applied to soil}} \times \text{FRAC}_{\text{leach}} \times \text{EF N}_2\text{O leaching} \times \frac{44}{28} \quad (12.14)$$

Where:

N ₂ O emissions leaching	: N ₂ O emissions (kg N ₂ O) from leaching and runoff of nitrogen added to the soil
N _{applied to soil}	: Amount of N (kg N) applied to the soil
FRAC _{leach}	: Fraction of nitrogen leaching and running off
EF N ₂ O leaching	: N ₂ O leaching emission factor (kg N ₂ O-N/kg N supply)
44/28	: Conversion factor from N ₂ O-N to N ₂ O

The amount of nitrogen (N_{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_{leach} is country-specific. Further background information on the FRAC_{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 aforementioned method is similar to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006), although the IPCC also differentiates another supply source: effluent discharged from sewage treatment plants into surface water. The nitrous oxide emissions created from effluent discharged into surface water are not included in the agricultural sector, but in CRF Category 5B.

The extent of the various supply sources is determined using country-specific data at the Tier 2 or Tier 3 level. The N₂O emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

12.9.2 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).

12.9.3 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)

12.9.4 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).

12.10 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%	37%	45%
3Da2a	Animal manure applied to soils	3%	66%	66%
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	15%	64%	67%
3Da4	Crop residues	7%	35%	35%
3Da6	Cultivation of organic soils (i.e. histosols)	18%	37%	41%
3Db1	Atmospheric deposition	26%	400%	414%
3Db2	Nitrogen from leaching and runoff	51%	233%	267%
	Total, agricultural soils			36%

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, 2019).

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, 2019).

The NMVOC emissions from the application of manure are calculated as follows:

$$\text{NMVOC manure application} = \sum \text{AAP}_i \times \text{NMVOC animal housing}_i \times (\text{NH}_3 \text{ manure application}_i / \text{NH}_3 \text{ animal housing}_i) \quad (13.1)$$

Where:

NMVOC manure application: NMVOC emissions (kg NMVOC) for manure application for livestock category (i)

AAP_i : Average animal population for livestock category (i)

$\text{NMVOC animal housing}_i$: NMVOC emissions (kg NMVOC/animal/year) from manure in livestock housing for animal category (i), as calculated in Section 8.2

NH₃ manure application_i : NH₃ emissions (kg NH₃/year) from manure application for livestock category (i), as calculated in Section 10.3

NH₃ animal housing_i : Total NH₃ emissions (kg NH₃/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 NH₃ from manure application and NH₃ 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, 2019).

Dairy and non-dairy cattle

The NMVOC emissions from urine and dung deposited by grazing of cattle are calculated as follows:

$$\text{NMVOC emissions pasture}_{\text{cattle}} = \sum \text{AAP}_i \times \text{GE}_i \times (1 - \text{FRAC}_{i, \text{ time spent inside}}) \times \text{EF NMVOC pasture}_i \quad (13.2)$$

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, 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:

$$\text{NMVOC emissions pasture}_{\text{other}} = \sum_i \text{AAP}_i \times \text{VS}_i \times (1 - \text{FRAC}_{i, \text{ time spent inside}}) \times \text{EF NMVOC pasture}_i \quad (13.3)$$

Where:

NMVOC 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, time spent inside}: Fraction of time spent inside housing facilities for other livestock category (i)

EF NMVOC 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, 2008 through 2018). 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, 2019). All emission factors are listed in Table 13.1.

Table 13.1 NMVOC emission factors (EF) of grazing used for each livestock category (EEA, 2019)

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, 2019). 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:

$$\text{NMVOC emissions silage storage}_{\text{cattle}} = \sum \text{AAP}_i \times \text{GE}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times (\text{FRAC}_{i, \text{ silage}} \times \text{EF NMVOC silage storage}_i) \times 0.25 \quad (13.4)$$

Where:

$\text{NMVOC emissions silage storage}_{\text{cattle}}$: 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)
$\text{FRAC}_{i, \text{ time spent inside}}$: Fraction of time spent inside animal housing for cattle category (i)
$\text{FRAC}_{i, \text{ silage}}$: Fraction of gross energy uptake consisting of silage (i)
$\text{EF NMVOC silage storage}_i$: 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:

$$\text{NMVOC emissions silage storage}_{\text{other}} = \sum_i \text{AAP}_i \times \text{VS}_i \times \text{FRAC}_{i, \text{ time spent inside}} \times (\text{FRAC}_{i, \text{ silage}} \times \text{EF NMVOC silage storage}_i) \times 0.25 \quad (13.5)$$

Where:

$\text{NMVOC emissions silage storage}_{\text{other}}$: 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)
$\text{FRAC}_{i, \text{ time spent inside}}$: Fraction of time spent inside animal housing for other livestock category (i)
$\text{FRAC}_{i, \text{ silage}}$: Fraction of feed given consisting of silage (i)
$\text{EF NMVOC silage storage}_i$: 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, 2008 through 2018). 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, 2019). 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, 2019)

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, 2019) 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, 2019).

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	4%	127%	127%
3Da3	Urine and dung deposited by grazing animals	1%	150%	150%
3Dc	Farm-level agricultural operations	1%	173%	173%
3De	Cultivated crops	13%	218%	218%
	Total, agricultural soils			99%

14 PM₁₀ 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 PM₁₀ 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:

$$\text{PM emissions crop cultivation} = \sum \text{area}_n \times \text{EF PM crop cultivation}_n \quad (14.1)$$

Where:

PM emissions crop cultivation: PM emissions (kg PM/year) from cultivated crops

Area_n : Cropped area for the defined crop (n) (ha)

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, 2019).

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, 2016). 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	1.49	0.212
Barley	1.25	0.168
Rye	1.15	0.149
Oats	1.78	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 (2016).

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, 2016) 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 PM₁₀ 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 PM₁₀ 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%	237%	237%	250%	250%
3Df	Use of pesticides	25%	100%	106%	100%	106%
	Total, agricultural soils			136%		111%

15 CO₂ emissions from liming (CRF category 3G)

15.1 Scope and definition

Calcareous fertilizers (calcic limestone (CaCO₃) and dolomite (CaMg(CO₃)₂) are used to reduce soil acidity. Emissions of CO₂ occur as carbonate lime dissolves and releases bicarbonate. Bicarbonate (2HCO₃⁻) dissolves into H₂O and CO₂.

15.2 Source-specific aspects

15.2.1 Calculation method

Emissions of CO₂ resulting from the use of lime on soils are determined for reporting in Table 3G of the CRF. The CO₂ emissions can be calculated according to the following Tier 1 method:

$$\text{CO}_2 \text{ emissions 3G} = (\text{limestone use} \times \text{EF CO}_2 \text{ limestone} + \text{dolomite use} \times \text{EF CO}_2 \text{ dolomite}) \times 44/12 \quad (15.1)$$

Where:

CO₂ emissions 3G : Carbon dioxide emissions (kg CO₂/year) from CRF Source Category 3G (Liming)

EF CO₂ limestone : Emission factor (kg CO₂-C/kg applied) for limestone

EF CO₂ dolomite : Emission factor (kg CO₂-C/kg applied) for dolomite
44/12 : Conversion factor from CO₂-C to CO₂

15.2.2 Activity data

Information on the amount of carbonate applied to soil originates from Wageningen Economic Research. Input on the use of carbonate comes from industrial processing records and import/export data from retailers of lime fertilizers. Beginning with 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 CO₂, 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 CO₂-C/kg limestone and 0.13 kg CO₂-C/kg dolomite). These values translate to 440 kg CO₂/ton pure limestone and 477 kg CO₂/ton pure dolomite.

15.2.4 Uncertainty

The uncertainty value for the use of limestone is 36.9%, and the uncertainty value for the use of dolomite is 34.0% (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 CO₂.

15.3 Uncertainty estimates

The uncertainty values for liming, implied emission factors and resulting CO₂ emissions are presented in Table 15.1.

Table 15.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and CO₂ emissions (U emissions) from liming

IPCC	Source category	U AD	U IEF	U emissions
	Limestone	37%	1%	37%
	Dolomite	34%	1%	34%
3G	Liming			25%

16 CO₂ emissions from urea application (CRF category 3H)

16.1 Scope and definition

Urea is applied to soils as an artificial nitrogen fertilizer. During and after the application, CO₂ 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 CO₂. The CO₂ 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 CO₂ from the atmosphere. However, the IPCC guidelines stipulate that the CO₂ emission should be allocated to the agriculture sector (IPCC, 2006).

16.2 Source-specific aspects

16.2.1 Calculation method

Emissions of CO₂ resulting from the application of urea are determined for reporting in Table 3H of the CRF. The CO₂ emissions can be calculated according to the following Tier 1 method:

$$\text{CO}_2 \text{ emissions 3H} = M_{\text{urea}} \times \text{EF CO}_2 \text{ urea} \times 44/12 \quad (16.1)$$

Where:

CO₂ emissions 3H : Carbon dioxide emissions (kg CO₂/year) from CRF source category 3H (Urea application)

M_{urea} : Mass of urea (kg)

EF CO₂ urea : Emission factor (kg CO₂-C/kg applied) for urea

44/12 : Conversion factor from CO₂-C to CO₂

16.2.2 Activity data

Usage figures of urea are taken from the synthetic fertilizer statistics available from Wageningen Economic Research. Since 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). However, due to time constraints it could not be verified that the amount of urea is also consistent throughout the time series. This will be amended in the NIR of 2022 and the next methodology report.

16.2.3 Emission factors

IPCC 2006 Tier 1 default values are used for the application of urea (i.e. 0.2 kg CO₂-C/kg limestone). These values translate to 440 kg CO₂/ton pure limestone and 477 kg CO₂/ton pure dolomite.

16.2.4 Uncertainty

The uncertainty value for the use of inorganic fertilizer in agriculture is 26.6%. 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 CO₂.

16.3 Uncertainty estimates

The uncertainty values for urea application, implied emission factors and resulting CO₂ emissions are presented in Table 16.1.

Table 16.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and CO₂ emissions (U emissions) from urea application

IPCC	Source category	U AD	U IEF	U emissions
3H	Urea application	27%	1%	27%

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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 1990-2019 period, as reported in the National Inventory Report 2021 (NIR; for greenhouse gases) and Informative Inventory Report 2021 (IIR; for air pollutants). With these annual reports, the Netherlands fulfils the reporting requirements of the Kyoto 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 2019 (air pollutants). The draft report was reviewed and approved by Peter Zijlema and Harry Vreuls (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 NH₃ 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 NH₃ emission. Therefore, the current aim is to estimate NH₃ 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 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 ratios 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).

A1.5 References

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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.	Weight 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 in 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

A.3 References

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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

Feed type	Reference year			2005	
	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 compositions 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 Uptake	1998			2005				
	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 from 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 farm 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

Feed type	Reference year			2005	
	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

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Annex 4 Mineralization and immobilization 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, CH₄ and CO₂ and depending on the composition of the manure, also NH₄⁺ are formed (mineralization). In manure containing straw (high C/N ratio) part of the NH₄⁺ will be fixed (immobilized) as organic N.

The method to calculate NH₃ 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 mineralization and immobilization of ammonium in manure storages. This is mainly because these processes are hard to determine through a balance method in manure from which also NH₃ is emitted. Another possibility to determine mineralization is the use of ¹⁵N 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 mineralization 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 mineralization increased strongly at increasing temperature. About 80% of the organic N was mineralized at 15-20 °C for 100-200 days. Mineralization was higher in pig manure than in cattle manure.

In an incubation study of Sørensen *et al.* (2003), mineralization 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 mineralization 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 of 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 ¹⁵N labelled urea was added (Beline *et al.*, 1998) the N mineralization was 19% of the organic N during 84 days at 20 °C. The manure was collected from a farm and 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 mineralization 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, mineralization 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 mineralization in the animal houses is calculated and not in the outside storage. Also in the outside storage mineralization 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% immobilization is assumed. In poultry manure, both solid and slurry, and slurry manure of other animals (rabbits and fur-bearing animals) no mineralization or immobilization takes place. It is recommended to conduct further research into (net) mineralization in cattle and pig slurry, since this has an effect on calculated NH₃ emissions from the animal house, manure storage and manure application.

A4.2 References

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- Velthof, G.L., J.A. Nelemans, O. Oenema & P.J. Kuikman, 2005. Gaseous nitrogen and carbon losses from pig manure derived from different diets. *Journal of Environmental Quality* 34, p. 698 – 706.

Annex 5 Emission factors for NH₃ from animal housing of cattle

In this annex the emission factors in kg NH₃ 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 pasture land. 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 NH₃ 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 procentual emission reduction then is:

$$2.61\% \times (\text{number of grazing hours per day}) \times (\text{number of grazing days}) / 365 \quad (\text{A5.1})$$

Based on the reference value of 13.0 kg NH₃ 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 not 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 NH₃ emission of dairy cattle housings an increase in emission per animal place from 11.0 kg NH₃ in 2001 to 13.0 kg in the measurement period 2007-2012 is assumed.

Table A5.1 Emission factors for traditional dairy housing (kg NH₃/animal place), 2007-2015

	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⁾
Traditional dairy housing/cubicle system						
Grazing system						
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) $2.61\% * B \times (A/365) \times (13.0 \text{ kg NH}_3)$.

4) $(A/365) \times (13.0 \text{ kg NH}_3) - C$.

5) $((365-A)/365) \times (13.0 \text{ kg NH}_3)$.

6) D + E.

For the emission year 2016 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 NH₃/animal for limited and unlimited grazing respectively.

The emission factors for low-emission housing systems (low emission techniques in a traditional housing setup) are adjusted based on the proportion between the new and old factor for traditional housing according to Ogink *et al.* (2014). In continuously indoors this means multiplication with factor 13.0/11.0 and in limited grazing multiplication with factor 11.74/9.5.

The average emission factor for low emission cubicle housing is derived from information in environmental permits (Van Bruggen *et al.*, 2011 p. 25 and Van Bruggen *et al.*, 2013 annex 1). The new year round emission factor for low-emission housing with limited grazing then becomes: $(11.74/9.5) \times 7.5 = 9.27$ and for continuously indoors: $(13.0/11.0) \times 8.8 = 10.40$. In Van Bruggen *et al.* (2011) the year round emission factor is divided over winter and grazing period based on the proportion between winter and grazing period in traditional housing with limited grazing. This means that in low emission cubicle housing 5.5 kg NH₃ is emitted during the winter period: $(6.98/11.74) \times 9.27$. For low emission cubicle housing with unlimited grazing no year round emission can be calculated based on environmental permits and is therefore not considered.

In Table A5.2 an overview is given of the emission factors for low-emission housing of dairy cattle. Compared to Van Bruggen *et al.* (2014) the emission factor of tie-stall housing has also been adjusted in the way proposed by Ogink *et al.* (2014): $4.3 \times (13.0/11.0)$.

Table A5.2 Emission factors for low emission dairy housing (kg NH₃/animal place), 2011-2014

	Winter period (kg NH ₃)	Grazing period(kg NH ₃)	Year-round (kg NH ₃)
Low emission cubicle housing			
Grazing system			
continuously indoors	5.51	4.89	10.40
limited grazing	5.51	3.76	9.27
Tie-stall with slurry	3.02	2.06	5.08

For the emission years 2015, 2016 and 2017, information from the Agricultural census on low emission cubicle housing was available. With continuously indoors year-round emission was 10.02, 9.22 respectively 9.18 kg NH₃/animal and limited grazing was calculated to be 9.05 for 2015 and 8.44 kg NH₃/animal in 2016 and 2017.

The emission factors in Tables A5.1 and A5.2 are converted into emission factors in percentage of the TAN excretion in the winter and grazing periods using the method described in section 5.2.

A5.2 Other cattle excluding veal calves

Ogink *et al.* (2014) propose to calculate NH₃ emission factors per animal place for other cattle categories with the formula:

$$\frac{(\text{TAN excretion in the animal house of livestock category})}{(\text{TAN excretion in the animal house dairy cattle})} \times 13.0 \quad (\text{A5.2})$$

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% mineralization of organic N. Ogink *et al.* (2014) however do not consider the 10% mineralization 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% mineralization of organic N.

In the calculation of the NH₃ emission of dairy cattle housings an increase in emission per animal place from 11.0 kg NH₃ 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 this means that for other cattle a comparable development has taken place in which the emission has increased over time.

In Table A5.3 the calculation of the emission factors is presented.

Table A5.3 Emission factors NH₃-N for other cattle categories in % of TAN excretion (including 10% net mineralization)

	1990-2001	2002	2003	2004	2005	2006	from 2007 on
Emission factor compared to TAN excretion	11.03	11.57	12.11	12.65	13.19	13.73	14.27

For the different cattle categories is based on the TAN excretion in the 2007-2012 period and the emission factors in Table A5.3, the subsequent emission calculated in kg NH₃ per animal place. This calculated emission is compared to the emission factor in the Rav.

Table A5.4 Emission factors NH₃-N for other cattle categories in % of TAN excretion (including 10% net mineralization)

	1990-2001	2002	2003	2004	2005	2006	2007-2015	2016-2017
	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
Female young stock - regular	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.3
Female young stock – low emission	1.5	1.5	1.6	1.7	1.8	1.8	1.9	1.8
Suckling-, fattening- and grazing cows	3.4	3.5	3.7	3.9	4.0	4.2	4.4	4.4
Bulls for service including male young stock	7.5	7.9	8.3	8.7	9.0	9.4	9.8	9.8
Meat bulls 1 year and over	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.2

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 NH₃ 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 NH₃/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 NH₃ 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 NH₃-N compared to the TAN excretion of white veal calves, including 10% mineralization of organic N, amounts to 28.2% in the reference year 1998. As a result of the higher TAN excretion in the new reference year 2012 belonging to the new emission factor per animal place the emission factor increases to 28.6%.

For rosé veal calves the emission factor compared to the TAN excretion, including 10% mineralization of organic N, is 13.2% in the reference year 1998. The revised emission of 3.7 kg NH₃ per animal place yields an emission factor of 22.9% 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 NH₃ to 3.1 kg NH₃ and for rosé veal calves an increase from 2.5 to 3.7 kg NH₃ 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 28.2 to 28.6% and for rosé veal calves a gradual increase from 13.2 to 22.9%.

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 emission factor for low-emission housing was previously established to be 0.60 kg NH₃ per animal place based on the shares of various types of air scrubbers in the environmental permits of provinces. This meant an average emission reduction of 76% compared to the regular emission factor of 2.5 kg NH₃ per animal place. With the same percentage reduction the emission factor for low-emission housing in white veal calves becomes $0.24 \times 3.1 = 0.74$ kg NH₃ per animal place and in rosé veal calves $0.24 \times 3.7 = 0.89$ kg NH₃ per animal place. Based on information from the Agricultural census, emission factors of 0.47 for 2015, 0.34 for 2016 and 0.37 kg NH₃/animal for 2017 were used for white veal calves. In rosé veal, emission factors were 0.56, 0.41 and 0.44 kg NH₃/animal for 2015, 2016 and 2017, respectively.

A5.4 References

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Annex 6 Emission factors for NH₃ from animal housing of pigs

In this annex the emission factors in kg NH₃ 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 NH₃ per animal place)

	kg NH₃ 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 Emission factors for reduced emission housing of sows with piglets (kg NH₃ per animal place)

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ /animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
<i>Air scrubbers</i>									
Biological air scrubber system 70% emission reduction	2.5		0.25	0.16	0.11	0.09			
Chemical air scrubber system 70% emission reduction	2.5		0.37	0.42	0.28	0.20			
Chemical air scrubber system 95% emission reduction	0.42		0.38	0.33	0.30	0.26			
Combined air scrubber system 85% emission reduction chemical and water washer	1.3		-	0.06	0.18	0.17			
Combined air scrubber system 70% emission reduction chemical and water washer, biofilter	2.5		-	0.00	0.01	0.01			
Combined air scrubber system 85% emission reduction chemical and water washer, biofilter	1.3		-	0.02	0.03	0.03			
Combined air scrubber system 85% emission reduction with water curtain and biological washer	1.3		-	-	0.10	0.24			
Average emission factor (kg NH₃/animal place)		N/A	1.7	1.9	2.2	2.4	2.5	2.5	2.4
<i>Floor/slurry pit adjustment</i>									
Rinsing gully system, rinsing with slurry	3.3		0.06	0.05	0.05	0.05			
Level coated pit floor with rack and pinion shove system	4.0		0.03	0.01	0.01	0.00			
Manure shove with coated sloping pit floor and urine gully	3.1		0.03	0.02	0.01	0.01			
Manure gully with manure discharge system	3.2		0.06	0.05	0.04	0.03			
Shallow slurry pits with manure and water canal	4.0		0.35	0.24	0.22	0.22			
Shovels in manure gully	2.5		0.05	0.04	0.02	0.02			

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
Cool deck system	2.4		0.12	0.10	0.09	0.08			
Manure pan/- box under farrowing pen	2.9		0.06	0.06	0.08	0.08			
Manure pan with water and manure canal under farrowing pen	2.9		0.16	0.19	0.18	0.16			
Water canal combined with separate manure canal or manure box	2.9		0.08	0.22	0.30	0.33			
Average emission factor (kg NH₃/animal place)		4.15	3.3	3.2	3.1	3.1	3.2	3.2	3.4

1) The emission reduction in this period is set to 50% compared to traditional housing (Van der Hoek, 2002).

2) Source: environmental permits in the province Noord-Brabant on 01-01-2005.

3) Source: environmental permits in the province Noord-Brabant on 01-01-2009.

4) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.

5) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

6) Source: agricultural census 2016.

7) Source: agricultural census 2017.

8) Source: agricultural census 2018.

Table A6.3 Emission factors for reduced emission housing of open and sows in pig (kg NH₃ per animal place)

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
<i>Air scrubbers</i>									
Biological air scrubber system 70% emission reduction	1.3		0.22	0.15	0.11	0.09			
Chemical air scrubber system 70% emission reduction	1.3		0.42	0.45	0.29	0.22			
Chemical air scrubber system 95% emission reduction	0.21		0.38	0.33	0.31	0.29			
Combined air scrubber system 85% emission reduction chemical and water washer	0.63		-	0.05	0.13	0.12			
Combined air scrubber system 70% emission reduction with water washer, chemical washer and biofilter	1.3		-	-	0.01	0.01			
Combined air scrubber system 85% emission reduction chemical and water washer, biofilter	0.63		-	0.01	0.03	0.03			
Combined air scrubber system 85% emission reduction water curtain and biological washer	0.63		-	0.00	0.11	0.23			
Average emission factor (kg NH₃/animal place)		N/A	0.90	1.00	1.10	1.10	1.20	1.20	1.20
<i>Floor/slurry pit adjustment</i>									
Narrow shallow manure canals with metal three sided grates and sewerage (individual housing)	2.4		0.28	0.24	0.25	-			
Manure gully with combined grates and frequent manure disposal (individual housing)	1.8		0.06	0.05	0.04	-			
Rinsing gully system with slurry (individual and group)	2.5		0.14	0.09	0.09	0.12			
Shovels in manure gully (individual housing)	2.2		0.02	0.01	0.01	-			
Cool deck system 115% cooling surface (individual and group)	2.2		0.12	0.08	0.07	0.10			
Cool deck system 135% cooling surface (individual and group)	2.2		0.12	0.14	0.11	0.15			

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
Group housing with feeding cubicles or feeding stations, without straw bed, tilting pit walls, metal three sided grate	2.3		0.12	0.20	0.17	0.22			
Group housing with feeding cubicles or feeding stations, without straw bed, tilting pit walls, other material grate	2.5			0.02	0.06	0.12			
Walk about housing with sow feeding station and straw bed (group)	2.6		0.14	0.15	0.20	0.28			
Average emission factor (kg NH₃/animal place)		2.1	2.3	2.3	2.4	2.4	2.6	2.4	2.4

1) The emission reduction in this period is set to 50% compared to traditional housing (Van der Hoek, 2002).

2) Source: environmental permits in province Noord-Brabant on 01-01-2005.

3) Source: environmental permits in province Noord-Brabant on 01-01-2009.

4) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.

5) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

6) Source: agricultural census 2016.

7) Source: agricultural census 2017.

8) Source: agricultural census 2018.

Table A6.4 Emission factors for reduced emission housing of weaned piglets (kg NH₃ per animal place)

	EF	1997- 2004 ¹⁾	2005- 2006 ²⁾	2007- 2010 ³⁾	2011- 2012 ⁴⁾	2013- 2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
<i>Air scrubbers</i>									
Biological air scrubber system 70% emission reduction	0.18		0.23	0.14	0.10	0.08			
Chemical air scrubber system 70% emission reduction	0.18		0.38	0.38	0.23	0.17			
Chemical air scrubber system 95% emission reduction	0.03		0.39	0.39	0.28	0.22			
Combined air scrubber system 85% emission reduction chemical and water washer	0.09		-	0.06	0.19	0.16			
Combined air scrubber system 70% emission reduction with water washer, chemical washer and biofilter	0.18		-	0.01	0.02	0.02			
Combined air scrubber system 85% emission reduction with water washer, chemical washer and biofilter	0.09		-	0.02	0.04	0.03			
Combined air scrubber system 85% emission reduction water curtain and biological washer	0.09		-	0.00	0.14	0.30			
Various combinations of low emission built housing with air scrubbers	ca. 0.03		-	-	0.01	0.01			
Average emission factor (kg NH₃/animal place)		N/A	0.12	0.13	0.15	0.18	0.18	0.18	0.18
<i>Floor/slurry pit adjustment</i>									
Level coated pit floor with rack and pinion shove system	0.18		0.01	0.01	0.02	0.02			
Rinsing gully system with slurry and partly slatted floor	0.21		0.07	0.05	0.03	0.03			
Manure capture in water combined with a manure disposal system	0.13		0.40	0.46	0.50	0.50			
Shallow slurry pits with water and manure channel of max. 0.13 m ² per animal place	0.26		0.09	0.07	0.08	0.08			

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
Shallow slurry pits with water and manure channel of max. 0.19 m ² per animal place	0.33		0.01	0.00	0.01	0.01			
Half grate with decreased manure surface	0.34		0.01	0.01	0.01	0.01			
Manure collection in and rinsing with acidified liquid fully slatted floor	0.16		0.02	0.01	0.01	0.00			
Manure collection in and rinsing with acidified liquid partly slatted floor	0.22		0.01	0.00	0.00	0.00			
Separated discharge manure and urine through tilting manure belt	0.20		0.01	0.00	0.00	0.00			
Cool deck system (150% cooling surface)	0.15		0.12	0.09	0.08	0.09			
Rearing pen with tilting pit wall max. 0.07 m ² emitting surface, regardless of group size	0.17		0.01	0.02	0.03	0.03			
Rearing pen with tilting pit wall > 0.07 m ² < 0.10 m ² emitting surface, up to 30 piglets	0.21		0.01	0.02	0.04	0.07			
Rearing pen with tilting pit wall > 0.35 m ² emitting surface > 0.07 m ² < 0.10 m ² , from 30 piglets on	0.18		0.12	0.15	0.11	0.10			
Fully slatted with water and manure canals eventually with tilted pit wall, emitting surface < 0.10 m ²	0.20		0.13	0.09	0.09	0.09			
Average emission factor (kg NH₃/animal place)		0.30	0.17	0.17	0.17	0.17	0.18	0.18	0.18

1) The emission reduction in this period is set to 50% compared to traditional housing (Van der Hoek, 2002).

2) Source: environmental permits in province Noord-Brabant on 01-01-2005.

3) Source: environmental permits in province Noord-Brabant on 01-01-2009.

4) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.

5) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

6) Source: agricultural census 2016.

7) Source: agricultural census 2017.

8) Source: agricultural census 2018.

Table A6.5 Emission factors for reduced emission housing of fattening pigs and young breeding pigs (kg NH₃ per animal place)

EF	1997-2004 ¹⁾		2005-2006 ²⁾		2007-2010 ³⁾		2011-2012 ⁴⁾		2013-2014 ⁵⁾		2015 ⁶⁾		2016 ⁷⁾		2017 ⁸⁾		
kg NH ₃ /animal place	Fraction (fr.)		fr.		fr.		fr.		fr.		fr.		fr.		fr.		
	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	
<i>Air scrubbers</i>																	
Biological air scrubber system 70% emission reduction	1.0	1.2		0.22	0.12	0.10	0.10										
Chemical air scrubber system 70% emission reduction	1.0	1.2		0.40	0.40	0.25	0.19										
Chemical air scrubber system 95% emission reduction	0.17	0.20		0.38	0.40	0.30	0.28										
Air scrubber, other than biological or chemical	0.51	0.60		-	0.08	0.34	0.42										
Various combinations of low emission built animal houses with air scrubbers	ca. 0.3	ca. 0.3		-	-	0.00	0.01										
Average emission factor (kg NH₃/animal place)		N/A	N/A	0.70	0.82	0.70	0.83	0.88	1.00	0.95	1.10	0.96	1.10	0.96	1.10	0.97	1.10

	EF	1997-2004 ¹⁾		2005-2006 ²⁾		2007-2010 ³⁾		2011-2012 ⁴⁾		2013-2014 ⁵⁾		2015 ⁶⁾		2016 ⁷⁾		2017 ⁸⁾		
	kg NH ₃ /animal place	Fraction (fr.)		fr.		fr.		fr.		fr.		fr.		fr.		fr.		
	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²
<i>Floor/slurry pit adjustment</i>																		
Manure collection in and rinsing with NH ₃ poor liquid	1.8	2.1			0.10	0.05			0.03	0.02								
Cool deck system 170% and metal three sided grate floor	1.9	2.3			0.13	0.08			0.04	0.03								
Manure collection in formaldehyde-liquid manure solution and metal three sided grate	1.1	1.3			0.04	0.04			0.01	0.01								
Manure collection in water and metal three sided grate	1.5	1.8			0.01	0.01			0.01	0.01								
Cool deck system 200% and metal grate, emitting surface max. 0.8 m ²	1.7	2.0			0.14	0.11			0.07	0.07								
Cool deck system 200% and metal grate,	1.4	1.6			0.00	0.00			0.00	0.00								

	EF	1997-2004 ¹⁾		2005-2006 ²⁾		2007-2010 ³⁾		2011-2012 ⁴⁾		2013-2014 ⁵⁾		2015 ⁶⁾		2016 ⁷⁾		2017 ⁸⁾		
	kg NH ₃ /animal place	Fraction (fr.)		fr.		fr.		fr.		fr.		fr.		fr.		fr.		
	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²
emitting surface max. 0.5 m ²																		
Cool deck system 200% and other than metal grate, emitting surface max. 0.6 m ²	1.8	2.1			0.04	0.05			0.04	0.03								
Cool deck system 200% and other than metal grate, 0.6 m ² < emitting surface < 0.8 m ²	2.7	3.1			0.00	0.00			0.00	0.00								
Water-manure channel, tilting pit wall, metal three sided grate, emitting surface max. 0.18 m ²	1.2	1.2			0.20	0.17			0.24	0.24								
Water-manure channel, tilting pit wall, metal three sided grate, 0.18 m ² < emitting surface < 0.27 m ²	1.7	1.7			0.02	0.03			0.06	0.07								
Water-manure channel, tilting	1.9	1.9			0.15	0.34			0.37	0.40								

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ / animal place	Fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²	0.8 m ² 1.0 m ²
pit wall, grate other than metal, emitting surface max. 0.18 m ²									
Water-manure channel, tilting pit wall, grate other than metal, 0,18 m ² < emitting surface < 0.27 m ²	2.3	2.3		0.04	0.03	0.03	0.04		
Spherical floor pen with concrete spill grate and metal three sided grate	1.7	2.3		0.02	0.02	0.02	0.02		
Pen with separate manure channels	2.1	2.1		0.01	0.01	0.01	0.01		
Rinsing gully system with metal three sided grates	1.4	1.6		0.03	0.02	0.02	0.02		
Rinsing gully system with other than three sided grates	2.0	2.3		0.07	0.06	0.04	0.04		

	EF	1997-2004 ¹⁾		2005-2006 ²⁾		2007-2010 ³⁾		2011-2012 ⁴⁾		2013-2014 ⁵⁾		2015 ⁶⁾		2016 ⁷⁾		2017 ⁸⁾	
	kg NH ₃ /animal place	Fraction (fr.)		fr.		fr.		fr.		fr.		fr.		fr.		fr.	
		0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²	0.8 m ²	1.0 m ²
Floating balls in the manure	ca. 3.3	ca. 4.0		-	-			0.00	0.01								
Average emission factor (kg NH₃/animal place)		2.1	N/A	1.7	1.9	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8	1.7	1.8

1) The emission reduction in this period is set to 50% compared to traditional housing (Van der Hoek, 2002).

2) Source: environmental permits in province Noord-Brabant on 01-01-2005.

3) Source: environmental permits in province Noord-Brabant on 01-01-2009.

4) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.

5) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

6) Source: agricultural census 2016.

7) Source: agricultural census 2017.

8) Source: agricultural census 2018.

Table A6.6 Emission factors for reduced emission housing of boars (kg NH₃ per animal place)

	EF	1997-2004 ¹⁾	2005-2006 ²⁾	2007-2010 ³⁾	2011-2012 ⁴⁾	2013-2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ /animal place	Fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
<i>Air scrubbers</i>									
Biological air scrubber system 70% emission reduction		1.7		0.22	0.16	0.08	0.07		
Chemical air scrubber system 70% emission reduction		1.7		0.47	0.50	0.48	0.27		
Chemical air scrubber system 95% emission reduction		0.28		0.31	0.26	0.19	0.22		
Combined air scrubber system 85% emission reduction chemical and water		0.83		-	0.05	0.15	0.15		

	EF	1997- 2004 ¹⁾	2005- 2006 ²⁾	2007- 2010 ³⁾	2011- 2012 ⁴⁾	2013- 2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
	kg NH ₃ /anim al place	Fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.
washer									
Combined air scrubber system 70% emission reduction with water washer, chemical washer and biofilter	1.7		-	0.01	0.02	0.02			
Combined air scrubber system 85% emission reduction with water washer, chemical washer and biofilter	0.83		-	0.01	0.02	0.01			
Combined air scrubber system 85% emission reduction water curtain and biological washer	0.83		-	-	0.06	0.26			
Average emission factor (kg NH₃/animal place)		1.65	1.3	1.4	1.6	1.6	1.6	1.6	1.6
<i>Floor/slurry pit adjustment through floating balls in the manure</i>	3.9								

- 1) The emission reduction (air scrubber) in this period is set to 70% compared to traditional housing (Van der Hoek, 2002).
- 2) Source: environmental permits in province Noord-Brabant on 01-01-2005.
- 3) Source: environmental permits in province Noord-Brabant on 01-01-2009.
- 4) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
- 5) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.
- 6) Source: agricultural census 2016.
- 7) Source: agricultural census 2017.
- 8) Source: agricultural census 2018.

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Annex 7 Emission factors for NH₃ from animal housing of poultry

In this annex the emission factors in kg NH₃ 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 depicted according to the classification of the Agricultural census. For some systems that comprise of several subsystems an emission factor is derived using information in environmental permits.

To the battery cage systems with slurry and manure belt also the compact battery is counted with an emission factor of 0.011 kg NH₃/animal place. The share of this system in environmental permits is negligibly small with 0.1%.

Table A7.1 (Derived) emission factors for laying hens under 18 weeks (kg NH₃ per animal place)

	1990-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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	0.020	0.020	0.020	0.020	0.020	0.020
Manure belt, forced manure drying 0.4 m ³ /animal/hour	0.006	0.006	0.006	0.006	0.006	0.006
Manure belt, forced manure drying 0.4 m ³ /animal/hour with air scrubber	0.001	0.001	0.001	0.001	0.001	0.001
Other battery cage solid manure	0.020	0.020	0.020	0.016	0.016	0.016
Ground housing without manure aeration						
Ground housing with air scrubber	-	-	-	0.035	0.042	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	0.030	0.029	0.028	0.028	0.028	0.030
Ground/aviary housing with	0.017	0.009	0.011	-	-	-

	1990-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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
air scrubber						
Other housing	0.139	0.157	0.094	0.106	0.108	0.109

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.

4) Source: agricultural census 2016.

5) Source: agricultural census 2017.

6) Source: agricultural census 2018.

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 m³ per hour is applied as minimal value.

The emission factor in the Rav applies to situations in which the manure is disposed of from the business immediately or stored for a maximum of two weeks in a covered container. In other cases an additional emission factor for post-processing techniques like after drying or other storage applies. The emission factor for the post-processing technique is to be added to the emission factor of the animal housing type. For rearing hens from the environmental permits an average additional emission factor for after drying of 0.005 kg NH₃ is derived. Although in animals with ground housing in the Agricultural census in some cases a post-processing technique is applied, this is not accounted for. The Rav does not provide an additional emission factor for post-processing techniques in ground housing.

A7.2 Laying hens

In Table A7.2 the housing systems are depicted according to the classification of the Agricultural census. For some systems that consist of several subsystems an emission factor is derived using information in environmental permits.

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 m³/hour) by businesses.

To the other battery cage systems with solid manure belong the canal 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 m³ per hour is applied as minimal value.

In Table A7.2 also the emission factors for systems consisting of several variations are derived. Air scrubbers hardly occur and are not considered further.

The emission factor in the Rav applies to situations in which the manure is disposed of immediately from the business or is stored for a period of at most two weeks in a covered container. In other cases an additional emission factor for post-processing techniques like after drying or other storage applies. The emission factor of the post-processing technique is to be added to the emission factor of the animal housing type. Based on information in environmental permits the average additional emission factor for after drying is 0.010 kg NH₃ up to 2010 and for the years after 0.008 kg NH₃ per animal place.

Table A7.2 (Derived) emission factors for laying hens (kg NH₃ per animal place)

	1990-2000	2001-2007	2008-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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
Battery cage with slurry								
Open storage	0.083	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Manure belt	0.035	0.042	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	0.035	0.042	0.042	0.042	0.042	0.042	0.042	0.042
Manure belt, forced manure drying 0.7 m ³ /animal/hour	0.010	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Manure belt, forced manure drying 0.7 m ³ /animal/hour with air scrubber	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Other battery cage solid manure	0.035	0.042	0.042	0.042	0.042	0.031	0.032	0.034
Ground housing								
Ground housing without manure aeration (including 0.1% with air scrubber)	0.315	0.315	0.402	0.402	0.402	0.402	0.402	0.402
Perfo system	0.110	0.110	0.140	0.140	0.140	0.140	0.140	0.140
Manure aeration	0.125	0.125	0.160	0.160	0.160	0.170	0.170	0.171
Manure belts	0.068	0.068	0.087	0.091	0.092	0.098	0.101	0.102
Aviary housing								
Aviary housing without forced manure drying	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
Aviary housing with forced manure drying	0.052	0.052	0.052	0.050	0.050	0.046	0.045	0.045
Aviary housing with after drying	0.100	0.100	0.100	0.098	0.098	0.109	0.110	0.112
Aviary housing with forced manure drying and after drying	0.062	0.062	0.062	0.058	0.058	0.059	0.061	0.060
Other housing	0.290	0.290	0.370	0.295	0.101	-	-	-

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.

4) Source: agricultural census 2016.

5) Source: agricultural census 2017.

6) Source: agricultural census 2018.

A7.3 Broiler breeders to circa 19 weeks

In Table A7.3 the animal housing systems are depicted according to the classification in the Agricultural census. For some systems that consist of several subsystems an emission factor is derived using information in environmental permits.

In Table A7.3 also the emission factors for other low-emission housing are presented.

Table A7.3 Emission factors for broiler breeders under 19 weeks (kg NH₃ per animal place)

	1990-2010	2011-2012 ¹⁾	2013-2014 ²⁾	2015 ³⁾	2016 ⁴⁾	2017 ⁵⁾
	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
Air scrubber/biofilter	-	0.012	0.012	0.016	0.016	0.016
Other low-emission housing	-	0.057	0.052	0.050	0.048	0.048

1) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.

2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

3) Source: agricultural census 2016.

4) Source: agricultural census 2017.

5) Source: agricultural census 2018.

A7.4 Broiler breeders

In Table A7.4 the housing systems are depicted according to the classification of the Agricultural census. For some systems consisting of several subsystems an emission factor is derived using information in environmental permits.

In Table A7.4 also emission factors for systems consisting of several variations are derived.

Table A7.4 Derived emission factors for broiler breeders (kg NH₃ per animal place)

	1990-2007	2008-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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	0.580	0.456	0.456	0.456	0.456	0.456	0.456
Enriched cage/group cage	0.080	0.063	0.063	0.063	0.063	0.063	0.063
Aviary housing with forced manure drying	0.170	0.134	0.131	0.127	0.127	0.128	0.129
Ground housing with manure aeration from above	0.250	0.196	0.196	0.196	0.196	0.196	0.196
Ground housing with vertical hoses in the manure or through tubes	0.435	0.342	0.342	0.342	0.342	0.342	0.342

	1990-2007	2008-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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
underneath the bin							
Perfo system	0.230	0.181	0.181	0.181	0.181	0.181	0.181
Air scrubber systems	0.080	0.080	0.113	0.111	0.056	0.046	0.046
Ground housing with manure belts without after drying	0.245	0.192	0.192	0.192	0.192	0.192	0.192
Ground housing with manure belts with after drying	0.255	0.202	0.200	0.200	0.242	0.205	0.205

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.

4) Source: agricultural census 2016.

5) Source: agricultural census 2017.

6) Source: agricultural census 2018.

The emission factor in the Rav applies to situations in which the manure is removed from the farm directly or stored for a period of no more than two weeks in a covered container. In the remaining cases an additional emission factor for post-processing techniques like after drying or other storage applies. The emission factor of the post-processing technique has to be added to the emission factor of the housing type. Based on the information in environmental permits the average additional emission factor for after drying amounts to 0.010 kg NH₃ up to 2010 and in the years after 0.008 kg NH₃ per animal place.

A7.5 Broilers

In Table A7.5 the housing systems are depicted according to the classification of the Agricultural census. For some systems consisting of several subsystems an emission factor is derived using information in environmental permits.

In Table A7.5 also emission factors for systems consisting of several variations are derived.

Table A7.5 (Derived) emission factors for broilers (kg NH₃ per animal place)

	1990-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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
Floor with litter drying	0.008	0.009	0.009	0.005	0.006	0.006
Storey systems	0.011	0.012	0.011	0.029	0.024	0.026
Air scrubber systems	0.008	0.010	0.010	0.010	0.010	0.010
Ground housing with floor heating and cooling	0.038	0.038	0.038	0.038	0.038	0.038
Mixed air ventilation, warmth heaters and fans, air blending	0.031	0.032	0.031	0.030	0.021	0.020

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.

4) Source: agricultural census 2016.

5) Source: agricultural census 2017.

6) Source: agricultural census 2018.

A7.6 Ducks for slaughter

In ducks for slaughter only traditional housing occurs with an emission factor of 0.210 kg NH₃ per animal place.

A7.7 Turkeys for slaughter

In Table A7.6 the housing systems are presented according to the classification of the Agricultural census. For some systems consisting of several subsystems an emission factor is derived using information of environmental permits.

In Table A7.6 also emission factors for systems consisting of several variations are derived.

Table A7.6 (Derived) emission factors for turkeys (kg NH₃ per animal place)

	1990-2007	2008-2010 ¹⁾	2011-2012 ²⁾	2013-2014 ³⁾	2015 ⁴⁾	2016 ⁵⁾	2017 ⁶⁾
	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	0.932	0.932	0.932	0.932	0.932	0.932
Low-emission housing	0.493	0.493	0.411	0.404	0.383	0.374	0.368

1) Source: environmental permits in province Noord-Brabant on 01-01-2009.

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.

4) Source: agricultural census 2016.

5) Source: agricultural census 2017.

6) Source: agricultural census 2018.

Annex 8 Animal house occupancy fractions

To convert emissions from animal housings in kg NH₃ per animal place to an emission factor in kg NH₃ per animal, the animal house occupancy fractions are needed. For instance an emission of 10.0 kg NH₃ per animal place at an occupancy fraction of 0.9 yields an emission of $10.0 / 0.9 = 11.1$ kg NH₃ 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
	2002-2017	2007-2012	1.0
Other cattle excluding meat calves	1990-2017	2007-2012	1.0
Meat calves, for white veal production	1990-1998	1998	0.93
	1999-2017	2012	0.93
Meat calves, for rosé meat production	1990-1998	1998	0.93
	1999-2017	2012	0.96
Female sheep	1990-2017	1991	1.0
Milk goats	1990-2017	1998	1.0
Horses, ponies and mules	1990-2017	1997	1.0
Fattening pigs and rearing pigs	1990-2017	2008-2009	0.97
Sows	1990-2017	1994	²⁾
Boars for service	1990-2017	1991	0.9
Broiler breeders < 18 weeks	1990-2017	2008	0.83
	1990-2007	1996	0.87
Broiler breeders ≥ 18 weeks	2008-2017	2008	0.87
	1990-2017	1991	0.9
Laying hens < 18 weeks battery cage slurry, dry manure 0.2 m ³ /h, other battery and other housing	1990-2017	1996	0.9
	1990-2017	2000	0.9
battery cage dry manure 0.4 m ³ /h free range housing without manure aeration and aviary with manure drying	1990-2017	1998	0.9
	1990-2017	1998	0.9
aviary without manure drying with air scrubber	1990-2017	1998	0.9
Laying hens ≥ 18 weeks battery slurry with open	1990-2017	1996	0.95

	Reporting period	Reference year ¹⁾	Animal house occupancy (fraction)
storage, battery dry manure 0.7 m ³ /h and deep pit			
battery slurry 2/week mucking, dry manure 0.5 m ³ /h, other battery	1990-2017	1991	0.95
floor housing and other housing	1990-2007	1996	0.95
	2008-2017	2008	0.95
aviary without manure drying	1990-2017	1996	0.95
aviary manure drying	1990-2017	2001	0.95
Broilers			
traditional, litter drying, storey system with slatted floor and aeration, air scrubber	1990-2017	2002	0.81
ground housing with floor heating and - cooling	1990-2017	1997-1998	0.81
mixed air ventilation	1990-2017	2005	0.81
Ducks	1990-2017	2000	0.84
Turkeys			
traditional	1990-2007	1998	0.95
	2008-2017	2008	0.95
low emission	1990-2017	2008	0.95
Rabbits (mother animals)	1990-2017	1998	1.0
Rabbits for slaughter	1990-2017	1998	0.85
Fur-bearing animals (mother animals)	1990-2017	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 9 Manure storage outside the animal house

Table A9.1 Manure storage outside animal housing (% of produced manure)

	1990-2004 ¹⁾	2005 ²⁾	2006 ²⁾	2007 ²⁾	2008 ²⁾	2009 ²⁾	2010-2011 ³⁾	2012 ³⁾	2013 ⁴⁾	2014 ⁵⁾	2015 ⁶⁾	2016 ⁷⁾	2017 ⁸⁾
Cattle slurry	25	27	27	27	27	27	24	24	23	23	23	23	20
Pig slurry	10	15	15	15	15	15	21	21	19	19	19	19	19
Poultry slurry	15	88	88	88	88	88	100	100	100	100	100	100	100
Slurry of fur-bearing animals	50	50	50	50	50	50	50	50	50	50	50	50	50
Solid manure of grazing animals, pigs and rabbits	100	100	100	100	100	100	100	100	100	100	100	100	100
Solid poultry manure													
deep pit housing	100	100	100	100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
pre-dried belt manure (battery cage and aviary)	100	100	100	100	100	100	100	100	100	100	100	100	100
aviary without post-drying	100	100	100	100	100	100	100	100	100	100	100	100	100
post-dried manure	100	100	100	100	100	100	100	100	100	100	100	100	100
laying poultry – litter manure	100	90	60	40	0	0	0	40	40	45	35	35	40
broiler manure	100	85	65	70	40	35	25	25	30	35	20	25	25
duck manure	100	100	100	100	85	90	95	95	100	85	70	65	75
turkey manure	100	75	5	95	0	0	0	0	0	0	25	30	15

1) Agricultural census 1993.

2) Agricultural census 2007 and registered manure transports.

3) Agricultural census 2010 and registered manure transports.

4) Agricultural census 2014 and registered manure transports.

5) Agricultural census 2015 and registered manure transports.

6) Agricultural census 2016 and registered manure transports.

7) Agricultural census 2017 and registered manure transports.

8) Agricultural census 2018 and registered manure transports.

Table A9.2 Covered manure storages (% of stored manure outside animal housing)

	1990 ¹⁾	1991 ¹⁾	1992-1996 ²⁾	1997-2004 ³⁾	2005-2017 ⁴⁾
Cattle slurry	25	25	67	97	100
Pig slurry	70	75	82	100	100
Poultry slurry					
Open storage	60	70	78	100	100
Manure belt disposal	0	17	78	100	100

1) Van der Hoek (1994).

2) Agricultural census 1993.

3) Van der Hoek (2002).

N.B. Other manure storages are not covered.

Table A9.3 NH₃ emission factors from manure storages outside animal housing (% stored manure)

	1990-2004 ¹⁾		2005-2017 ²⁾
	covered	uncovered	covered
Cattle slurry	0.96	4.80	1.00
Fattening pig slurry	1.66	8.30	2.00
Breeding pig slurry	2.36	11.80	2.00
Manure of fur-bearing animals and rabbits	2.00		2.00
Poultry slurry			
open storage	2.80	14.00	1.00
manure belt disposal	0.90	4.50	1.00
Solid grazing animal manure	0.49	2.45	2.00
Solid pig manure	N/A	N/A	2.00
Solid poultry manure			
deep pit	N/A	4.20	4.20
pre-dried belt manure battery cage housing	N/A	5.30	*
aviary housing	N/A	9.50 ³⁾	*
post-dried manure	N/A	0.00	0.00
laying poultry – litter manure	N/A	3.00	2.50
meat poultry – litter manure	N/A	2.70	2.50
*Pre-dried belt manure and aviary manure			kg NH ₃ per animal place
laying hens < 18 weeks			0.025
laying hens ≥ 18 weeks			0.050
broiler breeders			0.075

1) Van der Hoek (2002).

2) Oenema *et al.* (2000).

3) Hoogeveen *et al.* (2006).

Emission factors for N₂O, NO_x and N₂ from animal housing are usually expressed as percentage of the N excretion (Oenema *et al.*, 2000). Nitrogen emissions as NO_x and N₂O from manure management are described in Sections 6 and 7. For NH₃ the emission factors are based on TAN. In line with the TAN flow, the emission factors for N₂O, NO_x and N₂ have to be converted to percentages of TAN in order to determine the amount of TAN entering outside manure storages. Section 5.2 describes

this conversion along with the emission factors for NH₃ from animal housing.

The emission factor as percentage of the amount of TAN present at the start of the storage period is calculated from the proportion of the total amount of TAN that is excreted and mineralized in the animal house. For all livestock categories (i) and manure management systems (j), following calculations are performed:

$$EF_{NH_3-N \text{ storage}_{ij}} = EF_{NH_3 \text{ storage}_{ij}} \times ((N \text{ excretion}_i - N \text{ losses animal housing}_{ij}) / (TAN \text{ input}_{ij} - N \text{ losses animal housing}_{ij})) \quad (A9.1)$$

Where

EF NH₃-N storage_{ij} : NH₃ emission factor (% of TAN) for outside storages of livestock category (i) and manure management system (j)

EF NH₃ storage_{ij} : NH₃ emission factor (% of N stored) for outside manure storage of livestock category (i) and manure management system (j)

N losses animal housing_{ij}: Sum of NH₃-N, N₂O-N, NO_x-N and N₂-N losses (kg N/year) from animal houses for livestock category (i) and manure management system (j)

Also in manure storages emissions of N₂, N₂O and NO_x occur, but as emission factors for these include both animal housing and manure storage according to the IPCC Guidelines, these are not calculated separately. Emissions from manure storages are therefore included in the EFs described in section 5.3 (equation 5.5).

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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 fertilization 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 N₂O emissions from agricultural soils (including grazing).

Table A10.1 N₂O-N emission factors (% of the N supply) for calculation of direct N₂O emissions from agricultural soils and of N₂O 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 ₂ O-emission factor (%)		Grass land	Arable land	Weighted average all land use and soils	Was previously (1)*	Remarks
<i>Animal manure emission low</i>	All soils			0.9	2 (1.7)	1990: 1.5 2008: 1.9
	Mineral soils	0.3	1.3		Like all soils	
	Peat soils	1	N/A		Like all soils	
<i>Animal manure surface application</i>	All soils			0.4	1 (0.9)	
	Mineral soils	0.1	0.6		1 (0.8)	1990: 0.8 1999: 0.9
	Peat soils	0.5	N/A		2 (1.6)	1990: 1.5 1995: 1.7
<i>Inorganic N fertilizer</i>	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
<i>Grazing</i>	All soils			3.3	1.68 (1.56)	
	Mineral soils	2.5	N/A			
	Peat soils	6.0	N/A			
					1 (0.93) 2 (1.86)	faeces urine

N ₂ O-emission factor (%)		Grass land	Arable land	Weighted average all land use and soils	Was previously (1)*	Remarks
<i>Histosols</i>	Peat soils	**	N/A	**	2	No adjustment
<i>Crop residues</i>	Mineral soils	N/A	**	**	1	No adjustment
<i>Nitrogen fixation</i>	Mineral soils	N/A	**	**	1	No adjustment
<i>Sewage sludge</i>	????				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 N₂O-N emission factors

In 1994 based on laboratory scale experiments country-specific emission factors for the direct N₂O emission from agricultural soils were derived (Kroeze, 1994) for the distinguished sources. The N₂O-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 summarized in a methodology description (Spakman *et al.*, 1997). For surface spreading the country-specific N₂O-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 N₂O-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 N₂O-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 N₂O-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 N₂O emissions for surface spreading and low emission manure application, in which for comparison also the fertilization 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 N₂O-N emission factors than surface spreading.

The emission factors derived based were lower than the emission factors used for both fertilization techniques, and there were differences in the N₂O-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 N₂O 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 fertilization. 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 NH₃ 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 fertilization 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 N₂O emission factors. There is no N₂O emission factor available for fertilization 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 N₂O 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 yearly¹. 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) N₂O 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 N₂O-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) N₂O-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 free) inorganic N fertilizer. In the other 2 experiments there is no difference or the emission factor is even higher. 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 This as result of the transition to a new calculation methodology for the yearly national NH₃ calculations (Velthof *et al.*, 2009 and Van Bruggen *et al.*, 2011). The previously yearly used MAMBO model for the NH₃ calculations will be applied by the ER possibly only for the purpose of regionalization. This will likely be less frequent than yearly, for instance 3 yearly.

1 of Velthof and Mosquera, 2011b); it increases from circa 1.7 to 3.3% N₂O-N of the N supply.

A10.3.4 Other sources

For the emission factor of the smaller sources crop residues, N fixation, 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 and nitrogen fixation 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 crop residues

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 A10.2 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 is 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 N₂O-N emission factor for application animal manure based on N in animal manure 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	low emission manure application	N ₂ O-N emission factor (% of N supply) 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

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		N ₂ O-N emission factor (% of N supply) surface spreading
					grassland	low emission manure application	
1998	peat	1,193,763	37,554,142		11%		
	mineral	126,756,610	145,544,393	41%	47%	0.8	0.4
1999	peat	447,910	37,769,955		12%		
	mineral	163,289,415	129,991,784	50%	40%	0.9	0.4
2000	peat	215,418	35,090,459		11%		
	mineral	143,240,045	114,417,747	49%	39%	0.9	0.4
2001	peat	341,562	32,961,633		11%		
	mineral	131,772,857	124,241,918	45%	43%	0.8	0.4
2002	peat	230,807	36,298,625		12%		
	mineral	122,698,262	119,650,533	44%	43%	0.8	0.4
2003	peat	209,634	35,621,517		13%		
	mineral	126,006,911	117,602,005	45%	42%	0.8	0.4
2004	peat	164,073	35,520,456		13%		
	mineral	124,227,089	105,717,392	47%	40%	0.9	0.4
2005	peat	212,829	35,597,614		13%		
	mineral	117,023,028	104,205,390	46%	41%	0.9	0.4
2006	peat	251,242	35,832,769		14%		
	mineral	101,398,282	114,285,064	42%	48%	0.8	0.4
2007	peat	3,243,483	23,273,421		10%		
	mineral	111,809,202	117,300,043	44%	46%	0.8	0.4
2008	peat	3,634,559	23,164,601		9%		
	mineral	114,272,963	112,003,903	45%	45%	0.8	0.4
avg 1980-2005***			48%	41%	0.9		0.4
avg 1980-2008			47%	42%	0.8		0.4
					11%		

Table A10.6 Calculation weighted average N₂O emission factor for application inorganic N fertilizer based on N in inorganic N fertilizer to soil*

year	soil	N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N ₂ O-N emission factor (% of N supply)
		arable land	grassland	arable land**	grassland	
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

year	soil	N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N ₂ O-N emission factor (% of N supply)
		arable land	grassland	arable land**	grassland	
2007	peat	2,874,346	21,094,967		8%	1.2
	mineral	83,018,237	128,571,402	36%	56%	
2008	peat	2,165,854	18,554,082		8%	1.2
	mineral	83,433,097	123,167,371	37%	55%	
avg 1990-2005***				27%	60%	1.3
					13%	
avg 1990-2008				28%	60%	1.2
					12%	

Table A10.7 Calculation weighted average N₂O 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 ₂ O-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 $\text{NH}_3\text{-N}$ during application). Assumption is that the differences in evaporation of NH_3 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 fertilization 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 2015 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

Eric Arets
 André Bannink
 Cor van Bruggen
 Arthur Denneman
 Jan Dijkstra
 Karin Groenestein
 Marga Hoogeveen
 Jan Huijsmans
 Harry Luesink
 Frank de Ruijter
 Gerard Velthof
 Jan Vonk

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 Mosquera *et al.* (2010b)
 Mosquera *et al.* (2010c)
 Mosquera *et al.* (2011)
 Winkel *et al.* (2009)
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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 ER secretary by the task force leader.

The ER 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 ER 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 CRF 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.

Table A11.1 Uncertainty analysis results at database level for the reference year 2015

Ammonia (NH ₃) - 2015						
Emission source code	Description	Aggregated uncertainties			Emission kg NH ₃ /year	
		Activity data	Emission factor	Emission		
Animal houses						
0441105	Dairy cows	2%	41%	41%	18.705.974	
0442101	Young cattle for breeding	1%	37%	37%	5.880.802	
0444101	Meat calves	1%	42%	42%	3.428.085	
0443102	Young cattle for meat production	1%	31%	31%	667.101	
0443104	Suckling cows (incl. fattening/grazing)	2%	35%	35%	305.204	
0445102	Pigs for meat production	10%	43%	44%	10.811.363	
0446103	Pigs for breeding	4%	42%	42%	3.731.164	
0447106	Laying hens	4%	41%	42%	5.968.841	
0448101	Broilers	10%	48%	49%	1.461.078	

Ammonia (NH ₃) - 2015					
0448103	Ducks	10%	45%	46%	158.110
0448104	Turkeys	10%	44%	45%	807.487
0443401	Sheep	5%	88%	88%	90.747
0443403	Goats	5%	60%	60%	501.035
0445621	Horses and ponies	4%	58%	59%	412.835
0446001	Mules and asses	5%	71%	72%	2.784
0447303	Other animals (rabbits)	5%	51%	51%	139.980
0447304	Other animals (furbearing animals)	5%	43%	44%	167.162
Total, animal houses				19%	53.239.751
Outside storage					
0441106	Dairy cows	2%	181%	181%	530.680
0442103	Young cattle for breeding	1%	160%	160%	303.462
0443105	Suckling cows (incl. fattening/grazing)	2%	203%	203%	26.560
0443103	Young cattle for meat production	1%	146%	146%	80.024
0445103	Pigs for meat production	10%	208%	211%	240.122
0446104	Pigs for breeding	4%	166%	166%	123.245
0447107	Laying hens	4%	53%	53%	1.610.897
0448102	Broilers	10%	69%	70%	109.103
0448105	Ducks	10%	66%	67%	10.591
0448106	Turkeys	10%	67%	68%	4.892
0443402	Sheep	5%	269%	269%	10.338
0443404	Goats	5%	245%	245%	95.141
0445622	Horses and ponies	4%	209%	209%	61.594
0446002	Mules and asses	5%	254%	254%	282
0447305	Other animals (rabbits)	5%	238%	238%	6.679
0447306	Other animals (furbearing animals)	5%	211%	211%	27.427
Total, outside storage				47%	3.241.036
Manure treatment					
0441404	Dairy cows	50%	40%	67%	166.013
0441405	Young cattle	50%	40%	67%	41.621
0441407	Meat calves	50%	40%	67%	48.010
0441409	Fattening pigs	38%	34%	51%	323.841
0441410	Breeding pigs	44%	39%	59%	129.464
0441412	Laying hens	18%	41%	45%	85.289
0441411	Broilers	23%	28%	36%	19.240
0441413	Turkeys	25%	41%	48%	730
0441400	Dairy cows digestion	50%	40%	67%	31.966
0441401	Young cattle digestion	50%	40%	67%	8.014
0441402	Fattening pigs digestion	50%	40%	67%	114.136
0441403	Breeding pigs digestion	50%	40%	67%	56.730
Total, manure treatment				23%	1.025.055
Pasture land					
0441301	Dairy cows	2%	110%	110%	689.897
0442300	Young cattle for breeding	1%	86%	86%	474.900
0443302	Suckling cows (incl. fattening/grazing)	2%	101%	101%	90.515

Ammonia (NH₃) - 2015					
0443303	Young cattle for meat production	1%	91%	91%	35.725
0443600	Sheep	5%	101%	101%	185.623
0445630	Horses and ponies	4%	88%	88%	105.502
0446004	Mules and asses	5%	107%	107%	746
Total, pasture land				56%	1.582.909
Application					
0441200	Dairy cows	2%	69%	69%	18.967.445
0442200	Young cattle for breeding	1%	42%	42%	5.969.149
0443201	Young cattle for meat production	1%	34%	34%	1.203.223
0443202	Suckling cows (incl. fattening/grazing)	2%	42%	42%	493.278
0444200	Meat calves	1%	95%	95%	1.035.559
0445200	Pigs for meat production	10%	78%	79%	3.694.099
0446200	Pigs for breeding	4%	54%	54%	2.688.570
0447200	Laying hens	4%	4%	0%	0
0448200	Broilers	10%	113%	113%	268.154
0448201	Ducks	10%	107%	108%	125.519
0448202	Turkeys	10%	109%	110%	29.295
0443503	Sheep	5%	86%	86%	117.166
0443504	Goats	5%	63%	63%	948.387
0445610	Horses and ponies	4%	56%	56%	610.998
0446003	Mules and asses	5%	73%	73%	3.822
0447401	Other animals (rabbits)	5%	61%	61%	37.697
0447402	Other animals (furbearing animals)	5%	89%	90%	160.079
Total, application				38%	36.352.441
Other sources					
0400700	Fertilizer application	26%	26%	37%	11.704.533
0506802	Sewage sludge	25%	84%	88%	62.115
0400613	Compost	23%	106%	111%	429.821
0444601	Crop residues	7%	59%	59%	1.851.317
0400210	Ripening crops			300%	1.821.429
Total, other sources				44%	15.869.214
Application on nature territory, fertilizer and horses (outside agriculture)					
0447011	Application on nature territory	15%	25%	29%	3.337.728
0802001	Horses and ponies outside agriculture	50%	119%	129%	3.043.947
Total, outside agriculture				63%	6.381.674
Total agriculture				25%	111.310.406
Total outside agriculture				63%	6.381.674
Total of all sources				24%	117.692.080

Nitrous oxide (N₂O) - 2015

Nitrous oxide (N ₂ O) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg N ₂ O/year
		Activity rate	Emission factor	Emission	
Manure management					
0441101	Cows in milk and in calf	2%	200%	200%	560.016
0441103	Young stock for breeding	1%	200%	200%	207.321
0444102	Meat calves	1%	201%	201%	47.186
0441104	Young stock for fattening	1%	200%	200%	38.438
0442102	Suckling cows	2%	201%	201%	14.315
0446102	Fattening pigs	10%	202%	202%	145.404
0446100	Breeding pigs	4%	201%	201%	78.256
0447104	Laying hens	4%	201%	201%	60.859
0447103	Broilers	10%	207%	207%	33.182
0447108	Ducks	10%	204%	204%	1.084
0447109	Turkeys	10%	203%	203%	2.360
0443100	Sheep	5%	222%	222%	4.932
0444100	Goats	5%	203%	203%	85.362
0445600	Horses and ponies	36%	222%	225%	80.566
0445900	Mules and asses	5%	217%	217%	112
0447110	Rabbits	5%	201%	201%	3.178
0447111	Furbearing animals	5%	202%	202%	7.717
0444701	Atmospheric deposition manure management	17%	400%	406%	777.013
Total manure management				159%	2.147.301
Manure treatment					
0441404	Cows in milk and in calf	50%	200%	229%	46.704
0441405	Young stock for breeding	50%	200%	229%	11.709
0441407	Meat calves	50%	200%	229%	217.459
0441409	Fattening pigs	38%	170%	175%	65.998
0441410	Breeding pigs	44%	197%	202%	26.385
				143%	368.255
Agricultural soils					
0400500	Inorganic fertilizer application	24%	37%	45%	5.477.077
0400600	Manure application	3%	66%	66%	4.221.780
0440000	Pasture manure	15%	64%	67%	3.353.200
0444500	Histosols	20%	46%	51%	1.532.283
0400310	Other organic soils	35%	57%	70%	833.399
0444600	Crop residues	7%	38%	39%	956.570
0400400	Pasture renewal	25%	25%	36%	101.293
0400610	Compost	25%	100%	106%	45.886
0506800	Sewage sludge	25%	100%	106%	8.967
0444702	Atmospheric deposition agricultural soils	26%	400%	414%	912.456
0444800	Nitrogen leaching and run-off	51%	233%	267%	1.210.700
Total agricultural soils				36%	18.653.610
Total of all sources				36%	21.169.166

Nitrogen oxide (NO) - 2015

Nitrogen oxide (NO) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg NO/year
		Activity rate	Emission factor	Emission	
Manure management					
0441101	Cows in milk and in calf	2%	200%	200%	763.658
0441103	Young stock for breeding	1%	200%	200%	282.711
0444102	Meat calves	1%	201%	201%	64.344
0441104	Young stock for fattening	1%	200%	200%	52.415
0442102	Suckling cows (incl. fattening/grazing)	2%	201%	201%	19.521
0446102	Fattening pigs	10%	202%	202%	198.279
0446100	Breeding pigs	4%	201%	201%	106.712
0447104	Laying hens	4%	201%	201%	82.989
0447103	Broilers	10%	207%	207%	45.249
0447108	Ducks for slaughter	10%	204%	204%	1.478
0447109	Turkeys	10%	203%	203%	3.218
0443100	Ewes	5%	222%	222%	6.726
0444100	Milk goats	5%	203%	203%	116.403
0445600	Horses and ponies	4%	208%	208%	31.498
0445900	Mules and asses	5%	217%	217%	152
0447110	Rabbits	5%	201%	201%	4.334
0447111	Furbearing animals	5%	202%	202%	10.523
Total manure management				97%	1.790.210
Manure treatment					
0441404	Cows in milk and in calf	50%	200%	229%	63.688
0441405	Young stock for breeding	50%	200%	229%	15.967
0441407	Meat calves	50%	200%	229%	296.535
0441409	Fattening pigs	38%	170%	175%	89.997
0441410	Breeding pigs	44%	197%	202%	35.979
				143%	502.166
Agricultural soils					
0400600	Manure application	3%	160%	160%	7.524.152
0440000	Pasture	16%	160%	163%	1.420.863
0400500	Inorganic fertilizer	27%	160%	168%	6.478.680
0506800	Sewage sludge	25%	160%	167%	16.303
0400610	Compost	23%	160%	166%	146.571
0444600	Crop residues	6%	127%	127%	1.565.297
0400400	Pasture renewal	25%	160%	167%	72.328
0444500	Histosols	20%	167%	171%	1.253.686
0400310	Other organic soils	35%	167%	180%	681.872
Total agricultural soils				87%	19.159.752
Application on nature territory, fertilizer and horses (outside agriculture)					
0447011	Application on nature territory	16%	96%	98%	1.159.691
0802001	Horses and ponies outside agriculture	50%	240%	246%	78.364
Total, outside agriculture				93%	1.238.055
Total agriculture				78%	21.452.128

Nitrogen oxide (NO) - 2015		
Total outside agriculture	93%	1.238.055
Total of all sources	74%	22.690.183

Methane (CH ₄) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg CH ₄ /year
		Activity rate	Emission factor	Emission	
Manure management, tier 1					
0441422	Sheep, manure management	10%	181%	181%	31.493
0443501	Sheep, pasture	10%	37%	39%	148.281
0441423	Goats, manure management	10%	30%	32%	61.067
0445600	Horses, manure management	36%	64%	73%	426.177
0445700	Horses, pasture	36%	134%	139%	224.821
0445900	Mules and asses, manure management	5%	51%	52%	482
0446000	Mules and asses, pasture	5%	74%	74%	337
0441424	Rabbits, manure management	10%	30%	32%	30.491
0447111	Fur bearing animals, manure management	5%	30%	30%	695.663
Total (tier 1)				31%	1.618.813
Manure management, tier 2					
0441101	Dairy cows, manure management	2%	39%	39%	57.857.063
0441300	Dairy cows, pasture	2%	43%	43%	511.564
0441103	Young cattle for breeding, manure management	1%	28%	28%	12.655.572
0441104	Young cattle for meat production, manure management	1%	20%	20%	1.463.557
0441302	Young cattle, pasture	1%	34%	34%	302.669
0442102	Suckling cows (incl. fattening/grazing), manure management	2%	37%	37%	584.823
0443301	Suckling cows (incl. fattening/grazing), pasture	2%	43%	43%	59.583
0444102	Meat calves, manure management	1%	30%	30%	4.408.777
0441421	Pigs for breeding, manure management	4%	36%	36%	21.310.130
0446102	Pigs for meat production, manure management	10%	40%	41%	39.235.799
0447103	Broilers, manure management	10%	74%	75%	1.339.038
0447104	Laying hens, manure management	4%	54%	54%	1.517.260

Methane (CH ₄) - 2015					
0447108	Ducks, manure management	10%	74%	75%	25.420
0447109	Tukeys, manure management	10%	74%	75%	36.034
Total (tier 2)				20%	141.307.286
Manure treatment					
0441404	Dairy cows	50%	39%	66%	1.186.162
0441405	Young cattle	50%	39%	66%	255.860
0441407	Meat calves	50%	39%	66%	78.829
0441409	Fattening pigs	37%	33%	50%	4.492.688
0441410	Breeding pigs	44%	39%	58%	1.837.445
0441412	Laying hens	18%	55%	58%	67.037
0441411	Broilers	23%	69%	73%	75.378
0441413	Turkeys	25%	76%	80%	2.767
0441400	Dairy cows digestion	50%	39%	66%	298.273
0441401	Young cattle digestion	50%	39%	66%	64.339
0441402	Fattening pigs digestion	50%	40%	67%	511.580
0441403	Breeding pigs digestion	50%	40%	67%	270.347
Total, manure treatment				29%	9.140.705
Total (manure)				19%	152.066.805
Fermentation, tier 1					
0443500	Sheep	10%	40%	41%	7.569.432
0444501	Goats	10%	40%	41%	2.348.745
0445500	Horses	36%	40%	56%	7.511.526
0445800	Mules and asses	5%	40%	40%	10.780
0446500	Pigs	6%	40%	41%	18.904.332
Total (tier 1)				26%	36.344.815
Fermentation, tier 2 and 3					
0441501	Young cattle	1%	11%	11%	88.440.112
0442500	Suckling cows (incl. fattening/grazing)	2%	21%	21%	6.361.936
0441600	Dairy cows NW	3%	21%	21%	87.631.725
0441700	Dairy cows SE	2%	21%	21%	121.597.848
Total (tier 2 and 3)				11%	304.031.622
Total (fermentation)				10%	340.376.437
Total of all sources				9%	492.443.242

Non-methane volatile organic components (NMVOC) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg NMVOC/year
		Activity rate	Emission factor	Emission	
Manure management					
0441103	Young stock for breeding	1%	191%	191%	9.901.924
0441101	Cows in milk and in calf	2%	221%	221%	41.643.326
0444102	Meat calves	1%	231%	231%	1.398.421
0441104	Young stock for fattening	1%	142%	142%	1.650.645
0442102	Suckling cows (incl. fattening/grazing)	2%	307%	307%	303.962
0446102	Fattening pigs	10%	303%	303%	1.082.827
0446100	Breeding pigs	4%	295%	295%	2.285.846
0447103	Broilers	10%	303%	303%	3.852.145
0447104	Layers	4%	218%	218%	3.660.850
0447108	Ducks for slaughter	10%	303%	303%	45.117
0447109	Turkeys	10%	303%	303%	60.304
0443100	Sheep	5%	309%	309%	19.610
0444100	Goats	5%	302%	302%	405.517
0445600	Horses and ponies	4%	272%	272%	71.253
0445900	Mules and asses	5%	309%	309%	274
0447110	Rabbits	5%	302%	302%	2.972
0447111	Fur animals	5%	302%	302%	345.896
Total, manure management				143%	66.730.890
Agricultural soils					
0400600	Manure application	4%	127%	127%	12.661.953
0440000	Pasture manure	1%	150%	150%	292.298
0441430	Silage storage	1%	173%	173%	11.562.616
0400201	Crops	13%	218%	218%	1.497.565
Total, crop production and agricultural soils				99%	26.014.431
Total, agriculture				107%	92.745.321
Outside agriculture					
0802001	Horses and ponies private	50%	225%	231%	409.784
Total				106%	93.155.105

Particulate matter < 10µm (PM ₁₀) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg PM ₁₀ /year
		Activity rate	Emission factor	Emission	
Manure management					
0441103	Young stock for breeding	1%	23%	23%	66.808
0441101	Cows in milk and in calf	2%	24%	24%	206.642
0444102	Meat calves	1%	33%	33%	31.897
0441104	Young stock for fattening	1%	26%	26%	19.861
0442102	Suckling cows (incl. fattening/grazing)	2%	32%	32%	6.934
0446102	Fattening pigs	10%	35%	36%	659.099
0446100	Breeding pigs	7%	31%	32%	315.175

Particulate matter < 10µm (PM ₁₀) - 2015					
0447103	Broilers	10%	32%	34%	1.283.673
0447104	Layers	4%	36%	37%	2.891.801
0447108	Ducks for slaughter	10%	35%	36%	94.928
0447109	Turkeys	10%	33%	35%	82.069
0447110	Rabbits	5%	49%	49%	515
0447111	Fur-bearing animals	5%	49%	49%	8.287
0443100	Sheep	10%	32%	34%	1.726
0444100	Goats	5%	32%	32%	8.925
0445600	Horses and ponies	4%	40%	40%	25.808
0445900	Mules and asses	5%	40%	40%	172
Total, animal houses				21%	5.704.321
Outside agriculture					
0802001	Horses and ponies private	50%	45%	67%	66.000
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%	237%	237%	409.863
Total, agricultural soils				136%	729.863
Total agriculture				24%	6.434.184
Total outside agriculture				67%	66.000
Total of all sources				24%	6.500.184

Particulate matter < 2.5 µm (PM _{2.5}) - 2015					
Emission source code	Description	Aggregated uncertainties			Emission kg PM _{2.5} /year
		Activity rate	Emission factor	Emission	
Manure management					
0441103	Young stock for breeding	1%	25%	25%	18.423
0441101	Cows in milk and in calf	2%	26%	26%	56.958
0444102	Meat calves	1%	36%	36%	8.757
0441104	Young stock for fattening	1%	28%	28%	5.468
0442102	Suckling cows (incl. fattening/grazing)	2%	35%	35%	1.914
0446102	Fattening pigs	10%	43%	44%	31.034
0446100	Breeding pigs	7%	30%	31%	15.226
0447103	Broilers	10%	43%	44%	95.948
0447104	Layers	4%	79%	79%	177.061
0447108	Ducks for slaughter	10%	47%	48%	4.545
0447109	Turkeys	10%	45%	46%	38.489
0447110	Rabbits	5%	100%	100%	101
0447111	Fur-bearing animals	5%	100%	100%	4.297
0443100	Sheep	10%	35%	37%	518
0444100	Goats	5%	35%	35%	2.678
0445600	Horses and ponies	4%	40%	40%	16.423
0445900	Mules and asses	5%	40%	40%	108
Total, animal houses				31%	477.949

Particulate matter < 2.5 µm (PM _{2.5}) - 2015					
Outside agriculture					
0802001	Horses and ponies private	50%	45%	67%	42.000
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%	250%	250%	46.300
Total, agricultural soils				111%	110.300
Total agriculture				33%	588.249
Total outside agriculture				67%	42.000
Total of all sources				31%	630.249

Carbon dioxide (CO ₂) - 2015					
CRF code	Description	Aggregated uncertainties			Emission kg CO ₂ /year
		Activity rate	Emission factor	Emission	
Liming					
N320000	Limestone	37%	1%	37%	31.553.454
N320001	Dolomite	34%	1%	34%	37.163.773
Total liming				25%	68.717.227
Urea Application					
Urea application		27%	1%	27%	65.931.820
Total all sources				19%	134.649.048

A11.4 References

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Annex 12 List of abbreviations

B ₀	Maximum methane production potential
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
CRF	Common Reporting Format
DMI	Dry-matter intake
EEA	European Environment Agency
EMEP	European Monitoring and Evaluation Programme
EU	European Union
EZK	Ministry of Economic Affairs and Climate Policy
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 ₂ O	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
Y _m	Methane-conversion factor (for the calculation of CH ₄ from enteric fermentation)

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