

## 3.B - Manure Management

### Short description

NFR-Code	Name of Category	Method	AD	EF	State of reporting
3.B	Manure Management	see sub-category details			
consisting of / including source categories					
3.B.1.a & 3.B.1.b	Cattle	T3 (NH <sub>3</sub> ), T2 (NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	L: NH <sub>3</sub> (for 3.B.1.a)
3.B.2, 3.B.4.d, 3.B.4.e	Sheep, Goats, Horses	T2 (NH <sub>3</sub> , NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> ,NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	
3.B.3	Swine	T3 (NH <sub>3</sub> ), T2 (NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	
3.B.4.a	Buffalo				NO, from 1990 until 1995, since 1996 IE, considered in 3.B.1.b
3.B.4.f	Mules and asses				IE, considered in 3.B.4.e
3.B.4.g i-iv	Poultry	T2 (NH <sub>3</sub> , NO <sub>x</sub> , TSP, PM <sub>10</sub> , PM <sub>2.5</sub> ), T1 (NMVOC)	NS, RS	CS (NH <sub>3</sub> , NO <sub>x</sub> ), D (TSP, PM <sub>10</sub> , PM <sub>2.5</sub> , NMVOC)	T: NH <sub>3</sub> (for 3.B.4.g iii)
3.B.4.h	Other animals				NE

Key Category	SO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>	NMVOC	CO	BC	Pb	Hg	Cd	Diox	PAH	HCB	TSP	PM <sub>10</sub>	PM <sub>2.5</sub>
3.B.1.a	-	-/-	L/T	L/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.1.b	-	-/-	L/T	L/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.2	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.3	-	-/-	L/T	-/-	-	-	-	-	-	-	-	-	L/-	-/-	-/-
3.B.4.d	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.4.e	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.4.g.i	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	L/-	-/-	-/-
3.B.4.g.ii	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.4.g.iii	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-
3.B.4.g.iv	-	-/-	-/-	-/-	-	-	-	-	-	-	-	-	-/-	-/-	-/-

**T** = key source by Trend **L** = key source by Level

Methods	
<b>D</b>	Default
<b>T1</b>	Tier 1 / Simple Methodology *
<b>T2</b>	Tier 2*
<b>T3</b>	Tier 3 / Detailed Methodology *
<b>C</b>	CORINAIR
<b>CS</b>	Country Specific
<b>M</b>	Model

\* as described in the EMEP/EEA Emission Inventory Guidebook - 2019, in the group specific chapters.

#### AD - Data Source for Activity Data

<b>NS</b>	National Statistics
<b>RS</b>	Regional Statistics
<b>IS</b>	International Statistics
<b>PS</b>	Plant Specific data
<b>As</b>	Associations, business organisations
<b>Q</b>	specific Questionnaires (or surveys)
<b>M</b>	Model / Modelled
<b>C</b>	Confidential

#### EF - Emission Factors

<b>D</b>	Default (EMEP Guidebook)
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<b>C</b>	Confidential
<b>CS</b>	Country Specific
<b>PS</b>	Plant Specific data
<b>M</b>	Model / Modelled

## Country specifics



In 2020,  $\text{NH}_3$  emissions from category 3.B (manure management) were 48.6 % from total agricultural emissions, which is equal to  $\sim 249.2$  kt  $\text{NH}_3$ . Within those emissions 52.0 % originate from cattle manure ( $\sim 129.5$  kt), 34.0 % from pig manure (ca. 84.7 kt), and 10.8 % from poultry manure ( $\sim 27.0$  kt). Calculations take into account the impact of anaerobic digestion of manure on the emissions.

$\text{NO}_x$  emissions from category 3.B (manure management) contribute only 1.3 % ( $\sim 1.4$  kt) to the total agricultural  $\text{NO}_x$  emissions. They are calculated proportionally to  $\text{N}_2\text{O}$  emissions, see Vos et al. (2022)<sup>1)</sup>.

NM VOC emissions from category 3.B (manure management) contributed 96.9 % (289.8 kt) from total agricultural NM VOC emissions (298.9 kt).

In 2020, manure management contributed, respectively, 71.3 % (43.0 kt), 42.8 % (12.9 kt) and 84.8 % (3.7 kt) to the total agricultural TSP,  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  emissions (TSP: 60.3 kt,  $\text{PM}_{10}$ : 30.2 kt,  $\text{PM}_{2.5}$ : 4.4 kt, respectively).

### Activity data for all pollutants

The Federal Statistical Agency and the Statistical Agencies of the federal states carry out surveys in order to collect, along with other data, the head counts of animals. The results of these surveys are used for emission calculations, for details see Vos et al, 2022, Chapter 3.4.2.

The animal population figures used in the inventory are presented in Table 1. From 2017 to 2019 the animal population figures for horses, goats and poultry differ from the figures presented in the last IIR. In the last year's submission these figures were extrapolated from the year 2016. Now there are new figures available for the year 2020 and the years 2017-2019 have been interpolated. Buffaloes are included in the cattle population figures, mules and asses are included in the horse population figures (IE), see Vos et al. (2022), Chapters 4.1 and 7.1. In the first years after the German reunification in 1990 animal livestock decreased markedly. The head counts for cattle continued to decrease significantly until 2006/2007, followed by a more or less stable period until 2014. Since 2015 a slight decrease occurred. In 2020, dairy cattle numbers are 61.7 % of 1990 numbers, while the total population of other cattle is at 56.2 % of 1990. Swine numbers decreased until 1995 and then increased slightly. Since 2014 a slight decrease occurred (2020: 81.6 % of 1990). The 2020 numbers of horses, sheep and goats are, respectively, at 90,8 %, 54.5 % and 172.1 % of 1990.

Figures for broilers and turkeys are showing a massive increase since 1990. Since the year 2013, there have been only minor changes of total poultry numbers. In total, 2020 poultry population figures are at 152.0 % of 1990. A detailed description of the animal numbers used can be found in the National Inventory Report 2022 <sup>2)</sup>, Chapter 5.1.3.2.3.

Table 1: Population of animals

Population of animals (in 1000)															
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
dairy cattle	6'354.6	5'229.4	4'569.8	4'236.4	4'183.1	4'190.1	4'190.5	4'267.6	4'295.7	4'284.6	4'217.7	4'199.0	4'100.9	4'011.7	3'921.4
other cattle	13'133.4	10'660.5	9'968.9	8'800.4	8'628.7	8'340.4	8'319.1	8'418.4	8'446.5	8'350.8	8'248.9	8'082.2	7'848.2	7'627.9	7'380.5
buffalo	NO	NO	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
mules and asses	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
horses	499.5	634.1	499.5	508.4	461.8	461.6	461.5	461.3	454.9	448.4	442.0	444.9	447.8	450.7	453.7
sheep	3'266.1	2'990.7	2'743.3	2'643.1	2'245.0	1'979.7	1'965.9	1'877.2	1'892.4	1'866.9	1'851.0	1'863.2	1'846.0	1'813.6	1'780.3
goats	90.0	100.0	140.0	170.0	149.9	143.4	136.8	130.2	133.1	135.9	138.8	142.8	146.9	150.9	154.9
swine	26'502.5	20'387.3	21'767.7	22'742.8	22'244.4	22'787.9	23'648.3	23'391.2	23'666.9	22'978.5	22'761.2	22'920.8	22'019.2	21'596.4	21'622.0
laying hens	53'450.5	45'317.3	44'225.6	38'203.6	35'279.0	39'514.9	43'750.8	47'986.7	49'303.0	50'619.3	51'935.5	52'571.1	53'206.6	53'842.1	54'477.6
broilers	35'393.0	42'025.8	50'359.9	56'762.5	67'531.1	77'402.6	87'274.1	97'145.6	96'027.5	94'909.4	93'791.3	93'458.7	93'126.1	92'793.5	92'461.0
turkeys	5'029.2	6'742.0	8'893.1	10'611.1	11'344.0	11'981.2	12'618.5	13'255.7	12'957.1	12'658.5	12'359.9	12'164.7	11'969.5	11'774.3	11'579.1
pullets	17'210.8	14'592.0	14'240.5	12'301.4	11'303.3	12'749.3	14'195.2	15'641.2	14'734.7	13'828.3	12'921.8	12'736.3	12'550.7	12'365.1	12'179.6
ducks	2'013.7	1'933.7	2'055.7	2'352.2	3'164.3	3'029.5	2'894.6	2'759.7	2'585.3	2'410.8	2'236.4	2'209.1	2'181.9	2'154.6	2'127.4
geese	781.5	617.0	404.8	329.5	278.1	366.8	455.5	544.2	472.5	400.8	329.0	327.7	326.3	324.9	323.5
other animals: no data available a)															
a) Animal numbers of other animals are not available. Emissions of other animals were approximated with estimated population figures for a single year (see Rösemann et. al., 2017, Chapter 9, <sup>3)</sup> and submitted to the TERT of the NECD-Review. The TERT confirmed that emissions are below the threshold of significance. For GHG emission reporting the UNFCCC has acknowledged that the emissions from Germany's other animals are negligible. To ensure consistency between UNFCCC and UNECE/NEC reporting, no air pollutants from other animals are reported.															

## Additional data

Emission calculations in accordance with a Tier 2 or Tier 3 method require data on 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 the relevant feeding details (phase feeding, feed components, protein and energy content, digestibility and feed efficiency). To subdivide officially recorded total numbers of turkeys into roosters and hens, the respective population percentages need to be known. Details on data requirements for the modelling of emissions from livestock husbandry in the German inventory can be found in Voss et al. (2022), Chapters 4 to 8.

Most of the data mentioned above is not available from official statistics and was obtained from literature, from publications by agricultural associations, from regulations for agricultural consulting in Germany and from expert judgments. For 1991, 1995 and 1999, frequency distributions of feeding strategies, husbandry systems (shares of pasturing/stabling; shares of various housing methods), storage types as well as techniques of farm manure spreading were obtained with the help of the RAUMIS agricultural sector model (Regionalisiertes Agrar- und UmweltInformationssystem für Deutschland/ Regionalised agricultural and environmental information system for Germany). RAUMIS has been developed and is operated by the Institute of Rural Studies of the Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries). For an introduction to RAUMIS see Weingarten (1995) <sup>4)</sup>; a detailed description is provided in Henrichsmeyer et al. (1996) <sup>5)</sup>.

RAUMIS did not model complete time series but only selected years. RAUMIS data for the years 1991, 1995, and 1999 are used in the inventory for years 1990 – 1993, 1994 – 1997, and 1998 – 1999, respectively. For the year 2010, respective data are used that were derived from the 2010 official agricultural census and the simultaneous survey of agricultural production methods (Landwirtschaftliche Zählung 2010, Statistisches Bundesamt/ Federal Statistical Office) as well as the 2011 survey on manure application practices (Erhebung über Wirtschaftsdüngerausbringung, Statistisches Bundesamt/ Federal Statistical Office).

For the year 2015, data on techniques of farm manure spreading from the 2016 official agricultural census (Agrarstrukturerhebung 2016, Statistisches Bundesamt / Federal Statistical Office) are used. The gaps between the latest

corresponding emission factors are provided in NIR 2022, Chapter 19.3.2.

## NH<sub>3</sub> and NO<sub>x</sub>

## Method

## N in manure management

## N excretion

In order to determine  $\text{NH}_3$  and  $\text{NO}_x$  emissions from manure management of a specific animal category, the individual N excretion rate must be known as well as, for  $\text{NH}_3$ , the TAN content of the N excretions. Default excretion rates are provided by IPCC Guidelines and default TAN contents can be found in the EMEP Guidebook, 2019<sup>5)</sup>. However, the German agricultural emission inventory uses N mass balances to calculate the N excretions and the TAN contents of almost all reported animal categories to be reported. N mass balance calculations (see below) consider N intake with feed, N retention due to growth, N contained in milk and eggs, and N in offspring. Table 2 presents national means of N excretions and TAN contents. For methodological details and mass balance input data see Vos et al. (2022), Chapter 3.3.4.3 as well as Chapters 4 to 8.

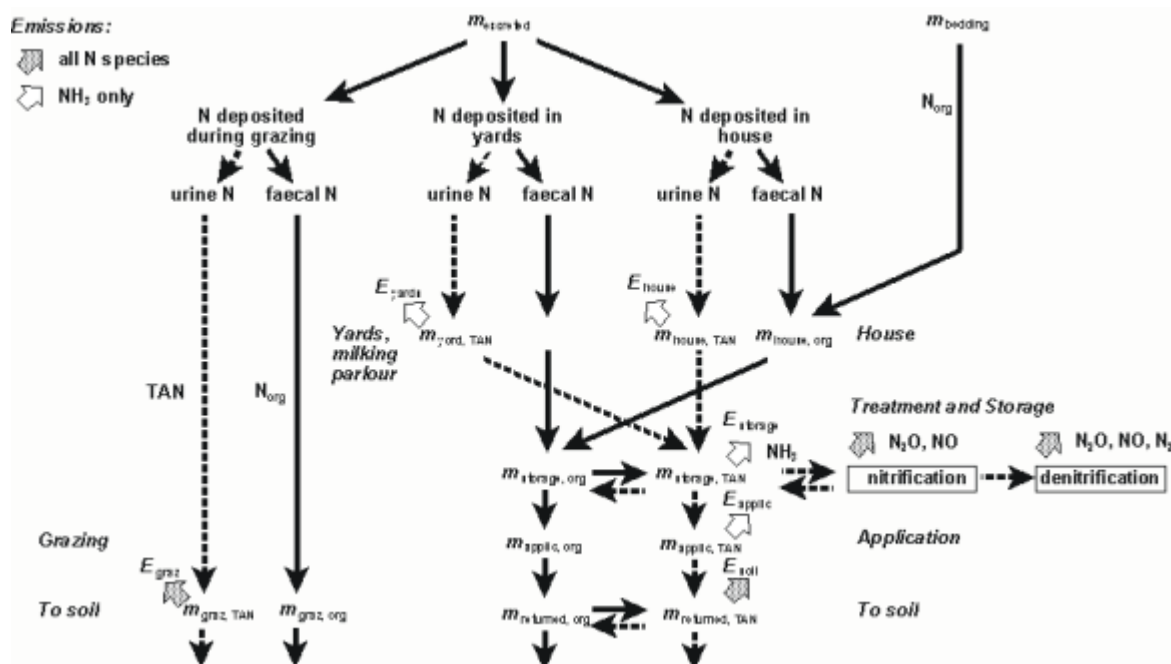
Table 2: National means of N excretions and TAN contents

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### N mass flow and emission assessment

The calculation of the emissions of  $\text{NH}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  from German animal husbandry is based on the so-called N mass flow approach (e. g. Dämmgen and Hutchings, 2008<sup>7)</sup>). This approach differentiates between N excreted with faeces (organic nitrogen Norg, i. e. undigested feed N) and urine (total ammoniacal nitrogen TAN, i. e. fraction of feed N metabolized). The N flow within the manure management system is treated as depicted in the figure below. This method reconciles the requirements of both the Atmospheric Emission Inventory Guidebook for  $\text{NH}_3$  emissions (EMEP, 2019), and the IPCC guidelines for greenhouse gas emissions (IPCC (2006)<sup>8)</sup>. Reidy et al. (2008),<sup>9)</sup> showed for several European countries (Germany, the Netherlands, Switzerland, United Kingdom) that their N-flow based inventory models yielded, in spite of national peculiarities, comparable results as long as standardised data sets for the input variables were used.

Not explicitly shown in the N mass flow scheme is air scrubbing in housing and anaerobic digestion of manure. These issues are separately described further below. Note that emissions from grazing and application are reported in sector 3.D.



*General scheme of N flows in animal husbandry*

*m*: mass from which emissions may occur. Narrow broken arrows: TAN (total ammoniacal nitrogen); narrow continuous arrows: organic N. The horizontal arrows denote the process of immobilisation in systems with bedding occurring in the house, and the process of mineralisation during storage, which occurs in any case. Broad arrows denote N-emissions assigned to manure management ( $E_{\text{yard}} \text{NH}_3$  emissions from yards;  $E_{\text{house}} \text{NH}_3$  emissions from house;  $E_{\text{storage}} \text{NH}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  emissions from storage;  $E_{\text{applic}} \text{NH}_3$  emissions during and after spreading;  $E_{\text{graz}} \text{NH}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  emissions during and after grazing;  $E_{\text{soil}} \text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  emissions from soil resulting from manure input).

The model allows tracing of the pathways of the two N fractions after excretion. The various locations where excretion may take place are considered. The partial mass flows down to the input to soil are represented. During storage Norg can be transformed into TAN and vice versa. Both, the way and the magnitude of such transformations may be influenced by manure treatment processes like, e. g., anaerobic digestion where a considerable fraction of Norg is mineralized to TAN. For details see Vos et al. (2022), Chapters 3.3.4.3 and 3.3.4.4. Wherever  $\text{NH}_3$  is emitted, its formation is related to the amount of the TAN present.  $\text{N}_2\text{O}$  emissions are related to the total amount of N available (Norg + TAN).  $\text{NO}_x$  emissions (i. e. NO emissions) are calculated proportionally to the  $\text{N}_2\text{O}$  emissions, see section 'Emission factors'. Note that the  $\text{N}_2\text{O}$ ,  $\text{NO}_x$  and  $\text{N}_2$  emissions from the various storage systems include the respective emissions from the related housing systems.

### Air scrubber systems in swine and poultry housings

For pig and poultry production the inventory model considers the effect of air scrubbing. Data on frequencies of air scrubbing facilities and the removal efficiency are provided by KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft / Association for Technology and Structures in Agriculture). The average removal efficiency of  $\text{NH}_3$  is 80 % for swine and 70 % for poultry, while for TSP and  $\text{PM}_{10}$  the rates are set to 90 % and for  $\text{PM}_{2.5}$  to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: certified systems that remove both  $\text{NH}_3$  and particles, and non-certified systems





	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
sheep	0.83	0.82	0.84	0.83	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.82	0.83	0.83
goats	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
swine	4.60	4.50	4.37	4.30	4.13	4.07	4.03	4.00	3.98	4.02	4.00	3.98	3.97	3.94	3.92
laying hens	0.212	0.203	0.199	0.198	0.142	0.144	0.144	0.145	0.146	0.146	0.147	0.147	0.148	0.149	0.150
broilers	0.143	0.120	0.128	0.131	0.128	0.118	0.103	0.092	0.094	0.094	0.094	0.093	0.094	0.092	0.089
turkeys	0.793	0.793	0.797	0.874	0.836	0.839	0.892	0.862	0.861	0.859	0.860	0.860	0.835	0.835	0.784
pullets	0.103	0.095	0.087	0.087	0.084	0.083	0.083	0.082	0.082	0.082	0.083	0.083	0.084	0.084	0.084
ducks	0.193	0.193	0.193	0.192	0.189	0.188	0.188	0.186	0.186	0.185	0.185	0.186	0.186	0.186	0.186
geese	0.384	0.384	0.384	0.383	0.380	0.380	0.380	0.379	0.379	0.378	0.378	0.378	0.378	0.378	0.378
<b>IEF in kg NO<sub>x</sub> per animal place</b>															
dairy cattle	0.106	0.114	0.125	0.130	0.125	0.123	0.119	0.117	0.117	0.118	0.120	0.120	0.123	0.126	0.129
other cattle	0.053	0.057	0.059	0.062	0.064	0.063	0.063	0.063	0.064	0.064	0.065	0.066	0.066	0.068	0.069
horses	0.084	0.084	0.086	0.086	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.086	0.086	0.086	0.086
sheep	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
goats	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
swine	0.011	0.013	0.012	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.012
laying hens	0.00027	0.00026	0.00026	0.00029	0.00035	0.00035	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034
broilers	0.00016	0.00014	0.00015	0.00018	0.00020	0.00019	0.00016	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
turkeys	0.00067	0.00067	0.00070	0.00084	0.00090	0.00091	0.00092	0.00090	0.00089	0.00089	0.00089	0.00089	0.00086	0.00085	0.00081
pullets	0.00011	0.00010	0.00009	0.00010	0.00012	0.00012	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011	0.00011
ducks	0.00024	0.00024	0.00024	0.00025	0.00027	0.00027	0.00026	0.00027	0.00027	0.00027	0.00027	0.00027	0.00027	0.00026	0.00026
geese	0.00024	0.00024	0.00025	0.00027	0.00030	0.00030	0.00028	0.00029	0.00028	0.00029	0.00029	0.00029	0.00028	0.00028	0.00028

#### Trend discussion for Key Sources

Dairy cattle, other cattle and swine are key sources of NH<sub>3</sub> emissions from manure management. The time series of the total NH<sub>3</sub> emissions from all three categories are predominantly driven by the development of the animal numbers, see Table 1. However, the effect of decreasing animal numbers is partly compensated by the continuously increasing animal performance. This leads to increasing N excretions per animal, see Table 2, which, in principle, is reflected by increasing implied emission factors, see Table 3. For swine, as of 2012, the IEF is almost constant over time due to the use of air scrubbing systems that, to a high degree, remove NH<sub>3</sub> from the housings.

For NO<sub>x</sub> there are no key categories.

#### Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Tables REC-1 and REC-2 compare the recalculated time series for NH<sub>3</sub> and NO<sub>x</sub> from 3B with the respective data of last year's submission. The total emissions of NH<sub>3</sub> slightly higher than those of submission 2021. The emissions from cattle are higher than in last year's submission mainly due to the incorporation of new housing data from the 2020 agricultural census. The extent of cattle housing in tied systems, which has a lower NH<sub>3</sub> emission factor than loose housing, has decreased in the last years. The NH<sub>3</sub> emissions from swine and poultry are lower than in the 2021 submission due to the use of new data on raw protein content in fattening pig and broiler feed. See main page of the agricultural sector ([Chapter 5 - NFR 3 - Agriculture \(OVERVIEW\)](#)), list of **recalculation reasons, No. 1, 7, and 8**.

The overall NH<sub>3</sub> emissions of other animals increased for the years 2017-2019 due to newly available figures on animal numbers of sheep and horses, see recalculations reasons No. 1 ([Chapter 5 - NFR 3 - Agriculture \(OVERVIEW\)](#)), list of **recalculation reasons, No. 1**. Further details on recalculations are described in Vos et al. (2022), Chapter 3.5.2.

Tables REC-1 and REC-2: Comparison of the NH<sub>3</sub> and NO<sub>x</sub> emissions of the submissions (SUB) 2021 and 2022

<b>NH<sub>3</sub> emissions from manure management, in Gg</b>																
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Total</b>	<b>2022</b>	307.85	257.56	256.39	256.42	251.11	252.27	257.23	259.54	262.08	261.24	259.61	259.48	254.22	251.43	249.17
	<b>2021</b>	303.26	256.08	256.91	257.32	252.88	253.17	257.21	258.42	260.03	256.36	253.73	252.85	247.20	243.31	

<b>Dairy cattle</b>	<b>2022</b>	62.19	54.13	50.82	51.39	52.87	53.48	53.79	55.15	56.27	57.48	57.79	58.21	58.22	58.88	59.09
	<b>2021</b>	62.19	54.13	50.81	51.28	52.71	52.44	51.86	52.30	52.48	52.72	52.10	51.64	50.74	50.40	
<b>Other cattle</b>	<b>2022</b>	91.43	78.85	76.86	71.97	73.10	71.17	71.64	73.40	74.47	74.55	74.32	73.70	72.46	71.69	70.41
	<b>2021</b>	91.39	78.88	76.79	71.73	72.48	69.75	69.39	70.26	70.48	69.85	68.90	67.62	65.85	64.47	
<b>Swine</b>	<b>2022</b>	121.81	91.84	95.23	97.70	91.92	92.81	95.19	93.59	94.09	92.36	91.07	91.20	87.44	85.01	84.75
	<b>2021</b>	117.12	89.92	95.08	98.23	93.21	94.56	97.47	96.29	97.28	94.06	93.26	93.92	90.54	88.50	
<b>poultry</b>	<b>2022</b>	22.84	21.58	24.10	25.93	24.79	26.62	28.46	29.33	29.25	28.95	28.64	28.52	28.22	27.95	27.00
	<b>2021</b>	22.96	21.99	24.87	26.65	26.06	28.23	30.34	31.50	31.80	31.84	31.68	31.95	32.45	32.43	
<b>Other animals</b>	<b>2022</b>	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.85	7.88	7.90	7.93
	<b>2021</b>	9.59	11.16	9.37	9.43	8.43	8.18	8.16	8.07	8.00	7.89	7.79	7.72	7.62	7.51	

<b>NO<sub>x</sub> emissions from manure management, in Gg</b>																
	<b>SUB</b>	<b>1990</b>	<b>1995</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>	<b>2016</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>
<b>Total</b>	<b>2022</b>	1.731	1.554	1.516	1.505	1.487	1.460	1.439	1.437	1.444	1.436	1.427	1.416	1.393	1.379	1.365
	<b>2021</b>	1.720	1.551	1.523	1.534	1.529	1.502	1.480	1.475	1.482	1.465	1.455	1.444	1.418	1.401	
<b>Dairy cattle</b>	<b>2022</b>	0.671	0.597	0.570	0.553	0.524	0.517	0.501	0.499	0.503	0.507	0.506	0.503	0.503	0.507	0.506
	<b>2021</b>	0.671	0.597	0.570	0.552	0.521	0.513	0.495	0.491	0.493	0.495	0.494	0.489	0.488	0.489	
<b>Other cattle</b>	<b>2022</b>	0.690	0.604	0.587	0.550	0.548	0.529	0.525	0.534	0.539	0.538	0.535	0.530	0.521	0.515	0.506
	<b>2021</b>	0.696	0.614	0.600	0.566	0.562	0.538	0.529	0.532	0.532	0.526	0.519	0.509	0.497	0.487	
<b>Swine</b>	<b>2022</b>	0.281	0.256	0.270	0.309	0.320	0.318	0.317	0.307	0.305	0.295	0.289	0.287	0.273	0.262	0.258
	<b>2021</b>	0.264	0.242	0.263	0.322	0.351	0.355	0.359	0.353	0.357	0.344	0.343	0.346	0.335	0.328	
<b>poultry</b>	<b>2022</b>	0.026	0.024	0.027	0.032	0.039	0.042	0.043	0.045	0.045	0.045	0.045	0.045	0.045	0.044	0.044
	<b>2021</b>	0.026	0.024	0.028	0.033	0.040	0.043	0.045	0.047	0.048	0.048	0.048	0.048	0.049	0.049	
<b>Other animals</b>	<b>2022</b>	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.051	0.051	0.052	0.052
	<b>2021</b>	0.063	0.073	0.062	0.062	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.050	0.050	0.049	

#### Planned improvements

No improvements are planned at present.

## NMVOC

In 2020, NMVOC emissions from manure management amount to 289.8 which is 96.9 % of total NMVOC emissions from the agricultural sector. 84.7 % originate from cattle, 4.8 % from pigs, and 9.4 % from poultry.

### Method

The Tier 2 methodology provided by EMEP (2019)-3B-28 was used to assess the NMVOC emissions from manure management for dairy cattle and other cattle. For all other animals the Tier 1 methodology (EMEP (2019)-3B-17) was used.

### Activity data

Animal numbers serve as activity data, see Table 1.

### Emission factors

For the Tier 2 methodology applied to dairy cattle and other cattle the following data was used:

- gross feed intake in MJ per year, country specific data from the annual reporting of greenhouse gas emissions, see NIR 2022, Chapter 5.1.3.3,
- proportion  $x_{\text{house}}$  of the year the animals spend in the livestock building: country specific data, being equal to  $1 - x_{\text{graz}}$  with  $x_{\text{graz}}$  the proportion of the year spent on pasture, see NIR 2022, Chapter 19.3.2,



- $FRAC_{\text{silage}}$ : 1 as proposed by EMEP (2019)-3B-29, since silage feeding for cattle is considered dominant in Germany
- $FRAC_{\text{silage store}}$ : 0.25 as proposed by EMEP (2019)-3B-30 for European conditions
- $EF_{\text{NMVOC, silage feeding}}$ ,  $EF_{\text{NMVOC, house}}$ ,  $EF_{\text{NMVOC, graz}}$  are taken from EMEP (2019)-3B-32, table 3.11 as 0.0002002, 0.0000353 and 0.0000069 kg NMVOC/MJ feed intake, respectively,
- $EF_{\text{NH}_3\text{ storage}}$ ,  $EF_{\text{NH}_3\text{ building}}$  and  $EF_{\text{NH}_3\text{ application}}$  are taken from the  $\text{NH}_3$  reporting (see above and 3.D).

For all other animal categories the Tier 1 emission factors for NMVOC were used as provided in EMEP (2019)-3B-18, Table 3.4 [10]: For horses the emission factors for feeding with silage was chosen, for all other animals the emission factors for feeding without silage. Due to missing country-specific emission factors or emission factors that do not correspond to the inventory's animal categories, the emission factors provided in EMEP (2019)-3B-18, Table 3.4, were used to define specific emission factors for weaners, boars, lambs, ponies/light horses and pullets, see Vos et al. (2022), Chapter 3.3.4.2. The implied emission factors given in Table 4 relate the overall NMVOC emissions to the number of animals in each animal category. The IEFs for dairy cattle and other cattle are much higher than the EMEP Tier 1 EF, which are 17.937 kg NMVOC for dairy cattle and 8.902 kg NMVOC for other cattle. The only possible explanation for those huge differences is that the EMEP Tier 2 and Tier 1 methods are not consistent.

The IEFs for the other categories provided in Table 4 correspond to the EMEP Tier 1 emission factors, except for horses, sheep, swine and other poultry. These categories comprise subcategories with different emission factors so that their overall IEFs in Table 4 represent subpopulation-weighted national mean values. Note that other poultry in Germany includes not only geese and ducks but also pullets. For pullets no default EF is given in the EMEP guidebook (EMEP, 2019), hence the EF of broilers has been adopted (because of similar housing). This assumption significantly lowers the overall IEF of other poultry in Table 4 (the IEFs are listed separately for each poultry category). The IEF of the sheep category is significantly lower than the EMEP Tier 1 emission factor, because for lambs the EF is assumed to be 40% lower compared to an adult sheep in accordance with the difference in N excretion between lambs and adult sheep.

Table 4: IEF for NMVOC from manure management

IEF in kg NMVOC per animal place															
	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>dairy cattle</b>	30.940	32.695	35.472	36.709	37.242	37.609	37.625	37.467	37.891	38.155	38.552	38.524	39.322	40.134	40.799
<b>other cattle</b>	11.738	11.729	11.852	11.720	11.769	11.694	11.638	11.617	11.540	11.533	11.483	11.475	11.481	11.533	11.574
<b>horses</b>	6.497	6.491	6.688	6.660	6.644	6.643	6.642	6.641	6.644	6.646	6.648	6.651	6.654	6.657	6.660
<b>sheep</b>	0.131	0.131	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
<b>goats</b>	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542	0.542
<b>swine</b>	0.695	0.698	0.690	0.682	0.669	0.663	0.656	0.654	0.652	0.651	0.649	0.648	0.648	0.648	0.642
<b>laying hens</b>	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
<b>broilers</b>	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
<b>turkeys</b>	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489
<b>pullets</b>	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108	0.108
<b>ducks</b>	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489
<b>geese</b>	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489	0.489

### Trend discussion for Key Sources

Dairy cattle and other cattle are key sources of NMVOC emissions from manure management. The total NMVOC emissions from both animal categories strongly correlate with the animal numbers given in Table 1 (dairy cattle:  $R^2 = 0.887$ ; other cattle:  $R^2 = 0.998$ ).

### Recalculations

All time series of the emission inventory have completely been recalculated since 1990. Table REC-3 compares the recalculated time series of the NMVOC emissions from 3.B with the respective data of last year's submission. The recalculated total emissions are slightly lower in some years and slightly higher in other years. This is due to improved methodology for the suckler cows (**recalculation reason 4**, see [main page of the agricultural sector](#)) and the use of the data from the official agricultural census of 2020 (recalculation reason 1) which are changing the  $\text{NH}_3$  emissions that have impact to the Tier 2 methodology which is applied for cattle NMVOC emissions. For other animals there are differences back to the year 2017. These differences are caused by updated animal numbers (see above). Further details on recalculations

are described in Vos et al. (2022), Chapter 3.5.2.

Table REC-3: Comparison of NMVOC emissions of the submissions (SUB) 2021 and 2022

NMVOC emissions from manure management, in Gg																
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	2022	391.24	332.95	318.87	298.26	297.23	297.42	299.37	304.56	306.95	305.72	302.74	299.98	296.20	293.49	289.79
	2021	390.80	332.18	318.01	297.65	296.79	297.13	299.17	304.38	306.74	305.38	303.07	300.94	297.86	295.83	
Dairy cattle	2022	196.61	170.97	162.10	155.51	155.79	157.59	157.67	159.89	162.77	163.48	162.60	161.76	161.25	161.00	159.99
	2021	196.61	170.97	162.10	155.50	155.75	157.45	157.39	159.40	162.04	162.45	161.82	161.15	160.81	160.84	
Other cattle	2022	154.16	125.04	118.15	103.14	101.55	97.54	96.82	97.80	97.48	96.31	94.72	92.75	90.10	87.97	85.42
	2021	153.72	124.27	117.29	102.54	101.14	97.38	96.89	98.11	98.00	97.00	95.83	94.23	91.95	90.15	
Other animals	2022	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.47	44.85	44.52	44.38
	2021	40.46	36.94	38.62	39.61	39.89	42.29	44.89	46.87	46.70	45.93	45.42	45.56	45.11	44.84	

### Planned improvements

No improvements are planned at present.

## TSP, PM<sub>10</sub> and PM<sub>2.5</sub>

In 2020, TSP emissions from manure management amount to 71.3 % of total emissions from the agricultural sector. Within the emissions from manure management 22.5 % originate from cattle, 39.5 % from pigs, and 37.4 % from poultry. 42.8 % of the PM<sub>10</sub> emissions from the agricultural sector are caused by manure management, where 34.4 % originate from cattle, 19.1 % from pigs, and 45.6 % from poultry. PM<sub>2.5</sub> emissions from the agricultural sector mostly originate from manure management (84.9 %), of which are 78.0 % from cattle, 3.0 % from pigs, and 17.5 % from poultry.

### Method

EMEP (2013-3B-26) provided a Tier 2 methodology. In the current Guidebook (EMEP, 2019), this methodology has been replaced by a Tier 1 methodology. However, EF for cattle derived with the EMEP 2013 Tier 2 methodology remained unchanged. Therefore, the EMEP 2013<sup>10)</sup> methodology was kept for cattle. For swine the EMEP 2013 methodology was formally kept but the EMEP 2019 Tier 1 EF was used both for slurry and solid based manure management systems. The same was done with the EMEP 2016 EFs for laying hens (used for cages and perchery). In case the EMEP 2019 EFs are simply rounded EMEP 2013 EFs, the unrounded EMEP 2013 EFs were kept. The inventory considers air scrubber systems in swine and poultry husbandry. For animal places equipped with air scrubbing the emission factors are reduced according to the removal efficiency of the air scrubber systems (90 % for TSP and PM<sub>10</sub>, 70 % for PM<sub>2.5</sub>). For details see Vos et al. (2022), Chapter 3.3.4.3.3.

### Activity data

Animal numbers serve as activity data, see Table 1.

### Emission factors

Tier 1 emission factors for TSP, PM<sub>10</sub> and PM<sub>2.5</sub> from livestock husbandry are provided in EMEP (2019-3B-19), Table 3.5 and 55, Table A1.7. For cattle the Tier 2 emission factors provided in EMEP (2013-3B-29), Table 3-11 were used, because they differentiate between slurry and solid manure systems and were also used to develop the EMEP 2019 Tier 1 emissions factors.

The implied emission factors given in Table 5 relate the overall TSP and PM emissions to the number of animals in each animal category. The Guidebook does not indicate whether EFs have considered the condensable component (with or without).

Table 5: IEF for TSP, PM<sub>10</sub> & PM<sub>2.5</sub> from manure management

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>IEF in kg TSP per animal place</b>															
dairy cattle	1.2124	1.4016	1.4544	1.4738	1.4882	1.4953	1.5028	1.5101	1.5189	1.5270	1.5365	1.5451	1.5540	1.5631	1.5721
other cattle	0.5194	0.5107	0.5017	0.4916	0.4804	0.4790	0.4788	0.4788	0.4775	0.4766	0.4763	0.4760	0.4758	0.4751	0.4746
horses	0.3514	0.3512	0.3558	0.3552	0.3548	0.3548	0.3548	0.3548	0.3548	0.3549	0.3549	0.3550	0.3551	0.3551	0.3552
sheep	0.0484	0.0478	0.0489	0.0486	0.0489	0.0485	0.0485	0.0485	0.0483	0.0482	0.0482	0.0482	0.0480	0.0482	0.0482
goats	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914	0.0914
swine	0.8260	0.8366	0.8320	0.8247	0.8104	0.8043	0.8086	0.8037	0.8002	0.7910	0.7918	0.7891	0.7865	0.7813	0.7858
laying hens	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1900	0.1899	0.1898	0.1897	0.1894	0.1890	0.1889
broilers	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0399	0.0399	0.0397	0.0396	0.0395	0.0394	0.0394
turkeys	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
pullets	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
ducks	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
geese	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400
<b>IEF in kg PM<sub>10</sub> per animal place</b>															
dairy cattle	0.5557	0.6426	0.6668	0.6757	0.6823	0.6855	0.6890	0.6923	0.6964	0.7001	0.7044	0.7084	0.7125	0.7166	0.7208
other cattle	0.2403	0.2363	0.2320	0.2273	0.2221	0.2214	0.2213	0.2213	0.2207	0.2203	0.2202	0.2200	0.2200	0.2196	0.2194
horses	0.1619	0.1619	0.1639	0.1636	0.1634	0.1634	0.1634	0.1634	0.1634	0.1634	0.1635	0.1635	0.1635	0.1635	0.1636
sheep	0.0194	0.0192	0.0196	0.0195	0.0196	0.0195	0.0194	0.0194	0.0194	0.0193	0.0193	0.0193	0.0192	0.0193	0.0193
goats	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368	0.0368
swine	0.1241	0.1255	0.1244	0.1230	0.1199	0.1187	0.1185	0.1177	0.1170	0.1158	0.1156	0.1151	0.1147	0.1139	0.1141
laying hens	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0399	0.0399	0.0398	0.0398
broilers	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0199	0.0198	0.0198	0.0198	0.0197	0.0197
turkeys	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100	0.1100
pullets	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
ducks	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400	0.1400
geese	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400	0.2400
<b>IEF in kg PM<sub>2.5</sub> per animal place</b>															
dairy cattle	0.3616	0.4181	0.4338	0.4396	0.4439	0.4460	0.4483	0.4505	0.4531	0.4555	0.4583	0.4609	0.4636	0.4663	0.4690
other cattle	0.1574	0.1548	0.1520	0.1490	0.1457	0.1453	0.1452	0.1452	0.1448	0.1445	0.1445	0.1444	0.1443	0.1441	0.1439
horses	0.1027	0.1026	0.1039	0.1038	0.1036	0.1036	0.1036	0.1036	0.1036	0.1037	0.1037	0.1037	0.1037	0.1037	0.1038
sheep	0.0059	0.0059	0.0060	0.0060	0.0060	0.0060	0.0060	0.0060	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059	0.0059
goats	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112	0.0112
swine	0.0056	0.0057	0.0056	0.0056	0.0054	0.0054	0.0053	0.0053	0.0053	0.0052	0.0052	0.0052	0.0052	0.0052	0.0051
laying hens	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030
broilers	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
turkeys	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200
pullets	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
ducks	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180	0.0180
geese	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320	0.0320

### Trend discussion for Key Sources

Swine and laying hens are key sources of TSP emissions from manure management. The total TSP emissions from swine mainly follow the animal numbers given in Table 1. However, due to air scrubbing and different emission factors of the different housing systems of the four swine subcategories (sows with piglets, weaners, fattening pigs, boars) and the varying population shares in those housing systems the R<sup>2</sup> of the linear regression is lower than 1 (0.78). For laying hens and

broilers, due to the low prevalence of air scrubbing systems. TSP emissions almost perfectly correlate with the animal numbers provided in Table 1 ( $R^2 = 1$ ).

## Recalculations

Table REC-4 shows the effects of recalculations on emissions of particulate matter. Changes in the years 1990 through 1999 are a consequence of the update of the dairy cow model (**recalculation reason 1**, see [main page of the agricultural sector](#)). This update includes a modified calculation of the share of year spent on pasture, resulting in longer grazing periods and therefore lower emissions of particulate matter from manure management in the years 1990 through 1999. Differences of TSP and PM emissions in the years as of 2005 are due to updated activity data of air scrubbing systems for sows, weaners, fattening pigs and broilers, see **recalculation reasons 8 and 10** on [the main page of the agricultural sector](#). Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-4: Comparison of particle emissions (TSP,  $PM_{10}$  &  $PM_{2.5}$ ) of the submissions (SUB) 2020 and 2021

TSP, PM10, PM2.5 emissions from manure management, in Gg																
	SUB	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TSP	2022	50.04	42.24	42.43	41.25	40.30	41.80	43.95	45.14	45.45	44.74	44.54	44.59	43.65	43.04	42.99
TSP	2021	50.04	42.24	42.44	41.26	40.32	41.79	43.90	45.06	45.33	44.58	44.35	44.40	43.55	42.90	
PM <sub>10</sub>	2022	14.34	12.71	12.63	12.29	12.31	12.76	13.33	13.84	13.82	13.63	13.48	13.43	13.20	13.02	12.91
PM <sub>10</sub>	2021	14.34	12.71	12.63	12.29	12.32	12.75	13.31	13.80	13.77	13.56	13.39	13.36	13.17	13.00	
PM <sub>2.5</sub>	2022	5.01	4.47	4.18	3.89	3.85	3.87	3.93	4.03	4.04	4.02	3.97	3.94	3.86	3.79	3.72
PM <sub>2.5</sub>	2021	5.01	4.47	4.18	3.89	3.86	3.86	3.91	4.01	4.01	3.97	3.91	3.88	3.80	3.72	

## Planned improvements

No improvements are planned at present.

## Uncertainty

Details will be described in [chapter 1.7](#).

<sup>1)</sup>

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<sup>3)</sup>

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<sup>4)</sup>

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<sup>5)</sup>

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<sup>7)</sup>

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<sup>9)</sup>

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<sup>10)</sup>

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