European Commission

JRC TECHNICAL REPORT

Methodological overview on the calculation of air pollutant and greenhouse gas emissions from agricultural activities

2020

Banja, M., Crippa, M.



Joint Research Centre

EUR 30338 EN

This publication is a Technical report by the Joint Research Centre (JRC), the European Commission's science and knowledge service. It aims to provide evidence-based scientific support to the European policymaking process. The scientific output expressed does not imply a policy position of the European Commission. Neither the European Commission nor any person acting on behalf of the Commission is responsible for the use that might be made of this publication. For information on the methodology and quality underlying the data used in this publication for which the source is neither Eurostat nor other Commission services, users should contact the referenced source. The designations employed and the presentation of material on the maps do not imply the expression of any opinion whatsoever on the part of the European Union concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Contact information
Name: Monica Crippa
Address: European Commission, Joint Research Centre, via E. Fermi, 2749 – 21027 Ispra (VA), Italy
Email: monica.crippa@ec.europa.eu

EU Science Hub
https://ec.europa.eu/jrc

JRC121579

EUR 30338 EN

PDF ISBN 978-92-76-25423-2 ISSN 1831-9424 doi:10.2760/255034

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Banja. M. and Crippa. M., *Methodological overview on the calculation of air pollutant and greenhouse gas emissions from agricultural activities*, EUR 30338 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25423-2, doi:10.2760/255034, JRC121579.

This report is a re-edition of: Banja. M. and Crippa. M., *Methodological overview on the calculation of air pollutant and greenhouse gas emissions from agricultural activities*, EUR 30338 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21415-1, doi:10.2760/240, JRC121579.

Contents

Acknowledgements

This report was prepared by the Air and Climate Unit (C.5) at Joint Research Centre under the Administrative Arrangement Directorate General for Environment - Clean Air (ENV.C.3) / JRC-C.5 related to the "Support to the improvement of national emission inventories for the agricultural sector in Europe".

A special thank goes to the reviewers Marilena Muntean and Enrico Pisoni (JRC, C.5), Viviane Andre (ENV.C.3), Susanne Lindahl (ENV.C.3), Zlatko Kregar (ENV.C.3) and Gerardus Klaassen (DG Clima C.1).

The report benefited from the discussions with the Agriculture Expert Panel of the Task Force on Emission Inventories and Projections Barbara Amon and Nicholas John Hutchings, as well as the input and support of Federico Antognazza from the European Environment Agency.

Authors

Manjola Banja collected the most recent information on air pollutant and greenhouse gas emissions in each EU country for agricultural sectors, collected methodologies applied for each agricultural category in each EU country, collected activity data and emission factors available for each EU country agricultural sector, carried out data analysis, prepared the graphs and tables, prepared the examples of questionnaires and drafted the report.

Monica Crippa is the overall responsible of the report defining the working methodology, the structure and supervising the entire work developed under this Administrative Arrangement and this report.

Abstract

Improving the estimates of air pollutant and greenhouse gas (GHG) emissions from agricultural activities is important not only in relation to the magnitude of the impact of these activities on air quality and climate change, but also to understand their contribution in relation to other activities such as energy, industrial processes, waste etc. The complexity of the existing farming systems brings to the necessity of the transparency and harmonisation on how the quantitative estimation of air pollutant and GHG emissions from such activities are performed and reported.

The aim of this report is to provide an overview of the different methodologies and parameters needed to estimate air pollutant and GHG emissions from all agricultural sub-sectors, following the EMEP/EEA and IPCC guidelines.

The report findings will contribute to the development of a database on activity data and emission factors as input for a tool to support the development of robust agricultural air pollutant emission inventories at Member State level.

1. Introduction

Agriculture is a primary sector of the EU[1] economy contributing with €176.9 billion (1.1% in relative terms) of the EU's overall GDP in 2018 (Eurostat, 2019). Livestock production in the EU covers 45% of the EU´s agricultural production value. This contribution is much higher in Ireland (74.2%), Denmark (66.4%), United Kingdom (60.2%) and Belgium (58.9%) (BLE, 2019).

The EU adopted in 2001, the National Emission Ceilings Directive (2001/81/EC) setting the emissions ceilings per country for main air pollutants. In 2016, this was replaced by the National Emission reduction Commitments Directive (NECD) (2016/2284/EU).

The NECD established emission reduction commitments for each country and required the development and implementation of first National Air Pollution Control Programmes by 2019, and every 4 years thereafter, setting out measures to comply with the 2020-2029 and 2030 reduction commitments.

The introduction over time of the Common Agriculture Policy (CAP) and other regulations, especially those related to the environment, have influenced the EU livestock sector. In 2018, the EU livestock population consisted of 2084 million animals, 1.8% less than the number in 1990. Among this population there were around 980 million broilers (17% more than in 1990), 507.8 million laying hens (9% less), 137.5 million pigs (16.8% less), 99.4 million sheep (31.8% less) and 87.9 million cattle (25% less) (Eionet, 2020).

The newly proposed CAP for 2021-2027, in the EU countries including climate adaptation strategies or national adaptation plans, has enabled adaptation actions in the agricultural sector (EEA, 2019).

Processes such as fertilisers use, livestock production, decomposition of manure, burning of agricultural residues, etc., are carried out within the agricultural sector through several activities such as enteric fermentation, manure management and agricultural soils. These activities are a source of greenhouse gases (GHGs) such as methane (CH_4), and nitrous oxide (N_2O) and air pollutants like ammonia (NH_3), nitrogen oxides (NO_x expressed as NO_2), particulate matter (PM_{10}, $PM_{2.5}$, TSP), non-methane organic volatile compounds (NMVOC), sulfur dioxide (SO_2), carbon monoxide (CO), heavy metals, and contributors to air pollution such as pesticides.

Deposition of air pollutants as NH_3 and NO_x can lead to adverse effects on public health but also on ecosystems, in the form of eutrophication and acidification whereas exposure to particulate matter and NO_x can cause detrimental health effects and their emissions can contribute also to the acidification and climate change. Even that NH_3 is not a GHG it is an indirect precursor of N_2O emissions.

In 2018, the NH_3 emissions from agricultural sector sourced nearly 93% of total NH_3 emissions in the EU, half of which coming from agricultural soils activities. In meanwhile the agricultural activities contributed with respectively 19% and 16% in the total EU emissions of NMVOC and PM_{10} in 2018 (Eionet, 2020).

In this year, the GHG emissions from the agricultural sector covered 10.3% of total GHG emissions in the EU. Methane emissions from enteric fermentation represented more than 40% of all GHG emissions from agriculture (EEA, 2019).

The United Nations Economic Commission for Europe (UNECE) Emission Reporting Guidelines under the Air Convention[2] (UNECE, 2015) set down principles and procedures for the annual inventory reporting on air pollutant emissions. The joint Guidebooks of Co-operative Programme for Monitoring and Evaluation of the Long-Range Transboundary of Air Pollutants in Europe (EMEP) and European Environment Agency (EEA) published in 2013, 2016 and 2019[3] provide general methods for the preparation of such inventories.

As signatories to international conventions, the EU countries have the obligation to prepare annual emission inventories for both air pollutants and GHG. The relevant documents for agriculture currently used under the UNFCCC are the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and the 2019 refinement of these guidelines (IPCC, 2019). The Intergovernmental Panel on Climate Change (IPCC) has

([1]) This report present an analysis that cover the period 1990-2018. Hereafter the European Union including UK will be referred as EU.
[2] UNECE Convention on Long-Range Transboundary Air Pollution
([3]) EMEP/EEA Guidebook 2019 https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

developed guidance documents on how GHG emissions as CH_4 and N_2O from all anthropogenic sectors including agriculture should be calculated.

The aim of this report is to provide an overview of the methodologies applied for the estimation of air pollutant and GHG emissions in each EU country for the agricultural subsectors (enteric fermentation, manure management and agricultural soils).

The report also provides an overview of the parameters already available in CAPRI (Common Agricultural Policy Regionalised Impact), EDGAR (Emissions Database for Global Atmospheric Research), GAINS (Greenhouse Gas and Air Pollution Interactions and Synergies) models, and other scientific sources to quantify such emissions.

Based on the findings of this report in relation to the calculation of air pollutant emissions from agriculture, examples of questionnaires that can be used to collect information at farm level are also compiled.

The findings presented in this report will further contribute to the development of a database on activity data and emission factors as input for a tool to support the development of robust agricultural air pollutant emission inventories at Member State level.

2. General methodology to estimate agricultural emissions

2.1 Overview of the Tier 1-2-3 methodologies - EMEP/EEA Guidebooks and IPCC Guidelines

Methodologies to estimate the agricultural air pollutants and greenhouse gas emissions in place in the EU countries are based on and in line with the **EMEP/EEA Guidebooks (2013, 2016 and 2019), the IPCC Guidelines (1997, 2006 and 2019) and the IPCC Good Practice Guidance (IPCC, 2000).** From the survey carried out in the countries reporting it was found that consistency exists among methodologies applied to compile the agricultural emission inventories under the UNFCCC and UNECE/Air Convention. This consistency is guaranteed through an integrated activity data collection, preparation of inventories and reporting to the respective international conventions and EU Directives. The comparison between the reporting in the National Inventory Report/Common Reporting Format (NIR/CRF) for the GHG emissions inventory and the reporting in the Informative Inventory Report/Nomenclature for Reporting (IIR/NFR) is coherent and consistent. Changes to the NFR structure since 2001 have ensured a continuing consistency with the IPCC source nomenclature. Box 1 summarises the different methods available to compute air pollutant emission estimations.

Figure 1. EMEP/EEA approaches for quantifying air pollutants emissions from agricultural activities

Tier 1 with default values and simple approaches

Tier 2 to be applied for key categories using country-specific (CS) activity data (AD) and emission factors (EFs)

Tier 3 recommended when enough data are available to develop for e.g. sophisticated models

Box. 1. Short overview of the EMEP/EEA Guide 2019 calculation methods

Tier 1 method (T1)

The Tier 1 method assumes that between activity data and emission factors a simple linear relation exists. The default Tier 1 emission factors are chosen to represent 'typical' or 'averaged' process conditions and they tend to be technology independent. For example, the following equation is applied for manure management:

$$E_{pollutant\_animal} = AAP_{animal} * EF_{pollutant\_animal} \quad [1]$$

where:

$E_{pollutant\_animal}$ - is the emission of a certain pollutant from a certain livestock category
AAP_{animal} – is the number of animals of a livestock category on average within the year (annual average population)
$EF_{pollutant\_animal}$ – is the emission factor for each pollutant emitted from each livestock category (kg/AAP/yr)

The AAP indicator for the manure management subsector is sourced and complemented using country national statistics (NS), Food and Agriculture Organisation (FAO), Eurostat, UNFCCC reporting - Common Reporting Format (CRF) Tables), National Emission reduction Commitments Directive (NECD) reporting under Annex I (the template).

Tier 2 method (T2)

The Tier 2 method uses the same or similar activity data as the Tier 1 method, but it applies country-specific emission factors. This method can be recommended especially when large livestock populations are present. However, emission calculations in accordance with this method require more detailed data. For example, to calculate NH_3 emissions from manure management, detailed data are required on animal performance (related with forage or feed quality) and on the feeding details for which default values may not be available as those for manure fractions (slurry or solid), ratio slurry/solid stored on farms and used for biogas production (for each livestock), proportion of slurry manure deposited in houses (for each livestock). Applying a Tier 2 method better reflects the management practices and animal productivity (quality and quantity of production during a specific period), allowing to catch the effects on the corresponding emissions and to shape mitigation policies.

Tier 3 method (T3)

The Tier 3 method goes further than the two above mentioned methods. It can include more detailed facility-level data and/or sophisticated models taking in consideration a detailed diet composition, seasonal variation of animal population or feed quality, the application of abatement measures, possible mitigation strategies and factors affecting feed requirements.

Source: EMEP/EEA Guidebook 2019

2.2 Overview of the EDGAR methodology to compute agricultural emissions

The estimation of air pollutant (CO, NH_3, NOx, NMVOC, SO_2, TSP, PM_{10}, $PM_{2.5}$, BC and OC) and GHG (CO_2, CH_4, N_2O, HFCs, PFCs and SF6) emissions using the Emissions Database for Global Atmospheric Research[4] (EDGAR) provides an independent input of emission data to e.g. atmospheric models, IPCC Assessment Reports, etc. This estimation is carried out using consistent methodologies based on available international statistics, scientific literature, and EMEP/EEA and IPCC guidance documents. The emission calculation in EDGAR is based on a technology dependent emission factor approach consistently applied for all countries. The structure of the emission calculation in EDGAR is presented in Equation 2:

$$EM_c(y,x) = \sum_{I,j,k} [AD_{c,i}(y) * TECH_{c,i,j}(y) * EOP_{c,i,j,k}(y,x) * EF_{c,i,j}(y,x) * (1 - RED_{c,i,j,k}(y,x)] \qquad [2]$$

where:

$EM_c(y,x)$ – Emissions for country (c) calculated on annual basis (y) for each compound (x),
$AD_{c,i}(y)$ – Country specific activity data for each sector (i) on annual basis (y),
$TECH_{c,i,j}(y)$ – Country specific mix of technologies (j) in each sector (i) on annual basis (y),
$EOP_{c,i,j,k}(y,x)$ – The abatement percentage by one of the k end-of-pipe measures for each technology (j) in each sector (i) and in each country (c) on annual basis (y),
$EF_{c,i,j}(y,x)$ – Country specific emission factor in each country (c) for each sector (i) and technology (j) on annual basis (y) for each compound (x),
$RED_{c,i,j,k}(y,x)$ – Relative reduction of the uncontrolled emission by installed abatement measure (k) in each country (c), each sector (i) and each technology (j) calculated on annual basis (y) and for each compound (x).

Activity data used in EDGAR to calculate emissions from the agricultural sector are presented in Table 1 whereas livestock categories for the estimation of air pollutant and GHG emissions are shown in Table 2.

Table 1. EDGAR agricultural activity data categories applied for each compound

EDGAR code	Compound	Description	unit
ENF	CH_4	Enteric fermentation (several animal types)	1000 head
MNM	CH_4, N_2O, NH_3, NO_x	Manure management (several animal types)	1000 head
AGS.ANW	N_2O, NH_3, NO_X	N in manure used as fertiliser (several animal	Gg N
AGS.CRP	N_2O, NO_x, NH_3	N in crop residues left to soils (several crop	Gg N
AGS.HIS	N_2O	Managed organic soils (two climate types)	Ha
AGS.LMN	CO_2	Liming of croplands and grasslands	kton lime
AGS.NFE	N_2O, NH_3, NO_x	Fertiliser application (several fertiliser types)	Gg N
AGS.URE	CO_2	C in urea fertiliser applied	Gg C
AGS.RIC	CH_4	Rice cultivation	Ha
AGS. [animal type].[animal	N_2O, NH_3, NO_x	Animal manure excreted in pasture	1000 head
AWB.CRP	NO_x, CO, N_2O, CH_4, NH_3, SO_2, PM_{10}, $PM_{2.5}$, NMVOC, BC, OC	Field burning of agricultural residues (several crop types)	Gg dry matter
N_2O.IDR	Indirect N_2O	N available for leaching/runoff in agricultural	Gg N

Table 2. Livestock categories included in estimation of air pollutant and GHG emissions from agricultural activities in EDGAR

EDGAR code	NFR code	Description	Enteric fermentation (ENF)	Manure management (MNM)	Manure in pasture (AGS)
DCH	3B1a	Dairy cattle	x	x	x
NCH	3B1a	Non-dairy cattle	x	x	x
SHP	3B2	Sheep	x	x	x
PGS	3B3	Swine	x	x	x
BFL	3B4a	Buffalo	x	x	x
GTS	3B4d	Goats	x	x	x
HRS	3B4e	Horses	x	x	x
SSS	3B4f	Mules and Asses	x	x	x
TRK	3B4giii	Turkey	-	x	-
CHC	3B4giv	Chicken	-	x	-
DCK	3B4giv	Ducks	-	x	-
CML	3B4h	Camels	x	x	x

([4]) (https://edgar.jrc.ec.europa.eu/index.php

Livestock numbers used in EDGAR for the estimation of emissions from both enteric fermentation and manure management are sourced from FAOSTAT and updated every year. Area on rice cultivation is also sourced from FAOSTAT. Data on fertilisers (12 types) are sourced from International Fertiliser Association (IFA) statistics. 24 different crop types are included in the categories Crop residues left on soils (AGS.CRP) and Field burning of agricultural residues (AWB.CRP).

2.2.1 Enteric fermentation

The estimation of CH_4 emissions from enteric fermentation in EDGAR is based on the Tier 2 method suggested by the IPCC 2006 Guidelines, Vol.4, Ch.10 (IPCC, 2006). Emission factors for CH_4 emissions from dairy cattle for enteric fermentation are calculated accordingly with Eq. 10.21 of the IPCC 2006 Guidelines based on the estimated daily gross energy intake (GE) or feed intake and a CH_4 conversion rate (see section 3.1). For other cattle livestock categories the emission factors are calculated based on the IPCC 2006, Vol.4, Ch.10, Eq. 10.16. The country-specific milk yield trend of FAO is used to estimate the trend in emission factors over time. IPCC 2006 defaults parameters are applied for digestible energy (DE%).

2.2.2 Manure Management

Country specific CH_4 emission factors for manure management are estimated applying the IPCC 2006 Tier 2 approach that uses the emission factors for each country group and temperature zone (Vol.4, Ch.10, tables 10.14 and 10.15). Detailed cattle maps are used to estimate the distribution of agricultural activities in each country accordingly with temperature zones, and country-specific emission factors are calculated on this basis. Only one country-specific emission factor was developed for each country, as the IPCC defaults include the information on the average use of manure management systems.

In the EDGAR model, the split for different technologies is applied for manure management. 9 different manure management technologies are defined for the livestock, except for poultry, including (i) pasture/range/paddock, (ii) solid storage, (iii) liquid/slurry, (iv) lagoon, (v) dry lot, (vi) daily spread of manure, (vii) pit, (viii) digester and (ix) burned for fuel.

Emission factors needed to estimate the N_2O, NH_3 and NOx emissions from manure management using EDGAR are calculated as in the following (Eq. 3, 4 and 5):

$$EFN_2O = N_{ex} \times TAM \times N_2O_{factor} \quad [3]$$

$$EFNH_3 = N_{ex} \times TAM \times NH_{3factor} \quad [4]$$

$$EFNOx = N_{ex} \times TAM \times NOx_{factor} \quad [5]$$

where
N_{ex} - is the nitrogen (N) excreted rate (kg N / kg_animal_mass) [5]
TAM - is the typical animal mass (kg) [6]
N_2O_{factor} - is the emission of N_2O per kg N excreted for each manure management system[7]
$NH_{3factor}$ - is compiled based on the volatilisation of NH_3 from manure management (kg NH_3/kg N excreted)[8]
NOx_{factor} - is estimated at 0.3% of the N input in the manure management system

Table 3 shows NH_3 factors for some livestock used in the Equation 4 to calculate the NH_3 emission factors that are applied to estimate NH_3 emissions from manure management.

Nitrogen excreted for cattle, pigs, and chicken (N_{ex} x TAM) for EU countries is sourced by the "Common Agricultural Policy Regionalised Impact" (CAPRI) model. Trend in carcass weight sourced from FAO are used to estimate the development of TAM over the years. N_2O_{factor} for burning is assumed 65% of the N_2O_{factor} for pasture/range/paddock manure management system. The same livestock categories as in manure management (see Table 2) are used to estimate emissions from livestock waste that is used as fertiliser.

(5) IPCC 2006, Vol.4, Ch.10, Table 10.19. Country specific data available in the CRF Tables part of UNFCCC reporting obligations.
(6) IPCC 2006 Annex Table 10A-2. Country specific data available in the CRF Tables part of UNFCCC reporting obligations.
(7) IPCC 2006, Vol.4, Ch.10, Table 10.21
(8) IPCC 2006, Vol.4, Ch.10, Table 10.22

Nitrogen excreted in manure management is used as a basis to calculate the activity data. Nitrogen in manure used as fertiliser for each livestock (ADx) is calculated as in Equation 6:

$$ADx = \Sigma i\,(Nx,i - \text{loss of } Ni + N_{\text{from bedding material } x,i}) \qquad [6]$$

where:

$N_{x,i}$ - is the amount of N excreted by livestock type (x) in manure management system (i) calculated by using N rate by country and number of livestock under manure management system for each country,
loss of Ni - is the loss of nitrogen that occurs from manure management system (i) before manure is used as fertiliser,
N from bedding material $_{x,i}$ - is the additional nitrogen from bedding material applied for animal type (x) in manure management system (i).

Table 3. EDGAR NH_3 factors for some livestock applied to estimate NH_3 emission factors in MMS (kg NH_3/kg N ex)

Livestock	**Manure management system**	NH_3**_factor**
Cattle, Buffalo, Pigs	Digester	0
Dairy cattle	Burned for fuel	0.063
Non-dairy cattle	Burned for fuel	0.065
Dairy cattle	Pasture/range/paddock	0.098
Non dairy cattle, Buffalo, Pigs	Pasture/range/paddock	0.1
Cattle, Buffalo, Pigs	Daily spread of manure	0.121
Dairy cattle	Other	0.18
Dairy cattle	Dry lot	0.182
Non-dairy cattle	Other	0.204
Dairy cattle	Solid storage	0.243
Cattle, Buffalo	Liquid/slurry	0.243
Cattle, Buffalo, Pigs	Dry lot	0.273
Cattle, Buffalo	Pit	0.304
Cattle, Buffalo	Lagoon	0.364
Non dairy cattle, Buffalo, Pigs	Solid storage	0.364

2.2.3 Agricultural soils

For the agricultural soils, the emission factors for NH_3 emissions from different fertiliser types (AGS.NFE) and from animal waste used as fertiliser (AGS.ANW) are sourced from (Bowman et al, 2002).

Table 4. EFs for some synthetic nitrogen fertilisers and animal waste used as fertiliser (kg compound/kg N)

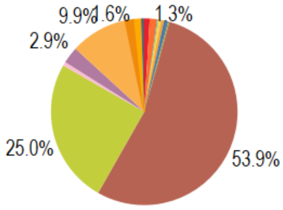
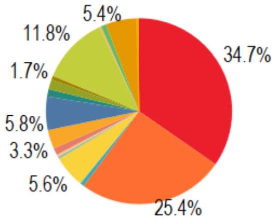
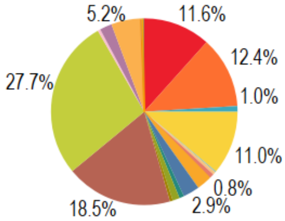
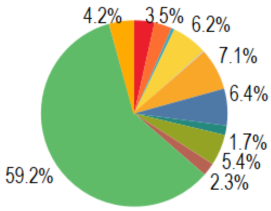
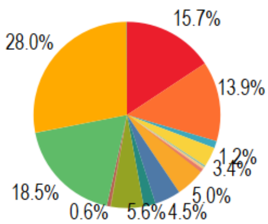
Technology code	**Geo code**	**Pollutant**	**Emission Factors**
AGS.NFE.ASL (ammonium sulphate)	AAA	NH_3	0.194
AGS.NFE.URE (urea)	AAA	NH_3	0.255
AGS.NFE.AMN (ammonium nitrate)	AAA	NH_3	0.073
AGS.NFE.CAM (calcium ammonium nitrate)	AAA	NH_3	0.036
AGS.NFE. * (N fertiliser)	AAA	N_2O	0.0157
AGS.ANW. * (animal waste)	AAA	NO_2	0.0181

The emission factors for NH_3 from crop residues corresponds to 1% of N input based on the estimate for NH_3 from biomass in soils. N_2O emission factors for fertilisers, livestock waste and crop residues are sourced from IPCC 2006 based on the assumption that 1% of N input forms N_2O. In the case of NO_x, the emission factors are calculated based on the assumption that 0.55% of the N forms NOx. Emission factors for field burning of crop residues applied in EDGAR are sourced from EMEP/EEA Guidebook 2019, Table 3.3. This is a Tier 2 method that incorporates different emission factors for several major crops.

3. Detailed methodology by sector, air pollutant and greenhouse gas

The main sources of air pollutant (NH_3, NO_x, NMVOC, PM_{10}, $PM_{2.5}$, SO_2, CO, BC) emissions in the EU agricultural sector as well as the breakdown by country in the year 2018 are presented in Table 5. Under the Air Convention (Convention on Long-range Transboundary Air Pollution -CLRTAP), data on the emissions of these pollutants are available for 47 countries (including each EU Member State).

Table 5. The EU agriculture air pollutant emissions breakdown by subsectors, 2018

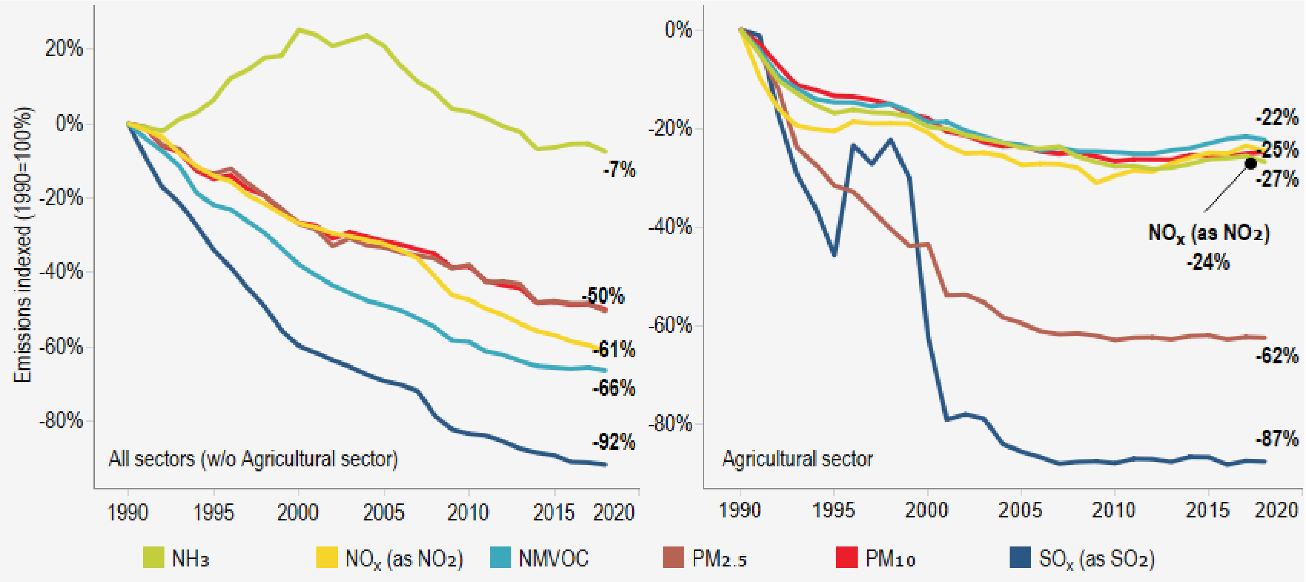
<table>
<tr><th>Pollutants</th><th>Key categories</th><th>Emissions breakdown by subsectors</th><th>Share in total EU air pollutant emissions</th></tr>
<tr><td>NOx (as NO_2)</td><td>3Da1, 3Da2a, 3Da3,</td><td>
</td><td>In 2018, NOx emissions from agriculture were 592 kt, representing 8.2% of the total NOx emissions in the EU. Within the agricultural sector the main source of NOx emissions are agricultural soils activities which cover more than 95% of this contribution.</td></tr>
<tr><td>NMVOC</td><td>3B1a,3B1b, 3B3, 3B4gii, 3Da2a, 3De</td><td>
</td><td>NMVOC emissions from agricultural activities have reached 1316 kt in 2018, corresponding to nearly 19% of total NMVOC emissions in the EU. The manure managememt subsector is the main agricultural source, covering more than 80% of this contribution.</td></tr>
<tr><td>NH_3</td><td>3Da2a, 3Da1, 3B1b, 3B1a, 3B3,</td><td>
</td><td>Emissions of NH_3 from agricultural activities were 3582 kt in 2018. This contribution represents almost 93% of total NH_3 emissions in the EU. Manure management and agricultural soils represent 42.3% and 50.5%, respectively, of total NH_3 emissions in the EU.</td></tr>
<tr><td>PM_{10}</td><td>3Dc, 3B4gi, 3B4gii, 3B3, 3B4giv</td><td>
</td><td>16% of PM_{10} emissions in the EU are sourced from agricultural activities which corresponds to a quantity of 315 kt in 2018. PM_{10} emissions from agricultural soils cover nearly two thirds of this contribution.</td></tr>
<tr><td>$PM_{2.5}$</td><td>3F, 3Dc, 3B1a, 3B1b</td><td>
</td><td>Emissions of $PM_{2.5}$ from agriculture were 45 kt in 2018, representing only 3.6% of total $PM_{2.5}$ emissions in the EU. The contribution of manure management subsector is slighlty higher compared with the agricultural soils subsector covering almost 53% of this contribution.</td></tr>
<tr><td colspan="4">3B1a Dairy cattle
3B1b Non-dairy cattle
3B2 Sheep
3B3 Swine
3B4a Buffalo
3B4d Goats
3B4e Horses
3B4f Mules and asses
3B4gi Laying hens
3B4gii Broilers
3B4giii Turkeys
3B4giv Other poultry
3B4h Other animals
3Da1 Inorganic N-fertilizers
3Da2a Animal manure applied to soils
3Da2b Sewage sludge applied to soils
3Da2c Other organic fertilisers to soils
3Da3 Urine & dung deposited by grazing
3Da4 Crop residues applied to soils
3Db Indirect emissions from managed soils
3Dc Farm-level agricultural operations
3Dd Off-farm storage, handling & transport..
3De Cultivated crops
3Df Use of pesticides
3F Field burning of agricultural residues
3I Agriculture other</td></tr>
</table>

Source: (Eionet, 2020)

Over period 1990 – 2018 the air pollutant emissions in the EU decreased: NH_3 emissions decreased by 26%; SO_2 emissions decreased by 91%; NMVOC emissions decreased by 62%; NOx emissions decreased by 60%, PM2.5 emissions decreased by 51% and PM10 emissions decreased by 47% (Eionet, 2020).

Due to limited legislation in agricultural sector this decrease has been smaller than in the other sectors. This was the case of NOx, NMVOC, PM_{10} and SO_2 emissions (see Figure 2). In the case of NH_3 emissions a decrease by 27% since 1990 was found, compared with the decrease by 7% in other sectors taken altogether. Only $PM_{2.5}$ emissions from agricultural sector decreased more comparing with respective emissions from all other sectors.

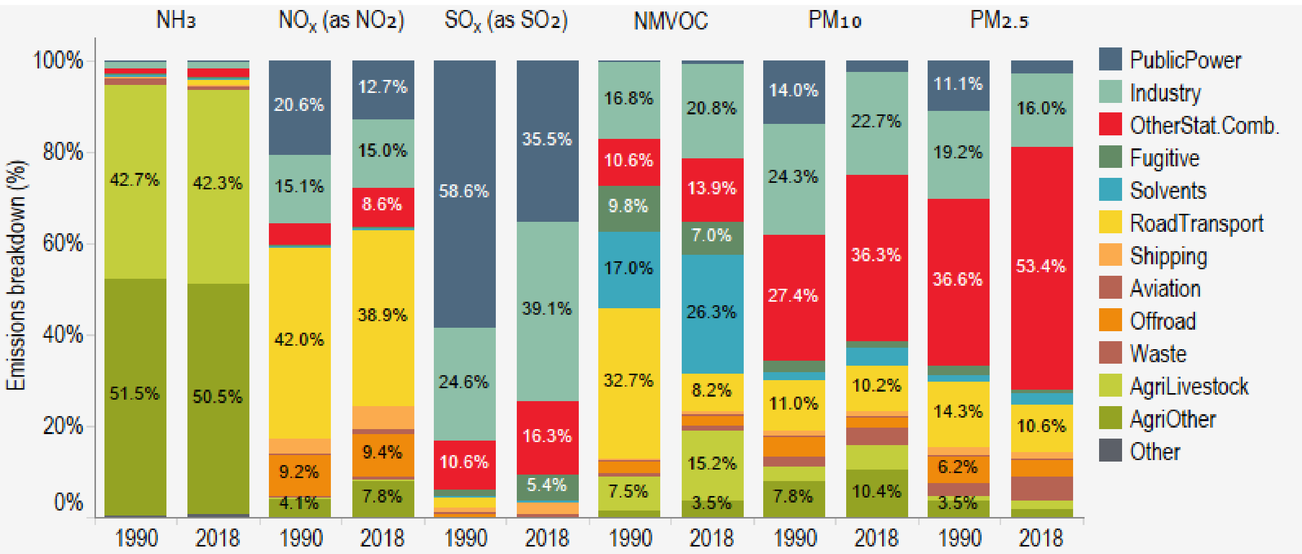
Figure 2. Trend of main air pollutant in the EU: all sectors w/o agricultural sector (left) – agricultural sector (right), 1990-2018



Source: (Eionet, 2020)

As shown in Figure 3 in 2018 comparing with 1990 the contribution of NH_3 emissions from agriculture has decreased slightly whereas the contributions of NOx emissions from agricultural soils and NMVOC emissions from manure management has doubled, respectively from 4% to nearly 8% and from 7.5% to 15.2%.

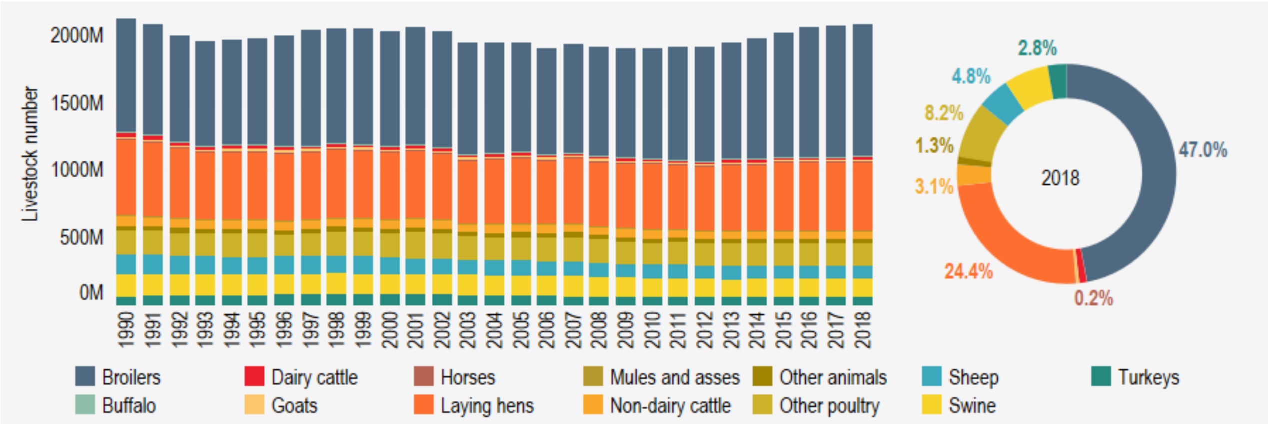
Figure 3 The EU NECD air pollutant emissions breakdown by anthropological activities, 1990 – 2018



Source: (Eionet, 2020)

Within the EU agricultural sector, the main livestock categories[9] are Broilers (3B4gii) and Laying hens (3b4gi) both covering more than 86% of livestock in this subsector in 2018 (see Figure 4). Almost two-third of the EU livestock population are present in Italy (18.6%), France (14.7%), Poland (9.8%), Germany (9.2%) and Spain (9%). However, nearly 60% of air pollution from the EU livestock sector is sourced from Dairy cattle (3B1a) and Non-dairy cattle (3B1b) categories. The contribution from poultry categories reach nearly 18% of air pollution from the EU livestock sector (Eionet, 2020).

Figure 4. EU livestock population 1990-2018 (left) - breakdown by livestock categories in 2018 (right)



Source: (Eionet, 2020)

Table 6 illustrates the main sources for NH_3, NO_x, NMVOC, TSP, PM_{10}, $PM_{2.5}$ and SO_2 emissions in the agricultural sector reported under the NECD Annex I (NECD, 2018 Inventory).

Table 6. Main sources of air pollutants in EU countries agricultural sector reported in their 2020 IIRs

Pollutant	Manure Management	Agriculture Soils
NH_3	BE, BG, CY, FI, IT, LV, MT, NL	AT, CZ, HR, DK, FR, DE, EE, IE, EL, LT, LU, HU, PL, PT, RO, SI, SK, ES, SE, UK
NO_X	CZ	Other countries
NMVOC	Other countries	FR, ES
TSP	Other countries	AT, BG, CZ, DK, EE, EL, FI, FR, IE, LT, LV, RO
PM_{10}	BE, CY, MT, NL, SI, UK	Other countries
$PM_{2.5}$	Other countries	BG, CZ, DK, EL, ES, FI, FR, LT, LV, PT, RO
SO_2	-	AT, BG, CY, DK, EL, ES, FI, FR, HR, HU, IT, LV, PL, PT, RO

Source: (Eionet, 2020)

Manure management is the main source of NH_3 emissions in only 8 EU countries while in other countries, it is agricultural soils. NO_x emissions from the agricultural sector in the EU are almost totally sourced from agricultural soils activities.

Only in Czech Republic NO_x emissions are reported under the manure management while in other countries they are reported under agricultural soils. Livestock are the main source for NMVOC emissions from agriculture in almost all EU countries, except for France and Spain. PM_{10} agricultural emissions are sourced from manure management in Belgium, Cyprus, Malta, Netherlands, Slovenia, and UK.

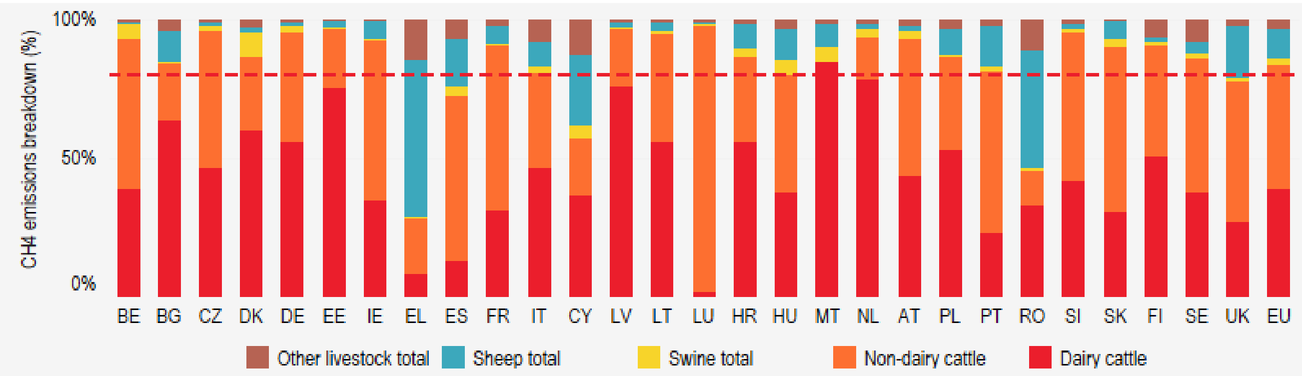
11 EU countries report their $PM_{2.5}$ emissions from agriculture under the agriculture soils subsector. SO_2 agricultural emissions are sourced from the category of field burning of agricultural residues (3F) in 14 EU countries. Only in Latvia this pollutant is reported under the category 3I (Agriculture other).

(9) Key categories are those which, when summed together in descending order of magnitude, cumulatively add up to 80% of the total level (EMEP/EEA Guidebook 2019 Ch.2 Table 2-1).

3.1 Enteric Fermentation (3A)

During the digestion of feed, ruminal and/or intestinal fermentation processes take place producing methane (CH_4) as a by-product. Enteric fermentation is the main source of CH_4 emissions from the livestock sector in the EU countries. Only in 7 EU countries (BE, DK, ES, HR, HU, NL, and SI) CH_4 emissions from enteric fermentation are less than 80% of total CH_4 emissions from the livestock sector. Cattle is the key livestock category of CH_4 emissions from enteric fermentation in almost all EU countries. In Greece, Cyprus, and Romania sheep is also a key category (see Figure 5). In 2018 CH_4 emission from enteric fermentation were 193.7 Mt CO_2-eq (7750 kt) covering more than 80% of CH_4 emissions from agriculture.

Figure 5. CH_4 emissions from enteric fermentation in each EU country breakdown by livestock categories, 2018



Source: (UNFCCC, 2020)

Box. 2. IPCC methodology to calculate CH_4 emissions from enteric fermentation

The IPCC Guidelines provide both Tier 1 and Tier 2 methods for the calculation of CH4 emissions from enteric fermentation. The Tier 2 method is based on livestock gross energy intake and is developed mainly for emissions from cattle and sheep categories. The Tier 2 method is based on the feed intake estimation which is calculated using several parameters such as the (i) Net Energy for livestock maintenance (NEm), (ii) Net Energy mobilised (NEmob,; (iii) Net Energy for activity (NEa), (iv) Net Energy for livestock growth (NEg), (v) Net Energy for work (NEw), (vi) Net Energy for lactation (NEl), (vii) Net Energy for pregnancy (NEp), and (viii) Net Energy for wool production (NEwool) (Eq.7):

$$GE = [(NEm + NEmob. + NEa + Nel + NEw + NEp)/(NEm/DE)] + [(NEg + NEwool) / (NEg/DE)]\} / (DE/100) \qquad [7]$$

The method provides the necessary steps to calculate emission factors for each livestock category and for each country based on gross energy intake (GE) or feed intake (as dry matter intake DMI) and the conversation rate of CH_4 (Ym, percentage of gross energy in feed converted to CH_4).

$$EEF_{CH4} = EFi * AAPi \qquad [8]$$
$$EFi = (GEi * Ymi * 365)/55.65 \qquad [9]$$

where

i – is the index for each livestock category
DE – is the digestible energy expressed as a percentage of gross energy
GEi – is the gross energy intake for each livestock category (MJ/head/day)
EFi – is the emission factor for CH_4 for each livestock category (kg CH_4/head/yr)
Ymi – is the CH_4 conversion rate for each livestock category (%)
55.65 – is the energy content of CH_4 (MJ/kg CH_4)
APPi – is the number of livestock category

Source: IPCC 2006, Vol. 4, Chapter 10

Currently most of the EU countries use Tier 2 approach to calculate CH_4 emissions from enteric fermentation. When a country specific model is applied it can influence the calculated data such as feed intakes or CH_4 conversion rates. Such practices are in place in some EU countries which use specific approaches to define livestock characteristics or performance, to estimate feed intake, to transform energy intake to CH_4 emissions, to develop energy balance and CH_4 production models based on existing models for livestock (Global Research Alliance, 2018).

3.2 Manure management (3B)

Air pollutants and GHG emissions estimated under the manure management subsector are:

- **Ammonia (NH_3)** and **non-methane volatile organic compounds (NMVOC)** sourced by livestock housing and holding areas, manure storage, excreta deposited while grazing and field applied manure,
- **Nitrogen oxides (NOx)** sourced by manure storage, excreta deposited while grazing and field applied manure**,**
- **Particulate Matter (PM)** sourced by livestock feeding, livestock housing and holding areas,
- **Methane (CH_4) and Nitrous oxide (N_2O)** sourced from manure decomposition.

Sourced from the Informative Inventory Reports (IIRs), a short description of the methods applied in those EU countries that use country-specific emission factors (see Tables 7-17) to calculate air pollutants emissions from their manure management systems (MMS), is presented below,. In more details the methods (Tier 1, 2 and/or 3) applied in each country for each pollutant and NFR category can be found in Annex A.3.

In ***Belgium***, the methodologies differ among the regions for the calculation of NH_3 emissions from manure management, even though the methods applied can be considered all Tier 2 methods. The Tier 2 method is used in the Wallon and Flanders regions to calculate NMVOC emissions for cattle and swine whereas a Tier 1 approach for other livestock categories. In the region of Brussels-Capital a Tier 1 method is used for all livestock categories. To calculate NOx emissions from manure management, Tier 1 (Flanders region) and Tier 2 (Wallonia and Brussels region) methods are used. A Tier 1 approach is used for the calculation of PM emissions from manure management. Default emission factors are used for almost all livestock except for fattening pigs (IIR BE 2020).

Table 7. Particulate Matter Emission Factors for Fattening Pigs in Belgium's MMS, 2018

Region	Livestock	Pollutant	EF	Unit
Flanders	Fattening pigs	TSP	0.749	kg PM /yr/animal
Flanders	Fattening pigs	PM_{10}	0.0999	kg PM /yr/animal
Flanders	Fattening pigs	$PM_{2.5}$	0.0078	kg PM /yr/animal

Source: (IIR BE 2020)

In ***Czech Republic***, the Tier 2 method is applied for NH_3 emissions from manure management using country specific emission factors (IIR CZ 2020). ***Denmark*** applies the Tier 2 method for NH_3 emissions from manure management. Country-specific emission have changed over years for all livestock categories (IIR DK 2020).

Table 8. NH_3 EFs for cattle in Denmark's MMS, 1990-2018 (kg NH_3/animal/yr)

Livestock	1990	1995	2000	2005	2010	2015	2016	2017	2018
Dairy cattle	10.5	10.37	11.49	13.5	12.84	13.07	13.52	13.13	13.57
Non-dairy cattle	3.17	3.02	3.56	2.81	3.38	3.44	3.39	3.34	3.34

Source: (IIR DK 2020)

Estonia applies a Tier 3 method to calculate NH_3 emissions from cattle and swine. The Tier 2 method is applied for these emissions from laying hens, broilers, and other poultry whereas the Tier 1 method is applied for goats and horses. To calculate NO_x emissions the Tier 2 method is applied for cattle, swine, laying hens, broilers, and other poultry. The Tier 1 method is applied for the other livestock. Country-specific emission factors are used in the calculations (IIR EE 2020).

Table 9. NH_3 and NO EFs for some livestock in Estonia's MMS, 2018 (kg NH_3-N (AAP d)$^{-1}$)

Livestock	NH_3 house		NH_3 storage		NH_3 applications		NH_3 grazing	NO storage	
	slurry	solid	slurry	solid	slurry	solid		slurry	solid
Dairy cattle	0.2	0.066	0.2	0.27	0.55	0.79	0.1	-	0.008
Other cattle	0.2	0.190	0.2	0.27	0.55	0.79	0.6	-	0.008
Swine (fattening)	0.28	0.270	0.14	0.45	0.40	0.81	-	-	0.008
Swine (sows)	0.22	0.025	0.14	0.45	0.29	0.81	-	-	0.008

Source: (IIR EE 2020)

Germany applies a Tier 3 method to calculate NH_3 emissions from manure management using the country specific emission factors. To calculate NO_x emissions the Tier 2 method is applied using country specific emission factors. For other pollutants default emission factors are applied (IIR DE 2020).

Table 10. NH_3, NO_x, NMVOC and $PM_{2.5}$ EFs for some livestock in Germany's MMS, 1990-2018 (kg pollutant/animal place)

Livestock	Pollutant	1990	1995	2000	2005	2010	2015	2016	2017	2018
Dairy cattle	NH_3	11.8	12.5	13.5	14.7	15.3	15,4	15.5	15.5	15.7
Swine	NH_3	4.42	4.41	4.37	4.32	4.19	4.10	4.10	4.11	4.12
Dairy cattle	NOx	0.114	0.122	0.132	0.137	0.131	0.123	0.125	0.124	0.127
Other cattle	NOx	0.06	0.065	0.069	0.074	0.074	0.072	0.072	0.072	0.072
Dairy cattle	NMVOC	36.49	37.098	38.760	39.538	39.820	40.278	40.679	40.697	41.446
Other cattle	NMVOC	12.723	12.647	12.964	12.854	12.839	12.807	12.831	12.837	12.923
Dairy cattle	$PM_{2.5}$	0.3717	0.4277	0.4339	0.4398	0.4442	0.4423	0.4425	0.4423	0.4422
Other cattle	$PM_{2.5}$	0.1574	0.1548	0.1521	0.1493	0.1463	0.1458	0.1458	0.1458	0.1459

Source: (IIR DE 2020)

Greece applies a Tier 2 method to calculate NH_3 emissions from cattle, sheep, swine, laying hens and broilers using country specific emission factors and a Tier 1 method for all other livestock (IIR EL 2020).

Table 11. NH_3 EF for cattle, sheep, swine, laying hens and broilers in Greece's MMS, 2018

Livestock	Nitrogen excreted, N_{ex} (kg N/yr)	Proportion Total Ammoniacal Nitrogen (TAN)	EF (kg NH_3/animal/yr)
Dairy cattle	140	0.6	31.7
Non-dairy cattle	54.3	0.6	8.63
Sheep	14.9	0.5	0.4
Swine	13.5	0.7	4.46
Laying hens	0.77	0.7	0.31
Broilers	0.36	0.7	0.12

Source: (IIR EL 2020)

France applies the Tier 2 method to estimate NH_3, NO_x, NMVOC and PM emissions from manure management. Country-specific emission factors are developed only for NH_3 emissions from poultry. ***Italy*** applies the Tier 2 method to calculate NH_3 (see Table 12), NOx and NMVOC emissions from manure management. Country-specific emission factors are used only for NH_3 and NO_x (IIR IT, 2020).

Table 12. NH_3 average EFs for main livestock categories and type of technology applied in Italy's MMS in 2018 (kg NH_3/animal/yr)

Livestock	Housing	Storage	Land	Grazing	Total
Dairy cattle	16.73	20.69	13.36	0.1	50.88
Non-dairy cattle	6.95	8.85	5.77	0.1	21.66
Swine (sows)	4.86	3.59	2.42		10.87
Other swine	2.38	1.68	1.13		5.2
Broilers	0.08	0.04	0.03		0.15

Source: (IIR IT, 2020)

Croatia applies the Tier 2 method for NH_3 and NOx emissions from almost all livestock categories except for swine and poultry for which the Tier 3 method is applied. A combination of default and country-specific emissions factors is used in the calculations (IIR HR, 2020).

Hungary applies the Tier 2 method for NH_3 emissions using country-specific emission factors which represent a modification of the Tier 1 default emission factors as regards to the length of housing period. Tier 1 and 2 methods are applied for NMVOC emissions using default and country-specific emission factors. (IIR HU, 2020).

Table 13. NH_3 EFs for some livestock categories in Hungary's MMS in 2018 (kg NH_3/animal/yr)

	Dairy cattle	Non-dairy cattle	Sheep	Swine (sows)	Swine (finishing pigs)	Laying hens	Broilers
EF	26.5	12.91	1.63	5.32	3.19	0.17	0.21

Source: (IIR HU, 2020)

The Netherlands applies the Tier 3 method to calculate NH_3 and NO_x emissions from manure management developing country-specific emission factors. The Tier 2 method is applied for PM emissions also using country-specific emission factors (IIR NL, 2019).

Table 14. PM_{10} EFs applied in Netherlands 'MMS (housing) 1990-2017, (g PM_{10}/animal)

Livestock	1990	1995	2000	2005	2010	2015	2016	2017
Dairy cattle	115	115	115	120	124	127	128	127
Non-dairy cattle	67	64	57	54	51	50	49	52
Laying hens	15	16	23	34	39	50	51	50
Broilers	27	27	27	27	27	26	26	26
Turkeys	100	98	95	95	95	95	95	94

Source: (IIR NL, 2019)

Austria has developed a Tier 3 method for NH_3 emissions from cattle and swine categories. The Tier 2 method is applied for other livestock categories. In the case of PM emissions, the Tier 1 method is applied using country-specific emission factors sourced by RAINS[10] model (IIR AT, 2020).

Table 15. RAINS TSP EFs applied in Austria's MMS in 2018, (kg TSP/animal)

	Cattle	Swine (fattening, sows)	Goats, Horses	Poultry (Laying hens, Broilers, Turkeys)	Other
EF	0.235	0.108	0.153	0.016	0.016

Source: (IIR AT, 2020)

Poland applies the Tier 2 method for NH_3 and NO_x emissions implying country-specific emission factors (IIR PL, 2020). ***Slovakia*** *applies* a Tier 2 method for NH_3 and NO_x emissions using a combination of country-specific emission factors (cattle, sheep, swine) and default emission factors (other livestock) (IIR SK, 2020).

Table 16. NH_3 and NOx EFs for some livestock in Poland's MMS, 1990-2018, (kg compound/animal)

Pollutant	Livestock	1990	1995	2000	2005	2010	2015	2016	2017	2018
NH_3	Dairy cattle	22.27	22.24	24.68	27.63	28.56	29.12	32.18	32.18	32.18
NH_3	Other cattle	12.54	12.49	12.37	12.37	12.87	12.53	12.44	12.77	12.77
NH_3	Swine (Fattening pigs)	4.72	4.71	4.72	4.72	4.25	4.1	4.1	4.1	4.1
NH_3	Swine (sows)	10.34	10.3	10.31	10.34	10.24	10.2	10.2	10.2	10.2
NOx	Dairy cattle	0.215	0.216	0.242	0.252	0.266	0.27	0.306	0.306	0.306
NOx	Other cattle	0.128	0.13	0.128	0.126	0.133	0.128	0.127	0.131	0.131
NOx	Swine (Fattening pigs)	0.039	0.04	0.04	0.039	0.035	0.034	0.034	0.034	0.034
NOx	Swine (sows)	0.082	0.083	0.083	0.082	0.08	0.081	0.081	0.081	0.081

Source: (IIR PL, 2020)

Finland applies a country specific method that has some characteristics of the Tier 2 method (related to the increased numbers of livestock and types of manure categories involved). Country-specific emission factors are applied for all livestock categories in the case of NH_3 and NO_x emissions (IIR FI, 2020). ***Sweden*** applies a modified Tier 2 method for NH_3 and NO_x emissions as it uses the total nitrogen (N) instead of total ammoniacal nitrogen (TAN) for emissions from manure storage. Additionally, Sweden has developed a country-specific model for NH_3 emissions including more variables for emissions from storage and application of manure. Country-specific emission factors are developed (IIR SE, 2020).

A Tier 3 method is applied in the ***United Kingdom*** to calculate NH_3 emissions from manure management. The emission factors at each management stage are calculated as a percentage of the TAN at that stage. NOx emissions are calculated using the same method as for NH_3 assuming that these emissions are equal to 0.1 of N_2O emissions (IIR UK, 2020).

Table 17. NH_3 EFs for some livestock applied in UK's MMS (housing and storage) in 2018

Pollutant	MMS	Livestock	EF	Unit
NH_3	Housing	Dairy - Dairy Cows	10.995	kg NH_3/head
NH_3	Housing	Poultry - Laying Hens	0.162	kg NH_3/head
NH_3	Housing	Pig - Sow	3.041	kg NH_3/head
NH_3	Housing	Poultry - Turkeys	0.493	kg NH_3/head
NH_3	Housing	Other cattle - Cows	3.473	kg NH_3/head
NH_3	Storage	Dairy - Dairy Cows	3.944	kg NH_3/head
NH_3	Storage	Pig - Sow	0.675	kg NH_3/head

Source: (IIR UK, 2020)

([10]) Regional Air Pollution information and Simulation (RAINS) model has been developed by IIASA https://user.iiasa.ac.at/~schoepp/doc/manual/intro.htm

Table 18. Methods used in the EU countries for the estimation of air pollutant emissions from manure management

Country	NH_3	EF NH_3	NO_X	EF NOx	NMVOC	EF NMVOC	PM	EF PM	EMEP/EEA Guidebook (Default)
BE	T2	CS/D	T1/T2	D	T1/T2	D	T1	D	2019
BG	T1	D	T1	D	T1	D	T1	D	2019
CZ	T2	CS/D	T1	D	T1	D	T1	D	2019
DK	T2	CS	T1	D	T2	D	T1	CS/D	2019
DE	T3/T2	CS	T2	CS	T1/T2	CS	T1/T2	D	2016 (NMVOC), 2013/2016 (PM)
EE	T1/T2/T3	CS	T1/T2	CS	T1/T2	CS/D	T1	D	2016
IE	T2	CS	T2	CS	T2	D	T1	D	2019
EL	T1/T2	CS	T1	D	T1	D	T1	D	2016/2019
ES	T2	D	T2	D	T2	D	T1	D	2019
FR	T2	CS/D	T2	D	T2	D	T2	D	2016
IT	T2	CS	T2	CS/D	T2	D	T1	CS/D	2016/2019
CY	T2	D	T2	D	T2	D	T2	D	2016
LV	T1/T2	D	T2	D	T1/T2	D	T1/T2	D	2016
LT	T1/T2	D	T1/T2	D	T1	D	T1	D	2016
LU	T2	D	T2	D	T2	D	T1	D	2016
HR	T2/T3	CS/D	T2/T3	CS/D	T2	D	T1	D	2016 (PM), 2019 (other)
HU	T1/T2	CS/D	T1	D	T1/T2	D	T1	D	2019
MT	T2	D	T2	D	T2	D	T1	D	2016
NL	T3	CS	T3	CS	T2	D	T2	CS	2016
AT	T2/T3	CS/D	T2	D	T2	CS/D	T1	CS	2019
PL	T2	CS	T2	CS	T1	D	T1	D	2016
PT	T2	D	T2	D	T2	D	T1	D	2016
RO	T1/T2	D	T1	D	T1/T2	D	T1	D	2016
SI	T2	D	T2	D	T2	D	T1	D	2016
SK	T2	CS/D	T2	CS/D	T1/T2	D	T1	D	2016
FI	T3/T2	CS	T2	CS/D	T2	D	T1	D	2016 (PM), 2019 (other)
SE	T2	CS	T2	CS	T2	D	T1	CS/D	2016
UK	T3	CS	T3	D	T2	D	T1	CS/D	not specified

Source : EU countries IIRs 2020

Table 18 provides a summary of the methods (Tier 1 (T1), Tier 2 (T2), Tier 3 (T3)) and type of emission factors (country specific (CS) or default (D)) applied for the calculation of NH_3, NOx, NMVOC and PM emissions from the manure management subsector whereas Table 19 presents a summary of the methods applied for each livestock category. By the end of 2018 almost all EU countries, except for Bulgaria, have developed for at least one livestock category a T2 method to calculate NH_3 emissions from manure management. Estonia, Croatia, Austria, Finland, and UK have also developed country specific T3 methods. Several EU countries apply default emission factors set in the EMEP/EEA 2013, 2016 and 2019 Guidebooks. 13 EU countries apply only country specific emission factors and the rest a combination of default and country-specific emission factors. 20 EU countries have developed a T2 method to calculate NOx emissions. Country specific emission factors for NOx emissions are used in only 8 EU countries. A combination with default emission factors is used only in 3 EU countries. To calculate NMVOC emissions the T2 method is applied in 22 EU countries. However, almost all countries apply the default emission factors except for Hungary. In the case of PM emissions, the T2 method is applied in 6 EU countries and only 2 EU countries use country specific emission factors.

Table 19. Summary of methods applied to each livestock category for air pollutant emissions from manure management

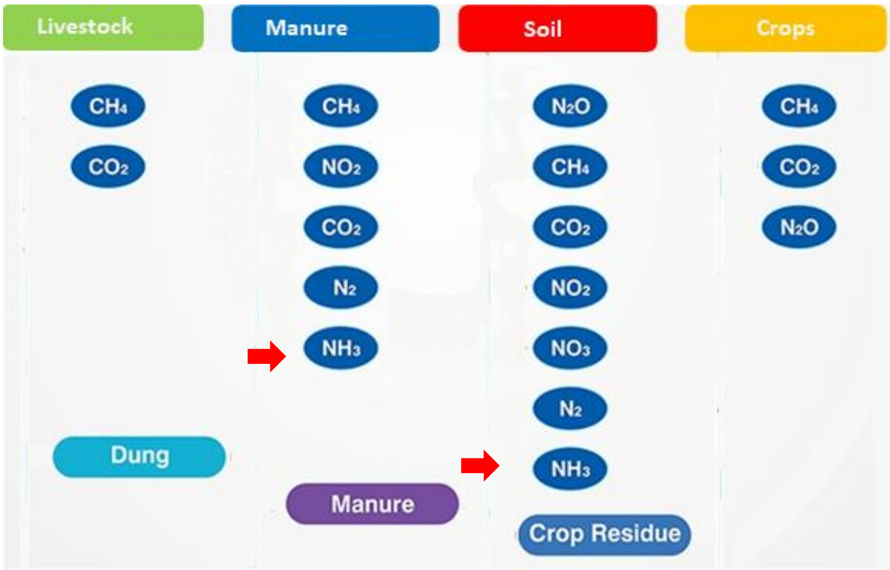
NFR code	Livestock category	Method	EF calculation
3B1a, 3B1b	Cattle	T2/T3/T1 (NH_3), T2/T1/T3 (NOx), T2/T1 (NMVOC), T1/T2 (PM_{10}, $PM_{2.5}$)	CS/D (NH_3, NOx), D/CS (NMVOC, PM_{10}, $PM_{2.5}$)
3B4a, 3B2, 3B4d, 3B4e, 3B4f	Buffalo, Sheep, Goats, Horses, Mules & Asses	T2/T1/T3 (NH_3), T2/T1 (NOx), T1/T2 (NMVOC, PM_{10}, $PM_{2.5}$)	D/CS (NH_3, NOx, NMVOC) D (PM_{10}, $PM_{2.5}$),
3B3	Swine	T2/T3/T1 (NH_3), T2/T1/T3 (NOx), T2/T1 (NMVOC, PM_{10}, $PM_{2.5}$)	CS/D (NH_3, NOx), D/CS (NMVOC, PM_{10}, $PM_{2.5}$)
3B4gi, 3B4gii, 3B4giii, 3B4giv	Poultry	T2/T1/T3 (NH_3, NOx), T1/T2 (NMVOC, PM_{10}, $PM_{2.5}$)	CS/D (NH_3, NOx), D/CS (NMVOC, PM_{10}, $PM_{2.5}$)
3B4h	Other	T2/T1/T3 (NH_3), T2/T1 (NOx), T1/T2 (NMVOC, PM_{10}, $PM_{2.5}$	CS/D (NH_3, NOx), D/CS (NMVOC, PM_{10}, $PM_{2.5}$)

Source: EU countries IIRs 2020

3.2.1 NH_3 emissions from manure management

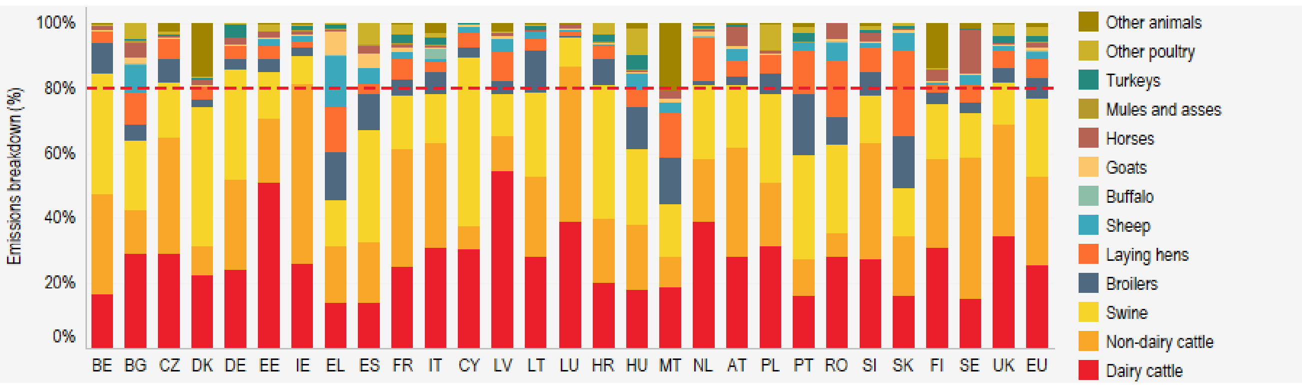
NH_3 is produced from urinary nitrogen (N) and mineralised organic N in the faeces that altogether form what is called total ammoniacal nitrogen (TAN). TAN in manure is derived from the feed composition on a yearly basis. NH_3 is emitted in large quantities from manure management systems and animal housing.

Figure 6. NH_3 emissions sources within farm activities



The main factors influencing NH_3 emissions from manure management are (i) the proportion of time spent by animals indoors and outside, e.g. at pasture or in yards or housed, and animal behavior (e.g. feeding behavior), (ii) the way how the animal excreta is handled (solid or slurry), (iii) the floor area per livestock, and (iv) whether or not manure is stored inside the building (EMEP/EEA Guidebook, 2019). Manure management covers more than half of total NH_3 emissions in 8 EU countries. Main contributors of NH_3 emissions from manure management are Germany (16.4%), France (14.3%), Spain (12.8%) and Italy (12.7%). Within the EU manure management system (MMS), the key categories for NH_3 emissions are cattle (dairy and non-dairy) and swine. Broilers and Laying hens are included as key categories in 9 and 8 EU countries, respectively (see Figure 7 and Table A. 5).

Figure 7. Breakdown of NH_3 emissions in the EU and each country MMS by livestock categories, 2018



Source: (Eionet, 2020)

Nitrogen excreted (which can be calculated using the IPCC 2006 Eq. 10.31) is one of the main parameters needed for the calculation of NH_3 emissions from manure management as well as for the NH_3 emission factors. The IPCC method does not require this parameter to be split between ammoniacal and organic nitrogen whereas the EMEP/EEA Guidebook require this split to calculate NH_3 emissions.

Box. 3. EMEP/EEA methodology to calculate NH_3 emissions from manure management

Tier 1 and Tier 2 methods are available for the calculation of NH_3 emissions from manure management. When using the T1 method NH_3 emissions can be reported under NFR 3B category for emissions from livestock housing, open yards and manure stores, while emissions from grazing and manure application can be reported under the NFR 3D.a.3 category (urine and dung deposited by grazing animals).

The EMEP/EEA Tier 2 method suggested for the calculation of NH_3 emissions from manure management uses a mass-flow approach based on the flow of total ammoniacal nitrogen (TAN) through the manure management system. The application of a Tier 2 method requires detailed emission factors for NH_3 to describe the emissions from various housing and storage systems. The Tier 2 method assures a consistency between N compounds reported under the CLRTAP and IPCC. A Tier 3 method is encouraged to be developed based on the Tier 2 mass-flow method providing more benefits mainly related with the introduction of abatement techniques.

The calculation of NH_3 emissions from this sector is done applying Eq. 10:

$$EMMS_{NH3} = (E_{yard} + E_{house\_slurry} + E_{house\_solid} + E_{storage\_slurry} + E_{storage\_solid}) \times 17/14 \quad [10]$$

where:

m – is the amount of N excreted/TAN deposited in yards and during housing, storage and grazing
E_{yard} - NH_3 emission from the yard $E_{yard} = m_{yard,TAN} \times EF_{yard}$
E_{house_slurry} - NH_3 emissions from livestock housing (slurry) $E_{house\_slurry} = m_{house\_slurry\_TAN} \times EF_{house\_slurry}$
E_{house_solid} - NH_3 emissions from livestock housing (solid) $E_{house\_solid} = m_{house\_solid\_TAN} \times EF_{house\_solid}$
$E_{storage\_slurry}$ - NH_3 emissions from manure storage (solid) $E_{storage\_solid} = m_{storage\_solid\_TAN} \times EF_{storage\_solid}$
$E_{storage\_solid}$ - NH_3 emissions from manure storage (slurry) $E_{storage\_slurry} = m_{storage\_slurry\_TAN} \times EF_{storage\_slurry}$
17/14 – is the conversion factor from N to NH_3

NH_3 emissions from housing systems are calculated from the number of livestock per category, the total N excreted during housing, the fraction of TAN in the excreted N, the N net mineralisation and immobilisation of manure during storage, and the NH_3 emission factor for housing systems. NH_3 emission factors are, in general, related to the TAN available at the various stages of the Nitrogen (N) flow chain. Nitrogen excreted rate must be known as well as, the TAN content of the N excreted. Default excretion rates are provided by the IPCC Guidelines and default TAN contents can be found in the EMEP/EEA Guidebook 2019, Ch.3B, Table 3-9. The N excreted values vary among livestock categories. Variations exist also within a livestock category depending on the purpose the livestock are kept. NH_3 emissions during housing and storage depend on (i) livestock category; (ii) bedding material; and (iii) the TAN content in excreta. The mass-flow balance Tier 2 method is applied through the following steps:

Step 1 – define the livestock categories that are homogeneous for feeding, excretion, and age/weight range
Step 2 - calculate the total annual excretion of N by the animals (Nex; kg AAP^{-1} a^{-1}) (IPCC 2006, Ch.4, Eq. 10.31-32-33)
Step 3 - calculate Total N excreted deposited in housing (x_{house}), on yards x_{yards}) and on grazed land (x_{graz})
Step 4 – calculate the allocation of organic-N and TAN excreted (x_{TAN}) between housing, outdoor yards, and grazing
Step 5 - estimate the amounts of TAN deposited in housing as slurry or solid
Step 6 - calculate NH_3 emissions from housing and yards
Step 7 - calculate total-N and TAN leaving housing (only solid)
Step 8 - calculate Total-N and TAN entering storage (slurry and solid)
Step 9 - calculate TAN from which slurry storage emissions will occur (only slurry)
Step 10 - calculate NH_3-N, N_2O-N, NO-N and N_2 storage emissions
Step 11 - calculate organic-N and TAN applied to field
Step 12 - calculate emissions during and immediately following application to field (reported under 3Da2a NFR category)
Step 13 - calculate total-N and TAN returned to soil after NH_3 emissions (does not account for NO and N_2O emissions)
Step 14 - calculate NH_3 - N emissions from grazing
Step 15 – Summing up all NH_3 emissions that are reported under Chapter 3B as in Eq.10

When NH_3 emission are calculated using NH_3-N emission factors expressed as % of TAN, the emission factors are directly or indirectly derived from measurements of NH_3 emissions from animal houses and expressed relative to the respective TAN-excretions. Separate calculations are performed for NH_3 emissions from manure storages outside the animal housing. Because N-emissions are calculated using the TAN-flow principle, the amount of TAN in storage should corrected for all N losses taking place in the housing system.

Source: EMEP/EEA Guidebook 2019

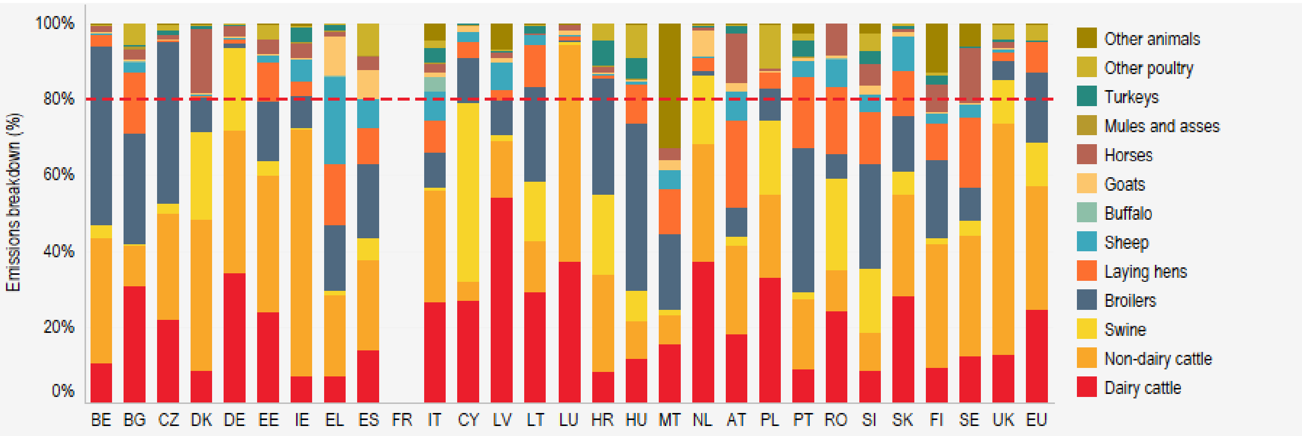
3.2.2 NO_X emissions from manure management

Emissions of nitrogen (N) as NOx are also part of the TAN flow and originate from the de-nitrification process[11] of manure produced in animal houses, and then stored temporarily and/or processed before being transported elsewhere. NOx is mainly estimated as NO which is then converted to NO_2. Results from some experiments have shown that NO emissions from manure storage are an order of magnitude of half the emissions of N_2O from soils receiving mineral fertilisers or livestock manures (EMEP/EEA Guidebook, 2019).

The share of NOx emissions from manure management to the total NOx emissions from agriculture is low and reaches up to 12% only in Belgium, the Netherlands, and Portugal. In other EU countries this share is below 10%. Spain covers more than 22% of the NOx emissions from manure management in the EU followed by the Netherlands (14.3%), Poland (8.8%) and Italy (6.7%).

Only in Czech Republic NOx agricultural emissions (expressed as NO_2) are reported totally as sourced from manure management. No NOx emissions from manure management are reported from France as they are reported in the category "Other not included in national total of the entire territory" (6B). Within this subsector the cattle category is the main source of NOx emissions together with swine (Cyprus), broilers (Belgium, Czech Republic and Hungary) and laying hens (Portugal) (see Figure 8 and Table A. 6).

Figure 8. Breakdown of NOx emissions in the EU and each country MMS by livestock categories, 2018



Source: (Eionet, 2020)

Box. 4. EMEP/EEA methodology to calculate NOx emissions from manure management

NOx emissions from manure management include both emissions of NO_2 and those of NO which are converted to NO_2. Emissions of NO are encouraged to be estimated using a Tier 2 method. NOx emissions are assumed to be equal to N_2O emissions in terms of amounts nitrogen lost, and the calculation is based on the IPCC default emission factors for N_2O.

Accordingly, with Annex I of the NFR Reporting Guidelines, NO emissions must be reported as NO_2 as shown in Eq.11

$$EMMS_{NO2} = [TAN_{storage\_slurry} \times EF_{storage\_NOslurry} + TAN_{storage\_solid} \times EF\grave{\imath}_{storage\_NOsolid}] \times 46/14 \qquad [11]$$

where

$EMMS_{NO2}$ - are the emissions from the manure management of NO_2 (kg)
$TAN_{storage\_slurry}$ - is the TANstored by livestock category and managed in slurry system
$TAN_{storage\_solid}$ - is the TANstored by livestock category and managed in solid system
$EF_{storage\_NOslurry}$ - is the emission factor for NO in slurry system (EMEP/EEA Guidebook 2019 Table 3.10 default EFs)
$EF\grave{\imath}_{storage\_NOsolid}$ – is the emission factor for NO in solid system (EMEP/EEA Guidebook 2019 Table 3.10 default EFs)
46/14 – is the conversion factor from N to NO_2

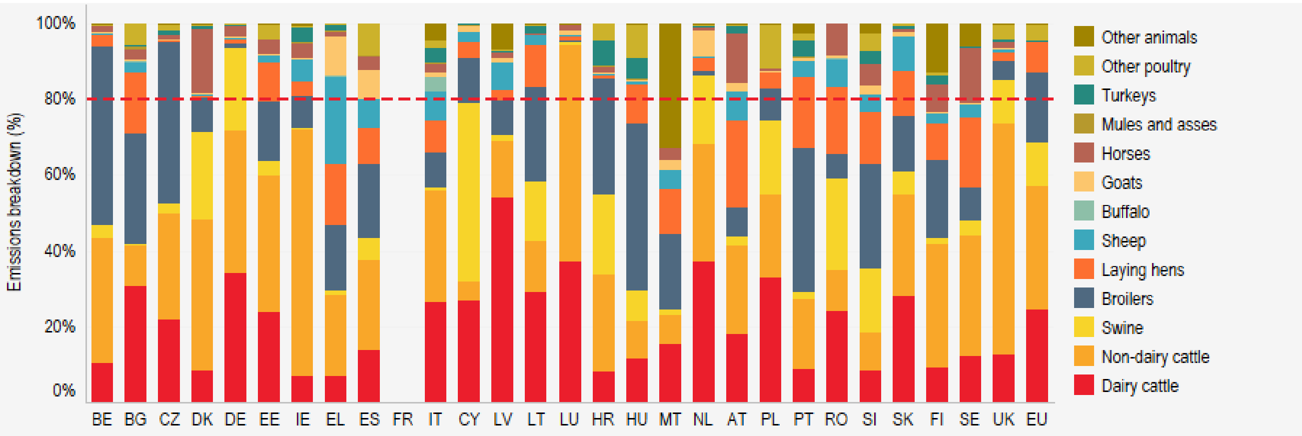
Source: EMEP/EEA Guidebook 2019

([11]) Denitrification is the process whereby, under low-oxygen circumstances, bacteria can convert nitrate (NO^{-3}) into the gaseous nitrogen compound N_2, with N_2O as a by-product.

3.2.3 NMVOC emissions from manure management

Manure management is the main source of NMVOC emissions in the agricultural sector in 18 EU countries. Only in France NMVOC agricultural emissions are reported totally under the agricultural soils subsector (see Figure 8). The main activities that produce NMVOC emissions are the (i) silage stores, (ii) feeding (if silage is used for feeding), (iii) livestock housing, (iv) outdoor manure stores, (v) manure application, and (vi) grazing animals. Cattle is the main livestock category for NMVOC emissions from manure management in most of EU countries (see Figure 9 and Table A. 7).

Figure 9. Breakdown of NVMOC emissions in the EU and each country MMS by livestock categories, 2018



Source: (Eionet, 2020)

As seen in Table 20 the main subsectors/categories for NMVOC emissions within the agricultural sector are 3B (Manure Management) and 3De (Cultivated crops) followed by 3Da2a and 3Da3.

Table 20. EU countries reporting breakdown of NMVOC emissions from manure management calculation

Country	3B	3Da2a	3Da2b	3Da3	3Dc	3De	3F	3I
BE	x					x		
BG	x					x	x	
CZ	x							
DK	x					x	x	
DE	x					x		
EE	x					x		
IE	x					x		
EL	x					x	x	
ES	x	x		x		x	x	
FR							x	
IT	x	x		x		x	x	
CY	x					x	x	
LV	x					x		x
LT	x					x		
LU	x					x		
HR	x					x		
HU	x					x		
MT	x					x		
NL	x	x		x	x	x		
AT	x	x		x		x	x	
PL	x					x	x	
PT	x	x		x		x	x	
RO	x					x	x	
SI	x			x				
SK	x	x		x		x		
FI	x	x		x		x	x	
SE	x	x	x	x		x		
UK	x					x	x	

France reports NMVOC emissions only under the 3F category (field burning of agriculture residues). The calculated NMVOC emissions from manure management and agricultural soils are reported in the category

“Other not included in national total of the entire territory” (6B). Austria reports NMVOC emissions from feeding, housing, and storage under the 3B subsector, those from manure application to soil under the 3Da2a category and those from manure grazing under the 3Da3 category. More than half of NMVOC emissions from agriculture in Spain are sourced from agricultural soils activities. NMVOC emissions from manure management in the EU have reached 1068 kt in 2018, covering more than 81% of total NMVOC emitted from the agricultural sector. The main contributors in the EU NMVOC emissions from manure management in 2018 were Germany (29.7%), Italy (10.2%), Poland (9.2%), Spain (7.4%) and UK (6.3%).

Box. 5. EMEP/EEA methodology to calculate NMVOC emissions from manure management

Both the Tier 1 and Tier 2 are described in the EMEP/EEA Guidebook 2019. The Tier 2 method suggested for the calculation of NMVOC emissions from manure management uses feed intake (for cattle) and volatile solids (for other livestock) estimates

The calculation of NMVOC emissions from this sector is done applying Eq. 12:

$$EMMS_{NMVOC} = AAP_{animal} * (E_{silage\_store} + E_{silage\_feeding} + E_{house} + E_{manure\_storage} + E_{manure\_application} + E_{manure\_grazing}) \quad [12]$$

where:

AAP_{animal} – the annual average population of livestock
E_{silage_store} – NMVOC emissions from silage storage process
$E_{silage\_feeding}$ – NMVOC emissions from silage feeding process
E_{house} – NMVOC emissions from livestock housing
$E_{manure\_storage}$ – NMVOC emissions from manure storage
$E_{manure\_application}$ – NMVOC emissions from manure applied to soils
$E_{manure\_grazing}$ – NMVOC emissions from animal grazing

Emissions are calculated separately for silage storage and feeding, housing, manure storage and field application of manure. The emissions are calculated for every animal category with annually calculated parameters. In each activity, emissions are calculated for the count of one animal. The animal- and year-specific emissions are then multiplied by the average annual population. The Tier 2 method applied to calculate NMVOC emissions from manure management ai applied for cattle using feed intake option (FI) and for other livestock using volatile substances excreted option (VS), goes through the following steps:

Step 1 – calculate emissions from silage storage

$$FI/VS \times x_{house} \times (EF_{\_NMVOC\_silage} \times Frac_{silage}) \times Frac_{silage\_store} \quad [13]$$

Step 2 – calculate emissions from silage feeding

$$FI/VS \times x_{house} \times (EF_{\_NMVOC,silage\_feeding} \times Frac_{silage}) \quad [14]$$

Step 3 – calculate emissions housing

$$FI/VS \times x_{house} \times (EF_{\_NMVOC,house}) \quad [15]$$

Step 4 – calculate emissions from manure storage

$$E_{\_NMVOC\_house} \times (E_{\_NH3\_storage}/E_{\_NH3\_house}) \quad [16]$$

Step 5 – calculate emissions from manure applications

$$E_{\_NMVOC\_house} \times (E_{\_NH3appl.}/E_{\_NH3\_house}) \quad [17]$$

Step 6 – calculate emissions from grazing (feed intake for cattle and volatile excreted for other livestock)

$$FI/VS \times (1 - x_{house}) \times EF_{\_NMVOC\_graz} \quad [18]$$

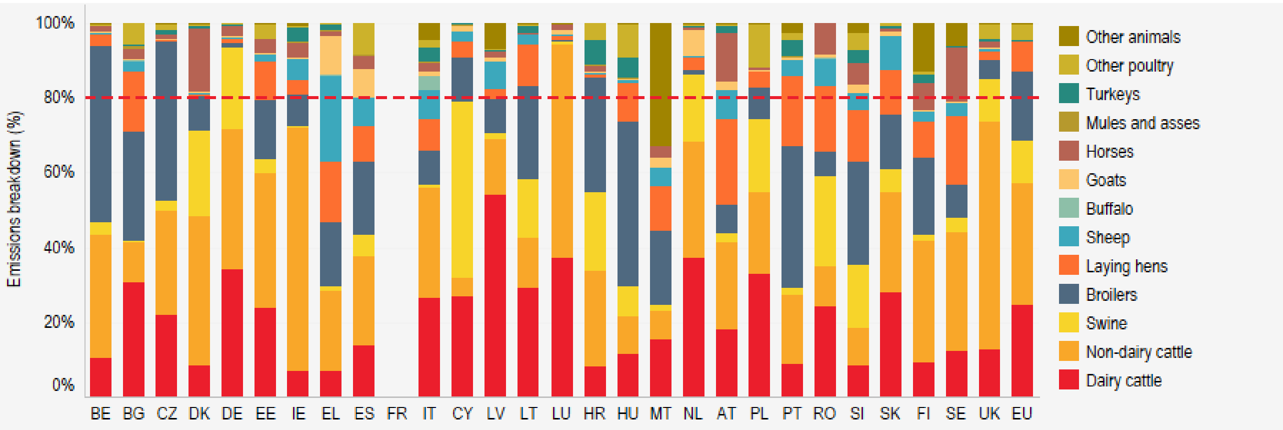
Step 7 – summing up all emissions as in Eq. (xx) and allocate in each category as it is shown in Table 20

Source: EMEP/EEA Guidebook 2019

3.2.4 Particulate matter emissions from manure management

Particulate matter (PM_{10} and $PM_{2.5}$) emissions from manure management mainly originate and depend on the livestock housing systems consisting of skin, manure, feed, and bedding particles. Main sources of PM_{10} emissions are poultry, cattle, and swine livestock categories. Only in Luxembourg these emissions are reported to be sourced from dairy cattle and non-dairy cattle categories (see Figure 10 and Table A. 8). In the case of $PM_{2.5}$ emissions the main categories are the manure management activities performed by dairy cattle and non-dairy cattle. When considering the TSP emissions, the key sources are swine and poultry.

Figure 10. Breakdown of PM_{10} emissions in the EU countries MMS by livestock categories, 2018



Source: (Eionet, 2020)

Box. 6. EMEP/EEA methodology to calculate particulate matter emissions from manure management

The estimation of particulate matter emissions from the livestock sector lack of inputs from measurements and the guidelines provide only parameters for the application of a Tier 1 method.

The Tier 1 method entails multiplying the AAP in each livestock category by a single default EF, in kg PM AAP^{-1} a^{-1}. This EF and the available methodology represent emissions from housing only, because of a lack of available information on emissions from other sources. The PM_{10} and $PM_{2.5}$ EFs are based on the most up-to-date literature. Table 3.5 provides the EFs for particulate matter emissions under Tier 1 method.

$$EMMS_{PM} = AAP_{animal} * x_{house} * \beta * (x_{slurry} * EF_{slurry} + (1-x_{slurry}) * EF_{solid}) \quad [19]$$

$EMMS_{PM}$ (PM_{10}or $PM_{2.5}$) - emission for an animal category (in kg/yr),
β - mass units conversion factor
X_{house} - share of time the animals spend in the animal house (in a a-1),
X_{slurry} - share of population kept in slurry-based systems,
EF_{slurry} - EF for slurry-based system (in kg PM/AAP/yr),
EF_{solid} - EF for solid manure-based system (in kg PM/AAP/yr).

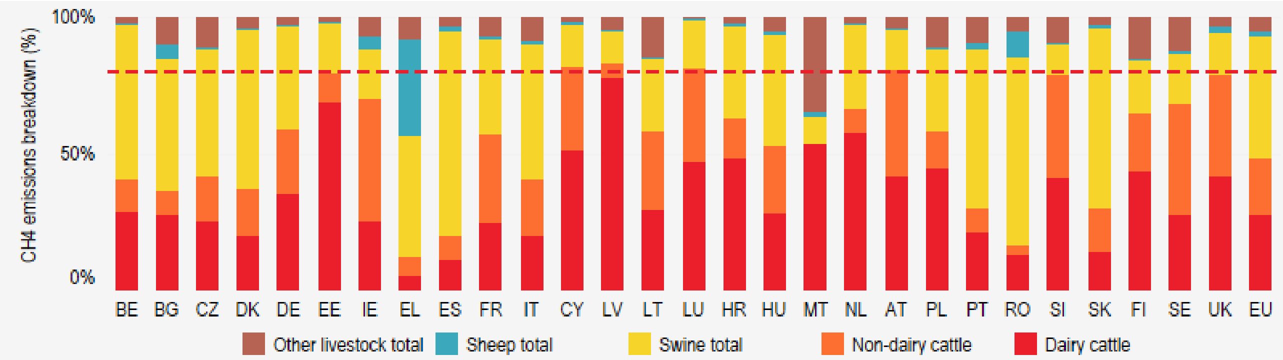
To develop emission factors expressed per unit of livestock number (AAP), transformation factors are needed for the conversion of livestock units into AAP. In addition, inhalable and respirable dust concentrations have to be transformed into the corresponding PM concentrations. In the cases for which PM EFs are not directly available, the quantities of inhalable and respirable dust have to be transformed into quantities of PM_{10} and $PM_{2.5}$. For horses, a transformation factor like the one for cattle has been assumed. Transformation factors for the conversion of inhalable dust (ID) into PM_{10} and $PM_{2.5}$ are 0.46 (kg PM_{10}/kg ID) and 0.30 (kg $PM_{2.5}$/kg ID) respectively. These transformation factors are applied for cattle and horses. For cattle, the Tier 1 EFs are based on the solid/liquid distribution of the livestock manure management systems (LMMSs). The LMMS solid/liquid distribution in the EU for dairy cattle is 49/51 and for non-dairy cattle is 59/41. Based on these values, the LMMS solid/liquid distribution is assumed to 50/50 for dairy cattle and 60/40 for other cattle.

Source: EMEP/EEA Guidebook 2019

3.2.5 CH_4 emissions from manure management

Key factors that affect CH_4 emissions from manure management are the manure characteristics (proportion of manure that can generate CH_4), the quantity of manure produced (which depends on livestock categories), the manure management systems (solid or slurry) and climate (cool, warm, cold) (Jun, Gibbs, & Gaffney). Cattle and swine are the main livestock categories for CH_4 emissions from manure management activities in the EU countries (see Figure 11). Within the cattle category, dairy cattle is the key source in 22 EU countries. Non-dairy cattle livestock is the main source of CH_4 emissions from cattle category in Ireland, Greece, France, Italy, Slovakia, and Sweden. The swine category is the main source of CH_4 emissions from livestock in manure management systems in 11 EU countries (BE, BG, CZ, DK, EL, ES, IT, CY, PT, RO, and SK). In 2018 CH_4 emissions from manure management in the EU were 41.27 Mt CO_2-eq (1638.5 kt), equal to 17.2% of total CH_4 emissions from agriculture.

Figure 11. Breakdown of CH_4 emissions in the EU and each country MMS by livestock categories, 2018



Source: (UNFCCC, 2020)

Box. 7. IPCC methodology to calculate CH_4 emissions from manure management

The IPCC Guidelines include two tiers to estimate CH_4 emissions from livestock manure. The Tier 1 approach is a simplified method that only requires livestock population data by animal category and climate region, to estimate emissions. The IPCC Guidelines provides a general approach to estimate methane emissions from livestock. The IPCC equation (Eq. 4.17) for CH_4 emissions from manure management does not differ between cattle and sheep.

$$EMMS_{CH4} = EFi * AAPi \quad [20]$$
$$EFi = VSi \times 365 \times Boi \times 0.67 \times \sum jk\ MCFjk \times MSijk \quad [21]$$

where
i – is the index for each livestock category
EFi – is the emission factor for CH_4 for each livestock category (kg CH_4/head/yr)
APPi – is the number of livestock category
VSi – is the daily volatile solids (VS) excreted (in kg) for livestock category i
Boi – is the maximum methane producing capacity (m^3/kg of VS) for manure produced by livestock category i
MCFjk – is the methane conversion factors for each manure management system j by climate region k;
MSijk – is the fraction of livestock category i's manure handled using manure system j in climate region k (%)
0.67 – is the conversion factor of m^3 CH_4 to kg CH_4 (kg/m^3)

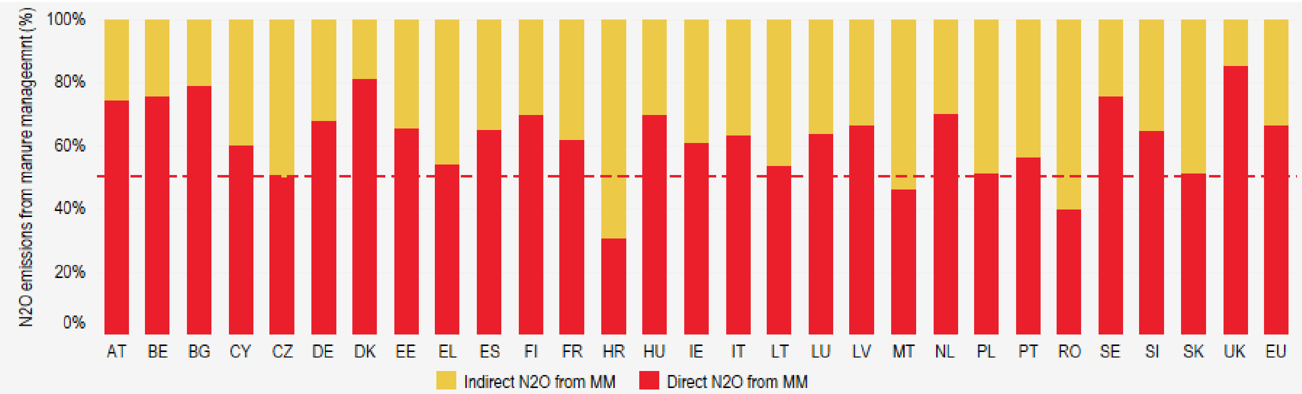
Tier 2 emission factors are calculated based on country-specific data on manure composition, manure methane producing capacity, climate, and waste system usage. Volatile Solids (VS) is the portion of the manure that produces methane. Often, data on average daily volatile solids excretion are not available. Therefore, the volatile solids values may need to be estimated from feed intake levels and characteristics. The methane producing potential varies from animal type and diet. The IPCC Guidelines provide default values for each major world region. The methane conversion factor (MCF) varies with the way the manure is managed and the climate and can theoretically range from 0% to 100%. Manure managed as a liquid under warm conditions has a high MCF (from 65% to 90%). Manure managed as dry material in cold climates has a low MCF at around 1%.

Source: IPCC 2006, Vol.4, Ch.4

3.2.6 N_2O emissions from manure management

N_2O emissions (direct and indirect) from manure management are produced during the storage and treatment of manure before it is applied to the land. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. Direct N_2O emissions occur via combined nitrification and denitrification of the nitrogen contained in the manure whereas the indirect emissions result from volatile nitrogen losses that occur primarily in the forms of NH_3 and NO_x. Only in 4 EU countries (CZ, HR, MT and RO) the indirect N_2O emissions from manure management covers more than half of total N_2O emissions from the subsector (see Figure 12).

Figure 12. Breakdown of N_2O emissions in the EU and each country MMS by type, 2018



Source: (UNFCCC, 2020)

Box. 8. IPCC methodology to calculate N_2O emissions from manure management

For the calculation of N_2O emissions from manure management the IPCC Guidelines recommend an approach like the Tier 2 method for the calculation of CH_4 emissions. Information on how manure is managed is used to identify default emission factors. These emission factors are used with nitrogen excreted estimates for each livestock group based on livestock population data to estimate N_2O emissions. N_2O emissions from all waste management systems are reported under this emissions source category except for (i) manure that is applied to agricultural soils as daily spread; (ii) manure deposited by grazing animals on fields (pasture range and paddock); and (iii) manure used for fuel. Calculation of N_2O emissions from manure management is expressed as multiplication of the total amount of N excreted (from all animal species/categories) in each type of manure management system with an emission factor for that type of manure management system.

$$EMMS_{N2O} = \sum [\ Nex_{MMS} \text{ x } EF_{MMS}] \quad [22]$$

Three main types of activity data for estimating N_2O emissions from manure management systems are needed: (i) livestock population data, (ii) nitrogen excreted data for each animal species/category, and (ii) manure management system usage data. An adjustment factor is applied in the case of young animals. Equation [23] illustrates the calculation of this activity data:

$$Nex_{MMS} = \sum_I [Ni \text{ x } Nexi \text{ x } MMSi] \quad [23]$$

where
i – is the index for each livestock category
Nex_{MMS} – is the N excreted per manure management system (kg/yr)
Nex_i – is the N excreted of each livestock category (kg N/ animal/yr)
Ni – is the number of livestock
MMSi – is the fraction of Nexi that is managed in one of the different distinguished MMS for each livestock

The IPCC guidelines give tentative default values for N_2O emission factors from animal waste management systems specified in the guidelines (Table 4.12, 4.15) and not specified in the guidelines (Table 4.13).

Source : IPCC 2006, Vol.4, Ch.4. Agriculture

3.3 Agricultural soils (3D)

Air pollutants and greenhouse gas emissions estimated under the agricultural soils subsector are:

- **Ammonia (NH_3)** sourced from mineral N fertilisers, livestock manure applied to soils, organic waste application and crop processes,**Nitrogen oxides (NOx)** sourced from soil microbial processes,
- **Non-methane volatile organic compounds (NMVOC)** sourced from crop processes,
- **Particulate matter (PM**) sourced from soil cultivation and crop harvesting.

Below a short description of methods applied in the EU countries that use country-specific emission factors (see Tables 21-27) to calculate air pollutants emissions from their agricultural soils activities is presented when this is available. In more details the methods applied in each country for each pollutant and NFR category can be found in Annex A.3.

Flemish region in ***Belgium*** applies a Tier 2 method to calculate NH_3 emissions from inorganic fertilisers applying region specific emission factors for each type of fertiliser expressed in percentage. This region applies a Tier 3 method to calculate NH_3 emissions from urine and dung deposited by grazing animal and a country specific emission factor of 8% is applied (IIR BE 2020).

Table 21. NH_3 EFs for some inorganic fertilisers in Flemish region, Belgium, 2018

Fertiliser	EF (%)
Urea	15
Ammonium sulphate (AS)	4
Ammonium nitrate	2
Nitrogen solutions	9

Source: (IIR BE 2020)

Italy estimates NH_3 emissions from inorganic fertilisers using a Tier 2 method with validated emission factors based on the results of a research study that estimated, at NUTS 2 level, emissions for the use of synthetic N-fertilisers considering the type of cultivation, altitude, and climatic conditions (IIR IT, 2020).

Germany applies both the Tier 1 and Tier 2 methods for NH_3 and NOx emissions from agricultural soils[12] activities using a combination of country specific and default emission factors. To calculate NOx emissions from manure application a Tier 1 method is used. The applied NH_3 emission factor for manure application to soils is defined as the ratio of total NH_3-N emission from manure application to the total amount of N spread with manure (IIR DE 2020).

Table 22. NH_3 EFs for manure application to soils, 2018 (kg NH_3-N/ kg N applied manure)

Source category	1990	1995	2000	2005	2010	2015	2016	2017	2018
Manure application to soils	0.211	0.196	0.190	0.179	0.172	0.160	0.160	0.160	0.160

Source: (IIR DE 2020)

Austria estimates NH_3 emissions from the use of inorganic fertilisers applying a country specific methodology that requires more information related to the use of urea application. The default emission factors applied in this category are adjusted based on the pH values (65% normal pH and 35% high pH) and weighted emission factors are calculated (IIR AT, 2020).

Table 23. NH_3 EFs for some fertilisers in Austria, 2018 (g NH_3/kg N applied)

Fertiliser	Weighted EF
Calcium ammonium nitrate (CAN)	11
N solutions (Urea AN)	97
Ammonium sulphate (AS)	116
Urea	158

Source: (IIR AT, 2020)

([12]) In the Germany's IIR 2020 it is noted that "the units of the NH_3 emission factor (for sewage sludge) provided in EMEP/EEA Guidebook 2016 are incorrect. It must read 0.13 kg NH_3 per kg N applied instead of 13 kg NH_3 per capita as in the Appendix A1.2.2.1 of this guidebook" (IIR DE 2020).

The Netherlands applies a Tier 3 method for NH_3 and NO_x emissions from agricultural soils using country-specific and default emission factors, respectively. A Tier 2 method is applied to calculate PM emissions from agricultural soils applying both the default and country-specific emission factors. NMVOC emissions are calculated using both Tier 2 and Tier 1 methods with default emission factors.

Table 24. NH_3 EFs for some agricultural soils' categories in Netherlands, 1990-2017 (kg NH_3/ kg N supply)

Source category	1990	1995	2000	2005	2010	2015	2016	2017
Inorganic N fertilisers	0.04	0.04	0.04	0.05	0.04	0.05	0.04	0.04
Animal manure	0.5	0.2	0.19	0.18	0.13	0.12	0.12	0.13
Sewage sludge	0.29	0.08	0.09	0.10	0.10	0.10	0.10	0.10
Other organic fertilisers	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
Urine and dung deposited by grazing animals	0.08	0.08	0.04	0.03	0.03	0.03	0.03	0.03
Crop residues	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.03

Source: (IIR NL, 2019)

Hungary adapts the default emission factors for NH_3 emissions from inorganic fertilisers, using high resolution soil maps to define the level of pH (41% soil with normal pH and 59% soil with high pH) and calculate the weighted emission factors (IIR HU, 2020).

Table 25. NH_3 EFs for some fertilisers in Hungary, 2018 (kg NH_3/ kg N)

Fertiliser	EF
Ammonium nitrate	0.025
Urea	0.160
Anhydrous ammonia	0,028
Ammonium phosphate	0,074
Ammonium sulphate (AS)	0.134
Calcium ammonium nitrate	0.013
Other straight N compounds (calcium nitrate)	0.015

Source: (IIR HU, 2020)

Poland applies country specific activity data to calculate the NMVOC emission factors for each type of cultivated crops (IIR PL, 2020).

Table 26. NMVOC EFs for cultivated crops in Poland, 2018, (kg NMVOC/ha/yr)

Crops	Weighted EF
Wheat	0.08
Rye	0.10
Rape	0.15
Grass (15°C)	0.08
NMVOC IEF 2018	0.41

Source: (IIR PL, 2020)

The ***United Kingdom*** NH_3 emissions from grazing and outdoor livestock are estimated using UK-specific activity data on the proportion of livestock associated with grazing and the proportion of the year those livestock spend outdoors and country specific emission factors derived from experimental measurements.

Table 27. NH_3 EFs for livestock excreta returns at grazing

Livestock	EF (% of TANex)
Cattle	6
Sheep, goats, horses and deer	6
Outdoor pigs	25
Free-range poultry	35

Source: (IIR UK, 2020)

Compared to the manure management subsector the application of preferred and suggested Tier 2 method is less spread in the agricultural soils subsector (see Table 28). The implementation of the Tier 2 method is more advanced for the calculation of NH_3 emissions mainly in the calculation of emissions from inorganic fertiliser uses, application of manure to soils and the urine and dung deposited by grazing animal. This progress is affected mainly by the N mass-flow cycle within which the emissions of NH_3, N_2O, NOx and N_2 are included.

Table 28. Methods used in the EU countries for air pollutants emissions from agriculture soils

Country	NH_3	EF NH_3	NO_X	EF NOx	NMVOC	EF NMVOC	PM	EF PM	EMEP/EEA Guidebook (Default)
BE	T2/T1/T3	CS/D	T1	D	T1	D	T1	D	2019
BG	T2/T1	D	T1	D	T1	D	T1	D	2019
CZ	T2	CS/D	NE	-	NA	-	T2	D	2019
DK	T1/T2	CS/D	T1/T2	D	T2	CS/D	T2	CS/D	2019
DE	T1/T2/T3	CS/D	T1/T2	CS/D	T2	D	T1	D	2016
EE	T1/T2	D	T1	D	T1/T2	D	T1	D	2016/2019
IE	T2	CS/D	T1	D	T1/T2	D	T1	CS/D	2019
EL	T1/T2	D	T1	D	T1	D	T1	D	2019
ES	T2	D	T1	D	T2	D	T1	D	2019
FR	T1/T2	D	T1/T2 (IE)	D	T2 (IE)	D	T1	D	2016
IT	T1/T2/CS	CS/D	T1/T2	CS/D	T1/T2	D	T1	D	2019
CY	T1	D	T1	D	T1	D	T1	D	2016/2019
LV	T1/T2	D	T1	D	T1	D	T1	D	2016
LT	T2	D	T1	D	T1	D	T1	D	2016
LU	T1	D	T1	D	T1	D	T1	D	2016
HR	T1/T2	D	T1	D	T1/T2	D	T1	D	2019
HU	T1/T2	CS	T1	D	T1	D	T1	D	2019
MT	T1/T2	D	T1/T2	D	T2	D	T1	D	2016
NL	T3	CS	T3	D	T2	D	T2	CS/D	2016
AT	T3/T1	CS	T1	D	T2	D	T1	D	2019
PL	T2	CS	T2	CS	T1	D	T1	CS/D	2016
PT	T1/T2	D	T1	D	T1	D	T1	D	2016
RO	T1/T2	CS/D	T1	D	T1/T2	D	T1	D	2019
SI	T1/T2	D	T1	D	T1/T2	D	T1/T2	D	2016
SK	T1/T2	D	T1/T2	D	T2	D	T1	D	2016
FI	T1/T2	CS/D	T1	D	T1	CS/D	T1	D	2019
SE	T2	D	T1	D	T2	CS/D	T1	D	2016
UK	T1/T2/T3	CS	T1/T2	CS/D	T1	CS/D	T1	CS/D	not specified

Source : EU countries IIRs 2020

However, few countries apply country specific emission factors to estimate air pollutant emissions from agricultural soils. The estimation of NH_3 emissions in this subsector is carried out by a combination of both Tier 1 and Tier 2 methods and in some cases the Tier 3 method is applied (for categories 3Da.2a and 3Da3). Only 2 EU countries apply a Tier 1 method for the estimation of NH_3 emissions from agricultural soils. 5 EU countries apply only a country specific emission factor whereas 4 countries apply a combination of default and country specific emission factors. The Tier 1 method dominates the estimation of NOx emissions from agricultural soils. Even when a Tier 2 method is applied to calculate NOx emissions from manure management, not in all cases the same method is used to estimate NOx emissions in agricultural soils. The Tier 1 method dominates in the NMVOC emissions estimation and only default emission factors are used. In the case of PM only 2 countries apply a combination of country specific and default emission factors. Czech Republic does not estimate the NOx emissions from its agricultural activities whereas the estimation of NMVOC emissions is not applied. France reports both NOx and NMVOC emissions from agricultural soils under category 6B (Other not included in national total of the entire territory).

Table 29. Summary of the methods applied for air pollutant emissions from the agricultural soils subsector

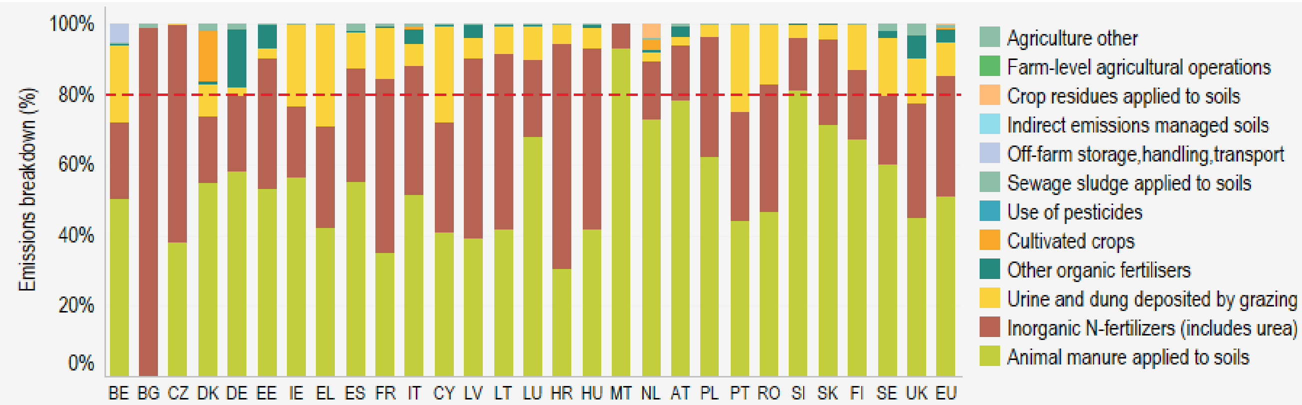
NFR	Agricultural Soils	Method	EF calculation
3Da1	Inorganic N-fertilisers (urea application included)	T2/T1/T3 (NH_3), T2/T1 (NOx)	D/CS (NH_3, NOx)
3Da2a	Animal manure applied to soils	T2/T1/T3 (NH_3), T1/T2 (NOx, NMVOC)	D/CS (NH_3, NOx), D (NMVOC)
3Da2b	Sewage sludge applied to soils	T1/T2 (NH_3), T1 (NOx)	D/CS (NH_3, NOx)
3Da2c	Other organic fertilisers applied to soils	T1/T2 (NH_3, NOx)	D/CS (NH_3, NOx)
3Da3	Urine and dung deposited by grazing animals	T2/T1/T3 (NH_3, NOx), T2/T1 (NMVOC)	D/CS (NH_3, NOx), D (NMVOC)
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	T1/T2 (TSP, PM_{10}, $PM_{2.5}$,)	D/CS (TSP, PM_{10}, $PM_{2.5}$,)
3Dd	Off-farm storage, handling and transport of bulk agricultural products	T1 (TSP, PM_{10}, $PM_{2.5}$,)	D (TSP, PM_{10}, $PM_{2.5}$,)
3De	Cultivated crops	T2/T1/CS (NH_3), T2/T1 (NMVOC)	D/CS (NH_3, NMVOC)

Source: EU countries IIRs 2020

3.3.1 NH_3 emissions from agricultural soils

Agricultural soils covers more than half of NH_3 emissions from agriculture in 20 EU countries. NH_3 emissions in this subsector represent the amount of N inputs to the soils. Animal manure applied to soils (3Da1), inorganic fertilisers (3Da2a) and urine and dung deposited by grazing animals (3Da3) are the main sources of NH_3 from agricultural soils activities in almost all EU countries except for Bulgaria which reports these emissions almost totally under the category 3Da1 (see Figure 13 and Table A. 5).

Figure 13. Breakdown of NH_3 emissions in the EU and each country by agricultural soils categories, 2018



Source: (Eionet, 2020)

Box. 9. EMEP/EEA methodology to calculate NH_3 emissions from agricultural soils

Tier 1 and Tier 2 methods are available for the calculation of NH_3 emissions from agricultural soils. The Tier 1 method does not distinguish between emissions from ***manure management*** and emissions from ***manure applied to land (3Da2a)*** or those from ***excreta deposited during grazing (3Da3).*** For each livestock category, the emissions should be reported under 3Da2a if the livestock are in animal housing for most of the year or under 3Da3 if they are predominantly grazed. The emission from ***sewage sludge (3Da2b)*** is calculated by multiplying the emission per capita by the human population of the country. The EMEP/EEA Tier 2 method suggested for the calculation of NH_3 emissions from this sector (EAS_{NH3}) is presented in Eq. 24

$$EAS_{NH3} = NH_{3fertiliser} + NH_{3manure\ application} + NH_{3sewage\ sludge} + NH_{3compost} + NH_{3grazing} + NH_{3crop\ residues} \quad [24]$$

where:

$NH_{3fertiliser}$ - emissions from the use of N fertilisers. Calculation as in Eq.25.

$$NH_{3\_fertiliser} = \sum (EF\ NH_{3\_fertiliser}\ x\ N_{\_fertiliser})\ x\ 17/14 \quad [25]$$

$NH_{3manure\ application}$ - emissions from manure application to soils. Calculation as in Eq. 26.

$$NH_{3manure\_application} = m_{applic\_slurry\_TAN} \times EF_{applic\_slurry} + m_{applic\_solid\_TAN} \times EF_{applic\_solid} \quad [26]$$

$NH_{3sewage\ sludge}$ - emissions from sewage sludge. Calculation as in Eq.27

$$NH_{3sewage\ sludge} = N_{sewage\_sludge}\ x\ 0.013\ (kg\ NH_3/kg\ N_{applied}) \quad [27]$$

$NH_{3compost}$ – emissions from organic fertilisers. Calculation as in Eq.28

$$NH_{3other} = m_{other\_NH3}\ x\ EF_{other\_NH3} \quad [28]$$

$NH_{3grazing}$ – emissions from animal grazing. Calculation as in Eq.29

$$NH_{3grazing} = m_{graz\_TAN} \times EF_{grazing} \quad [29]$$

$NH_{3crop\ residues}$ – emissions from crop residues. Calculation as in Eq.30

$$NH_{3\ crop\ residues} = \sum area\ crops\ x\ N_{in\ residue}\ x\ EF_{NH3\ crop\ residue}\ x\ Fract_{contribution}\ x\ 17/14 \quad [30]$$

where

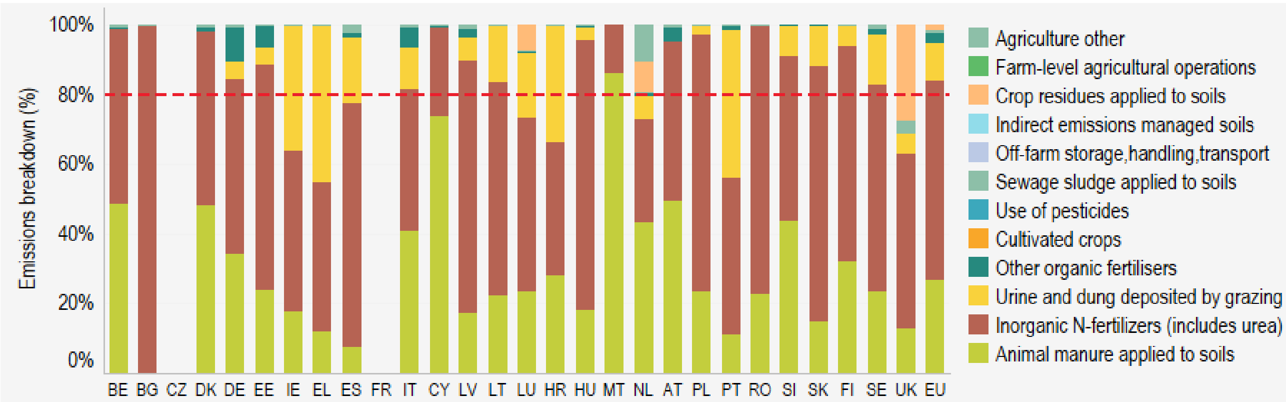
$Fract_{contribution}$ - is the fraction of the contribution for each crop residues

Source: EMEP/EEA Guidebook 2019

3.3.2 NO_x emissions from agricultural soils

NOx emissions from this subsector occur when the N is applied to agricultural soils. None of the EU countries report NOx emissions from categories: (i) Indirect emissions from managed soils (3Db), (ii) farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc), (iii) off-farm storage, handling and transport of bulk agricultural products (3Dd), (iv) cultivated crops (3De) and (v) use of pesticides (3Df). Inorganic N fertilisers (3Da1), animal manure applied to soils (3Da2a) and urine and dung deposited by grazing animal (3Da3) are the main sources of NOx emissions in this subsector (see Figure 14). In 2018, NOx emissions from agricultural soils were 565.8 kt, covering 96% of total NOx from agriculture.

Figure 14. Breakdown of NOx emissions in the EU and each country by agriculture soils categories, 2018



Source: (Eionet, 2020)

Box. 10. EMEP/EEA methodology to calculate NOx emissions from agricultural soils

NOx emissions from agricultural soils are estimated in the form of nitric oxide (NO). Then the conversion factor 30/14 is applied. According to the Tier 1 method the emissions of NO from manure applied to land are calculated as following

$$EM_{Mappl}\_NO = AAP \times Nex \quad [32]$$

where

AAP – annual average livestock population

Nex – nitrogen excreted (EMEP/EEA Guidebook 2019, Table 3-7, Ch.3B)

The Tier 1 method does not distinguish between ***manure management emissions*** and those from ***manure applied to land (3Da2a)*** or those from ***excreta deposited during grazing (3Da3).*** For each livestock category, the emissions should be reported under 3Da2a if the livestock are in animal housing for most of the year or under 3Da3 if they are predominantly grazed. The emission from ***sewage sludge (3Da2b)*** is calculated by multiplying the emission per capita (EMEP/EEA Guidebook 2019, Table 3.1) by the human population of the country. The contribution of digestates produced as a result of anaerobic digestion of organic wastes (including manure) to the N applied in other organic wastes (3Da2c) should be obtained from Chapter 5B2 (Biological treatment of waste - Anaerobic digestion at biogas facilities). There is not a Tier 2 method for the calculation of NO emissions from agricultural soils activities. However, if a Tier 2 method is applied to calculate NH_3 emissions from manure management some of the outputs can be used to calculate NO emissions: (i) when calculating the manure application to soils (3Da2a) emissions, the N applied should be calculated as the sum of $m_{applic\_slurry}\_N$ and $m_{applic\_solid}\_N$

$$m_{applic\_slurry}\_N = m_{applied\_direct\_slurry}\_N + mm_{storage\_slurry}\_N + mm_{dig}\_N - E_{storage\_slurry} \quad [33]$$

$$m_{applic\_solid}\_N = m_{applied\_direct\_solid}\_N + mm_{storage\_solid}\_N - E_{storage\_slurry\_solid} \quad [34]$$

$$EM_{Mappl\_AS}\_NO = EF\_NO_{\_Managed\_Soils\_Manure} \times (m_{applic\_slurry}\_N + m_{applic\_solid}\_N) \quad [35]$$

and (ii) when calculating urine and dung deposited by grazing animals (3Da3) emission, the N applied should be calculated as m_{graz}_N

$$m_{graz}\_N = x_{graz} \times N_{ex} \quad [36]$$

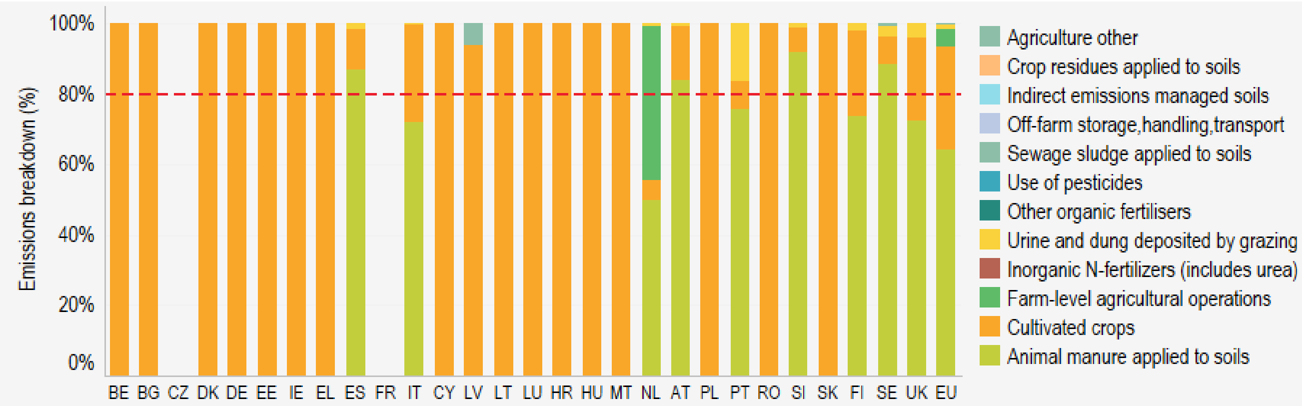
$$E\_{grazing\_NO} = EF\_{NO\_Managed\_Soils\_Excreta} \times m_{graz\_N} \quad [37]$$

Source: EMEP/EEA Guidebook 2019

3.3.3 NMVOC emissions from agricultural soils

NMVOC emissions from agricultural soils activities are mainly sourced from crop cultivation activities and during the animal manure application to soils. As shown in Figure 15 animal manure applied to soils is the main category of NMVOC emissions in this subsector in Austria, Spain, Sweden and Slovenia. In Netherlands, NMVOC emissions originate also from farm-level agricultural operations including storage, handling, and transport of agricultural products.

Figure 15. Breakdown of NMVOC emissions in the EU and each country by agricultural soils categories, 2018



Source: (Eionet, 2020)

Box. 11. EMEP/EEA methodology to calculate NMVOC emissions from agricultural soils

Both Tier 1 and Tier 2 methods are available for the calculation of NMVOC emissions from agricultural soils categories. Default emission factors are provided for both methods. However, these emission factors are sourced from studies from 1993 and 1995 that describe short term measurements which is also a characteristic of the more recent studies. Several other assumptions are included in the aggregated methodologies.

The EFs include partial EFs for isoprene, terpenes, alcohols, aldehydes, ketones, ethers and other organic compounds, and their contribution to overall emissions.

$$EAS_{NMVOC\_crop} = \sum A_i \times mD\__i \times t_i \times EF_i \qquad [38]$$

Where

EAS_{NMVOC_crop} - is the NMVOC emission flux from cropped areas (kg NMVOC /yr);
A_i -is the area covered by $crop_i$ (ha/yr);
$mD\__i$ - is the mean dry matter of $crop_i$ (kg/ha/yr)
ti - is the fraction of year during which $crop_i$ is emitting (in a/yr)
EFi - is the EF for crop i (kg /kg NMVOC).

Where the EFs of the 1993 and 1995 studies for the same crop differed widely the Guidebook calculate an average emission factor. Since these studies were conducted not in the same growing period of the crops under analysis, different types of VOC might have been prevalent. Additionally, in these studies emission factors for maize are missing and for grassland better studies are available.

The emission factors depend on the growing period and the dry matter content of the plants. For the growing period for wheat, rye, rape and grassland, the values of 0.5 and 0.3, respectively, are given in Table 3.3 of the EMEP/EEA Guidebook 2019. This table and the data provided can be used to calculate the Tier 1 weighted emission factor for NMVOC emission from crop cultivation processes.

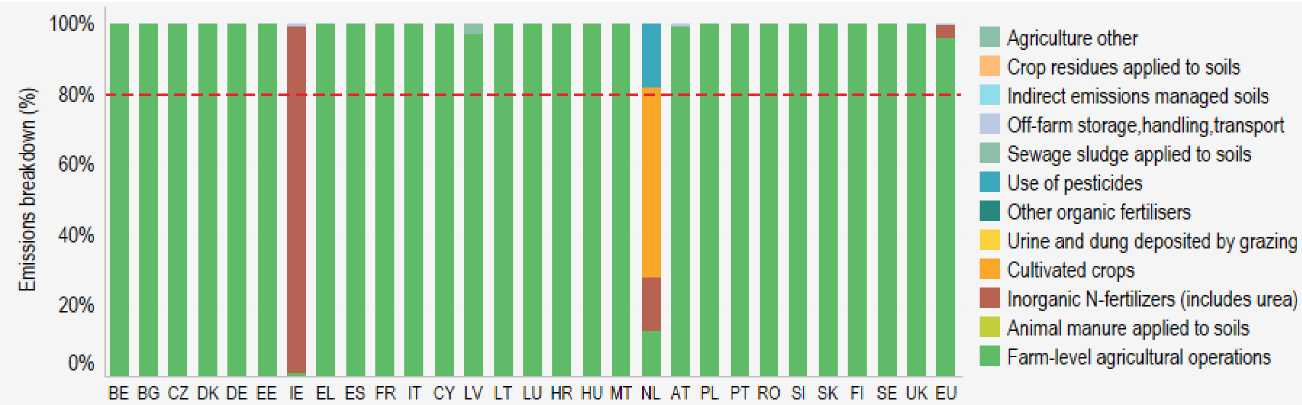
Source: EMEP/EEA Guidebook 2019

3.3.4 Particulate matter emissions from agricultural soils

Particulate matter (PM_{10} and $PM_{2.5}$) is emitted during the storage, handling and transport of agricultural products, the cultivation of agricultural soils, crop harvesting and during the use of inorganic N-fertilisers. 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.

Farm-level agricultural operations including storage, handling, and transport of agricultural products (3Dc) is the key category of PM_{10} emissions in agricultural soils in almost all EU countries except for Ireland and the Netherlands where the inorganic fertilisers and cultivated crops, respectively, are reported as main categories (see Figure 16, Table A. 8 and Table A. 9).

Figure 16. Breakdown of PM emissions in the EU countries by agricultural soils categories, 2018



Source: (Eionet, 2020)

Box. 12. EMEP/EEA methodology to calculate particulate matter emissions from agricultural soils

The Tier 2 method described in the EMEP/EEA Guidebook 2019 provides emission factors (Tables 3.1 and 3.5-3.8) for different agricultural operations for dray and wet climate. PM emissions calculated here are intended to reflect the amounts found immediately adjacent to the field operations. A substantial proportion of this emission will normally be deposited within a short distance of the location at which it is generated

However, no default emission factors for particulate matter from fertiliser, pesticides or from grassland are provided. Particulate matter emissions are mainly from combined harvesting and soil cultivation.

Few studies that report emission factors from crop harvesting are available. Several studies are available for operations regarding soil cultivation. Some studies report emission factors for cotton. There are also studies that provide separate emission factors for operations on soils and operation on crops activities. Almost all the studies are reporting the emission factors only for PM_{10}.

Particulate matter emissions from crop cultivation are calculated following Eq. 39.

$$EAS_{PM} = \sum_i Area_i \times EF_i \times n \qquad [39]$$

where
$Area_i$ - Cropped area for the defined crop (i) (ha)
EF_i - Emission factor for the defined crop (i) in kg per ha
n : Number of times the operation is performed on the crop

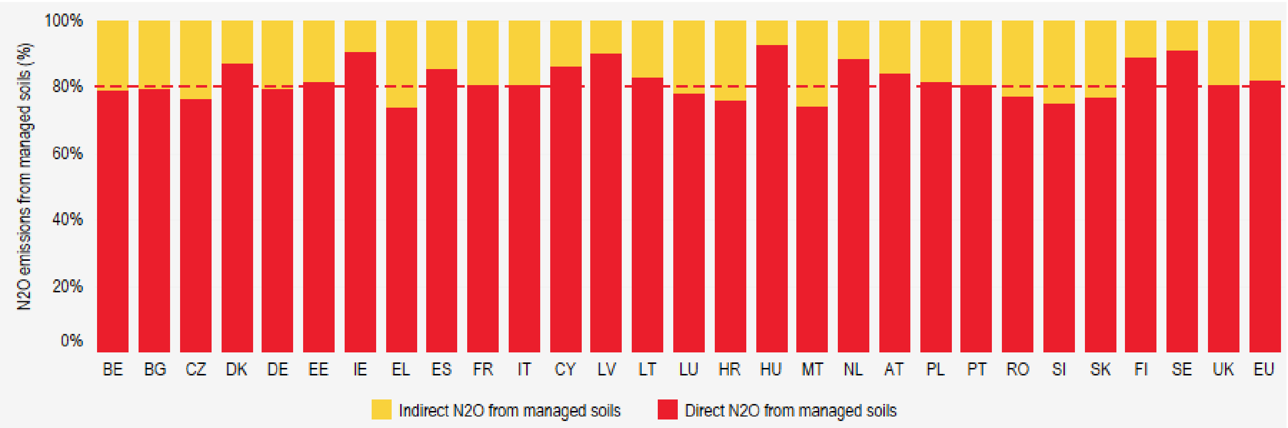
Information is required on the annual national consumption of the N fertiliser types. If spatially disaggregated inventories of fertilised culture emissions are required, information on the spatial distribution of different crop types and average N fertiliser inputs to each crop type may be used. In the absence of data on the use of different fertilisers for crop types, the average N fertiliser inputs to crops may be combined with the average NH_3 EF for a country, which is calculated as estimated total NH_3 emission divided by total N fertiliser consumption.

Source: EMEP/EEA Guidebook 2019

3.3.5 N_2O emissions from agricultural soils

N_2O emissions (direct and indirect) occur when N is applied to agricultural soils and when the incorporation of livestock manure into the soil takes place. The main activities that produce N_2O within this subsector are: (i) application of synthetic N fertilisers, (ii) application of manure in soils, (iii) direct deposition of manure by grazing and animals, and (iv) crop residue management. Direct N_2O emissions dominate the total N_2O emissions from agricultural soils in all EU countries (see Figure 17). In 2018, almost 88% of N_2O emissions (789.9 kt) from agriculture were covered by agricultural soils activities.

Figure 17. Breakdown by type of N_2O emissions in the EU and each country from the agricultural soils subsector, 2018[13]



Source: (UNFCCC, 2020)

Box. 13. IPCC methodology to calculate N_2O emissions from agricultural soils

The IPCC Guidelines (2006) give separate estimates of the direct and indirect emissions of nitrous oxide from the agricultural sector. Direct emissions occur in the agricultural system, primarily because of the application of inorganic N-fertilisers and livestock manure. Indirect emissions of nitrous oxide concern the formation of N_2O in soils and aquatic systems because of nitrogen losses from the soil to air and water.

$$EAS_{N2O\_direct/indirect} = \sum N_{sources} \times EF_{sources} \times 44/28 \text{ (Tier 1b)} \quad [40]$$

where

$N_{sources}$ - amount of N for the selected sources
$EF_{sources}$ - emission factor for the selected source (kg N_2O-N/kg N input)

The selected sources in the case of direct N_2O estimation include: (i) annual amount of synthetic fertiliser nitrogen (FSN) applied to soils adjusted to account for the amount that volatilises as NH_3 and NOx, (ii) annual amount of animal manure nitrogen (FAM) intentionally applied to soils adjusted to account for the amount that volatilises as NH_3 and NOx, (iii) amount of N fixed by N-fixing crops (FBN) cultivated annually, (iv) amount of N in crop residues (FCR) returned to soils annually, (v) area of organic soils (FOS) cultivated annually. Equations 4.22 – 4.29 in the IPCC Vol.4 Guideline for agriculture describe methods on how to perform the estimation of selected sources. Emission factors needed to estimate direct N_2O emissions from agricultural soils should indicate the amount of N_2O emitted from the various nitrogen additions to soils (EF1) and the amount of N_2O emitted from cultivation of organic soils (EF2). Table 4-17 of the IPCC Guide provides the default emission factors for direct N_2O emissions from agricultural soils activities. The default value of EF1 is 1.25% of the nitrogen applied to soils. To estimate the indirect N_2O emissions the following sources are taken in consideration: (i) volatilisation of applied synthetic fertiliser and animal manure N, and its subsequent atmospheric deposition as NOx and NH4, (ii) leaching and runoff of applied fertiliser and animal manure N, and (iii) discharge of human sewage N into rivers or estuaries. Table 4-18 of the IPCC Guidelines provides the default emission factors for the estimation of indirect N_2O emissions from agricultural soils.

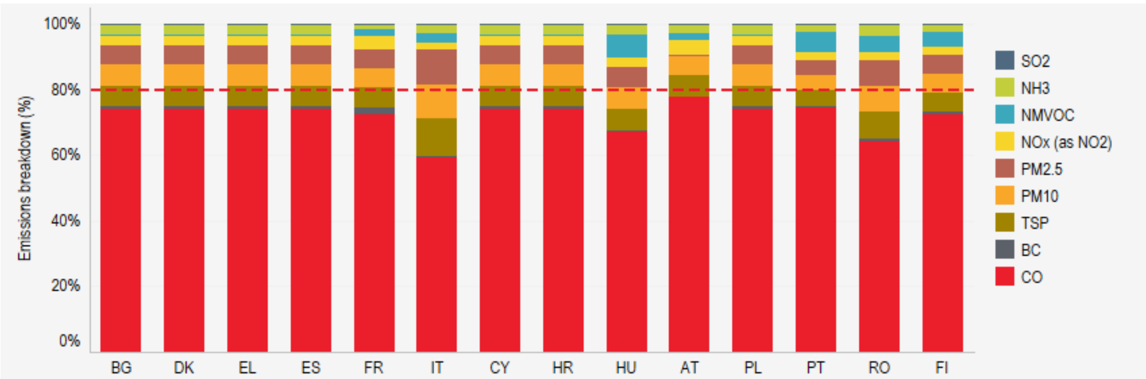
Source: IPCC 2006 Guide, Ch.4. Agriculture

([13]) Indirect N_2O emissions presented in Figure 16 include only the atmospheric deposition as NOx and NH_4 as it is reported by EU countries in their CRF tables submitted to UNFCCC.

3.4 Field burning of agricultural residues (3F)

Burning of agricultural crop residues leads to the emission of several air pollutants such as NH_3, NOx, NMVOCs, SO_2, CO, PM_{10}, $PM_{2.5}$, TSP also including black carbon (BC). The pollution from such activity is mainly in the form of CO and PM emissions (see Figure 18). Burning agricultural crop residues has been banned by the EU countries national laws however, this activity continues in 14 countries although in a smaller scale. In Austria such activity is legally restricted by provincial laws and since 1993 even by the federal law, but occasionally it is permitted to take place (IIR AT, 2020). In Bulgaria, the national law prohibits this activity which however somehow continues (IIR BG 2020). In Denmark field burning prohibited by law since 1990 may be applied only to eliminate the grass seeds with repeated production on fields and in cases of wet or broken bales of straw (IIR DK 2020). In Spain only the emissions from burning of cotton crops residues are included in this subsector (IIR ES, 2020). Agricultural crop residues burning is prohibited in France, except in cases for agronomic reasons or crop diseases. The main crops burned are flax and rice (IIR FR, 2020). In Finland, the burning of agricultural residues is banned since 2009 occurring however at small scale and straw is assumed the most important agricultural residue burned (IIR FI, 2020).

Figure 18. Breakdown of air pollutants emissions from agricultural crop residues field burning, 2018



Source: (Eionet, 2020)

Box. 14. EMEP/EEA methodology to calculate air pollutants emissions from agricultural residues field burning

Tier 1 and Tier 2 methods provided by the EMEP/EEA Guidebooks are based on the IPCC 2006 area of agricultural crops, average yield of these crops, the fraction of residue burned and the dry matter content of the residues as shown in Equation 41:

$$EAR_{residue\_burnt} = A * Y * s * d * pb * Cf \quad [41]$$

where

A (ha) – is the area of land on which crops are grown whose residues are burned,
Y - is the average yield of those crops (e.g. grain), (kg ha-1 fresh weight),
s - is the ratio between the mass of crop residues and the crop yield,
d - is the dry matter content of that yield,
pb - is proportion of those residues that are burned (as opposed to being incorporated in the soil, consumed by livestock on the field or removed from the field for use elsewhere),
Cf - is the combustion factor (proportion of the fuel present at the time of the fire that is burned).

Default values of the above mentioned activity data are source from Table 2.6 of IPCC 2006, Vol.4, Ch.2. The default Tier 1 emission factors are those for wheat that is assumed to be the most prevalent crop. The most important activity data are the quantity of crops produced (by type) with residues that are commonly burned. Data on maize, rice, sugar cane, wheat and many other crops can be derived from FAOSTAT and national statistics. The Tier 2 emission factors calculation extends the Tier 1 method by incorporating separate emission factors for major crops. The EMEP/EEA Guidebook 2019 provides Tier 2 emission factors for barley, maize, and rice. A Tier 3 method is suggested to be developed based on the parameters in equation 3.18 in Chapter 3 of IPCC 2006 and national inventory data should be used to assure that no burning of crop residues is being omitted. In this method fine-resolution activity data disaggregated at sub-national to fine grid scales are required.

Source: EMEP/EEA Guidebook 2019

4. Approaches for the improvement of agricultural emissions estimates

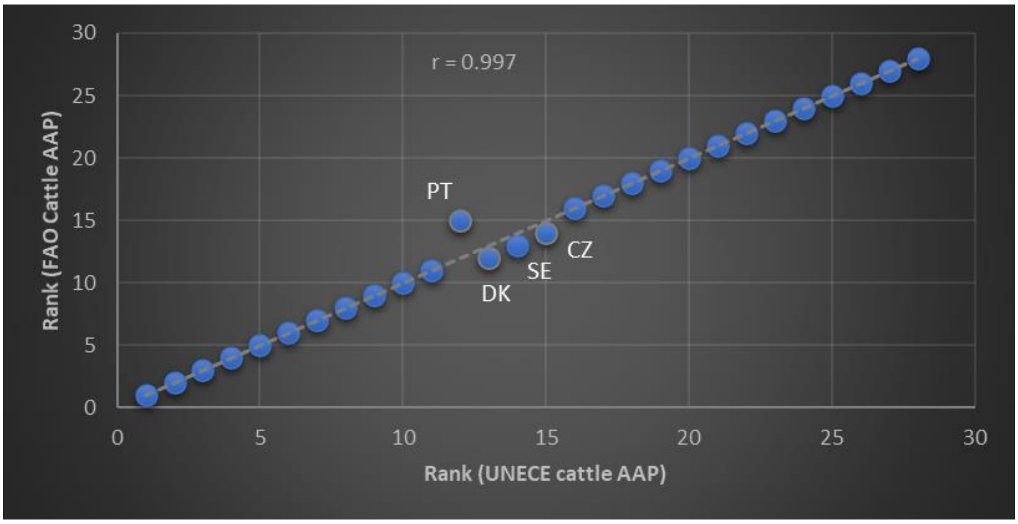
Default activity data and emission factors provided in the EMEP/EEA Guidebooks and IPCC Guidelines offer every country the possibility to compile an inventory and report air pollutant and GHG emissions from anthropogenic sources. However, default activity data and emission factors do not reflect the real conditions of a country. Approaches such as the comparative analysis between country-specific and default activity data and emission factors that provide quantitative insights on the existing differences, can help the improvement of the estimation of air pollutant and GHG emissions from agricultural activities.

4.1 Comparing country-specific vs default activity data, emission factors and calculated data

Activity data availability is a common determinant on the choice of the methods for the calculation of air pollutants and GHG emissions from agricultural activities. For example the manure management emission calculations in accordance with a Tier 2 or Tier 3 method require data on (i) animal performance (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, numbers of eggs and weights of eggs) and on (ii) feeding details (phase feeding, feed components, protein and energy content, digestibility and feed efficiency). Several data can be retrieved from National Statistics (NS), FAO, reporting under UNFCC (CRF Tables), reporting under UNECE (IIRs), Eurostat and other sources.

Livestock population (AAP) is one of the activity data that is reported in the EU countries IIRs (UNECE) as well as in the reporting to the UNFCCC (CRF Tables). These data can also be sourced from FAOSTAT, Eurostat and NS. A comparison between FAO and UNECE data on cattle AAP applying a multivariate analysis[14] using the Spearman's rank correlation coefficient[15], is shown in Figure 19.

Figure 19. Cattle population in the EU countries – comparison between FAO and UNECE reporting, 2018



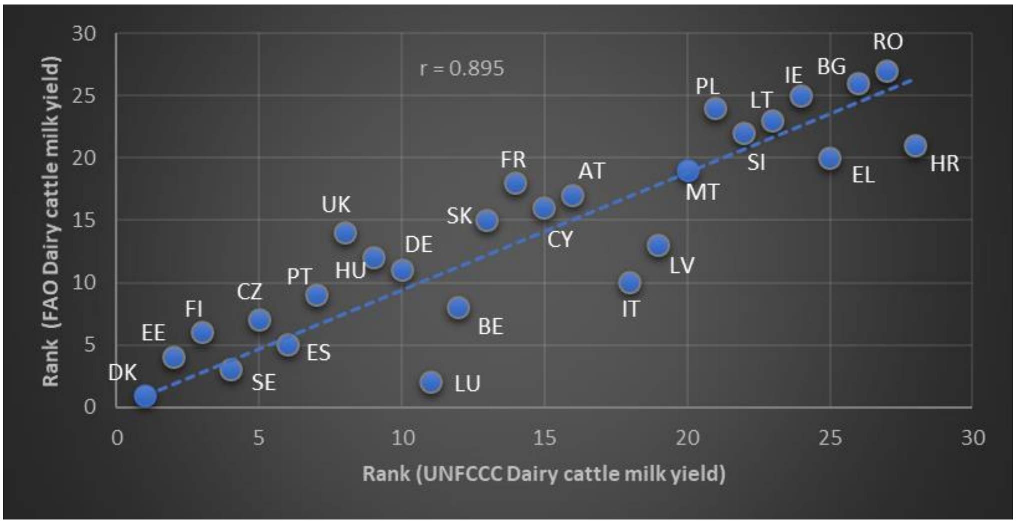
Source: (FAOSTAT, 2020), (Eionet, 2020)

As shown in Figure 19 a good relationship exists between FAO and UNECE data sets on cattle population. The largest difference was found in Portugal where the cattle population reported by FAO is 16% higher than the cattle population reported in the UNECE (IIRs). However, in some cases inconsistencies between the data sets and national statistics (NS) are observed. For example, in the Austrian's IIRs 2020 it is stated "…there is often a time gap of one year between the two data sets (FAO and NS). FAOSTAT data are seemingly based on the official *Statistik Austria* data but there is an annual attribution error" (IIR AT, 2020). A check performed on 2017 cattle numbers in the Austria's IIR 2020 confirms this statement: 1943 thousand cattle reported in FAO for year 2018 (1912 thousand cattle in Austria's IIR 2020) is in fact the number of cattle reported by *Statistik Austria* for year 2017. Checking the EU countries IIRs 2020, no other inconsistencies were found.

([14]) The uncertainties of all data sets are not taken in consideration when applying the multivariate analysis.
([15]) The Spearman's rank correlation coefficient is used to determine the strength of a relationship between two data sets.

Milk yield is the other important activity data that can be sourced from CRF Tables, FAOSTAT or NS. The comparison between FAO and UNFCCC data on dairy cattle milk yield applying the same correlation method is shown in Figure 20.

Figure 20. Dairy cattle milk yield in EU countries – comparison between FAO and UNFCCC reporting, 2018

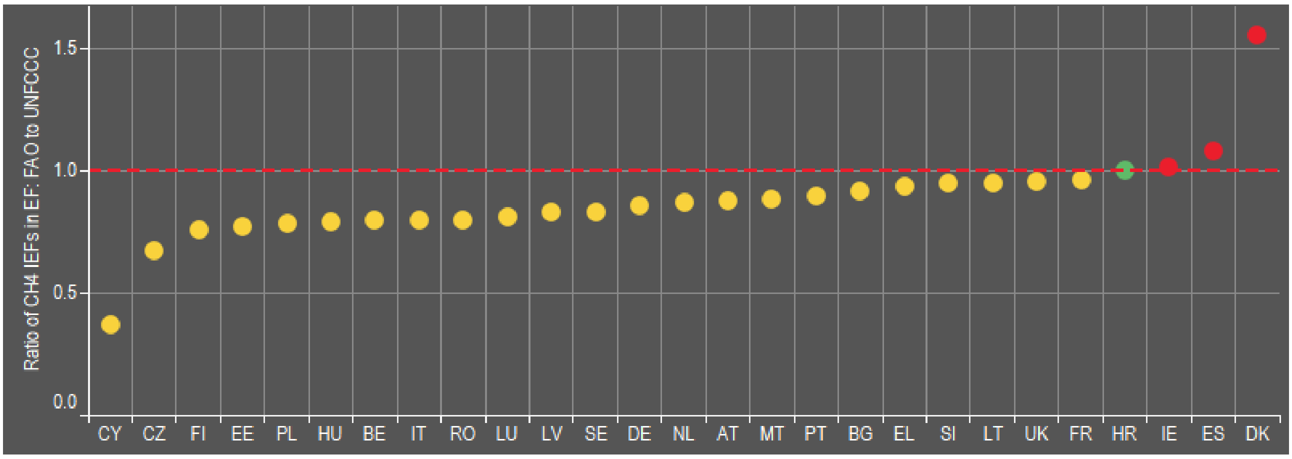


Source: (FAOSTAT, 2020), (UNFCCC, 2020)

In the case of the milk yield a Spearman correlation coefficient of 0.895 was found for the FAO and UNFCCC data sets. The largest differences are observed for Croatia, Greece, and Luxembourg where the FAO data are respectively 53%, 41% and 20% lower than the data submitted to the UNFCCC. Positive differences are found for Poland (+7%), Portugal (+4%), UK (+3.2%), Czech Republic (+2.7%), France (+1.9%) and differences lower than +1% are found for Estonia, Cyprus, and Hungary. Only for Germany the two data sets provide the same milk yield for dairy cattle.

The application of accurate ***emission factors*** is important since this is a representative value that links the quantity of an air pollutant or GHG released to the atmosphere with the activity associated with this release. A comparison of implied emission factors (IEFs) for the estimation of CH_4 emissions from enteric fermentation as they are sourced by FAO and reported to UNFCCC is shown in Figure 21. As shown, for several countries there are considerable differences among the IEFs involved in the comparison. FAO IEFs are sourced from the IPCC 2006 Guideline Table 10.11 that provides regional Tier 1 default emission factors, whereas in almost all EU countries the Tier 2 method for CH_4 emissions from enteric fermentation is applied. Only for Ireland, Spain, and Denmark the reported IEFs for CH_4 are lower than the regional default implied emission factors.

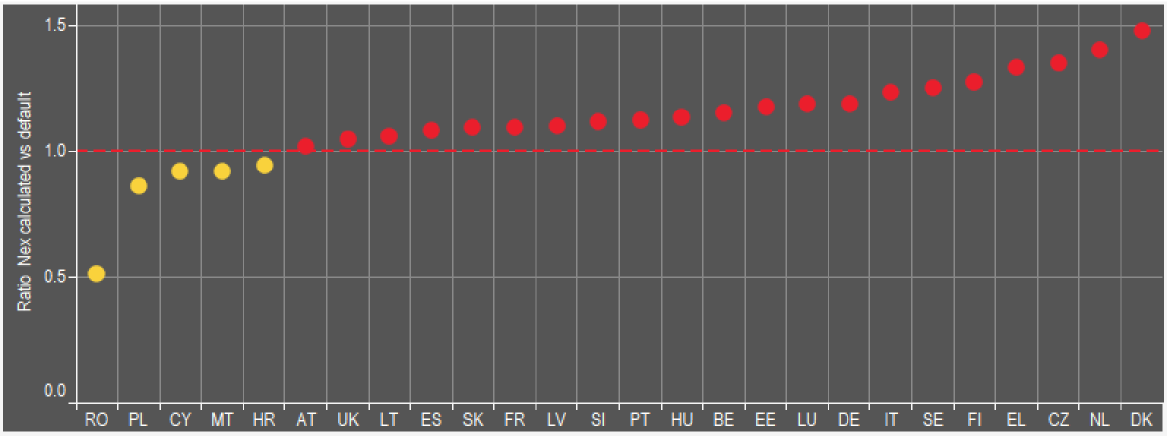
Figure 21. Ratio of FAO CH_4 implied emission factors from enteric fermentation to the UNFCCC reporting for EU countries



Source: (FAOSTAT, 2020), (UNFCCC, 2020)

Nitrogen excreted (Nex) rate is one of the calculated data needed for the estimation of NH_3 emissions from manure management as well as for the NH_3 emission factors. The Nex rate is calculated as the difference between the intake of N and retention of N in animal products, using standard N balance calculation methods. Figure 22 illustrates the 2018 ratio of nitrogen excreted for dairy cattle calculated as in the IPCC 2006 Guidelines (assumed Tier 2 approach) and reported by the EU countries in the CRF tables vs the default value provided in the (EMEP/EEA Guidebook, 2019), Table 3.9[16]. Only in 5 EU countries the nitrogen excreted country specific value was found to be lower (yellow dots) than the default value.

Figure 22. Ratio of nitrogen excreted rates for dairy cattle in EU countries manure management systems: calculated vs default, 2018



Source: (UNFCCC, 2020), EMEP/EEA Guidebook 2019

4.2 Comparing country specific vs default NH_3 dairy cattle emission factors in manure management system

The following section provides a comparison between the dairy cattle default and country specific emission factors for NH_3 in manure management system (MMS). Table 30 shows the Tier 2 default dairy cattle emission factors for the estimation of NH_3 emissions in some types of MMS.

Table 30. Default dairy cattle NH_3 emission factors in manure management system

Livestock	Fuel	MMS type	EF (Fraction of TAN)	EF[17] (kg NH_3/head/yr)
Dairy cattle	Slurry	Housing	0.24	18.29
Dairy cattle	Solid	Housing	0.08	6.1
Dairy cattle	Slurry	Yard	0.3	22.86
Dairy cattle	Solid	Yard	0.3	22.86
Dairy cattle	Slurry	Storage	0.25	19.05
Dairy cattle	Solid	Storage	0.32	24.38
Dairy cattle	Slurry	Grazing/Outdoor	0.09	6.86
Dairy cattle	Solid	Grazing/Outdoor	0.09	6.86
Dairy cattle	Slurry	Manure application	0.55	41.91
Dairy cattle	Solid	Manure application	0.68	51.82

Source: (EMEP/EEA Guidebook, 2019)

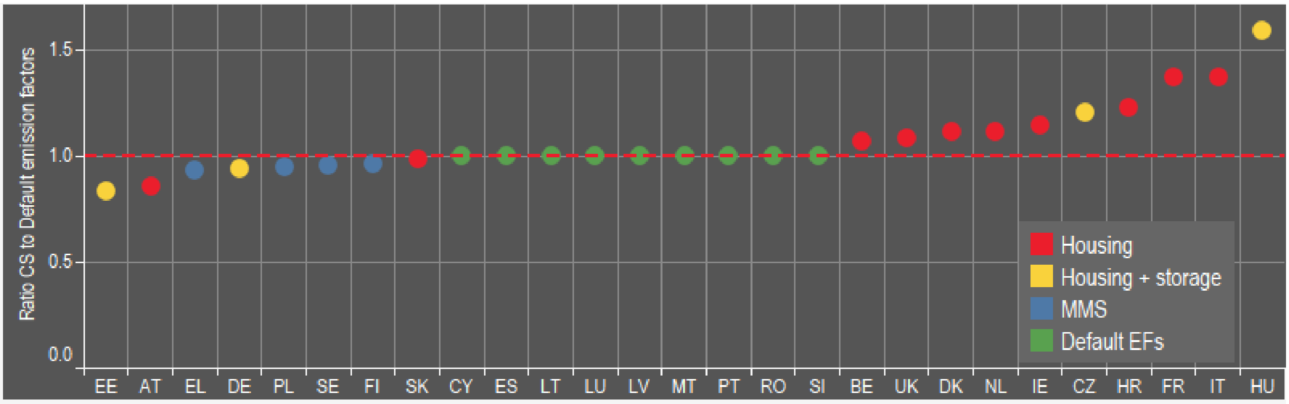
While a Tier 2 method is applied to estimate NH_3 emissions from cattle manure management systems in almost all EU countries (except Bulgaria), the default emission factors are used in 10 countries while country-specific only or combined with default emission factors in 18 countries. However, it is not easy to extract these country-specific emission factors from the available IIRs submitted to Eionet under the NECD obligations. Some countries have reported only NH_3 emission factors for all manure management systems without the division on housing, yards or solid and slurry. Some countries report these emission factors in kg NH_3-N/animal/yr units and some other in kg NH_3-N/kg Nex, in kg NH_3-N/kg TAN or as fraction of TAN (recommended in the EMEP/EEA Guidebook 2019) or as percentage of N.

([16]) There is no division between Western European Countries/Eastern European Countries in the EMEP/EEA Guidebook 2019.

([17]) Default parameters are sourced from Table 3.9 of the EMEP/EEA Guidebook 2019 as fraction of TAN. Conversion to "kg NH_3/head/yr" is done using default values of housing period (180 days), Nex (105 kg N/head/yr) and TAN fraction (0.6). The conversion factor of N-NH_3 used is 17/14.

Figure 23 illustrates the ratio between Tier 2 country-specific manure management dairy cattle NH_3 emission factors for the selected manure management system e.g. housing, housing and storage or whole manure management system (average EFs) and the respective default dairy cattle NH_3 emission factors as in the EMEP/EEA Guidebook 2019.

Figure 23[18]. Ratio of NH_3 average EFs for dairy cattle in the EU countries manure management systems to the default respective EFs



Source: EU countries IIRs 2020, EMEP/EEA 2019 Guidebook

Based on the information provided by MS in their IIRs, comparison of NH_3 country specific vs default dairy cattle emission factors for housing and storage is carried out for Czech Republic, Germany, Estonia, and Hungary. This comparison for the manure management system is done for Greece, Poland, Finland, and Sweden. For housing system, the comparison is done for Belgium, Denmark, Ireland, France, Italy, Croatia, Netherlands, Austria, Slovakia, and UK.

As shown in Figure 23, 10 out of 18 EU countries that apply a country-specific emission factor to estimate NH_3 emissions from dairy cattle report higher values than the corresponding default emission factor. For these countries, the average emission factor was higher by 5-55%. In the rest of the countries, country-specific emission factors were lower by 1-17% compared with the corresponding default emission factors. Because country-specific emission factors are not reported in the same measurement unit, for some countries, calculations are performed to convert these emission factors in the default emission factors unit. For example, France's NH_3 dairy cattle emission factor applied for the housing system is expressed as kg N-NH3/kg TANex (total ammoniacal nitrogen excreted). Based on this emission factor and the reported values of Nex, fraction of TANex and conversion of N to NH_3, the measurement unit is converted to the default emission factor unit. For Sweden the emission factors is calculated based on Nex, fraction of TAN in liquid and solid manure and the emission factors expressed as percentage of TAN.

Among the factors that influence these differences can be mentioned the housing period, the proportion of solid, liquid and yard manure, the proportion of grazing, the value of Nex, and the content of TAN in excreta. For example, in Hungary the period for dairy cattle housing is significantly higher (319 days) compared with the EMEP/EEA Guidebook 2019 default value (180 days), the proportion of grazing is very low and the value of Nex is higher (by 13%) than the corresponding default value (IIR HU, 2020). In Austria country specific emission factors for dairy cattle in manure storage system are lower than the corresponding default values, with values of 0.15 (slurry) and 0.3 (solid) expressed as fraction of TAN (IIR AT, 2020).

([18]) The comparison includes the emission factors for MMS as housing or both housing and storage or whole MMS depending on the availability of information reported in the EU countries IIRs 2020. Average EFs are calculated for each MMS type e.g. the average default EFs for housing are calculated as an average of the sum of EFs for slurry manure and EFs for solid manure. In cases when the ratio slurry/solid is reported in the countries IIRs the same ratio is applied to calculate the average default EFs. The average default EFs for both housing and storage is calculated as the sum of average EFs for housing (average of slurry + solid) and average EFs for storage (average of slurry + solid). **Ranking of countries cannot be used as a criterion of comparison for the emission factors they are applying to calculate NH_3 emissions because the calculations are based on different manure management systems due to the data availability.** A ratio of CS/D >1 indicates a higher Tier 2 country-specific emission factor, and a ratio <1 indicates a lower Tier 2 country-specific emission factor compared to default value.

4.3 Activity data and emission factors needed to improve agricultural emission estimates

When a Tier 2 or Tier 3 method is adopted and all the parameters needed are available, default values and other data sources can be used (see section A.4 in Annex). A list of activity data and emission factors needed to perform the Tier 2 calculations of air pollutants emissions from manure management (MM) and agricultural soils (AS) subsectors can be found in Table 31.

Table 31. Tier 2 method activity data and emission factors needed to calculate air pollutant emissions from agricultural activities

Subsector	Activity data		Emission Factor (EF)
MM	Percentage of excreta on yards		EF NH_3 house, slurry
MM	Animal weight		EF NH_3 house, solid
MM	House period		EF NH_3 yard
MM	Proportion of N excreta as TAN		EF NH_3 storage, slurry
MM	Annual straw use in litter		EF NH_3 storage, solid
MM	Nitrogen content in straw		EF NH_3 application, slurry
MM	Nitrogen added in straw		EF NH_3 application, solid
MM	Nitrogen immobilised to TAN		EF NH_3 grazing
MM	TAN immobilised in organic matter		EF NO storage, slurry
MM	N from bedding		EF NO storage, solid
MM	Mass of bedding		EF N_2 storage, slurry
MM	Grazing time		EF N_2 storage, solid
MM	Manure handling system		EF N_2O storage, slurry
MM	Share of pastured animals		EF N_2O storage solid
MM	Night housing in pasturing period		EF storage leaching, solid
MM	Hours inside in nights		EF NMVOC house – feed intake
MM	Abatement measures		EF NMVOC silage feeding – feed intake
MM	Farm-yard manure system		EF NMVOC grazing – feed intake
MM	Manure spreading		EF NMVOC house – VS excreted
MM	Ratio slurry/solid stored on farms and used for biogas		EF NMVOC silage feeding – VS excreted
MM	Proportion of slurry manure deposited in houses		EF NMVOC grazing – VS excreted
MM	Share of manure stored in manure storage system		EF TSP (housing)
MM	Share of manure applied with different application techniques		EF PM_{10} (housing)
MM	Feed intake		EF $PM_{2.5}$ (housing)
MM	Volatile solids (VS) excreted		
MM	Fraction silage/Fraction silage storage		
AS	Total amount of inorganic N fertilisers sold		EF for inorganic fertilisers (in % of N)
AS	N content by type of fertilisers		EF NH_3 by type of inorganic N fertilisers (climate and soil pH)
AS	Amount of N per supply source		EF NH_3 from managed soils
AS	Abatement factor for urea incorporation		EF NH_3 for solid sewage sludge
AS	Factor class value (inorganic N fertilisers are surface applied)		EF NH_3 for compost
AS	Factor class value (soil pH)		EF NH_3 crop residue
AS	Factor class value (climate)		EF N_2O from grazing
AS	Amount of N organic waste compost		EF N_2O for inorganic fertilisers
AS	Amount of N green refuse compost		EF N_2O livestock manure application
AS	TAN in compost		EF N_2O compost
AS	TAN excreted on pastureland		EF N_2O crop residue
AS	TAN fraction pasture		EF N_2O sewage sludge
AS	N excreted by mass of animal		EF N_2O cultivation of organic soils
AS	N excreted pasture		EF NO from managed soils manure
AS	N in sewage sludge (t & % of dm)		EF NO from managed soils excreta
AS	Sewage sludge production		EF N-fixing crops
AS	Sewage sludge used in agriculture (t & t of dm)		EF NMVOC from managed soils
AS	Sewage sludge in solid form (fraction)		EF NMVOC from cultivated crops
AS	TAN in liquid sewage sludge (fraction)		EF TSP for farm level activities
AS	TAN in solid sewage sludge (fraction)		EF PM_{10} for farm level activities
AS	N from animal grazing		EF $PM_{2.5}$ for farm level activities
AS	N input from N-fixing crops (t & per ha)		
AS	N in crop residues		
AS	N added to soil leaching and running off		
AS	Crop residue NH_3 contribution factor		
AS	Surface of N-fixing crops and other crops		
AS	Production of N-fixing crops and other crops		
AS	Surface of cultivated crops		
AS	Surface of arable crops		
AS	Surface of horticultural land		
AS	Surface of grassland		
AS	N content in compost		
AS	Total amount of compost		
AS	Amount of active substances containing HCB as impurity		

4.4 Best inventory practices – compilation and reporting

The EU countries make use of integrated data management systems since when the EU Nitrates Directive has required Member States to control agricultural nitrate pollution sources. There are links between countries reporting under the UNFCCC and UNECE as for example the livestock population, nitrogen excreted (N_{ex}) in the manure management sector, quantity of fertilisers, burned area of agriculture residues etc.

Linkages exist also between methodologies and livestock characterisation used to calculate emissions from both enteric fermentation and manure management and some countries have developed a structured data management system.

In the view of these linkages, countries such as Denmark are applying already a Database Model for Agricultural Emissions (IDA) for both air pollutant (NH_3, PM, NO_x, CO, NMVOC, SO_2, heavy metals, dioxin, PAH, HCB, PCB) and GHG (N_2O, CH_4 and CO_2) emissions from agriculture. The model includes 39 different livestock categories, divided on weight class and age.

France has implemented the PACRETE system (Access Program for the Regionalized Calculation of Atmospheric Emissions from Livestock) to better manage these calculations. The system allows to gather regional data, coming from different sources, on animal numbers, feeding, types of livestock buildings, spreading practices effluents, time spent grazing, etc. It also allows to calculate, at regional level and in a consistent manner, all the emissions linked to livestock farming summed up then for the entire country.

The UK uses a combined mass-flow GHG (N_2O) and NH_3 emission model for agriculture. The model calculates the flow of total N and TAN through the livestock production and manure management system. UK has established a web National Atmospheric Emissions Inventory (NAEI)[19] where users can investigate and download the activity data and the emission factors applied to calculate air pollutant and GHG emissions from agricultural subsectors. Countries as Ireland, Croatia, and Poland provide a full and detailed range of activity data, emission factors, abatement techniques etc. that are used to calculate air pollutants emissions from agriculture. Germany, Finland, the Netherlands, and Sweden provides additional literature explaining in very detail how they perform the estimation of air pollutants and GHG emissions from several agricultural activities.

A variety of sources are drawn upon to provide the best available estimate of the distribution of manure in different management systems in Finland. Austria and Bulgaria have managed to improve the availability of data on manure management systems by incorporating related questions in regular surveys (Global Research Alliance, 2018).

Box. 15. Calculation of gaseous and particulate matter emissions from agriculture in Germany

Germany applies a GAS-EM model, with a basic time step of one year, to estimate gaseous and particulate emissions from animal agriculture and crop production including professional horticulture. The assessment of emissions within GAS-EM uses the definitions of agriculture according to the definitions of IPCC 2006 and the EMEP/EEA Guidebook 2016. In a few specific cases, however, older guidelines must be used as the EMEP/EEA Guidebook 2013 e.g. for animal husbandry and manure management.
German agricultural emission inventory uses N mass balances to calculate the N excretions and the TAN contents of almost all animal categories. N mass balance calculations consider N intake with feed, N retention due to growth, N contained in milk and eggs, and N in offspring. The equations applied are primarily based on equations given in EMEP/EEA 2016 Guidebook for the Tier 2 methodology. The German inventory uses detailed methods for the calculation of N excretions for the important animal categories (e. g. dairy cows, fattening pigs, fattening poultry) and relies in many cases on national emission factors and mitigation measures transforming so the Tier 2 method into a Tier 3 method.

Source: (Haenel et al. , 2020)

([19]) UK National Atmospheric Emissions Inventory https://naei.beis.gov.uk/about/

Box. 16. Examples from Finnish and Dutch experience in the estimation of air pollutants emissions from agriculture

Finland methodology to calculate atmospheric nitrogen emissions from agricultural sector

In Finland, a specific national model for ammonia and other gaseous nitrogen emissions from agriculture has been used for the emission inventory since 1998. The model has been updated regularly to comply with the emission calculation guidelines. Recently, the calculation of NMVOC emissions has also been included in the model. The latest model upgrade was realised during the years 2014-2017, simultaneously with the development of the Finnish Normative Manure System. In the Finish approach the flow of total ammoniacal nitrogen (TAN) and total nitrogen (tot-N) are followed through the manure management system so that the more NH3 and other nitrogen compounds are emitted at the previous stage of the manure management system, the less TAN and tot-N remain available for emissions at later stages. The model also includes ammonia emission calculation for mineral N-fertilisers. The method follows the pathways of nitrogen starting from nitrogen excretion of the livestock and ending at application of manure to the fields. In general, the Finnish agricultural ammonia emission calculation model follows the principles of Tier 2 method described in the emission inventory guidebook (EMEP/EEA 2016). However, it has some features which move it strongly towards the Tier 3 method as a greater number of livestock categories and manure types than listed under Tier 2, inclusion of emission abatement measures, and application of temperature correction factors.

Emission are estimated per each livestock category and manure type using the unabated and non-temperature corrected emission firstly. Then, based on the prevalence and efficiency of the emission abatement measures in animal houses, an abated emission level is calculated (abated emissions are subtracted from the unabated emission level). Applying a temperature correction factor the temperature corrected emission value is calculated. As an example, the calculation of NH3 emissions during housing period is presented in the following equation:

$$E_{build\_mms\_NH3\text{-}N} = ((m_{build\_mms\_TAN} * EF_{build\_mms\_NH3\text{-}N}) - (\sum(m_{build\_mms\_TAN} * EF_{build\_mms\_NH3\text{-}N} * X_{build\_mms\_am} * AF_{build\_mms\_am})))*TCF \quad [42]$$

where
mms - is the manure management system
$m_{build\_mms\_TAN}$ - is the mass of TAN excreted inhouse in manure management system
$EF_{build\_mms\_NH3\text{-}N}$ - is the unabated emission factor as % of $m_{build\_mms\_TAN}$
am - is the abatement measure
$X_{build\_mms\_am}$ - is the share of abatement measure in MMS (frequency of emission abatement measure, % of manure)
$AF_{build\_mms\_am}$ - is the abatement factor (emission reduction efficiency, %) of the abatement measure in MMS
TCF - is the temperature correction factor

Source: (Grönroos J., et.al., 2017)

The Netherlands methodology to calculate NH_3 emissions factors for animal housing

The Netherlands has developed a NH_3-inventory model, called NEMA (National Emission Model for Ammonia). NH_3 emission factors derived from the measurements are expressed per animal place[20]. For the TAN-flow, these are converted into an emission factor expressed as a percentage of TAN present considering the vacancy in housing. For all animal housing systems (k) per livestock category (i) NH_3 emission factors for animal housing system in Netherlands are calculated using the following equation:

$$EF\ NH_3\text{-}N\_{}_{animal\ houseik} = \Sigma\ (EF\ NH_{3\_animal\ houseik} \times (14/17) / (1 - Frac\_{}_{vacik})) / TAN\_{}_{inputik} \times 100 \quad [43]$$

where

$EF\ NH_3\text{-}N\_{}_{animal\ houseik}$ – NH_3 emission factor (% of TAN excreted) for livestock category (i) and housing system (k)
$EF\ NH_{3\_animal\ houseik}$ – NH_3 emission factor (kg NH_3/animal place/year) for livestock category (i) and housing system (k)
$Frac\_{}_{vacik}$ - Fraction of vacancy for livestock category (i) and housing system (k), during the housing period
$TAN\_{}_{inputik}$ - TAN input (kg N/animal/year) for livestock category (i) and housing system (k)
14/17 - Conversion factor from NH_3 to NH_3-N based on molecular weight

Source: (Wageningen WUR, 2016)

(20) Animal place is the average capacity for a housed livestock category that is usually occupied (EMEP/EEA Guidebook, 2019)

4.5 Quantifying Tools for air pollutant and GHG emissions from agricultural activities

4.5.1 IPCC Inventory Software

The IPCC Inventory software[21] implements a Tier 1 method for all anthropogenic emitting sectors and a Tier 2 method for most of the categories including those of agriculture. The IPCC 2006 methodology can be applied to calculate with the same GHG emissions activity data CH_4 emissions from enteric fermentation and manure management and N_2O emissions from manure management.

4.5.2 N-flow approach

This tool that should be used linked with the latest EMEP/EEA Guidebook 2019 chapters 3B and 3D, provides a Tier 2 approach to calculate N compound emissions from

- Manure Management (3B),
- Manure Applied to Soils (3Da2a),
- Urine and Dung Deposited by Grazing Animals (3Da3).

The tool is part of EEA/EMEP Guidebook 2019 and is available for download[22]. The tool is based on the concept of a flow of TAN through the manure management system. In such approach NH_3, N_2O, NO and N_2 emissions are calculated from the N flows and corresponding emission factors. 22 default parameters such as Nex by mass of animal, livestock housed period, typical animal mass, proportion of Nex as TAN, annual straw use in litter-based manure management systems etc., and the available default emission factors are included in the tool. Countries can apply the tool with the default activity data and emission factors, or they can insert their specific data improving the estimation of air pollutant emissions. In the case of NH_3 emissions from manure management the default activity data and emission factors cover almost all the needed inputs for the calculation, with the exception of the information related to the allocation of manure types (slurry/solid) within the system. Background data needed to calculate NH_3 emissions and emission factors within the N-flow tool are presented in Box. 17.

Box. 17. Background data to calculate livestock NH_3 emission and emission factors

Input data	Units	Description
Livestock population	Average Annual Population (AAP)	Number of animals of a category that are present, on average, within the year
Proportion cattle slurry with/without natural crust	Fraction	Proportion of cattle slurry with natural crust vs the proportion of cattle slurry without natural crust.
Proportion excreta on yards	Fraction	Proportion of manure excreted which is deposited on yards. Required to calculate the amount of manure deposited on yards,
X_{store_slurry}	Fraction	Proportion of slurry manure which is stored on farms. No default value available.
X_{store_solid}	Fraction	Proportion of solid manure which is stored on farms. No default value available.
X_{biogas_slurry}	Fraction	Proportion of slurry manure which is used for biogas production. No default value available.
X_{biogas_solid}	Fraction	Proportion of solid manure which is used for biogas production. No default value available.
X_{house_slurry}	Fraction	Proportion of manure deposited in housing which is "slurry"
Nex	Kg N/head/yr	Nitrogen excreted from livestock sector
TAM	kg	Typical animal mass

Source: EMEP/EEA Guidebook 2019 and N-flow approach

(21) https://www.ipcc-nggip.iges.or.jp/software/index.html
(22) https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

Conclusions

The reduction of air pollutant and GHG emissions is a priority for the EU and ambitious targets are set up to 2030. The agricultural sector is an important source of emissions and deserves attention **due to its contribution to air pollution and to climate change**. Agriculture covers more than 52% and 92% of total CH_4 and NH_3 emissions in the EU, respectively, being as such a key sector for the reduction of these emissions. GHG emissions from the agricultural sector cover 10% of total GHG emissions in the EU. Agriculture contributes to the acidification and eutrophication of the environment, particulate matter formation and biodiversity loss, in combination with emissions from other sources, such as transport and industry, due to long-range transport process.

This report discusses the issues related to the estimation of emissions from the agricultural sector with an overview summarising the methods applied in the EU countries for the main air pollutants (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$ and TSP) and GHGs (CH_4 and N_2O), having in focus the enteric fermentation, manure management and agricultural soils subsectors.

Inventories on air pollutants and GHG emissions from agricultural activities are required to be comparable, complete, transparent, and accurate. To this end, the **Tier 2 is the highly advisable method** that can reflect changes in livestock production and productivity, measure the effects of the changes in the agricultural sector or measure the specific mitigation actions on air pollutant emissions. The Tier 2 method can provide an accurate view of these changes only if the activity data and emission factors are updated on regularly basis. However, an **optimum number of activity data for each subsector** should be established for this method to avoid the return to the Tier 1 method even for the key categories.

The **IPCC 2006** Guidelines **provide methods/equations** for the calculation of both emissions and emission factors for GHGs (CH_4 and N_2O) in the agricultural sector, as well as **default emission factors**. An inventory software is also available to be used applying both the Tier 1 and Tier 2 methods. The **EMEP/EEA Guidebooks** (2013, 2016, and 2019) **provide methodologies and default emission factors** for the estimation of air pollutant emissions from agricultural activities. These default emission factors are mainly based on selected studies which provide results of measurements or experiments. However, these emission factors that should represent the specific conditions of countries related to their environmental conditions, livestock categories, management practices and agricultural activities, vary and **require an accurate selection** procedure by the countries to be more representative for their conditions. An elaborated excel tool, applying a Tier 2 methodology, is also provided by the EMEP/EEA Guidebook 2019 to calculate the NH_3, N_2O, NO and N_2 emissions using the N mass-flow approach. Both IPCC and EMEP/EEA provide flexibility on how a Tier 2 method can be applied.

There is a lot of information in the EU countries that, if organised well, can provide an adequate starting point for compiling an inventory using the Tier 2 method. By the end of 2018, **almost all EU countries applied a Tier 2 method to calculate NH_3 emissions from the manure management** subsector. The Tier 2 method is also broadly spread for the estimation of NOx and NMVOC emissions. The Tier 1 method within this subsector is mainly used for the estimation of particulate matter emissions. Some countries apply dynamic emission factors to estimate NH_3 emissions from livestock activities better reflecting the changes in time of the manure management system. However, there are countries that use static emission factors which cannot reflect changes in livestock production, productivity, and associated air pollutant and GHG emissions over time.

Methodologies to estimate air pollutant and GHG emissions from the manure management subsector **are more advanced for cattle, swine, and sheep categories**. Almost all EU countries apply a Tier 2 method and in some countries a Tier 3 method is used. This is linked with the fact that these livestock categories are key sources of air pollutant and GHG emissions in almost all EU countries.

The **Tier 2 methods are not so often applied in** the estimation of air pollutant emissions from **agricultural soil activities** and, if this is the case, it is mainly related with the estimation of NH_3 emissions and NOx emissions and is "pushed" due to the use of N-mass flow method. **Country-specific emission factors in manure management are used to a small extent**, mainly for the calculation of NH_3 emissions and partly for NOx emissions.

There is no obligation in the UNECE template **to report the country-specific emission factors for air pollutants** in the recommended unit (fraction of TAN) and **there is no obligation to report these emission factors for each system of manure management or category of agricultural soils.** This fact makes difficult the process of comparison between country-specific emission factors and default ones but also across countries.

Not all countries provide a detailed description of their methodologies (in case of a country-specific methodology) and **few countries provide additional documentation on methodologies and online tools** where the activity data and emission factors can be found and downloaded. Even in these cases these tools are in the original language or emission factors are reported in a different measurement unit compared with the emission factors that can be found in their IIRs.

Country-specific activity data and emission factors sourced from countries reporting under obligations such as NECD or UNFCCC can be retrieved from countries integrated databases and incorporated in the available methodologies. Other sources of data, such as FAO and Eurostat, also provide activity data and emission factors. However, **discrepancies exist for some activity data and emission factors** sourced from such databases depending on the fact that some organisations provide calculated data based on long-term time series, without including information from country's national statistics.

The use of models gives the possibility of introducing methods **for the calculation of activity data which are not available** and for which **the default values are not provided**. However, to improve the estimates of air pollutant and GHG emissions from a certain activity, these models should regularly update their inputs and compare those with activity data provided by countries.

Activity data collection process has a significant impact on data quality. The definition of activity data collection methodologies should ensure the best balance between quality and uncertainty. **Performing regularly farm-level surveys or introducing questionnaires** that cover many aspects of farm activities can improve the quality of activity data minimising uncertainties. The creation of a database on activity data and emission factors is thus required as input for the development of a tool to support the computation of more accurate air pollutant emission inventories at Member State level.

The way forward to improve agricultural emission estimates should be:

- Encouraging the application of country-specific activity data and emission factors,
- Increasing the transparency related to country specific activity data and emission factors,
- Improving the reporting of country-specific emission factors related to each system of manure management and each category of agricultural soils activities,
- Improving the reporting template to provide the possibility of collecting country-specific emission factors in an unified measurement unit which will facilitate not only the comparison with default values but also the comparison among countries,
- A deeper investigation of the relationship between activity data and emission factors,
- Expanding the existing N mass-flow tool also including calculations for other air pollutants such as NMVOC or PM,
- Support the application of surveys and questionnaires on farms statistics.

References

Andreae, M. O., & Merlet, P. (2001). Emission of trace gases and aerosols from biomass burning. Global biogeochemical cycles, 15(4), 955-966, https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2000GB001382

Bouwman, A., L. Boumans, N. Batjes. 2002. Estimation of global NH_3 volatilisation loss from synthetic fertilisers and animal manure applied to arable land and grasslands. Global biogeochemical cycles, Vol. 16, No. 2. pp 8-1 to 8-15, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2000GB001389

Britz, W., & Keeney, R. (2010). The CAPRI model-an overview with a focus on comparison to GTAP, https://www.gtap.agecon.purdue.edu/resources/download/4715.pdf

CAPRI Model, Online Manual, Last access July 2020, https://www.capri-model.org/dokuwiki_help/doku.php?id=introduction

Dämmgen, U., Hutchings, N.J., 2008. Emissions of gaseous nitrogen species from manure management: a new approach. Environmental Pollution 154, 488-497 https://www.sciencedirect.com/science/article/abs/pii/S0269749107001947

Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32001L0081

Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2016.344.01.0001.01.ENG&toc=OJ:L:2016:344:TOC

EC, DG CLIMA, The GAINS Model, https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/gains_en.pdf

EC. DG Environment, 2014, Collection and Analysis of Data for the Control of Emissions from the Spreading of Manure, https://ec.europa.eu/environment/air/pdf/Final%20Report.pdf

European Environment Agency (EEA), (2019). Climate-change-adaptation-in-the-agriculture-sector-in-Europe. Retrieved from https://www.euroseeds.eu/app/uploads/2019/09/Climate-change-adaptation-in-the-agriculture-sector-in-Europe.pdf

EEA Eionet. (2020). Central Data Repository. http://cdr.eionet.europa.eu/ReportekEngine/searchdataflow?dataflow_uris=http%3A%2F%2Frod.eionet.europa.eu%2Fobligations%2F748&years%3Aint%3Aignore_empty=&partofyear=&reportingdate_start%3Adate%3Aignore_empty=&reportingdate_end%3Adate%3Aignore_empty=&count

Euractiv. (2016). Agriculture and Climate Change- the role of the new CAP. Retrieved from https://euractiv.eu/wp-content/uploads/sites/2/special-report/EURACTIV-Special-Report-Agriculture-and-climate-change-the-role-of-the-new-CAP.pdf

Eurostat. (2019). Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php/Performance_of_the_agricultural_sector#Value_of_agricultural_output

Eurostat. (2020). Retrieved from https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf

FAOSTAT. (2020). Retrieved from http://www.fao.org/faostat/en/#home

FAO, Livestock Activity Data Guidance, L-ADG, (2020), http://www.fao.org/documents/card/en/c/CA7510EN/#:~:text=The%20Livestock%20Activity%20Data%20Guidance,the%20IPCC%20Tier%202%20approach.

FAO, Estimating GHG emissions in agriculture: A manual to address data requirements for developing countries, (2015), http://www.fao.org/3/a-i4260e.pdf

FAO and Global Research Alliance on Agricultural Greenhouse Gases. 2020. Livestock Activity Data Guidance (L-ADG): Methods and guidance on compilation of activity data for Tier 2 livestock GHG inventories. https://doi.org/10.4060/ca7510en

Federal Office for Agriculture and Food (BLE), Germany, (2019). Drivers of change and development in the EU livestock sector, https://www.faccejpi.net/upload_mm/2/9/e/9647e499-2221-4208-b017-e7775572f2b3_Drivers_of_change_and_development_in_the_EU_livestock_sector_BLE_CASA_STUDY_0.pdf

Fellmann, T., Witzke, P., Weiss, F., Van Doorslaer, B., Drabik, D., Huck, I., ... & Leip, A. (2018). Major challenges of integrating agriculture into climate change mitigation policy frameworks. Mitigation and adaptation strategies for global change, 23(3), 451-468, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6054014/

Finnish Environment Institute, Centre for Sustainable Consumption and Production, SYKE, Air Pollutant Emission Factor Library http://www.apef-library.fi/index.php

Gac, A., Béline, F., Bioteau, T., Maguet, K., 2007. A French inventory of gaseous emissions (CH_4. N_2O. NH_3) from livestock manure management using a mass-flow approach. Livestock Science 112, 252-260 https://www.sciencedirect.com/science/article/abs/pii/S1871141307004751

Grönroos J., et.al. 2017, Calculation of atmospheric nitrogen and NMVOC emissions from Finnish agriculture, https://helda.helsinki.fi/handle/10138/229364

Guidelines for reporting emissions and projections data under the Convention on Long-Range Transboundary Air Pollution, https://www.unece.org/fileadmin/DAM/env/documents/2015/AIR/EB/English.pdf

Haenel et al., 2020, Calculations of gaseous and particulate emissions from German agriculture 1990 - 2018: Report on methods and data (RMD) Submission 2020, https://www.econstor.eu/handle/10419/216755

Hutchings, N.J., Sommer, S.G., Andersen, J.M., Asman, W.A.H., 2001. A detailed ammonia emission inventory for Denmark. Atmospheric Environment 35, 1959-1968, https://www.sciencedirect.com/science/article/abs/pii/S1352231000005422

IIASA, GAINS Model, Last access July 2020, http://gains.iiasa.ac.at/

IPCC Guidelines (2006). Emissions from Livestock and Manure Management, Retrieved from https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

IPCC. (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Retrieved from https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Jun, P., Gibbs, M., & Gaffney, K. (n.d.). CH_4 and N_2O emissions from livestock manure. Retrieved from https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_2_CH4_and_N2O_Livestock_Manure.pdf

Kupper, T., Bonjour, C., & Menzi, H. (2015). Evolution of farm and manure management and their influence on ammonia emissions from agriculture in Switzerland between 1990 and 2010. Atmospheric Environment, 103, 215-221

Reidy. B., et.al., (2008), Comparison of models used for national agricultural ammonia emission inventories in Europe: Liquid manure systems, https://www.sciencedirect.com/science/article/abs/pii/S1352231007003469?via%3Dihub

Wilkes.A., van Dijk. S., (2018), Tier 2 inventory approaches in the livestock sector: a collection of agricultural greenhouse gas inventory practices (2018).. Retrieved from https://globalresearchalliance.org/wp-content/uploads/2018/12/Livestock-Tier-2-collection_Final_181130.pdf

Wageningen WUR (2016). Methodology for estimating emissions from agriculture in the Netherlands, https://library.wur.nl/WebQuery/wurpubs/549203

UNECE. (2015). Guidelines for reporting emissions and projections data under the Convention on Long-Range Transboundary Air Pollution. Retrieved from https://www.unece.org/fileadmin/DAM/env/documents/2015/AIR/EB/English.pdf

UNFCCC. (2020), Annex I Parties GHG emission inventories, Retrieved from https://unfccc.int/ghg-inventories-annex-i-parties/2020

Austria Informative Inventory Report (2020), IIR AT, Eionet Central Data Repository

Belgium Informative Inventory Report (2020), IIR BE, Eionet Central Data Repository

Bulgaria Informative Inventory Report (2020), IIR BG, Eionet Central Data Repository

Czech Republic Informative Inventory Report (2020), IIR CZ, Eionet Central Data Repository

Denmark Informative Inventory Report (2020), IIR DK, Eionet Central Data Repository

Germany Informative Inventory Report (2020), IIR DE, https://iir-de.wikidot.com/3-agriculture

Estonia Informative Inventory Report (2020), IIR EE, Eionet Central Data Repository

Ireland Informative Inventory Report (2020), IIR IE, Eionet Central Data Repository

Greece Informative Inventory Report (2020), IIR EL, Eionet Central Data Repository

Spain Informative Inventory Report (2020), IIR ES, Eionet Central Data Repository

France Informative Inventory Report (2020), IIR FR, Eionet Central Data Repository

Italy Informative Inventory Report (2020), IIR IT, Eionet Central Data Repository

Cyprus Informative Inventory Report (2020), IIR CY, Eionet Central Data Repository

Latvia Informative Inventory Report (2020), IIR LV, Eionet Central Data Repository

Lithuania Informative Inventory Report (2020), IIR LT, Eionet Central Data Repository

Luxembourg Informative Inventory Report (2020), IIR LU, Eionet Central Data Repository

Croatia Informative Inventory Report (2020), IIR HR, Eionet Central Data Repository

Hungary Informative Inventory Report (2020), IIR HU, Eionet Central Data Repository

Malta Informative Inventory Report (2020), IIR MT, Eionet Central Data Repository

Netherlands Informative Inventory Report (2020), IIR NL, Eionet Central Data Repository

Poland Informative Inventory Report (2020), IIR PL, Eionet Central Data Repository

Portugal Informative Inventory Report (2020), IIR PT, Eionet Central Data Repository

Romania Informative Inventory Report (2020), IIR RO, Eionet Central Data Repository

Slovenia Informative Inventory Report (2020), IIR SI, Eionet Central Data Repository

Slovakia Informative Inventory Report (2020), IIR SK, Eionet Central Data Repository

Finland Informative Inventory Report (2020), IIR FI, Eionet Central Data Repository

Sweden Informative Inventory Report (2020), IIR SE, Eionet Central Data Repository

United Kingdom Informative Inventory Report (2020), IIR UK, Eionet Central Data Repository

List of abbreviations and definitions

AAP	Average annual population
AS	Agriculture soils
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
CH_4	Methane
CLRTAP	UN Convention on Long Range Transboundary Air Pollution
CORINAIR	CORe INventory AIR
CRF	Common reporting format
DM	Dry matter
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
EF	Emission factor
EMEP	European Monitoring and Evaluation Programme
FAO	Food and Agriculture Organization of the United Nations
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GHG	Greenhouse gas
IFA	International Fertiliser Association
IIASA	International Institute for Applied Systems Analysis
IIR	Informative Inventory Report
IPCC	Intergovernmental Panel on Climate Change
MCF	Methane conversion factor
MMS	Manure Management System
MNM	Manure Management
N	Nitrogen
N2	Dinitrogen
N_2O	Nitrous oxide
NECD	National Emission reduction Commitments Directive
NH_3	Ammonia
NIR	National Inventory report
NMVOC	Non methane volatile organic compounds
PM	Particulate Matter
TAM	Typical Animal Mass
TAN	Total Ammoniacal Nitrogen
TSP	Total Suspended Particulate Matter
UNECE	United Nations Economic Commission for Europe
UNFCCC	UN Framework Convention on Climate Change
VS	Volatile solids

List of boxes

List of figures

List of tables

Annex

A.1 NECD Reporting Eionet (NFR Categories)[23]

Table A. 1 Main categories included in the NECD reporting

3B1a	Dairy cattle
3B1b	Non-dairy cattle
3B2	Sheep
3B3	Swine
3B4a	Buffalo
3B4d	Goats
3B4e	Horses
3B4f	Mules and asses
3B4gi	Laying hens
3B4gii	Broilers
3B4giii	Turkeys
3B4giv	Other poultry
3B4h	Other animals (specified in IIR)
3Da1	Inorganic N-fertilisers (also includes urea application)
3Da2a	Animal manure applied to soils
3Da2b	Sewage sludge applied to soils
3Da2c	Other organic fertilisers applied to soils
3Da3	Urine and dung deposited by grazing animals
3Da4	Crop residues applied to soils
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
3Df	Use of pesticides
3F	Field burning of agricultural residues
3I	Agriculture other (specified in the IIR)

Table A. 2 Pollutants reported under NECD

Pollutants	**Unit**
NOx (as NO_2)	kt
NMVOC	kt
SOx (as SO_2)	kt
NH_3	kt
$PM_{2.5}$	kt
PM_{10}	kt
TSP	kt
BC	kt
CO	kt
Pb	tonnes
Cd	tonnes
Hg	tonnes
As	tonnes
Cr	tonnes
Cu	tonnes
Ni	tonnes
Se	tonnes
Zn	tonnes
PCDD/ PCDF (dioxins/ furans)	g I-TEQ (toxic equivalency)
1. benzo(a) pyrene	tonnes
2. benzo(b) fluoranthene	tonnes
3. benzo(k) fluoranthene	tonnes
4. Indeno (1,2,3-cd) pyrene	tonnes
Total 1-4	tonnes
HCB	kg
PCBs	kg

([23]) Emissions reported by Member States is consistent and harmonised with international requirements following the methodologies agreed under the UNECE LRTAP Convention. The activity data (covering the period 1990 – 2018 for the EU 27 countries and United Kingdom (UK)), include the livestock population size (1000 heads) the use of inorganic fertilisers and burned area of agricultural residues.

A.2 UNFCCC reporting (CRF categories)

According to the Common Reporting Format (CRF) the following livestock categories are included in the calculation of CH_4 emissions from enteric fermentation and N_2O emissions from manure management.

Table A. 3 Livestock categories reported to UNFCCC following the CRF template and the suggested estimation methods

Sector	Livestock main category	CRF code	Livestock subcategory	Suggested method
Enteric Fermentation/Manure Management	Cattle	3A1a	Mature dairy cattle	T2/T3
Enteric Fermentation/Manure Management	Cattle	3A1b	Other mature cattle	T2/T3
Enteric Fermentation/Manure Management	Cattle	3A1c	Growing cattle	T27T3
Enteric Fermentation/Manure Management	Sheep	3A2	Sheep	T1/T2
Enteric Fermentation/Manure Management	Swine	3A3	Swine	T1
Enteric Fermentation/Manure Management	Other livestock	3A4a	Buffalo	T1/T2
Enteric Fermentation/Manure Management	Other livestock	3A4b	Camels	T1
Enteric Fermentation/Manure Management	Other livestock	3A4c	Deer	T1
Enteric Fermentation/Manure Management	Other livestock	3A4d	Goats	T1
Enteric Fermentation/Manure Management	Other livestock	3A4e	Horses	T1
Enteric Fermentation/Manure Management	Other livestock	3A4f	Mules and asses	T1
Enteric Fermentation/Manure Management	Other livestock	3A4g	Poultry	Not developed
Enteric Fermentation/Manure Management	Other livestock	3A4h	Other	T1

Table A. 4. Activity data reported under UNFCCC

Activity data	Unit
Weight	kg
Feeding situation	
Milk yield	kg/day
Work	hours/day
Pregnancy	(%)
Digestibility of feed	(%)
Gross Energy Intake	MJ/head/day
Population size	1000 head
Average CH_4 conversion rate (Ym)	%
Manure allocation by climate	%
VS daily excretion	kg dry mass/head/day
N excretion rate	kg N /head/yr
N excretion per MMS	kg N/yr
Total N excreted	kg N/yr
Total N volatilized as NH_3 and NOx	kg N/yr
Inorganic fertilisers	kg N/yr
Inorganic N fertilisers	kg N/yr
Organic N fertilisers	kg N/yr
a. Animal manure applied to soils	kg N/yr
b. Sewage sludge applied to soils	kg N/yr
c. Other organic fertilisers applied to soils	kg N/yr
Urine and dung deposited by grazing animals	kg N/yr
Crop residues	kg N/yr
Atmospheric deposition	kg N/yr
Nitrogen leaching and run-off	kg N/yr
Fraction of N from other organic N fertilisers applied that volatilizes as NH_3 and Nox	Fraction
Fraction of livestock N excretion that volatilizes as NH_3 and NOx - FracGASM indirect	Fraction
Fraction of N from sewage sludge applied that volatilizes as NH_3 and NOx	Fraction
Implied emission factors for CH_4: Manure management and Enteric fermentation	kg CH_4/head/yr
Implied emission factors for N_2O: Manure management and agricultural soils	kg N_2O/head/yr and kg N_2O-N/kg N

A.3 Category and methodology analysis (summary)[24]

The following Tables illustrates the key categories and methods (Tier 1, 2 and 3) applied by EU countries for each NFR category in manure management and agricultural soils. Key categories within each subsector are highlighted in green. Blank boxes mean that no data are reported in that category.

Table A. 5. Key categories and methodologies applied for each category to estimate NH_3 emissions from manure management and agriculture soils activities in the EU countries

NFR code	Category name	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
3B1a	Dairy cattle	T3	T2	T1	T2	T2	T3	T2	T3	T2	T2	T3/T2	T2	T2	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T2	T2	T2	T2	T3
3B1b	Non-dairy cattle	T3	T2	T1	T2	T2	T3	T2	T3	T2	T2	T3/T2	T2	T2	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T2	T2	T2	T2	T3
3B2	Sheep	T2	T2	T1	T2	T2	T2	T2	T1	T1	T2	T3/T2	T2	T2	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T2	T2	T2	T2	T3
3B3	Swine	T3	T2	T1	T2	T2	T3	T2	T3	T2	T2	T3/T2	T2	T3	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T2	T2	T2	T2	T3
3B4a	Buffalo			T1						T1					T1		T2	T2				T3			T1				
3B4d	Goats	T2	T2	T1	T2	T2	T2	T2	T1	T1	T2	T3/T2	T2	T2	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T3
3B4e	Horses	T2	T2	T1	T2	T2	T2	T2	T1	T1	T2	T3/T2	T2	T2	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T3
3B4gii	Broilers	T2	T2	T1	T2	T2	T2	T2	T2	T2	T2	T3/T2	T2	T3	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T3
3B4gi	Laying hens	T2	T2	T1	T2	T2	T2	T2	T2	T2	T2	T3/T2	T2	T3	T2	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T2	T2	T2	T2	T3
3B4f	Mules and asses			T1	T2					T1	T2		T2	T2	T1	T2	T2	T2				T3		T2					
3B4giii	Turkeys	T2		T1	T2	T2	T2	T2		T1		T3/T2	T2	T3	T1	T2	T2	T2		T1/T2		T3		T2		T2	T2	T2	T3
3B4giv	Other poultry	T2	T2	T1		T2	T2	T2	T2	T1	T2	T3/T2	T2	T3	T1	T2	T2	T1	T2	T1/T2		T3	T2	T2			T2	T2	T3
3B4h	Other animals	T2	T2			T2		T2	T1			T3/T2	T2		T1	T2	T2	T1	T2	T1/T2	T2	T3	T2	T2		T2	T2		T3
3Da1	Inorganic N-fertilisers	T3	T2/T1	T2	T1	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T1	T2	T1	T2	T2	T2	T2	T2	T2	T1	T3
3Da2a	Animal manure applied to soils	T3	T2		T2	T2	T2/T3	T2	T2	T1/T2	T2	T2	T2	T2	T2	T2	T2	T2	T1	T1/T2	T1	T2	T2	T2	T1/T2	T2	T2	T2	T1
3Da2b	Sewage sludge applied to soils	T1	T1	T1	T1		T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1		T2	T1	T1	T1/T2	T2			T1
3Da2c	Other organic fertilisers to soils	T1	T1		T1		T2	T1	T1		T1		T1		T1		T1	T1	T1	T1		T1		T1		T2	T1	T2	T1
3Da3	Urine & dung deposited by grazing	T3	T2/T3		T2	T2	T2	T2	T2	T1/T2	T2	T2	T2	T2	T2	T2	T2	T2	T2	T1/T2		T2	T2	T2	T1/T2	T2	T2	T2	T2
3Da4	Crop residues applied to soils																					T2							
3Dd	Indirect emissions from managed soils		T2																										
3De	Cultivated crops							T2									CS					T1							
3F	Field burning of agricultural residues	T1		T1	T1			T1		T1	T1	T1/T2	T1	T1	T1		T1						T1	T1	T2				
3I	Agriculture other						T1	T1												T1									

([24]) Key categories are those which, when summed together in descending order of magnitude, cumulatively add up to 80% of the total level (EMEP/EEA Guidebook 2019 Ch.2 Table 2-1). In Tables A.5 up to A.9. a combination of methods is applied to estimate the emissions of air pollutants from manure management and agricultural soils activities. This includes not only the emission factors applied but also the activity data used. For example, one country might apply country specific activity data (that can be considered as Tier 2) and default emission factors (that can be Tier 1 or Tier 2). Or it can use default activity data (Tier 1 or Tier 2) applying country specific emission factors (Tier 2). The definition "T1/T2" is not linked with the ranking related to the application of these methods.

Table A. 6 Key categories and methodologies applied for each category to estimate NOx emissions from manure management and agricultural soils activities in the EU countries

NFR code	Category name	AT	BE	BG	CY	CZ[25]	DE	DK	EE	EL	ES	FI	FR[26]	HR	HU	IE	IT	LT	LU	LV	MT	NL[27]	PL	PT	RO	SE	SI	SK	UK
3B1a	Dairy cattle	T2	T1/T2	T1	T2	T1	T2	T1	T2	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B1b	Non-dairy cattle	T2	T1/T2	T1	T2	T1	T2	T1	T2	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B2	Sheep	T2	T1/T2	T1	T2	T1	T2	T2	T1	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B3	Swine	T2	T1/T2	T1	T2	T1	T2	T1	T1	T1	T2	T2		T3	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B4a	Buffalo			T1						T1					T1		T2								T1				
3B4d	Goats	T2	T1/T2	T1	T2	T1	T2	T2	T1	T1	T2	T2		T2	T1	T1	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B4e	Horses	T2	T1/T2	T1	T2	T1	T2	T2	T1	T1	T2	T2		T2	T1	T1	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B4gii	Broilers	T2	T1/T2	T1	T2	T1	T2	T2	T1	T1	T2	T2		T3	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B4gi	Laying hens	T2	T1/T2	T1	T2	T1	T2	T2	T1	T1	T2	T2		T3	T1	T2	T2	T2	T2	T1/T2	T2	T3	T2	T2	T1	T2	T2	T2	T2
3B4f	Mules and asses			T1	T2					T1	T2			T2	T1	T2	T2					T3		T2					T2
3B4giii	Turkeys	T2		T1	T2	T1	T2	T2		T1		T2		T3	T1	T2	T2	T2		T1/T2		T3		T2		T2	T2	T2	T2
3B4giv	Other poultry	T2	T1/T2	T1		T1	T2	T2	T1	T1	T2	T2		T3	T1	T2	T2	T1	T2	T1/T2		T3	T2	T2			T2	T2	T2
3B4h	Other animals	T2	T1/T2			T1		T2	T1			T2			T1	T2	T2	T1	T2	T1/T2	T2	T3	T2	T2		T2	T2		T2
3Da1	Inorganic N-fertilisers	T1	T1	T1	T1		T1	T1	T1	T1	T1	T1		T1	T1	T1	T1	T1	T1	T1	T1/T2	T1	T1	T1	T2	T1	T1	T1	T2
3Da2a	Animal manure applied to soils	T1	T1		T1		T1	T1	T1	T1	T1	T1		T1	T1	T1	T2	T1	T1	T1/T2	T1/T2	T1	T1	T1	T1	T1	T1	T2	T2
3Da2b	Sewage sludge applied to soils	T1	T1	T1	T1		T1	T1	T1	T1	T1	T1		T1	T1	T1	T1	T1	T1	T1		T1	T1	T1	T1	T1			T1
3Da2c	Other organic fertilisers to soils	T1	T1		T1		T1	T1	T1		T1				T1		T1	T1	T1	T1		T1		T1		T1	T1	T2	
3Da3	Urine & dung deposited by grazing						T1		T1	T1	T1	T1		T1	T1	T1	T2	T1	T1	T1/T2		T2	T1	T1		T1	T1	T2	T2
3Da4	Crop residues applied to soils																		T1			T1							T1
3F	Field burning of agricultural residues	T1		T1	T1			T1		T1	T1	T1/T2	T2	T1	T1		T1						T1	T1	T2				
3I	Agriculture other						T1													T1		T1							

([25]) Emissions of NOx from agricultural soils activities in Czech Republic are not estimated (NE).

([26]) According to France's reporting under Annex I of NECD the estimated NOx emissions from manure management and agricultural soils are reported as included elsewhere (IE) and included in the category 6B. The methodology applied by France to estimate the NOx emissions from these subsectors is presented in Table 18 and Table 28.

([27]) NOx emissions from the cultivation of organic soils in Netherlands are allocated to the category 3I (Agriculture other)

Table A. 7. Key categories and methodologies applied for each category to estimate NMVOC emissions from manure management and agricultural soils activities in the EU countries

NFR code	Category name	AT	BE	BG	CY	CZ[28]	DE	DK	EE	EL	ES	FI	FR[29]	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
3B1a	Dairy cattle	T2	T2	T1	T2	T1	T2	T2	T2	T1	T2	T2		T2	T2	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T2	T2	T2	T2	T2
3B1b	Non-dairy cattle	T2	T2	T1	T2	T1	T2	T2	T2	T1	T2	T2		T2	T2	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T2	T2	T2	T2	T2
3B2	Sheep	T2	T1	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B3	Swine	T2	T2	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B4a	Buffalo			T1						T1					T1		T2								T1				
3B4d	Goats	T2	T1	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B4e	Horses	T2	T1	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T2	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B4gii	Broilers	T2	T1	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T1	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B4gi	Laying hens	T2	T1	T1	T2	T1	T1	T2	T1	T1	T2	T2		T2	T1	T1	T2	T2	T2	T1/T2	T2	T2	T1	T2	T1	T2	T2	T1	T2
3B4f	Mules and asses			T1	T2					T1	T2			T2	T1	T2	T2					T2		T2					
3B4giii	Turkeys	T2		T1	T2	T1	T1	T2		T1		T2		T2	T1	T1		T2		T1/T2		T2	T1	T2		T2	T2	T1	T2
3B4giv	Other poultry	T2	T1	T1		T1	T1	T2	T1	T1	T2	T2		T2	T2	T1	T2	T1	T2	T1/T2		T2	T1	T2			T2	T1	T2
3B4h	Other animals	T2	T1			T1		T2	T1			T2			T1	T2	T2	T1	T2	T1/T2	T2	T2	T1	T2		T2	T2		T2
3Da1	Inorganic N-fertilisers																												
3Da2a	Animal manure applied to soils	T2									T2	T2					T2					T2		T1		T2	T1		T1
3Da2b	Sewage sludge applied to soils																									T2			
3Da3	Urine & dung deposited by grazing	T2									T2	T2					T2					T2		T1		T2	T1		T1
3Dc	Farm-level agricultural operations																					T2							
3De	Cultivated crops	T2	T1	T1	T1		T2	T2	T1	T1	T2	T2		T2	T1	T2	T1	T1	T1	T1	T2	T1	T2	T1	T1	T2	T1	T1	T1
3F	Field burning of agricultural residues	T1		T1	T1			T1		T1	T1	T1/T2	T1	T1	T1		T1						T1	T1	T2				
3I	Agriculture other																			T1									

([28]) The estimation of NMVOC from agricultural soils activities in Czech Republic is not applied (NA).

([29]) According to France's reporting under Annex I of NECD the estimated NMVOC emissions from manure management and agricultural soils are reported as included elsewhere (IE) and included in the category 6B. The methodology applied by France to estimate the NOx emissions from these subsectors is presented in Table 18 and Table 28.

Table A. 8. Key categories and methodologies applied for each category to estimate PM_{10} emissions from manure management and agricultural soils activities in the EU countries

NRF code	Category name	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
3B1a	Dairy cattle	T1	T1	T1	T1	T1	T2	T1	T2	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B1b	Non-dairy cattle	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B2	Sheep	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B3	Swine	T1	T1	T1	T1	T1	T1/T2	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4a	Buffalo			T1						T1					T1		T1								T1				
3B4d	Goats	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4e	Horses	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4gii	Broilers	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4gi	Laying hens	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4f	Mules and asses			T1	T1					T1	T1		T2	T1	T1	T1	T1					T3		T1					
3B4giii	Turkeys	T1		T1	T1	T1	T1	T1		T1		T1	T2	T1	T1	T1		T1		T1		T3		T1		T1	T1	T1	T1
3B4giv	Other poultry	T1	T1	T1		T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1		T3	T1	T1			T1	T1	T1
3B4h	Other animals	T1	T1					T1	T1			T1	T2			T1	T1	T1	T1	T1	T1	T3	T1	T1		T1			T1
3Da1	Inorganic N-fertilisers															T1						T1							
3Dc	Farm-level agricultural operations	T1	T1	T1	T1	T2	T1	T2	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T2	T1	T1	T1
3Dd	Off-farm storage	T1														T1													
3De	Cultivated crops																					T1							
3Df	Use of pesticides																					T1							
3F	Field burning of agricultural residues	T1		T1	T1			T2		T1	T1	T1/T2	T1	T1	T1		T1						T1	T1	T1				
3I	Agriculture other																			T1									

Table A. 9. Key categories and methodologies applied for each category to estimate $PM_{2.5}$ emissions from manure management and agricultural soils activities in the EU countries

NRF code	Category name	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
3B1a	Dairy cattle	T1	T1	T1	T1	T1	T2	T1	T2	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B1b	Non-dairy cattle	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B2	Sheep	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B3	Swine	T1	T1	T1	T1	T1	T1/T2	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4a	Buffalo			T1						T1					T1		T1								T1				
3B4d	Goats	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4e	Horses	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4gii	Broilers	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4gi	Laying hens	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T1	T3	T1	T1	T1	T1	T1	T1	T1
3B4f	Mules and asses			T1	T1					T1	T1		T2	T1	T1	T1	T1					T3		T1					T1
3B4giii	Turkeys	T1		T1	T1	T1	T1	T1		T1		T1	T2	T1	T1	T1		T1		T1		T3		T1		T1	T1	T1	T1
3B4giv	Other poultry	T1	T1	T1		T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1		T3	T1	T1			T1	T1	T1
3B4h	Other animals	T1	T1					T1	T1			T1	T2			T1	T1	T1	T1	T1	T1	T3	T1	T1		T1			T1
3Da1	Inorganic N-fertilisers															T1						T1							
3Dc	Farm-level agricultural operations	T1	T1	T1	T1	T2	T1	T2	T1	T1	T1	T2	T1	T1	T1	T1	T1	T1	T1	T2	T1	T1	T1	T1	T1	T2	T1	T1	T1
3Dd	Off-farm storage	T1														T1													
3De	Cultivated crops																					T1							
3Df	Use of pesticides	T1																				T1							
3F	Field burning of agricultural residues			T1	T1			T2		T1	T1	T1/T2	T1	T1	T1		T1						T1	T1	T1				
3I	Agriculture other																			T1									

A.4 Other sources for activity data and emission factors

Eurostat

Eurostat data on manure storage, animal housing and manure application techniques are available from a special survey carried out in 2010 for the 27 MS that the EU counted at that time (Croatia had not yet joined). Manure storage statistics currently is under construction and archived data are available until year 2013[30]. Animal housing statistics is available for cattle and swine. Indicators provided in relation to the agricultural sector are presented in Table A. 10.

Table A. 10. Eurostat agricultural indicators

Indicator	Period
Share of manure applied with different application techniques and incorporation time	Up to 2010
Share of animals in different housing systems	Up to 2010
Manure storage facilities by NUTS3 (2000, 2003, 2010)	from 2012 onwards
Organic livestock (number)	1997-2011; 2012-2018
Organic crop production by crops (t)	1999-2011; 2012-2018
Structure of rearing (cattle, pigs, goats, sheep)	1993-2007
Main livestock indicators (under farming structure)	2013 and 2016
Livestock population annual and by NUTS 2	1979-2019
Total livestock density (livestock unit/ha)	2005 - 2016
Share of major livestock types (cattle, equidae, sheep, goats, pigs and poultry) in total livestock	Up to 2016
Grazing livestock density (grazing livestock units/hectares of fodder area)	2005-2016
Poultry farming (number, eggs) (poultry, laying hens, duck, geese)	2008-2019
Consumption of inorganic fertilisers (N, P)	2000-2018
Consumption of mineral fertilisers (N, P)	2008-2018
Sales of manufactured fertilisers (N, P, P_2O5, K, K_2O)	1985-2017
Gross nutrient balance (N, P)	1990-2017
UUA (1000 ha)	1990-2017
N/P in nutrient input/output per ha UUA	1990-2017
Total N/P emissions	1990-2017
Consumption of organic fertilisers (except manure) (N, P)	1990-2017
N in manure input	1990-2017
N in manure production from livestock (total cattle, pigs, sheep and goats, poultry, other livestock	1990-2017
N in manure withdrawals	1990-2017
N in nutrient removal by harvest crops (cereals, dried pulses, root crops, industrial crops, other)	1990-2017
N in nutrient removal by crop residues removed from the field	1990-2017
N in nutrient removal by crop residues burned on the field	1990-2017
N in nutrient removal by harvest and grazing of fodder	1990-2017
N in nutrient removal by harvest and grazing of permanent grassland	1990-2017
N in nutrient removal by harvest of plants harvested green from arable land	1990-2017

CAPRI model

The "Common Agricultural Policy Regionalised Impact" (CAPRI) is a large scale partial equilibrium model of the agricultural sector with a focus on the European Union (CAPRI Online Manual, 2020). The model can help the analysis of the socio-economic and environmental effects of agricultural policies and trade agreements, environmental policies, and changes in drivers such as population or GDP. CAPRI models the future trends in animal numbers until 2030 based on PRIMES 2012 baseline (EC, DG Environment, 2014).

The CAPRI model since 2016 has become more friendly to the user which have the possibility to download the code of the model (current version STAR 2.6) that includes the raw data and the compiled database including calibrated baselines (CAPRI Online Manual, 2020). The CAPRI model has two interacting modules: a supply module and a market module. The supply module comprises independent aggregated optimization models representing agricultural activities (28 crop and 13 animal activities) in all 273 Nomenclature of Territorial Units for Statistics (NUTS2) regions within the EU (Fellmann Th. et.al, 2018). The CAPRI model

(30) https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Agriculture_-_manure_storage_statistics

estimates the main agricultural parameters such as yields, crop shares, fertiliser application rates, and stocking densities at high resolution of 1x1 km pixels. The CAPRI model data base is mainly sourced via official, harmonized statistical data from Eurostat and FAOSTAT with a baseline since 1985 for almost all time series (Britz & Keeney, 2010). The most recent update of CAPRI database has been performed in May 2020 (CAPRI Online Manual, 2020).

The CAPRI model, sometimes in combination with other models such as the Greenhouse Gas and Air Pollution Interactions and Synergies model (GAINS) or Assessment of Nitrogen Flows in Agriculture model (MITERRA), can calculate the balances for N, P, K, and GHG. The CAPRI model is a source of several parameters such as Nex, N in mineral fertilisers, animal energy, protein needed for the estimation of GHG and air pollutants emissions from agricultural activities.

In CAPRI, the energy requirements and the emission factors are computed per unit of the respective activity level, which is per single animal (per head) and associated process length. The calculation of Nex is presented as the difference between N_{intake} and $N_{retention}$ of livestock. This parameter can be used as an input for the EDGAR model to calculate emission factors for N_2O, NH_3 and NOx emissions from manure management activities.

CAPRI performs calculations of CH_4 emissions from enteric fermentation following the Tier 2 method as suggested by IPCC (IPCC, 2006). The model can calculate endogenously the gross energy intake (from the summation of the different feed types fed to an animal). Using its feed module CAPRI can distribute the available feed in a region over the animals, based on energy and nutrient requirements. To perform CH_4 calculations activity data such as live body weight (BW), daily weight gain (WG), milk yield (Milk), fat content of milk (fat) etc. are used.

CH_4 emissions from manure management are calculated applying a Tier 2 approach, using shares of grazing and storage systems from the GAINS database.

Table A. 11. Some parameters (inputs and outputs) of CAPRI model related to air pollutants emissions from agriculture

Group	Type	Item	Code in CAPRI
Inputs	Mineral and organic fertiliser	Nitrogen fertiliser	NITF
Inputs	Mineral and organic fertiliser	Phosphate fertiliser	PHOF
Inputs	Mineral and organic fertiliser	Potassium fertiliser	POTF
Inputs	Mineral and organic fertiliser	Calcium fertiliser	CAOF
Inputs (extracted from Guide)	Mineral and organic fertiliser	Efficiency factor applied to each fertiliser	
Inputs (extracted from Guide)	Mineral and organic fertiliser	Nutrient content in the regional manure	
Inputs (extracted from Guide)	Mineral and organic fertiliser	Quantity of manure traded	
Outputs	Cereals	Soft wheat	SWHE
Outputs	Cereals	Durum wheat	DWHE
Outputs	Cereals	Rye and Meslin	RYEM
Outputs	Cereals	Barley	BARL
Outputs	Cereals	Oats	OATS
Outputs	Cereals	Paddy rice	PARI
Outputs	Cereals	Maize	MAIZ
Outputs	Cereals	Other cereals	OCER
Outputs	Intermediate products from animal	Nitrogen from manure	MANN
Outputs	Intermediate products from animal	Phosphate from manure	MANP
Outputs	Intermediate products from animal	Potassium from manure	MANK
Outputs (extracted from Guide)	Manure	Crops	
Outputs (extracted from Guide)	Manure	Manure nutrient for livestock	
Outputs (extracted from Guide)	Manure	Nutrient availability ratio	
Outputs (extracted from Guide)	Crop residues	Nutrient availability ratio	

Source: (CAPRI Online Manual, 2020)

GAINS model

The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model is an integrated assessment model dealing with costs and potentials for air pollution control and GHG mitigation and assessing interactions between policies (IIASA, 2020).

GAINS addresses air pollution impacts on human health from fine particulate matter and ground-level ozone, vegetation damage caused by ground-level ozone, the acidification of terrestrial and aquatic ecosystems and excess nitrogen deposition) of soils, in addition to the mitigation of greenhouse gas emissions. GAINS describes the inter-relations between these multiple effects and the range of pollutants (SO_2, NOx, PM, NMVOC, NH_3, CO2, CH_4, N_2O, F-gases) that contribute to these effects at the European scale.

CH4 emissions are estimated separately for the animal types (dairy cows, non-dairy cattle, pigs, poultry, sheep and goats, buffaloes, and horses). For dairy cows, non-dairy cattle and pigs, animal numbers are further split by whether animals are subjected to liquid or solid manure management.

Country specific emission factors corresponding to the implied emission factors reported to UNFCCCCRF (2016) referring to the year 2005 are adopted for enteric fermentation and manure management emissions, respectively.

Using these country specific implied emission factors, the derived linear relationship determines the future emission pathway from the development in milk yield and animal numbers. Information on the average number of days per year that animals spend indoor has been collected by animal category in the GAINS database.

Nitrous oxide emissions are typically computed as a fraction of the nitrogen deposited on soils. Nitrogen input in GAINS is derived from nitrogen contained in mineral fertiliser, animal manure and crop residue left on the field. Information on mineral fertiliser use and projections till 2050 derive from results of the CAPRI model, which also provides numbers of animals on farms.

A.5 Examples of questionnaires to collect information at farm level

The major part of the activity data needed to calculate air pollutant emissions from agricultural activities can be part of a questionnaire to be filled in by the farmers. Good examples on such questionnaire come from Austria and Switzerland.

In Austria, full farm surveys were performed in 2010, 2013 and 2016. A questionnaire was prepared under the framework of a project "Animal husbandry and manure management systems in Austria" TIHALO I (since 2017 TIHALO II) and distributed in 5000 copies with a return rate of 37%. The questionnaire assessed relevant parameters in all stages of animal husbandry systems: housing and exercise yard, grazing, waste and washing water, manure storage, manure application, animal feeding, and mineral fertiliser application. TIHALO II questionnaire was available online and was used by more than 50% of the participants in the survey providing new information on livestock feeding, management systems and practices as well as application techniques (IIR AT, 2020).

In Switzerland, the Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL) collected data on farm and manure management at farm-level with a detailed representative questionnaire in 2002, 2007, 2010 and 2015. The questionnaire contained detailed questions on livestock housing, feeding and grazing for different livestock categories, as well as manure storage and spreading, and fertilization (IIR CH, 2020). Data from these surveys on (i) livestock rations, (i.e. types of roughage and amount of concentrates in summer and winter dairy cow rations and the protein content of pig rations), (ii) housing systems, (iii) types of manure stores and (iv) techniques used for the application of slurry and solid manure, are transferred to a database which is used for further analyses (Kupper et al., 2015).

Some EU countries have in place surveys for the collection of the information on the livestock sector, the use of fertilisers, the allocation of manure etc. Sweden has applied since 1988 the survey "Use of fertilisers and animal manure in agriculture" being performed by the Statistic Sweden every 2-3 years. The last survey was in 2015/2016 period (IIR SE, 2020). Statistical information applied since 2017 in updating the NH_3 emissions from agriculture in Czech Republic are sourced by the Czech Statistical Office which publishes the results of "Farm structure survey-2016[31]". The German Federal Statistical Office and the Statistical Agencies of the federal states carry out agricultural structure surveys in order to collect, along with other data, the head counts of cattle, pigs, sheep, horses (from 2010 onwards: equids) and poultry .

Poland organizes every 3 years regular surveys on the structure of agricultural holdings to use the obtained information in the calculation of air pollutants emissions (for example it retrieves data regarding the consumption of mineral fertilisers).

Hungary organizes two censuses of animal numbers per year since 2009. One survey is conducted in June and the other in December. Agricultural Censuses in the country were conducted in 2000 and 2010 whereas the Farm Structure Surveys were conducted in 2003, 2005, 2007, 2013 and 2016 (IIR HU, 2020).

The UK uses data from the "Survey data on manure spreading practices from the British Survey of Fertiliser Practice 2016"[32] to develop timeseries of livestock housing and manure management practices for each country (England, Wales, Scotland and Northern Ireland) from which a weighted average was derived for the whole country (IIR UK, 2020).

Compiling a Tier 2 air pollutant or GHG emissions inventory should be based on the systematic collection of activity data at farm level applying the following steps[33]:

1. Identify the activity data needed to apply a Tier 2 method. The main purposes of this step are:
   - Define the inventory structure that can be supported by the activity data
   - Identify activity data gaps due to the lack of information
   - Identify the activity data quality gaps

2. Identify the organization that will collect the activity data. These organizations can be universities or non-governmental organizations (NGOs).

3. Identify the farms that fulfill the criteria to be representative for the activity data selected

4. Prepare a spreadsheet that will record all available activity data needed. The spreadsheet should contain options to collect both static and dynamic activity data.

5. Analyze the activity data collected to assess the data quality.

6. Define data gaps and provide a method to fill these gaps. Establish the database.

(31) https://www.czso.cz/csu/czso/agriculture-total
(32) https://www.gov.uk/government/statistics/british-survey-of-fertiliser-practice-2016
(33) Adopted from FAO and Global Research Alliance on Agricultural Greenhouse Gases. 2020. Livestock Activity Data Guidance (L-ADG): Methods and guidance on compilation of activity data for Tier 2 livestock GHG inventories.

The section below provides some examples of questionnaires that can be used to collect activity data at farm level.

Questionnaire on Livestock (cattle example)

Livestock	Number		Housing system (tied stalls)			Housing system (multi pen-loose)						Climate		
Cattle 2 years and older			Slurry only	Slurry & solid		Slurry	Solid	Compost	Freezer	Solid floor		Warm	Cool	Cold
Dairy cows		head			%						%			
Suckler cows		head			%						%			
Calfs		head			%						%			
Bulls		head			%						%			
Oxen		head			%						%			
Young cattle 1 to under 2 years														
Bulls		head			%						%			
Oxen		head			%						%			
Calves (breeding)		head			%						%			
Calves (Mast)		head			%						%			
Young cattle under 1 year														
Slaughter calves up to 300 kg		head			%						%			
Calves and young cattle (breeding)		head			%						%			
Calves and young cattle (mast)		head			%						%			

Pasture	Hours/day					Days/year						
Cattle 2 years and older	0	1 - 5	5 - 12	12 - 20	>20	<20	20 - 60	61 - 90	91 - 120	121-	151-230	>230
Dairy cows												
Suckler cows												
Calfs												
Bulls												
Oxen												
Young cattle 1 to under 2 years												
Bulls												
Oxen												
Calves (breeding)												
Calves (Mast)												
Young cattle under 1 year												
Slaughter calves up to 300 kg												
Calves and young cattle (breeding)												
Calves and young cattle (mast)												

Phasing out cattle (no pasture)	Discontinued area?		Stall size		Time of the day			Days per year				
Cattle 2 years and older	Yes	No			2 PM	5-12 PM	all the time	< 40	40 - 90	91 -150	151-230	>230
Dairy cows				m2								
Suckler cows				m2								
Calfs				m2								

Bulls				m2									
Oxen				m2									
Young cattle 1 to under 2 years													
Bulls				m2									
Oxen				m2									
Calves (breeding)				m2									
Calves (Mast)				m2									
Young cattle under 1 year													
Slaughter calves up to 300 kg				m2									
Calves and young cattle (breeding)				m2									
Calves and young cattle (mast)				m2									

Feeding/running areas	**Removal interval in cattle shed (times/day, times/week)**							**Column cleaner**		**Deforestation interval**			
Cattle 2 years and older	>4/day	3-4/day	2/day	1/day	2-	1/w	<1/w	yes	no	1/day	2-3/w	1/w	<1/w
Dairy cows													
Suckler cows													
Calfs													
Bulls													
Oxen													
Young cattle 1 to under 2 years													
Bulls													
Oxen													
Calves (breeding)													
Calves (Mast)													
Young cattle under 1 year													
Slaughter calves up to 300 kg													
Calves and young cattle (breeding)													
Calves and young cattle (mast)													

Acces time in yards	**Access per day**		**Days per year**						
Cattle 2 years and older	Temporary	Always	<20	20 -	61 - 90	91 - 120	121-150	151-230	>230
Dairy cows									
Suckler cows									
Calfs									
Bulls									
Oxen									
Young cattle 1 to under 2 years									
Bulls									
Oxen									
Calves (breeding)									
Calves (Mast)									
Young cattle under 1 year									
Slaughter calves up to 300 kg									

Calves and young cattle (breeding)									
Calves and young cattle (mast)									

Grazing hours			Hours/day						Days/year			
Cattle 2 years and older	0	1 - 5	5 - 12	12 - 20	>20	<20	20 - 60	61 - 90	91 - 120	121-	151-230	>230
Dairy cows												
Suckler cows												
Calfs												
Bulls												
Oxen												
Young cattle 1 to under 2 years												
Bulls												
Oxen												
Calves (breeding)												
Calves (Mast)												
Young cattle under 1 year												
Slaughter calves up to 300 kg												
Calves and young cattle (breeding)												
Calves and young cattle (mast)												

Questionnaire on farm level (livestock manure and nitrogen consumed in feed example)

Farm characteristics[34]	small	medium	large	unit
Number of farms				Count
Share				%
Number of animals				heads
Share of livestock in liquid manure system				%
Share of livestock in solid manure system				%
Milk production				kg/head/yr
N excreted				kg N/head/yr
Amount/Fraction of TAN				kg TAN/head/yr - Fraction
Protein content of milk	<3.2%	3.2%-3.8%	>3.8%	
				%
Nitrogen consumed in feed				
Animal weight				kg

(34) Physical size of farms based on their utilised agricultural area (UUA is defined as small farm when it covers 2 – 20 ha of UUA, medium farm when it covers 20 - 100 ha of UUA and large farm when it covers more than 100 ha of UUA (Eurostat, 2020).

Average weight gain per day		kg/day
Average milk production per day		kg/day
Average milk fat content		%
Average wool growth		kg
Hours of works/excersise		hours
Percentage of females that give birth in a year		%
Digestibility of feed		%
Protein content of feed		%
Housed		%
Grazing		%
Mean winter temperature		^{o}C

Livestock	**Cattle**	repeat for each livestock category
Number of heads		Heads
Housing system		type
Housing period		Days
Manure separation (liquid/solid)		%
Housing tied		%
Housing loose		%
Year of change from tied to loose housing system		year
Housing mechanical ventilation		%
Days/hours in grazing		Days/hours
Stall dimensions		Heads
Days/hours in yards		Days/hours
Housing : air scrubber		%
Amount of straw added as bedding		kg dry mass/head/yr
Manure direct spreading		%
Liquid manure applied to field		%
Solid manure applied to field		%
Slurry manure stored in open tanks		%
Slurry manure stored in covered tanks		%
Slurry manure stored in lagoons		%
Slurry manure stored in underfloor pits		%
Manure stored in manure heaps		%
Manure composted		%
Manure incinerated		%
Manure solid imported/exported		kg/yr
Manure liquid imported/exported		kg/yr
Solid storage and dry lot		%
Pasture		%
Other (specify)		
Slurry manure storage capacity		months

Slurry manure storage during warm and cold season		months
Slurry manure for anaerobic digestion		%
Drinkers		type

Livestock diet

Feeding components (check the appropriate feed)

	Summer	Winter
Forage		
Hey/aftermath		
Grass silage		
Maize silage		
Maize pellets		

Frequency of manure removal from the house		period
Gaseous N losses from animal housing		kg/yr
Gaseous N losses from manure storage		kg/yr

Questionnaire on manure (storage example)

Manure storage

	Number	Year of construction	Community Lagoon		Share if yes
			yes	no	
Container/Pit					
Lagoon					%

Manure slurry storage and treatment

Container/Pit	**Volume (in m3)**	**Depth (in m-with decimal)**	**Slurry separated**		**Biogas from slurry**		**Co-substrate outside the farm for biogas**	
			yes	no	yes	no	yes	no
No.1								
No.2								
No.3								
No.4								
Other (as Lagoon)								

Times per year the slurry mixed (including mixing before application)

Container/Pit	Daily	up to 1 time/week	up to 2 times/month	up to 1 time/month	only for application	max. 2 times/year
No.1						
No.2						
No.3						
No.4						
Other (as Lagoon)						

Slurry diluted with water (ratio slurry / water)

Container/Pit	1:<0.5	1:0.5	1:1	1:1.5	1:2	1:>2
No.1						
No.2						
No.3						
No.4						
Other (as Lagoon)						

Type of manure stored

Container/Pit	Cattle manure	Pig manure	Poultry droppings
No.1			
No.2			
No.3			
No.4			
Other (as Lagoon)			

Type of cover

Container/Pit	No cover	Concrete/wooden	Perforated	Floating film	Tent roof	Floats	Natural floating layer	Chopped straw
No.1								
No.2								
No.3								
No.4								
Other (as Lagoon)								

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from EU Bookshop at: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

KJ-1A-30338-EN-N

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office of the European Union

doi:10.2760/255034

ISBN 978-92-76-25423-2