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

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

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T.C. van der Zee et al.

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T.C. van der Zee (author), RIVM
A. Bleeker (author), RIVM
C. van Bruggen (author), Statistics Netherlands
W. Bussink (author), Nutriënten Management Instituut
C.M. Groenestein (author), Wageningen Livestock Research
J.F.M. Huijsmans (author), Wageningen Plant Research
H. Kros (author), Wageningen Environmental Research
L.A. Lagerwerf (author), Wageningen Livestock Research
K. Oltmer (author), Wageningen Economic Research
M. Ros (author), Wageningen Environmental Research
M. van Schijndel (author), Netherlands Environmental Assessment Agency
L. Schulte-Uebbing (author), Netherlands Environmental Assessment Agency
G.L. Velthof (author), Wageningen Environmental Research

Contact:
Tim van der Zee
Stoffen Monitoring & Onderzoek Stikstof
Tim.van.der.zee@rivm.nl

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

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Synopsis

Methodology for the calculation of emissions from agriculture

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

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.

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 Paris Agreement, 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, National Inventory Report (NIR), Informative 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.

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

De uitstoot wordt berekend met het National Emission Model for Agriculture (NEMA), dat in Nederland is ontwikkeld. 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. De methoden die voor verschillende stoffen worden gebruikt zijn beschreven, plus de wijzigingen die in het model zijn doorgevoerd.

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 verdrag van Parijs, 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

Contents

Summary

Emissions to air from agricultural activities in the Netherlands are estimated using the National Emission Model for Agriculture (NEMA). Calculations include the emission of ammonia (NH_3), nitrogen oxides (NO_x), nitrous oxide (N_2O), non-methane volatile organic compounds (NMVOC), methane (CH_4), particulate matter (PM_{10} and $PM_{2.5}$) and carbon dioxide (CO_2). These emissions originate from various processes within the agricultural production chain, grouped in the main categories enteric fermentation (CH_4), manure management (CH_4, NH_3, NO_x, N_2O, NMVOC and PM), crop production and agricultural soils (NH_3, NO_x, N_2O, NMVOC and PM), and lime application and urea application (CO_2). The calculations for greenhouse gas emissions are based on the 2006 IPCC Guidelines. 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 IPPC Tier 2 approach. The excretion of volatile solids is calculated from rations fed. The emission of CH_4 is calculated by multiplying volatile solids by the maximum methane production potential (B_o) and the methane-conversion factor (MCF). Slurry and solid manure are distinguished from manure excreted on pasture land. Emissions from other livestock categories are calculated using the IPCC 2006 defaults in kg CH_4 per head per year (Tier 1).

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 have their own default emission factors from the IPCC. When applied in the TAN-flow model, these emissions are converted into a percentage of TAN.

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

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

Crop production and agricultural soils

As part of the TAN flow, available N in manure intended for application is calculated by subtracting N losses from animal housing, manure treatment and outside manure storage from the total N excreted by the animals. The N losses include NH_3-N, N_2O-N, NO_x-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, NH_3 emission factors based on TAN excreted during grazing are used. The NH_3 emissions from the application of inorganic N fertilizer, sewage sludge and compost, crop ripening and crop residues left on the field are calculated using country-specific emission factors based on literature and measurements for these sources. The distribution of the different forms of N inputs over grassland and arable land and organic and mineral soils is based on calculations using the INITIATOR model.

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

After the application of manure, NMVOC emissions occur, and a Tier 2 calculation method using the EMEP default emission factors is applied to calculate these emissions. Although no direct emission factors for NMVOC emissions are available for manure application, a correlation has been found between the volume of NH_3 emissions and the volume of NMVOC emissions. it is therefore assumed that the ratio of NMVOC from application to NMVOC from animal housing is equal to the ratio of NH_3 from application to NH_3 from animal housing (EEA, 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 PM_{10} and $PM_{2.5}$ emissions from the tillage of crops. Fixed estimates are used for other sources of PM emissions (concentrates, inorganic fertilizers and pesticides).

Liming

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

Urea application

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

Overview of methods and emission factors used

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

Table S.1 Methods and emission factors (EF) used in NEMA for air pollutants, by level as distinguished by the EMEP Guidebook 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_2O	
	Method	**EF**	**Method**	**EF**	**Method**	**EF**
3. Agriculture						
A. Enteric fermentation	N/A	N/A	T1, T2, T3	CS, D	N/A	N/A
B. Manure management	N/A	N/A	T1, T2	CS, D	T2	D
C. Rice cultivation	N/A	N/A	NO	NO	N/A	N/A
D. Agricultural soils	N/A	N/A	N/A	N/A	T1, 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

CRF source categories		CO_2		CH_4		N_2O	
		Method	**EF**	**Method**	**EF**	**Method**	**EF**
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 follow 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 CH_4, NH_3, N_2O, NO_x, NMVOS, PM10, PM2.5 en CO_2 met het National Emission Model for Agriculture (NEMA) – Update 2023

Om emissies naar de lucht uit landbouwkundige activiteiten in Nederland te schatten, wordt het National Emission Model for Agriculture (NEMA) gebruikt. De berekeningen omvatten emissies van ammoniak (NH_3), stikstofoxiden (NO_x), lachgas (N_2O), niet-methaan vluchtige organische stoffen (NMVOS), methaan (CH_4), fijnstof (PM_{10}, $PM_{2,5}$) en koolstofdioxide (CO_2). Deze emissies zijn afkomstig van diverse processen in de landbouwproductieketen, gegroepeerd in de hoofdcategorieën enterische fermentatie (CH_4), mestmanagement (CH_4, NH_3, NO_x, N_2O, NMVOS en PM), gewasproductie en landbouwbodems (NH_3, NO_x, N_2O, NMVOS en PM), bekalking en de aanwending van ureum (CO_2). De berekeningen voor broeikasgassen zijn gebaseerd op de 2006 IPCC Guidelines. 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 CH_4 gevormd. Daarom wordt in lijn met de key source (belangrijkste bronnen) analyse, een landspecifieke (IPCC Tier 3) methode toegepast voor melkkoeien waarin de enterische fermentatieprocessen gemodelleerd worden. Voor de andere rundveecategorieën worden emissies jaarlijks berekend op basis van de rantsoenen volgens een IPCC Tier 2-benadering. De emissies van kleine herkauwers en darmfermentatie door eenmagige dieren worden berekend met IPCC 2006 default emissiefactoren in kg CH_4 per dier per jaar (Tier 1).

Mestmanagement

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

Uit de fermentatie van organische stof in opgeslagen of be- of verwerkte mest van landbouwhuisdieren komen emissies van CH_4 voort. De omvang van de emissie hangt af van de chemische samenstelling van de mest en omgevingsfactoren zoals temperatuur en de beschikbaarheid van zuurstof. Rundvee, varkens en pluimvee worden beschouwd als key source, en worden daarom geschat met een IPCC Tier 2-benadering. De excretie van organische stof wordt berekend uit de gevoerde rantsoenen. De organische stof vermenigvuldigd met het biochemisch methaanpotentieel (B_o) en methaanconversiefactor (MCF) geeft de CH_4-emissies. Er wordt onderscheid gemaakt tussen drijf- en vaste mest, en mestexcretie tijdens beweiden. Emissies van andere diercategorieën worden berekend met IPCC 2006 default (Tier 1) emissiefactoren in kg CH_4 per dier.

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

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

Gewasproductie en landbouwbodems

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

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

Bij het toedienen van mest emitteert ook NMVOS. Op het moment zijn er nog geen emissiefactoren voor deze emissies. Er is er wel een correlatie gevonden tussen de NH_3- en NMVOS-emissies (EMEP Guidebook). De verhouding NMVOS uit mesttoediening tot NMVOS uit stal wordt 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 $PM_{2,5}$- emissies door het verbouwen van gewassen. Voor andere bronnen van PM-emissies (krachtvoer, anorganische meststoffen en pesticidengebruik) worden vaste schattingen per jaar gebruikt.

Bekalking

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

Aanwending ureum

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

Overzicht van gebruikte methoden en emissiefactoren

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

Tabel S.1 Methoden en emissiefactoren (EF) gebruikt in NEMA voor luchtvervuilende stoffen, naar niveau zoals onderscheiden in het EMEP guidebook 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_2O	
	Methode	**EF**	**Methode**	**EF**	**Methode**	**EF**
3. Landbouw						
A. Enterische fermentatie	N/A	N/A	T1, T2, T3	CS, D	N/A	N/A
B. Mestmanagement	N/A	N/A	T1, T2	CS, D	T2	D
C. Rijstbouw	N/A	N/A	NO	NO	N/A	N/A
D. Landbouwbodems	N/A	N/A	N/A	N/A	T1, T1b, T2	CS, D
E. Voorgeschreven verbranding van savannes	N/A	N/A	NO	NO	NO	NO
F. Verbranden gewasresten op het veld	N/A	N/A	NO	NO	NO	NO
G. Bekalking	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	NO	N/A	N/A	N/A	N/A
J. Overig	N/A	N/A	NO	NO	NO	NO

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 2021, the agricultural sector was responsible for more than 85% of all ammonia (NH_3) emissions in the Netherlands. Agriculture is also a significant contributor to the emission of nitrogen oxides (NO_x). The deposition of NH_3 and NO_x can have adverse effects in the form of eutrophication and acidification. Both NO_x and Non-Methane Volatile Organic Compounds (NMVOC) have an effect on the formation of ozone, which, in turn, can have a negative effect on human health and plant growth. Agricultural activities constitute a considerable source of particulate matter (PM) emissions as well, especially in the coarse fraction of up to 10 μm in size (PM_{10}). Particulate matter, both 10 μm and 2.5 μm ($PM_{2.5}$) can have detrimental health effects, and it constitutes an uncertain factor in climate change.

With regard to the greenhouse gases methane (CH_4) and nitrous oxide (N_2O), agriculture is the largest contributor to total national emissions. In 2020, the two gases combined and expressed as carbon dioxide equivalents (CO_2-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 CO_2 emissions reported in the agricultural sector originate from calcareous fertilizers (liming) and the application of urea.

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

Reporting requirements and institutional arrangements

Under the Paris Agreement and under EU legislation, the Netherlands is required to set up and maintain a national system for monitoring its greenhouse gas emissions. One element of this system is a transparent and verifiable description of the methods and processes used within this monitoring system. These methods must meet international guideline criteria, which are defined by the United Nations (UN) and the European Union (EU), as described in the *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.* (2022). 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 CH_4, NH_3, N_2O, NO_x, NMVOC, PM_{10}, $PM_{2.5}$ and CO_2 from the agricultural sector. This report contains updated uncertainty calculations.

Emissions data are available through the website www.emissieregistratie.nl, as well as in annual reports on greenhouse-gas emissions (National Inventory Report, NIR) and other pollutants (Informative Inventory Report, IIR). Data from the PRTR are also used for the evaluation of national environmental policy and in many other environmental reports. For this reason, annual reports are also published in Dutch with updated NEMA results (Van Bruggen *et al.*, 2023; 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 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines and the EMEP Guidebook 2019 has been followed in this regard (IPCC, 2006; 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.

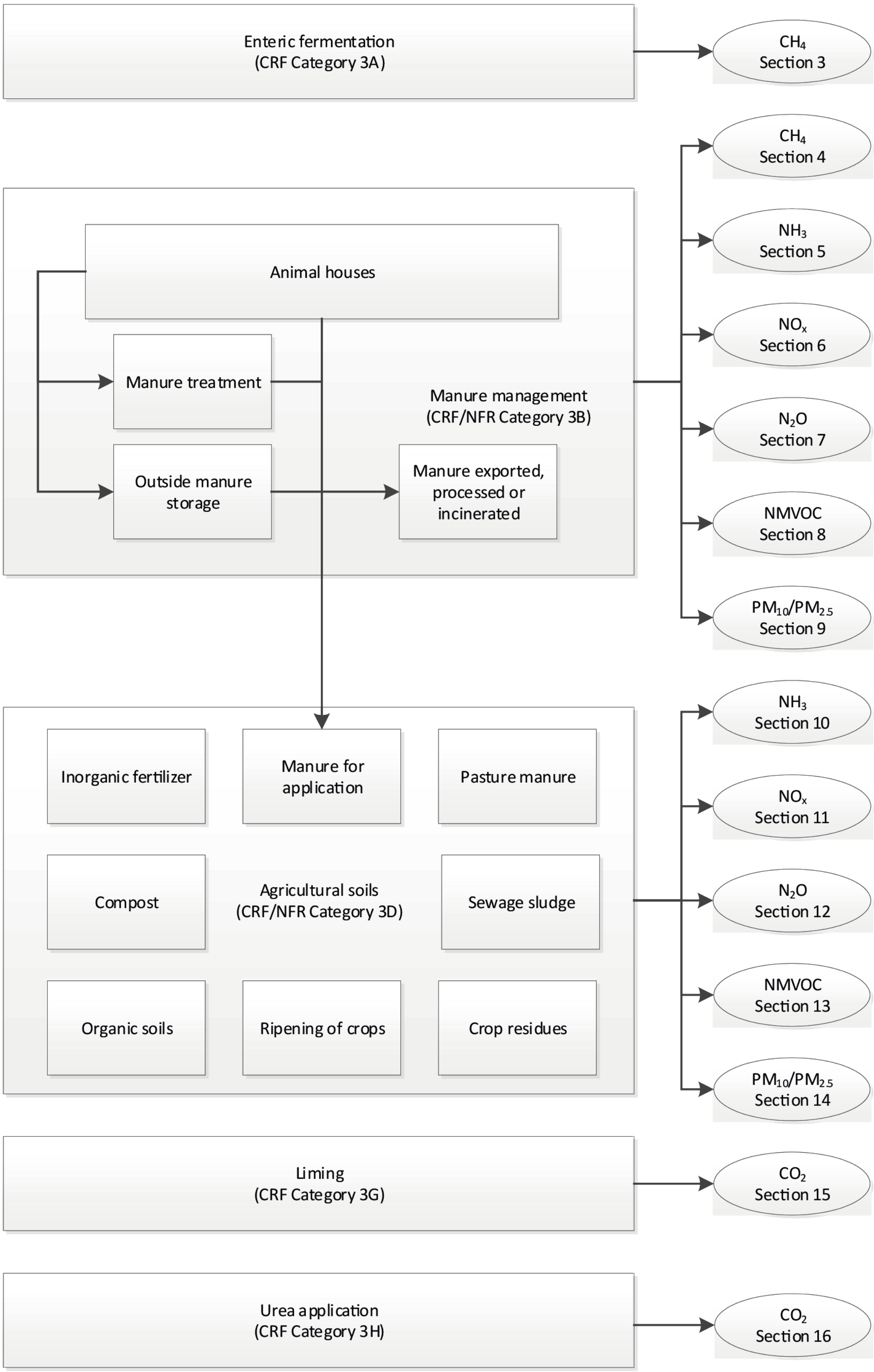

Figure 1.1 Processes and emissions in agriculture, with allocations to CRF and NFR reporting categories.

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).

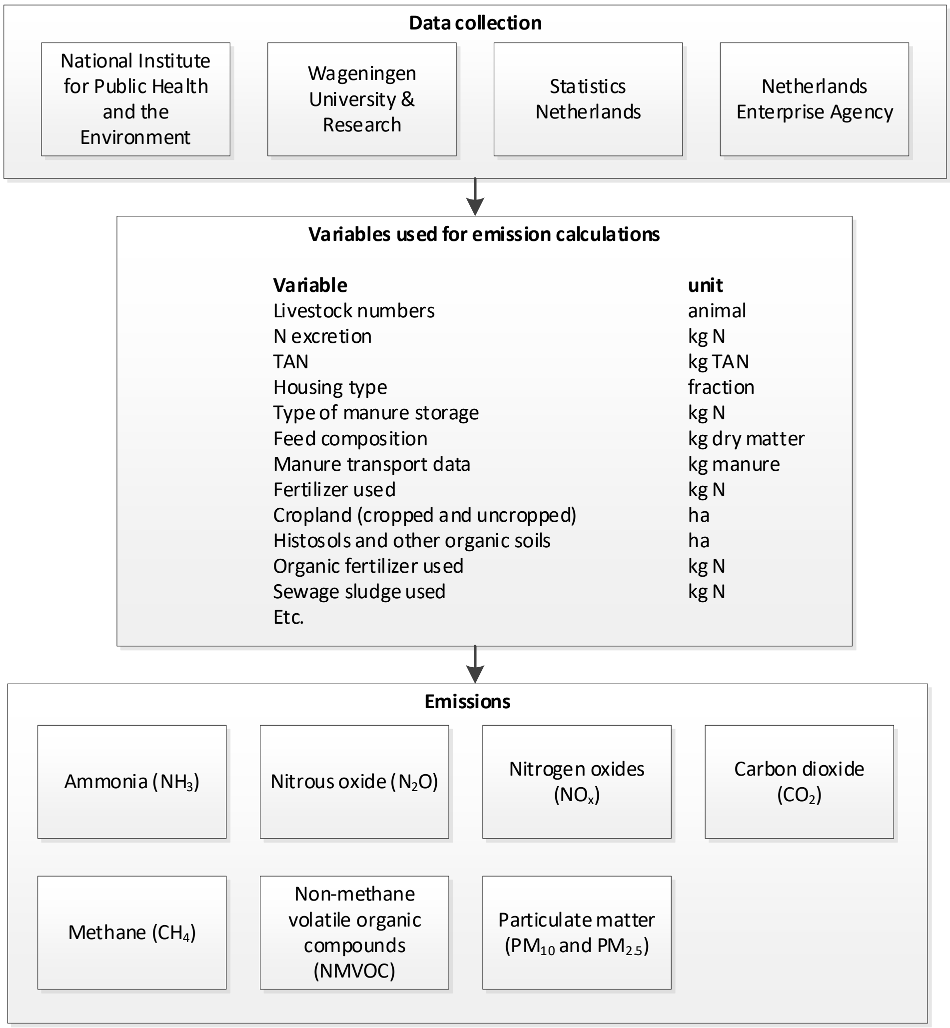

Figure 2.1 Institutes collaborating to gather the data necessary for calculating emissions

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.* (2023). The livestock categories are presented in Figure 2.2, as included in the Agricultural Census.

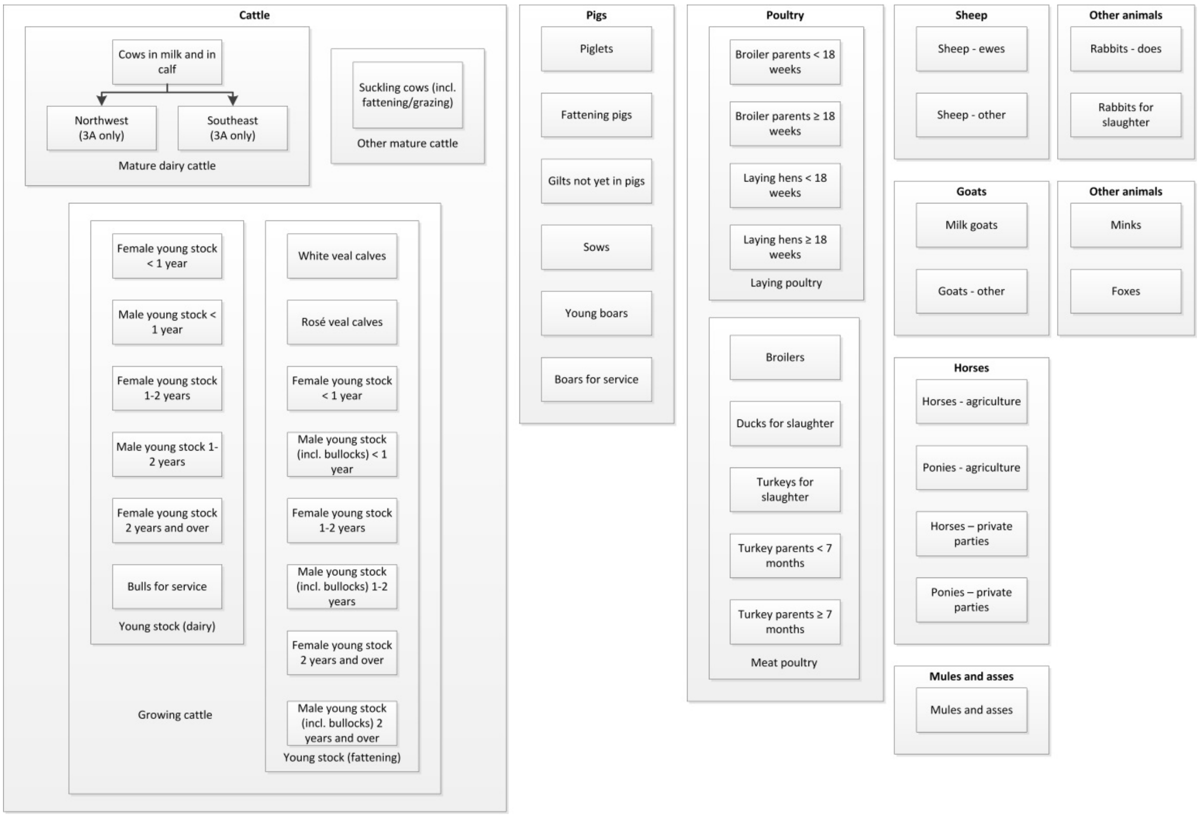

Figure 2.2 Livestock categories in the Agricultural Census

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 (I&R) system from RVO. The I&R is a system of the Netherlands Enterprise Agency in which farmers have to register animals that are born, arrive on the farm and leave the farm (CBS, 2020 and RVO, 2020). The I&R is used from 2017 for cows and from 2018 for poultry, sheep and goats. The use of I&R for poultry resulted in lower poultry numbers, especially broilers, as farmers tended to report a full animal house in the Agricultural Census when their housing was empty on the reference date (1st of April) and did not take mortality into account when reporting their poultry, leading to a systematic overestimation of poultry numbers. The use of data from the agricultural census till 2017 and the use of I&R-data from 2017 resulted in an inconsistent time series for broilers and ducks. The relative difference between broiler and duck numbers from the agricultural census and the I&R of 2017 has been used to correct the time series by linearly extrapolating the number of broilers and ducks between 1990 and 2016. The number of ducks was decreased by 12.5% and the number of broilers by 7.5% using this correction of the time series. Unfortunately 2017 was the only year with overlap as the agricultural census had no legal grounds to include questions on poultry numbers after the I&R had proved to be sufficient. For turkeys, it was not possible to implement a correction to the time series, because comparison of the difference between the agricultural census and the I&R in 2017, shows that turkey numbers had been underestimated. No explanation can be given for this underestimation. It should also be noted that the number of turkeys is low compared to broilers (566.206 turkeys vs. 44 million broilers in 2020) and that the number of turkeys varies strongly per year (Van Bruggen *et al.,* 2023).

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

2.2.2 *N excretions*

The N excretions in animal houses (taking into account excretions on 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, 2019-2022; 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, 2022).

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.
- *Rabbit*s are kept indoors year-round and produce solid manure.
- *Fur-bearing animals (minks and foxes*) are kept indoors year-round and produce liquid manure. Foxes have been banned in the Netherlands since 2008, minks since 2021.

2.2.4 *Manure application and grazing*

The amount of animal manure applied in the Netherlands is calculated as the TAN excretions minus N emissions in animal houses, manure treatment and during manure storage, and minus exported N. The amount of exported manure is reported by the RVO, based on the transportation documents that are mandatory for exported and imported manure. However, the N content reported in the transportation documents are not used as they are deemed to be too high to be realistic (Van Bruggen *et al.,* 2015). Instead, the average N content of manure as calculated by the WUM is used. The remaining manure is subsequently distributed over the different land types (grassland, cropland uncropped, cropland cropped) and soil types (mineral soil and organic soil) using the Initiator model (Kros *et al.,* 2019). The application methods are provided by the annual agricultural census.

The amount of N that is excreted during grazing is based on the amount of time animals spent grazing. The amount of time cattle spend grazing is provided by the annual agricultural census. Fixed values are applied for horses, ponies, mules and asses and sheep (Van Bruggen, 2008).

2.3 Emission calculations

In the Netherlands, agriculture is a major source of NH_3, NO_x, N_2O, NMVOC, CH_4, PM_{10} and $PM_{2.5}$ emissions. Both NH_3 and NO_x contribute to the eutrophication and acidification of soils, while N_2O and CH_4 are greenhouse gases, and N_2O and NMVOC damage the ozone layer. Particulate matter affects human health, and N emissions reduce the efficiency of nitrogen use in agriculture.
Commissioned by the Ministry of Economic Affairs and Climate Policy, the NEMA working group of the CDM developed a method to calculate NH_3 emissions in 2009 (Velthof *et al.*, 2009). The method includes emissions from animal housing, manure treatment and manure storage for livestock categories in the Dutch Agricultural Census, as well as from livestock grazing in pastures and applications of animal manure and fertilizers to the soil. At the request of the PRTR, modules for the calculation of NO_x, N_2O, CH_4, PM_{10} and $PM_{2.5}$ have been included in the model since the emission calculations of 2012 (Van Bruggen *et al.*, 2014). The name of the model was therefore changed from the National Emission Model for Ammonia to the National Emission Model for Agriculture (NEMA). With the implementation of the 2006 IPCC Guidelines in 2013, a module for the calculation of CO_2 from calcareous fertilizers (liming) was added as well. The 2016 update to the EMEP Guidebook led to the addition of NMVOC emission calculations in 2018. In 2021 the CO_2 emissions from the application of urea were added This is in line with the approach in the 2006 IPCC Guidelines to allocate emissions of urea during 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 Paris Agreement.

Reporting at higher levels

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

2.4 Uncertainty calculations

2.4.1 General

Models are not an exact representation of reality, and their estimates are therefore uncertain to some extent. In activity data, the availability and representativeness of data constitute the main source of uncertainty. When applying emission factors, uncertainties emerge from possible measurement errors, statistical random-sampling errors or missing data. Other causes of uncertainty include lack of completeness due to unrecognised emission sources or lack of measurement methods. These aspects are not taken into account in the current uncertainty analysis. For more details on causes of uncertainty, see Chapter 3 of the 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 2022 inventory (1990-2020 time series), new uncertainty estimates for the agricultural sector were calculated using the propagation-of-error approach for the most recent reference year (2020). Uncertainty values were estimated based on literature and expert judgements. Previous estimates were reconsidered and revised as needed, based on new insights or changed methods. Data from this uncertainty analysis were also used as input for the Monte Carlo analysis of uncertainties conducted on the 2022 inventory of emissions in the Netherlands. A more in-depth methodology of the uncertainty analysis is provided in the following subsections. A detailed overview of quality assurance and quality control is provided in Annex 10, which also contains outlines for the verification of data.

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

2.4.2 *Calculation method*

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

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

Where

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

Uncertainty over all emission sources 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 task force agricultural emissions.

To achieve a better approximation of the emissions, Tier 2 or Tier 3 methods can be used to estimate emissions. The uncertainty values associated with these calculations are derived based on literature and expert judgement. The list of experts consulted is provided in Annex 10. Higher-tier methods generally use more parameters for emission calculations, which increases the uncertainty. Less-complicated methods could yield lower uncertainty, while higher-tier methods (with possibly higher uncertainties) provide a better approximation of the complexity of the model, the availability of scientific data and the possibility of gaining insight into mitigation measures.

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

Levels of calculation and reporting

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

2.4.3 *Uncertainties of general activity data*

Uncertainty of livestock numbers

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

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

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

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) updated in 2022 based on expert judgement

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

Livestock category	Uncertainty
Ducks	5%[3)]
Turkeys	5%[3)]
Other animals	
Rabbits (does)	5%
Other rabbits	10%[1)]
Mink	5%

1) Expert judgement.
2) Expert judgement: the 10% uncertainty value for piglets was estimated according to the following calculation. In 2012, there were 2.37 litters per sow (Agrovision). The number of full-grown piglets was 27.8 per sow. Assuming that piglets die primarily in the beginning, there would be 11.7 (27.8/2.37) piglets per litter. After 78 days, piglets become fatteners, while the next litter comes after 154 days (365/2.37). The average number of piglets per sow during a year is thus 78/154x11.7 = 5.93. With 938,000 sows in 2012, there were 5.93 x 938,000 = 5.6 million piglets. The Agricultural Census counted 5.2 million piglets.
3) Expert judgement, updated in 2022.

Uncertainty of N excretions

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

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

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

Where:

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

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

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

Livestock category	U total N excretion per head	U animal house N excretion per head	U pasture N excretion per head
Cattle for breeding			
Female young stock < 1 year	4.9%	3.9%	30.2%
Male young stock < 1 year	5.5%	-	-
Female young stock ≥ 1 year	4.1%	3.8%	12.7%
Male young stock ≥ 1 year	5.3%	-	-
Dairy cows	5.8%	4.7%	33.5%
Cattle for fattening			
Veal calves, for white veal production	14.8%	-	-
Veal calves, for rosé veal production	9.5%	-	-
Female young stock < 1 year	4.9%	3.9%	31.2%
Male young stock < 1 year (incl. young bullocks)	11.3%	-	-
Female young stock ≥ 1 year	4.1%	3.7%	12.9%
Male young stock ≥ 1 year (incl. young bullocks)	8.9%	-	-
Suckling cows	5.3%	7.9%	7.1%
Other grazing animals			
Sheep (ewes, including young animals and males)	6.0%	44.1%	4.7%
Dairy goats ≥ 1 year (including young animals and males)	14.5%	-	-
Horses (agriculture)	21.4%	28.4%	32.4%
Ponies (agriculture)	21.4%	33.5%	27.6%
Mules and asses[1)]	21.4%	33.5%	27.6%
Pigs			
Fattening pigs	9.9%		
Sows (including piglets)	11.4%		
Breeding pigs	9.8%		
Boars	7.9%		
Poultry			
Broiler breeders < 18 weeks	10.7%		
Broiler breeders ≥ 18 weeks	6.8%		
Laying hens <18 weeks	10.8%		
Laying hens ≥ 18 weeks	8.3%		
Broilers	21.6%		
Ducks	14.6%		
Turkeys	13.1%		
Other animals			
Rabbits (does, including young animals and males)	9.4%		

Livestock category	U total N excretion per head	U animal house N excretion per head	U pasture N excretion per head
Mink (females, including young animals and males)	11.8%		

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

Uncertainty of manure management systems

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

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

Livestock category	Manure management system	U fraction solid/slurry
Cattle for breeding		
Cows in milk and in calf	Slurry	10
	Solid	0.20
Female young stock < 1 year	Slurry	1.24
	Solid	10
Male young stock < 1 year	Slurry	7.24
	Solid	10
Female young stock ≥ 1 year	Slurry	1.24
	Solid	10
Male young stock ≥ 1 year	Slurry	7.24
	Solid	10
Cattle for fattening		
Veal calves, for white veal production	Slurry	0
Veal calves, for rosé veal production	Slurry	0
Female young stock < 1 year	Slurry	10
	Solid	10
Male young stock (incl. young bullocks) < 1 year	Slurry	10
	Solid	10
Female young stock ≥ 1 year	Slurry	10
	Solid	10
Male young stock (incl. young bullocks) ≥ 1 year	Slurry	10
	Solid	10
Suckling cows (incl. fattening/grazing) ≥ 2 years	Slurry	10
	Solid	10
Pigs		
Fattening pigs	Slurry	0
Rearing pigs	Slurry	0
Sows	Slurry	0.42
	Solid	10

Livestock category	Manure management system	U fraction solid/slurry
Boars for service	Slurry	4.08
	Solid	10
Poultry		
Broilers	Solid	0
Ducks	Solid	0
Turkeys	Solid	0
Broiler breeders < 18 weeks	Solid	0
Broiler breeders ≥ 18 weeks	Solid	0
Laying hens < 18 weeks	Solid	0
Laying hens ≥ 18 weeks	Solid	0

2.5 Quality assurance and quality control

2.5.1 General

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

2.5.2 Quality assurance

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

- The task force for agriculture emissions, which consists of experts from different institutes, with backgrounds in animal husbandry, crop production, and emissions meets several times during the year to discuss possible methodological changes based on new scientific insights, points brought up by reviewers, changes to the EMEP Guidebook or IPCC Guidelines and changes made by neighbouring countries. Members of this committee are:
  - G. Velthof (Wageningen Environmental Research)
  - M. Ros (Wageningen Environmental Research)
  - H. Kros (Wageningen Environmental Research)
  - K. Groenestein (Wageningen Livestock Research)
  - L. Lagerwerf (Wageningen Livestock Research)
  - J. Huijsmans (Wageningen Plant Research)
  - H. Luesink (Wageningen Economic Research) (till 1 January 2023)
  - K. Oltmer (Wageningen Economic Research)
  - C. van Bruggen (Centraal Bureau voor de Statistiek)
  - A. Bleeker (Rijksinstituut voor Volksgezondheid en Milieu)
  - T. van der Zee (Rijksinstituut voor Volksgezondheid en Milieu)
  - W. Bussink (Nutriënten Management Instituut)
  - M. van Schijndel (Planbureau voor de Leefomgeving)
  - L. Schulte-Uebbing (Planbureau voor de Leefomgeving)
- A logbook is used to record when activity data and emission factors are sent to Statistics Netherlands and when they are implemented in NEMA. The logbook also contains a schedule of the expected period when the activity data and emission factors are sent to Statistics Netherlands.
- After every methodological change the model is run and the new emission totals are saved, allowing to assess the magnitude of the individual changes.

2.5.3 *Quality control*

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

- After all changes are implemented the model is sent from Statistics Netherlands to the RIVM which performs an additional check focussing on the implementation of the methodological changes and the consistency of the new year in the time series with the previous years.
- A file is sent to the members of the task force for agriculture emissions which shows the differences in emissions between the new time series and the previous time series, and the change in emissions between the newest year and the previous year. The file also gives an explanation for the changes in terms of activity data and emission factors. The members of the task force for agriculture emissions check the changes.
- In 2020, a review was performed by the NIE during which the methodology report was discussed with Statistics Netherlands and the RIVM.
- A meeting is organised during which all sectors (Agriculture, LULUCF, Industrial processes and product use, Transport, Energy, Waste and Other) present their new time series and methodological changes. During this meeting members from the different contributing organisations are present as well as people not involved with compiling the emissions.
- A file with the time series is sent to the NIE for approval.
- The methodology report is sent to the NIE for approval.
- After the submission of the NIR and the IIR, reviews take place performed by reviewers from other countries.

3 CH_4 emissions from enteric fermentation (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 CH_4 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 CH_4 production compared to ruminants. The gastro-intestinal tracts of polygastric ruminants (e.g. cattle, sheep and goats) are adapted to digest fibrous material, especially in the rumen. In the process of intensive microbial fermentation, the rumen generates substantial amounts of CH_4.

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

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

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

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

3.2 Source-specific aspects

3.2.1 Calculation method

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

$$CH_4 \text{ emissions enteric fermentation} = \sum_i AAP_i \times EF\ CH_4 \text{ enteric fermentation}_i \qquad (3.1)$$

Where:

CH_4 emissions enteric Fermentation	:	Methane emissions (kg CH_4/year) for all defined livestock categories (i) within the CFR source category 3A (Enteric fermentation)
AAPi	:	Average animal population for livestock category (i)

EF CH_4 enteric Fermentation	:	Emission factor (kg CH_4/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 CH_4 in the rumen and the large intestine. The simulation model predicts the gross energy intake from feed and the production of CH_4 in the rumen and large intestine from feed intake and dietary characteristics (e.g. dry-matter intake, chemical composition and rumen degradation characteristics of chemical fractions in dry feed matter). The model subsequently calculates the methane-conversion factor from predicted CH_4 emissions and gross energy intake. It therefore predicts the methane-conversion factor as a model output, instead of assuming a constant methane-conversion factor value as a model input, as is the case with the Tier 2 approach.

3.2.2 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 average dietary composition and milk yield of both regions can be found in the reports: Dierlijke mest en mineralen (2011-2022)). 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.,* 2022). The Tier 3 approach does not account for the effects of feed additives that could demonstrably mitigate enteric CH_4 emissions.

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

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

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

Where

Y_m	:	Methane conversion factor (fraction of GE intake converted into CH_4)

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

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

1. The chemical composition of dry-matter intake in the various dietary components (e.g. grass herbage, grass silage, maize silage, low-protein concentrates, protein-rich concentrates and wet by-products). A distinction is made between soluble carbohydrates (including sugars), starch, cell walls (hemi-cellulose, cellulose and lignin), crude protein (including a distinction of the ammonia fraction), crude fat and crude ash. Data on the composition is derived from information provided by the laboratory of Eurofins Agro (formerly Blgg and AgroXpertus) (eurofins-agro.com), which analyses the majority of roughages in the Netherlands, as well as from producers of compound feed. The data used for these calculations have been described previously by Smink *et al.* (2005). Between 1990 and 2008, CBS (2019) revised the WUM rations, including new calculations and data on chemical composition developed by Bannink (2011). Part of the ensiled roughage is not fed to dairy cattle in the same year in which the roughage analysis was performed. A correction for ensiled roughage has therefore been made in the annual ration calculations (Cbs, 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 2022). 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 CH_4 production. Because they are internal model parameters, they do not have to be provided as input to the model. In the current method, the simulation model adopts empirical equations to predict the fractional passage rates and fluid volume as a function of dry-matter intake, and acidity is calculated as a function of the predicted concentration of volatile fatty acids according to Mills *et al.* (2001). The sensitivity of model predictions for these parameter values and their effect on uncertainty have been described previously (Bannink, 2011).

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:

$$\text{EF } CH_4 \text{ enteric fermentation}_{\text{dairy cattle}} = (DM \times 365 \times GE / DM_{\text{average}} \times Y_{m,\text{ average}} / 55.6 \quad (3.3)$$

Where

EF CH_4 enteric fermentation$_{\text{dairy cattle}}$	:	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
$Y_{m,\text{ average}}$	:	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 (Ruyssenaars *et al.*, 2022) and therefore, for all cattle categories excluding mature dairy cattle, a country specific Tier 2 approach is used to calculate country-specific and year-specific emission factors for this group. The general emission-factor calculation is expressed by the following equation:

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

Where

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

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

Gross energy intake is calculated according to the following equation:

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

Where

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

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

Feed intake and rations of cattle, excluding mature dairy cattle

Feed intake levels and dry-matter intake were calculated by WUM (Cbs, 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:

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

Where

$EF\ CH_4$ enteric fermentation$_{\text{white veal}}$	:	Emission factor (kg CH_4/animal/year) from enteric fermentation of white veal calves
$Y_{m,\ \text{milk products}}$	:	Methane conversion factor for milk products
$GE_{\text{milk products}}$	:	Gross energy intake (MJ/animal/year) with milk products
$Y_{m,\ \text{other ration components}}$	:	Methane conversion factor for other ration components
$GE_{\text{other ration components}}$	:	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 CH_4 is assumed to bear no uncertainty. For mature dairy cattle the uncertainty is determined based on model simulations and estimated to be 15% (Bannink *et al*., 2011; Bannink, 2011).

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

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

Livestock category	**U DM intake**	**U feed energy content**	**U Y_m**	**U energy content CH_4**
Young cattle				
Female young stock for breeding < 1 year	5%	2.5%	20%	0%
Male young stock for breeding < 1 year	10%	2.5%	20%	0%
Female young stock for breeding ≥ 1 year	5%	2.5%	20%	0%
Male young stock for breeding ≥ 1 year	10%	2.5%	20%	0%
Veal calves, for white veal production	2%	2.5%	10%	0%
Veal calves, for rosé veal production	2%	2.5%	10%	0%

Livestock category	U DM intake	U feed energy content	U Y_m	U energy content CH_4
Female young stock for fattening < 1 year	5%	2.5%	20%	0%
Male young stock (incl. young bullocks) for fattening < 1 year	10%	2.5%	20%	0%
Female young stock for fattening ≥ 1 year	5%	2.5%	20%	0%
Male young stock (incl. young bullocks) for fattening ≥ 1 year	10%	2.5%	20%	0%
Other mature cattle				
Suckling cows (incl. fattening/grazing) ≥ 2 years	5%	2.5%	20%	0%

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 CH_4 from enteric fermentation.

Table 3.3 Uncertainty estimates (% of value) for CH_4 emissions, activity data (AD) and implied emission factors (IEF) from 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%	23%	23%
3A1c	Growing cattle	1%	12%	12%
3A2	Sheep	10%	40%	41%
3A3	Swine	6%	40%	41%
3A4a	Goats	10%	40%	41%
3A4b	Horses	39%	40%	58%
3A4c	Mules and Asses	5%	40%	41%
	Total			11%

4 CH_4 emissions from manure management (CRF sector 3B)

4.1 Scope and definition

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

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

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

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

4.2 Source-specific aspects for CH4 emissions from manure storage

4.2.1 Calculation method

Because cattle, pigs and poultry are regarded as key sources (Ruyssenaars *et al.*, 2022), emission factors are calculated according to a Tier 2 approach.

Tier 2

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

$$CH_4 \text{ emissions manure management} = \sum AAP_i \times FRAC_{j,\text{ manure management}} \times EF\ CH_4 \text{ manure management}_{ij} \quad (4.1)$$

Where:

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

Tier 1

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

$$CH_4 \text{ emissions manure management} = \sum AAP_i \times EF\ CH_4 \text{ manure management}_i \quad (4.2)$$

Where:

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

4.2.2 Activity data

Livestock numbers

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

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

Distribution between manure management systems
The proportions of slurry and solid manure 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:

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

Where

EF for CH_4 manure management$_{ij}$	:	Emission factor (kg CH_4/animal) for the manure management of livestock category (i) and manure management system (j)
VS_i	:	Volatile solids (kg VS/year) excreted by the livestock category (i)

$FRAC_{manure\ treatment}$	:	Fraction of the manure that is treated
B_{oi}	:	Maximum methane production potential (m^3 CH_4/kg VS) for the manure produced by the livestock category (i)
MCF_{ij}	:	Methane-conversion factor for the livestock category (i) and manure management system (j)
0.67	:	Density of methane (kg/m^3)

Maximum methane production potential (B_o)
The value of B_o depends on the degradability of the organic components in the manure. This value is expressed in m^3 CH_4/kg VS and is 0.22 for cattle manure, 0.31 for pig manure, and 0.34 for poultry manure (Groenestein *et al.*, 2016).

Methane-conversion factor (MCF)
The MCF indicates the share of B_o that will actually be converted into methane, depending on the environmental conditions. The most important factors are storage time, inoculation, temperature, the availability of oxygen, dry-matter content and manure coverage (hard cover, floating, crust or otherwise). In the Netherlands, farmers are required to store the manure for six or seven months, as it is forbidden to apply manure from September to February (obligation related to implementtation of the Nitrates Directive). For this reason, long-term measurements are needed in order to estimate the annual CH_4 emissions from which the MCF can be deduced, while environmental factors must be representative of the Dutch situation. Additionally, in analysing the measurements from housing systems, correction for enteric methane production is necessary 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
Slurry	
Cattle	0.17
Pigs	0.36
Laying hens	0.36
Solid manure	
Cattle	0.02[1]
Pigs	0.02[1]
Poultry	0.015
Pasture manure	
Cattle	0.01[1]

1) Default IPCC MCF values

4.2.4 *Uncertainty*

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

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

Livestock category	**MMS**	**U MCF (%)**	**U B_o (%)**	**U VS (%)**
Cows in milk and in calf	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
	Pasture	35.3	11.1	20
Female young stock for breeding	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
	Pasture	35.3	11.1	20
Male young stock for breeding	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
Veal calves, for white veal production	Slurry	35.3	11.1	10
Veal calves, for rosé veal production	Slurry	35.3	11.1	10
Female young stock for fattening	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
	Pasture	35.3	11.1	20
Male young stock (incl. young bullocks) for fattening	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
Suckling cows (incl. fattening/grazing) ≥ 2 years	Slurry	35.3	11.1	10
	Solid	70.5	11.1	10
	Pasture	35.3	11.1	20
Pigs	Slurry	35.3	13.6	10
	Solid	70.5	13.6	10
Poultry	Solid	70.5	13.6	10
	Slurry	35.3	13.6	10

4.3 Source-specific aspects for CH4 emissions from manure treatment

4.3.1 *Calculation method*

The CH_4 emissions from manure treatment are calculated based on the amount of VS in the treated manure. The following six types of manure treatment are distinguished: separation, nitrification/denitrification, production of mineral concentrates, incineration, pelleting/drying and manure digestion. It is assumed that half of the regular CH_4 emissions from manure storage has taken place before the manure is treated. For all techniques except for digestion, these values are replaced by emissions from the storage of manure treatment products. Emissions are assumed to occur in the digestion-only process. For purposes of simplification, storage emissions during and after processing are combined and expressed as a single emission factor for ingoing VS manure.

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

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

Where:

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

4.3.2 *Activity data*

Livestock numbers

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

Volatile solids (VS)

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

Fraction of treated manure

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

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
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%	30%
Young cattle	Separation	50%	30%
Veal calves	Separation	50%	30%
Fattening pigs	Separation	50%	30%
	Mineral concentrates	50%	30%
Breeding pigs	Separation	50%	30%
	Mineral concentrates	50%	30%
Laying hens	Pelleting/drying	25%	30%
	Incineration	25%	30%
Broilers	Pelleting/drying	25%	30%
	Incineration	25%	30%
Turkeys	Pelleting/drying	25%	30%
	Incineration	25%	30%
Mature dairy cattle	Digestion	50%	30%
Young cattle	Digestion	50%	30%
Fattening pigs	Digestion	50%	30%
Breeding pigs	Digestion	50%	30%

4.4 Uncertainty estimates

In NEMA uncertainty values for manure management and manure treatment are calculated separately, in order to account for differences in circumstances and thus in the associated emissions. The output of the model is at the level of detail shown in Table 4.3, Table 4.5 and Annex 10.

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 CH_4 emission from manure management.

Aggregation of uncertainties for CH_4 manure management and manure treatment
Uncertainty values for emissions from manure management and manure treatment are aggregated to the 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 CH_4 emissions from manure management

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

5 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 NH_3 emissions from manure management, using the following NFR categories:

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

Buffalo (3B4a) are reported as '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 NH_3 from manure management are the sum of emissions from animal housing (including inside manure storage), outside manure storage and manure treatment (Figure 5.1). These emissions originate mainly from nitrogen excreted in the urine and to a small extent from mineralised organically bound N in faeces. In mammals, this N is excreted as urea (CH_4N_2O) and, in birds, as uric acid ($C_5H_4O_3N_4$). Both urea and uric acid are converted by bacterial enzymes (urease and uricase) into ammonium (NH_4^+). For urea, this process usually takes less than 24 hours (Elzing and Monteny, 1997), while uric acid breaks down more slowly (Groot Koerkamp, 1998). At high pH levels, NH_4^+ is converted to NH_3, which is emitted in a process affected by various factors, both physical (e.g. air speed, area and temperature) and chemical (e.g. NH_4^+ concentration, pH and ion strength).

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

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

- Gaseous N components are formed from NH_4^+ in manure. Research under controlled conditions has demonstrated that NH_3 emissions are more closely related to NH_4^+ content than to the content of total N in manure (e.g. Velthof *et al.*, 2005).
- A measure that does not change the total amount of N in the manure, but that does change the amount of TAN affects NH_3 emissions as well. This effect cannot be calculated with an emission factor based on total N. In addition to having an effect on total N excretions, rations have an effect on the share of TAN in the excretions (Annex 1, Annex 2 and Annex 3). The effects of ration composition on NH_3 emissions is better quantified with a methodology based on TAN.
- The emission factor for the application of manure is based on TAN (Section 10.3). In the methodology that was previously used in the Netherlands, emissions after application were calculated based on standard TAN contents in the manure, as derived from literature. These data are not influenced by changes in rations or housing systems. The calculation of NH_3 emissions after the application of manure according to the calculated TAN content of the manure also reveals the effects of rations and housing systems on TAN in emissions after application.
- The TAN-based methodology draws connections to internationally accepted concepts of NH_3 calculation methods (Reidy *et al.*, 2008; Reidy *et al.*, 2009), as well as to the Emission Inventory Guidebook of EMEP/EEA that is used in European and UNECE contexts (EEA, 2019).

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

The method for calculating NH_3 emissions based on TAN excretion rates also takes into account the net mineralisation of organic N that occurs in the manure (Annex 4). Methods for calculating the animal-excretion rate of TAN are based on ration data and animal productivity, as drafted in Annex 1, Annex 2 and Annex 3. These calculations are performed annually by the WUM to quantify dietary effects in estimates of TAN excretion and NH_3 emissions (e.g. changes in roughage production and composition, and the consequent changes in the composition and feeding quality of rations). The actual ration compositions and N-digestibility of the separate components are taken as the starting point for the TAN calculations, instead of fixed TAN values or empirically averaged digestion values (Velthof et al., 2012). The method for calculating the TAN excretions of dairy cattle is consistent with the Tier 3 approach for estimating enteric 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 NH_4^+, especially in dried manure. The amount of NH_4^+/uric acid in the applied manure is uncertain. For this reason, no correction has been made. In subsequent sections, uniform calculation rules are provided, based on TAN values for all livestock categories.

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

1. The TAN excreted by the animal is calculated as the excretion of N in urine.
2. The amount of TAN produced by net mineralisation is calculated from the excretion of organic N in faeces. In slurry, mobilisation exceeds immobilisation, while the reverse occurs in solid manure (for poultry manure, it is assumed that no mobilisation or immobilisation occurs).
3. The total amount of TAN in manure is equal to the sum of TAN excretions from Steps 1 and 2.
4. The emissions of NH_3 and other N compounds (N_2, N_2O 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.

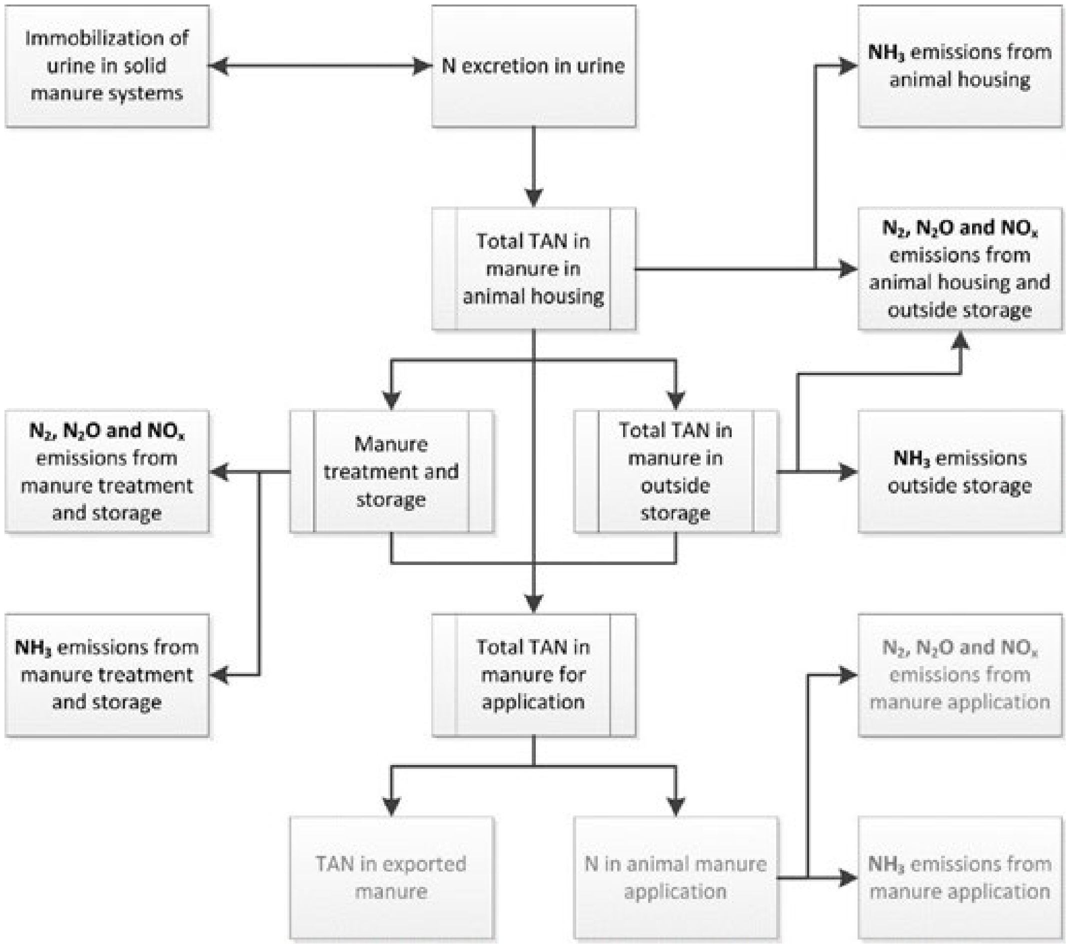

Figure 5.1 The flow of TAN throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to manure management

5.2 Source-specific aspects for NH3 emissions from animal housing

5.2.1 Calculation method

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

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

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

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

Where:

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

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

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

Where

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

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

5.2.3 *Emission factors*

NH_3 emission factor for each livestock category and housing system
Although different housing systems may have the same manure management system, this does not necessarily mean that their emission

factors will be the same. For this reason, a different emission factor is used for each type of housing system. The shares of housing systems for each livestock category are based on the Agricultural Census. If insufficient information on the shares of housing systems was available, other sources were used (e.g. environmental permit files for housing systems issued by the local authorities).

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

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

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

Where:

EF NH_3–N_{TAN} animal housing_{ij}	:	NH_3 emission factor (% of TAN excretions) for livestock category (i) and manure management system (j)
EF $NH_{3,}$ animal housing_{ik}	:	NH_3 emission factor (kg NH_3/animal place/year) for livestock category (i) and housing system (k)
$FRAC_{k,\ \text{occupancy},\ \text{Rav year}}$	:	Fraction of occupancy for each animal place for livestock category (i) and housing system (k), for the year in which the EF NH_3 for animal housing_{ik} was determined
$TAN_{i,\ \text{animal housing},\ \text{Rav year}}$	:	Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) for the year in which the emission factor for animal housing_{ij} was determined
$FRAC_{ik,\ \text{animal housing}}$	:	Fraction of housing system (k) for livestock category (i)
14/17	:	Conversion factor from NH_3 to NH_3-N, based on molecular weight

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

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

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

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

$$(\text{Nrest})_{\text{low}} = (\text{Nloss calculated from change in N/P-ration})_{\text{low}} - [(\text{NH}_3 \text{ calculated with emission factor})_{\text{low}} + (\text{Nother calculated with emission factor})] \quad (5.4)$$

Where:

$(\text{Nrest})_{\text{low}}$	:	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.
$(\text{Nloss calculated from change in N/P-ration})_{\text{low}}$	:	Amount of nitrogen lost based in difference in N/P ratio
$(\text{NH}_3 \text{ calculated with emission factor})_{\text{low}}$	:	Amount of N lost in the form of NH_3 based on the emission factor of low emission housing.

(Nother calculated with emission factor) : Amount of N lost in the form of N_2O, NO and N_2 based on the emission factor, which is a standard percentage from the N excretion.

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

Where:

(Nrest)$_{regular}$: The difference between the nitrogen loss from regular emission housing based on the change in N/P ratio and the calculated emissions with emission factors for NH_3 and for other N compounds such as N_2O, NO and N_2.

(Nloss calculated from change in N/P-ration)$_{regular}$: Amount of nitrogen lost based in difference in N/P ratio

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

(Nother calculated with emission factor) : Amount of N lost in the form of N_2O, NO and N_2 based on the emission factor, which is a standard percentage from the N excretion.

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

Where:

(NH_3 low emission housing) : Amount of NH_3 lost from low emission housing

(NH_3 calculated with emission factor)low : Amount of NH3 lost from low emission housing based on the emission factor of low emission housing

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

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

- The emission factor of low-emission housing of dairy was set equal to the emission factor of traditional housing, with the exception of the tie stall with liquid manure. Few farms still use this housing system and the study performed by statistics Netherlands could not ensure that their study was representative for the entire time series. Therefore it was decided to keep the current emission factor of this housing system.
- The emission factor of low-emission housing of all pig categories with floor or manure storage adaptations was adjusted. This was based on the change in N/P ratio of manure in housing systems for fattening pigs. When both the emission factors and the N/P ratios of traditional and low emission housing were compared, more nitrogen from low emission housing was lost between the moment of excretion and export from the farm. The difference is assumed to be in the form of NH_3. The result is a higher emission factor for NH_3. The effect of housing systems with air scrubbers could not be assessed in the study of Statistics Netherlands because information about the removal of nitrogen in the flushing water of air scrubbers is lacking. Housing systems with air scrubbers therefore keep their low emission factor.
- The emission factor of low-emission housing of poultry was adjusted depending on the housing system. Aviary systems without aeration of manure were not changed as these systems cannot be compared to the traditional housing system. The emission factor of aviary systems with manure aeration were set to the emission factor of the traditional aviary system. For the other laying hen housing systems 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.* (2022). Occupancy refers to the number of animal places that are actually occupied by animals during the year. There are several reasons to explain why an animal housing unit might not be filled to capacity. In most cases, the reason is related to a period in which the animal housing unit is unoccupied between production rounds. Loss of animals, earlier selection of animals or other reasons for vacancies during a period of growth and rearing (as described in Stichting Groen Label, 1996) and in Ogink *et al.*, 2008) are not considered.

5.2.4 *Uncertainty*
Calculation of the overall uncertainty of NH_3 emissions from animal housing begins by estimating the uncertainty value for TAN excretions for each aggregated livestock category over a given manure type. These uncertainty estimates are subsequently multiplied by the uncertainty value for the NH_3 emission factor for animal housing. This method was

selected because the emission factors of housing systems for the various livestock subcategories can originate from the same activity data, and they are therefore dependent on each other.

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

5.3 Source-specific aspects for NH3 emissions from manure treatment

5.3.1 Calculation method

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

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

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

Where:

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

5.3.2 *Activity data*

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

Treated manure N
The amount of manure that has been treated and its N content can be estimated based on registered manure transports (data from the Netherlands Enterprise Agency; RVO).

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

5.3.3 *Emission factors*

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

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

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

5.3.4 *Uncertainty*

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

5.4 Source-specific aspects for 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 NH_3, NO_x, N_2O and N_2. The input of TAN into outside storage facilities is established by multiplying the result by the fraction of manure stored.

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

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

Where

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

5.4.2 *Activity data*

Livestock numbers

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

TAN in animal housing

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

Activity data for outside manure storage

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

5.4.3 *Emission factors*

NH_3 emission factor for outside manure storage

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

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

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

$management_{ij}$	:	N_2 emissions (kg N) for animal housing for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined
$FRAC_{ik,\ animal\ housing}$	:	Fraction of housing system (k) within animal category (i)
$TAN_{ij,\ animal\ housing}$	:	Sum of urine excretions and net N mineralisation in animal housing (TAN; kg N/year) for livestock category (i) and manure management system (j) for the year in which the emission factor for outside storage was determined

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

Fraction of manure stored outside
Information on the fractions of manure stored outside animal housing, are taken from the Agricultural Census and complemented with data taken from literature. An overview of the percentages and sources is provided in annex 13 of van Bruggen (2023).

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

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

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

5.5 Uncertainty estimates
In NEMA the uncertainty values for emissions from animal housing and outside manure storage facilities are calculated separately, in order to

account for differences in circumstances and thus in the associated emissions. The output of the model is at the level of detail shown in Table 5.1 and Annex 11 (available through www.prtr.nl).

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

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

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

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

6.1 Scope and definition

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

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

Category 3B4a (Buffalo) is reported as '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 (NH_4^+) is converted into nitrate by bacteria under conditions of high oxygen. In this process, nitrous oxide can be formed as a by-product, particularly if the nitrification is limited through lack of oxygen. Nitrification does not require the presence of any organic substances (volatile solids). Straw-rich solid manure and poultry manure can possess a relatively open and loose structure, allowing O_2 to diffuse far more easily than it does in slurry, thus enabling nitrification.

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

6.2 Source-specific aspects for NOx emissions from manure storage

6.2.1 Calculation method

In contrast to the case of NH_3 from animal housing and outside manure storage, emissions of NO_x are calculated for animal housings and outside manure storages combined. The following formula is used to calculate NO_x emissions from animal manure:

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

Where:

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

6.2.2 Activity data

Livestock numbers

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

N excretions per animal and manure management system

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

6.2.3 Emission factors

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

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

Manure management system	EF in kg NO_x-N/kg N manure excreted in animal housing
Slurry (except poultry)	0.002
Solid manure (except poultry)	0.005

Manure management system	EF in kg NO_x-N/kg N manure excreted in animal housing
Poultry	0.001
Goats, deep bedding	0.01

6.2.4 *Uncertainty*

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

6.3 Source-specific aspects for NOx emissions from manure treatment

6.3.1 *Calculation method*

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

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

$$NO_x \text{ emissions manure treatment} = \sum N_{io,\text{ manure treatment}} \times EF\ NO_x \text{ from manure treatment}_{io} \tag{6.2}$$

Where:

NO_x emissions manure Treatment	:	NO_x emissions from manure treated (kg NO_x/year)
$N_{io,\text{ manure treatment input}}$	:	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).

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

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

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

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

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

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

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

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

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

7 N_2O emissions from manure management (CRF sector 3B)

7.1 Scope and definition

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

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

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

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

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

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

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

7.2 Source-specific aspects for direct N2O emissions from manure storage

7.2.1 *Calculation method*

Direct N_2O emissions from animal manure are calculated as follows:

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

Where:

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

Comparison to IPCC methodology

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

7.2.2 *Activity data*

Livestock numbers

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

N excretions for each animal and manure management system

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

7.2.3 *Emission factors for direct 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 N_2O from manure management are available in the Netherlands. The available data suggest that emissions of N_2O from animal housing and outside manure storage facilities could be lower than the defaults. Due to the limited data available, however, it was decided to maintain the current methodology based on the IPCC Guidelines and Oenema *et al.* (2000), thus resulting in a conservative estimate of emissions.

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

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

7.2.4 *Uncertainty*

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

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

7.3.1 *Calculation method*

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

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

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

Where:

N₂O emissions manure Treatment : N_2O emissions from manure treated (kg N_2O/year)

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

7.3.2 *Activity data*

Livestock numbers

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

N excretions for each livestock category in a given year

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

Treated manure N

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

NH_3, NO_x and N_2 emissions

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

7.3.3 *Emission factors*

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

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

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

7.3.4 *Uncertainty*

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

7.4 Source-specific aspects for indirect N2O emissions from manure management

7.4.1 Calculation method

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

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

Where:

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

Comparison to IPCC methodology

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

7.4.2 *Activity data*

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

7.4.3 *Emission factors*

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

7.4.4 *Uncertainty*

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

7.5 Uncertainty estimates

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

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

Uncertainty values calculated for emissions from direct manure management, manure treatment and indirect manure management are aggregated to the 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 N_2O emissions from manure management

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

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

8.1 Scope and definition

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

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

Category 3B4a (Buffalo) is reported as ‘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:

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

Where:

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

Other livestock

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

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

Where:

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

8.2.2 *Activity data*

Livestock numbers

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

Feed intake

The gross energy intake of cattle, the VS excretion of pigs and poultry, and the time spent inside animal housing are calculated by the WUM (CBS, 2008 through 2022). 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:

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)
FRAC$_{i,\ \text{time spent inside}}$	:	Fraction of time spent inside animal housing (i)
EF NMVOC silage feeding$_i$	:	Emission factor (kg NMVOC/MJ) of NMVOC from the feeding of silage for cattle category (i)
FRAC$_{i,\ \text{silage}}$	:	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:

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$_i$	:	Average animal population for livestock category (i)
VS$_i$	:	Excreted volatile solids

		(kg/animal/year) for livestock category (i)
$FRAC_{i, \text{time spent inside}}$	:	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)
$FRAC_{i, \text{silage}}$	:	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:

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

Where:

NMVOC emissions manure storage_{cattle}	:	NMVOC emissions (kg NMVOC) for all cattle categories (i) within NFR category 3B (Manure management)
AAP_i	:	Average animal population for cattle category (i)
NMVOC emissions animal housing_{cattle}	:	NMVOC emissions (kg NMVOC/animal/year) from manure in animal housing for cattle category (i)
NH_3 emissions manure storage_i	:	NH_3 emissions (kg NH_3/year) from manure storage facilities outside animal housing for cattle category (i)
NH_3 emissions animal housing_i	:	NH_3 emissions (kg NH_3/year) from animal housing for cattle category (i)

Other livestock

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

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

Where:

NMVOC emissions manure storage_{other}	:	NMVOC emissions (kg NMVOC) for all other livestock categories (i) within NFR category 3B (Manure management)
NMVOC emissions animal housing_i	:	NMVOC emissions (kg NMVOC/animal/year) from manure in animal housing for livestock category (i)
NH_3 emissions outside storage_i	:	NH_3 emissions (kg NH_3/year) from outside manure storage facilities for livestock category (i) NH_3 emissions
animal housing_i	:	NH_3 emissions (kg NH_3/year) from

animal housing for livestock category (i)

8.4.2 Activity data

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

8.4.3 Emission factors

The Tier 2 default emission factors from the EMEP Guidebook are used (EEA, 2019).

8.4.4 Uncertainty

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

8.5 Uncertainty estimates

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

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

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

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

EMEP	Livestock category	U AD	U IEF	U emissions
3B1a	Dairy cattle	2%	220%	220%
3B1b	Non-dairy cattle	1%	131%	131%
3B2	Sheep	6%	283%	283%
3B3	Swine	8%	221%	221%
3B4d	Goats	5%	302%	302%
3B4e	Horses	42%	256%	260%
3B4f	Mules and asses	12%	252%	252%
3B4gi	Laying hens	2%	209%	209%
3B4gii	Broilers	5%	302%	302%
3B4giii	Turkeys	5%	302%	302%
3B4giv	Other poultry	5%	302%	302%
3B4h	Other animals	5%	297%	297%
3B	Total			152%

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

9.1 Scope and definition

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

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

Category 3B4a (Buffalo) is reported as '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 PM_{10} and $PM_{2.5}$ emissions in Dutch agriculture. Over time, slurry-based housing systems for laying hens have been replaced by systems that produce solid manure, leading to higher emissions of PM. Pigs and cattle contribute to the production of PM as well, albeit to a lesser extent. The increasing use of air scrubbers in housing systems for pigs is decreasing the emission of PM (Melse *et al.*, 2018).

9.2 Source-specific aspects

9.2.1 Calculation method

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

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

Where:

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

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

9.2.2 *Activity data*

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

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

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

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

9.2.3 *Emission factors*

The emission factors are based on a measurement programme conducted by WUR Livestock Research between 2007 and 2009 (publication series 'Particulate matter emission from animal houses', in Dutch; (Mosquera *et al.*, 2009a; Mosquera *et al.*, 2009b; Mosquera *et al.*, 2009c; Winkel *et al.*, 2009a; Winkel *et al.*, 2009b; Winkel *et al.*, 2009c; Mosquera *et al.*, 2010a; Mosquera *et al.*, 2010b; Mosquera *et al.*, 2010c; Huis in 't Veld *et al.*, 2011; Mosquera *et al.*, 2011; Winkel *et al.*, 2011). Measurements of PM emissions from housing were not conducted for all livestock categories. For categories that were not measured, emission factors were deduced from factors measured for similar livestock categories, using ratios of fixed P excretions (Chardon and Van der Hoek, 2002) as a scale factor. An overview of housing systems and emission factors for PM_{10} and $PM_{2.5}$ is provided in Table 9.1.

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

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

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

Livestock category	Housing system	EF PM_{10}	EF $PM_{2.5}$
Dairy cattle			
Female young stock < 1 year	Traditional	37.7	10.4
Male young stock < 1 year	Traditional	170.1	46.8
Female young stock 1-2 years	Traditional	37.7	10.4
Male young stock 1-2 years	Traditional	170.1	46.8
Female young stock ≥ 2 years	Traditional	117.8	32.5
Cows in milk and in calf	Tie-stall system	80.8	22.3
	Cubicle system, grazing[1)]	117.8	32.5
	Cubicle system, no grazing[1)]	147.5	40.6
Bulls for service ≥ 2 years	Traditional	170.1	46.8
Cattle for fattening			
Veal calves, for white veal production	Traditional[2)]	35.7	9.8
Veal calves, for rosé veal production	Traditional[2)]	35.7	9.8
Female young stock < 1 year	Traditional	37.7	10.4
Male young stock < 1 year (incl. young bullocks)	Traditional	170.1	46.8
Female young stock 1-2 years	Traditional	37.7	10.4
Male young stock 1-2 years (incl. young bullocks)	Traditional	170.1	46.8
Female young stock ≥ 2 years	Traditional	86.2	23.8
Male young stock ≥ 2 years (incl. young bullocks)	Traditional	170.1	46.8
Suckling cows ≥ 2 years (incl. fattening/grazing)	Traditional	86.2	23.8
Pigs			
Piglets	Traditional partially raster[1), 2)]	81.2	2.0
	Traditional fully raster[1), 2)]	62.0	2.1
Fattening pigs and growing pigs	Traditional[1), 2)]	157.3	7.4
Sows, pregnant and open	Traditional, individual[1), 2)]	186.3	16.0

Livestock category	Housing system	EF PM_{10}	EF $PM_{2.5}$
	Traditional, group1), 2)	173.7	12.1
Sows with piglets	Traditional2)	164.9	14.2
Boars for service	Traditional2)	185.6	15.9
Poultry			
Broilers	Traditional1), 2), 4)	26.8	2.0
Broiler breeders < 18 weeks	Floor housing3)	17.0	1.3
Broiler breeders ≥ 18 weeks	Cage housing	8.7	1.8
	Floor housing + aviary1), 2), 4)	49.1	3.8
Laying hens < 18 weeks	Battery3), 5)	2.2	0.4
	Colony housing	9.6	0.9
	Floor housing2), 4)	34.8	1.7
	Aviary housing	26.9	1.6
Laying hens ≥ 18 weeks	Battery3), 5)	5.4	1.1
	Enriched cage/colony housing	24.0	2.3
	Floor housing1), 2), 4)	87.1	4.2
	Aviary housing1)	67.3	4.0
Ducks	Traditional	104.5	5.0
Turkeys	Traditional1)	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)	Traditional1)	8.1	4.2
Foxes (mother animals)	Traditional	8.1	4.2
Sheep	Traditional	19.0	5.7
Goats	Traditional	19.0	5.7
Horses6)	Traditional	220.0	140.0
Ponies6)	Traditional	220.0	140.0
Mules and asses6)	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 PM_{10} and $PM_{2.5}$ from manure management

Livestock category	Uncertainty PM_{10}	Uncertainty $PM_{2.5}$	Source
Dairy cows	32%	35%	Greatest uncertainty[1)] in particulate-matter emissions from animal housing: dairy cows (Mosquera *et al.*, 2010a) (47.4 x 100% / 147.5 = 32%)
Other cattle	32%	35%	Equal to dairy cows
Goats	32%	35%	Equal to dairy cows
Fattening pigs	45%	55%	Greatest uncertainty in particulate-matter emissions from animal housing: fattening pigs (Mosquera *et al.*, 2010b) (65.4 x 100% / 144.0 = 45%)
Sows	48%	52%	Greatest uncertainty in particulate-matter emissions from animal housing: gestating sows (Winkel *et al.*, 2009b; Mosquera *et al.*, 2010c) (82.6 x 100% / 173.7 = 48%)
Laying hens	44%	100%	Greatest uncertainty in particulate-matter emissions from animal housing: laying hens in animal housing with a drying tunnel (Mosquera *et al.*, 2009a; Mosquera *et al.*, 2009b; Winkel *et al.*, 2009a; Winkel *et al.*, 2011) (1.7 x 100% / 3.9 = 44%)
Broilers	33%	45%	Greatest uncertainty of particulate-matter emissions from animal housing: broilers (Winkel *et al.*, 2009c) (8.8 x 100% / 26.8 = 33%)
Ducks	33%	45%	Equal to broilers
Turkeys	33%	45%	Equal to broilers
Rabbits	49%	100%	Greatest uncertainty in gaseous emissions and particulate matter from rabbit animal housing with manure storage under the welfare cages (Huis in ’t Veld *et al*., 2011) and report minks (Mosquera *et al*., 2011) (5.21 x 100% / 10.7 = 49%)
Fur-bearing animals	49%	100%	Uncertainty value for rabbits used

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 PM_{10} and $PM_{2.5}$ emissions from animal housing

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

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

10.1 Scope and definition

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

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

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

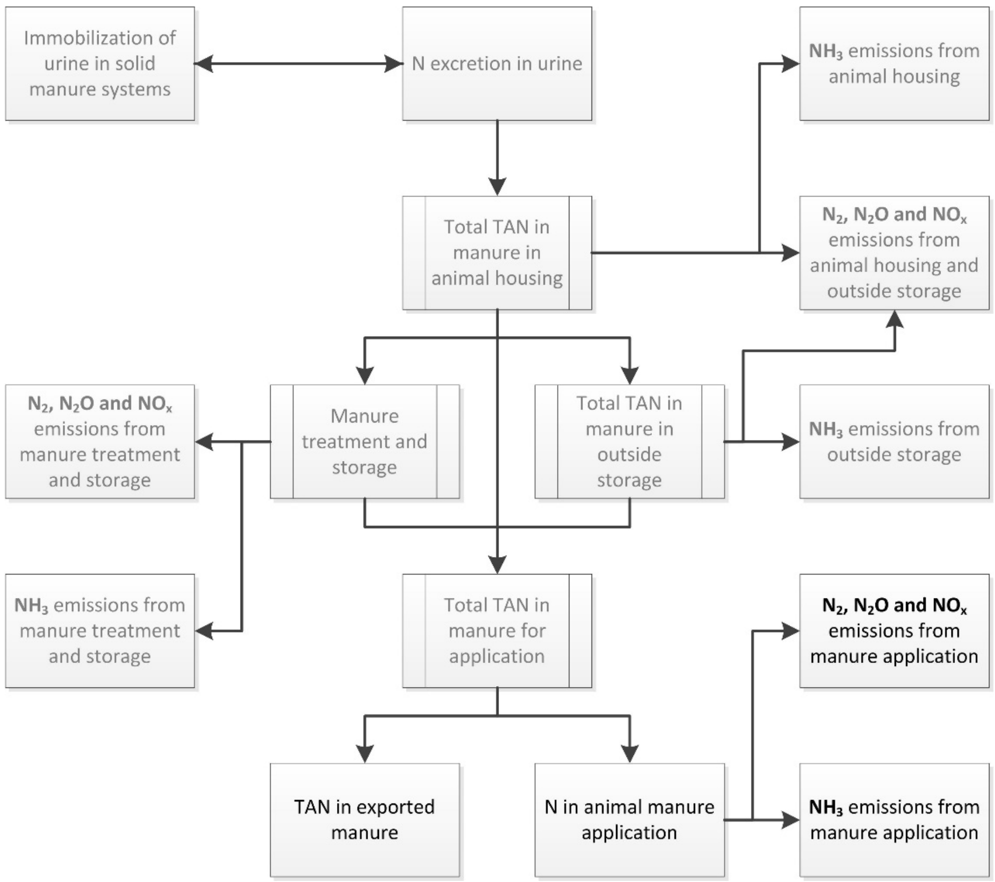

Figure 10.1 TAN flow throughout the model and the accompanying emissions, with the text in boldface including all emissions relevant to crop production and agricultural soils.

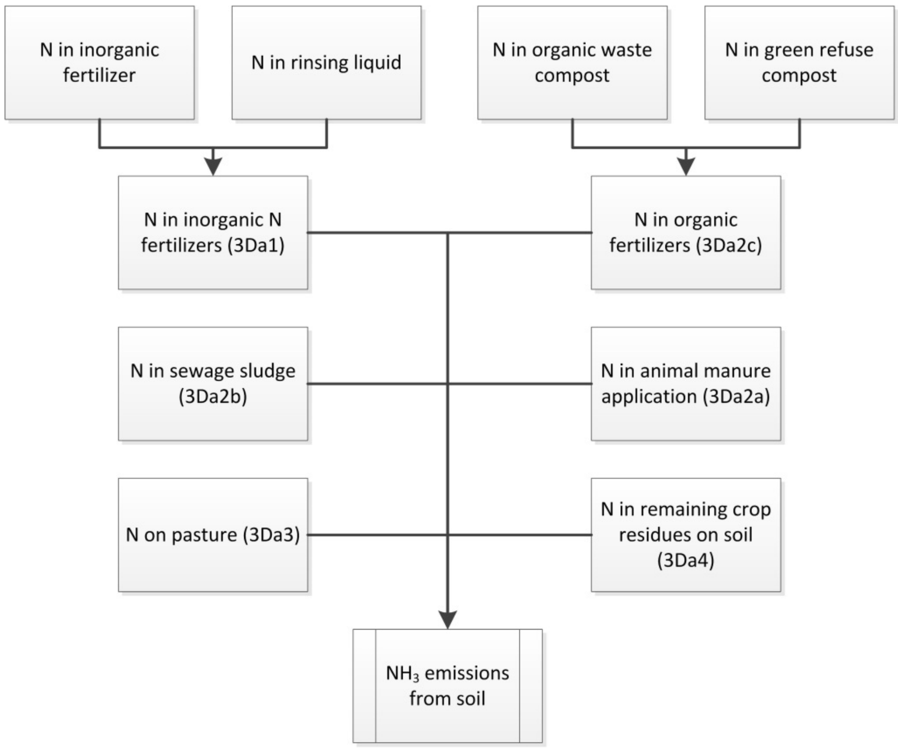

Figure 10.2 Source categories contributing to NH_3 emissions from agricultural soils

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

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

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

10.2.1 Calculation method

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

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

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

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

Where:

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

10.2.2 *Activity data*

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

Crop

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

Fertilizer type

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

- Ammonium sulphate nitrate: This fertilizer type contains both ammonium nitrate and ammonium sulphate. The emission factor

is equal to the average emission factor for ammonium nitrate and ammonium sulphate.
- Nitrogen magnesium: This type of fertilizer resembles calcium ammonium nitrate, but contains $MgCO_3$ besides $CaCO_3$. This difference does not require a different emission factor.
- Chilean nitrate, calcium nitrate and potassium nitrate: These types of fertilizer contain only nitrate N and no ammonium. Their use therefore does not result in NH_3 emissions from the soil, and the emission factor is set to 0%.
- 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 inhibiter	14.3
Urea – granular with urease inhibitor	5.9[2)]
Urea – liquid, surface-applied	7.5[2)]
Urea – liquid, injected	1.5[2)]
Urea – liquid with urease inhibitor or acid, surface-applied	3.1[2)]
Urea – greenhouse horticulture	0.0[2)]
Liquid ammonia	2.3
Sulphur-coated urea	7.1

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

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

10.2.4 *Uncertainty*
The uncertainty analyses are based solely on the total amount of fertilizer. Uncertainty estimates at higher levels of aggregation are more robust, while providing the same overall uncertainty values as those produced when estimating for each category separately. Only rinsing liquid is estimated separately. Uncertainty values for the total amount of inorganic fertilizer applied are estimated at 25%, excluding rinsing liquid. A small proportion of fertilizers is used outside agriculture. If the uncertainty values for the use of inorganic fertilizer for agriculture and private purposes are disaggregated, the uncertainty value for the use of inorganic fertilizer in agriculture is 27%. The uncertainty value for the use of rinsing liquid is 40%.

10.3 Source-specific aspects for 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 NH_3, N_2O, NO_x and N_2 inside animal housing and during outside storage and manure treatment
- Amount of manure that is exported or treated and subsequently used outside Dutch agriculture
- Manure can also be applied to soils directly through grazing animals. Emissions occurring during grazing are calculated directly from TAN. In addition to manure application and grazing, the application of inorganic N fertilizer (including the rinsing liquid from air scrubbers) to agricultural soils is a source of NH_3 emissions. Emissions of NH_3 occur only if the fertilizer contains urea or when ammonium (NH_4^+) is applied to calcareous soils.

10.3.1 *Calculation method*

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

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

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

Where:

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

$FRAC_{j,\ application\ technique\ cropped\ land}$	:	Fractions of manure application techniques (m) for manure management system (j) used on cropped land
EF NH_3 application technique on cropped $land_{jm}$	:	NH_3-N emission factor (% of TAN) for manure application technique (m) for manure management system (j) used on cropped land
17/14	:	Conversion factor from NH_3-N to NH_3

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

The amount of TAN available for each livestock category/manure type is calculated by subtracting N emissions in animal housing, during manure storage and during manure treatment from the TAN excretion in animal housing. 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:

TAN for $application_{ij}$	:	Amount of manure (kg N) applied to agricultural soils, for livestock category (i) and manure management system (j)
TAN_i	:	TAN excretions (kg N) in animal housing for livestock category (i)
$FRAC_{j,\ manure\ management}$	:	Fraction of manure in the various management systems (j)
N losses in animal $housing_{ij}$	:	Sum of NH_3, N_2O, NO_x and N_2 losses (kg N) from animal housing for livestock category (i) and manure management system (j)
NH_3 emissions $storage_{ij}$	:	NH_3 emissions from outside manure storage facilities (kg N) for livestock category (i) and manure management system (j)
NH_3 emissions $treatment_{ij}$	:	NH_3 emissions from manure treatment (kg N) for livestock category (i) and manure management system (j)
N used outside $agriculture_{ij}$	:	Amount of manure (kg N) processed and marketed outside agriculture, for livestock category (i) and manure

		management system (j)
N $export_{ij}$	:	Amount of manure (kg N) exported, for livestock category (i) and manure management system (j), with import denoted as negative export

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

10.3.2 *Activity data*

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

Fractions of manure applied to land type
The amounts of manure applied to grassland, uncropped arable land and cropped arable land for the years 1990-1999 are based on the results of the calculations performed for purposes of monitoring the manure market. The data are supplied by the FADN of Wageningen Economic Research, and data on manure transports from the Netherlands Enterprise Agency have been used (Luesink *et al.*, 2008; De Koeijer *et al.*, 2012; De Koeijer *et al.*, 2014). For the years 2000-2021, the distributions of manure to grassland and arable have been derived with calculations using the Initiator model (Kros *et al.,* 2019). These distributions are the same as for the calculations of N_2O emissions from manure application (section 12.3.2).

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

10.3.3 *Emission factors*

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

The emission factors for manure application on grassland are based upon the exponential concentration profile model. This model fits the measured emissions of 160 different experiments to calculate the emission factors of the different application techniques for grassland. Emission factors for grassland were calculated using the Ryden & McNeill model. However, new research has shown that a better fit was achieved using an exponential concentration profile model. The new model leads to emission factors that are on average 10% lower than the previous emission factors (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 NH_3 volatilisation can be achieved on arable land. However, the reduction achieved by incorporation in a second pass is highly dependent on the time-lag between surface spreading and incorporation (Huijsmans and De Mol, 1999). The incorporation of the manure in a second pass always leads to a certain time lag. For this reason, the emission factors for surface incorporation in two passes and ploughing in were estimated as 46% and 35%, respectively, which are the average emission values for surface spreading and direct incorporation. The application and incorporation of slurry in two passes 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 NH_3 (% 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**
Grassland						
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
Cropland (uncropped)						
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
Cropland (cropped)						
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 NH_3 emissions from sewage-sludge application, a distinction is made between liquid and solid sludge, with a different TAN fraction for each type:

$$NH_3 \text{ emissions sewage sludge} = \sum (N_{sewage\ sludge} \times FRAC_{liquid} \times TAN_{liquid\ sewage\ sludge} \times EF\ NH_3 \text{ liquid sewage sludge}_m + N_{sewage\ sludge} \times FRAC_{solid} \times TAN_{solid\ sewage\ sludge} \times EF\ NH_3 \text{ solid sewage sludge}) \times 17/14 \quad (10.4)$$

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.) are used.
An exception is made for the first two years of the time series (1990 and 1991), in which the emission factor for surface spreading was used for both liquid and solid sewage sludge. The reason is that, before 1992, there was no obligation to incorporate sewage sludge into the soil immediately, but within a few days of application. With the use of this technique, NH_3 emissions had already occurred before incorporation.

10.4.4 Source-specific uncertainty

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

10.5 Source-specific aspects for 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 10.2), it is assumed that the fraction of TAN in both sources is equal. All compost is surface-applied on uncropped land:

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

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 23%. The uncertainty value for TAN is 25%. Uncertainty of the emission factor is estimated to be 100%. This differs from the uncertainty value for the emission factor for manure application, as emission factors are measured for manure and not for compost application.

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

10.6.1 *Calculation method*
The NH_3 emissions from urine and dung deposited by grazing animals is calculated from the following values:

- N excretions on 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 NH_3 emissions from grazing for all livestock categories (i) is calculated as follows:

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

Where:

NH_3 emissions grazing	:	NH_3 emissions (kg NH_3/year) from grazing
AAP_i	:	Average animal population for livestock category (i)
$TAN_{i,\,grazing}$	:	TAN excretions on pasture land (kg

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

TAN excretions on pasture land are calculated as follows:

$$TAN_{i,\ grazing} = N\ excretions\ on\ pasture_i \times FRAC_{i,\ TAN\ pasture} \quad (10.7)$$

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 P_2O_5 (Luesink *et al.*, 2011). This disposal of pasture manure is divided over the livestock categories based on the production of phosphate in pasture manure. The disposal of nitrogen is calculated from the disposal of phosphate and the N/P_2O_5 ratio of pasture manure. In addition to the production of pasture manure on nature terrain, the disposal of stored animal manure on nature terrain is subject to accounting through transport documents. The disposals registered through transport documents are counted as disposal on natural grassland, with the manure being applied above ground.

10.6.3 Emission factors

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

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

Application of inorganic N fertilizer

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

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

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

Grazing system

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

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

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

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

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

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

Where:

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

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

10.6.4 *Uncertainty*
The uncertainty values for livestock numbers, including the aggregation and disaggregation of subcategories, are provided in Section 2.4.3.

Uncertainty values for TAN are estimated at 10%. The uncertainty value of TAN excretions in nature areas is estimated at 50%, and that of the grazing emission factor is 100%.

10.7 Source-specific aspects for 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):

$$NH_3 \text{ emissions crop residues} = \sum \text{area}_n \times \text{N in above-ground residue}_n \times FRAC_{n,\ residues} \times EF\ NH_3 \text{ crop residue}_n \times 17/14 \qquad (10.10)$$

Where:

NH_3 emissions crop Residues	:	NH_3 emissions (kg NH_3/year) from crop residues
$Area_n$	:	The area covered by crop (in ha) for crop type (n)
N in above-ground $residue_n$	:	N contained within the crop residues (kg N/ha) for crop (n)
$FRAC_{n,\ residues}$	:	Fraction of residues contributing to NH_3 emissions (i.e. not incorporated into the soil in the first days after harvest) for crop (n)
EF NH_3 crop $residue_n$	:	Emission factor (% of N) for crop residues (n)
17/14	:	Conversion factor from NH_3-N to NH_3

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

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

10.7.2 Activity data

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

10.7.3 Emission factors

Data from the WUM were used to calculate the N contents of crop residues consisting of grass. Data available from De Ruijter *et al.* (2019) were used to calculate the N content of residues from other crops.

To calculate the percentage of N that is emitted as NH_3 from crop residues, a regression model was derived from literature describing the relationship between NH_3 emissions and the N content of residues (De Ruijter and Huijsmans, 2019):

$$EF\ NH_3\ crop\ residue = 0.41 \times N\ content_m - 5.42 \quad (10.11)$$

Where:

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

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

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

10.8 Source-specific aspects for 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 NH_3 between the stomata of the plants, the air layer directly above the crop and the atmosphere are modelled. Emission or deposition occurs, depending on the ambient NH_3 concentration and type of crop. These values were determined on an hourly basis and aggregated over the growing season.

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

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

10.8.3 *Emission factors*

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

10.8.4 *Uncertainty*

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

10.9 Uncertainty estimates

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

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

EMEP	Source category	U AD	U IEF	U emissions
3Da1	Inorganic N fertilizers	26%	26%	36%
3Da2a	Animal manure applied to soils	2%	30%	31%
3Da2b	Sewage sludge applied to soils	25%	85%	88%
3Da2c	Other organic fertilizers applied to soils	23%	106%	111%
3Da3	Urine and dung deposited by grazing animals	1%	48%	48%
3Da4	Crop residues applied to soils	18%	44%	45%
3De	Cultivated crops			300%
	Total, agricultural soils			25%

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

11.1 Scope and definition

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

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

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

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

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

11.2.1 Calculation method

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

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

Where:

NO_x emissions fertilizer	:	NO_x emission (kg NO_x/year, expressed as nitrogen monoxide) for inorganic N fertilizers
$N_{\text{inorganic fertilizer}}$	:	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. As of 2016, the usage of the various types of inorganic N fertilizers is taken from the statistics on inorganic fertilizer statistics available from the FADN. Consistency between these two data sources has been verified and confirmed (Van Bruggen *et al.,* 2019).

11.2.3 *Emission factors*

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

11.2.4 *Source-specific uncertainty*

The uncertainty value for usage is estimated at 27% for inorganic N fertilizer and 40% for rinsing liquid (Section 10.2.4). The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2019).

11.3 Source-specific aspects for NOx emissions from animal manure applied to soils

11.3.1 *Calculation method*

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

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

Where:

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

11.3.2 *Activity data*

The amount of N that is applied with manure to the soil is calculated from N excretions 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 NOx emissions from sewage sludge applied to soils

11.4.1 *Calculation method*
Total NO_x emissions from sewage sludge applied to soils are calculated as follows:

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

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 NOx emissions from other organic fertilizers applied to soils (including compost)

11.5.1 *Calculation method*
Total NO_x emissions from compost are calculated as follows:

$$NO_x \text{ emissions organic fertilizers} = \Sigma\, N_{\text{organic fertilizers}} \times \text{EF } NO_x \text{ organic fertilizers} \times 30/14 \quad (11.4)$$

Where:

NO_x emissions organic fertilizers	:	NO_x emissions (kg NO_x/year,

		expressed as nitrogen monoxide) from compost applied to agricultural soils
$N_{organic\ fertilizers}$	:	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 NOx emissions from urine and dung deposited by grazing animals

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

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

Where:

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

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

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

11.6.4 *Uncertainty*

The uncertainty value for the amount of nitrogen deposited on pasture land is calculated to be 19%, as described in Section 10.6. The uncertainty value for the emission factor is given as 160% in the EMEP Guidebook (EEA, 2019).

11.7 Source-specific aspects for NOx emissions from crop residues

2.1.1 *Calculation method*

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

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

Where:

NO_x emissions crop residues	:	NO_x emissions (kg NO_x/year, expressed as nitrogen monoxide) from crop residues left on agricultural soils
$N_{\text{crop residues}}$	:	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 NOx emissions from the agricultural use of organic soils

11.8.1 *Calculation method*

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

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

Where:

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

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

11.8.2 *Activity data*

The areas of organic soils cultivated are estimated from the land-use maps of the sector classified as ‘Land Use, Land Use Change and Forestry’ (LULUCF). Maps are available for the base years 1990, 2004, 2009, 2013, 2017 and 2021. Between these years, interpolation takes place. An overview of the areas is provided in Annex 22 of Van Bruggen *et al.* (2022).

11.8.3 *Emission factors*

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

11.8.4 *Uncertainty*

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

11.9 Uncertainty estimates

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

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

EMEP	Source category	U AD	U IEF	U emissions
3Da1	Inorganic N fertilizers	24%	160%	166%
3Da2a	Animal manure applied to soils	3%	160%	160%
3Da2b	Sewage sludge applied to soils	25%	160%	167%

EMEP	Source category	U AD	U IEF	U emissions
3Da2c	Other organic fertilizers applied to soils	25%	160%	167%
3Da3	Urine and dung deposited by grazing animals	19%	160%	164%
3Da4	Crop residues applied to soils	2%	153%	153%
	Total, agricultural soils			87%

12 N_2O emissions from crop production and agricultural soils (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 N_2O from the soil as a result of agricultural activities in the Netherlands. It refers to the CRF source categories 3Da (Direct N_2O emissions from managed soils) and 3Db (Indirect N_2O emissions from managed soils), subdivided into:

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

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

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

12.2 Source-specific aspects for direct N2O emissions from the application of inorganic N fertilizer

12.2.1 Calculation method

For the years 2000 to 2021, direct N_2O emissions from inorganic N fertilizers are calculated by multiplying the amount of nitrogen of inorganic N fertilizers by a country-specific emission factor which also takes the soil type and land use into account:

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

Where:

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

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

N_2O emissions inorganic fertilizer =∑ N$_{\text{inorganic fertilizer}}$ x EF N_2O inorganic fertilizer x 44/28 (12.1)

Where:

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

To prevent a time series inconsistency between 1990-1999 and 2000-2021, it was decided to apply for the years 1990-1999 the splicing overlap technique from the IPCC (IPCC, 2006).

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

Where:

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

X_0 : the estimate developed using the previously used method

Y_i : estimated emission using the new method during the overlap period
X_i : estimated emission using the old method during the overlap period
m : first year of the overlap period (2000)
n : last year of the overlap period (2007)

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

12.2.2 *Activity data*

Amount of nitrogen in inorganic N fertilizer applied to soil
Usage figures for the various types of inorganic N fertilizers are taken from the statistics on synthetic fertilizer available from Wageningen 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 2000-2021 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 N_2O-N per kg applied N This factor is the weighted mean of inorganic N fertilizers applied on mineral and peat soils (Velthof *et al.*, 2010; Velthof and Mosquera, 2011; Van Schijndel and Van der Sluis, 2011, see Annex 4). For the years 2000-2021, the emission factors for the application of inorganic N fertilizer are 0.008 N_2O-N per kg net applied N for grassland on mineral soil, 0,007 N_2O-N per kg applied N for arable land on mineral soil and 0,030 N_2O-N per kg applied N from grassland on both mineral and organic soils (Velthof and Mosquera, 2011).

12.2.4 *Uncertainty*

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

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

12.3.1 *Calculation method*

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

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

Where:

N_2O emissions manure application	:	N_2O emissions (kg N_2O) from the application of animal manure to agricultural soils
$N_{animal\ manure}$	:	Amount of N (kg N/year) from animal manure applied to soils
EF N_2O manure application$_i$	:	Emission factor (kg N_2O-N/kg N) for the application of N from animal manure for application technique (i)
44/28	:	Conversion factor from N_2O-N to N_2O

The use of animal manure is divided into two types of manure application techniques, above-ground application and incorporation into the soil. Each having its own country-specific emission factor, weighed for soil type (see Annex 9 and Velthof and Mosquera, 2011).

For the period 2000-2021, the direct N_2O emissions from the application of N from animal manure are calculated by multiplying the amount of nitrogen application from animal manure by a country-specific emission factor which takes the soil type and the land use into account.

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

Where:

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

These emissions are reported under their respective 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 9). For the years 2000-2021 the emission factors for surface spreading are: 0.005 kg N_2O-N per kg applied N on organic soils (both grassland and arable land), and 0.001 kg N_2O-N per kg applied N for grassland on mineral soil and 0.006 kg N_2O-N per kg applied N for arable land on mineral soil (Velthof and Mosquera, 2011). The emission factors of low-emission techniques are: 0.010 kg N_2O-N per kg applied N on organic soils (both grassland and arable land), and 0,003 kg N_2O-N per kg applied N for grassland on mineral soil and 0.013 kg N_2O-N per kg applied N for arable land on mineral soils. The amounts of manure applied using surface spreading and using low-emission techniques are taken from the Agricultural Census.

12.3.4 *Uncertainty*

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

12.4 Source-specific aspects for direct N2O emissions from sewage sludge applied to soils

12.4.1 *Calculation method*

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

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

Where:

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

These emissions are reported under their respective 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).

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

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

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

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

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

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

Where:

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

These emissions are reported under their respective 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).

12.5.2 *Activity data*

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

12.5.3 *Emission factors*

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

12.5.4 *Uncertainty*

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

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

12.6.1 *Calculation method*

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

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

Where:

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

For the period 2000-2021 the direct N_2O emissions from the application of N from urine and dung deposited by grazing animals are calculated by multiplying the amount of nitrogen by a country-specific emission factor which also takes the soil type into account.

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

Where:

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

These emissions are reported under their respective CRF categories.

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

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

12.6.3 *Emission factors*
An average emission factor of 0.033 kg N_2O-N per kg net applied N is used for grazing for the years 1990-1999. This factor is a weighted mean over soil types (see Annex 9). For the years 2000-2021 an emission factor of 0.025 kg N_2O-N per kg net applied N is used for mineral soils and 0.060 kg N_2O-N per kg net applied N for organic soils.

12.6.4 *Uncertainty*
The uncertainty value for nitrogen excretion is described in Section 2.4.3. The uncertainty for the emission factor is 64%. The uncertainty value is calculated using uncertainty values for the emission factors for each soil type and for the distribution of manure distribution over these soil types (Annex 10).

12.7 Source-specific aspects for direct N2O emissions from crop residues

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

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

Where:

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

These emissions are reported under their respective CRF categories.

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

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

Where:

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

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

12.7.2 *Activity data*

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

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

12.7.3 *Emission factors*

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

12.7.4 *Uncertainty*

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

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

12.8.1 Calculation method

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

$$N_2O \text{ emissions organic soils} = \Sigma \text{ area}_{p,\ soil\ type} \times \text{mineralisation}_p \times EF\ N_2O \text{ organic soils} \times 44/28 \quad (12.12)$$

Where:

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

These emissions are reported under their respective CRF categories.

Comparison to IPCC methodology

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

12.8.2 Activity data

Nitrous oxide emissions are determined by multiplying the area of peat and other organic soils by specific Dutch mineralisation rates and emission factors. The extent of the areas of cultivated land are estimated from the land-use maps of the sector designated as ‘Land Use, Land Use Change and Forestry’ (LULUCF). Maps of land use are available for the years 1990, 2004, 2009, 2013, 2017 and 2021. Additionally two maps with geographically explicit information on soil types (1977 and 2014) plus a map with projected extent of peat and peaty soils in 2040 are used in the LULUCF sector to assess combined land-use change and soil information trajectories (see Arets et al, 2022 for details on the maps and methodologies). Overlays of the maps determine the annual extent of drained and cultivated peat and peaty soils with their respective land-uses over time.

The areas of organic soils reported in Table CRF Table 4.C under the LULUCF sector report total area of organic soils, which also includes nature grasslands, while for the N2O emissions reported in CRF Table 3.D in the Agriculture sector only the area of cultivated grassland is considered (see NIR Chapter 6.6.2). An overview of the resulting areas of cultivated grassland and cropland on peat and peaty soils is provided in Annex 24 of Van Bruggen *et al.* (2022).

12.8.3 Emission factors

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

12.8.4 *Uncertainty*

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

12.9 Source-specific aspects for indirect N2O emissions after atmospheric depositions of NH3 and NOx

12.9.1 *Calculation method*

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

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

$$N_2O \text{ emissions indirect soil} = N_{\text{atmospheric deposition}} \times \text{EF } N_2O \text{ emissions indirect soil} \times 44/28 \qquad (12.13)$$

Where:

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

Comparison to IPCC methodology

The aforementioned method is similar to the IPCC method, as described in the IPCC Guidelines (IPCC, 2006), although the IPCC also differentiates another supply source: N_2O formed in the atmosphere from NH_3 emissions. Because the IPCC provides no calculation method for this source, the nitrous oxide emissions created by NH_3 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 N_2O emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

12.9.2 *Activity data*

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

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

12.9.3 *Emission factors*

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

12.9.4 *Uncertainty*

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

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

12.10.1 *Calculation method*

Indirect nitrous oxide emissions from aquatic systems occur through leaching and runoff of nitrogen (especially nitrate) from agricultural soils. Nitrate undergoes de-nitrification in groundwater or surface water, thereby creating nitrous oxide.

The following calculation rule is used for calculating nitrous oxide emissions for this supply source:

$$N_2O\ \text{emissions leaching} = N_{\text{applied to soil}} \times FRAC_{\text{leach}} \times EF\ N_2O\ \text{leaching} \times 44/28 \qquad (12.14)$$

Where:

N_2O emissions leaching	:	N_2O emissions (kg N_2O) from leaching and runoff of nitrogen added to the soil
$N_{\text{applied to soil}}$	:	Amount of N (kg N) applied to the soil
$FRAC_{\text{leach}}$	:	Fraction of nitrogen leaching and running off
EF N_2O leaching	:	N_2O leaching emission factor (kg N_2O-N/kg N supply)

44/28 : Conversion factor from N_2O-N to N_2O

The amount of nitrogen ($N_{applied\ to\ soil}$) 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 N_2O emissions are determined through Tier 1 analysis. Default IPCC emission factors are used.

12.10.2 *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).

12.10.3 *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)

12.10.4 *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).

12.11 Uncertainty estimates

An overview of all uncertainty values for the activity data, the implied emission factors and the emissions included in the category of N_2O emissions from crop production and agricultural soils is provided in Table 12.2.

Table 12.2 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and N_2O emissions (U emissions) from crop production and agricultural soils

IPCC	Source category	U AD	U IEF	U emissions
3Da1	Inorganic N fertilizers	24%	34%	42%
3Da2a	Animal manure applied to soils	3%	68%	69%
3Da2b	Sewage sludge applied to soils	25%	100%	106%
3Da2c	Other organic fertilizers applied to soils	25%	100%	106%
3Da3	Urine and dung deposited by grazing animals	19%	64%	68%
3Da4	Crop residues	2%	41%	41%
3Da6	Cultivation of organic soils (i.e. histosols)	18%	37%	41%
3Db1	Atmospheric deposition	27%	400%	415%
3Db2	Nitrogen from leaching and runoff	51%	233%	267%
	Total, agricultural soils			37%

13 NMVOC emissions from crop production and agricultural soils (NFR Sector 3D)

13.1 Scope and definition

This section provides a description of the methods and working processes for determining NMVOC emissions from silage storage, manure application, urine and dung deposited by grazing animals and crop production, according to the following NFR categories:

- 3Da2a Animal manure applied to soils
- 3Da3 Urine and dung deposited by grazing animals
- 3Dc Farm-level agricultural operations including storage, handling and transport of agricultural products
- 3De Cultivated crops

The emission of NMVOC occurs when manure is applied to the soil, during grazing (through the depositing of urine and manure) and during the storage of silage. No estimates are provided for NMVOC emissions during the application of organic/inorganic fertilizer or sewage sludge, as no emission factors are available for these sources.

The NMVOC from manure are produced during the degradation of fats, carbohydrates and proteins present in the manure. The composition of manure therefore influences the emission of NMVOC. Given the existence of a correlation between NH_3 and NMVOC emissions from manure management, the ratio of NH_3 emissions from animal housing to those from manure application is used to divide NMVOC emissions over these categories, as described in the EMEP Guidebook (EEA, 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:

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

Where:

NMVOC manure application	:	NMVOC emissions (kg NMVOC) for manure application for livestock category (i)
AAP_i	:	Average animal population for livestock category (i)
NMVOC animal $housing_i$	:	NMVOC emissions (kg NMVOC/animal/year) from manure in

		livestock housing for animal category (i), as calculated in Section 8.2
NH_3 manure application$_i$	:	NH_3 emissions (kg NH_3/year) from manure application for livestock category (i), as calculated in Section 10.3
NH_3 animal housing$_i$	:	Total NH_3 emissions (kg NH_3/year) from animal housing for livestock category (i), as calculated in Section 5.2

13.2.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in sections 2.2.1 and 2.4.3, respectively. The NMVOC emissions from animal housing are described in Section 8.2. The emissions of NH_3 from manure application and NH_3 from animal housing are described in Sections 10.3 and 5.2, respectively.

13.2.3 *Emission factors*

The NMVOC emissions from animal manure applied to soils are based on the emissions of animal manure in housing (described in Section 8.2).

13.2.4 *Uncertainty*

The uncertainty value for livestock numbers, including the aggregation/disaggregation of subcategories, is given in Section 2.4.3. The uncertainty value for the emission factors is 300% (estimate based on expert judgement).

13.3 Source-specific aspects for NMVOC emissions from urine and dung deposited by grazing animals

13.3.1 *Calculation method*

The methods used are described in the EMEP Guidebook (EEA, 2019).

Dairy and non-dairy cattle

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

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

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:

$$\text{NMVOC emissions pasture}_{other} = \sum_i AAP_i \times VS_i \times (1\text{- } FRAC_{i,\text{ time spent inside}}) \times \text{EF NMVOC pasture}_i \qquad (13.3)$$

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)
$FRAC_{i,\text{ time spent inside}}$	:	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 2022). 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:

$$\text{NMVOC emissions silage storage}_{cattle} = \sum AAP_i \times GE_i \times FRAC_{i,\text{ time spent inside}} \times (FRAC_{i,\text{ silage}} \times \text{EF NMVOC silage storage}_i) \times 0.25 \qquad (13.4)$$

Where:

NMVOC emissions silage storage$_{cattle}$	:	NMVOC emissions (kg NMVOC/year) from the storage of silage for all cattle categories (i)
AAP_i	:	Average animal population for cattle category (i)
GE_i	:	Gross energy intake in megajoules (MJ/animal) per year (i)
$FRAC_{i,\text{ time spent inside}}$	:	Fraction of time spent inside animal housing for cattle category (i)
$FRAC_{i,\text{ silage}}$	:	Fraction of gross energy uptake consisting of silage (i)
EF NMVOC silage storage$_i$	:	Emission factor (kg NMVOC/MJ) for NMVOC from the storage of silage for cattle category (i)
0.25	:	Fraction of emissions from silage storage compared to emissions from silage feeding in animal housing

Other livestock

The NMVOC emissions from silage storage for livestock categories other than cattle that are fed silage are calculated as follows:

$$\text{NMVOC emissions silage storage}_{other} = \sum_i AAP_i \times VS_i \times FRAC_{i,\text{ time spent inside}} \times (FRAC_{i,\text{ silage}} \times \text{EF NMVOC silage storage}_i) \times 0.25 \qquad (13.5)$$

Where:

NMVOC emissions silage storage$_{other}$	:	NMVOC emissions (kg NMVOC/year) from the storage of silage for all other livestock categories (i)
VS_i	:	Volatile solids (kg VS/year) excreted by livestock category (i)
$FRAC_{i,\text{ time spent inside}}$	:	Fraction of time spent inside animal housing for other livestock category (i)
$FRAC_{i,\text{ silage}}$	:	Fraction of feed given consisting of silage (i)

EF NMVOC silage storage$_i$	:	Emission factor (kg NMVOC/animal) for NMVOC from the storage of silage for livestock category (i)
0.25	:	Fraction of emissions from silage storage compared to emissions from silage feeding in animal housing

13.4.2 *Activity data*

Livestock numbers constitute the activity data for this emission source. Livestock numbers and their uncertainty estimates are described in Section 2.2.1 and 2.4.3. Gross energy intake and uncertainties are described in Section 3.2.

The gross feed intake of cattle, the VS excreted by pigs and poultry, the feed composition and the time spent inside animal housing are calculated by the WUM (CBS, 2008 through 2022). 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:

$$\text{NMVOC emissions crop cultivation} = \text{area x EF NMVOC crop cultivation} \quad (13.6)$$

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	5%	125%	125%
3Da3	Urine and dung deposited by grazing animals	5%	159%	159%
3Dc	Farm-level agricultural operations	1%	176%	176%
3De	Cultivated crops	12%	218%	218%
	Total, agricultural soils			104%

14 PM_{10} and $PM_{2.5}$ emissions from crop production and agricultural soils (NFR category 3D)

14.1 Scope and definition

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

- 3Dc Farm-level agricultural operations, including the storage, handling and transport of agricultural products
- 3De Cultivated crops
- 3Df Use of pesticides

Emissions of PM occurring during the use of inorganic N fertilizers, as well as during the loading of fertilizer application equipment. These values are therefore not reported under category 3Da1 (Inorganic N fertilizers, including urea application) but under category 3Dc (Farm-level agricultural operations, including the storage, handling and transport of agricultural products). No emissions of PM occur in source categories 3Da2a (Livestock manure applied to soils), 3Da2a (Sewage sludge applied to soils), 3Da2c (Other organic fertilizers applied to soils, including compost), 3Da3 (Urine and dung deposited by grazing animals), 3Da4 (Crop residues applied to soils) and 3Db (Indirect emissions from managed soils).

Activities falling under category 3Dd (Off-farm storage, handling and transport of bulk agricultural products) are covered by other sectors. Given that field burning is prohibited by law (Article 10.2 of the Environmental Management Act; in Dutch, *Wet Milieubeheer*), no emissions take place in category 3F (Field burning of agricultural residues). Finally, the Netherlands has opted not to report PM emissions under category 3I (Agriculture other).

Particulate matter emissions from crop production occur during soil cultivation or crop harvesting, and depend on crop sort, soil type, methods used and the weather. Particulate matter is also emitted during other agricultural activities (e.g. during haymaking and in the use of concentrates, inorganic N fertilizers and pesticides). These emissions are allocated to NFR categories 3De and 3Dc, respectively.

14.2 Source-specific aspects for PM emissions from farm-level operations

14.2.1 Calculation method

Emissions of PM from farm-level operations consist of PM_{10} and $PM_{2.5}$ from the use of feed, fertilizer and pesticides. Emissions of PM during the transport and handling of feed, fertilizer and pesticide have been calculated once, using a country-specific method (Chardon and Van der Hoek, 2002) and kept constant for the entire time series.

14.2.2 Activity data

Activity data for the use of inorganic fertilizer are described in Section 10.2.2.

14.2.3 *Emission factor*

The emission estimates for farm-level operations are presented in Table 14.1.

Table 14.1 Emission estimates for particulate matter from farm-level operations

Source category	PM_{10} (ton/year)	$PM_{2.5}$(ton/year)
Inorganic fertilizers	105.0	21.0
Concentrates	90.0	18.0
Pesticides	125.0	25.0

Source: Chardon and Van der Hoek (2002).

14.2.4 *Uncertainty*

Uncertainty values for the use of fertilizer, pesticide and feed are estimated at 25% (based on expert judgement). The use of rinsing liquid does not result in any emission of PM, as a liquid is involved. Uncertainty values for the emission estimates are estimated at 100% (based on expert judgement).

14.3 Source-specific aspects for PM emissions from crop cultivation

14.3.1 *Calculation method*

Emissions of PM from crop cultivation are calculated using a Tier 2 method. The area of each crop is multiplied by a specific emission factor. The total PM emissions from all crop sorts are then calculated by summing the PM emissions for each crop.

Crop cultivation is calculated using the following formula:

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

Where:

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

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

$\text{EF PM crop cultivation}_n$: Emission factor (kg PM/ha) for the defined crop (n)

The emission factor in the aforementioned formula considers the following operations in wet climate conditions:

1. Soil cultivation
2. Harvesting
3. Cleaning
4. Drying

Emissions from haymaking have been calculated by multiplying production by an emission factor. Due to a high degree of uncertainty, however, the emissions are kept constant throughout the time series.

These emissions are reported under NFR category 3Dc (Farm-level agricultural operations, including the storage, handling and transport of agricultural products).

Comparison to EMEP methodology
The methodology described above conforms to the method of the EMEP Guidebook (EEA, 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 PM_{10} and $PM_{2.5}$ emissions from crop production and agricultural soils is provided in Table 14.3.

Table 14.3 Uncertainty values for activity data (U AD), implied emission factors (U IEF) and PM_{10} and $PM_{2.5}$ emissions (U emissions) from crop production and agricultural soils

EMEP	Source category	U AD	U IEF PM_{10}	U emissions PM_{10}	U IEF $PM_{2.5}$	U emissions $PM_{2.5}$
3Da1	Inorganic fertilizers	25%	100%	106%	100%	106%
3Dc	Farm-level agricultural operations	25%	100%	106%	100%	106%
3De	Cultivated crops	2%	225%	225%	222%	222%
3Df	Use of pesticides	25%	100%	106%	100%	106%
	Total, agricultural soils			125%		94%

15 CO_2 emissions from liming (CRF category 3G)

15.1 Scope and definition

Calcareous fertilizers (calcic limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) are used to reduce soil acidity. Emissions of CO_2 occur as carbonate lime dissolves and releases bicarbonate. Bicarbonate ($2HCO_3^-$) dissolves into H_2O and CO_2.

15.2 Source-specific aspects

15.2.1 Calculation method

Emissions of CO_2 resulting from the use of lime on soils are determined for reporting in Table 3G of the CRF. The CO_2 emissions can be calculated according to the following Tier 1 method:

$$CO_2 \text{ emissions 3G} = (\text{limestone use} \times EF\ CO_2 \text{ limestone} + \text{dolomite use} \times EF\ CO_2 \text{ dolomite}) \times 44/12 \qquad (15.1)$$

Where:

CO_2 emissions 3G	:	Carbon dioxide emissions (kg CO_2/year) from CRF Source Category 3G (Liming)
EF CO_2 limestone	:	Emission factor (kg CO_2-C/kg applied) for limestone
EF CO_2 dolomite	:	Emission factor (kg CO_2-C/kg applied) for dolomite
44/12	:	Conversion factor from CO_2-C to CO_2

15.2.2 Activity data

Information on the amount of carbonate applied to soil originates from Wageningen Economic Research. Input on the use of carbonate comes from industrial processing records and import/export data from retailers of lime fertilizers. As of 2016, the usage of the various types of inorganic N fertilizers is taken from the statistics on inorganic fertilizer statistics available from the FADN. The available figures are totals, and they do not specify application on grassland and cropland separately. Given that all C will eventually be emitted as CO_2, there is no need to derive separate emission factors. For this reason, totals are used.

15.2.3 Emission factors

IPCC 2006 Tier 1 default values are used for the use of lime on soils (i.e. 0.12 kg CO_2-C/kg limestone and 0.13 kg CO_2-C/kg dolomite). These values translate to 440 kg CO_2/ton pure limestone and 477 kg CO_2/ton pure dolomite.

15.2.4 Uncertainty

The uncertainty value for the use of limestone is 28%, and the uncertainty value for the use of dolomite is 49% (calculated from 25% in total use; based on expert judgement). The uncertainty value for both emission factors is 1% (based on expert judgement). This uncertainty is very low, as all C will ultimately be emitted as CO_2.

15.3 Uncertainty estimates

The uncertainty values for liming, implied emission factors and resulting CO_2 emissions are presented in Table 15.1.

Table 15.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and CO_2 emissions (U emissions) from liming

IPCC	Source category	U AD	U IEF	U emissions
	Limestone	28%	1%	28%
	Dolomite	49%	1%	49%
3G	Liming			25%

16 CO_2 emissions from urea application (CRF category 3H)

16.1 Scope and definition

Urea is applied to soils as an artificial nitrogen fertilizer. During and after the application, CO_2 is emitted as urea reacts with water and urease enzymes in the soil, breaking down into ammonium, hydroxyl ion and bicarbonate. The bicarbonate subsequently evolves into water and CO_2. The CO_2 emissions from this process were previously allocated to the production of urea, as the production of urea entails the removal of an equal amount of CO_2 from the atmosphere. However, the IPCC guidelines stipulate that the CO_2 emission should be allocated to the agriculture sector (IPCC, 2006).

16.2 Source-specific aspects

16.2.1 Calculation method

Emissions of CO_2 resulting from the application of urea are determined for reporting in Table 3H of the CRF. The CO_2 emissions can be calculated according to the following Tier 1 method:

$$CO_2 \text{ emissions } 3H = M_{urea} \times EF\ CO_2 \text{ urea} \times 44/12 \qquad (16.1)$$

Where:

CO_2 emissions 3H	:	Carbon dioxide emissions (kg CO_2/year) from CRF source category 3H (Urea application)
M_{urea}	:	Mass of urea (kg)
EF CO_2 urea	:	Emission factor (kg CO_2-C/kg applied) for urea
44/12	:	Conversion factor from CO_2-C to CO_2

16.2.2 Activity data

Usage figures of urea are taken from the synthetic fertilizer statistics available from Wageningen Economic Research. As of 2016 usage figures of urea application is derived from the statistics on inorganic fertilizer available from the FADN. Consistency between the two data sources has been verified and confirmed in terms of total nitrogen applied (Van Bruggen *et al.,* 2019).

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 25%. The uncertainty value for the emission factor is 1% (based on expert judgement). This uncertainty is very low, as all C will ultimately be emitted as CO_2.

16.3 Uncertainty estimates

The uncertainty values for urea application, implied emission factors and resulting CO_2 emissions are presented in Table 15.1.

Table 16.1 Uncertainty values (U) for activity data (AD), implied emission factors (IEF) and CO_2 emissions (U emissions) from urea application

IPCC	Source category	U AD	U IEF	U emissions
3H	Urea application	25%	1%	25%

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Justification

This report is an account of the methods used for the calculation of emissions to air from agriculture in the Netherlands over the 1990-2021 period, as reported in the National Inventory Report 2023 (NIR; for greenhouse gases) and Informative Inventory Report 2023 (IIR; for air pollutants). With these annual reports, the Netherlands fulfils the reporting requirements of the Paris Agreement and Gothenburg protocols. Yearly, the results are published in Van Bruggen *et al.* (in Dutch).

Emissions are assessed with the National Emission Model for Agriculture (NEMA) which is approved by the independent Dutch Scientific Committee of the Manure Act (CDM). Statistics Netherlands (CBS) is the administrator of the NEMA model. The work is guided by the task force Agriculture and Land Use of the Pollutant Release and Transfer Register (PRTR, or 'Emissieregistratie' (ER) in Dutch). For greenhouse gas reporting, the Netherlands Enterprise Agency (RVO.nl) reviews proceedings acting as the National Inventory Entity (NIE).

The methodologies used follow or comply with the 2019 IPCC Guidelines (greenhouse gases) and the EMEP guidebook 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 NH_3 emission is estimated by means of an emission percentage applied on total N excretion. It is however mainly the excretion of urine N that is responsible for the NH_3 emission. Therefore, the current aim is to estimate NH_3 emission based on excreted urine N. Excretion of urine N is comparable to that of total ammoniacal N (TAN). A description of the calculation method of TAN is given here.

A1.2 Calculation method

The total N excretion is calculated in accordance with the method used by the WUM, also used by Tamminga et al. (2000; 2004), to derive the fixed excretion figures for various livestock categories. In this method the uptake of N with the separate ration components is calculated, and total N excretion as the difference between N uptake and N retained in animal products (milk, growth, offspring).
For the results reported in the present document, the same method was used but it was extended with an estimation of the digestion coefficient (DC) for crude protein (CP). Introduction of DC-CP is required to be able to calculate TAN. The calculation is performed for each feedstuff in the ration separately. With the DC-CP per feedstuff the percentage of crude protein uptake can be calculated that is absorbed by the intestine (= digested). The remainder (100% - DC-CP) of crude protein uptake leaves the body with the faeces. Protein absorbed by the intestine is either used for production (milk, growth and offspring) or excreted as urine N by the kidneys. By setting the TAN equal to the excretion of urine N, TAN is calculated by the following steps:

- Summation of the amount crude protein uptake that is absorbed in the intestine for all feedstuffs in the ration;
- Conversion of absorbed protein to absorbed N;
- Calculation of N retained with animal production;
- Calculation of excreted urine N as the difference between absorbed N and N retained with animal production.

Calculation of the DC-CP
The CVB animal feed table (Centraal Veevoederbureau, 2005b) lists DC-CP values (as a % of crude protein content) for all common products. For roughages this is dependent on the quality of the roughage. Regression equations have been published to calculate the DC-CP based on chemical composition (crude protein content, crude ash content and crude crude fibre content; Centraal Veevoederbureau (2005a)). In Table A1.1 the DC-CP is given for the various ration components fed to young stock.

Faecal N digestibility of dairy is now calculated using the Tier 3 method because above method gives an overestimation. For young cattle above method is corrected using the difference calculated for dairy cattle.

A1.3 Used data

The amounts of feed that has been provided yearly to the different livestock categories are according to the report of the Working group on Uniformity of Manure and mineral data (WUM). Also, data are available for milk production, and the composition of roughages (based on yearly statistics on analyses of silages by the laboratory Eurofins Agro (formerly Blgg and AgroXpertus), concentrates (based on reports of feed manufacturers) and by-products (based on amounts of products marketed). These figures are recently used and described by Smink *et al.* (2005) for the calculation of the methane emission of dairy cattle and the same data are used in the present study. For moisture-rich by-products it is assumed that these consisted of 25, 40 and 35% of brewers' grains, potato products and sugar beet pulp. This division compares well to the WUM report of the availability by-products for cattle (respectively 26, 35 and 26%; 30:40:30 ratio).

For young stock the WUM rations of 1990 have been used in accordance with the starting points in the available WUM excretion data. The composition of roughages and concentrates was assumed equal to that of dairy cattle in the year 2001.

Table A1.1 The CP content, the ammonia content and the faecal CP digestibility for the various ration components in the ration of young stock

	CP content[1)]	**Ammonia content**	**DC-CP[2)]**
	g CP/kg DM	**% CP**	**%**
Fresh grass / grass herbage	229	0	85
Grass silage (+ hay)	191	10	77
Maize silage	81	10	50
Standard concentrate	180	0	70
Protein-rich concentrate	330	0	82
By-products[3)]			
Brewers' grains	250	0	80
Potato pulp	85	0	36
Pressed sugar beet pulp	115	0	65
Whole milk	35	0	86

1) Including ammonia N.
2) Concerns an estimation of the real instead of apparent digestibility of crude protein.
3) Only most abundant product in the category mentioned here (brewers' grains for category protein-rich by-products, potato pulp for category of rest material potato processing industry, pressed sugar beet pulp for category of pulps and vegetables).

A1.4 Other starting points/assumptions

Correction CP content for ammonia fraction. It was assumed that ammonia N (expressed as CP) accounted for 10% of the total CP content in both grass silage and maize silage.

Correction feed uptake for so-called "feed losses". For the time being no corrections have been made for feed losses because these also seem not to have been made in the calculation of the N excretions in WUM. If the corrections in the feeding of dairy cattle according to the current WUM methodology (0, 5, 3 and 2% feed losses for respectively fresh grass, grass silage, maize silage, moist by-products and concentrates) were to be made this would lead to much lower N excretions than the reported 131.0 kg N/dairy cow/year according to WUM.

Composition urine N. For the time being 100% of the urine N is considered as TAN and no differentiation is made between N holding components that do not (quickly) lead to ammonia formation (Reijs, 2007).

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Annex 2 Calculation of TAN excretion for pigs

Translation with adaptation of the annex from Age Jongbloed (Animal Sciences Group (ASG), Wageningen UR, Lelystad) in Velthof *et al.*, 2009.

A2.1 The excretion of nitrogen in pig farming

A2.1.1 Nitrogen content in pigs

In Table A2.1 is indicated what the N contents (g per kg live weight) are in the livestock categories distinguished. Also, the sources are indicated.

Table A2.1 N contents in livestock categories distinguished (Ref. = reference year)

Livestock category	Physiological status	Ref.	Weight Ref. (kg)	N content Ref.	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 is 1994 was 29.0 and in 2005 this content was 28.8 g/kg. The N digestibility of the piglet feed is in 1994 and 2005 83.0%.

A2.10.2 Results piglets of 6 weeks to 25 kg

In Table A2.11 is based on abovementioned assumptions for piglets of 6 weeks to ca. 25 kg an overview given of the nitrogen balance as a pig place would be occupied the whole year (no loss of days).

Table A2.11 N uptake and excretion (kg) by piglets of 6 weeks to ca. 25 kg on yearly basis (category 407)

Category 407	1994			2005		
	g N/kg	DC-N	N uptake (kg)	g N/kg	DC-N	N uptake (kg)
Uptake piglet feed	29.0	83.0	8.18	28.8	83.0	7.04
Fixation			3.92			3.56
Excretion			4.26			3.48
In faeces			1.4			1.2
In urine			2.9			2.3
In urine (%)			67.3			65.6

Table A2.11 shows that the N excretion per weaned piglet of 6 weeks to ca. 25 kg per year compared to 1994 decreased considerably in 2005 and that considerably less N is excreted through the urine. The percentage of the N excretion in the urine decreased from 67.3 to 65.6%.

A2.11 Sows for slaughter (category 410)

A2.11.1 Starting points

The start and end weight of the sows for slaughter in 1994 is 205 kg and for 2005 220 kg. The average length of the period kept is 7 days. It is assumed that in both years per day 3 kg lactating sow feed is taken up.

The N content of the sow feed in 1994 was 24.5 g/kg and of the lactating sow feed in 2005 25.2 g/kg. The N digestibility of these feeds was 78.9 respectively 78.0%.

A2.11.2 Results sows for slaughter

In Table A2.12 is based on abovementioned assumptions for sows for slaughter an overview given of the nitrogen balance if a pig place would be occupied the whole year (no loss of days).

Table A2.12 N uptake and excretion (kg) by sows for slaughter of 220 kg on yearly basis (category 410)

Category 410	1994			2005		
	g N/kg	DC-N	N uptake (kg)	g N/kg	DC-N	N uptake (kg)
Uptake sow feed	24.5	78.9	26.83	25.2	78.0	27.59
Fixation			0.0			0.0
Excretion			26.83			27.59
In faeces			5.7			6.1
In urine			21.2			21.5
In urine (%)			78.9			78.0

Table A2.12 shows that the N excretion per sow for slaughter per year compared to 1994 remained almost equal in 2005 and that the percentage of the N excretion in the urine decreased somewhat from 78.9 to 78.0%.

A2.12 Fattening pigs of ca. 25 to ca. 110 kg (category 411)

A2.12.1 Starting points

The start and end weight of the pigs in 1991 is set to 25 respectively 109 kg (WUM, 1994). In 2005 these weights are 25.6 respectively 115.7 kg (Agrovision, 2005). The average growth per animal per day was 712 g in 1991 (WUM, 1994) and in 2005 that was 773 g (Agrovision, 2005). The length of the growth period was therefore 118 respectively 117 days. The feed conversion of the fattening pigs was 2.87 in 1991 and in 2005 that was 2.67. In 1991 during the first part of the lay on period an average amount of 44 kg starting feed and 197 kg fattening pig feed was given (WUM, 1994). In 2005 45 kg starting feed per pig was taken up, 70 kg growth feed and 126 kg finishing feed (Agrovision, 2005). The N content of the starting feed and fattening pig feed in 1991 was 28.2 respectively 26.0 g/kg. For 2005 these contents in the feeds are on average 25.2 g/kg (Jongbloed and Van Bruggen, 2008). The N digestibility of the starting feed in 1991 is estimated based on the raw material composition according to Van der Peet-Schwering (1990) and Kloosterman and Huiskes (1992) and was on average 81.9%. The N digestibility of the fattening pig feed in 1991 is estimated based on the raw material composition according to Van der Peet-Schwering (1990), Kloosterman and Huiskes (1992) and Wahle and Huiskes (1992) and was on average 80.1%.

The N digestibility of the starting feed in 2005 is estimated based on the starting point that as result of the addition of amino acids and somewhat different raw materials, so that it is ca. 1% unit lower than in 1991 and thus 81.0% is assumed. The N digestibility of the fattening pig feed in 2005 is estimated based on the raw material composition of a composite feed manufacturer in the first half year of 2006 and was on average 78.6% of the feeds with an energy value of 1.05 and 1.10.

A2.12.2 Results fattening pigs

In Table A2.13 is based on abovementioned starting points for fattening pigs an overview given of the nitrogen balance if a pig place would be occupied during the whole year (no lost days).

Table A2.13 N uptake and excretion (kg) by fattening pigs of ca. 25 to 114 kg on yearly basis (category 411)

Category 411	1991			2005		
	g N/kg	DC-N	N uptake (kg)	g N/kg	DC-N	N uptake (kg)
Starting feed	28.2	81.9	3.83	25.2	81.0	3.55
Fattening pig feed	26.0	80.1	15.83	25.2	78.6	15.43
Total uptake			19.66			18.98
Fixation			5.97			7.07
Excretion			13.70			11.91
In faeces			3.8			4.0
In urine			9.8			7.9
In urine (%)			71.9			66.6

A2.12.3 Discussion fattening pigs

Table A2.13 shows that the N excretion per fattening pig per year compared to 1991 decreased considerably in 2005. As result of the higher N retention the percentage of the N excretion in the urine decreased considerably from 71.9 to 66.6%.

For fattening pigs is examined what the effect is on the excretion in faeces and urine if the digestibility of N in the feeds for fattening pigs is 1% unit lower or higher than in the starting situation (Table A2.14).

Table A2.14 N uptake and excretion (kg) by fattening pigs of ca. 25 to 114 kg on yearly basis (category 411) at a higher or lower N digestibility

Category 411	1991			2005		
	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher
Total uptake	19.66	19.66	19.66	18.98	18.98	18.98
Excretion	13.70	13.70	13.70	11.91	11.91	11.91
In faeces	4.04	3.84	3.65	4.17	3.98	3.79
In urine	9.65	9.85	10.05	7.75	7.94	8.13
In urine (%)	70.5	71.9	73.4	65.0	66.6	68.2

From Table A2.14 it can be seen that in the dependability of the digestibility of N with a deviation of 2% units, no large shifts occur in the division of N over faeces and urine; this is a difference of 2.9% units in 1991 and 3.2% units in 2005.

A2.13 General discussion

An important attention point is a good insight in the N contents of the various feeds. Also, because the use of a whole range of feeds for various categories pigs it is sometimes difficult to know how long those feeds are given. However, by means of data from Levies Office (Bureau Heffingen) that insight can be obtained for some important feeds but are lacking for small livestock categories. This needs to receive more attention.

Another point is the N digestibility. Also because of a storage period of five to six years, data on this are lacking in the compound feed industry particularly for the reference years (1991 to 2002). The N digestibility also is not of interest in the formation of the feeds: for protein this is based on ileal or faecal digestible amino acids. Also, for the year 2005 it was not possible to gain a reliable insight in the N digestibility. Besides there is such a large array of feeds that it is difficult to classify these correctly. It is hard for the compound feed industry to calculate these data, and possibly competition is a reason not to make these available after all. Ways should be found to obtain more reliable data on the N digestibility in the feeds.

A.2.14 Summary pigs

In Table A2.15 a summary is given of the excretion of N and % TAN by various categories of pigs in the reference year and in 2005 in g/year.

Table A2.15 Overview of the excretion of N and % TAN by the various categories of pigs in the reference year and 2005 (kg/year)

Category	Number	Ref. year	N in ref. year	% TAN in ref. year	N in 2005	% TAN in 2005
Breeding sows with piglets up to 6 weeks of age	400	1994	23.0	72.9	21.9	62.2
Breeding sows with piglets to ca. 25 kg	401	1994	31.4	71.9	29.8	62.7
Gilts not yet in pig of ca. 25 kg to ca. 7 months	402	2001	12.9	69.9	13.4	67.8
Gilts not yet in pig of ca. 7 months to first mating	403	2001	16.9	74.6	17.5	72.3
Gilts not yet in pig of ca. 25 kg to ca. 7 months	404	2001	13.7	71.4	14.1	68.8
Young boars of ca. 25 kg to ca. 7 months	405	1991	12.4	68.9	12.8	66.0
Breeding boars of ca. 7 months and older	406	1991	24.3	76.4	24.4	75.1
Piglets of ca. 6 weeks to ca. 25 kg	407	1991	4.3	67.3	3.5	65.6
Sows for slaughter	410	1994	27.8	78.9	27.6	78.0
Fattening pigs	411	1991	13.7	71.9	11.9	66.6

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Annex 3 Calculation of TAN excretion for poultry

Translation with adaptation of the annex from Age Jongbloed (Animal Sciences Group (ASG), WUR, Lelystad) in Velthof *et al.*, 2009.

A3.1 The excretion of nitrogen in the poultry sector

For the approach followed reference can be made to section A2.1.2 and A2.1.3 (see Annex 2).

A.3.1.1 Contents of nitrogen in chickens and chicken eggs

In Table A3.1 is indicated what are the N contents (g per kg live weight or per kg produce) for the livestock categories distinguished. Also the references are indicated. The start weight of day-old chickens for respectively the meat sector and the laying sector is set to 42 and 36 g in these calculations.

Table A3.1 Weights and contents of N in various categories of chickens (Ref. = reference year)

Livestock category	Physiological status	Ref.	Weight Ref. (g)	N content Ref. (g/kg)	Weight 2005 (g)	N content 2005 (g/kg)	Literature contents
Egg meat sector	-	1993	62	19.2	62	19.3	1
Day-old chicken meat	1 day		42	30.4	42	30.4	3
Broiler	Delivery	2002	2,100	27.8	2,200	27.8	2
Broiler mother breeder	19 weeks	2000	2,000	33.4	2,000	33.4	1
Broiler father breeder	19 weeks	2000	2,750	34.5	2,750	34.5	1
Broiler mother breeder	≥19 weeks	1996	3,600	28.4	3,900	28.4	1
Broiler father breeder	≥19 weeks	1996	4,800	35.4	5,000	35.4	1
Egg laying sector	-	1993	62.4	19.2	62.5	18.5	2
Day-old chicken laying	1 day	1993	36	30.4	35	30.4	3
Laying hens battery light	17 weeks	1991	1,215	28.0	1,285	28.0	2
Laying hens battery heavy	17 weeks	1991	1,420	28.0	1,520	28.0	2
Laying hens other heavy	17 weeks		1,520	28.0	1,520	28.0	2
Laying hens battery light	≥18 weeks	1993	1,750	28.0	1,600	28.0	2
Laying hens battery heavy	≥18 weeks	1993	2,050	28.0	1,800	28.0	2
Laying hens other heavy	≥18 weeks	1998	1,900	28.0	1,800	28.0	2

1 = Versteegh and Jongbloed, 2000; 2 = Jongbloed and Kemme, 2002; 3 = LNV, 2004.

A3.1.2 The N content and N digestibility in chicken feeds

In Table A3.2 an overview is given of the N contents and the digestibility of N in the various chicken feeds with which calculations are made in this study. In the corresponding sections the basis for the N contents and the N digestibility in the feeds is described further.

Table A3.2 Overview of the N contents and the N digestibility (DC-N) in the various chicken feeds for the reference year and in 2005

	Reference year			**2005**	
Feed type	**Year**	**g N/kg**	**DC-N (%)**	**g N/kg**	**DC-N (%)**
Laying hens feed 1	1993	29.1	83.1	24.9	84.5
Laying hens feed 2	1993	29.1	82.8	24.9	84.5
Laying hens feed 3	1993	29.1	82.2	24.9	84.0
Rearing feed start laying varieties	1991	31.3	80.7	27.0	79.1
Laying hens feed 1	1998	26.4	83.1	24.9	84.5
Laying hens feed 2	1998	26.4	82.8	24.9	84.5
Laying hens feed 3	1998	26.4	82.2	24.9	84.0
Rearing feed start laying varieties	1998	28.6	79.1	27.0	79.1
Rearing feed 1 (laying varieties)	1991	31.3	80.7	26.1	80.7
Rearing feed 2 (laying varieties)	1991	31.3	79.1	26.1	79.1
Rearing feed start meat varieties	-	-	-	31.0	84.2
Rearing feed 1 (meat varieties)	2000	28.6	80.8	28.4	80.8
Rearing feed 2 (meat varieties)	2000	28.6	80.8	25.2	80.8
Start feed (broiler breeders)	1996	31.0	80.8	25.2	80.8
Breeding brood feed 1 (broiler breeders)	1996	27.8	83.2	24.3	83.2
Breeding brood feed 2 (broiler breeders)	1996	27.8	82.3	24.2	82.3
Broiler feed 1	2002	34.6	85.1	36.0	85.4
Broiler feed 2	2002	32.0	84.3	34.1	83.9
Broiler feed 3	2002	30.9	84.3	33.1	83.4

A3.2 Rearing hens and roosters of laying varieties younger than ca. 18 weeks in battery housing (category 300A)

A3.2.1 Starting points

The start weight of the rearing laying hens for both 1993 and 2005 is set to 35 g (Reuvekamp, 2004). The end weight of this category in 1993 is for middle heavy and white laying hens 1,420 respectively 1,215 g (KWIN-V, 1991). For 2005 these weights are 1,520 respectively 1,285 g. The length of the rearing period is 122.5 respectively 119 days (KWIN-V, 1991; 2005). The division over middle heavy and white laying hens in battery housing was in 1991 56:44 (WUM, 1994) and for 2005 50:50 is taken (Cijferinfo Pluimveesector 99/11; PVE, 1999). Per rearing period is for 1991 the feed uptake per delivered hen respectively 5.6 and 5.0 kg (KWIN-V, 1991) resulting in 5.5 and 4.9 kg feed per hen present for middle heavy and white laying hens (on average 5.2 kg) and a feed conversion of 4.04. The ratio between uptake of rearing feed 1 and 2 is in 1991 20:80. For 2005 the feed uptake per rearing period per delivered hen for middle heavy and white laying hens 5.6 respectively 5.2 kg (per hen present 5.4 respectively 5.2 kg), resulting in an average feed uptake of 5.3 kg per hen present and a feed conversion of 3.87. The ratio between uptake of start feed, rearing feed 1 and 2 in 2005 is 5.6:25.9:68.5 (KWIN-V, 2005).

The loss of animals amounts for 1991 to 4.5% for both middle heavy and white laying hens and for 2005 that is 3.0 respectively 5.0%. This percentage is only used for conversion of delivered hen to average present hen. In 1991 the rearing feeds contained on average 31.3 g N/kg, while these feeds in 2005 contained on average 26.1 g N/kg. The digestibility of the rearing feeds in 1991 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a and 1995b). For rearing feed 1 there were three observations just like as for rearing feed 2. For the start feed the digestibility of the rearing feed 1 is taken. Because of the lack of data about composition and N digestibility of rearing feeds in 2005 the same N digestibilities as for 1991 are taken.

A3.2.2 Results rearing hens and roosters of laying varieties younger than ca. 18 weeks in battery housing

In Table A3.3a is based on abovementioned starting points an overview given of the N uptake and excretion for rearing hens and roosters of laying varieties younger than ca. 18 weeks housed in batteries. Also in Table A3.3b and A3.3c the results are presented if 100% rearing hens respectively middle heavy (brown) rearing hens are kept. The calculated excretion is expressed per animal year (1 animal present the whole year).

Table A3.3a Nitrogen balance (g) in rearing hens and roosters (ca. 50% white) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)

Category 300A	**1991**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Start feed	-	-	-	26.1	80.7	24
Rearing feed 1	31.3	80.7	96	26.1	80.7	110
Rearing feed 2	31.3	79.1	405	26.1	79.1	290
Total uptake			501			424
Fixation			112			117
Excretion			389			307
In faeces			103			86
In urine			286			220
In urine (%)			73.5			71.8

Table A3.3b Nitrogen balance (g) in rearing hens and roosters (100% white) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)

Category 300A	**1991**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Start feed	-	-	-	26.1	80.7	23
Rearing feed 1	31.3	80.7	96	26.1	80.7	105
Rearing feed 2	31.3	79.1	360	26.1	79.1	281
Total uptake			456			410
Fixation			99			107
Excretion			357			303
In faeces			94			84
In urine			263			219
In urine (%)			73.7			72.4

Table A3.3c Nitrogen balance (g) in rearing hens and roosters (100% brown) of laying varieties younger than ca. 18 weeks in battery housing in kg N per animal year (category 300A)

Category 300A	1991			2005		
	g N/kg	DC-N (%)	N uptake (g)	g N/kg	DC-N (%)	N uptake (g)
Start feed	-	-	-	26.1	80.7	24
Rearing feed 1	31.3	80.7	109	26.1	80.7	117
Rearing feed 2	31.3	79.1	402	26.1	79.1	308
Total uptake			510			450
Fixation			116			127
Excretion			394			322
In faeces			105			92
In urine			290			231
In urine (%)			73.4			71.6

Results in Tables A3.3a, A3.3b and A3.3c show that the N excretion in 2005 is much lower than in 1991, mainly because of the lower N content of the feeds. Since the N retention hardly differs between both years there is a much lower N excretion in the urine. The proportion of the percentage N in urine : N in faeces is on average 1.7% unit lower in 2005 compared to 1991.

A3.3 Rearing hens and roosters of laying varieties younger than ca. 18 weeks in housing other than battery (category 300B)

In section A3.2 some general remarks are made which are also valid for this section. Also it needs to be mentioned that to make an estimation of the technical results in this housing systems research data of free range housing is used.

A3.3.1 Starting points

In the alternative housing (free range) almost completely middle heavy hens are used (Cijferinfo Pluimveesector 99/11; PVE, 1999). Also the data from research concerns these hens. As a result it is chosen to take only middle heavy hens for this category, both for 2002 and 2006.

The start weight of the rearing hens for both 2000 and 2005 is set to 35 g (Reuvekamp, 2004). The end weight of this category is for both 2000 and 2005 1,520 g (Managementgids Isabrown, 2004; Vermeij, 2005; Hendrix-Poultry, 2005). The length of the rearing period is 119 days (KWIN-V, 2000; 2005). Per rearing period for 2000 the feed uptake per delivered hen is 5.9 kg (per middle heavy hen present 5.8 kg) (KWIN-V, 2000). This results in a feed conversion of 4.20. The ratio between uptake of rearing feed 1 and 2 is 20:80. For 2005 the feed conversion per rearing period per animal present for middle heavy laying hens is 6.0 kg and the feed conversion is 3.96. The ratio between uptake of start feed, rearing feed 1 and 2 in 2005 is 5:26:69. The loss of animals for 2000 is 4.0% and for 2005 also 4.0%. The percentage animals lost is only used for the conversion of delivered hen to average present hen.

In 2000 the rearing feeds contain on average 28.6 g N/kg, while these feeds in 2005 contain on average 26.1 g N/kg. The digestibility of the rearing feeds in 2000 is derived from the feed compo-sitions of Van Niekerk and Reuvekamp (1994; 1995a and 1995b). For rearing feed 1 there were three observations and for rearing feed 2 the same. For the start feed the digestibility of rearing feed 1 is taken. Because the lack of data on rearing feeds in 2005 the same digestibilities as in 2000 are used.

A3.3.2 *Results rearing hens and roosters of laying varieties younger than ca. 18 weeks in housing other than battery*

In Table A3.4 is based on abovementioned starting points an overview given of the N uptake and excretion for rearing hens and roosters of laying varieties younger than ca. 18 weeks in non-battery housing systems. The calculated excretion is expressed per animal year (1 animal that is present the whole year). With this the figure differs from usual parameters within the sector.

Table A3.4 Nitrogen balance (g) in rearing hens and roosters (100% brown) of laying varieties younger than ca. 18 weeks in non-battery housing in kg N per animal year (category 300B)

Category 300B	**2000**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Start feed	-	-	-	26.1	80.7	24
Rearing feed 1	28.6	80.7	99	26.1	80.7	121
Rearing feed 2	28.6	79.1	408	26.1	79.1	326
Total uptake			507			471
Fixation			119			128
Excretion			388			343
In faeces			104			96
In urine			284			247
In urine (%)			73.1			72.0

Results in Table A3.4 show that the N excretion in 2005 is somewhat lower than in 2000, mostly due to the somewhat lower N content of the feeds. Since the N retention hardly differs between both years the N excretion in the urine is lower. The division of the percentage N in urine : N in faeces becomes 1.1% unit lower in 2005 compared to 2000.

A.3.4 Hens and roosters of laying varieties ca. 18 weeks and older in battery housing (category 301A)

In this section the calculations for hens in battery systems are examined further. Here also the differences are calculated if only white leghorns or brown laying hens are kept in a battery system.

A3.4.1 *Starting points*

The start weight of the middle heavy and white laying hens for 1993 is 1,420 respectively 1,215 g (KWIN-V, 1993). For 2005 these weights are 1,520 respectively 1,285 g. The end weight of this category at the end of the laying period is in 1993 for middle heavy and white laying hens 2,050 respectively 1,750 g (KWIN-V, 1993). For 2005 these weights are 1,800 respectively 1,600 g. The length of the laying period is 417 days (399 days actual laying period, 18 days rearing) (KWIN-V, 1993). The division over middle heavy and white laying hens in battery housing is 56:44 (WUM, 1994) and for 2005 50:50 is taken (Cijferinfo Pluimveesector 99/11; PVE, 1999).

The feed uptake of the middle heavy and white laying hens amounts 90 respectively 85 g/day during rearing and 117.5 respectively 110 g/day during the actual laying period for 1993, and for 2005 110 respectively 109.5 g/day is taken (KWIN-V 1993 respectively 2005). Per round the feed uptake in 1993 is on average 42.6 kg per hen present. In 1993 per hen laid on 19.9 (middle heavy) or 20.4 kg (white laying hen) eggs are produced. In this is calculated with another 5 eggs produced during rearing with the same egg weight. The average feed conversion is 2.23 (KWIN-V, 1993), which is based on feed uptake from 20 weeks on and egg production from 17 weeks.

Per round the feed uptake in 2005 is on average 41.1 kg per hen present. In 2005 per hen laid on 20.5 (middle heavy) or 22.3 kg (white laying hen) eggs are produced. In this is calculated with another 5 eggs produced during rearing with the same egg weight. The average feed conversion is 2.02 (KWIN-V, 2005), which is based on feed uptake from 20 weeks on and egg production from 17 weeks.

The loss of animals amounts to 6.3 and 7.3% for middle heavy and white laying hens in 1993 and for 2005 the same values have been taken. The percentage of animals lost is only used for the conversion of delivered hen to average present hen.

The start and laying feeds contain in 1993 on average 29.1 g N/kg (WUM, 1994). For 2005 the average N content in the start and laying feeds was 24.9 g N/kg (Van Bruggen, 2007). The ratio between the laying feeds 1, 2 and 3 over the laying period is 40:40:20, both for 1993 and 2005. There are also businesses where laying feed 2 is used to the end of the laying period instead of switching to laying feed 3. In the calculations this is not taken into account.

The digestibility of the laying hen feeds in 1993 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a; 1995b; 1997) and Emous *et al.* (1999). For laying feed 1 there were six observations with an average N digestibility of 84.1%. Of laying feed 2 there were six observations too with an average N digestibility of 83.8%, while for laying feed 3 there were four observations with an average N digestibility of 83.2%. For 2005 we had the disposal of data on laying feed 1 of the first half year of 2006. The average N digestibility was 84.5%. For laying feed 2 the same N digestibility was taken and for laying feed 3 an N digestibility of 84.0% was taken. The N digestibility of the start feed is set equal to that of the laying feed 2.

A3.4.2 Results hens and roosters of laying varieties ca. 18 weeks and older in battery housing

In Tables A3.5a, A3.5b and A3.5c is based on abovementioned starting points an overview given of the N excretion for hens and roosters of laying varieties of ca. 18 weeks and older in batteries.

Table A3.5a Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (ca. 50% white) in kg N per animal year (category 301A)

Category 301A	**1993**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Rearing feed	29.1	79.1	39	27.0	79.1	40
Laying feed 1	29.1	84.1	464	24.9	84.5	380
Laying feed 2	29.1	83.8	464	24.9	84.5	380
Laying feed 3	29.1	83.2	232	24.9	84.0	190
Total uptake			1,200			990
Fixation			350			362
Excretion			850			628
In faeces			196			156
In urine			654			472
In urine (%)			76.9			75.1

Table A3.5b Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (100% white) in kg N per animal year (category 301A)

Category 301A	**1993**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Rearing feed	29.1	79.1	36	27.0	79.1	36
Laying feed 1	29.1	84.1	448	24.9	84.5	380
Laying feed 2	29.1	83.8	448	24.9	84.5	380
Laying feed 3	29.1	83.2	224	24.9	84.0	190
Total uptake			1,155			986
Fixation			345			365
Excretion			810			620
In faeces			189			156
In urine			622			465
In urine (%)			76.7			74.9

The results in Table A3.5a are for businesses with a division of ca. 50% white and 50% middle heavy (brown) laying hens; those in Table A3.5b and A3.5c are for businesses with 100% white respectively 100% brown laying hens. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). As such this figure differs from the usual parameters in the sector.

A3.4.3 Discussion laying hens in battery housing

Tables A3.5a, A3.5b and A3.5c show that differences in total N excretion between the various laying varieties do exist, but that there are hardly differences in the share TAN in the excreta. Compared to 1993 the share TAN in the excreta decreased somewhat with on average 1.8% unit. Examined is also what the effect on the excretion of N in faeces and urine is, if the N digestibility is 1% unit higher or lower. Table A3.6 gives the results of this.

Table A3.5c Nitrogen balance (g) in hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (100% middle heavy; brown) in kg N per animal year (category 301A)

Category 301A	1993			2005		
	g N/kg	DC-N (%)	N uptake (g)	g N/kg	DC-N (%)	N uptake (g)
Rearing feed	29.1	79.1	42	27.0	79.1	44
Laying feed 1	29.1	84.1	477	24.9	84.5	380
Laying feed 2	29.1	83.8	477	24.9	84.5	380
Laying feed 3	29.1	83.2	239	24.9	84.0	190
Total uptake			1,235			994
Fixation			354			358
Excretion			881			636
In faeces			202			157
In urine			679			479
In urine (%)			77.1			75.2

Table A3.6 N uptake and N excretion (g) by hens and roosters of laying varieties of ca. 18 weeks and older in battery housing (ca. 50% white) in kg N per animal year (category 301A)

Category 301A	1993			2005		
	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher
Total uptake	1,200	1,200	1,200	990	990	990
Excretion	850	850	850	628	628	628
In faeces	208	196	184	166	156	147
In urine	642	654	666	462	472	481
In urine (%)	75.5	76.9	78.3	73.5	75.1	76.7

From Table A3.6 follows that in the dependability of the differences in the N digestibility there are no large shifts in the relative N excretion through the faeces and urine; with a 2% unit difference in N digestibility the relative share in the urine increases with ca. 3% units.

A3.5 Hens and roosters of laying varieties ca. 18 weeks and older in housing other than battery (category 301B)

In section A3.4 some general remarks have been described that also concern this section. Also needs to be mentioned that in estimating the technical results in this housing systems research data of free range housing has been used. In this two types occur, with and without outside access. According to Statistics Netherlands (CBS, 2004) the number of animals is divided equally over both systems and the technical results over both systems are averages (KWIN-V, 1998; 2005).

A3.5.1 Starting points for 1998 and 2005

In the alternative housing (free range) almost completely middle heavy hens are used (Cijferinfo Pluimveesector 99/11; PVE, 1999). Also the data from research concern these hens. Therefore it has been chosen to take only the middle heavy hens for this category, both for 1998 as 2005.

The start weight of the middle heavy laying hens for 1998 and 2005 is 1,470 respectively 1,520 g (KWIN-V, 1998; 2005). The end weight of this category at the end of the laying period for 1998 and 2005 is 1,900 respectively 1,800 g (KWIN-V, 1998; 2005). In 1998 the length of the laying period is 401 days (380 days actually laying period, 21 days rearing) and in 2005 that is 406 (385 actual laying period, 21 days rearing (KWIN-V, 1998; 2005).

The feed uptake is 97.5 g/day during the rearing and 119 g/day during the actual laying period (KWIN-V, 1998), while in 2005 the uptakes are 100 respectively 121 g/day (KWIN-V, 2005). Per round the feed uptake for 1998 is on average 49.6 kg per hen present and 20.28 kg eggs are produced. This production takes place at an average feed conversion of 2.29. For 2005 the feed uptake is on average 48.7 kg per hen present and the egg production 20.19 kg, resulting in an average feed conversion of 2.25. The loss of animals amounts to 8.3% for 1998 and 9.3% for 2005. The percentage loss of animals is only used for the conversion of delivered hen to average hen present.

The start and laying feeds in 1998 contain on average 26.4 g N/kg (Tamminga *et al.*, 2000). For 2005 the average N content in the start and laying feeds was 24.9 g N/kg (Van Bruggen, 2007). The ratio between the laying feeds 1, 2 and 3 over the laying period is 40:40:20, both for 1993 and 2005. There are also businesses where laying feed 2 is given to the end of the laying period instead of switching to laying feed 3. In the calculations this is not considered.

The digestibility of the laying hen feeds in 1998 is derived from the feed compositions of Van Niekerk and Reuvekamp (1994; 1995a; 1995b; 1997) and Emous *et al.* (1999). For laying feed 1 there were six observations with an average N digestibility of 84.1%. Of laying feed 2 there were also six observations with an average N digestibility of 83.8%, while for laying feed 3 there were four observation with an average N digestibility of 83.2%. For 2005 we had the disposal of data on laying feed 1 of the first half year of 2006. The average N digestibility was 84.5%. For laying feed 2 the same N digestibility as of laying feed 1 is taken and for laying feed 3 84.0% is taken. The N digestibility of the start feed is set equal to that of the rearing feed 2.

A3.5.2 Results hens and roosters of laying varieties ca. 18 weeks and older in housing other than battery

In Table A3.7 is based on abovementioned starting points an overview given of the N excretion for hens and roosters of laying varieties of ca. 18 weeks and older in housing other than batteries. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

Table A3.7 N uptake and excretion (g) by hens and roosters of brown laying varieties ca. 18 weeks and older in housing other than batteries in kg N per animal year (category 301B)

Category 301B	**1998**				**2005**			
Uptake	**kg feed**	**g N/kg**	**DC-N (%)**	**kg N**	**kg feed**	**g N/kg**	**DC-N (%)**	**kg N**
Rearing feed	1.8	28.6	79.1	51	1.9	27.0	79.1	51
Laying feed 1	16.5	26.4	83.1	436	16.8	24.9	84.5	417
Laying feed 2	16.5	26.4	82.8	436	16.8	24.9	84.5	417
Laying feed 3	8.2	26.4	82.2	218	8.4	24.9	84.5	209
Total	43.0			1,140	43.8			1,094
Fixation				348				357
Excretion				792				736
In faeces				187				173
In urine				605				563
In urine (%)				76.4				76.5

From Table A3.7 follows that the N excretion form 1998 to 2005 decreased somewhat, but that there is no difference in the share TAN in the excreta.

A3.6 Rearing hens and roosters of meat varieties 0 to 19 weeks (category 310)

Category 310 concerns the young breeder animals for the broiler sector. Different from the laying sector this is a clearly distinguished category. Differences between hens and roosters have been taken into account. Conversion of parameters took place because in the manure legislation both the hens and roosters are counted, while parameters in some cases are expressed per hen.

A.3.6.1 Starting points for 2000 and 2005

The start weight of the rearing breeder animals (the chicks) is for both 2000 and 2005 set to 42 g (Van Middelkoop, 2000). The end weight of this category at ca. 19 weeks of age is for roosters and hens in 2000 2,750 respectively 2,000 g (Ross, 2004) and for 2005 the same weights are taken. The length of the rearing period is for 2000 and 2005 calculated to 126 days (KWIN-V, 2000; 2005). The number of roosters at lay on is 15%. On average there are 14.0% roosters per reared hen (KWIN-V, 2000; 2005). At the end of the rearing period selection of the roosters takes place. At lay on for the laying period 10% roosters are deployed. Per rearing period is for 2000 the feed uptake of rearing feed 1 and 2 per hen delivered 2.0 respectively 6.5 kg and per average hen present 1.68 respectively 5.47 kg, resulting in an average feed conversion of 3.49. For 2005 the same values are taken.

The loss of animals in 2000 amounts to 7.0 and 14.0% for hens and roosters and also for 2005. The percentage animals lost is only used for the conversion of delivered hen to average present animal.

The rearing feed contains in 2000 on average 28.3 g N/kg (Tamminga *et al.*, 2000) and in 2005 the average N content of the start and rearing feed is 26.1 g/kg (Van Bruggen, 2007). These contents are copied from those of rearing laying hens, since no data was available for the rearing of broiler breeders. The digestibility of the rearing feeds in 2000 is derived from the feed compositions of Van der Haar and Meijerhof (1996) and of a feed supplier. For rearing feed 1 there were two observations (average 80.8%) and for rearing feed 2 seven observations (average 80.7%). For the start feed is based on information from a feed supplier an N digestibility of 84.2% taken. For the rearing feeds 1 and 2 is an average N digestibility taken of 80.7%. Since data on rearing feeds in 2005 are lacking the same digestibilities as in 2000 are used.

A3.6.2 *Results rearing hens and roosters of meat varieties 0 to 19 weeks*

In Table A3.8 is based on abovementioned starting points an overview given of the N excretion for rearing hens and roosters of meat varieties 0 to 19 weeks. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

Table A3.8 N uptake and excretion (g) by rearing hens and roosters of meat varieties 0 to 19 weeks in kg N per animal year (category 310)

Category 310	**2000**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Rearing feed start	-	-	-	31.0	84.2	38
Rearing feed 1	28.6	80.8	140	28.4	80.8	104
Rearing feed 2	28.6	80.8	453	25.2	80.8	400
Total uptake			593			541
Fixation			200			200
Excretion			393			342
In faeces			114			99
In urine			280			242
In urine (%)			71.1			71.0

From Table A3.8 follows that the N excretion decreased somewhat from 2000 to 2005, but that there is no difference in the share TAN in the excreta.

A3.7 Breeders of meat varieties ca. 19 weeks and older (category 311)

Category 311 concerns the breeder animals for the broiler sector. Different from the laying sector this is a clearly distinguished category. Differences between hens and roosters are taken into account. Conversion of parameters took place because in the manure legislation both the hens and the roosters are counted, while parameters in some cases are expressed per hen.

A3.7.1 *Starting points*

The start weight of the hens respectively roosters for 1996 is 1,900 respectively 2,600 g and for 2005 2,000 respectively 2,750 g (Ross, 2004). The end weight of this category at the end of the production period is for hens and roosters for 1996 3,600 respectively 4,800 g and for 2005 3,700 respectively 4,800 g (KWIN-V, 1996; 2005). The length of the production cycle is for 1998 and 2006 calculated to 346 respectively 343 days (KWIN-V, 1996; 2005).

Goal for both 1996 as for 2005 is to have 10% roosters at the start of the laying period. Over the whole period on average 95.51 hens and 8.44 roosters are present. Per laying round is for 1996 the feed uptake on average 3.0 kg pre laying feed and 45.0 kg breeding brood feed per laid on hen (2.9 kg respectively 43.3 kg per average animal present) and 148 brood eggs and 10 consumption eggs of on average 62 grams apiece are produced. This results in 9.27 kg eggs per average present animal. For 2005 the feed uptake per round is on average 3.30 kg pre laying feed and 44.7 kg breeding brood feed per laid on hen (3.20 kg respectively 43.0 kg per average animal present) and 150 brood eggs and 10 consumption eggs of on average 62 grams are produced. This results in 9.54 kg eggs per average animal present. The loss of animals amounts for 1996 to 1.0 respectively 3.5% for hens and roosters during rearing and 10.0 respectively 35.0% during the laying period. For 2005 the percentages loss of animals during rearing are 1.0 respectively 3.6 and 10.0 respectively 35.0% during the laying period. The percentage animals lost is only used for the conversion of delivered hen to average present animal.

The N content in the pre laying feed and the breeding brood feed for 1996 is calculated by taking the average content of 1992 (WUM, 1994) and that of Tamminga *et al.* (2000). The pre laying feed then contains 31.0 g N/kg and the breeding brood feed 27.8 g N/kg. In 2005 the pre laying feed, breeding brood feed 1 and 2 contained respectively 25.2, 24.3 and 24.2 g N/kg (Van Bruggen, 2007). Of the N digestibility of the feeds in 1996 no data are available. For 2005 for the pre laying feed the N digestibility of the rearing feed 2 (80.8%) was taken. Based on data of a composite feed manufacturer beginning 2008 an N digestibility of the breeding brood feed 1 and 2 of 83.2 respectively 82.3% was calculated. These digestibilities are also taken for the feeds of 1996.

A3.7.2 *Results hens and roosters of meat varieties from ca. 19 weeks and older*

In Table A3.9 is based on abovementioned starting points an overview given of the N uptake and excretion for hens and roosters of meat varieties from ca. 19 weeks and older. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

Table A3.9 Nitrogen balance (g) in hens and roosters of meat varieties ca. 19 weeks and older in kg N per animal year (category 311)

Category 311	**1996**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Start feed	31.0	80.8	103	25.2	80.8	92
Breeding brood feed 1	27.8	83.2	614	24.3	83.2	538
Breeding brood feed 2	27.8	82.3	768	24.2	82.3	662
Total uptake			1,484			1,293
Fixation			258			262
Excretion			1,227			1,030
In faeces			259			225
In urine			968			805
In urine (%)			78.9			78.1

From Table A3.9 follows that the N excretion clearly decreases from 1998 to 2005 but that there is hardly difference in the share TAN in the excreta.

A3.8 Broilers (category 312)

A3.8.1 Starting points

The start weight of the broilers is for both 2002 and 2006 set to 42 g (Van Middelkoop, 2000). The end weight of broilers at 43 days of age is for 2002 and 2005 2,100 respectively 2,200 g (KWIN-V, 2003; 2007). Per production round is for 2002 the average feed conversion 1.76 (KWIN-V, 2002), resulting in a feed uptake of on average 3.70 kg. For 2005 the production period is 43 days, the feed conversion on average 1.79, resulting in a feed uptake of 3.94 kg (KWIN-V, 2005).

The broiler feed 1, 2 and 3 for 2002 contained 34.6, 32.0 respectively 30.9 g N/kg. The contents for 2005 are 36.0, 34.1 respectively 33.1 g/kg (Van Bruggen, 2007). Of the broiler feed 1 per production round 300 g is taken up, of broiler feed 2 1,500 g and the remainder is broiler feed 3. There are also businesses where besides compound feed also wheat or corn cob mix is fed additionally but in the calculations this is not taken into account.

The digestibility of the broilers is estimated based on various feed compositions of broiler feed 2 at a composite feed manufacturer in the first half of 2006. This was on average 83.9%. Based on discussions with experts it seems reasonable to raise the N digestibility of broiler feed 1 by 2.5% units, so that it becomes 85.4%. Also is assumed that the N digestibility of broiler feed 3 is 0.5% lower than of broiler feed 2, so that the N digestibility then becomes 83.4%. The digestibilities above are taken for 2005. For 2002 based on discussion with some experts an N digestibility for broiler feed 1, 2 and 3 of 85.1, 84.3 respectively 84.3 is taken.

A3.8.2 Results broilers

In Table A3.10 based on abovementioned assumptions an overview is given of the N excretion for broilers. The calculated excretion is expressed in g N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

Table A3.10 Nitrogen balance (g) in broilers in g N per animal year (category 312)

Category 312	**2002**			**2005**		
	g N/kg	**DC-N**	**N uptake (g)**	**g N/kg**	**DC-N**	**N uptake (g)**
Broiler feed 1	34.6	85.1	87	36.0	85.4	92
Broiler feed 2	32.0	84.3	403	34.1	83.9	434
Broiler feed 3	30.9	84.3	492	33.1	83.4	601
Total uptake			981			1,127
Fixation			479			508
Excretion			502			618
In faeces			153			183
In urine			349			435
In urine (%)			69.5			70.4

A3.8.3 *Discussion broilers*

From Table A3.10 follows that the N excretion from 2002 to 2005 increased clearly, but also that the share TAN in the excreta increased somewhat.

Table A3.11 N uptake and N excretion (kg) by broilers in g N per animal year (category 312)

Category 312	2002			2005		
	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher	DC-N 1 unit lower	DC-N starting point	DC-N 1 unit higher
Total uptake	981	981	981	1,127	1,127	1,127
Excretion	502	502	502	618	618	618
In faeces	163	153	144	194	183	172
In urine	339	349	359	424	435	446
In urine (%)	67.5	69.5	71.4	68.6	70.4	72.2

It has been examined what the effect of an N digestibility 1% unit higher or lower is on the excretion in faeces and urine. Table A3.11 gives the results of this.

From Table A3.11 follows that in the dependability of a difference in N digestibility of 2% units the amount N in urine as percentage of the total N excretion yields a difference of ca. 4% units.

A3.9 General discussion poultry

A3.9.1 *Reliability contents of and digestibility of N in chicken feeds and effects on the N excretion*

Not for all feeds there is a reliable picture of the correct content of N in feeds for chickens. Often these data are lacking in the various years. Also it is difficult or even not feasible to obtain these contents from compound feed manufacturers. In addition the raw material composition of the feeds is not released by most of the compound feed manufacturers. It is amply known that by whether or not taking up free amino acids in the feeds the N content in the feeds can be lowered, but at the same time it is also possible to take up protein containing raw materials of poorer quality in the feed. Depending on the strategy at the firm both the N content and the N digestibility can vary. It is desirable to collect better underpinned data hereof.

A3.10 Summary poultry

In Table A3.12 a summary is given of the excretion of N by various chicken categories in the reference year and in 2005 in g/year.

Table A3.12 Overview of the excretion of N and % TAN by various chicken categories in the reference year and 2005 (g/year)

Category	Number	Ref. year	N in ref. year	% TAN in ref. year	N in 2005	% TAN in 2005
Rearing laying hens (battery)	300A	1991	389	73.5	307	71.8
Rearing laying hens (ground)	300B	2000	388	73.1	343	72.0
Laying hens (battery)	301A	1993	850	76.9	628	75.1
Laying hens (ground)	301B	1998	792	76.4	736	76.5
Rearing broiler breeders	310	2000	393	71.1	342	71.0
Broiler breeders	311	1996	1,227	78.9	1,030	78.1
Broilers	312	2002	502	69.5	618	70.4

A3.11 Turkeys

A3.11.1 General

In Table A3.13 data on the average content of N in the animal product and in Table A3.14 the contents of protein and N and the faecal digestibility of N in the various turkey feeds are shown. The contents in the various turkey feeds in 1998 are derived from Veldkamp (1996) and Veldkamp *et al.* (1999) and in 2005 from Jongbloed and Kemme (2005). Also information was obtained from dr. Veldkamp, turkey specialist of ASG (Veldkamp, 2008).

Table A3.13 Weights and contents of N in various turkey categories and in turkey eggs

Livestock category	Weight (g) 1998	Weight (g) 2005	Physiological status	N content (g/kg)	Literature contents
Turkey egg	89	89	-	19.4	WUM, 1994
One-day turkey chick	57	57	-	30.0	LNV, 2004
Turkey for slaughter hen	9,500	9,800	Ca. 16.5 weeks	33.0	LNV, 2004
Turkey for slaughter rooster	18,500	19,500	Ca. 21 weeks	33.0	LNV, 2004

Table A3.14 Overview of the average N contents and digestibility of N in the various turkey feeds for 1998 and 2005

	Reference year			2005	
Feed type	**Year**	**g N/kg**	**DC-N (%)**	**g N/kg**	**DC-N (%)**
Start feed	1998	45.8	85.0	44.7	85.0
Turkey feed phase 2	1998	41.4	83.6	40.9	83.6
Turkey feed phase 3	1998	37.4	83.4	35.8	83.4
Turkey feed phase 4	1998	31.3	83.1	29.6	83.1
Turkey feed phase 5	1998	31.3	83.1	26.1	83.1
Turkey feed phase 6	1998	27.6	84.0	24.2	84.0

A3.11.2 Turkeys for slaughter (category 210)

To assess various technical results of turkeys for slaughter the data of KWIN are used. Furthermore information given by dr. Veldkamp (2008) has been processed.

A3.11.3 Starting points for 1998 and for 2005

The start weight of turkeys for slaughter for both 1998 and 2005 is set to 57 g (Veldkamp, 2008). For 1998 the end weight of the roosters and hens on an age of 147 and 116 days (on average 132 days) is 18.50 respectively 9.50 kg (average 14.00 kg). For 2005 the end weight of the roosters respectively hens on an age of 145 respectively 112 days (on average 128 days) is 19.50 respectively 9.80 kg (average 14.60 kg). Per production period is for 1998 the average feed conversion per kg delivered weight 2.63, resulting in a feed uptake of 36.9 kg per round and 99.9 kg per year. For 2005 the average feed conversion is 2.63, resulting in a feed uptake of 38.7 kg per round and 105.7 kg per year. The division of the feed uptake over the various phases is derived from British United Turkeys (2006).

The N contents in the various feeds for turkeys for slaughter are shown in Table A3.15. The N contents in the feeds for the year 1998 are derived from Veldkamp (1996) and Veldkamp *et al.* (1999) and are averages for each phase. The N contents in the various turkey feeds for 2005 are the same as mentioned by Jongbloed and Kemme (2005). Based on the feed composition according to Veldkamp *et al.* (1999) the digestibility of N in the various feeds for turkeys for slaughter are estimated. The digestibility of N in the distinguished feeds is kept equal for both years (Table A3.15) based on Veldkamp (2008).

A3.11.4 Results turkeys for slaughter

In Table A3.15 is based on abovementioned starting points an overview given of the N excretion for turkeys for slaughter. The calculated excretion is expressed in kg N per animal year (1 animal that is present the whole year). In this the figure differs from usual parameters in the sector.

From the results according to Table A3.15 follows that N excretion has decreased because of the lower N content in the feeds and a higher retention of N. As a result less N is excreted through the urine and share N in urine as percentage of the total N excretion decreased from 72.6 to 70.5%.

Table A3.15 Nitrogen balance (kg) in turkeys for slaughter in kg N per animal year (category 210)

Category 210	**1998**			**2005**		
	g N/kg	**DC-N (%)**	**N uptake (g)**	**g N/kg**	**DC-N (%)**	**N uptake (g)**
Start feed	45.8	85.0	53	44.7	85.0	54
Turkey feed phase 2	41.4	83.6	134	40.9	83.6	141
Turkey feed phase 3	37.4	83.4	553	35.8	83.4	561
Turkey feed phase 4	31.3	83.1	767	29.6	83.1	768
Turkey feed phase 5	31.3	83.1	992	26.1	83.1	876
Turkey feed phase 6	27.6	84.0	676	24.2	84.0	625
Total uptake			3,175			3,025
Fixation			1,248			1,321
Excretion			1,927			1,704
In faeces			527			502
In urine			1,400			1,202
In urine (%)			72.6			70.5

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Annex 4 Mineralisation and immobilisation of nitrogen in manure

A4.1 Translation of the annex from G.L. Velthof in Velthof *et al.*, 2009.

Part of the organic matter in manure is easily degradable and will already be broken down in the animal house or storage. During this process, CH_4 and CO_2 and depending on the composition of the manure, also NH_4^+ are formed (mineralisation). In manure containing straw (high C/N ratio) part of the NH_4^+ will be fixed (immobilised) as organic N.

The method to calculate NH_3 emission described in this report is based on TAN. As a result, changes in TAN during the storage of manure have to be taken into account.

In the literature, only little data is available on mineralisation and immobilisation of ammonium in manure storages. This is mainly because these processes are hard to determine through a balance method in manure from which also NH_3 is emitted. Another possibility to determine mineralisation is the use of ^{15}N labelled N, that is added to the ration of the animal or the manure.

In an incubation study of Sommer *et al.* (2007) the N mineralisation was low at 10 °C, for both cattle and pig slurry. The manure has been collected fresh and was stored frozen, until the start of the incubation study. The mineralisation increased strongly at increasing temperature. About 80% of the organic N was mineralised at 15-20 °C for 100-200 days. Mineralisation was higher in pig manure than in cattle manure.

In an incubation study of Sørensen *et al.* (2003), mineralisation of 9-50% of the organic N in cattle slurry was found. The fresh manure was incubated at 8 °C for 16 weeks first, and then for 4 weeks at 15 °C.

Processing of data from an incubation study of Velthof *et al.* (2005) shows that the N mineralisation of organic N of pig slurry at high temperature (90 days at 35 °C) was on average 15%, with a variation of -11 to +30% (depending 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 ^{15}N labelled urea was added (Beline *et al.*, 1998) the N mineralisation was 19% of the organic N during 84 days at 20 °C. The manure was collected from a farm and thus been stored for a while (it is not clear how long the storage period was).

In models used in England and Germany for calculation of ammonia emissions on the national scale the N mineralisation is set to 10% of the organic N (with reference to the research of Beline *et al.*, 1998). In the models used by Denmark and Switzerland, mineralisation is not (yet) taken into account.

In the methodology described in this report, it is assumed that 10% of the organic N in slurry stored in the animal house mineralizes. This might be a conservative assumption. Given the uncertainties only mineralisation in the animal houses is calculated and not in the outside storage. Also in the outside storage mineralisation can occur, but this is possibly lower since the easily degradable organic N will mineralize quickly after excretion in the animal house.

For solid manure except poultry manure, 25% immobilisation is assumed. In poultry manure, both solid and slurry, and slurry manure of other animals (rabbits and fur-bearing animals) no mineralisation or immobilisation takes place. It is recommended to conduct further research into (net) mineralisation in cattle and pig slurry, since this has an effect on calculated NH_3 emissions from the animal house, manure storage and manure application.

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Annex 5 Emission factors for NH_3 from animal housing of cattle

In this annex the emission factors in kg NH_3 per animal place are given that form the basis for the calculation of emission factors with respect to the TAN excretion (Section 5.2)

A5.1 Dairy cows

In the calculation model NEMA the N excretion is divided over the winter and grazing period. During the grazing period dairy cows spend part of their time in the animal house and another part on 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 NH_3 per animal place is calculated for dairy cattle kept continuously indoors in traditional housing systems. These are cubicle housings with slatted floors as walking area and manure storage below the grates (Rav-code A1.100). Decrease in emissions per hour of grazing is determined to be 2.61%. On a yearly basis the percentual emission reduction then is:

2.61% x (number of grazing hours per day) x (number of grazing days) / 365 (A5.1)

Based on the reference value of 13.0 kg NH_3 per animal place and above formula, in Table A5.1 emission factors are calculated for the winter period and for the time spent in the animal house during the grazing period for each grazing system. Ogink *et al.* (2014) do no split the year round emission. The calculation of the emission reduction by grazing of the working group NEMA differs somewhat from the calculation in Ogink *et al.* (2014). The working group NEMA takes the average number of grazing days in the years emission measurements took place (2007-2012) as the starting point, where in Ogink *et al.* (2014) the length of the grazing period of 2012 and a weighted average number of hours grazing per day are used.

In the calculation of the NH_3 emission of dairy cattle housings an increase in emission per animal place from 11.0 kg NH_3 in 2001 to 13.0 kg in the measurement period 2007-2012 is assumed.

Table A5.1 Emission factors for traditional dairy housing (kg NH_3/animal place), 2007-2015

	Grazing period (days)	Hours grazing per day	Emission reduction (kg NH_3)	Grazing period (kg NH_3)	Winter period (kg NH_3)	Year-round (kg NH_3)
	A[1)]	B[2)]	C[3)]	D[4)]	E[5)]	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 x (A/365) x (13.0 kg NH3).
4) (A/365) x (13.0 kg NH3) – C.
5) ((365-A)/365) x (13.0 kg NH3).
6) D + E.

For the emission years 2016-2018 the hours grazing per day were reconsidered, limited grazing was set to 7 hours and unlimited grazing to 19 hours leading to year-round emission factors of 11.90 and 10.01 kg NH_3/animal for limited and unlimited grazing respectively. For the years 2019-2020 the hours grazing per day for unlimited grazing were reconsidered and set to 18 hours, for 2021 they were set at 17 hours per day. These changes resulted in an emission factor of 10.17 kg NH_3/animal for unlimited grazing in 2019-2020 and 10.33 in 2021.

The emission factors for low-emission housing have been set to equal the emission factor of regular housing for the entire time series as with the exception of the tie stall with liquid manure. Few farms still use this housing system and the study performed by statistics Netherlands could not ensure that their study was representative for the entire time series. Therefore it was decided to keep the current emission factor of this housing system (van Bruggen *et al.,* 2023).

A5.2 Other cattle excluding veal calves

Ogink *et al.* (2014) propose to calculate NH_3 emission factors per animal place for other cattle categories with the formula:

(TAN excretion in the animal house of livestock category)/(TAN excretion in the animal house dairy cattle) x 13.0 (A5.2)

This therefore means that the emission factor for traditional housing compared to the TAN excretion for all cattle categories is equal. In NEMA emission factors are calculated compared to the TAN excretion including 10% mineralisation of organic N. Ogink *et al.* (2014) however do not consider the 10% mineralisation of organic N and as a result emission factors calculated with above formula differ somewhat because the percentage organic N differs between cattle categories. To prevent these differences the calculation in Ogink *et al.* (2014) is applied on TAN excretion including 10% mineralisation of organic N.

In the calculation of the NH_3 emission of dairy cattle housings an increase in emission per animal place from 11.0 kg NH_3 in 2001 to 13.0 kg in the measurement period 2007-2012 is assumed. By relating the emission factor for other cattle to that of dairy cows, the emission factor of other cattle increases as well.

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

Table A5.3 Emission factors NH_3-N for other cattle categories in % of TAN excretion (including 10% net mineralisation)

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

The emission factors for the different cattle categories are based on the TAN excretion in the 2007-2012 period and the emission factors in Table A5.3.

Table A5.4 Emission factors NH_3-N for other cattle categories in % of TAN excretion (including 10% net mineralisation)

	1990-2001	2002	2003	2004	2005	2006	2007-2021
	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	3.7	3.9	4.0	4.2
Female young stock – low emission	1.5	1.5	1.6	1.7	1.7	1.7	1.8
Suckling-, fattening- and grazing cows	3.4	3.5	3.7	3.8	3.9	4.1	4.2
Bulls for service including male young stock	7.5	7.9	8.2	8.5	8.9	9.2	9.5
Meat bulls 1 year and over	4.0	4.2	4.4	4.6	4.8	4.9	5.1

A5.3 Meat calves

In Groenestein *et al.* (2014) emission factors for meat calves are reconsidered in which separate emission factors are proposed for white veal calves and rosé veal calves. The factor for both categories was 2.5

kg NH_3 per animal place in the reference year 1998 with an occupancy rate of 0.93. The husbandry of meat calves and management thereof have evolved such that the available older measurement series are no longer representative of current practice. The new emission factors are derived from the emission factor of dairy cows (13.0 kg NH_3/animal place) in which differences in TAN excretion, size of emitting surfaces (Groenestein *et al.*, 2014) and the contribution of the grates and slurry pit to the emission of the animal house are taken into account. This method therefore differs from the method used in determining the emission factors for other cattle in above text. The new reference year is 2012.

The new factors are 3.1 and 3.7 kg NH_3 per animal place respectively for white veal calves and rosé veal calves, at an occupancy rate of 0.93 for white veal calves and 0.96 for rosé veal calves.

The emission factor for NH_3-N compared to the TAN excretion of white veal calves, including 10% mineralisation of organic N, is 27.15% in the years 1990-1998. As a result of the higher TAN excretion in the new reference year 2012 the emission factor per animal place gradually increases from 1999-2012 to 27.47% through linear interpolation.

For rosé veal calves the emission factor compared to the TAN excretion, including 10% mineralisation of organic N, is 12.99% in the years 1990-1998. The revised emission of 3.7 kg NH_3 per animal place yields an emission factor of 22.53% compared to the TAN excretion in the reference year 2012. Between 1998 and 2012 the emission factor is gradually increased through interpolation. The occupancy rate is increased from 0.93 to 0.96.

Since between the reference years 1998 and 2012 a gradual change in management took place, the emission factor is being interpolated. For meat calves two different methods for interpolation between 1998 and 2012 are possible: interpolation of the proposed Rav factor or interpolation of the emission factor compared to the TAN excretion. Interpolation of the proposed Rav factor means for white veal calves a gradual increase from 2.5 kg NH_3 to 3.1 kg NH_3 and for rosé veal calves an increase from 2.5 to 3.7 kg NH_3 per animal place. In the second method of interpolation the emission factor compared to the TAN excretion is gradually adjusted. For white veal calves this means the emission factor increases from 27.15 to 27.47% and for rosé veal calves a gradual increase from 12.99 to 22.53%.

The choice was made to interpolate the emission factor on the basis of net TAN excretion. With interpolation of the proposed Rav factor yearly fluctuations in the emission factor compared to the TAN excretion would occur, because TAN excretion also have yearly fluctuations. The latter is not logical since one would expect the emission factor compared to the TAN excretion to be constant or gradually changing because of changing management, but not to fluctuate yearly.

The average emission reduction of low-emission housing for the years 1990-1998 was established to be 76% compared to regular housing for both white and rose veal calves. From 2015 onwards average emission reduction percentages vary as more detailed information is available on housing systems. The average emission reduction peaked in 2016 at 89%. In 2021 the average emission reduction was 86%.

A5.4 References

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Annex 6 Emission factors for NH_3 from animal housing of pigs

In this annex the emission factors in kg NH_3 per animal place are given that form the basis for the calculation of emission factors relative to the TAN excretion (Section 5.2).

Table A6.1 Emission factors for traditional pig housing (kg NH_3 per animal place)

	kg NH_3 per animal place
Sows with piglets	8.3
Open and sows in pig	4.2
Weaned piglets	
Pen surface ≤ 0.35 m^2/animal place	0.60
Pen surface > 0.35 m^2/animal place	0.75
Fattening and rearing pigs	
Slurry pit under complete animal place, pen surface 0.8 m^2/animal place	5.0
Slurry pit under complete animal place, pen surface 1.0 m^2/animal place	6.1
Slurry pit under part of the animal place, pen surface 0.8 m^2/animal place	3.4
Slurry pit under part of the animal place, pen surface 1.0 m^2/animal place	4.0
Boars for service	5.5

Table A6.2 Emission factors for reduced emission housing of sows with piglets (kg NH_3 per animal place)

	EF	**1997-2004[1)]**	**2005-2006[2)]**	**2007-2010[3)]**	**2011-2012[4)]**	**2013-2014[5)]**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**
Air scrubbers													
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	3.4		-	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	3.4		-	0.02	0.03	0.03							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.	fr.
and water washer, biofilter													
Combined air scrubber system 85% emission reduction with water curtain and biological washer	3.4		-	-	0.10	0.24							
Average emission factor (kg NH_3/animal place)		**N/A**	**1.7**	**1.9**	**2.2**	**2.4**	**2.5**	**2.5**	**2.4**	**2.0**	**1.8**	**1.9**	**2.0**
Floor/slurry pit adjustment													
Rinsing gully system, rinsing with slurry	6.0		0.06	0.05	0.05	0.05							
Level coated pit floor with rack and pinion shove system	7.3		0.03	0.01	0.01	0.00							
Manure shove with coated sloping pit floor and urine gully	5.7		0.03	0.02	0.01	0.01							
Manure gully with manure discharge system	5.9		0.06	0.05	0.04	0.03							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**
Shallow slurry pits with manure and water canal	7.3		0.35	0.24	0.22	0.22							
Shovels in manure gully	4.6		0.05	0.04	0.02	0.02							
Cool deck system	4.4		0.12	0.10	0.09	0.08							
Manure pan/- box under farrowing pen	5.3		0.06	0.06	0.08	0.08							
Manure pan with water and manure canal under farrowing pen	5.3		0.16	0.19	0.18	0.16							
Water canal combined with separate manure canal or manure box	5.3		0.08	0.22	0.30	0.33							
Average emission factor (kg NH_3/animal place)		**7.6**	**6.0**	**5.9**	**5.7**	**5.7**	**5.9**	**5.9**	**6.2**	**6.4**	**6.4**	**5.9**	**5.9**

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.

Table A6.3 Emission factors for reduced emission housing of open and sows in pig (kg NH_3 per animal place)

	EF	**1997-2004[1)]**	**2005-2006[2)]**	**2007-2010[3)]**	**2011-2012[4)]**	**2013-2014[5)]**	**2015**	**2016**	**2017**	**2018-2021**
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**
Air scrubbers										
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	1.72		-	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	1.72		-	0.01	0.03	0.03				
Combined air scrubber system 85% emission reduction water curtain and biological washer	1.72		-	0.00	0.11	0.23				
Average emission factor (kg NH_3/animal place)		**N/A**	**0.90**	**1.00**	**1.10**	**1.10**	**1.20**	**1.20**	**1.20**	**1.00**
Floor/slurry pit adjustment										
Narrow shallow manure canals with metal three sided grates and sewerage (individual housing)	4.2		0.28	0.24	0.25	-				
Manure gully with combined grates and frequent manure disposal (individual housing)	3.3		0.06	0.05	0.04	-				

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018-2021
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**
Rinsing gully system with slurry (individual and group)	4.2		0.14	0.09	0.09	0.12				
Shovels in manure gully (individual housing)	4.0		0.02	0.01	0.01	-				
Cool deck system 115% cooling surface (individual and group)	4.0		0.12	0.08	0.07	0.10				
Cool deck system 135% cooling surface (individual and group)	4.0		0.12	0.14	0.11	0.15				
Group housing with feeding cubicles or feeding stations, without straw bed, tilting pit walls, metal three sided grate	4.2		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	4.2			0.02	0.06	0.12				
Walk about housing with sow feeding station and straw bed (group)	4.2		0.14	0.15	0.20	0.28				
Average emission factor (kg NH_3/animal place)		**3.8**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**

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.

Table A6.4 Emission factors for reduced emission housing of weaned piglets (kg NH_3 per animal place)

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**					
Air scrubbers													
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	0.25		-	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	0.25		-	0.02	0.04	0.03							
Combined air scrubber system 85% emission reduction water curtain and biological washer	0.25		-	0.00	0.14	0.30							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	fraction (fr.)	fr.	fr.	fr.	fr.	fr.	fr.					
Various combinations of low emission built housing with air scrubbers	ca. 0.03		-	-	0.01	0.01							
Average emission factor (kg NH_3/animal place)		**N/A**	**0.12**	**0.13**	**0.15**	**0.18**	**0.18**	**0.18**	**0.18**	**0.15**	**0.15**	**0.15**	**0.16**
Floor/slurry pit adjustment													
Level coated pit floor with rack and pinion shove system	0.33		0.01	0.01	0.02	0.02							
Rinsing gully system with slurry and partly slatted floor	0.38		0.07	0.05	0.03	0.03							
Manure capture in water combined with a manure disposal system	0.24		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	0.48		0.09	0.07	0.08	0.08							
Shallow slurry pits with water and manure channel of max. 0.19 m^2 per animal place	0.60		0.01	0.00	0.01	0.01							
Half grate with decreased manure surface	0.60		0.01	0.01	0.01	0.01							
Manure collection in and rinsing with acidified liquid fully slatted floor	0.29		0.02	0.01	0.01	0.00							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**	**fr.**					
Manure collection in and rinsing with acidified liquid party slatted floor	0.40		0.01	0.00	0.00	0.00							
Separated discharge manure and urine through tilting manure belt	0.366		0.01	0.00	0.00	0.00							
Cool deck system (150% cooling surface)	0.27		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	0.31		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	0.38		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	0.33		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	0.37		0.13	0.09	0.09	0.09							
Average emission factor (kg NH_3/animal place)		**0.55**	**0.31**	**0.31**	**0.31**	**0.31**	**0.33**	**0.33**	**0.33**	**0.31**	**0.31**	**0.31**	**0.31**

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.

Table A6.5 Emission factors for reduced emission housing of fattening pigs and young breeding pigs (kg NH_3 per animal place)

	EF	**1997-2004[1)]**	**2005-2006[2)]**	**2007-2010[3)]**	**2011-2012[4)]**	**2013-2014[5)]**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	kg NH_3/ animal place	**Fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**							
	0.9 m²	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**
Air scrubbers													
Biological air scrubber system 70% emission reduction	1.11		0.22	0.12	0.10	0.10							
Chemical air scrubber system 70% emission reduction	1.11		0.40	0.40	0.25	0.19							
Chemical air scrubber system 95% emission reduction	0.19		0.38	0.40	0.30	0.28							
Air scrubber, other than biological or chemical	0.56		-	0.08	0.34	0.42							
Various combinations of low emission built animal houses with air scrubbers	ca. 0.3		-	-	0.00	0.01							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**Fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**							
	0.9 m²	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**	**0.9 m²**
Average emission factor (kg NH_3 per animal place)		**NA**	**0.76**	**0.77**	**0.94**	**1.03**	**1.03**	**1.03**	**1.04**	**0.83**	**0.81**	**0.82**	**0.84**
Floor/slurry pit adjustment													
Floor/slurry pit adjustment													
Manure collection in and rinsing with NH_3 poor liquid	1.8		0.10	0.05	0.03	0.02							
Cool deck system 170% and metal three sided grate floor	1.9		0.13	0.08	0.04	0.03							
Manure collection in formaldehyde-liquid manure solution and metal three sided grate	1.1		0.04	0.04	0.01	0.01							
Manure collection in water and metal three sided grate	1.5		0.01	0.01	0.01	0.01							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	Fraction (fr.)	fr.	fr.	fr.	fr.							
	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2
Cool deck system 200% and metal grate, emitting surface max. 0.8 m^2	1.7		0.14	0.11	0.07	0.07							
Cool deck system 200% and metal grate, emitting surface max. 0.5 m^2	1.4		0.00	0.00	0.00	0.00							
Cool deck system 200% and other than metal grate, emitting surface max. 0.6 m^2	1.8		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		0.00	0.00	0.00	0.00							
Water-manure channel, tilting pit wall, metal three sided grate, emitting	1.2		0.20	0.17	0.24	0.24							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	Fraction (fr.)	fr.	fr.	fr.	fr.							
	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2	0.9 m^2
surface max. 0.18 m^2													
Water-manure channel, tilting pit wall, metal three sided grate, 0.18 m^2 < emitting surface < 0.27 m^2	1.7		0.02	0.03	0.06	0.07							
Water-manure channel, tilting pit wall, grate other than metal, emitting surface max. 0.18 m^2	1.9		0.15	0.34	0.37	0.40							
Water-manure channel, tilting pit wall, grate other than metal, 0,18 m^2 < emitting surface < 0.27 m^2	2.3		0.04	0.03	0.03	0.04							
Spherical floor pen with concrete spill	1.7		0.02	0.02	0.02	0.02							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**Fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**							
	0.9 m^2	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**	**0.9 m^2**
grate and metal three sided grate													
Pen with separate manure channels	2.1		0.01	0.01	0.01	0.01							
Rinsing gully system with metal three sided grates	1.4		0.03	0.02	0.02	0.02							
Rinsing gully system with other than three sided grates	2.0		0.07	0.06	0.04	0.04							
Floating balls in the manure	ca. 3.3		-	-	0.00	0.01							
Average emission factor (kg NH_3 per animal place)		3.40	3.29	3.2	3.2	3.2	3.2	3.2	3.2	3.29	3.29	3.29	3.29

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.

Table A6.6 Emission factors for reduced emission housing of boars (kg NH_3 per animal place)

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	Fraction (fr.)	fr.	fr.	fr.	fr.							
Air scrubbers													
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 washer	2.26		-	0.05	0.15	0.15							
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	2.26		-	0.01	0.02	0.01							
Combined air scrubber system 85% emission reduction water curtain and biological washer	2.26		-	-	0.06	0.26							

	EF	1997-2004[1)]	2005-2006[2)]	2007-2010[3)]	2011-2012[4)]	2013-2014[5)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**Fraction (fr.)**	**fr.**	**fr.**	**fr.**	**fr.**							
Average emission factor (kg NH_3/animal place)		**1.65**	**1.3**	**1.4**	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**0.68**	**1.3**	**1.2**	**1.2**
Floor/slurry pit adjustment through floating balls in the manure	5.5												

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.

References

Hoek, K.W. van der, 2002. Uitgangspunten voor de mest- en ammoniakberekeningen 1999 tot en met 2001 zoals gebruikt in de Milieubalans 2001 en 2002, inclusief datasets landbouwemissies 1980-2001 (in Dutch). RIVM report 773004013/2002. National Institute for Public Health and the Environment, Bilthoven, the Netherlands.

Annex 7 Emission factors for NH3 from animal housing of poultry

In this annex the emission factors in kg NH_3 per animal place are given that form the basis for the calculation of emission factors relative to the TAN excretion (section 5.2).

A7.1 Laying hens younger than ca. 18 weeks

In Table A7.1 the housing systems are given according to the former classification of the Agricultural census.

It is not clear which systems have been filled in by businesses under 'other battery cage housing solid manure' in the Agricultural census of 2008. To the other battery cage systems with solid manure belong the channel animal house (E1.4) and the battery cage system with manure belt aeration and above laying drying tunnel (E1.6). Although it concerns over 7% of the animal places in the Agricultural census of 2008, systems mentioned hardly occur in the environmental permits. Possibly it concerns businesses with manure belt aeration with the aeration turned off but producing solid manure after all through after drying, and therefore have filled in battery cage housing with solid manure (Ellen, 2010). The emission factor of manure belt with forced manure drying 0.2 m^3 per hour is applied as minimal value.

Table A7.1 (Derived) emission factors for laying hens under 18 weeks (kg NH_3 per animal place)

	1990-2010[1)]	2011-2012[2)]	2013-2014[3)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place	kg NH_3/ animal place
Battery cage with slurry										
Open storage	0.045	0.045	0.045	0.045	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	0.020	0.020	0.020	0.020
Battery cage with solid manure										
Manure belt, forced manure drying 0.2 m^3/animal/hour	0.025	0.026	0.026	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Manure belt, forced manure drying 0.4 m^3/animal/hour	0.011	0.012	0.012	0.006	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	0.006	0.007	0.007	0.001	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	0.020	0.020	0.020	0.020
Ground housing without manure aeration	0.170	0.170	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Ground housing with air scrubber	-	-	-	0.035	0.042	0.042	0.017	0.037	0.038	0.043
Aviary system										
Aviary housing without forced manure drying	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Aviary housing with forced manure drying	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Ground/aviary housing with air scrubber	0.017	0.009	0.011	-	-	-	-	-	-	-

	1990-2010[1)]	2011-2012[2)]	2013-2014[3)]	2015	2016	2017	2018	2019	2020	2021
	kg NH_3/ animal place	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**
Aviary system with manure drying										
Aviary housing without forced manure drying	0.055	0.056	0.056	0.062	0,067	0,060	0,065	0,063	0,062	0,059
Aviary housing with forced manure drying	0.055	0.056	0.056	0.062	0,063	0,059	0,064	0,066	0,066	0,067
Ground/aviary housing with air scrubber	0.022	0.015	0.017	-	-	-	-	-	-	-
Other housing	0.139	0.157	0.094	0.118	0.120	0,121	0,120	0,121	0,120	0,120

1) Source: environmental permits in province Noord-Brabant on 1-1-2009.
2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
3) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

A7.2 Laying hens

In Table A7.2 the housing systems are given according to the former classification of the Agricultural census.

It is assumed that the enriched cages and colony housing, both with manure belt aeration, have been filled in with battery cage housing with forced manure drying (0.7 m^3/hour) by businesses.

The "other battery cage system with solid manure" consists of canals animal house (E2.4 and the battery cage system with manure belt aeration and above lying drying tunnel (E2.6). These systems hardly occur. In other battery cage housing with solid manure it concerns most likely businesses with manure belt drying that have switched off the aeration. Possibly part of these businesses have after drying so that they produce solid manure after all (Ellen, 2010). For the share animals with housing type other battery cage solid manure the emission factor of manure belt with forced manure drying 0.042 m^3 per hour is applied as minimal value.

Table A7.2 (Derived) emission factors for laying hens (kg NH_3 per animal place)

	1990-1996 kg NH_3/ animal place	1997 kg NH_3/ animal place	1998 kg NH_3/ animal place	1999 kg NH_3/ animal place	2000 kg NH_3/ animal place	2001 kg NH_3/ animal place	2002 kg NH_3/ animal place	2003 kg NH_3/ animal place	2004 kg NH_3/ animal place	2005 kg NH_3/ animal place
Battery cage with slurry										
Open storage	0,083	0,083	0,083	0,083	0,083	0,100	0,100	0,100	0,100	0,100
Manure belt	0,035	0,035	0,035	0,035	0,035	0,042	0,042	0,042	0,042	0,042
Battery cage with solid manure										
Manure belt, forced manure drying 0.5 m^3/animal/hour	0,045	0,045	0,045	0,045	0,045	0,052	0,052	0,052	0,052	0,052
Manure belt, forced manure drying 0.7 m^3/animal/hour	0,020	0,020	0,020	0,020	0,020	0,022	0,022	0,022	0,022	0,022
Manure belt, forced manure drying 0.7 m^3/animal/hour with air scrubber	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011	0,011
Other battery cage solid manure	0,035	0,035	0,035	0,035	0,035	0,042	0,042	0,042	0,042	0,042
Ground housing										
Ground housing without manure aeration (including 0.1% with air scrubber)	0,315	0,322	0,329	0,336	0,342	0,349	0,356	0,363	0,370	0,377
Perfo system	0,110	0,112	0,115	0,117	0,119	0,122	0,124	0,127	0,129	0,131
Manure aeration	0,223	0,227	0,232	0,237	0,242	0,247	0,252	0,257	0,262	0,267
Manure belts	0,143	0,146	0,149	0,152	0,155	0,159	0,162	0,165	0,168	0,171
Manure belts with drying	0,153	0,156	0,159	0,162	0,165	0,169	0,172	0,175	0,178	0,181
Aviary housing										
Aviary housing without forced manure drying	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090
Aviary housing with forced manure drying	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090	0,090
Aviary housing with after drying	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100

	1990-1996 kg NH_3/ animal place	1997 kg NH_3/ animal place	1998 kg NH_3/ animal place	1999 kg NH_3/ animal place	2000 kg NH_3/ animal place	2001 kg NH_3/ animal place	2002 kg NH_3/ animal place	2003 kg NH_3/ animal place	2004 kg NH_3/ animal place	2005 kg NH_3/ animal place
Aviary housing with forced manure drying and after drying	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100
Other housing	0,290	0,296	0,303	0,309	0,315	0,322	0,328	0,334	0,341	0,347

Table A7.2 continued

	2006 kg NH_3/ animal place	2007 kg NH_3/ animal place	2008-2010[1] kg NH_3/ animal place	2011-2012[2] kg NH_3/ animal place	2013-2014[3] kg NH_3/ animal place	2015 kg NH_3/ animal place	2016 kg NH_3/ animal place	2017 kg NH_3/ animal place
Battery cage with slurry								
Open storage	0,100	0,100	0.100	0.100	0.100	0.100	0.100	0.100
Manure belt	0,042	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	0,052	0,052	0,052	0,050	0,050	0,050	0,050	0,050
Manure belt, forced manure drying 0.7 m^3/animal/hour	0,022	0,022	0,022	0,020	0,020	0,020	0,020	0,020
Manure belt, forced manure drying 0.7 m^3/animal/hour with air scrubber	0,011	0,011	0,011	0,009	0,009	0,009	0,009	0,009
Other battery cage solid manure	0,042	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)	0,384	0,391	0,402	0,402	0,402	0,402	0,402	0,402
Perfo system	0,134	0,136	0,140	0,140	0,140	0,140	0,140	0,140
Manure aeration	0,272	0,277	0,285	0,285	0,285	0,303	0,303	0,304
Manure belts	0,174	0,177	0,183	0,191	0,193	0,206	0,212	0,214

	2006 kg NH_3/ animal place	2007 kg NH_3/ animal place	2008-2010[1)] kg NH_3/ animal place	2011-2012[2)] kg NH_3/ animal place	2013-2014[3)] kg NH_3/ animal place	2015 kg NH_3/ animal place	2016 kg NH_3/ animal place	2017 kg NH_3/ animal place
Manure belts with drying	0,184	0,187	0,193	0,201	0,203	0,216	0,241	0,239
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	0,090	0,090	0,090	0.090	0.090	0.090	0.090	0.090
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	0,100	0,100	0,100	0,098	0,098	0,103	0,106	0,105
Other housing	0,353	0,359	0,370	0.295	0.101	-	-	-

Table A7.2 continued

	2018 kg NH_3/ animal place	2019 kg NH_3/ animal place	2020 kg NH_3/ animal place	2021 kg NH_3/ animal place
Battery cage with slurry				
Open storage	0,100	0,100	0,100	0,100
Manure belt	0,042	0,042	0,042	0,042
Battery cage with solid manure				
Manure belt, forced manure drying 0.5 m^3/animal/hour	0,042	0,042	0,042	0,042
Manure belt, forced manure drying 0.7 m^3/animal/hour	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
Other battery cage solid manure	0,038	0,037	0,037	0,036

	2018 kg NH_3/ animal place	2019 kg NH_3/ animal place	2020 kg NH_3/ animal place	2021 kg NH_3/ animal place
Ground housing				
Ground housing without manure aeration (including 0.1% with air scrubber)	0,402	0,402	0,402	0,402
Perfo system	0,140	0,140	0,140	0,140
Manure aeration	0,308	0,301	0,303	0,303
Manure belts	0,216	0,212	0,210	0,216
Manure belts with drying	0,249	0,242	0,240	0,243
Aviary housing				
Aviary housing without forced manure drying	0,087	0,087	0,086	0,086
Aviary housing with forced manure drying	0,090	0,090	0,090	0,090
Aviary housing with after drying	0,111	0,112	0,107	0,108
Aviary housing with forced manure drying and after drying	0,113	0,113	0,111	0,112
Other housing	**-**	**-**	**-**	**-**

1) Source: environmental permits in province Noord-Brabant on 1-1-2009.
2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
3) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

A7.3 Broiler breeders to circa 19 weeks

In Table A7.3 the animal housing systems are given according to the former classification in the Agricultural census.

Table A7.3 Emission factors for broiler breeders under 19 weeks (kg NH_3 per animal place)

	1990-2010	**2011-2014[1)]**	**2015[2)]**	**2016-2017**	**2018**	**2019**	**2020**	**2021**
	kg NH_3/ animal place	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**
Traditional housing	0.122	0.122	0.122	0.122	0,122	0,122	0,122	0,122
Air scrubber/biofilter	-	0.012	0.016	0.016	0,015	0,016	0,017	0,017
Other low-emission housing	-	0.122	0.122	0.121	0,116	0,113	0,111	0,111

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.

A7.4 Broiler breeders

In Table A7.4 the housing systems are given according to the former classification of the Agricultural census.

Table A7.4 Derived emission factors for broiler breeders (kg NH_3 per animal place)

	1990-1996 kg NH_3/ animal place	1997 kg NH_3/ animal place	1998 kg NH_3/ animal place	1999 kg NH_3/ animal place	2000 kg NH_3/ animal place	2001 kg NH_3/ animal place	2002 kg NH_3/ animal place	2003 kg NH_3/ animal place	2004 kg NH_3/ animal place
Traditional housing	0.580	0.576	0.572	0.568	0.564	0.560	0.556	0.552	0.548
Enriched cage/group cage	0.080	0.079	0.079	0.078	0.078	0.077	0.077	0.076	0.076
Enriched cage/group cage with after drying	0.090	0.089	0.089	0.088	0.088	0.087	0.087	0.086	0.086
Aviary housing with forced manure drying	0.170	0.169	0.168	0.167	0.165	0.164	0.163	0.162	0.161
Aviary housing with forced manure drying with after drying	0.180	0.179	0.178	0.177	0.175	0.174	0.173	0.172	0.171
Ground housing with manure aeration from above	0.395	0.392	0.389	0.387	0.384	0.381	0.378	0.375	0.373
Ground housing with vertical hoses in the manure or through tubes underneath the bin	0.580	0.576	0.572	0.568	0.564	0.560	0.556	0.552	0.548
Perfo system	0.363	0.361	0.358	0.356	0.353	0.351	0.349	0.346	0.344
Air scrubber systems	0.080	0.079	0.079	0.078	0.078	0.077	0.077	0.076	0.076
Ground housing with manure belts without after drying	0.387	0.384	0.382	0.379	0.376	0.373	0.370	0.368	0.365
Ground housing with manure belts with after drying	0.397	0.394	0.392	0.389	0.386	0.383	0.380	0.378	0.375

Table A7.4 continued

	2005 kg NH_3/ animal place	2006 kg NH_3/ animal place	2007 kg NH_3/ animal place	2008-2010 kg NH_3/ animal place	2011-2012 kg NH_3/ animal place	2013-2014 kg NH_3/ animal place	2015 kg NH_3/ animal place	2016 kg NH_3/ animal place	2017 kg NH_3/ animal place
Traditional housing	0.544	0.540	0.536	0.456	0.456	0.456	0.456	0.456	0.456
Enriched cage/group cage	0.075	0.075	0.074	0.063	0.063	0.063	0.063	0.063	0.063
Enriched cage/group cage with after drying	0.085	0.085	0.084	0.073	0.071	0.071	0.063	0.063	0.113
Aviary housing with forced manure drying	0.160	0.159	0.157	0.134	0.131	0.127	0.127	0.128	0.129
Aviary housing with forced manure drying with after drying	0.170	0.169	0.167	0.144	0.139	0.135	0.127	0.154	0.162
Ground housing with manure aeration from above	0.370	0.367	0.364	0.310	0.310	0.310	0.310	0.310	0.310
Ground housing with vertical hoses in the manure or through tubes underneath the bin	0.544	0.540	0.536	0.456	0.456	0.456	0.456	0.456	0.456
Perfo system	0.341	0.339	0.336	0.286	0.286	0.286	0.286	0.286	0.286
Air scrubber systems	0.075	0.075	0.074	0.063	0.113	0.111	0.056	0.046	0.046
Ground housing with manure belts without after drying	0.362	0.359	0.357	0.303	0.303	0.303	0.303	0.303	0.303
Ground housing with manure belts with after drying	0.372	0.369	0.367	0.313	0.311	0.311	0.353	0.316	0.318

Table A7.4 continued

	2018	2019	2020	2021
	kg NH_3/ animal place	**kg NH_3/ animal place**	**kg NH_3/ animal place**	**kg NH_3/ animal place**
Traditional housing	0.456	0.456	0.456	0.456
Enriched cage/group cage	0.063	0.063	0.063	0.063
Enriched cage/group cage with after drying	0.065	0.065	0.065	0.065
Aviary housing with forced manure drying	0.119	0.118	0.115	0.116
Aviary housing with forced manure drying with after drying	0.153	0.147	0.146	0.151
Ground housing with manure aeration from above	0.310	0.310	0.310	0.310
Ground housing with vertical hoses in the manure or through tubes underneath the bin	0.456	0.456	0.456	0.456
Perfo system	0.286	0.286	0.286	0.286
Air scrubber systems	0.046	0.046	0.061	0.080
Ground housing with manure belts without after drying	0.303	0.303	0.303	0.303
Ground housing with manure belts with after drying	0.329	0.305	0.303	0.303

1) Source: environmental permits in province Noord-Brabant on 1-1-2009.
2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
3) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

A7.5 Broilers

In Table A7.5 the housing systems are depicted according to the former classification of the Agricultural census.

Table A7.5 (Derived) emission factors for broilers (kg NH_3 per animal place)

	1990-2010[1)] kg NH_3/ animal place	**2011-2012[2)] kg NH_3/ animal place**	**2013-2014[3)] kg NH_3/ animal place**	**2015 kg NH_3/ animal place**	**2016 kg NH_3/ animal place**	**2017 kg NH_3/ animal place**	**2018 kg NH_3/ animal place**	**2019 kg NH_3/ animal place**	**2020 kg NH_3/ animal place**	**2021 kg NH_3/ animal place**
Traditional housing	0.068	0.068	0.068	0.068	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	0.007	0.007	0.005	0.005
Storey systems	0.011	0.012	0.011	0.029	0.024	0.026	0.016	0.016	0.016	0.017
Air scrubber systems	0.008	0.010	0.010	0.010	0.010	0.010	0.009	0.008	0.009	0.009
Ground housing with floor heating and cooling	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
Mixed air ventilation, warmth heaters and fans, air blending	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068

1) Source: environmental permits in province Noord-Brabant on 1-1-2009.
2) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2012.
3) Source: environmental permits in provinces: Overijssel, Gelderland, Utrecht, Noord-Brabant and Limburg on 01-01-2014.

A7.6 Ducks for slaughter

Ducks for slaughter are mostly held in traditional housing with an emission factor of 0.210 kg NH_3 per animal place. However, since 2015, ducks for slaughter are also kept in housing with air scrubbers. The emission factor of these ducks is 0.021 kg NH_3 per animal place.

A7.7 Turkeys for slaughter

In Table A7.6 the housing systems are presented according to the former classification of the Agricultural census (traditional housing and low emission housing).

Table A7.6 (Derived) emission factors for turkeys (kg NH_3 per animal place)

	1990-1998 kg NH_3/ animal place	1999 kg NH_3/ animal place	2000 kg NH_3/ animal place	2001 kg NH_3/ animal place	2002 kg NH_3/ animal place	2003 kg NH_3/ animal place	2004 kg NH_3/ animal place	2005 kg NH_3/ animal place	2006 kg NH_3/ animal place	2007 kg NH_3/ animal place
Traditional housing	0.680	0,719	0,758	0,797	0,837	0,876	0,915	0,954	0,993	1,032
Low-emission housing	0.493	0,493	0,493	0,493	0,493	0,493	0,493	0,493	0,493	0,493

Table A7.6 continued

	2008-2010 kg NH_3/ animal place	2011-2012 kg NH_3/ animal place	2013-2014 kg NH_3/ animal place	2015 kg NH_3/ animal place	2016 kg NH_3/ animal place	2017 kg NH_3/ animal place	2018 kg NH_3/ animal place	2019 kg NH_3/ animal place	2020 kg NH_3/ animal place	2021 kg NH_3/ animal place
Traditional housing	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932
Low-emission housing	0,493	0,411	0,404	0,383	0,374	0,368	0,364	0,378	0,377	0,383

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.

Annex 8 Animal house occupancy fractions

To convert emissions from animal housings in kg NH_3 per animal place to an emission factor in kg NH_3 per animal, the animal house occupancy fractions are needed. For instance an emission of 10.0 kg NH_3 per animal place at an occupancy fraction of 0.9 yields an emission of 10.0 / 0.9 = 11.1 kg NH_3 per animal entered in the Agricultural census. Table A8.1 presents reference year, occupancy fraction and period to which these apply (reporting period).

Table A8.1 Animal house occupancy (fraction) and reference year

	Reporting period	**Reference year[1)]**	**Animal house occupancy (fraction)**
Dairy cows	1990-2001	2001	0.9
	2002-2021	2007-2012	1.0
Other cattle excluding meat calves	1990-2021	2007-2012	1.0
Meat calves, for white veal production	1990-2021	1998	0.93
	1999-2021	2012	0.93
Meat calves, for rosé meat production	1990-1998	1998	0.93
	1999-2021	2012	0.96
Female sheep	1990-2021	1991	1.0
Milk goats	1990-2021	1998	1.0
Horses, ponies and mules	1990-2021	1997	1.0
Fattening pigs and rearing pigs	1990-2021	2008-2009	0.97
Sows	1990-2021	1994	[2)]
Boars for service	1990-2021	1991	0.9
Broiler breeders < 18 weeks	1990-2021	2008	0.83
Broiler breeders ≥ 18 weeks	1990-2007	1996	0.87
	2008-2021	2008	0.87
Laying hens < 18 weeks			
battery cage slurry, dry manure 0.2 m^3/h, other battery and other housing	1990-2021	1991	0.9
battery cage dry manure 0.4 m^3/h	1990-2021	1996	0.9
free range housing without manure aeration and aviary with manure drying	1990-2021	2000	0.9
aviary without manure drying with air scrubber	1990-2021	1998	0.9
Laying hens ≥ 18 weeks			

	Reporting period	Reference year[1)]	Animal house occupancy (fraction)
battery slurry with open storage, battery dry manure 0.7 m^3/h and deep pit	1990-2021	1996	0.95
battery slurry 2/week mucking, dry manure 0.5 m^3/h, other battery	1990-2021	1991	0.95
floor housing and other housing	1990-2007	1996	0.95
	2008-2021	2008	0.95
aviary without manure drying	1990-2021	1996	0.95
aviary manure drying	1990-2021	2001	0.95
Broilers			
traditional, litter drying, storey system with slatted floor and aeration, air scrubber	1990-2021	2002	0.81
ground housing with floor heating and -cooling	1990-2021	1997-1998	0.81
mixed air ventilation	1990-2021	2005	0.81
Ducks	1990-2021	2000	0.84
Turkeys			
traditional	1990-2007	1998	0.95
	2008-2021	2008	0.95
low emission	1990-2021	2008	0.95
Rabbits (mother animals)	1990-2021	1998	1.0
Rabbits for slaughter	1990-2021	1998	0.85
Fur-bearing animals (mother animals)	1990-2021	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 NH_3 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 Emission factors for calculation direct nitrous oxide emissions from agricultural soils (including grazing)

Marian van Schijndel and Sietske van der Sluis (PBL), 2011

For fertilisation with inorganic N fertilizers and animal manure and for grazing emission factors have been established and applied in the NIR 2011. For an overview see Table A10.1. This memorandum describes the derivation of the (weighted average) emission factors that are applied in the NIR 2011 for the period from 1990 to now in the ER-calculations of direct N_2O emissions from agricultural soils (including grazing).

Table A9.1 N_2O-N emission factors (% of the N supply) for calculation of direct N_2O emissions from agricultural soils and of N_2O emissions as a result of grazing (based on Velthof and Mosquera, 2011b and Van der Hoek et al., 2007). The marked emission factors are applied since the NIR 2011 (Van der Maas et al., 2011).

N_2O-emission factor (%)		Grass land	Arable land	Weighted average all land use and soils	Was previously (1)*	Remarks
Animal manure emission low	All soils			0.9	2 (1.7)	1990: 1.5 2008: 1.9
	Mineral soils	0.3	1.3		Like all soils	
	Peat soils	1	N/A		Like all soils	
Animal manure surface application	All soils			0.4	1 (0.9)	
	Mineral soils	0.1	0.6		1 (0.8)	1990: 0.8 1999: 0.9
	Peat soils	0.5	N/A		2 (1.6)	1990: 1.5 1995: 1.7
Inorganic N fertilizer	All soils			1.3	1 (1.04)	
	Mineral soils	0.8	0.7		Nitrate containing 1 (0.97). Ammonium containing 0.5 (0.48)	varying over the years
	Peat soils	3	N/A		Nitrate containing 2 (1.94). Ammonium containing 1 (0.97)	varying over the years
Grazing	All soils			3.3	1.68 (1.56)	
	Mineral soils	2.5	N/A			
	Peat soils	6.0	N/A			
					1 (0.93)	faeces
					2 (1.86)	urine

N_2O-emission factor (%)		Grass land	Arable land	Weighted average all land use and soils	Was previously (1)*	Remarks
Histosols	Peat soils	**	N/A	**	2	No adjustment
Crop residues	Mineral soils	N/A	**	**	1	No adjustment
Nitrogen fixation	Mineral soils	N/A	**	**	1	No adjustment
Sewage sludge	????				1	No adjustment

(1) Van der Hoek *et al.*, 2007.
* Between brackets the emission factors related to total gross N supply to soil (without deducting NH_3-N in fertilizing). In the old method the N_2O-N was calculated based on net N supply to soil, i.e. after deduction of NH_3-N. In the new method no NH_3-N deduction is applied anymore. Reason is that this also not happens in the N_2O measurements in field experiments.
** No (new) data available.

A9.1 Reason revision N_2O-N emission factors

In 1994 based on laboratory scale experiments country-specific emission factors for the direct N_2O emission from agricultural soils were derived (Kroeze, 1994) for the distinguished sources. The N_2O-N emission factor for low emission manure application and surface spreading were respectively 2 and 1% of the N supply to the soil. Thus the emission factor for low emission manure application was compared to surface spreading a factor 2 higher. In 1997 this was summarised in a methodology description (Spakman *et al.*, 1997). For surface spreading the country-specific N_2O-N emission factor was somewhat lower than the IPCC 1996 default (1% versus 1.25% of the N supply).

For the NIR 2005 (Klein Goldewijk *et al.*, 2005) the methodology was developed further and adjusted (Van der Hoek *et al.*, 2007). Amongst others the emission factor for inorganic N fertilizer is refined based on research of Velthof *et al.*, 1997. This refinement comprised that for a separate category inorganic N fertilizers (ammonium containing inorganic N fertilizers that do not contain nitrate) a 50% lower emission factor was applied than used before for all kinds of inorganic N fertilizer.

Based on field experiments in the Netherlands there seemed to be indications that the N_2O-N emission factor for low emission manure application was lower than the 2% of the N supply used (Velthof *et al.*, 2003 and Van Groeningen *et al.*, 2004). This led to the question whether low emission manure application in practice indeed had a higher N_2O-N emission factor than surface spreading. An overview of Dutch and international research results published after the publication of Kroeze in 1994 (Kuikman *et al.*, 2006) offered insufficient reason to adjust and/or further refine the emission factors for low emission manure application and surface spreading (Van der Hoek *et al.*, 2007). In the Netherlands only a very limited number of comparative experiments had been carried out between surface spreading and low emission manure application. These resulted in relatively low emission factors (< 0.1% of the N supply) for both application techniques (Velthof *et al.*, 1997). Results of international comparative field experiments showed that the nitrous oxide emissions for low emission manure application were mostly higher than for surface spreading. However it was not possible to derive long year average N_2O-N emission factors and adjust these for Dutch circumstances. It was concluded that more research was needed (see also the NIR 2006; Brandes *et al.*, 2006).

Between 2007 and 2010 in the Netherlands 2 to 3 year lasting comparative field experiments have been conducted to map the N_2O emissions for surface spreading and low emission manure application, in which for comparison also the fertilisation with inorganic N fertilizer was researched (Velthof *et al.*, 2010 and Velthof and Mosquera, 2011a). It was found that low emission manure application has higher N_2O-N emission factors than surface spreading.

The emission factors derived based were lower than the emission factors used for both fertilisation techniques, and there were differences in the N_2O-N emission factors between grassland and arable land and between animal manure and inorganic N fertilizer. These findings were the incentive to follow-up research. Based on all available Dutch and other NW European measurements of N_2O emission factors starting from the beginning of the nineties it was recommended to adjust the emission factors for manure application and inorganic N fertilizer use (Velthof and Mosquera, 2011b). PBL Netherlands Environmental Assessment Agency has reviewed the statistical analysis performed by Velthof and Mosquera on behalf of the Emission Registration (see annex 2 of this Annex).

A9.2 Motivation for calculating weighted average emission factors

Table 1 distinguishes for animal manure low emission manure application and surface fertilisation. Further for animal manure, inorganic N fertilizer and grazing there are separate emission factors for mineral soils, peat soils, grassland and arable land (see data in italics) as determined by Velthof and Mosquera, 2011b.

A9.2.1 Data series N supply to soil

Based on the historical data for N supply to grassland and arable land (part of the manure and NH_3 calculation for the Emission Registration, see for instance Hoogeveen *et al.*, 2010) for four soil types a yearly and multiannual weighted average emission factor can be calculated (Table A10.5 up to 7). For this the data series of 1990-2005 is used, because the data 2006-2008 show a trend break with the data of 1990-2005. Especially there is a factor 8 to 15 increase in the supply of respectively inorganic N fertilizer and animal manure to arable land on peat soil. Also there is almost a bisection in the supply of N in manure (through fertilisation and grazing) to grassland on peat.

This correlates to specific data becoming available on the cultivation of crops on several soil types through the Agricultural census since 2006. Up to 2006 this information was not available and crops were allocated to soil types. Grassland was situated on peat soil as much as possible and only in case of too little grassland also arable land was situated on peat soil. The supply of manure to arable land on peat soil was as a result of this limited to << 1% and deemed negligible.

In the assumption that the supply of manure to arable land is negligible, use of the whole data series (1990-2008) leads to a weighted average emission factor that is circa 0.1% lower than in using the data series 1990-2005. For the current emission calculations the data series of 1990-2005 is used to prevent underestimation of the emissions.

From the new information that is available over the period 2006-2008 it turns out that the supply of manure on arable land on peat soil is circa 1 to 2% higher. At this moment it is unknown whether including the supply of manure to arable land on peat leads to significant higher N_2O emission factors. There is no N_2O emission factor available for fertilisation of arable land on peat with animal manure or inorganic N fertilizer.

A sensitivity analysis shows that including the supply of manure to arable land on peat does not lead to a higher weighted average emission factor.

Only with an emission factor that is a factor 6 to 8 higher for supply of animal manure to arable land on peat the weighted average emission factor becomes 0.1% point higher. For inorganic N fertilizer this is only the case when the emission factor is a factor 40 higher.

Experiments on grassland show that the emission factor for peat soils is often a factor 3 to 5 higher than the emission factor for mineral soils. Assuming this increase also applies to arable land it is assumed that the weighted average emission factor is correct.

A9.2.2 *Variation in N supply to soil*

The share of the N supply to arable land coming from animal manure is for the whole period of 1990 until now on average circa 48%, this share varies between 36 and 57%.

Deviation of the average is therefore at maximum around 25%. For grassland the average N supply from animal manure is circa 52%, this varies between 43 and 64%. Deviation of the average is therefore at maximum around 20%. For grassland on peat soils an average N supply of circa 11% (9-14%) applies.

The share of the N supply to arable land coming from inorganic N fertilizer is for 1990 until now on average 27%, in which this share varies between circa 23 to circa 41%. Deviation of the average is therefore at maximum around 50%. For grassland the average N supply coming from inorganic N fertilizer is circa 73%, in which this share varies between circa 59 to 77%. Deviation from the average is therefore at maximum around 20%.

The variation in the shares of the N supply to arable land versus grassland therefore is tens of per cents. Also for the emission factors derived for the various sources the uncertainty is tens of per cents (see standard deviations in Velthof and Mosquera, 2011b).
The uncertainties of the emission factors and in the yearly N supply to mineral versus organic soils with grassland and arable land do not make it necessary to conduct yearly calculation for the distinguished sources.

Also for the supply of N_2O emission figures in international reports disaggregated emission factors are not necessary. From 2011 on the disaggregated data on N supply possibly will not become available yearly[1]. For these reasons multiannual weighted average emission factors are derived for surface spreading, for low emission manure application, for application of inorganic N fertilizers and for grazing.

A9.3 Weighted average emission factors

A9.3.1 Animal manure

For animal manure the (multiannual weighted average) N_2O emission factor for surface spreading and low emission manure application is respectively 0.4% and 0.9% of the N supply to soil. That is circa a factor 2 lower than the value applied up to now. This applies to surface spreading (decrease from circa 1 to 0.4% of the N supply) as well as low emission manure application (decrease from circa 2 to 0.9% of the N supply).

There is a significant difference in emission factors for low emission manure application and surface spreading. For low emission manure application the N_2O-N emission factor is a factor 2 higher than for surface spreading, namely 0.9% versus 0.4% of the N supply (Velthof *et al.*, 2010). The share of N in surface spreading decreases strongly between 1990 and 1995 (from 100 to 5%). This makes it necessary to calculate these sources separately in the yearly emission calculations and thus to differentiate separate emission factors for surface spreading and low emission manure application.

A9.3.2 Inorganic N fertilizer

For inorganic N fertilizer the (multiannual weighted average) N_2O-N emission factor is circa 30% higher than the value applied up until now (from circa 1 to 1.3% of the N supply). Reason is that especially for grassland on peat soils the emission factor based on measurement turns out to be higher than assumed (3% instead of 2%).

Also no longer a lower emission factor for ammonium containing (nitrate free) inorganic N fertilizer is applied, because the available measurements do not provide sufficient basis for different factors. In the Netherlands very few measurement were done; only 3 comparative experiments with a duration of more than 8 months. In 1 of the 3 experiments there seems to be a lower emission factor for the ammonium containing (nitrate fee) inorganic N fertilizer. In the other 2 experiments there is no difference or the emission factor is even higher. Also literature research into international measurements does not provide a definite answer (Velthof and Mosquera, 2011b).

A9.3.3 Grazing

For grazing the (multiannual weighted average) emission factor is circa a factor 2 higher based on measurements (urine/dung data in Appendix 1 of Velthof and Mosquera, 2011b); it increases from circa 1.7 to 3.3% N_2O-N of the N supply.

[1] This as result of the transition to a new calculation methodology for the yearly national NH_3 calculations (Velthof *et al.*, 2009 and Van Bruggen *et al.*, 2011). The previously yearly used MAMBO model for the NH_3 calculations will be applied by the ER possibly only for the purpose of regionalisation. This will likely be less frequent than yearly, for instance 3 yearly.

A9.3.4 *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%).

A9.3.5 *Comparison to IPCC defaults*

The new emission factor for crop residues

A9.3.6 *Uncertainties of weighted average emission factors*

Velthof and Mosquera (2011b) give uncertainties for the emission factors for animal manure, inorganic N fertilizer and grazing. For the calculation of the uncertainty of the weighted average emission factors an expert judgement (Luesink) was made on the uncertainty if the amount of manure going to different soil types and land use.

Table A9.2 Animal manure

Agricultural soil	Manure to soil	U manure to soil	EF (%)	U EF
Low emission (total x2)				70%
Organic grassland	21.6	40%	1.0	45%*
Mineral grassland	106.5	40%	0.3	33%
Mineral arable land	108.7	40%	1.3	23%
Surface spreading (total x2)				81%
Organic grassland	1.1	40%	0.5	45%*
Mineral grassland	5.5	40%	0.1	20%
Mineral arable land	5.6	40%	0.6	33%

* Velthof and Mosquera (2011b) do not give an uncertainty. The highest uncertainty of the other emission factors in taken, rounded at 5%.

Table A9.3 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 A9.4 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 A9.5 Calculation weighted average N_2O-N emission factor for application animal manure based on N in animal manure to soil**

		N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N_2O-N emission factor (% of N supply)	
year	**soil**	**arable land**	**grassland**	**arable land****	**grassland**	**low emission manure application**	**surface spreading**
1980	mineral	124,056,517	131,190,515	43%	46%	0.8	0.4
	peat	12,025	31,254,013		11%		
1984	mineral	149,064,760	121,560,842	50%	40%	0.9	0.4
	peat	39,840	29,774,908		10%		
1985	mineral	163,478,854	118,770,657	52%	38%	0.9	0.4
	peat	48,463	29,830,481		10%		
1987	mineral	177,840,312	109,262,083	56%	35%	0.9	0.4
	peat	65,403	29,254,982		9%		
1988	mineral	164,940,815	131,212,093	51%	40%	0.9	0.4
	peat	135,656	29,503,622		9%		
1989	mineral	175,935,382	120,319,586	54%	37%	0.9	0.4
	peat	190,745	28,275,924		9%		
1990	mineral	186,513,236	113,568,424	57%	35%	0.9	0.4
	peat	227,961	28,102,535		9%		
1991	mineral	160,111,819	149,104,352	46%	43%	0.8	0.4
	peat	212,422	36,882,599		11%		
1992	mineral	190,789,097	148,340,643	51%	40%	0.9	0.4
	peat	272,982	35,694,657		10%		
1993	mineral	168,860,398	172,584,027	44%	45%	0.8	0.4
	peat	290,342	42,588,332		11%		
1994	mineral	161,482,717	172,727,227	43%	46%	0.8	0.4
	peat	312,744	39,521,343		11%		
1995	mineral	127,921,589	175,486,807	36%	50%	0.8	0.3
	peat	416,212	47,621,425		14%		
1996	mineral	183,453,286	157,935,264	48%	41%	0.9	0.4
	peat	1,599,323	42,963,547		11%		
1997	mineral	161,978,074	133,007,449	49%	40%	0.9	0.4

		N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N$_2$O-N emission factor (% of N supply)	
year	**soil**	**arable land**	**grassland**	**arable land****	**grassland**	**low emission manure application**	**surface spreading**
	peat	1,193,763	37,554,142		11%		
1998	mineral	126,756,610	145,544,393	41%	47%	0.8	0.4
	peat	447,910	37,769,955		12%		
1999	mineral	163,289,415	129,991,784	50%	40%	0.9	0.4
	peat	215,418	35,090,459		11%		
2000	mineral	143,240,045	114,417,747	49%	39%	0.9	0.4
	peat	341,562	32,961,633		11%		
2001	mineral	131,772,857	124,241,918	45%	43%	0.8	0.4
	peat	230,807	36,298,625		12%		
2002	mineral	122,698,262	119,650,533	44%	43%	0.8	0.4
	peat	209,634	35,621,517		13%		
2003	mineral	126,006,911	117,602,005	45%	42%	0.8	0.4
	peat	164,073	35,520,456		13%		
2004	mineral	124,227,089	105,717,392	47%	40%	0.9	0.4
	peat	212,829	35,597,614		13%		
2005	mineral	117,023,028	104,205,390	46%	41%	0.9	0.4
	peat	251,242	35,832,769		14%		
2006	mineral	101,398,282	114,285,064	42%	48%	0.8	0.4
	peat	3,243,483	23,273,421		10%		
2007	mineral	111,809,202	117,300,043	44%	46%	0.8	0.4
	peat	3,634,559	23,164,601		9%		
2008	mineral	114,272,963	112,003,903	45%	45%	0.8	0.4
	peat	4,184,001	22,771,321		9%		
avg 1980-2005***			48%	41%	0.9		0.4
					11%		
avg 1980-2008			47%	42%	0.8		0.4
					11%		

*Table A9.6 Calculation weighted average N_2O emission factor for application inorganic N fertilizer based on N in inorganic N fertilizer to soil**

		N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N_2O-N emission factor (% of N supply)
year	**soil**	**arable land**	**grassland**	**arable land****	**grassland**	
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

		N supply (kg N) to	N supply (kg N) to	share N supply to	share N supply to	N_2O-N emission factor (% of N supply)
year	**soil**	**arable land**	**grassland**	**arable land****	**grassland**	
	peat	2,874,346	21,094,967		8%	
2007	mineral	83,018,237	128,571,402	36%	56%	1.2
	peat	2,165,854	18,554,082		8%	
2008	mineral	83,433,097	123,167,371	37%	55%	1.2
	peat	1,913,870	18,795,236		8%	
avg 1990-2005***				27%	60%	1.3
					13%	
avg 1990-2008				28%	60%	1.2
					12%	

*Table A9.7 Calculation weighted average N_2O emission factor for grazing based on N in pasture manure to soil**

year	N supply (kg N) to mineral	N supply (kg N) to peat	N_2O-N emission factor (% of N supply)
1980	107,508,357	24,674,512	3.2
1984	119,347,758	27,232,572	3.2
1985	121,731,826	28,144,527	3.2
1987	123,537,968	28,990,668	3.2
1988	115,887,919	27,259,575	3.2
1989	115,780,711	27,211,678	3.2
1990	121,894,046	28,534,860	3.2
1991	124,259,557	29,059,000	3.2
1992	119,230,167	28,189,410	3.2
1993	119,802,693	28,642,606	3.2
1994	110,172,205	26,420,847	3.2
1995	110,190,780	26,542,838	3.2
1996	112,515,810	30,676,162	3.2
1997	105,550,182	32,090,792	3.3
1998	94,709,103	28,909,070	3.3
1999	81,121,551	25,597,115	3.3
2000	74,318,394	23,178,293	3.3
2001	75,716,792	23,705,551	3.3
2002	60,076,981	19,368,654	3.4
2003	61,799,968	19,573,558	3.3
2004	60,023,293	21,370,347	3.4
2005	59,810,261	21,389,229	3.4
2006	66,689,712	12,502,196	3.1
2007	60,286,513	11,358,872	3.1
2008	64,312,534	11,955,203	3.0
avg 1990-2005***			3.3
avg 1990-2008			3.2

* N to soil after subtraction of NH_3-N during application because data without subtraction of NH_3-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 NH_3-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 fertilisation and grazing) to grassland on peat. This correlates to specific data becoming available on the cultivation of crops on several soil types through the Agricultural census from 2006 on.
In the assumption that the supply of manure to arable land is negligible, use of the whole data series (1990-2008) leads to a weighted average emission factor that is circa 0.1% point lower than in use of the data series 1990-2005. For the emission calculation the weighted average emission factor based on the data series 1990-2005 is used to prevent underestimation of the emissions. From a sensitivity analysis follows that there is a reasonable chance that weighing in the supply of manure to arable land on peat does not lead to an even higher weighted average emission factor.

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Annex 10 Uncertainty, quality assurance and verification

A10.1 Estimating uncertainties

For the PRTR dataset of 2020 uncertainties are calculated with the propagation of error method based on literature and expert judgements. Since calculation methods of activity data and emission factors do not change often, this dataset of uncertainties can be used for multiple years. When a calculation method is changed, the uncertainty of the considered activity data or emission factor is adjusted based on literature and expert judgements. This keeps the data set of uncertainties up to date.

List of experts consulted
Albert Bleeker
Cor van Bruggen
Karin Groenestein
Jan Huijsmans
Lotte Lagerwerf
Harry Luesink
Gerard Velthof

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Table A10.1 Uncertainty analysis results at database level for the reference year 2020

Ammonia (NH_3) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission**
		Activity data	**Emission factor**	**Emission**	**kg NH_3/year**
	Animal houses				
0446649	Dairy cows	2%	41%	41%	22.810.646
0446626	Young cattle for breeding	1%	37%	37%	4.491.893
0446671	Meat calves	1%	42%	43%	3.600.688
0446631	Young cattle for meat production	1%	31%	31%	703.826
0446683	Suckling cows (incl. fattening/grazing)	2%	35%	35%	229.504
0446679	Pigs for meat production	10%	43%	45%	8.816.144
0446679	Pigs for breeding	4%	42%	42%	3.363.266
0446645	Laying hens	2%	41%	41%	7.308.018

Emission source code	Description	Activity data	Emission factor	Emission	Emission kg NH_3/year
Ammonia (NH_3) - 2020					
		Aggregated uncertainties			
0446675	Broilers	5%	48%	48%	2.400.391
0446610	Ducks	5%	44%	45%	107.217
0446636	Turkeys	5%	44%	44%	457.364
0446667 and **0446719**	Sheep (all ewes)	6%	84%	84%	109.282
0446621	Goats	5%	59%	60%	823.058
0446640	Other animals (rabbits)	5%	51%	51%	107.351
0446661	Other animals (furbearing animals)	5%	43%	44%	59.260
Total, animal houses				20%	**55.387.907**
Outside storage					
0446648	Dairy cows	2%	184%	184%	532.993
0446625	Young cattle for breeding	1%	163%	163%	188.782
0446682	Suckling cows (incl. fattening/grazing)	2%	210%	210%	28.012
0446630	Young cattle for meat production	1%	213%	213%	93.062
0446678	Pigs for meat production	10%	208%	210%	206.717
0446614	Pigs for breeding	4%	179%	179%	115.902
0446644	Laying hens	2%	66%	66%	1.103.148
0446674	Broilers	5%	68%	69%	43.324
0446609	Ducks	5%	66%	67%	8.763
0446635	Turkeys	5%	5%	0%	0
0446666 and **0446718**	Sheep (all ewes)	6%	265%	265%	12.449
0446620	Goats	5%	244%	244%	156.290
0446639	Other animals (rabbits)	5%	238%	238%	5.122
0446660	Other animals (furbearing animals)	5%	211%	211%	9.723
Total, outside storage				57%	**2.504.287**
Manure treatment					
0441404	Dairy cows	50%	40%	67%	51.433
0441405	Young cattle	50%	40%	67%	8.811
0441407	Meat calves	50%	40%	67%	53.947
0441409	Fattening pigs	40%	36%	54%	619.989
0441410	Breeding pigs	43%	39%	58%	282.195
0441412	Laying hens	18%	42%	46%	78.314
0441411	Broilers	24%	25%	34%	15.289
0441413	Turkeys	25%	41%	48%	614
0441400	Dairy cows digestion	50%	40%	67%	36.378
0441401	Young cattle digestion	50%	40%	67%	6.232
0441402	Fattening pigs digestion	50%	40%	67%	130.901
0441403	Breeding pigs digestion	50%	40%	67%	66.717
Total, manure treatment				29%	1.350.820
Pasture land					
0446651	Dairy cows	2%	111%	111%	764.665
0446628	Young cattle for breeding	1%	86%	86%	270.378

Ammonia (NH_3) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission kg NH_3/year**
		Activity data	**Emission factor**	**Emission**	
0446685	Suckling cows (incl. fattening/grazing)	2%	101%	101%	76.798
0446633	Young cattle for meat production	1%	91%	91%	28.603
0446669	Sheep	5%	101%	101%	226.500
0446658	Horses and ponies	4%	92%	92%	93.040
0446606	Mules and asses	5%	108%	108%	595
0446715	Horses and ponies private parties	50%	110%	121%	341.215
0446706	mules and asses private parties	50%	121%	131%	182
0446724	Ewes private parties	50%	113%	124%	16.472
0400530	grazing nature areas	29%	64%	70%	83.443
Total, pasture land				53%	1.901.889
Application					
0446647	Dairy cows	2%	57%	57%	18.231.745
0446624	Young cattle for breeding	1%	50%	50%	4.226.420
0446629	Young cattle for meat production	1%	33%	33%	997.111
0446681	Suckling cows (incl. fattening/grazing)	2%	38%	38%	332.149
0446670	Meat calves	1%	87%	87%	1.089.770
0446677	Pigs for meat production	10%	76%	76%	2795223
0446613	Pigs for breeding	4%	41%	41%	1.485.463
0446643	Laying hens	2%	2%	0%	0
0446673	Broilers	5%	54%	55%	268.394
0446608	Ducks	5%	54%	54%	113.308
0446634	Turkeys	5%	5%	0%	0
0446664	Sheep	5%	71%	71%	118780
0446619	Goats	5%	57%	57%	1.668.933
0446653	Horses and ponies	4%	57%	57%	625.268
0446601	Mules and asses	5%	57%	57%	2.988
0446638	Other animals (rabbits)	5%	24%	25%	11.736
0446659	Other animals (furbearing animals)	5%	43%	44%	62.566
0446716	Ewes private parties	50%	82%	96%	10.489
0446710	Horses and ponies private parties	50%	94%	106%	1.997.022
0446701	Mules and asses private parties	50%	116%	126%	721
0400530	application outside agriculture	13%	27%	31%	1.637.507
Total, application				31%	35.675.593
Other sources					
0400500 and **0446707**	Fertilizer application	26%	26%	36%	9.856.599
0506800	Sewage sludge	25%	85%	88%	25.501
0400612 and **0446708**	Compost	23%	106%	111%	630.088
0444601	Crop residues	2%	44%	45%	2.231.179
0400210	Ripening crops			300%	1.821.429

Ammonia (NH_3) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission**
		Activity data	**Emission factor**	**Emission**	**kg NH_3/year**
Total, other sources				46%	14.564.796
	Outside agriculture				
0446713	Horses and ponies housing	39%	76%	86%	1.764.668
0446704	Mules and asses housing	15%	62%	64%	3.407
0446712	Horses and ponies outside storage	39%	268%	271%	263.022
0446703	Mules and asses outside storage	15%	246%	247%	346
Total, outside agriculture				82%	2.031.443
Total agriculture				23%	**111.385.292**
Total outside agriculture				82%	**2.031.443**
Total of all sources				23%	**113.416.735**

Nitrous oxide (N_2O) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission**
		Activity rate	**Emission factor**	**Emission**	**kg N_2O/year**
	Manure management				
0446650	Cows in milk and in calf	2%	70%	69,976%	643.036
0446627	Young stock for breeding	1%	48%	48%	147.746
0446672	Meat calves	1%	72%	72%	51.808
0446632	Young stock for fattening	1%	34%	33,82%	41.613
0446684	Suckling cows	2%	78%	78%	12.603
0446680	Fattening pigs	10%	101%	102%	89.793
0446617	Breeding pigs	4%	78%	78%	55.005
0446646	Laying hens	4%	75%	75%	55.187
0446676	Broilers	5%	105%	105%	28.558
0446611	Ducks	5%	102%	102%	750
0446637	Turkeys	5%	102%	102%	1.415
0446668 and 0446720	Sheep	6%	117%	117%	5.738
0446623	Goats	5%	102%	102%	137.927
0446657 and 0446714	Horses and ponies	39%	83%	91%	104.603
0446605 and 0446705	Mules and asses	12%	90%	91%	147
0446641	Rabbits	5%	101%	101%	2.437
0446662	Furbearing animals	5%	102%	102%	2.736

Nitrous oxide (N_2O) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission kg N_2O/year**
		Activity rate	**Emission factor**	**Emission**	
0444701	Atmospheric deposition manure management	18%	400%	407%	811.226
Total manure management				152%	**2.192.326**
Manure treatment					
0441404	Cows in milk and in calf	50%	100%	122%	14.470
0441405	Young stock for breeding	50%	100%	122%	2.479
0441407	Meat calves	50%	100%	122%	244.348
0441409	Fattening pigs	40%	89%	98%	126.352
0441410	Breeding pigs	43%	97%	106%	57.511
Total Manure treatment				74%	**445.160**
Agricultural soils					
0400500 and **0446707**	Inorganic fertilizer application	24%	34%	42%	3.846.269
0400600 and **0400530**	Manure application	3%	68%	69%	3.945.615
0440000 and **0446709**	Pasture manure	19%	64%	68%	2.987.542
0444500	Histosols	20%	46%	51%	1.499.094
0400310	Other organic soils	35%	57%	70%	824.417
0444600	Crop residues	2%	42%	42%	1.006.556
0400400	Pasture renewal	25%	160%	167%	101.338
0400610 and **0446708**	Compost	25%	100%	106%	52.522
0506800	Sewage sludge	25%	100%	106%	3.663
0444702	Atmospheric deposition agricultural soils	29%	400%	418%	819.703
0444800	Nitrogen leaching and run-off	51%	233%	267%	1.177.480
Total agricultural soils				37%	**16.264.201**
Total of all sources				37%	**18.901.686**

Nitrogen oxide (NO) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission kg NO/year**
		Activity rate	**Emission factor**	**Emission**	
Manure management					
0446650	Cows in milk and in calf	2%	70%	70%	876.867
0446627	Young stock for breeding	1%	48%	48%	201.472
0446672	Meat calves	1%	72%	72%	70.647
0446632	Young stock for fattening	1%	34%	34%	56.745
0446684	Suckling cows (incl. fattening/grazing)	2%	78%	78%	17.186
0446680	Fattening pigs	10%	101%	102%	122.445
0446617	Breeding pigs	4%	78%	78%	75.007
0446646	Laying hens	2%	75%	75%	75.254

Nitrogen oxide (NO) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission**
		Activity rate	**Emission factor**	**Emission**	**kg NO/year**
0446676	Broilers	5%	105%	105%	38.942
0446611	Ducks for slaughter	5%	102%	102%	1.022
0446637	Turkeys	5%	102%	102%	1.929
0446668 and **0446720**	Ewes	6%	110%	110%	7.825
0446623	Milk goats	5%	102%	102%	188.083
0446641	Rabbits	5%	101%	101%	3.323
0446662	Furbearing animals	5%	102%	102%	3.730
Total manure management				39%	**1.740.478**
Manure treatment					
0441404	Cows in milk and in calf	50%	100%	122%	19.731
0441405	Young stock for breeding	50%	100%	122%	3.380
0441407	Meat calves	50%	100%	122%	333.202
0441409	Fattening pigs	40%	89%	98%	172.299
0441410	Breeding pigs	43%	97%	106%	78.424
Total Manure treatment				74%	**607.036**
Agricultural soils					
0400600 and **0400530**	Manure application	3%	160%	160%	8.071.608
0440000 and **0446709**	Pasture	19%	160%	164%	1.563.969
0400500 and **0446707**	Inorganic fertilizer	24%	160%	166%	6.284.299
0506800	Sewage sludge	25%	160%	167%	6.661
0400610 and **0446708**	Compost	25%	160%	167%	214.864
0444600	Crop residues	2%	160%	160%	1.647.092
0400400	Pasture renewal	25%	160%	167%	72.361
0444500	Histosols	20%	167%	171%	1.226.531
0400310	Other organic soils	35%	167%	180%	674.523
Total agricultural soils				87%	**19.761.908**
outside agriculture					
0446657 and **0446714**	Horses and ponies	39%	82%	91%	142.640
0446605 and **0446705**	Mules and asses	12%	89%	89%	200
Total, outside agriculture				91%	**142.840**

Nitrogen oxide (NO) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg NO/year
Total agriculture				78%	**22.109.421**
Total outside agriculture				91%	**142.840**
Total of all sources				77%	**22.252.261**

Methane (CH_4) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg CH_4/year
	Manure management, tier 1				
0446668 and **0446720**	Sheep, manure management	10%	181%	181%	31.767
0443501 and **0446723**	Sheep, pasture	10%	37%	39%	149.570
0446623	Goats, manure management	10%	30%	32%	82.240
0446657 and **0446714**	Horses, manure management	39%	67%	77%	418.850
0446658 and **0446715**	Horses, pasture	39%	141%	147%	220.805
0446605 and **0446705**	Mules and asses, manure management	15%	56%	58%	519
0446606 and **0446706**	Mules and asses, pasture	15%	81%	83%	363
0446641	Rabbits, manure management	10%	30%	32%	26.797
0446662	Fur bearing animals, manure management	5%	30%	30%	295.937
Total (tier 1)				39%	**1.226.847**
	Manure management, tier 2				
0446650	Dairy cows, manure management	2%	39%	39%	58.971.672
0446651	Dairy cows, pasture	2%	43%	43%	465.822
0446627	Young cattle for breeding, manure management	1%	27%	27%	9.288.775
0446632	Young cattle for meat production, manure management	1%	20%	20%	1.296.033
0446663	Young cattle, pasture	1%	33%	33%	154.074

Methane (CH_4) - 2020					
Emission source code	**Description**	**Aggregated uncertainties**			**Emission**
		Activity rate	**Emission factor**	**Emission**	**kg CH_4/year**
0446684	Suckling cows (incl. fattening/grazing), manure management	2%	37%	37%	351.695
0446685	Suckling cows (incl. fattening/grazing), pasture	2%	43%	43%	44.883
0446672	Meat calves, manure management	1%	28%	28%	5.263.350
0441421	Pigs for breeding, manure management	4%	36%	36%	18.166.847
0446680	Pigs for meat production, manure management	10%	40%	41%	35.174.918
0446676	Broilers, manure management	5%	74%	74%	1.160.161
0446646	Laying hens, manure management	2%	53%	53%	1.378.633
0446611	Ducks, manure management	5%	74%	74%	28.540
0446637	Turkeys, manure management	5%	74%	74%	40.726
Total (tier 2)				21%	**131.786.128**
Manure treatment					
0441404	Dairy cows	50,00%	30,00%	60,21%	409.170
0441405	Young cattle	50,00%	30,00%	60,21%	63.744
0441407	Meat calves	50,00%	30,00%	60,21%	142.808
0441409	Fattening pigs	39,43%	26,45%	47,48%	9.532.457
0441410	Breeding pigs	42,58%	28,56%	51,27%	4.266.216
0441412	Laying hens	17,69%	21,89%	28,15%	53.404
0441411	Broilers	23,65%	29,25%	37,62%	80.485
0441413	Turkeys	25,00%	30,92%	39,76%	4.380
0441400	Dairy cows digestion	50,00%	30,00%	60,21%	328.579
0441401	Young cattle digestion	50,00%	30,00%	60,21%	51.188
0441402	Fattening pigs digestion	50,00%	30,00%	60,21%	616.368
0441403	Breeding pigs digestion	50,00%	30,00%	60,21%	308.569
Total, manure treatment				32%	**15.857.368**
Total (manure)				19%	**148.870.343**
Fermentation, tier 1					
0443500 and **0446717**	Sheep	10%	40%	41%	7.635.224
0444501	Goats	10%	40%	41%	3.163.080
0446654 and **0446711**	Horses	39%	40%	58%	7.380.630
0446602 and **0446702**	Mules and asses	15%	40%	41%	11.600

Methane (CH_4) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg CH_4/year
0446500	Pigs	6%	40%	41%	17.790.564
Total (tier 1)				25%	**35.981.098**
	Fermentation, tier 2 and 3				
0441501	Young cattle	1%	12%	12%	69.325.807
0442500	Suckling cows (incl. fattening/grazing)	2%	23%	23%	4.540.097
0441600	Dairy cows NW	3%	21%	21%	93.196.328
0441700	Dairy cows SE	2%	21%	21%	124.804.681
Total (tier 2 and 3)				12%	291.866.913
Total (fermentation)				11%	**327.848.011**
Total of all sources				9%	**476.718.354**

Non-methane volatile organic components (NMVOC) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg NMVOC/year
	Manure management				
0446627	Young stock for breeding	1%	187%	187%	6.995.797
0446650	Cows in milk and in calf	2%	220%	220%	43.619.517
0446672	Meat calves	1%	223%	223%	1.658.113
0446632	Young stock for fattening	1%	136%	136%	1.594.376
0446684	Suckling cows (incl. fattening/grazing)	2%	307%	307%	221.482
0446680	Fattening pigs	10%	303%	303%	1.120.234
0446617	Breeding pigs	4%	294%	295%	2.256.059
0446646	Broilers	5%	302%	302%	3.161.698
0446676	Layers	2%	209%	209%	2.943.581
0446611	Ducks for slaughter	5%	302%	302%	51.356
0446637	Turkeys	5%	302%	302%	67.746
0446668 and **0446720**	Sheep	6%	283%	283%	21.060
0446623	Goats	5%	302%	302%	612.424
0446641	Rabbits	5%	302%	302%	2.364
0446662	Fur animals	5%	302%	302%	147.145
Total, manure management				152%	**64.472.951**
	Agricultural soils				
0400600 and **0400530**	Manure application	5%	125%	125%	9.734.323
0440000 and **0446709**	Pasture manure	5%	159%	159%	234.279
0441430	Silage storage	1%	176%	176%	11.434.212

Non-methane volatile organic components (NMVOC) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg NMVOC/year
0400201	Crops	12%	218%	218%	1.462.359
Total, crop production and agricultural soils				104%	**22.865.172**
Total, agriculture				115%	**87.338.124**
Outside agriculture					
0446657 and **0446714**	Horses and ponies	42%	256%	260%	243.411
0446605 and **0446705**	Mules and asses	12%	252%	252%	295
Total outside agriculture				259%	**243.706**
Total				115%	**87.581.830**

Particulate matter < 10µm (PM_{10}) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg PM_{10}/year
Manure management					
0446627	Young stock for breeding	1%	22%	22%	48.689
0446650	Cows in milk and in calf	2%	25%	25%	199.258
0446672	Meat calves	1%	33%	33%	33.060
0446632	Young stock for fattening	1%	25%	25%	19.581
0446684	Suckling cows (incl. fattening/grazing)	2%	32%	32%	5.026
0446680	Fattening pigs	10%	29%	31%	545.153
0446617	Breeding pigs	8%	31%	32%	279.595
0446646	Broilers	5%	28%	28%	1.079.923
0446676	Layers	2%	36%	36%	2.290.180
0446611	Ducks for slaughter	5%	35%	35%	71.276
0446637	Turkeys	5%	32%	32%	53.258
0446641	Rabbits	5%	49%	49%	410
0446662	Fur-bearing animals	5%	49%	49%	3.525
0446668 and **0446720**	Sheep	10%	37%	39%	1.741
0446623	Goats	5%	32%	32%	12.020
Total, animal houses				19%	4.642.695
Outside agriculture					
0446657 and **0446714**	Horses and ponies	39%	36%	53%	90.208
0446605 and **0446705**	Mules and asses	12%	29%	31%	186
Agricultural soils					

Emission source code	Description	Activity rate	Emission factor	Emission	Emission kg PM_{10}/year
Particulate matter < 10µm (PM_{10}) - 2020					
		Aggregated uncertainties			
0449300	Concentrates	25%	100%	106%	90.000
0449400	Inorganic fertilizer	25%	100%	106%	105.000
0449500	Pesticides	25%	100%	106%	125.000
0449600	Harvesting	2%	225%	225%	374.990
Total, agricultural soils				125%	**694.990**
Total agriculture				23%	**5.337.685**
Total outside agriculture				53%	**90.393**
Total of all sources				23%	**5.428.078**

Emission source code	Description	Activity rate	Emission factor	Emission	Emission kg $PM_{2.5}$/year
Particulate matter < 2.5 µm ($PM_{2.5}$) - 2020					
		Aggregated uncertainties			
Manure management					
0446627	Young stock for breeding	1%	24%	24%	13.425
0446650	Cows in milk and in calf	2%	27%	28%	54.935
0446672	Meat calves	1%	35%	35%	9.076
0446632	Young stock for fattening	1%	28%	28%	5.391
0446684	Suckling cows (incl. fattening/grazing)	2%	35%	35%	1.388
0446680	Fattening pigs	10%	35%	37%	25.704
0446617	Breeding pigs	8%	30%	31%	13.092
0446646	Broilers	5%	37%	38%	80.937
0446676	Layers	2%	77%	77%	139.759
0446611	Ducks for slaughter	5%	46%	47%	3.409
0446637	Turkeys	5%	43%	43%	24.977
0446641	Rabbits	5%	100%	100%	80
0446662	Fur-bearing animals	5%	100%	100%	1.828
0446668 and **0446720**	Sheep	10%	37%	39%	522
0446623	Goats	5%	35%	35%	3.606
Total, animal houses				30%	378.129
Outside agriculture					
0446657 and **0446714**	Horses and ponies private	39%	36%	53%	57.401
0446605 and **0446705**	Mules and asses	12%	33%	35%	116
Agricultural soils					
0449300	Concentrates	25%	100%	106%	18.000
0449400	Inorganic fertilizer	25%	100%	106%	21.000
0449500	Pesticides	25%	100%	106%	25.000

Particulate matter < 2.5 µm ($PM_{2.5}$) - 2020					
Emission source code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg $PM_{2.5}$/year
0449600	Harvesting	2%	222%	222%	40.756
Total, agricultural soils				94%	104.756
Total agriculture				31%	482.885
Total outside agriculture				53%	57.521
Total of all sources				29%	540.406

Carbon dioxide (CO_2) - 2020					
CRF code	Description	Aggregated uncertainties			Emission
		Activity rate	Emission factor	Emission	kg CO_2/year
		Liming			
N320000	Limestone	28%	1%	28%	19.267.521
N320001	Dolomite	49%	1%	49%	11.767.290
Total liming				25%	31.034.811
		Urea Application			
0400510	Urea application	25%	1%	25%	47.171.958
Total all sources				18%	**78.206.768**

A10.2 Quality assurance and quality control (QA/QC)

The PRTR task force leader on Agriculture is responsible for:

1. well documented and adopted data;
2. calculations having been implemented correctly;
3. assumptions are consistent, specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

A yearly check on the above mentioned responsibilities is performed. Any actions that result from these checks are noted on an '*action list'* by the ER secretary. The task force leader is responsible for improvements and communicates by e-mail regarding these QC checks, actions and results with the ER secretary.

While adding a new emission year the task force leader performs a *trend analysis*, in which data from the new year are compared with data from the previous years. The task force leader provides an explanation if the increase or decrease of emissions exceeds the minimum level of 5% at target group level or 0.5% at national level. These explanations are also sent by e-mail to the PRTR secretary by the task force leader.

The PRTR secretary keeps a logbook of all these QC checks and trend explanations and archives all concerned e-mails on the ER network. This shows explicitly that the required checks and corrections have been carried out. Based on the results of the trend analysis and the feedback on the control and correction process ('action list') the Working Group on Emissions Monitoring (WEM) gives advice to the institute representatives (Deltares on behalf of Rijkswaterstaat, Statistics

Netherlands (CBS) and Netherlands Environmental Assessment Agency (PBL)) to approve the dataset. The PRTR project leader at RIVM defines the dataset, on receipt of an e-mail by the institute representatives, in which they give their approval.

Furthermore, all changes of emissions in the whole time series as a *result of recalculations* are documented in CRF table 8(b).

A10.3 Verification

To check the quality of the calculated emissions for the sources named in this report, general QA/QC-procedures have been followed that are in line with the IPCC Guidelines. These are described further in the QA/QC-programme used by the National System, and the annual working plans published by the PRTR.

Sector-specific QC
No additional specific verification procedures are implemented for the sources defined in this sector.

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Annex 11 List of abbreviations

B_o	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_2O	Nitrous oxide
NEC	National Emission Ceilings
NEMA	National Emission Model for Agriculture
NFR	Nomenclature For Reporting
NH_3	Ammonia
NIE	National Inventory Entity
NO_x	Nitrogen oxides
PBL	PBL Netherlands Environmental Assessment Agency
PM_{10}	Particulate matter up to 10 µm in size
$PM_{2.5}$	Particulate matter up to 2.5 µm in size
PRTR	Pollutant Release and Transfer Register
RIVM	National Institute for Public Health and the Environment
RVO	Netherlands Enterprise Agency
TAN	Total Ammoniacal Nitrogen
UN	United Nations
VS	Volatile Solids
WUR	Wageningen University & Research
Y_m	Methane-conversion factor (for the calculation of CH_4 from enteric fermentation)

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