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_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$, NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	L: NH_3 (for 3.B.1.a)
3.B.2, 3.B.4.d, 3.B.4.e	Sheep, Goats, Horses	T2 (NH_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 ,NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	
3.B.3	Swine	T3 (NH_3), T2 (NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, 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_3 , NO_x , TSP, PM_{10} , $PM_{2.5}$), T1 (NMVOC)	NS, RS	CS (NH_3 , NO_x), D (TSP, PM_{10} , $PM_{2.5}$, NMVOC)	T: NH_3 (for 3.B.4.g iii)
3.B.4.h	Other animals				NE

Key Category	SO_2	NO_x	NH_3	NMVOC	CO	BC	Pb	Hg	Cd	Diox	PAH	HCB	TSP	PM_{10}	$PM_{2.5}$
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	
D	Default
RA	Reference Approach
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/CORINAIR Emission Inventory Guidebook - 2007, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
AS	Associations, business organisations

AD - Data Source for Activity Data	
Q	specific questionnaires, surveys

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific
PS	Plant Specific data

Country specifics

In 2020, NH_3 emissions from category 3.B (manure management) were 48.6 % from total agricultural emissions, which is equal to ~ 249.2 kt NH_3. Within those emissions 52.0 % originate from cattle manure (~ 129.5 kt), 34.0 % from pig manure (ca. 84.7 kt), and 10.8 % from poultry manure (~ 27.0 kt). Calculations take into account the impact of anaerobic digestion of manure on the emissions.

NO_x emissions from category 3.B (manure management) contribute only 1.3 % (~ 1.4 kt) to the total agricultural NO_x emissions. They are calculated proportionally to N_2O emissions, see Vos et al. (2022) [1].

NMVOC emissions from category 3.B (manure management) contributed 96.9 % (289.8 kt) from total agricultural NMVOC 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, PM_{10} and $PM_{2.5}$ emissions (TSP: 60.3 kt, PM_{10}: 30.2 kt, $PM_{2.5}$: 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 [2)], 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, [3)] 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 UmweltInformationsystem 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) [4)]; a detailed description is provided in Henrichsmeyer et al. (1996) [5)].

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 RAUMIS model data (1999) and the first official data (2010) were closed by linear interpolation on district level. For the year 2020 data from the 2020 official agricultural census (Landwirtschaftszählung 2020) are used for housing systems, storage systems and manure spreading systems. For 2011 to 2019 the housing and storage systems data was linearly interpolated between the censuses of 2010 and 2020. The data on manure spreading techniques was linearly interpolated between the census data from 2010 and 2015, and for 2016 to 2019 between the censuses conducted in 2015 and 2020. In addition, it was taken into account that, as of 2012, slurry spread on bare soil has to be incorporated within four hours. For a description of the RAUMIS data, the data from official surveys and additional data from other sources see Vos et al. (2022), Chapter 3.4. Time series of frequency distributions of housing systems, storage systems and application techniques as well as the corresponding emission factors are provided in NIR 2022, Chapter 19.3.2.

NH_3 and NO_x

Method

N in manure management

N excretion

In order to determine NH_3 and NO_x emissions from manure management of a specific animal category, the individual N excretion rate must be known as well as, for 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[6]. 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

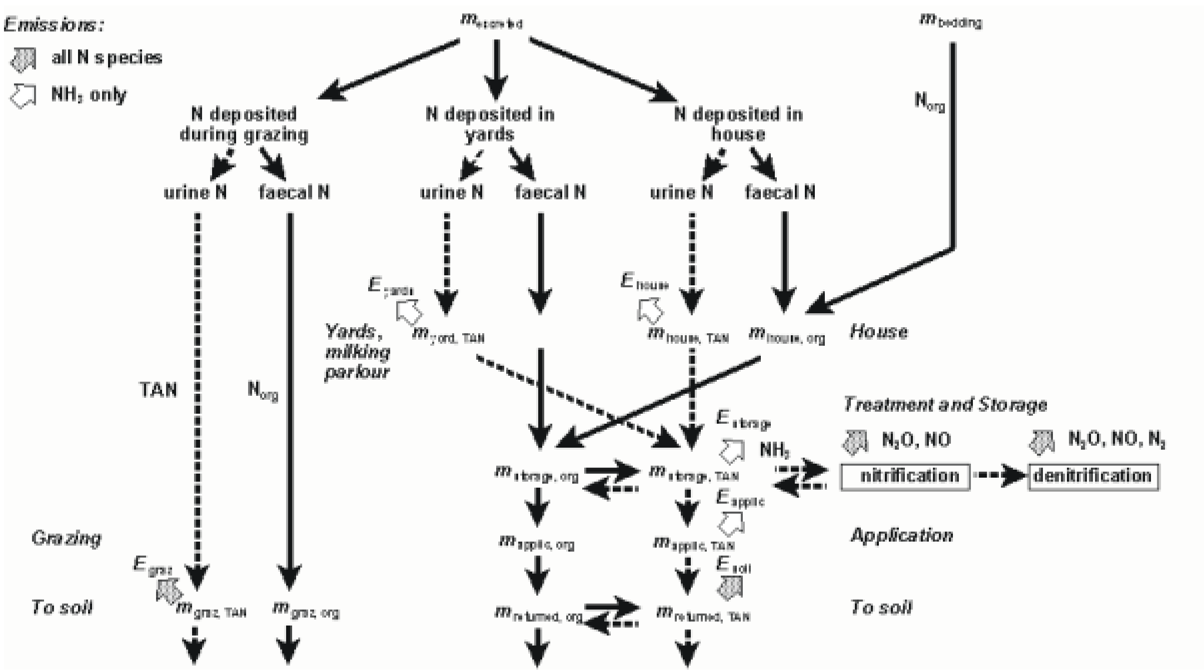
	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
mean N excretions in kg per animal place															
dairy cattle	92.0	97.9	103.8	108.9	110.3	110.9	111.1	110.5	111.5	112.8	114.2	113.9	116.4	119.5	121.8
other cattle	37.9	39.9	41.3	41.2	42.1	42.0	42.0	42.1	42.2	42.5	42.5	42.7	42.9	43.3	43.7
horses	48.2	48.1	49.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
sheep	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
goats	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
swine	13.0	13.4	13.2	13.0	12.8	12.8	12.8	12.8	12.8	13.0	13.1	13.1	13.1	13.0	13.0
laying hens	0.81	0.78	0.76	0.79	0.87	0.87	0.88	0.88	0.88	0.89	0.89	0.89	0.90	0.90	0.90
broilers	0.48	0.41	0.45	0.49	0.51	0.48	0.42	0.38	0.40	0.40	0.40	0.40	0.41	0.40	0.39
turkeys	2.0	2.0	2.0	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.1
pullets	0.32	0.29	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29
ducks	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
geese	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
mean TAN contents in %															
dairy cattle	58.0	55.0	52.9	51.3	49.9	49.5	49.2	49.1	48.6	48.5	48.2	48.0	47.4	47.0	46.6
other cattle	65.5	65.7	65.7	65.7	66.0	66.1	66.1	66.2	66.3	66.3	66.3	66.3	66.3	66.4	66.4
horses	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
sheep	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
goats	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
swine	72.0	71.7	71.1	71.8	72.3	72.1	71.9	71.8	71.7	71.8	71.7	71.6	71.5	71.4	71.3
laying hens	70.2	69.6	69.0	69.3	70.0	70.0	70.0	70.2	70.2	70.2	70.2	70.2	70.2	70.2	70.2
broilers	60.8	58.9	56.4	53.5	50.0	49.4	48.8	48.2	47.6	46.9	46.5	46.1	45.7	45.2	44.8

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
turkeys	64.7	64.7	63.0	63.9	63.0	63.1	63.8	63.5	63.5	63.5	63.5	63.3	63.0	63.0	62.1
pullets	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8	67.8
ducks	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9	49.9
geese	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0

N mass flow and emission assessment

The calculation of the emissions of NH_3, N_2O, NO_x and N_2 from German animal husbandry is based on the so-called N mass flow approach (e. g. Dämmgen and Hutchings, 2008 [7]). 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 NH_3 emissions (EMEP, 2019), and the IPCC guidelines for greenhouse gas emissions (IPCC (2006)[8]. Reidy et al. (2008),[9], 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_{yard} NH_3 emissions from yards; E_{house} NH_3 emissions from house; $E_{storage}$ NH_3, N_2O, NO_x and N_2 emissions from storage; E_{applic} NH_3 emissions during and after spreading; E_{graz} NH_3, N_2O, NO_x and N_2 emissions during and after grazing; E_{soil} N_2O, NO_x and 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 NH_3 is emitted, its formation is related to the amount of the TAN present. N_2O emissions are related to the total amount of N available (Norg + TAN). NO_x emissions (i. e. NO emissions) are calculated proportionally to the N_2O emissions, see section 'Emission factors'. Note that the N_2O, NO_x and N2 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 NH_3 is 80 % for swine and 70 % for poultry, while for TSP and PM_{10} the rates are set to 90 % and for $PM_{2.5}$ to 70 % for both animal categories. For swine two types of air scrubbers are distinguished: certified systems that remove both NH_3 and particles, and non-certified systems that remove only particles.

According to the KTBL data, 7.5 % of all pig places were equipped with certified systems in 2020, another 0.7 % were equipped with non-certified systems. For poultry 0.6 % of all laying hen places and 1.8 % of all broiler places were equipped with air scrubbers that remove both NH_3 and particles. The amounts of NH_3-N removed by air scrubbing are completely added to the pools of total N and TAN for landspreading. For details see Vos et al. (2022), Chapter 3.3.4.3.3.

Anaerobic digestion of manure

According to IPCC (2006), anaerobic digestion of manure is treated like a particular storage type that, however, comprises three sub-compartments (pre-storage, fermenter and storage of digestates). For details see Vos et al. (2022), Chapters 3.3.4.4 and 3.4.4.2. The resulting digestates are considered as liquid. Two different types of digestates storage systems are considered: gastight storage and open tank. For open tanks formation of a natural crust because of co-fermentation with energy crops is taken into account. Furthermore, the modelling of anaerobic digestion and spreading of the digestates takes into account that the amount of TAN in the digestates is higher than in untreated slurry and that the frequencies of spreading techniques differ from those for untreated slurry.

NH_3 and NO emissions occur from pre-storage of solid manure, from non-gastight storage of digestates and from land-spreading of digestates (NH_3 emissions and NO emissions from landspreading of digested manure are reported in 3.Da.2.a). There are no such emissions from pre-storage of slurry, from the fermenter and from gastight storage of digestates. Note that NH_3 and NO emissions calculated with respect to the digestion of animal manures do not comprise the contributions by co-digested energy crops. The latter are dealt with separately in 3.D.a.2.c and 3.I.

Emission Factors

Application of the N mass flow approach requires detailed emission factors for NH_3, N_2O, NO_x and N_2 describing the emissions from the various housing and storage systems.

The detailed NH_3 emission factors are, in general, related to the amount of TAN available at the various stages of the N flow chain. The emission factors for laying hens, broilers, pullets, ducks and turkeys are related to N. Most NH_3 emission factors are country-specific but some are taken from EMEP (2019). No specific NH_3 emission factors are known for the application of digested manure. However, due to co-fermentation with energy crops, the viscosity of digested manure resembles that of untreated cattle slurry. Hence, the emission factors for untreated cattle slurry are adopted for the application of digested manure. For the detailed emission factors of livestock husbandry see Vos et al. (2022), Chapters 4 to 8; for emission factors of digested manure see Vos et al. (2022), Chapter 3.4.4.2.4. Table 3 provides, by animal category, the implied NH_3 emission factors for manure management (housing and storage). The overall German NH_3 IEF for manure application is reported in section 3.D.a.2.a.

The detailed emission factors for N_2O, NO_x and N_2 relate to the amount of N available which is N excreted plus, in case of solid manure systems, N input with bedding material. The N_2O emission factors are taken from IPCC (2006). The emission factors for NO_x and N_2 are approximated as being proportional to the N_2O emission factors, i.e. the NO-N and N_2 emission factors are, respectively, one-tenth and three times the value of the N_2O-N emission factor, see Vos et al. (2022), chapter 3.3.4.3.5. This proportionality is also applied to anaerobic digestion of manure, where N_2O emissions occur from pre-storage of solid manure and non-gastight storage of digestates with the emission factors being those used for normal storage of solid manure and the storage of untreated slurry with natural crust provided by IPCC (2006). Note that the inventory model calculates NO rather than NOx. The conversion of NO emissions into NO_x emissions is achieved by multiplying the NO emissions with the NO_2/ NO molar weight ratio of 46/30. This relationship also holds for NO and NO_x emission factors.

Table 3 shows the implied emission factors of NH_3 and NO_x for the various animal categories. These emission factors normalize emissions from an animal category as the ratio of the total emission to the respective number of animals.

Table 3: IEF for NH_3 & NO_x from manure management

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IEF in kg NH_3 per animal place															
dairy cattle	9.8	10.4	11.1	12.1	12.6	12.8	12.8	12.9	13.1	13.4	13.7	13.9	14.2	14.7	15.1
other cattle	7.0	7.4	7.7	8.2	8.5	8.5	8.6	8.7	8.8	8.9	9.0	9.1	9.2	9.4	9.5
horses	13.5	13.5	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
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
IEF in kg NO_x per animal place															
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_3 emissions from manure management. The time series of the total NH_3 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_3 from the housings.

For NO_x 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_3 and NO_x from 3B with the respective data of last year's submission. The total emissions of NH_3 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_3 emission factor than loose housing, has decreased in the last years. The NH_3 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_3 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_3 and NO_x emissions of the submissions (SUB) 2021 and 2022

NH₃ emissions from manure management, in Gg																
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Total	**2022**	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
	2021	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	
Dairy cattle	**2022**	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
	2021	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	
Other cattle	**2022**	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
	2021	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	
Swine	**2022**	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
	2021	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	
poultry	**2022**	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
	2021	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	
Other animals	**2022**	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
	2021	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	

NOₓ emissions from manure management, in Gg																
	SUB	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Total	**2022**	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
	2021	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	
Dairy cattle	**2022**	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
	2021	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	
Other cattle	**2022**	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
	2021	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	
Swine	**2022**	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
	2021	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	
poultry	**2022**	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
	2021	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	
Other animals	**2022**	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
	2021	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 2019, NMVOC emissions from manure management amount to 295.8 which is 97.2 % of total NMVOC emissions from the agricultural sector. 84.8 % originate from cattle, 4.7 % from pigs, and 9.4 % from poultry. All NMVOC emissions from the agricultural sector are excluded from emission accounting by adjustment as they are not considered in the NEC and Gothenburg commitments (see Chapter 11 - Adjustments and Emissions Reduction Commitments).

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 2021, Chapter 5.1.3.3,
- proportion x_{house} of the year the animals spend in the livestock building: country specific data, being equal to 1 – x_{graz} with x_{graz} the proportion of the year spent on pasture, see NIR 2021, Chapter 19.3.2,
- $FRAC_{silage}$: 1 as proposed by EMEP (2019)-3B-29, since silage feeding for cattle is considered dominant in Germany
- $FRAC_{silage\ store}$: 0.25 as proposed by EMEP (2019)-3B-30 for European conditions
- $EF_{NMVOC,\ silage\_feeding}$, $EF_{NMVOC,\ house}$, $EF_{NMVOC,\ graz}$ are taken from EMEP (2019)-3B-32, table 3.11 as 0.0002002, 0.0000353 and 0.0000069 kg NMVOC/MJ feed intake, respectively,
- $EF_{NH_3,storage}$, $EF_{NH_3,building}$ and $EF_{NH_3,application}$<sub> are taken from the NH<sub>3 reporting (see above and 3.D).

For all other animal categories the Tier 1 emission factors for NMVOC as provided in EMEP (2019)-3B-18, Table 3.4 [10] were used: 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 Rösemann et al. (2021), 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 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**
dairy cattle	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
other cattle	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
horses	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
sheep	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
goats	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
swine	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
laying hens	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
broilers	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
turkeys	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
pullets	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
ducks	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
geese	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 = 0.895; other cattle: R^2 = 0.995).

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 lower by 4 to 11 %. This is due to improved methodology for the cattle sector (**recalculation reasons 1 through 4**, see main page of the agricultural sector). Emissions of other animals remained unchanged. Further details on recalculations are described in Rösemann et al. (2021), Chapter 3.5.2.

Table REC-3: Comparison of NMVOC emissions of the submissions (SUB) 2020 and 2021

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, PM10 and PM2.5

In 2019, TSP emissions from manure management amount to 71.1 % of total emissions from the agricultural sector. Within the emissions from manure management 22.4 % originate from cattle, 39.3 % from pigs, and 37.7 % from poultry. 42.7 % of the PM_{10} emissions from the agricultural sector are caused by manure management, where 34.0 % originate from cattle, 18.9 % from pigs, and 46.2 % from poultry. $PM_{2.5}$ emissions from the agricultural sector mostly originate from manure management (84.8 %), of which are 77.5 % from cattle, 3.0 % from pigs, and 18.0 % from poultry.

Method

EMEP (2013)-3B-26 [9] 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. So the EMEP 2013[10)] 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 just the 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_{10}, 70 % for $PM_{2.5}$). For details see Rösemann et al. (2021), 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_{10} and $PM_{2.5}$ 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_{10} & $PM_{2.5}$ from manure management

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
IEF in kg TSP per animal place															
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
IEF in kg PM_{10} per animal place															
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
IEF in kg $PM_{2.5}$ per animal place															
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^2 of the linear regression is lower than 1 (0.79). 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**
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
TSP	**2020**	50.26	42.41	42.44	41.26	40.32	41.79	43.91	45.07	45.36	44.61	44.39	44.44	43.62	
PM_{10}	**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_{10}	**2020**	14.44	12.78	12.63	12.29	12.32	12.75	13.31	13.80	13.78	13.57	13.40	13.38	13.19	
$PM_{2.5}$	**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
$PM_{2.5}$	**2020**	5.08	4.52	4.18	3.89	3.86	3.86	3.91	4.01	4.01	3.97	3.91	3.88	3.80	

Planned improvements

No improvements are planned at present.

Uncertainty

Details will be described in chapter 1.7.

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