



MELS DELIVERABLE D5.3

D5.3: Guidance document on methods to obtain activity data to support emission inventories

WP5: Improving national emission inventories and projections

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Authors:

ATB: Federico Dragoni, Gültac Cinar, Barbara Amon



MELS partners

ATB	Leibniz Institute for Agricultural Engineering and Bioeconomy	Germany	
AU	Aarhus University	Denmark	
TEAG	TEAGASC – Agriculture and Food Development Authority	Ireland	
AgR	AgResearch	New Zealand	
UZG	University of Zielona Góra	Poland	
INIA	Instituto de Investigaciones Agropecuarias	Chile	
IN1	INRAe UMR Sol, Agro et hydro systèmes, Spatialisation	France	
IN2	INRAe, UMR Ecosystème Prairial	France	
CUBS	Cork University Business School	Ireland	
AUA	Agricultural University of Athens	Greece	



Table of Contents

Introduction	5
Activity data used for GHG and NH ₃ emission inventories.....	6
Methodology.....	6
Summary of survey results.....	7
Detailed survey results	13
How are activity data collected for emission inventories?	13
Animal category/number information availability.....	14
Diet Composition information availability.....	16
Feed Intake/Energy requirement information availability	18
Nex values calculation/information availability	19
VS excretions calculations/information availability	22
Manure Management/Waste management Systems (MMS or WMS) information.....	24
Influence of application time on stored liquid slurry information availability.....	26
Animal housing information availability	28
Farmyard manure management/distribution information availability	29
Greatest barriers for maintaining and improving the accuracy and detail of activity data.....	30
Approaches for the improvement of inventories and the collection of activity data including the reduction of uncertainties.....	32
Uncertainties in national emission inventories.....	36
Assessing the availability and relevance of activity data	38
MELS traffic light system on the collation of activity data at farm and at national level.....	39
Ammonia.....	41
Nitrous oxide.....	43
Methane	45
References.....	47



Introduction

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 CH₄ and NH₃ 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.

Activity data collection has a significant impact on the estimation of air pollutant and GHG emissions. The definition of activity data collection methodologies should ensure the best balance between quality, uncertainty and effort to collect these data. For instance, performing regularly farm-level surveys or introducing questionnaires that cover many aspects of farm activities can improve the quality of activity data minimising uncertainties. Surveys are required where national country statistics do not cover relevant activity data.

In MELS WP2, NH₃, N₂O and CH₄ emission data and activity/ancillary data from the manure storage and livestock housing components of the manure management chain were gathered from scientific and grey literature, and then collated to the DATAMAN database (<https://www.dataman.co.nz/>). The analysis carried out in WP3 allowed to calculate emission factors related to several specific environmental and management conditions. Functional relationships linking the emission factors to continuous variables into linear models valid into specific value ranges (e.g. barn temperature ranges, manure organic C ranges, etc.) were also drawn. The specific emission factors and the functional relationships need the collected activity data to fulfil certain requirements, or they would have scarce chance of being adopted.

Finally, MELS WP5 analysed the activity data used by selected countries to estimate N₂O, CH₄ and NH₃ emissions of livestock systems, developing a guidance on relevant activity data to support emission inventories owing to i) the needs highlighted by inventory experts, and ii) the needs emerged from the results of the experimental activity in MELS WP3. This report contains the outcomes of the survey on emission inventory reports from selected countries, carried out in collaboration with the whole MELS consortium and inventory experts from the MELS countries and other countries, as well as an outlook on further improvements to the collection of activity data (T5.3).



Activity data used for GHG and NH₃ emission inventories

Methodology

A questionnaire to review the methods to obtain activity data to support national emission inventories was prepared and circulated to all MELS partners. The questions included were:

1. How are activity data collected for emission inventories?
2. Animal category/number: information availability
3. Diet Composition: information availability
4. Feed Intake/Energy requirement: information availability
5. Nex values: calculation/information availability
6. VS excretions: calculations/information availability
7. Manure Management/Waste management Systems (MMS or WMS) information
8. Influence of application time on stored liquid slurry: information availability
9. Animal housing: information availability
10. Farmyard manure management/distribution: information availability

The questionnaires were completed for Germany, Austria, Greece, Denmark, France, Poland, New Zealand and Ireland. A table was prepared to compare the data gathered for emission calculations in each country. Furthermore, a final section reports additional information voluntarily provided by the experts of some of the surveyed countries about the greatest barriers for maintaining and improving the accuracy and detail of the inventories.



MELS DELIVERABLE D5.3



Summary of survey results

Table 1. Summary of survey results. CS=country-specific; N.C.=Not considered by the methodology

	Germany	Austria	Greece	Denmark	Poland	France	Ireland	New Zealand
<i>How activity data are collected</i>	Official statistics, association statistics, scientific studies and third-party research projects	Several statistics collected by "Statistik Austria" and national/international studies	National statistics	Obligatory annual reporting to government from all farmers	National statistics and expert information	Most of the data provided by statistics, some data are collected from specific surveys (not on a yearly basis)	The majority of data compiled and published by the Central Statistics	Annually collated by statistics authorities, livestock corporations
Animal category/number information	Provided by The Federal Statistical Office and the statistical offices of the states and annual LS censuses	Provided annually by The Austrian official statistics	Annually reported	Obligatory annual reporting to government from all farmers	Annually available from national statistics	Available from statistics	Provided by the Central Statistics	Annually collated by statistics authorities



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Diet composition information	CS data reported by the Thünen Institute	CS Cattle diet composition is available in the inventories.	No data at country level	CS data from farmer advisory organisations	N.C.	CS information available	CS information available	CS The inventory methodology for diet composition is in the process of being revised.
Feed intake/Energy requirement information	CS information available for dairy cows, other cattle and swine	CS information available for dairy cows and other cattle	No data at country level, GEI is estimated according to IPCC Tier 2	CS data from farmer advisory organisations	Default IPCC methodology With CS data for all cattle, D values for other animals	CS information available	CS for cattle IPCC Tier 1 for all other LS	CS for for dairy and beef cattle, sheep and deer. Other LS types IPCC Tier 1



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Nex values calculation	N excretions are calculated as the difference between the amount of N taken in with feed and basic and yield-based N requirements	The Austrian N excretion data were calculated following the guidelines of the European Commission according to the requirements of the European nitrate directive	Dairy cattle: IPCC Tier 2 All other anima: D	CS calculations by the Dept of Animal Sciences, Aarhus University	A mix of CS and IPCC methodology depending on the LS type	CS calculation methods	CS calculation for cattle For other LS, estimates are derived from SI 605 of 2017	CS for for dairy and beef cattle, sheep and deer. Other LS types IPCC Tier 1
VS excretions calculations	CS calculation for dairy cows, other cattle, swine and poultry	CS For sucking cows: calculated depending on milk yield For cattle: CS feed intake with IPCC Tier 2 methodology For swine: derived from CS data and kept constant	Default IPCC methodology	CS calculations by the Dept of Animal Sciences, Aarhus University	Dairy: IPCC methodology with CS data Swine: Default IPCC values Other LS: not available	CS calculation methods for cattle, pigs, sheep and goats. For default values from the 2006 IPCC GLs	CS evaluation	IPCC Tier 2 with CS EFs and IPCC Tier 1 for minor LS classes



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<p>MMS/ WMS information</p>	<p>CS annual frequency distributions of storage systems are provided</p>	<p>CS on the national surveys</p>	<p>Based on expert opinion</p>	<p>Obligatory to report annually by the farmers for all livestock</p>	<p>Country specific data on WMS shares for livestock were elaborated by Walczak (2006, 2009, 2011, 2012, 2013] but no updated information available, the most detail data are available only from agricultural censuses performed every 10-11 years only</p>	<p>Information available under 2 group. For cattle Other animals</p>	<p>For cattle: CS information provided from national surveys</p>	<p>Currently not used for inventory reporting. A new methodology has been proposed for inclusion in 2023 (see below)</p>
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Animal housing information	CS Frequency distributions of animal housing procedures in % is given for different livestock categories	CS Assessed from surveys	N.C.	Obligatory to report annually by the farmers for all livestock	Information not available	Data from the livestock building survey (1994, 2001, 2008) and the livestock practice survey (2015)	The partitioning of the year into pasture and housing periods are based on surveys	Animals are sheltered only in winter – not used in the inventory calculations
FYM management information	No information	Not widely practiced	N.C.	Obligatory to report imports of manure at the farm scale annually	Information not available	Same as WMS.	On average 81% of cattle manure is stored as slurry and 19% as FYM according to the study of Buckley et al (2020).	Off-paddock facilities are used



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<p>Influence of application time on stored liquid slurry</p>	<p>CS Frequency distribution of application procedures for different livestock manure is provided</p>	<p>CS Provided from surveys</p>	<p>N.C.</p>	<p>No information collected</p>	<p>about 40% of farmers apply manure and slurry by spreading and incorporating them into arable land within 4 hours. In about 20% of farms manure is not plowed, usually at grassland</p>	<p>Data is available at regional level the quantities of nitrogen Applied, by type of effluent, by equipment, and to know the delay of incorporation after spreading.</p>	<p>CS information available from The Department of Agriculture, Food and the Marine</p>	<p>N.C.</p>
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Detailed survey results

How are activity data collected for emission inventories?

Germany: Data collection and documentation take place under the responsibility of the relevant experts.

Evaluate official statistics, association statistics, studies, periodicals and third-party research projects. own research projects, applying personally available information and exchanging data via

relevant Federal/Länder channels.

Data collection steps:

- Definition of requirements,
- Determination of the category-specific quality criteria for the data,
- Requesting of data from data providers (carried out by the relevant experts' group), and Receipt of data.

Austria: The main data supplier for the Austrian Emission Inventories is Statistik Austria

Activity data needed for the calculation of non-energetic emissions are based on several statistics collected by Statistik Austria and national and international studies.

National studies

National agricultural statistics obtained from Statistik Austria

National fertilizer statistics obtained from Agrarmarkt Austria (AMA)

Distributing company (sales data)

Calculations of the University of Natural Resources and Applied Life Sciences

Greece: In Greece, the main data sources used are the Hellenic Statistical Authority, the national energy balance, the government ministries/agencies involved and large private enterprises, along with the verified reports from installations under the EU ETS.

The government ministries and agencies and the individual private or public industrial companies referred previously should have collected and delivered to the MEEN Climate Team and the technical consultant (National Technical University of Athens, NTUA) the respective activity data needed for the inventory (for year X-2) and any changes in activity data for the period 1990 to year X-2, within the time period of May to November of year X-1 (X is the submission year of CRF tables and NIR referred to X-2 GHG emissions inventory).

Denmark: Mainly through obligatory reporting to government from all farmers (other than hobby farms). This includes livestock, manure management and cropping.

Some activity data concerning manure application to soil are collated from digital records sent voluntarily by farmers to the farmers' advisory centre.

Poland: Basic information on activity data was derived from Statistics Poland (GUS) databases. Activity data that were not available in GUS were evolved by experts commissioned specifically for the emission inventory purposes.

France: The activity data used in the inventory for agriculture mainly come from statistics produced by the French Agricultural Ministry. Some data are annual (livestock numbers, agricultural area), some data are collected from specific surveys conducted less often.

Ireland: The majority of activity data is compiled and published by the Central Statistics Office (CSO) and is the official source of the basic data for inventory purposes. The exception is for statistics on synthetic fertiliser use, poultry population statistics and information on cross border (with Northern Ireland) lamb and cattle slaughtering statistics, which are obtained from the Department of Agriculture Food and the Marine (DAFM). Some production parameters e.g., milk fed to calves is verified with data from the national farm survey (NFS). The CSO and DAFM are key data providers whose annual statistical inputs to the inventory agency are covered by Memorandum of Understanding (MOU) in Ireland's national system. There is significant collaboration between inventory experts, agricultural production and researchers within Teagasc, DAFM and the CSO.

New Zealand: Activity data is collected annually by MPI from a range of sources including Statistics NZ, Livestock Improvement Corporation, Beef + Lamb NZ, MPI and Fertiliser Association of NZ. A large amount of data is collected by Statistics NZ, through a census held every five years (the Agricultural Production Census, (APC)) or through a survey (the Agricultural Production Survey APS)) held annually between census years.

Animal category/number information availability

Germany: The Federal Statistical Office and the statistical offices of the Länder (federal states) carry out agricultural-structure surveys that, in addition to collecting other data, carry out censuses of cattle, swine, sheep, horses (as of 2010: equids) and poultry.

In addition to the agricultural-structure surveys, annual livestock censuses are carried out. Through 1998, such surveys were carried out semiannually for cattle and sheep (June, December), every four months for swine (April, August, December), and every two years, in even-numbered years (in December), for all animal species, i.e. also for horses and poultry.

Census data from official surveys are thus available for cattle, swine and sheep for all years since 1990.

Austria: The Austrian official statistics provides national data of annual livestock numbers on a very detailed level. These data are based on livestock counts held in December each year.

Greece: Data on animal population is provided by the Hellenic Statistical Authority (ELSTAT) and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues.

The total animal population on an annual basis is used for estimations of emissions

Dairy cattle were treated as a total number

Other cattle were disaggregated to the following categories:

- <1 year
 - For slaughter as calves
 - Females
 - Males
- 1-2 years
 - Females
 - Males
- >2 years
 - Females
 - Males

Swine and poultry were treated as a total number.

Nevertheless, to our knowledge, disaggregation data regarding the number of animals is available up to the degree required for reporting to Eurostat.

Denmark: Obtained continuously from obligatory reporting to government from all farmers (other than hobby farms). Summarised each year.

Poland: Data on animal population were taken from Statistics Poland (GUS). They are available on an annual basis in Statistical Yearbooks of the Republic of Poland, in other agricultural statistical publications and in the Local Bank Data in the Statistics Poland.

France: Livestock population come from the Annual Agricultural Statistics (AAS) published by the statistical service of the Ministry of Agriculture and Food (SSP – AGRESTE. Données téléchargeables sur: <http://agreste.agriculture.gouv.fr/page-d-accueil/article/agreste-donnees-en-ligne>).

Some adjustments have been done to harmonized livestock populations between two periods (before 2015 and after 2015, because of changes in the geographic scale of data collection – old/new regions).

Ireland:

The CSO produces two censuses of cattle numbers per year (numbers in June and populations in December). For the purposes of calculating emissions from breeding cattle (dairy cows and suckler cows), an average of the number in each category of breeding animals present in the national herd in June and December is used.

The Irish cattle herd is characterised by 11 principal animal classifications. Further subdivision of each category occurs to describe the system according to region. The number of cows in each category, given by CSO statistics, is allocated to the three regions using the Cattle Movement Monitoring System (CMMS) and Animal Identification and Movement (AIM) system reports published by DAFM.

All non-cattle livestock i.e. sheep, swine: CSO collects detailed national statistics of sheep and swine populations. The detailed CSO breakdown of sheep and swine populations considers lambs (assumed lifetime of 180 days before slaughter) and swine is subcategorised according to divergence from standard weight category of 82kg. IPCC default Efs are adjusted based on subcategorisation.

New Zealand:

Livestock population characteristics for different stock classes (dairy and beef cattle, sheep and deer). For example, for dairy cattle, stock classes include milking cows and heifers, growing females < 1 yr old, growing females 1-2 yrs old, and breeding bulls.

In total, there are 29 different stock class types for major species (dairy and beef cattle, sheep and deer).

Mostly sourced from national statistics.

Livestock production data (milk, meat, fibre) is also collected, by industry organisations and MPI.

Diet Composition information availability

Germany: Diet composition and properties used in the inventory for each livestock categories are reported in the Thünen Report 84, Calculations of gaseous and particulate emissions from German agriculture 1990 – 2019. The information depends on studies, statistical surveys and personal communication with relevant experts.

Austria: Cattle diet composition (green feeding, hay, grass and maize silage) for conventional and organic production systems is summarized in the inventories and largely based on data from feeding trials of the "Höhere Bundeslehr- und Forschungsanstalt für Landwirtschaft Raumberg-Gumpenstein". In Austria a high proportion of dairy farms are low input organic farms (both certified and uncertified) where a high proportion of the diet consists of non-intensively farmed alpine pastures and meadows.

Greece: Animal diet composition is not treated in the Greek emission inventories.

It is difficult to find animal diet composition data in databases at the country level. This is true for all animal categories. As far as we know, there is no database on the country level in which data about the diet composition for the various animal categories is added and available.

Reason for unavailability: Farmers are not obliged to share such data.

Denmark: Feed plans are collated by the farmer's advisory organization for cattle, pigs and chickens. Other diets are obtained through discussion between Aarhus University and farm advisors.

Poland: Information not available

France:

Sources :

- CIV, 2012. Alimentation des bovins : rations moyennes et autonomie alimentaire.
- INRA, 2007 et 2018. Alimentation des bovins, ovins et caprins - Besoins des animaux - Valeurs des aliments - Tables INRA 2007; 2018
- IFIP – GTE : Evolution des résultats moyens nationaux
- Eugène, M., Sauvant, D., Nozière, P., Viillard, D., Oueslati, K., Lherm, M., Mathias, E., & Doreau, M. (2019). A new Tier 3 method to calculate methane emission inventory for ruminants. *Journal of Environmental Management*, 231(October 2018), 982–988. <https://doi.org/10.1016/j.jenvman.2018.10.086>
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- EUGENE M., MANSARD L. – Outil de calcul accompagnant le rapport du projet MONDFERENT 2 «Emissions de méthane entérique et MOND des petits ruminants en France», 2015, non publié.
- Hassouna M., Meda B., Chantal A., Dourmad J-Y., Garcia Launay F. Excretions of organic matter and nitrogen of poultry and pig productions to assess gas emissions, MONDFERENT 2. Novembre 2015, non publié

Ireland: The diet of cattle is defined in terms of the type and quality of forages fed and the amount and quality of concentrate feedstuffs offered. The principal forages fed to Irish cattle are fresh grass and grass silage. Cattle graze on fresh grass following turnout to pasture in spring.. Grass silage is fed to the herd during the winter housing period. Daily intake of forage and feed is calculated according to an animal's daily energy requirements for maintenance, activity, production etc. The concentrate consumption pattern is fixed and supplementation

levels are estimated on a monthly basis in the dairy and suckler models and by grazing and housing period in the methane models for non-breeding cattle – growing and finishing animals. Forage intake is varied according to energy requirements. The Irish modifications to the INRAration programme were predominantly for animals at weanling and finishing stages (i.e. at times that concentrates were likely to be fed).

New Zealand: All pasture diet, with 'fixed' national average metabolisable energy (ME) content by month and single fixed monthly N content values, split into dairy cattle and sheep + beef cattle. The inventory methodology for diet composition is in the process of being revised. This includes revised pasture quality data ([Revised Pasture Quality Analysis in the Agricultural Greenhouse Gas Inventory](#)) and inclusion of supplements for [Beef](#), [Sheep](#) and [Dairy](#).

Feed Intake/Energy requirement information availability

Germany: Information about GE intake, Daily DM intake, digestibility of organic matter in feed, ash content of the feed is available for dairy cows, other cattle and swine.

For details refer to the animal-specific chapters in Rösemann et al. (2021)

The mean digestibility and the mean ash content of feed have been determined largely on the basis of German standard values for the various feed components, in combination with information provided by experts. Lacking data have been estimated on the basis of other sources and information provided by producers).

Austria: Feed intake was worked out based on GRUBER & STEINWIDDER 1996. Information about GE intake, Daily DM intake, digestibility of organic matter in feed, ash content of the feed is available for dairy cows and other cattle.

Greece: The IPCC Tier 2 approach is followed for estimating enteric CH₄ and CH₄ from manure management for dairy cattle and other cattle. Gross Energy Intake is the relevant parameter to feed intake that it is taken into account. This is estimated by consideration of the dietary energy needs of the cattle and not of the feed (both from quality and quantity point of view) which is supplied to the animals. Furthermore, the way that the dietary energy needs for dairy cattle and other cattle are estimated is unclear or the references for their value acquisition are not cited. In general feed intake data is not used for the development of Greek emission inventories. This is true for all animal categories.

Reason for unavailability: Farmers are not obliged to share such data.

Denmark: As for diet composition.

Poland: no country-specific methods are available for estimating feed intake; therefore equations provided by IPCC are used (Table 10.3 in IPCC 2006) in the inventories. For dairy cattle and other cattle: parameters required for estimation of gross energy (GE) values (dairy cattle pregnancy, milk production, and percent of fat in milk) were taken from national statistics (GUS). The following parameters: body weight, mean mass, daily weight gain, digestible energy (DE), were elaborated and updated by the National Research Institute of Animal Production (Tables 5.2.5-5.2.8 in NIR_PL 2021). For other animal categories: GE and DE are default values. Dry matter intake (DMI) was not calculated in the inventory.

France: Same sources as "diet composition information availability"

Ireland: The daily energy requirements of cows in each region is calculated using O'Mara (2006) energy requirement guidelines. This is then used to determine daily methane emissions per animal. A Tier 1 approach is used for all other livestock categories.

New Zealand: An understanding of an animal's energy requirements is used to estimate dry matter intake (DMI) from which livestock emissions are calculated. Energy requirements refers to the amount of energy that is needed for an animal to survive and produce animal products such as milk, meat, fibre, velvet and conceptus (pregnancy)

Calculations of energy requirements are combined with data on the energy content of pasture to estimate DMI. This information is used to calculate enteric methane emissions and nitrogen excretion (and resulting nitrous oxide emissions) for each livestock category.

The inventory energy requirement model is based on the Australian Feeding Standard's algorithms for cattle and sheep, which were developed from freely grazing ruminants and better reflect the New Zealand feeding situation compared to the default IPCC algorithms.

Gross energy intake based on ME requirement for dairy and beef cattle, sheep and deer. Other livestock types rely on IPCC Tier 1 approach.

Nex values calculation/information availability

Germany: N excretions are calculated as the difference between the amount of N taken in with feed and basic and yield-based N requirements (animal weight, weight gain, annual milk production or egg production (i.e. numbers of eggs) and, if relevant, numbers of young). The N intake with feed is determined on the basis of animal energy requirements and the energy and N content of the feed. For other animals, N-excretion data are taken from the pertinent German technical literature Haenel et al. (2020).

Austria: As recommended in the Centralized Review 2004, in the year 2005 Austrian N

excretion values were reviewed and recalculated. The revision resulted in higher N excretion rates of dairy and suckling cows.

N excretion values reported in the inventories are based on the following studies:

- GRUBER & PÖTSCH 2006,
- PÖTSCH et al. 2005
- STEINWIDDER & GUGGENBERGER 2003
- UNTERARBEITSGRUPPE N-ADHOC 2004 and ZAR 2004

The Austrian N excretion data were calculated following the guidelines of the European Commission according to the requirements of the European nitrate directive:

Cattle: Feed rations represent data of commercial farms consulting representatives of the working groups "Dairy production". These groups are managed by well-trained advisors. Their members, i.e. farmers, regularly exchange their knowledge and experience. Forage quality is based on field studies, carried out in representative grassland and dairy farm areas. The calculations depend on feeding ration, gain of weight, nitrogen and energy uptake, efficiency, duration of livestock keeping etc.

Pigs: breeding pigs, piglets, boars, fattening pigs: number and weight of piglets, daily gain of weight, energy content of feeding, energy and nitrogen uptake, share of animals with N-reduced feeding

Greece: For all animal categories except dairy cattle, the default values suggested for N excretion rate in the IPCC 2006 guidelines (i.e. in kg N/(1000kg animal mass*day)) were used for this assessment.

For the estimations of annual nitrogen excretion rate for dairy cattle, the proposed methodology Tier 2 IPCC 2006 Guidelines (EQUATION 10.31 and EQUATION 10.32) is utilized considering crude protein in diet percent (CP) by 16.5%.

Reason for unavailability: Farmers are not obliged to monitor N excretion.

Denmark: Calculations are made annually by the Dept of Animal Sciences, Aarhus University, after data has been collated (see above) and discussed with industry representatives. Aarhus University makes the final decision concerning Nex.

Poland: Data on Nex for swines, sheeps, horses, goats and poultry were elaborated by experts (Table 5.5. in Inventory Report Poland 2021) – country specific Nex were determined based on standard amounts of N in faeces and urine of each of the livestock (sub)categories, which were fed with standard quantity, sort and digestibility of fodder. Data on Nex for fur bearing animals were taken directly from 2006 IPCC GLs (Table 5.5 in Inventory Report Poland). Following reviewers' recommendations, in 2021 reports, Nex for dairy cattle and other cattle subcategories were recalculated based on the 2006 IPCC GLs methodology (equations 10.31 and 10.32) with country specific gross energy (GE) values as calculated in GHG inventory and

percent of crude protein in diet (CP%) based on country case study. For poultry: In 2021 reports, calculating poultry's Nex with 2006 IPCC GLs methodology was not possible because country specific GE intake data were not available for poultry.

France: The different document sources used in function of animal categories to evaluate Nex. Table 59 gives the reference values for each animal category defined by AAS.

Ireland: Nitrogen excretion rates (difference between N intake and N output) have been adopted in Ireland for all animal categories for which annual census data are published by the CSO. In 2011, the inventory agency reviewed the applicability of the nitrogen excretion rates used in the inventory in collaboration with the Department of Agriculture, Food and the Marine, agricultural researchers and animal nutritionists for dairy cows. Subsequent reviews, the most recent in 2017, and in this submission (based on O'Brien and Shalloo, 2019) have revised nitrogen excretion rates for all cattle categories. . In the case of cattle, the excretion rates are consistent with the nitrogen content of cattle feed intake as analysed in conjunction with the determination of Tier 2 CH₄ emission factors for enteric fermentation and manure management for cattle.

Nitrogen excretion values for livestock (excluding cattle) in national inventory estimates are derived from SI 605 of 2017 and can be found at this [link](#) (p 456). In some cases the nitrogen excretion associated with offspring are included in the adult female total (e.g. lowland ewes and lambs).

New Zealand: Estimated dry matter intake (DMI) (based on livestock metabolisable energy (ME) requirements (ME_{req}) and ME content of diet) multiplied by nitrogen (N) content of diet to estimate N excretion.

ME_{req} = based on animal production data and population characteristics.

Parameters to partition N intake between product, urine, dung and effluent.

For minor livestock classes (goats, swine, horses etc.), based on Tier 1; i.e. kg CH₄ and kg N excretion per head.

VS excretions calculations/information availability

Germany: The VS excretions for dairy cows, other cattle, swine and poultry (exception: geese) are calculated with the national procedure of Dammggen et al. (2011); cf. Chapter 3.3.3.1 in Haenel et al. (2020).

Austria: VS excretion of Austrian suckling cows is depending on milk yield. From 2004 onwards, a milk yield of 3 500 kg has been assumed, resulting in a daily VS excretion of 4.45 kg.

VS excretion rates for cattle were calculated based on country specific feed intake and equation 10.24 from the 2006 IPCC GLs.

VS excretion of swine was derived from country-specific data on VS content in the manure and kept constant for the whole time series.

Greece: VS excretion is only estimated for dairy and other cattle in the context of the estimation of CH₄ emissions from manure management (Tier 2, IPCC 2006 method), by using the default methodology (default values for DE, UE and ASH).

Denmark: As for Nex.

Poland: For dairy cattle and other cattle: VS excretion rates are calculated from equation 10.24 in 2006 IPCC GLs with the use of country specific GE and DE variables elaborated by experts (Walczak 2006, 2013, 2020). For swines: default VS values (IPCC 2006) are used for market and breeding swine. For other animal categories: no country specific information on VS excretions is available (Tier 1 method used).

France: VS excretion are estimated with models given in MONDFERENT 1 and MONDFERENT 2 studies (Table 72) for cattle, pigs, sheep and goats.

EUGENE, M., SAUVANT, D., NOZIERE, P., VIALARD, D., OUESLATI, K., LHERM, M., MATHIAS, E., & DOREAU, M. (2019). A new Tier 3 method to calculate methane emission inventory for ruminants. *Journal of Environmental Management*, 237(October 2018), 982–988.

<https://doi.org/10.1016/j.jenvman.2018.10.086>

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HASSOUNA M., MEDA B., CHANTAL A., DOURMAD J-Y., GARCIA LAUNAY F. Excretions of organic matter and nitrogen of poultry and pig productions to assess gas emissions, MONDFERENT 2. Novembre 2015, non publié

For poultry, most of the values used are default values from the 2006 IPCC Guidelines.

Ireland: The analysis of the feeding regime for cattle includes a full evaluation of the organic matter content of the feeds applicable to the 11 classifications that characterise the national herd. The emission factors for manure management are derived using the quantified organic matter excretion as volatile solids (VS), the methane production potential (BO) of manure, the allocation to manure management systems based on the manure management surveys and the corresponding values of MCF (methane conversion factor) given for the cool climate ($\leq 10^{\circ}\text{C}$) zone in Table 10.17 of the 2006 IPCC guidelines. Ireland uses the values of 0.24 m³ CH₄/kg VS and 0.18 m³ CH₄/kg VS for dairy cows and other cattle, respectively as outlined in Table 10A-4 and Table 10A-5 of the 2006 IPCC guidelines.

New Zealand: Manure storage is limited to dairy cattle excreta, with survey data (2015) suggesting 7.1% of excreta is stored in the form of farm dairy effluent (FDE) in effluent ponds. The IPCC approach is used, which assumes FDE ponds are represented by anaerobic lagoons (AL).

NZ's calculation of CH₄ from AL are based on faecal dry matter (FDM) outputs and system-specific CH₄ factors. A Tier 2 equation is used to link FDM to volatile solids (VS) for calculating CH₄ emissions from dairy cattle effluent ponds, along with IPCC default values: MCF (CH₄ conversion factor) of 0.74; B₀ (maximum methane-producing capacity) value of 0.24 m³ CH₄/kg VS.

For dung deposition during grazing, NZ's calculation of CH₄ = $FDM \cdot Ym$, with Ym = 0.98, 0.69 and 0.91 g CH₄/kg FDM for all cattle, sheep and deer, respectively.

Swine (minor class) based on country specific EF of 5.94 kg CH₄/hd/yr).

Poultry (minor class) based on country specific EF values of 0.022, 0.016 and 0.117 kg CH₄/hd/yr for 'broilers', 'layers' and 'other'.

Other minor classes: Tier 1

Manure Management/Waste management Systems (MMS or WMS) information

Germany: The German inventory uses annual frequency distributions, broken down by animal sub-categories, for the various husbandry systems (proportions for pasture grazing / stable housing; proportions for different housing systems), manure-storage systems and manure-application techniques, and time allotted to pasture grazing.

Frequency distribution of storage systems per year for different livestock manure is provided.

Austria: MMS data used in the national inventory are based on the national surveys on agricultural practices. They provide distribution of MMS by years for each livestock category (AMON et al. 2008 and PÖLLINGER et al. 2018). National surveys on a representative sample of farms were carried out in 1995 (small sample of farms), 2007 and 2018. Austria's country specific MMS data are provided in the inventories.

Greece: For the estimation of manure management systems' allocation, information received by several agricultural experts was utilized:

- the Ministry of Rural Development and Food
- the Greek Regions with high population of animals
- the Hellenic statistical Authority (EL.STAT.) and
- the Technological Educational Institute of Thessaloniki.

It seems that the definition and allocation of the types of manure management systems for all animal categories is based on expert opinion. As far as we know, there is no database on the country level in which data about the manure management system for the various animal categories is added and available.

Farmers are not obliged to share such data.

Denmark: Type of livestock housing and manure storage is reported (together with the number and type of livestock housed) is reported annually by the farmers for each livestock category. This also gives the type of manure stored. Reporting is obligatory.

Poland: Country specific data on WMS shares for livestock were elaborated based on data collected in a database of the National Research Institute of Animal Production. The database covers data collected during livestock monitoring on farms across country in frames of Multiannual Program: "Protection and management of national genetic resources of livestock in the sustainable use conditions (2011-2015)". Data related to WMS shares will be cross-checked and updated based on results of the next Agricultural Census (2020) performed by the Statistics Poland.

For dairy cattle and other cattle: the fractions (shares) of WMS were assessed on an annual basis for periods 1988–2002 and 2004–2012, data for 2003 was interpolated between 2002 and 2004. Data for 2012 were used also for 2013–2019 (Table 5.3 in IIR_PL 2021, Table 5.3.2. in NIR_PL 2021). Three categories of WMS are present: liquid systems, solid systems and pasture. For swine: the fractions (shares) of AWMS were assessed for 1988 and 2004–2012. For years 1988–2004, interpolation was made. Data for 2012 were used also for 2013–2019 (Table 5.3 in IIR_PL 2021). Two categories of WMS are present: liquid systems and solid systems. For other animals, permanent shares of WMS for the entire inventoried period were assumed based on data assessed for 2004–2012. For sheep, goats, horses two categories of WMS were established (solid system, pasture). For poultry also two categories of WMS are present: litter-free and solid system.

France: Data from the livestock building survey (1994, 2001, 2008) and the livestock practice survey (2015) are reprocessed to determine the share of animals managed in each of the following systems (Citepa with the support of technical institutes) (tables 50, 51, 52, 53):

For cattle: slurry with natural crust, slurry without natural crust, manure (solid storage), deep bedding (for less than one month for dairy cows and for more than one month for other animals), pasture.

For other animals: slurry without natural crust, manure (solid storage), pasture. Different sources make also possible to evaluate the time spent by certain categories of animals associated with certain types of housing inside the building and the quantity of straw for the litter.

Manure that goes through anaerobic digestion is also estimated, based on a database from ADEME (SINOE database), from manufacturer data and from regional observatory.

Ireland: For cattle, national surveys (Hyde et al., 2008; Buckley et al., 2020) provide detailed data on manure management practices to support the adoption of a higher tier method. The surveys were carried on out on a representative sample of farms, the results of which are available at both national level and for each of the three designated Nitrates Directive regions. The apportioning of manure management systems (MMS) within the model is undertaken on an individual subsystem basis. The partitioning of the year into pasture and housing periods is based on the results of O'Mara (2006), local authority guidelines and the manure management survey which estimates the length of the housing period and grazing season. This takes into account annual animal population numbers. Having derived the time spent at pasture and the time spent in housing for cattle, the manure management surveys are then used to determine the partitioning of liquid and solid manures to MMS within the housing period, and the estimation of the number of animals that are out-wintered (i.e. at pasture all year round).

The results of the manure management surveys provide a representation of manure allocation among the relevant animal manure management systems in the country while the excretion of organic matter by cattle is fully characterised as part of the analysis of their feed and energy requirements relating to enteric fermentation.

The Tier 2 approach in the 2006 IPCC Guidelines is used to estimate N₂O emissions from Manure Management for Sheep, Swine, Horses, Mules and Asses, Poultry, Deer and Fur-bearing animals.

New Zealand: The current inventory methodology assumes all stored manure (=7.1% of all dairy cattle excreta) is in the form of farm dairy effluent (FDE), stored in effluent ponds, based on a report produced for MPI: Trends in dairy effluent management (mpi.govt.nz). However, survey data shows that the 7.1% of excreta deposited onto off-paddock structures can be split into effluent (5.4%), feedpads/wintering/stand-off pads (1.1%), covered houses with bedding material (0.3%), covered houses with slatted concrete floors (0.4%) and free-stall barns (<0.1%). This information is currently not used for reporting GHG emissions in the national inventory.

A new inventory methodology has been proposed, which includes storage and land application of solid, liquid and slurry manures collected from standoff/feedpads, covered houses/barns and dairy sheds, providing improved accuracy of MMS Refining New Zealand's GHG Inventory Methodology: Manure Management¹

This new manure management methodology will be assessed for inclusion in the 2023 inventory submission.

Influence of application time on stored liquid slurry information availability

Germany: Frequency distribution of application procedures for different livestock manure is provided.

Austria: Cattle: The evaluation of the TIHALO (i.e. the survey on MMS in Austria) questionnaires (AMON et al. 2008) produced the following results:

32% of the slurry is applied in spring, 42% in summer and 25% in autumn (n=933 farms, projected by Statistik Austria to representative Austrian conditions).

Swine: The evaluation of the TIHALO questionnaires (AMON et al. 2008) produced the following results:

¹ mpi.govt.nz

57% of the slurry is applied in spring, 27% in summer and 16% in autumn (n=628 farms, projected by Statistik Austria to representative Austrian conditions).

Additionally, % liquid slurry storage for each livestock category is reported for warm and cold season in the national inventory and separate EFs are used.

Greece: The T1 methodology was also applied for the estimation of N₂O emissions from the use of animal manure as a fertilizing agent. Specifically, the total nitrogen excretion from animals was calculated, as in the case of manure management, and then corrected to account for the fraction that volatilises in ammonia and nitrous oxides and the fraction that is deposited in soils through pasture, range and paddock, by using the default emission factors.

The aforementioned is the information provided in the NIR of Greece, regarding this activity data category. The influence of application time has not been considered up to now for inventory compilation of the relevant emissions from soil (e.g. N₂O, NH₃)

Reason for unavailability: This is not required by the default IPCC methodologies.

Denmark: No information collected.

Poland: In the inventory report, short note about application time is given "about 40% of farmers apply manure and slurry by spreading and incorporating them into arable land within 4 hours. In about 20% of farms manure is not plowed, usually at grassland" (p.187, NIR_PL 2021).

France: The data on manure spreading are derived from the results of surveys called "cultivation practices", conducted for the years 2011 and 2017, provided by the statistics department of the Ministry of Agriculture. These data make it possible to know, at the regional level, the quantities of nitrogen applied (in tons of nitrogen) by type of effluent, by equipment, and to know the delay of incorporation after spreading.

Ireland: Approximately two-thirds of animal manure nitrogen is excreted at pasture annually, reflecting the relatively short period that cattle are housed in Ireland. Animal manures excreted at pasture and the associated emissions are accounted for under N₂O emissions from managed agricultural soils (Section 5.5.1). In 2019 the bulk of cattle manures in housing were managed in pit storage systems (94.8 per cent and 84.3 per cent for dairy cattle and other cattle respectively) for eventual spreading on agricultural lands. The remainder of animal manures produced in-house are in deep bedding systems. The emission factors given by the 2006 IPCC guidelines are used for calculations.

The date from which slurry, artificial fertiliser and farmyard manure can be spread depends on the region of Ireland the farm is based. The Department of Agriculture, Food and the Marine

developed three separate zones – A, B and C – going from the south-east and east to the north and north-west. All slurry is spread within the open periods in each zone.

New Zealand: NZ stores dairy effluent (as noted above) rather than slurry. Effluent storage duration varies greatly from farm to farm, ranging from 1 day to several months. As it is difficult to obtain accurate data, the influence of storage time is not currently used for reporting GHG emissions in the national inventory.

Animal housing information availability

Germany: Frequency distributions of animal housing procedures in % is given for different livestock categories.

Austria: Housing systems for cattle and swine were assessed by the TIHALO survey in 2005. The study also includes the grazing times for grazing cattle.

Greece: Animal housing information is not considered for emission inventory compilation in Greece. As far as we know, there is no database on the country level in which data about the animal housing procedures for the various animal categories is added and available.

Reason for unavailability: Farmers are not obliged to share such data.

Denmark: See MMS above

Poland: Information on types of animal housing is not available; this type of activity data hasn't been used in the inventory so far.

Information on grazing is present: 1) for dairy cattle, other cattle and swine as a proportion of WMS for selected years (Table 5.3.2. in NIR_PL 2021); 2) for other animals, constant proportions of grazing for the entire inventory period were assumed based on data assessed for 2004–2012.

France: Data from the livestock building survey (1994, 2001, 2008) and the livestock practice survey (2015)

Ireland: The partitioning of the year into pasture and housing periods is based on the results of the manure management surveys as mentioned above.

New Zealand: Animal shelters are typically used for the winter period – see below. This information is currently not used for reporting GHG emissions in the national inventory

Farmyard manure management/distribution information availability

Germany: No information provided.

Austria: Farmyard manure distribution is given in the inventories as well as other MMS.

Greece: Farmyard manure has not been defined as a manure management system type in any of the animal categories reared in Greece. Its use is probably very limited (if not non-existing) in the country.

Denmark: Imports of manure must be reported at the farm scale annually. This gives the type of manure imported and the amount of total N (based on standard values)

Farmers must have access to sufficient land that their manure can be utilised according to the national regulations concerning balanced N fertilization. They must own a proportion of this land.

Farms with excess manure must have legal contracts with other farmers to receive the surplus manure, The surplus would normally be due to excess N but in some areas where there is a problem with excess P in surface water, the excess may be due to P.

Poland: Management of solid manure is mentioned in relation to ammonia abatement techniques (Table 5.6., in IIR_PL 2021). Distribution of covers for solid manure for different animal categories and selected years is provided.

France: See waste management

Ireland: On average 81% of cattle manure is stored as slurry and 19% as FYM according to the study of [Buckley et al \(2020\)](#). The same study which assessed data from the NFS found that on average, 84% of slurry was applied via the splash plate method, 10% was applied via an umbilical systems, 3% was accounted for by LESS and 1% was applied via injection.

New Zealand: Off-paddock facilities (feed pads, stand-off pads, animal shelters) are used for short periods of the year, generally to avoid damage to paddocks when conditions are wet and reduce N leaching to groundwater. More detail on these systems can be found in [Refining New Zealand's GHG Inventory Methodology: Manure Management \(mpi.govt.nz\)](#)

Greatest barriers for maintaining and improving the accuracy and detail of activity data

Denmark: We lack access to data concerning the date, amount and location of synthetic fertilizer applications. These data are available from the farmers' advisory center but are not currently collated.

Also, we do not have digital records of the implementation of abatement/mitigation measures relating to livestock housing and manure management (e.g. installation of air scrubbers).

Austria: In Austria, many activity data need to be collected by dedicated surveys on representative farms as these data are not available in national statistics (e.g. manure management systems, storage duration, timing and method of manure application).

Greece: This is a reply regarding the inventory compilation in the agricultural and livestock sector, based on our experience at the Laboratory of Farm Structures at AUA:

- Transparency in the available activity data and collection of activity data in repositories that are readily available for interested parties.
- Absence of database at the country level regarding feed supply in different animal categories and sub-categories (diet composition, supplied quantities, chemical composition (e.g. Dry Matter content, Crude protein content, Ash content, phosphorus content etc.), animal dietary requirements)
- Absence of research for emission measurement and monitoring and development of country-specific emission factors both on the individual animal level and on the manure management chain level for various livestock categories.
- Absence of databases at the country level regarding the use of manure management systems as well as monitoring of manure characteristics (e.g. chemical composition) and the types of animal housing systems used.

Based on discussions with the Irish inventory compilers (EPA) the main barriers to improving the accuracy and detail of the inventories are:

- Further refinement and disaggregation of emission factors required to capture mitigation methods within the inventory.
- Regulations are not in place to obtain activity data for some commonly practiced mitigation measures e.g. E.g. LESS of pig slurry
- Enteric methane mitigation methods (i.e. supplementation) will be particularly difficult to capture in the inventory

Poland

- Methodological changes in collecting data on livestock population introduced by Statistics Poland (GUS) occur influencing the trend.

- Statistics does not cover all animal categories required by emissions inventories, for instance data on fur animals is published every few years; lack of goats population in early 1990-ties
- Country specific data for calculation of Nex needs to be collected / commissioned every few years from experts / research institutes. No new data on Nex for other than cattle animals is available (partially, data from early 2000s are used)
- Generally, lack of country specific data information. Country specific data needs to be collected / commissioned every few years; some initial data are collected by Statistics Poland (GUS), the most detail data are available only from agricultural censuses performed every 10-11 years only.

Approaches for the improvement of inventories and the collection of activity data including the reduction of uncertainties

In order to counteract climate change, many countries have committed to reducing greenhouse gas (GHG) emissions under the United Nations Framework Convention on Climate Change (UNFCCC), which covers the sources and sinks of the direct GHGs; carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and other pollutants. Building on the UNFCCC, the Kyoto Protocol, adopted in 1997, broke new ground with its legally-binding constraints on GHG emissions. In 2012, the Kyoto Protocol entered a second commitment period (2013–2020), and the EU committed to reduce GHG emissions by 20% compared to 1990 levels (UNFCCC 2020). The Emissions Database for Global Atmospheric Research (EDGAR) compiled global totals of CO₂, CH₄ and N₂O emissions for 2010 as 33.6 Pg CO₂ yr⁻¹, 0.34 Pg CH₄ yr⁻¹, and 7.2 Tg N₂O yr⁻¹ (Janssens-Maenhout et al 2019). According to the 'United in Science report' published by the World Meteorological Organization (2019), the emissions gap that the world needs to close to reach the agreed goals in the Paris Agreement is now larger than ever.

To achieve the aims of the Kyoto Protocol, the European Commission set binding targets for the member states to reduce GHG emissions for the year 2020, prepared a framework and policy objectives for the period 2021–2030 and set up a long-term strategy for 2050. Key targets for 2030 are more stringent than in the previous period, aiming to a 40% cut in GHG emissions from 1990 levels. To meet the target, non-emission trading system sectors, including agriculture, need to reduce emissions by 30% compared to 2005 levels (European Commission 2020a). The 2050 long-term strategy aims to reach climate neutrality in the EU by 2050 (European Commission 2020b). This aim aligns with the objective of the Paris Agreement to keep the global temperature increase below 2°C and seeking efforts to limit it to 1.5°C (UNFCCC 2015).

In addition to the GHG commitments, United Nations Economic Commission for Europe (UNECE) countries also agreed on reducing air pollutants. The European Parliament introduced a new National Emissions Ceilings (NEC) EU Directive (2016/2284/EU) in 2016 which sets national emission reduction targets for NO_x, ammonia (NH₃) and other pollutants emissions for the years 2020 and 2030 (European Parliament and Council 2016). According to the new directive, NO_x emissions from agricultural activities, namely manure management and agricultural soils, have to be accounted for; by 2020, a 2.3% reduction of NH₃ and a 3.2% reduction of NO_x relative to the 2017 levels is required across the EU, and by 2030 16% and 40% reductions from 2017 levels are expected (EEA 2019a).

Many EU member states are failing to meet the 2020 targets for NH₃ emissions reduction, according to their own projections. For the 2030 emission reduction commitments, the NEC Directive projections report (EEA 2019b) paints an even worse picture: 19 EU member states will fail to meet reduction commitments for NH₃ and 19 countries will fail to meet their targets for NO_x. N₂O emissions are

expected to increase in the future with increasing activities. Even with full implementation of mitigation measures by 2030, global emissions can only be reduced to the pre-2010 level (Winiwarter et al 2018). Riahi et al (2017) looked into the shared socioeconomic pathways including GHG emissions. They emphasize the magnitude of N₂O emissions sourced from agricultural soils and fertilizer use and show the significance of mitigation strategies.

While it is the total amount of GHG emissions that determine climate change globally, from a policy perspective it is essential that each emission source is correctly attributed to each sector. Vigan et al (2019) emphasize the importance of accurate knowledge of emission sources to implement effective mitigation strategies. All the GHG emission reduction and control policies point out that the emissions from the agricultural sector should be lowered with emissions from the livestock sector and emissions from agricultural soils. According to the latest IPCC Climate Change and Land report (Rivera et al 2017), the contribution of the sector Agriculture, Forestry and Other Land Use (AFOLU) to total net anthropogenic emissions (2007–2016) is 23%. In the livestock sector, advanced inventory methodologies are already available and offer opportunities for emissions mitigation by management of several key activities without reducing productivity.

The legally binding obligations to reduce both GHG and NH₃ emissions from agriculture require transparent and accurate emissions reporting. National emissions inventory reports (NIR) have become the main instrument for reporting emissions. They must be prepared annually to assess the status and track progress towards meeting the GHG and NH₃ reduction commitments. To support the compilation of NIR and to ensure that the information they provide is consistent, comparable, complete, accurate and transparent, the Intergovernmental Panel on Climate Change (IPCC) drew up its first GHG reporting guidelines in 1995, and published them in revised form in 1996 (IPCC 1996, 2015, Pulles 2013). A new version of the IPCC guidelines was launched in 2006, with important suggestions for improvement and restructuring the source categories to make the guidance clearer, more accurate (updated methods, improved default values) and more complete (more sources and sinks, more gases) (IPCC 2006). From 2015, these new guidelines became mandatory for Annex I 8 countries as part of their UNFCCC reporting obligations (UNFCCC 2014). A refinement of the IPCC 2006 Guidelines was prepared between 2016 and 2019 and was adopted during the 49th Session of the IPCC in May 2019. The IPCC 2019 Refinement updates, supplements, and further elaborates the 2006 IPCC guidelines and is meant to be used in conjunction with them (IPCC 2019). Finally, the EMEP/EEA air pollutant emission inventory guidebook sets out methodologies for emissions estimation, compatible with and complementary to the IPCC guidelines, and has also recently been updated (EEA 2019a).

Emissions are calculated by multiplying 'activity data'—quantitative estimates of the extent of specific types of agricultural practice—with emission factors (EF) that are intended to represent the emission rates from each of these practices. Therefore, high resolution activity data and realistic EFs are needed to create accurate emission inventories (Amon et al 2011). Only detailed knowledge of sources and EFs

enable development, application and/or enforcement of targeted mitigation measures (Reidy et al 2008, Bell et al 2014, Smith et al 2014).

Emission inventory guidelines have to find an appropriate balance between general, internationally comparable and relatively easily applicable procedures, and more accurate and specific information at national level, which requires methodologies that are more sophisticated. While this has been a common point of critique of earlier versions of the IPCC guidelines (see e.g. Salt and Moran 1997, Brown et al 2001), the guidelines have been improved and now allow for a reasonable and productive way to deal with the trade-offs between comparable procedures and more accurate information at national level. The IPCC guidelines do this mainly by providing 'Tiers' of methodology for use by different groups of countries depending on their ability to produce their own empirical data. Tier 1 is the simplest method and uses default values for EF and equations for each animal subcategory while Tier 2 is a more detailed approach requires country specific information on livestock and manure management (IPCC 2006). Tier 3, introduced with the 2006 IPCC guidelines, enables countries to do the most sophisticated analysis and modelling (IPCC 2006, 2019). This has the potential advantages of more accurate accounting and of discovering real and demonstrable mitigation opportunities that are less disruptive of agricultural practice and therefore easier to implement. NIRs are also expected to become more accurate and detailed with the IPCC 2019 Refinement, which provides supplementary methodologies, updates on default EFs considering the latest available scientific knowledge, and additional guidance on the 2006 IPCC Guidelines.

There is a range of publications that cover different pollutants (all GHG, non-CO₂ gases (CH₄ and N₂O), NH₃) at European and national levels, usually coupled with some form of uncertainty or sensitivity analysis. For instance Rypdal and Winiwarter (2001) provided a review on uncertainties in national GHG inventories. An inventory of N₂O emissions from agriculture in the UK including uncertainty and sensitivity analysis was published by Brown et al (2001). Fauser et al (2011) studied uncertainties of the Danish GHG emission inventory. NH₃ emission inventories from agriculture have been published for Switzerland (Kupper et al 2015), the Netherlands (Velthof et al 2012), and Denmark (Hutchings et al 2001). Covering Europe as a whole, Backes et al (2016) developed a dynamic NH₃ emission inventory using temporal profiles and geographical information, Reidy et al (2009) assessed NH₃ emissions from litter-based manure systems for beef cattle and broilers. The Austrian air emission inventories are based upon an integrated and consistent N-flow approach, where N losses estimated under the UN/CLRTAP inventory directly feed into GHG inventory estimations (Anderl et al 2013).

Focusing either on a broad range of GHG or on selected ones, NIRs have been validated by comparing them to specific (national) methods, measurements, or models, e.g. N₂O and CH₄ emissions for the UK (Brown et al 2001, Silgram et al 2001, Polson et al 2011) or N₂O emissions for the Netherlands (Van Der Laan et al 2009), Denmark (Fauser et al 2011, 2013), Norway (Borgen et al 2012) or globally (Seikaab et al 1996, Mosier et al 1999, Van Amstel et al 1999, Nevison 2000, Cushman 2003, Lokupitiya

and Paustian 2006). Studies on GHG emission inventories have also been published for countries such as Israel (Koch et al 2000) or China (Zhang et al 2015), and the specific challenges for developing countries have been discussed by Ogle et al (2013). Some more recent studies focused on ensuring comparability by the consistent use of clear methodologies, in order to assess policy effectiveness on all scale levels. Blujdea et al (2016) and Petrescu et al (2020) compared the different approaches used by EU member states for GHG inventories for the land use, land-use change, and forestry (LULUCF) and AFOLU sectors. Other authors have analysed regional (Garren and Brinkmann 2012) or local community levels (Sippel 2011, Brander et al 2013). Wolf et al (2017) explore the influence of the methodology on global and US livestock methane emissions estimates when applying a Tier 1 versus a Tier 2 approach.

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 (Nex) 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 (NH₃ and others, such as PM, NO_x, CO, SO₂, etc.) and GHG (N₂O, CH₄ and CO₂) 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 gathering regional data, coming from different sources, on animal numbers, feeding, types of livestock buildings, spreading practices effluents, time spent grazing, etc. It also allows calculating, 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 (N₂O) and NH₃ 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) 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 provide additional literature explaining in very high

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.

Uncertainties in national emission inventories

National emission inventories shall include an uncertainty analysis and shall strive to reduce uncertainties associated with the emissions. Rypdal and Winiwarter (2001) give a comprehensive overview of uncertainty assessment. The general procedure for the estimation of uncertainties in the GHG and ammonia inventories are lay out in the UNECE and IPCC inventory guidelines. The Tier 1 approach uses the error propagation method: it estimates the uncertainties for a specific source category and combines these uncertainties to an overall uncertainty. The Tier 2 method applies a Monte Carlo Simulation, but is less commonly used than the Tier 1 approach.

In order to estimate the overall uncertainty, the uncertainties of activity data and emission factors, respectively, have to be quantified. The uncertainties of activity data on sectoral level are based on the GHG uncertainty analysis (e.g. UMWELTBUNDESAMT 2019b). Uncertainties of emission factors of the relevant pollutants are based on the qualitative ratings following the EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP/EEA 2016). Often, the arithmetic mean value of the proposed upper and lower emission factor uncertainty is calculated and used for the calculation of the overall combined uncertainty. The quality of estimates for all relevant pollutants is rated by qualitative indicators in Chapter 5 of the EMEP/EEA air pollutant emission inventory guidebook 2016 (EMEP/EEA 2016). The definition of the ratings is given in Table 2.

Table 2: Rating definitions.

Rating	Definition	Typical Error Range
A	An estimate based on a large number of measurements made at a large number of facilities that fully represent the sector	10 to 30%
B	An estimate based on a large number of measurements made at a large number of facilities that represent a large part of the sector	20 to 60%
C	An estimate based on a number of measurements made at a small number of representative facilities, or an engineering judgement based on a number of relevant facts	50 to 200%
D	An estimate based on single measurements, or an engineering calculation derived from a number of relevant facts	100 to 300%
E	An estimate based on an engineering calculation derived from assumptions only	order of magnitude

Source: Table 3-2 Rating definitions, Chapter 5 of the EMEP/EEA emission inventory guidebook 2016.

Rypdal & Winiwarter (2001) noted that the largest contributor to uncertainty for several existing GHG inventories is N₂O emissions from soils. Thus it is worthwhile to consider this source in some more detail – even if no real improvement of the situation should be expected at this time. While IPCC (2000) assumes two orders of magnitude as the uncertainty margin, re-evaluation of basically the same data leads to a considerable improvement of the situation to estimated 30%–300% of the best estimate, lognormal distribution (IPCC 2006). This range is closer but still higher compared to the one estimated by Rypdal & Winiwarter (2001), who assumed uncertainty in a triangular distribution

The IPCC methodology (IPCC 2006) recommends separate treatment of direct and indirect emissions. Uncertainties of emission factors of indirect emissions are not significantly different from those of direct emissions, and the underlying processes (microbial nitrification/denitrification) are identical. It is likely that the uncertainties of direct and indirect emissions are correlated.

Activity data have a major impact on inventory uncertainties. Therefore, the MELS project also looked into details of activity data assessment, identified key activity data and assessed the potential to gather these regularly at farm and national level.

Assessing the availability and relevance of activity data

Emission inventories have two main purposes:

- estimate national emissions as accurately as possible, and
- show annual trends in emissions and effect of mitigation measures.

As emissions are estimated as product of activity data and emission factors, there are two possible ways of improving emission inventories: improvement of accuracy of activity data and of emission factors. This chapter lists suggestions for possibilities for future improvement of inventory quality including a suggestion of a traffic light system that was newly developed within MELS.

- Milk production and methane emissions from ruminants.

Emission estimates from milk production could be improved if more data were available on

- Differentiation between organic and conventional systems (milk yield and animal diet)
- Data on diet composition in key regions
- Correlation between diet composition and milk yield
- Differentiation of milk production systems in (low, medium, high intensity)
- Correlation between diet, milk yield and VS excretion
- Diet and manure composition of other cattle categories

- Methane and nitrous oxide emissions from manure management.

Methane emissions from liquid and solid manure are an important source. However, data quality in this field does not correspond to the importance of the emission source.

- B0 values are one of the weakest points in the inventory. IPCC default B0 values are derived from limited and highly variable data sources (see EraNet project M4Models for more detailed information)
- MCF Values have a great impact on estimation of methane emissions from manure management. They are highly uncertain. Efforts must be undertaken to improve the accuracy of MCF values. Currently, MCF values are derived from a limited number of laboratory studies and theoretical considerations. (see EraNet project M4Models for more detailed information)
- Manure management system distribution is a very important part of the inventory. Some countries carry out representative surveys which need to be repeated regularly to get more accurate and up to date activity data.
- N₂O emission factors from manure management are also rather uncertain and additional research is needed in this field. (See MELS project: still a limited amount of emission research here)
- N₂O (and NH₃) emissions strongly depend on N excretion values. Here, the same features apply as with methane emissions from ruminants: more accurate data on production levels, diets, and feed composition in key regions of Austria are required for cattle, pigs and poultry.

- Biogas – energy crops.

Calculation of biogas-related emissions would profit from more accurate data for every single year on biogas plants and the digested raw materials. This includes both manure (Nex) and digested energy crops (e.g. maize silage, green rye-silage). Furthermore, national N contents in the digested raw materials should be surveyed for estimation of N₂O from biogas plants and their slurry.

- N from Straw.

National average straw inputs should be investigated through surveys as the amount and quality of bedding has distinct influence on emissions. However, farmers may have difficulties to provide accurate and robust estimates; this requires a well-set questionnaire.

MELS traffic light system on the collation of activity data at farm and at national level

A model of the emission of a gas based on one or more variables is only useful for accounting for farm scale or national emissions if that variable can be obtained with an acceptable accuracy. There are two types of activity data: categorical and continuous. Changes in categorical data, such as type of animal housing, type of manure storage, tend to be associated with a significant financial investment, so changes intermittently at the farm scale and slowly at the national scale. Continuous data, such as indoor temperature and manure composition, changes in response to changes in management and environment, so changes over short temporal scales. The methods that must be used to capture these two types of activity data thus also vary.

Categorical data is readily available at the farm scale e.g. the farmer knows the types of animal housing on their farm and the ventilation types of those houses. At the national scale, categorical data can be obtained by observation (e.g. from satellite imagery), by surveying some or all farmers, or from records created during regulatory procedures (e.g. building control or environmental regulations, such as the EU Industrial Emissions Directive).

Some continuous data will be potentially or actually available at the farm scale. For example, in many parts of the world, it is necessary to control the indoor environment of pig housing using mechanical ventilation, sometimes supplemented by heating. Measurements of indoor temperature will therefore be necessary and in more modern systems, these data will be recorded digitally. Likewise for liveweight gain of livestock. In contrast, measurements of manure composition are rarely made by farmers. At the national scale, data concerning indoor temperature or manure pH will be rarely available and the measurements require significant expertise, due primarily to difficulties in sampling. For the same reason, measurements concerning the composition of manure also requires significant expertise.

In the following tables, we assess whether a variable is easy to obtain with acceptable accuracy (green), more difficult (yellow) or very difficult (red), at the farm and national scales. Note that for multi-variable models developed in MELS with a statistically significant interaction between variables (e.g. when NH₃ emission from slurry storage is dependent on animal type and manure total N), it will be necessary for the data to be co-located. Moreover, the assessment of which colour to allocate to the farm and national scales will vary from country to country. We expect that higher tier emission models will mainly be of initial relevance to countries with intensive livestock industries, who have associated challenges with regards to agricultural emissions to the environment.

Ammonia

Source	Variable	Use in models *	Data acquisition method			
			Farm scale		National scale	
Cattle housing	Type of housing	1	Records	●	Observation, survey or records	●
	Climate zone	1	Observation	●	Observation, survey or records	●
	Ventilation type	1	Records	●	Records	●
	Indoor temperature	1	Measurements	●	Measurements	●
	<i>Outdoor temperature</i>	<i>(proxy of indoor °C)</i>	<i>Measurements</i>	●	<i>Measurements</i>	●
Pig housing	Type of housing	1,3	Records	●	Observation, survey or records	●
	Age/type of pig	3	Records	●	National statistics	●
	Floor type	1	Records	●	Observation, survey or records	●
	Indoor temperature	1	Measurements	●	Measurements	●
	Liveweight gain per day	1,3	Measurements	●	Survey or records	●
	Type of bedding material	1,3	Records	●	Observation, survey or records	●

	Ventilation system	1,3	Records		Observation, survey or records	
Manure storage (cattle and pigs)	Slurry or solid	3	Records		Observation, survey or records	
	Cattle or pig	3	Records		Observation, survey or records	
	Duration of storage	1	Survey		Estimated	
	Manure organic C concentration	1,2,3	Measurements or estimation from animal diet		Measurements or estimation from animal diet	
	Manure total N concentration	2	Measurements or estimation from animal diet or animal performance		Measurements or estimation from animal diet or animal performance	
	Manure TAN concentration	2,3	Measurements or data from feed trials		Measurements or data from feed trials	
	Air temperature	1,3	Measurements; or use ambient temperature as a proxy		Measurements ; or use ambient temperature as a proxy	
	Manure DM concentration	2,3	Measurements or estimation from animal diet or animal performance		Measurements or estimation from animal diet or animal performance	
	Manure pH	1,2,3	Measurements or national standard values		Measurements or national standard values	

* variable can be used in models alone (1) or with 2 or 3 other variables

Nitrous oxide

Source	Variable	Use in model*	Data acquisition method			
			Farm scale		National scale	
Cattle housing	Type of housing	1	Records	●	Observation, survey or records	●
	Climate zone (temperate wet or dry)	1	Records	●	Observation, survey or records	●
Pig housing	Type of housing	3	Records	●	Observation, survey or records	●
	Slurry or solid	3	Records	●	Observation, survey or records	●
	Age/type of pig	3	Records	●	National statistics	●
	Type of forced ventilation air outlets	1	Records	●	Observation, survey or records	●
	Liveweight gain per day	1,3	Records	●	Survey or records	●
	Type of bedding material	1,3	Records	●	Observation, survey or records	●
	Indoor temperature	1	Measurements	●	Mesurements	●
Manure storage (cattle and pigs)	Cattle or pig	2	Records	●	Observation, survey or records	●
	Slurry or solid	1,2	Records	●	Observation, survey or records	●

	Duration of storage	1	Survey	●	Estimated	●
	Manure DM concentration	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●
	Manure organic C concentration	2	Measurements or estimation from animal diet	●	Measurements or estimation from animal diet	●
	Manure C:N ratio	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●
	Manure total N concentration	1,2	Measurements or estimation from animal diet/performance	●	Measurements or estimations from animal diet/performance	●
	Manure mean temperature	2	Measurements	●	Measurements	●
	<i>Outdoor temperature</i>	<i>(proxy)</i>	<i>Measurements</i>	●	<i>Measurements</i>	●

* variable can be used in models alone (1) or with 2 or 3 other variables

Methane

Source	Variable	Use in model*	Data acquisition method			
			Farm scale		National scale	
Cattle housing	Forced/natural ventilation	1	Records	●	Observation, survey or records	●
Pig housing	Type of housing	1	Records	●	Observation, survey or records	●
	Slurry or solid	1	Records	●	Observation, survey or records	●
	Age/type of pig	1	Records	●	National statistics	●
	Type of forced ventilation air outlets	1,2	Records	●	Observation, survey or records	●
	Liveweight gain per day	1,2	Measurements	●	Survey or records	●
	Type of bedding material	1,2	Records	●	Observation, survey or records	●
	Feed conversion ratio	1,2	Measurements or estimations	●	Measurements or estimations	●
Manure storage (cattle and pigs)	Cattle or pig	1	Records	●	Records	●
	Slurry or solid	1	Records	●	Observation, survey or records	●
	Manure DM concentration	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●

	Manure organic C concentration	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●
	Manure C:N ratio	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●
	Manure VS concentration	2	Measurements or estimation from animal diet/performance	●	Measurements or estimation from animal diet/performance	●
	Manure mean temperature	2	Measurements	●	Measurements	●
	<i>Outdoor temperature</i>	<i>(proxy)</i>	<i>Measurements</i>	●	<i>Measurements</i>	●

* variable can be used in models alone (1) or with 2 or 3 other variables

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