Australian Government
Department of Climate Change, Energy, the Environment and Water

DRAFT Greenhouse Gas Emissions Estimation and Reporting Guidelines for Agriculture, Fisheries and Forestry

Methodological Guidance

Chapter 4: Manure Management

Cataloguing data

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Acknowledgement of Country

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past and present.

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4 Scope 1 – Manure Management

Where appropriate, for each sector this chapter covers the following manure management systems:

Manure Management Systems (MMS)	
Subscript (m)	**MMS**
1	Anaerobic lagoon
2	Liquid systems
3	Daily spread
3a	Sump and dispersal
3b	Drains to paddock
4	Solid storage
5	Drylot
6	Composting (passive windrow)
7	Digestor/Covered lagoon
8	Deep litter
9	Pit storage (<1 month)
10	Poultry manure with littler
11	Poultry manure without litter
12	Direct processing into pelletised fertiliser
13	Direct application
14	Pasture range and paddock

Figure 4.1 demonstrates the relevant emissions calculations outlined in this chapter to each of these MMS. There two main components to methane emission estimates – manure excreted directly onto pasture, and managed manure through treatment systems. Managed manure also results in direct and indirect nitrous oxide emissions. For manure excreted onto pasture there are no nitrous oxide emissions from manure management, however emissions occur from the soil due to the metabolism of the deposited urine and faeces, and indirectly through atmospheric deposition and leaching and runoff. Emissions associated with manure from management systems that is subsequently applied to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser module.

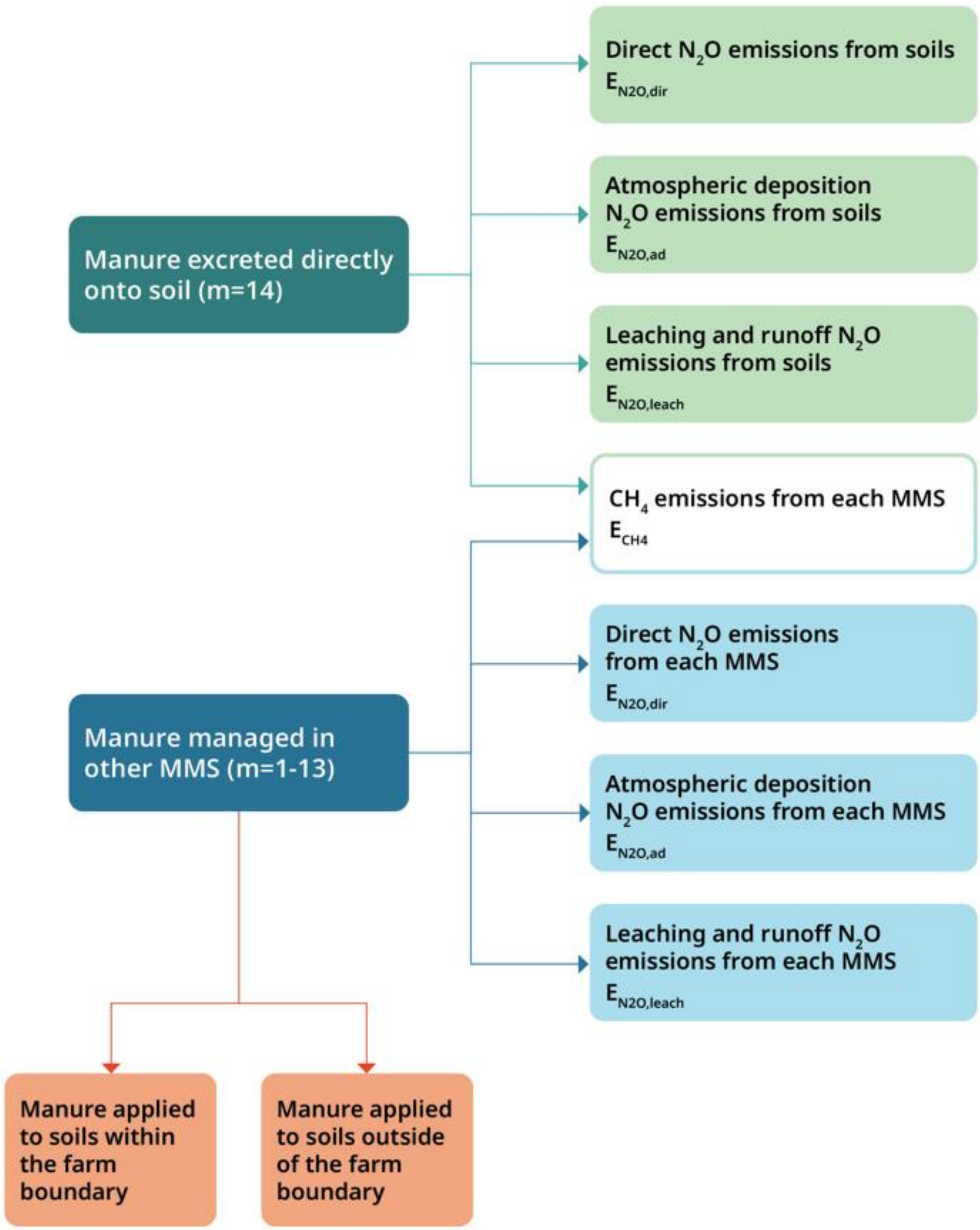

Figure 4.1: Example possible emissions sources from manure for livestock enterprises

4.1 Beef Feedlot

This module covers the estimation of methane and nitrous oxide that results from beef feedlot cattle manure management. Figure 4.2 summarises the emission sources associated with the manure from beef feedlot cattle. As cattle are housed the pasture, range and paddock MMS is not applicable in this chapter. However, emissions associated with manure from management systems that is subsequently applied to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser module.

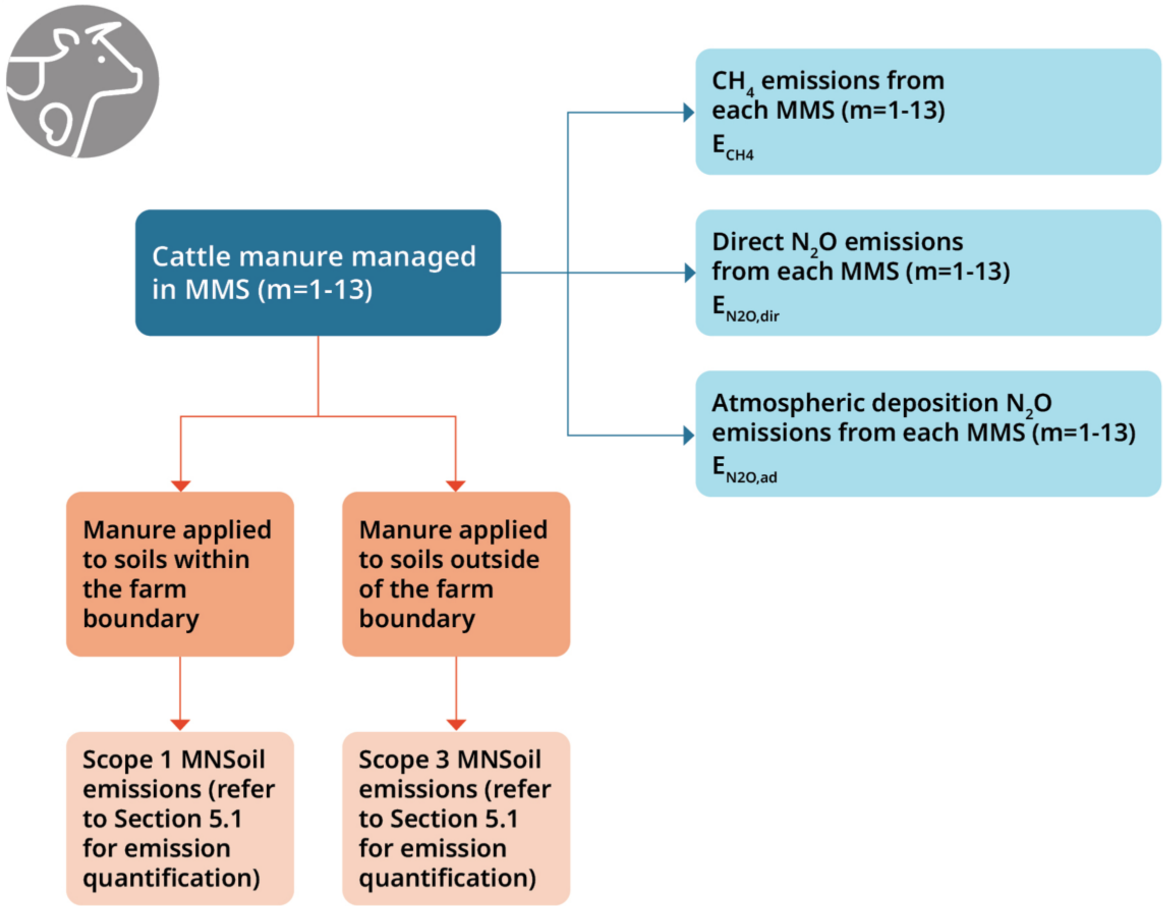

Figure 4.2: Summary of emissions sources associated with manure management in beef feedlot systems

The following subscripts are used in this module:

Subscript	Meaning
i	Temperature zone
j	Cattle group
m	Manure Management System (MMS)
T	Treatment Stage

Emissions are estimated based on groups of cattle with similar intake requirements and lengths of stay on the feed pad and the different stages and systems of manure treatment. The temperature zone will affect the selection of appropriate emission factors. The emissions are summed across each group and manure management system within the feedlot operation during the reporting period.

The number of groups per farm within the reporting period will depend on the size of the feedlot operation and the diversity of the intake and length of stay of the groups of cattle on the feed pad. Groups may be labelled as numbers e.g. Group 1, Group 2, Group 3 or given relevant names based on age or breed of group e.g. R2 Wagyu, R3 Angus, R3 Mixed for data entry purposes.

Manure from feedlot cattle may pass through multiple treatment stages. Therefore, volatile solid and nitrogen inputs and losses are estimated at each treatment stage (see Figure 4.3). It is assumed that the primary treatment stage (T=1) of all manure is the feedpad (considered to be a drylot system). Manure may then be transferred to a secondary treatment stage (T=2), such as a stock pile, after which the waste is assumed to be applied to soils. A fixed amount (2%) of manure is assumed to runoff from the feedpad into an anerobic lagoon, tertiary treatment stage (T=3), before also being applied to soils.

The manure management system (m) for secondary treatment stage (T=2) will need to be input so that the appropriate constants and emissions factors can be applied. Additionally, the temperature zone (i) the feedlot is operating in is needed to inform the methane conversion factor applied.

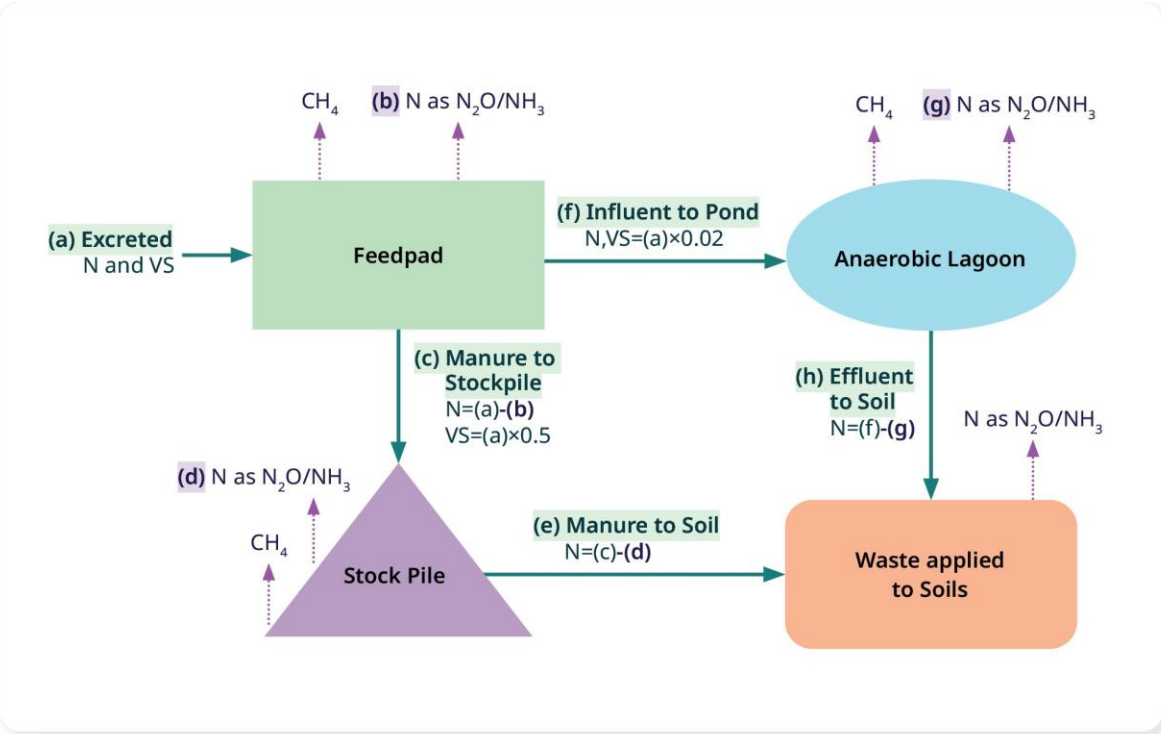

Figure 4.3 Example of the possible different stages of manure management in beef feedlot systems from the Australian National Inventory Report [1].

4.1.1 Estimation methodology

4.1.1.1 Method 1 — Manure Methane Beef Feedlot

(1) Total annual methane emissions from manure management E_{CH4} (t CH_4) is calculated as:

$$E_{CH4} = \sum_j \sum_m \sum_T (D_j \times M_{jmT} \times N_j) \times 10^{-3}$$

Where D_j = length of stay of each cattle group (days)

M_{jmT} = methane production from manure per cattle group, MMS, and treatment stage (kg CH_4/head/day)

N_j = numbers of beef cattle in each group (head)

Treatment stage 1 (primary system)

(2) In equation (1) production of methane in treatment stage 1 MMS $M_{jm=5\,T=1}$ (kg CH_4/head/day) is calculated as:

$$M_{jm=5\,T=1} = VS_j \times B_O \times MMS_{m=5\,T=1} \times MCF_{im=5} \times \rho$$

Where VS_j = volatile solid production from feedlot cattle in each group (kg/head/day)

B_O = emissions potential (m^3 CH_4/kg VS)

$MMS_{m=5\,T=1}$ = the fraction of manure in each primary system. Assumed to be 1 for the drylot MMS

$MCF_{im=5}$ = methane conversion factor for temperature zone and system. Under Method 1, the default state temperature zone is applied

ρ = density of methane (kg/m^3)

Treatment stage 2 (secondary system)

(3) In equation (2) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg CH_4/head/day) is calculated as:

$$M_{jmT=2} = (1 - VSL) \times VS_j \times B_O \times MMS_{mT=2} \times MCF_{im} \times \rho$$

Where VSL = fraction of volatile solids lost during storage in the primary system. (kg/head/day)

$MMS_{mT=2}$ = the fraction of manure in each secondary system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under

Method 1, the default state temperature zone is applied

Note: if all manure is directly applied to soils after it is scraped from the feed pad then methane emissions from the secondary stage is assumed to be zero i.e. if $MMS_{jm=13T=2} = 1$ then $M_{ijm=13T=2} = 0$.

Treatment stage 3 (tertiary system)

(4) In equation (2) production of methane in treatment stage 3 MMS $M_{ijm=1\,T=3}$ (kg CH_4/head/day) is calculated as:

$$M_{ijm=1\,T=3} = VS_j \times B_O \times MMS_{m=1T=3} \times MCF_{im=1} \times \rho$$

Where $MMS_{m=1\,T=3}$ = the fraction of manure to the tertiary system. Assumed to be 0.02 to an anaerobic lagoon MMS

$MCF_{im=1}$ = methane conversion factor for temperature zone and anerobic lagoon system. Under Method 1, the default state temperature zone is applied

(5) In equation (3) – (5) volatile solid production VS_j (kg/head/day) based on the BeefBal model (McGahan et al. (2004)) [2] is calculated as:

$$VS_j = I_j \times \left(1 - DMD_j\right) \times (\,1 - A\,)$$

Where I_j = dry matter intake for each group (kg DM/head/day)

DMD_j = dry matter digestibility for each group (fraction)

A = ash content of manure (fraction)

4.1.1.2 Method 2 — Manure Methane Beef Feedlot

Method 2 is the same as Method 1 except that under equations 4.1.1.1 (2) – (4) farm specific temperature zone is required for $MCF_{im=1}$.

4.1.1.3 Method 1 — Manure Direct N2O Beef Feedlot

(1) The total annual direct nitrous oxide emissions from manure management systems $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = \sum_j \sum_m \sum_T \left(MN_{jmT} \times EF_{jm} \times C_{N2O}\,\right) \times 10^{-3}$$

Where: MN_{jmT} = nitrogen per cattle group, MMS and treatment stage (kg N_2O)

EF_{jm} = nitrous oxide emission factor for MMS (kg N_2O-N/kg N)

C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

Note: exclude $MN_{jm=13T=2}$ which moves directly to $MNsoil$ calculation (equation 4.1.1.7(1))

Treatment stage 1 (primary system)

(2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jm=5\,T=1}$ (kg N_2O) is calculated as:

$$MN_{jm=5\,T=1} = AE_j \times MMS_{jm=5\,T=1}$$

Where: AE_j = total nitrogen excreted by each cattle group (kg N)

$MMS_{jm=5\,T=1}$ = fraction of manure in primary system. Assumed to be 1 for the drylot MMS

(3) In equation (2) annual nitrogen excretion AE_j (kg N) from each feedlot cattle group is calculated as:

$$AE_j = N_j \times NE_j \times D_j$$

Where N_j = number of cattle in each group (head)

NE_j = nitrogen excretion (kg N/head/day)

D_j = Duration of stay of cattle group (days)

(4) In equation (3) nitrogen excretion NE_j (kg/head/day) is calculated by:

$$NE_j = NI_j \times (1 - NR_j)$$

Where NI_j = nitrogen intake (kg/head/day)

NR_j = nitrogen retention expressed as a fraction of intake (per cent). Under Method 1, default NR_j values are applied.

(5) In equation (4) nitrogen intake NI_j (kg/head/day) of feedlot cattle is calculated by:

$$NI_j = I_j \times CP_j \div 6.25$$

Where I_j = dry matter intake (kg DM/head/day)

CP_j = crude protein content of feed (fraction)

6.25 = factor for converting crude protein into nitrogen

Under Method 1, default CP_j values are applied.

Treatment stage 2 (secondary system)

(6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jm\,T=2}$ (kg N_2O) is calculated as:

$$MN_{jm\,T=2} = NT_{jm\,T=2} \times MMS_{jmT=2}$$

Where $NT_{jm\,T=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

$MMS_{jmT=2}$ = fraction of manure in each to secondary system.

Note: if direct application occurs at treatment stage 2 the nitrogen ($MN_{jm=13T=2}$) moves directly to $MNsoil$ calculation (equation 4.1.1.7(1)) and is not included in direct nitrous oxide from manure management equation (Equation 4.1.1.3 (1)).

(7) In equation (6) nitrogen transferred to treatment stage 2 MMS $NT_{jmT=2}$ (kg N) is calculated as:

$$NT_{jmT=2} = \left(MN_{jm=5T=1} \times (1 - FracGASM_{m=5} - EF_{m=5})\right) - MN_{jmT=3}$$

Where $MN_{jmT=1}$ = nitrogen in MMS treatment stage 1 (kg N)

$FracGASM_{m=5}$ = fraction of N volatilised from drylot MMS

$MN_{jmT=3}$ = nitrogen in MMS treatment stage 3 (kg N)

$EF_{m=5}$= nitrous oxide emission factor for each MMS (kg N_2O-N/kg N deposited)

Treatment stage 3 (tertiary system)

(8) In equation (1) nitrogen in treatment stage 3 MMS $MN_{jm=1\,T=3}$ (kg N) is calculated as:

$$MN_{jm=1\,T=3} = AE_j \times MMS_{jm=1\,T=3}$$

Where $MMS_{m=1\,T=3}$ = fraction of manure to tertiary system. Assumed to be 0.02 to anaerobic lagoon MMS

4.1.1.4 Method 2 — Manure Direct N2O Beef Feedlot

Method 2 is the same as Method 1 except that under equation 4.1.1.3 (4) - (5) farm specific data for I_j,and CP_j is required and farm specific NR_j may be applied.

4.1.1.5 Method 1 — Manure Atmospheric Deposition Beef Feedlot

(1) Total annual atmospheric deposition emissions from manure management $E_{N2O,ad}$ (t

N_2O) is calculated as:

$$E_{N2O,ad} = (MMS_{ATMOS} \times EF_{N2O} \times C_{N2O}) \times 10^{-3}$$

Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) volatilised nitrogen from manure management MMS_{ATMOS} (kg N) is calculated as:

$$MMS_{ATMOS} = \sum_j \sum_m \sum_T MN_{jmT} \times FracGASM_{mT}$$

Where MN_{jmT} = nitrogen in each treatment stage MMS (kg N) (excluding $MN_{ijm=13T=2}$)

$FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH_3–N + NO_x–N)/kg N)

Note: in the case of direct application at treatment stage 2 the nitrogen ($MN_{jm=13T=2}$) moves directly to $MNsoil$ calculation (equation 4.1.1.7 (1)) and is not included in the atmospheric deposition from manure management calculation.

4.1.1.6 Method 2 — Manure Atmospheric Deposition Beef Feedlot

There is no Method 2 quantification option for this emission source

4.1.1.7 Method 1 — Manure Leaching and Runoff N2O Beef Feedlot

Due to strict environmental controls leaching from feedlot MMS are assumed to be zero. Run-off from MMS is included in the treatment stage 3 of the direct MMS estimates.

4.1.1.8 Method 2 — Manure Leaching and Runoff N2O Beef Feedlot

There is no Method 2 quantification option for this emission source

4.1.1.9 Manure Applied to Soils

It is assumed that all manure managed through MMS (m=1-13) will eventually be applied to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is transferred to Chapter 5 Section 5.1 to estimate emissions associated with the application of organic fertilisers, including the associated atmospheric deposition, and leaching and run-off emissions.

This manure may be applied to soils within the boundary of the feedlot or may be sent off-site and applied to another farming system or enterprise. Where manure is applied to soils within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be estimated and reported as Scope 1 emissions. Where the manure is used on other farming enterprises $MNSoil_{scope3}$, the emissions from shall be estimated and reported as Scope 3 emissions under Scope 3 Category 5 – waste generated in operations (see Chapter 7 Section 7.10).

(1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is calculated as:

$$MNSoil_{scope1} = \sum_j \sum_m \sum_T MN_{jmT=2,3} \times \left(1 - EF_{mT=2,3} - FracGASM_{mT=2,3}\right) \times PF$$

Where $MN_{jmT=2,3}$ = mass of N in secondary and tertiary treatment MMS stages as calculated for manure management (kg N)

$EF_{mT=2,3}$ = nitrous oxide emission factor for each MMS (kg N_2O-N/kg N)

$FracGASM_{mT=2,3}$ = fraction of animal waste N volatilised in each MMS for each cattle group ((kg NH_3–N + NO_x–N)/kg N)

PF = fraction of manure applied to soil within the feedlot boundary

Note: where direct application occurs at treatment stage 2 ($MN_{jm=13T=2,3}$), $EF_{jm=13T=2}$ and $FracGASM_{jm=13T=2}$ are set to zero.

(2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is calculated as:

$$MNSoil_{scope3} = \sum_j \sum_m \sum_T MN_{jmT=2,3} \times \left(1 - EF_{mT=2,3} - FracGASM_{mT=2,3}\right) \times (1 - PF)$$

4.1.2 Data/Parameters

4.1.2.1 Input Data (Required)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each cattle group
Data source	Farm stock records; system type records or purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay
Quality assurance / quality control considerations	The length of stay may be cross checked with duration of stay expected for the National Inventory Report feedlot cattle classes in the Appendix Table A.1.1.1. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may also be used for data assurance and control of entered values.

Data / Parameter	N_j
Data unit	head
Description	Number of beef cattle in each group
Data source	Farm stock records e.g. head counts, diary entries, purchase, and sales records
Quality assurance / quality control considerations	All animals purchased or sold in the reporting period are assumed to be reported. Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The classes of animals on farm may be checked against reported products from farm.

Data / Parameter	$MMS_{mT=2}$
Data unit	fraction
Description	Fraction of manure at treatment stage 2 for each manure management system i.e. what fraction of manure goes to what MMS once it has been removed from the feed pad. If there is only one available MMS then this should be equal to 1. This may be different for different cattle groups.
Data source	Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based on either weight or volume of manure. If treatment is different for different cattle groups this may also be recorded per cattle group.
Quality assurance / quality control considerations	The fraction of manure to each secondary manure management system should sum to one. If only one is MMS used to treat manure, then $MMS_{mT=2}$ shall be equal to 1. Note: if manure is directly applied to soils after it is scraped from the feedlot then methane and nitrous oxide emissions will be zero for this secondary treatment stage MMS. The nitrogen in the manure ($MN_{jm=13T=2}$) moves directly to $MNsoil_{jm}$ calculation (equation 4.1.17(1)) (see also Chapter 5 Section 5.1). It is excluded from equation 4.1.1.3 (1) and 4.1.1.4 (2)

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure applied to soil within the feedlot boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	If all of manure is not applied to soil within the feedlot boundary ensure it is appropriately tracked what proportion is sent off-site to other entities. If it is not known what proportion is sent off-site to other entities assume all manure is applied within the feed lot boundary until better data can be collected.

4.1.2.2 Data (Method 1 and 2 Options)

Data / Parameter	I_j
Data unit	kg DM/head/day
Description	Average dry matter intake per head per day of each lot of cattle.
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Select the default value appropriate to the length of stay of each cattle lot.
Method 2 data source	Farm records of dry matter content of total mixed ration (TMR), and daily feed and feed waste weights for each lot Noting that TMR may change over the duration of the stay therefore a weighted average of intake should be calculated based on the composition of feed throughout the stay of the cattle lot
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with the Method 1 defaults for the relevant cattle class.

Data / Parameter	DMD_i
Data unit	fraction
Description	Dry matter digestibility of diet used within feedlot system
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Apply the dry matter digestibility that best represents the duration of stay of each cattle class.
Method 2 data source	Farm records or feed receipt stating dry matter digestibility of TMR
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.

Data / Parameter	CP_j
Data unit	fraction
Description	Average crude protein content of the feed given to each cattle group. National default data based on length of stay is available if crude protein content of TMR for a group is not known.
Method 1 data source	See Appendix Table A.1.1.3
Method 1 value	Apply the crude protein per cent that best represents the duration of stay of each cattle class.
Method 2 data source	Farm records or feed receipt stating crude protein of TMR
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.

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Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.1.4
Method 1 value	Choose appropriate default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting an appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.1.4 and A.1.8.1 for data source information).

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Data / Parameter	NR_j
Data unit	per cent
Description	Nitrogen retention expressed as a per cent of intake based on length of stay of each cattle group on the feed pad.
Method 1 source	See Appendix Table A.1.1.2
Method 1 value	Apply the nitrogen retention that best represents the duration of stay of each cattle class.
Method 2 data source	Farm specific estimates of nitrogen retention estimated by a mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain and the nitrogen in the waste feed.

Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class.

4.1.2.3 Constants

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$MMS_{m=5T=1}$
Data unit	fraction
Description	Fraction of volatile solids to each primary system, assumed all primary systems are drylot.
Data source	Table A5.5.3.4, National Inventory Report, Volume 2 [4]
Value	1
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	*p*
Data unit	kg/m^3
Description	Density of methane.
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	VSL
Data unit	Fraction
Description	Fraction of volatile solids lost during storage in the primary system.

Data source	McGahan, et al. (2004) [2] and Wiedemann et al. (2014) [6]
Value	0.5
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$MMS_{m=1T=3}$
Data unit	fraction
Description	Fraction of volatile solids to each tertiary system assumed that 2 per cent is run-off from the feed pad.
Data source	Table A5.5.3.4, National Inventory Report, Volume 2 [4]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	A
Data unit	fraction
Description	Ash content of manure.
Data source	National Greenhouse Gas Inventory Report Vol 1. (2023) [1]
Value	0.16
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{mT}
Data unit	kg N_2O-N/kg N
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.1.5
Value	Apply the EF that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$FracGASM_{mT}$
Data unit	(kg NH_3–N + NO_x–N)/kg N
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.1.6
Value	Apply the FracGASM that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{N2O}
Data unit	kg N_2O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	Apply the atmospheric deposition EF that best represent the production systems immediately surrounding the feedlot. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

4.2 Beef Pasture, Range, and Paddock

This module covers the estimation of methane and nitrous oxide emission that results from grazing beef cattle manure management. Figure 4.4 summarises the emission sources associated with the manure of beef cattle on pasture, rangeland and paddock (PRP). There are two components to methane emission estimates –manure excreted directly onto PRP, and manure that runs-off into natural water sources and farm dams. There are no nitrous oxide emissions from manure management for manure excreted to PRP, however emissions from the soil occur from the metabolism of the deposited urine and faeces, and indirectly through atmospheric deposition and leaching and runoff.

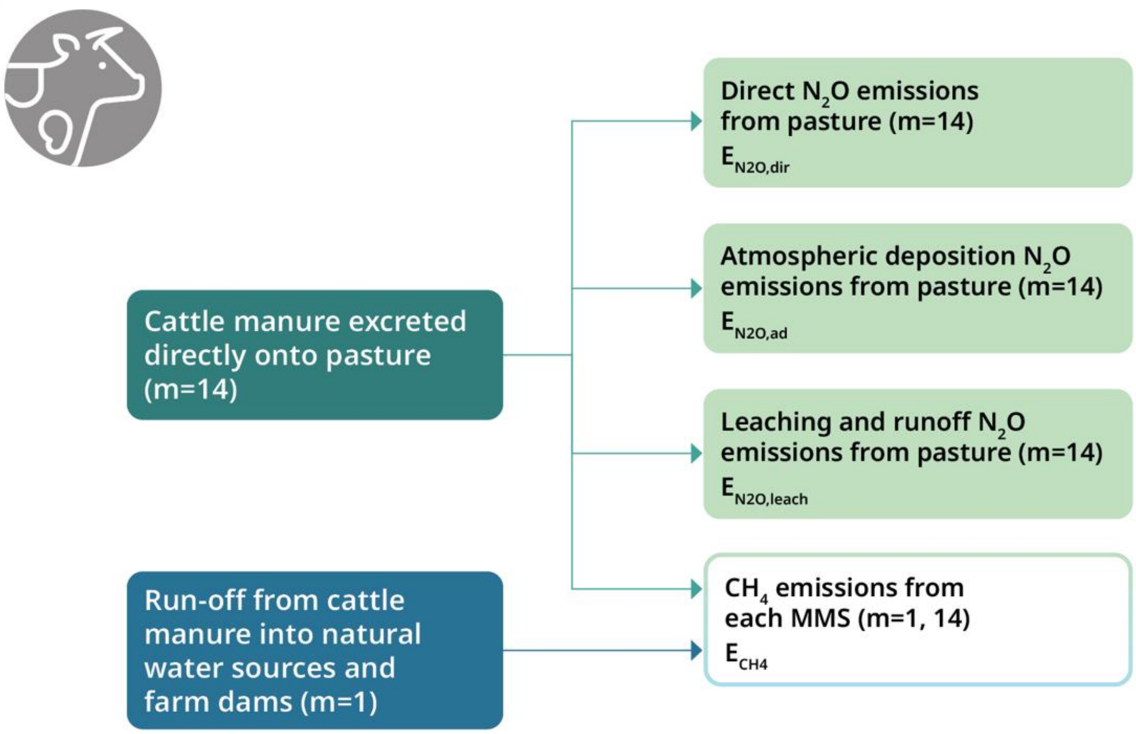

Figure 4.4: Emissions that result from manure of beef cattle on pasture, rangeland and paddock

The following subscripts are used in this module:

Subscript	Meaning
i	Temperature zone
j	Time-period (e.g season or month)
k	Beef cattle class
l	Beef cattle subclass
m	Manure management system

Emissions are estimated based on age and sex classes of cattle, time of the year and manure management system. The temperature zone will affect the selection of appropriate emissions factors. The emissions are summed across each class (and subclass), manure management system and time-period spent on farm during the reporting period.

The classes of cattle on the farm (‘Beef cattle input class’) will depend on the diversity of the farming operation. These classes need to be mapped back to default categories (‘Beef Cattle Classes (l) and Subclass (n)’) to allow the use of default values under Method 1.

The time-period selected will depend on availability of stock numbers and liveweight and liveweight gain data (see Herd Flow modelling guidance in Section 1.9).

Beef Cattle Classes (l)	Beef Cattle Subclass (n) [(a)]	Beef Cattle input classes
1 = Bulls < 1 year	1 = Bulls < 1 year	Bulls < 1 year
2 = Bulls > 1 year	2 = Bulls > 1 year	Bulls > 1 year
3 = Cows < 1 year	3 = Cows < 1 year	Cows < 1 year
4 = Cows 1-2 years	4 = Cows 1-2 years	Cows 1-2 years
5 = Cows > 2 years	5a = Cows 2-3 years	Cows 2-3 years
	5b = Cows > 3 years	Cows > 3 years
6 = Steers < 1 year	6 = Steers < 1 year	Steers < 1 year
7 = Steers > 1 year	7a = Steers 1-2 years	Steers 1-2 years
	7b = Steers 2-3 years	Steers 2-3 years
	7c = Steers >3 years	Steers >3 years

(a) Only available for cattle in QLD and NT

The only relevant manure management systems (m) for grazing beef are PRP (m=14) and anaerobic lagoons (m=1). Where farmers have unfenced natural water sources and farm dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these water sources.

4.2.1 Estimation methodology

4.2.1.1 Method 1 — Manure Methane Beef Grazing

(1) Total annual methane production from manure management E_{CH4} (t CH_4) for grazing beef cattle is calculated as:

$$E_{CH4} = \sum_j \sum_k \sum_l \sum_m \left(N_{jkl} \times M_{jklm} \times D_j \right) \times 10^{-3}$$

Where N_{jkl} = number of beef cattle in each time-period, class and sub class (head)

M_{jklm} = methane production from manure in each time-period, class, sub class and MMS (kg/head/day)

D_j= number of days in each time-period for each input class (days). This is 91.25 days under Method 1 as the default time-period is a season (quarter of a calendar year)

(2) In equation (1) methane production from the manure of grazing beef cattle M_{jkl} (kg/head/day) is calculated as:

$$M_{jklm} = VS_{jkl} \times B_O \times MMS_m \times MCF_{im} \times \rho$$

Where VS_{jkl} = volatile solid production (kg/day)

B_O = emissions potential (m^3 CH_4/kg VS)

MMS_m = fraction of waste in each manure management system

MCF_{im} = Methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied

ρ = density of methane (kg/m^3)

The primary manure management system (MMS) for pasture-fed beef is pasture range and paddock (m=14). Where natural water sources and farm dams are present the anaerobic lagoon (m=1) MMS is used to estimate the run-off of manure into these water sources. Where farmers can demonstrate animals are on bore or reticulated water systems, where water is provided in troughs (i.e., no unfenced natural water sources or farm dams), then the only relevant MMS to be considered shall be pasture range and paddock (m=14).

(3) In equation (2) volatile solid production from grazing beef VS_{jkl} (kg/head/day) is calculated by:

$$VS_{jkl} = \left(I_{jkl} \times \left(1 - DMD_{jkl}\right) + \left(0.04 \times I_{jkl}\right)\right) \times (1 - A)$$

Where I_{jkl} = dry matter intake as calculated in Chapter 3 Section 3.2.1 (kg/head/day)

DMD_{ijk} = dry matter digestibility expressed as a fraction. Default values applied under Method 1

A = ash content of feed intake expressed as fraction

4.2.1.2 Method 2 — Manure Methane Beef Grazing

Method 2 is the same as Method 1 except that under equations 4.2.1.1 (3) feed intake I_{jkl} is estimated as per section 3.2.1.2 and farm specific data for the selected time-period (i.e. seasonal, monthly or other) and for farm specific temperature zone is used for MCF_{im}. Farm specific data may be applied for DMD_{jk}.

Under Method 2 the selected time-period and associated D_j used in equation 4.2.1.1 (1) may be a season (D_j= 91.25 days), month (D_j=28-31 day depending on month) or a specific number of days in a month or season if the entry and exit from farm of a specific cohort of animals is being estimated

4.2.1.3 Method 1 — Soil Direct N2O Beef Grazing

(1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of urine and dung $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = (AE \times EF_{PRP} \times C_{N2O}) \times 10^{-3}$$

Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

EF_{PRP}= emission factor for nitrous oxide from urine and dung deposited to soil (kg N_2O-N/kg N deposited)

C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

(2) In equation (1) the total nitrogen excreted to pasture, range and paddock AE (kg N) is calculated as:

$$AE = \sum_j \sum_k \sum_l (N_{jkl} \times NE_{jkl} \times D_j)$$

Where N_{jkl} = number of beef cattle by time-period, class and sub class (head)

NE_{jkl} = nitrogen excreted in each time-period, by each class and subclass (kg N/head/day)

D_j= number of days in each time-period (days). This is 91.25 days under Method 1 as the default time-period is a season

(3) In equation (2) the nitrogen excreted NE_{jkl} (kg N/head/day) is calculated as:

$$NE_{jkl} = (I_{jkl} \times CP_j \div 6.25) + (0.032 \times MC_{jk=1,3,6} \div 6.38) - NR_{jkl} - [(1.1 \times 10^{-4} \times W_{jkl}{}^{0.75}) \div 6.25]$$

Where I_{jkl} = dry matter intake as calculated in Chapter 3 Section 3.2.1 (kgDM/head/day)

CP_j = crude protein content of dry matter intake

$MC_{jk=1,3,6}$= milk intake (kg/head/day)

NR_{jkl} = the amount of nitrogen retained by the body (kg N/head/day)

W_{jkl} = liveweight (kg/head)

Under Method 1, default CP_j and W_{jkl} values are applied.

(4) In equation (3) the amount of nitrogen retained by the body NR_{jkl} (kg N/head/day) is calculated as:

$$NR_{jkl} = (0.032 \times MP_{jk=5} \div 6.38) + \left\{ \left\{ 0.212 - 0.008 \times (L_{jkl} - 2) - \left[\frac{0.140 - 0.008 \times (L_{jkl} - 2)}{1 + e^{(-6 \times (Z_{jkl} - 0.4))}} \right] \right\} \times (LWG_{jkl} \times 0.92) \right\} \div 6.25$$

Where $MP_{jkl=5}$ = milk production (kg/head/day)

L_{jkl} = intake relative to that needed for maintenance

Z_{jkl} = relative size

LWG_{jkl} = liveweight gain (kg/head/day). Under Method 1, default LWG_{jkl} values are applied.

(5) In equation (4) milk production for the season of calving and season after calving $MP_{jkl=5}$ (kg/head/day) is calculated as:

$$MP_{jk=5} = LC_{jk=5} \times DMP_{jk=5}$$

Where $LC_{jk=5}$ = proportion of cows > 2 years (k=5) lactating for the season of calving and season after calving noting that for all other seasons $LC_{jk=5} = 0$

$DMP_{jk=5}$ = daily milk production (kg/head/day)

For farms with multiple calving seasons, the proportion of cows > 2 years in calf ($LC_{jk=5}$) should be reported separately for each season.

(6) In equation (4) intake relative to that needed for maintenance L_{jkl} is calculated as:

$$L_{jkl} = \frac{I_{jkl}}{\left(1.185 + 0.00454 \times W_{jkl} - 0.0000026 \times {W_{jkl}}^2\right)^2}$$

(7) In equation (4) The relative size of the cattle Z_{jkl}, is calculated as:

$$Z_{jkl} = \frac{W_{jkl}}{SRW_k}$$

Where SRW_k = standard reference weight (kg)

4.2.1.4 Method 2 — Soil Direct N2O Beef Grazing

Method 2 is the same as Method 1 except that under equations 4.2.1.3 (3),and (6) feed intake I_{jkl} is estimated as per section 3.2.1.2 and farm specific data is required for the selected time-period (i.e. seasonal, monthly or other) for W_{jkl} (Eq 4.2.1.3 (3), (6) and (7)), and LWG_{jkl} (Eq 4.2.1.3 (4)) and farm specific data may be applied for CP_{jkl} (Eq 4.2.1.3 (3)).

Under Method 2 the selected time-period and associated D_j used in equation 4.2.1.3 (2) may be a season (L_j= 91.25 days), month (L_j=28-31 day depending on month) or a specific number of days in a month or season if the entry and exit from farm of a specific cohort of animals is being estimated

4.2.1.5 Method 1 — Soil Atmospheric Deposition N2O Beef Grazing

(1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N2O,ad}$ (t N_2O) are calculated as:

$$E_{N2O,ad} = M_{vol} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on pasture (kg N)

EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

$$M_{vol} = AE \times FracGASMsoil$$

Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

$FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces deposited on pasture ((kg NH_3–N + NO_x–N)/kg N)

4.2.1.6 Method 2 — Soil Atmospheric Deposition N2O Beef Grazing

There is no Method 2 quantification option for this emission source.

4.2.1.7 Method 1 — Soil Leaching and Runoff N2O Beef Grazing

(1) Leaching and runoff emissions from urine and dung deposited on pasture $E_{N2O,leach}$ (t N_2O) are calculated as:

$$E_{N2O,leach} = M_{leach} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

EF_{leach} = emission factor for leaching and runoff (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} is calculated as:

$$M_{leach} = AE \times FracWet \times FracLEACH$$

Where AE = total mass of nitrogen excreted on PRP for beef cattle (kg N)

$FracWet$ = fraction of N available for leaching and runoff.

$FracLEACH$ = fraction of all N that is lost through leaching and runoff

4.2.1.8 Method 2 — Soil Leaching and Runoff N2O Beef Grazing

There is no Method 2 quantification option for this emission source

4.2.2 Data/Parameter tables

4.2.2.1 Input data (Required)

Data / Parameter	N_{jkl}
Data unit	head
Description	Number of pasture beef cattle per time-period, class and sub class
Data source	Farm stock records and herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The class of animals on farm may be crossed checked with expected enterprise on farm. For example, self-replacing systems vs purchased breeder or trading systems.

Data / Parameter	$LC_{jk=5}$
Data unit	fraction
Data source	Proportion of cows > 2 years in calf in the season of calving. This is used as a proxy for cows >2 lactating
Value	Farm records: Proportion of cows > 2 may be based on scanning numbers where available. If scanning results are not available weaning numbers may also be used to approximate the proportion of cows > 2 years lactating. For farms with multiple calving seasons, the proportion of cows > 2 years in calf $LC_{jk=5}$ should be reported separately for each season or time period. Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is used (see Chapter 1 Section 1.9) and that for all other time periods $Lj_{k=5} = 0$
Quality assurance / quality control considerations	Scanning records may be used to check input data. If scanning or weaning results are not recorded proportion of cows > 2 years may be cross checked from number of cows and calves in the reporting period.

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4.2.2.2 Data (Method 1 and 2 options)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each cattle, class and sub class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	91.25 as the default time period is a season (quarter of a calendar year).
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each cattle input class (see Chapter 1 Section 1.9 for more details on herd flow modelling)
Quality assurance / quality control considerations	Ensure that if animals are on the farm all year round the duration of stay is 365 days Ensure that if animals are only born part way through the reporting period their duration of stay reflect this. If Method 1 is used inputs should be completed seasonally throughout the calculations. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values.

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Data / Parameter	DMD_j
Data unit	fraction
Description	Dry matter digestibility
Method 1 data source	See Appendix Table A.1.2.5
Method 1 value	Select the appropriate default value for location of cattle and season
Method 2 data source	Farm source records for seasonally dry matter digestibility of feed.
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class. If farm data is only available for one (or more) seasons, use data available for season(s) and supplement missing data with inventory data.

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Data / Parameter	CP_j
Data unit	fraction
Description	Crude protein content of feed dry matter
Method 1 data source	See Appendix Table A.1.2.6
Method 1 value	Select the appropriate default value for location of cattle and season
Method 2 data source	Farm source records for seasonally crude protein of feed.
Quality assurance / quality control considerations	In Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data source is used this input may be cross checked with to Method 1 defaults for the relevant cattle class. If farm data is only available for one (or more) seasons, use data available for season(s) and supplement missing data with inventory data.

Data / Parameter	W_{jkl}
Data unit	kg
Description	Average liveweight of beef pasture cattle per time-period, class and subclass
Method 1 data source	See Appendix Table A.1.2.1 & A.1.2.2
Method 1 value	Select the appropriate default value for location of cattle, class/subclass and season
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. if autumn calving, ensure default weights reflect this with lowest weight value applied in autumn for stock <1 year and/or that default weights reflect when stock are expected to be at the lightest and heaviest. If Method 2 is used purchase and sale weight records (invoices) may be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.

Data / Parameter	LWG_{jkl}
Data unit	kg/head/day
Description	Average liveweight gain of beef pasture cattle per time-period, class and sub class
Method 1 data source	See Appendix Table A.1.2.2 & A.1.2.3
Method 1 value	Select the appropriate default value for location of cattle, class/subclass and season
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. that default liveweight gain reflects when stock are expected to be growing more due to feed quality and availability. If Method 2 is used purchase and sale weight records (invoices) may be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.

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Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.2.10
Method 1 value	Select default value based on State, Region and MMS.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

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577 #### 4.2.2.3 Constants

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19

Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	MMS_m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	See Appendix Table A.1.2.9
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS_m values shall be selected based on State, Region and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and $MMS_{m=14}$ = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	A
Data unit	fraction
Description	Ash content of feed intake
Data source	National Greenhouse Gas Inventory Report Vol 1. (2023)
Value	0.08
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$MC_{jk=1,3,6}$
Data unit	kg/head/day
Description	Milk intake
Data source	See Appendix Table A.1.2.7
Value	Select the appropriate default value based on the cattle breed. Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is provided (see Chapter 1 Section 1.9) and the season after calving the 3 months after this period.
Quality assurance / quality control considerations	Ensure all other stock classes other than cattle <1 year old are defaulted to zero. Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$DMP_{jk=5}$
Data unit	kg/head/day
Description	Daily milk production
Data source	See Appendix Table A.1.2.7
Value	Select the appropriate default value based on the cattle breed. Noting that the calving season should be considered 3 months from the calving month if Method 2 herd flow data is provided (see Chapter 1 Section 1.9) and the season after calving the 3 months after this period.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	SRW_k
Data unit	kg
Description	Standard reference weight
Data source	See Appendix Table A.1.2.8
Value	Select the appropriate default value based on cattle class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	EF_{PRP}
Data unit	kg N_2O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	See Appendix Table A.2.2.2.
Value	The appropriate EF_{PRP} shall be selected by using the IPCC values for EF_{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	EF_{N2O}
Data unit	kg N_2O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the cattle are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	FracGASMsoil

Data unit	(kg NH_3–N + NOx–N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

Data / Parameter	FracLEACH
Data unit	fraction
Description	Default fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

4.3 Dairy

This module covers the estimation of methane and nitrous oxide emission that results from dairy cattle manure management. Figure 4.5 summarises the emission sources associated with the manure from dairy cattle. There are two components to methane emission estimates – manure excreted directly onto pasture, and managed manure from the milking shed or and feedpad. Managed manure also results in direct and indirect nitrous oxide emissions. For manure excreted to pasture there are no nitrous oxide emissions from manure management, however emissions from the soil occur from the metabolism of the deposited urine and faeces, and indirectly through atmospheric deposition and leaching and runoff. Note that emissions associated with manure from management systems that is subsequently applied to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser module.

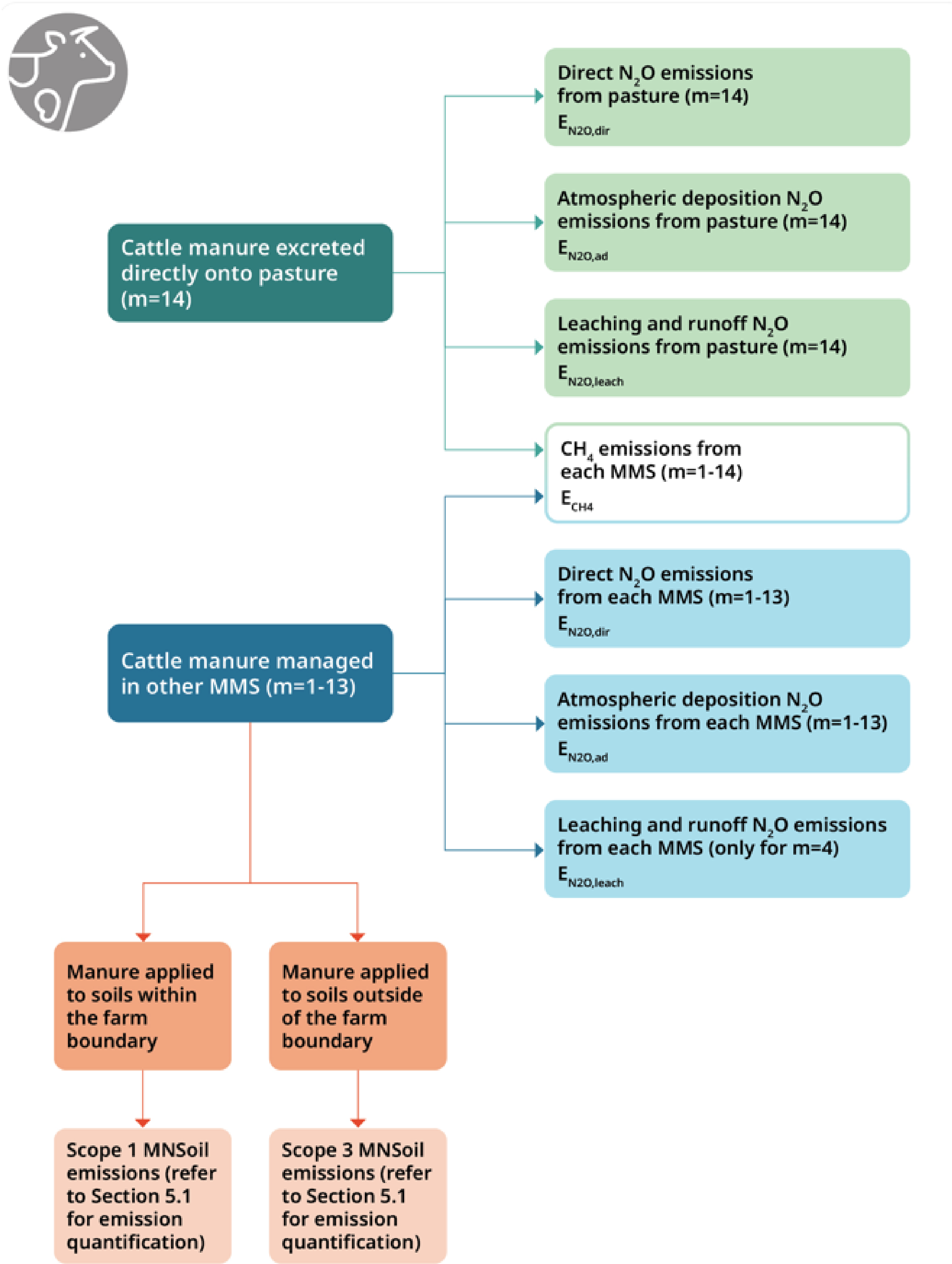

Figure 4.5: Emissions that result from dairy cattle manure

The following subscripts are used in this module:

Subscript	Meaning
I	Temperature zone
J	Livestock class
M	Manure management system

Emissions are estimated based on age and sex classes of cattle and the manure management system. The temperature zone will affect the selection of appropriate emissions factors. The emissions are summed across each class, manure management system and time-period spent on farm during the reporting period.

The classes of cattle on the farm (‘dairy input class’) will depend on the diversity of the farming operation. The number of heifer and bull calves should be reported separately to weaned stock less than 12 months in age to capture emissions from calves sold at weaning. These classes need to be mapped back to default categories (‘dairy cattle class j’) to allow the use of default inventory values under Method 1.

Dairy Cattle Class j	Possible Dairy Input Class
1 = Milking cows	Milking cows
2 = Heifers > 1 year	Heifers > 1 year
3 = Heifers < 1 year	Replacement heifers < 1 year, weaned
	Heifer Calves, <1 year, preweaning
4 = Bulls > 1 year	Mature bulls
5 = Bulls < 1 year	Other weaned stock < 1 (non-replacement heifers, steers or bulls)
	Bull Calves, <1 year, preweaning

The National Inventory Report and Method 1 defaults for dairy assume that all “other stock” will be sold from the dairy at 12 months or less. In cases where other stock such as steers or bulls are retained beyond 12 months Method 1 default values for liveweight and liveweight gain may be taken from the appropriate beef pasture, range and paddock defaults (see Section **Error! Reference source not found.** for more detail).

Nitrous oxide emissions from managed manure are only relevant for milking cows (j=1). The manure management systems (m) will differ for manure excreted while animals are grazing or in the milking shed or feedpad. Manure from other dairy cattle classes (j=2-5) is all assumed to be excreted to pasture (m=14)

4.3.1 Estimation methodology

4.3.1.1 Method 1 — Manure Methane Dairy

(1) Total annual methane production from manure management E_{CH4} (t CH_4) is calculated as the sum of methane from manure from dairy cows, bulls, young stock and pre-weaned calves:

$$E_{CH4} = \sum_j \sum_m \Big(\big(N_{j=1,2,4} \times M_{j=1,2,4m} \times D_{j=1,2,4}\big) + \big(N_{j=3,5} \times M_{j=3,5,m} \times D_{j=3,5}\big) + \big(N_{j=3,5} \times MPW_{manure,j=3,5} \times D_{j=3,5}\big)\Big) \times 10^{-3}$$

Where N_j = number of dairy cattle in each class

M_{jm} = methane production from manure of weaned dairy cattle in each class in each MMS (kgCH_4/head/day)

$MPW_{manure,j=3,5}$= methane production from manure of pre-weaned heifer and bulls calves (<1 year) (kg CH_4/head/day)

D_j = Duration of stay on the farm (days). Method 1 default values for these time periods are provided in data tables.

(2) Methane from manure production M_{jm} (kgCH_4/head/day) from weaned dairy cattle is calculated by:

$$M_{jm} = VS_j \times FVS_{jm\,T=1} \times MCF_{im} \times B_o \times \rho$$

Where: VS_j= daily volatile solids production per head for dairy cattle (kg/head/day)

FVS_{jm}= fraction of waste from each class in each management system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied

B_o = emissions potential (m^3 CH_4/kgVS)

ρ = density of methane (kg/m^3)

(3) In equation (2), for weaned dairy cattle, volatile solids VS_j (kg/head/day) are calculated as:

$$VS_j = \big(I_j \times (1 - DMD_j) + (0.04 \times I_j)\big) \times (1 - A)$$

Where I_j = dry matter feed intake as calculated in Chapter 3 Section 3.3.1 (kgDM/head/day)

DMD_j = dry matter digestibility. Default values applied under Method 1

A = ash content of feed intake

Note: volatile solids values for pre-weaned cattle $VS_{j=3,5}$ are provided as constants in Section 4.3.2.3

(4) In equation (2) the fraction of volatile solids in each system FVS_{jm} , other than solid

storage (m=4), is calculated as:

$$FVS_{jm} = MMS_{jm} \times (1 - SS_m)$$

Where:

SS_m = fraction of volatile solids separated to solid storage for each MMS

MMS_{jm} = fraction of manure to each primary MMS for each class prior to solid separation

(5) In equation (3) the fraction of volatile solids in solid storage, $MMS_{jm=4}$ is calculated as:

$$FVS_{jm=4} = MMS_{jm=4} + (MMS_{jm=1,7,9} \times SS_m)$$

Note: Where solid separation systems are applied, the separated solids are currently assumed to be treated through solid storage.

4.3.1.2 Method 2 — Manure Methane Dairy

Method 2 is the same as Method 1 except that under equations 4.3.1.1 (3) feed intake I_j is estimated as per section 3.3.1.2 and farm specific data is required for MCF_{im}. Farm specific data may be applied for DMD_k.

Under Method 2 the selected time-period and associated D_j used in equation 4.3.1.1 (1) may be a year ,$D_{j=1,2,4}$= 365 days, or $D_{j=3,5}$=284 or 84 days depending on pre or post weaning or a specific number of days if the entry and exit from farm of a specific cohort of animals is being estimated

4.3.1.3 Method 1 — Manure Direct N2O Dairy

(1) The total annual direct nitrous oxide emissions from manure management systems $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = \sum_j \sum_m \left(MN_{jm} \times EF_m \times C_{N2O}\right) \times 10^{-3}$$

Where MN_{jm} = total nitrogen in each MMS for dairy cattle classes (kg N)

EF_m= nitrous oxide emission factor for each MMS (kg N_2O-N/kg N deposited)

C_{N2O} = factor to convert elemental mass of N_2O to molecular mass

(2) In equation (1) total nitrogen in each MMS MN_{jm} (kg N) is calculated as:

$$MN_{jm} = AE_j \times MMS_{jm}$$

Where AE_j = total nitrogen excreted by each dairy class (kg N)

(3a) In equation (2) total annual nitrogen excreted by dairy cattle >1 year old, $AF_{j=1,2,4}$ (kg N) is calculated as:

$$AE_{j=1,2,4} = (N_{j=1,2,4} \times NE_{j=1,2,4} \times 365)$$

Where: $NE_{j=1,2,4}$= nitrogen excreted by dairy cattle >1 year old (kg N/head/day)

(3b) In equation (2) total annual nitrogen excreted by dairy cattle <1 year old, $AF_{j=3,5}$ (kg N) is calculated as:

$$AF_{j=3,5} = \left(N_{j=3,5} \times NE_{j=3,5} \times 281\right) + \left(N_{j=3,5} \times NPW_{j=3,5} \times 84\right)$$

Where: $NE_{j=3,5}$= nitrogen excreted by weaned dairy cattle <1 year old (kg N/head/day)

$NPW_{j=3,5}$= nitrogen excreted by pre-weaned calves (kg N/head/day)

(4) In equation (3) nitrogen excreted NE_j(kg N/head/day) by dairy cattle >1 year old is calculated as:

$$NE_j = \left(\frac{CPI_j}{6.25}\right) - NR_j - \left[\frac{1.1 \times 10^{-4} \times W_j^{0.75}}{6.25}\right]$$

Where CPI_j = crude protein intake (kg/head/day)

NR_j = amount of nitrogen retained by the body (kg N/head/day)

W_j = liveweight (kg). Default values applied under Method 1

(5) In equation (4) the crude protein intake CPI_j (kg/head/day) of dairy cattle is calculated as:

$$CPI_j = I_j \times CP_j$$

Where CP_j = crude protein content of feed intake (fraction). Default values applied under Method 1

(6) In equation (4) the amount of nitrogen retained by the body NR_j is calculated as:

$$NR_j = \left(\frac{0.032 \times MP_j \times 1.03}{6.38}\right) + \left\{\left\{0.212 - 0.008 \times (L_j - 2) - \left[\frac{0.140 - 0.008 \times (L_j - 2)}{1 + e^{-6\times(Z_j - 0.4)}}\right]\right\} \times (LWG_j \times 0.92)\right\} \times \frac{1}{6.25}$$

Where MP_j = milk production (L/head/day)

L_j = intake relative to that needed for maintenance

Z_j = relative size

LWG_j = liveweight gain (kg/day). Default values applied under Method 1

1.03 = conversion factor for milk in litres to kg

Where daily milk production data is collected in quantities of milk solids rather than litres of milk, refer to Chapter 3 Section 3.3.1 for converting milk solids to litres.

(7) In equation (6) intake relative to maintenance L_j is calculated as:

$$L_j = \frac{I_j}{\left(1.185 + 0.00454 \times W_j - 0.0000026 \times W_j^{2}\right)^2 \times MR_j + MI_j}$$

Where MR_j = increase in metabolic rate when producing milk (kgDM/head/day)

MI_j = additional intake required for milk production, as calculated in Chapter 3 Section 3.3.1 (kgDM/head/day)

(8) In equation (6) The relative size Z_j is calculated as;

$$Z_j = \frac{W_j}{WR_j}$$

Where WR_j = reference weight (kg)

4.3.1.4 Method 2 — Manure Direct N2O Dairy

Method 2 is the same as Method 1 except that under equations 4.3.1.3 (5), and (7) feed intake I_j is estimated as per section 3.2.1.2 and farm specific data is required for the selected time-period (i.e. seasonal, monthly or other) for W_j (Eq 4.3.1.3 (4), (7) and (8)), LWG_j (Eq 4.3.1.3 (6)) and may be applied for CP_j (Eq 4.2.1.3 (5)).

4.3.1.5 Method 1 — Manure Atmospheric Deposition Dairy

(1) Annual atmospheric deposition emissions from MMS $E_{N2O,MMS,ad}$ is calculated as:

$$E_{N2O,MMS,ad} = MN_{ATMOS} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where MN_{ATMOS} = mass of N volatilised from MMS (kg N)

EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) total of nitrogen volatilised from MMS MN_{ATMOS} (kg N) is calculated as:

$$MN_{ATMOS} = \sum_j \sum_m (MN_{jm} \times FracGASM_m)$$

Where $FracGASM_m$ = fraction of N volatised from MMS (fraction)

4.3.1.6 Method 1 — Manure Leaching and Runoff N2O Dairy

(1) Annual emissions from leaching and run off from each MMS $E_{N2O,leach}$ (t N_2O) is calculated as:

$$E_{N2O,leach} = \sum_j \sum_{m=1-13} (MNLeach_{jm} \times EF_{leach} \times C_{N2O}) \times 10^{-3}$$

Where $MNLeach_{jm}$ = mass of N lost through leaching and runoff from each MMS (kg N)

EF_{leach} = nitrous oxide emission factor for leaching and runoff (kg N_2O-N/kg N)

$MNLeach_m$is assumed to be zero for anaerobic lagoons (m=1), and for daily spread treatments (sump and dispersal m=3a, and drains to paddock m=3b) is nitrogen is transferred directly to manure applied to soils (see section 4.3.1.8 Manure applied to Soil)

Emissions from leaching and run off are only estimated for the solid storage MMS (m=4). This simplifies the equation to:

$$E_{N2O,leach} = MNLeach_{jm=4} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

(2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage systems $MNLeach_{jm=4}$ (kg N) is calculated as:

$$MNLeach_{jm=4} = MN_{jm=4} \times FracWET_i \times FracLEACH_{MS}$$

Where $FracWET_i$ = fraction of N available for leaching and runoff

$FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

4.3.1.7 Method 2 — Manure Leaching and Runoff N2O Dairy

There is no Method 2 quantification option for this emission source

4.3.1.8 Manure Applied to Soils

It is assumed that all manure managed through an MMS (m=1-13) will eventually be applied to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is transferred to Chapter 5 Section 5.1 to estimate emissions associated with the application of manure to soils as organic fertilisers, including associated atmospheric deposition and leaching and run-off emissions.

The manure may be applied to soils within the boundary of the farm or may be sent off-site and applied to another farming enterprise. Where manure is applied to soils within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be estimated and reported as Scope 1 emissions. Where the manure is used on other farming enterprises $MNSoil_{scope3}$, the emissions from shall be estimated and reported as Scope 3 emissions under Scope 3 Category 5 – waste generated in operations (see Chapter 7 Section 7.10).

(1) The mass of nitrogen from manure that is applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is calculated as:

$$MNSoil_{scope1} = \sum_j \sum_m (MN_{jm=1-13} \times (1 - EF_{m=1-13} - FracGASM_{m=1-13}) - MNLeach_{jM}) \times PF$$

Where PF_{scope} = fraction of manure applied to soil within the farm boundary

$EF_{m=1-13}$ = Emission factor for nitrous oxide emissions per MMS (kg N_2O-N/kg N)

(2) The mass of nitrogen from manure that is applied to soils for scope 3 $MNSoil_{scope3}$ (kg N) is calculated as:

$$MNSoil_{scope3} = \sum_j \sum_m (MN_{jm=1-13} \times (1 - EF_{m=1-13} - FracGASM_{m-1-13}) - MNLeach_{jM}) \times (1 - PF)$$

4.3.1.9 Method 1 — Soil Direct N2O Dairy

(1) Direct nitrous oxide emissions $E_{N2O,dir}$ (t N_2O) on to pasture are calculated as:

$$E_{N2O,dir} = \sum_j (MN_{jm=14} \times EF_{PRP} \times C_{N2O}) \times 10^{-3}$$

Where $MN_{jm=14}$ = mass of nitrogen excreted on pasture, range, and paddock for each dairy cattle class (kg N)

EF_{PRP}= emission factor for nitrous oxide emissions for urine and dung deposited on PRP (kg N_2O-N/kg N deposited)

4.3.1.10 Method 1 — Soil Atmospheric Deposition N2O Dairy

(1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N2O,ad}$ (t N_2O) are calculated as:

$$E_{N2O,ad} = M_{vol,m=14} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where $M_{vol,m=14}$ = mass of nitrogen volatilised from urine and faeces deposited on pasture (kg N)

EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen volatilised $M_{vol,PRP}$ (kg N) is calculated as:

$$M_{vol,m=14} = \sum_j (MN_{jm=14} \times FracGASMsoil)$$

Where $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces deposited on pasture ((kg NH_3-N + NO_x-N)/kg N)

4.3.1.11 Method 2 — Soil Atmospheric Deposition N2O Dairy

There is no Method 2 quantification option for this emission source

4.3.1.12 Method 1 — Soil Leaching and Runoff N2O Dairy

(1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N2O,leach}$ (t N_2O) are calculated as:

$$E_{N2O,leach} = M_{leach.m=14} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Where $M_{leach,m=14}$ = mass of nitrogen lost to leaching and runoff from urine and faeces deposited on pasture (kg N)

(2) In equation (1) the mass of nitrogen lost to leaching and runoff $M_{leach,m=14}$ is calculated as:

$$M_{leach,m=14} = \sum_j \left(MN_{jm=14} \times FracWet \times FracLEACH\right)$$

4.3.1.13 Method 2 — Soil Leaching and Runoff N2O Dairy

There is no Method 2 quantification option for this emission source

4.3.2 Data/Parameters

4.3.2.1 Input Data (Required)

Data / Parameter	N_j
Data unit	head
Description	Number of dairy cattle in each class j
Data source	Farm stock records and herd flow model see Chapter 1 Section 1.9 Noting that the number of heifer and bull calves should be reported separately to weaned stock less than 12 months in age to capture emissions from calves sold at weaning.
Quality assurance / quality control considerations	The number of heifer and bull calves should be reported separately to weaned stock less than 12 months in age to capture emissions from calves sold at weaning. Number of cattle reported may be cross checked with average stocking density for farm size and system (if known). The class of animals on farm align may be checked against expected enterprise on farm: for example, self-replacing systems vs purchased breeder or trading systems.

Data / Parameter	MP_j
Data unit	L/head/day
Description	Daily milk production per milking cow
Data source	Farm milk sales records and number of milking cows. The average amount of milk sold per day (in litres) may be divided by the average number of milking cows on the farm to calculated the daily milk production per milking cow. If milk production records are in terms of milk solids rather than litres of milk, refer to Chapter 3, section 3.3.1 for converting milk solids (MS_j) into litres (MP_j).
Quality assurance / quality control considerations	Farm source data may be compared to National Inventory Report state-based values to check for possible data entry errors. State-based values can be found in Appendix Table A.1.3.9. Milk production data may be reviewed through milking parlour software and corroborated via milk collection receipts.

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure from MMS applied to soil within the farm boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the farm boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	Any quantities of manure sent off-site and outside the entity / farm boundary to other entities should be recorded and tracked. If it is not known what proportion of manure is sent offsite to other entities, assume all manure is applied within the entity boundary until better data can be collected.

4.3.2.2 Data (Method 1 and 2 Options)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each dairy cattle input class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	For all manure stock (j = 1,2,4) D_j = 365 For pre-weaned young stock (j=3,5) D_j = 84 For weaned stock <1 year (j = 3,5) D_j = 281
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each cattle input class (see Chapter 1 Section 1.9 for more details on herd flow modelling).
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 is used consider if input classes of animals are on the farm all year round (and if so the duration of stay is 365 days) and that if animals are only born part way through the reporting period their duration of stay reflect this. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values.

Data / Parameter	MMS_m
Data unit	Fraction
Description	Fraction of waste voided to each manure management system m
Method 1 data source	Annual fraction of time spent on pasture, in the milking shed or on a feedpad is based on the assumptions underlying the defaults for MMS_{jm} used in the National Greenhouse Gas Inventory MMS calculations. User-defined data for fraction of waste from the milking shed and feedpad that goes to each MMS may be based on farm records of MMS quantities (where available), or estimates based on experience and observations made throughout the year.
Method 1 value	MMS_{jm} is determined based on the fraction of time dairy cows or heifers spend on pasture, in the milking shed, or on feedpad. The user shall select which feeding system is most representative of the dairy operation, to then determine the fraction of time the cows spend in each area. The fraction of volatile solids voided to pasture ($MMS_{jm=14}$) is equal to the annual fraction of time spent on pasture in the provided table. The annual fraction of time spent in the milking shed and on the feedpad are used to allocate manure to different MMS. The user shall indicate what percentage of waste is allocated to each MMS that is used to manage waste from the feedpad and from the milking shed respectively. The following MMS options are available: • Anerobic lagoon (m = 1) • Sump and dispersal system (m = 3a) • Drains to paddocks (m = 3b) • Solid storage (m = 4) MMS_{jm} is calculated as the percentage of waste allocated to the MMS from that area multiplied by the time spent in that area. For example, for a grazing-only system ($MMS_{jm=14}$ = 0.89) where 50% of the waste from the milking shed is drained to paddocks and the remaining 50% is spread a through sump and dispersal system: $MMS_{jm=3a}$ = 0.11*0.50 = 0.055 $MMS_{jm=3b}$ = 0.11*0.50 =0.055
Method 2 data source	If the time spent between pasture, milking shed and feedpad is different to the systems 1-4 offered in the Method 1 option, then the annual fraction of time spent in each area may be estimated from farm records for time split between paddock and housed for each livestock class. Alternatively,the ADCC tool provides a questionnaire-based approach to these calculations, which may be utilised to calculate MMS_{jm} [10].
Quality assurance / quality control considerations	The sum of all MMS_{jm} values should equal one Ensure MMS and time spent in each system align with dairy system recorded on farm, i.e., housed or pasture-based system. If Method 1 is used ensure the most recent estimate for annual fraction of time spent per area is used.

Data / Parameter	SS_j
Data unit	Fraction
Description	Fraction of waste separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SS_j = 0.20 If solid separation does not occur SS_j = 0
Method 2 data source	User specified input as to what fraction of waste is screened before flowing in to primary MMS.
Quality assurance / quality control considerations	Ensure solid separation system aligns with dairy system recorded on farm, i.e., housed or pasture-based system.

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Data / Parameter	CP_j
Data unit	fraction
Description	Crude protein content of feed intake
Method 1 data source	Table 5.5.1.4, National Inventory Report, Volume 2 [4]
Method 1 value	0.20
Method 2 data source	Farm records or feed receipt stating crude protein of TMR (total mixed ration) for different livestock classes. The ADCC, 2025 [10] provides support on how to calculate CP from feed sources. For any stock classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 is used, farm source data may be cross checked against Method 1 default values. The ADCC, 2025 [10] provides ranges of CP for different forage of non-forage supplements which may alternatively be used to review entered data.

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Data / Parameter	W_j
Data unit	kg
Description	Liveweight of each class of stock.
Method 1 data source	See Appendix Table A.1.3.1 and Table A.1.3.2
Method 1 value	Select the appropriate live weight based on breed and animal class.
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used. If Method 2 is used, farm source data may be cross checked against Method 1default values.

	Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may also be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values.

Data / Parameter	LWG_j
Data unit	kg/head/day
Description	Liveweight gain of each class of stock.
Method 1 data source	See Appendix Table A.1.3.3
Method 1 value	Select the appropriate live weight gain based on breed and animal class.
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used. If Method 2 is used, farm source data may be reviewed against Method 1 default values Additional checks of farm source data are within expected ranges. Typical liveweight gain for heifers of various milking breeds are (ADCC, 2025): • smaller breeds, such as Jerseys, approximately 0.45 to 0.5 kg/head/day; • medium breeds, such as Friesians, approximately 0.60 to 0.65 kg/head/day • larger breed, such as Holstein Friesians, approximately 0.7 to 0.75 kg/head/day. Checking purchase and sale weight records against entered values may be used for data assurance and control.

Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.3.6
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.3.6 and A.1.8.1 for data source information).

4.3.2.3 Constants

Data / Parameter	$MPW_{manure,j=3,5}$
Data unit	kg CH_4/head/day
Description	Methane production from manure of pre-weaned heifer and bull calves
Data source	See Appendix Table A.1.3.8

Value	Select appropriate default values based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	A
Data unit	fraction
Description	Ash content of manure
Data source	National Inventory Report, Volume 1 [1]
Value	0.08
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$VS_{j=3,5}$
Data unit	kg/head/day
Description	Volatile solids production for pre-weaned calves
Data source	See Appendix Table A.1.3.5
Value	Select appropriate default values based on animal class. Default values for are only provided for pre-weaned calves. For all other

	classes volatile solids shall be calculated as described in Section 4.3.1.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	$NPW_{j=3,5}$
Data unit	kg/head/day
Description	Nitrogen excreted by pre-weaned calves
Data source	See Appendix Table A.1.3.5
Value	Select appropriate default value based on animal class. Default values for are only provided for pre-weaned calves. For all other classes nitrogen excreted in faeces shall be calculated as described in Section 4.3.1.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	MR_j
Data unit	kg DM/head/day
Description	Increase in metabolic rate when producing milk
Data source	See Appendix Table A.1.3.9
Value	Select appropriate value based on livestock class
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	WR_j
Data unit	kg
Description	Reference weight
Data source	See Appendix Table A.1.3.4
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{PRP}
Data unit	kg N_2O-N/kg N
Description	Emission factor for nitrous oxide emissions per amount of urine and dung deposited
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.1 [8]
Value	Select the appropriate EF_{PRP} specific to the climate zone. Please see Appendix Table A.2.2.2. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	FracGASMsoil
Data unit	(kg NH_3-N + NO_x-N)/kg N
Description	Fraction of nitrogen volatilized from urine and faeces deposited on pasture.
Data source	National Inventory Report, Volume 1 [1]
Value	0.21
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	FracWET
Data unit	fraction
Description	Fraction of nitrogen available for leaching and run-off
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

Data / Parameter	FracLEACH
Data unit	fraction
Description	Default fraction of N that is lost through leaching and runoff when manure is excreted to pasture, range and paddock (m=14).
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.24
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	EF_m
Data unit	kg N_2O-N/kg N
Description	Emission factor for nitrous oxide emissions per MMS
Data source	See Appendix Table A.1.3.7
Value	Select the appropriate emission factor based on the MMS in place
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	EF_{N2O}
Data unit	kg N_2O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Select the value based on the production system which most accurate describes the land the dairy cattle are grazing for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. If animals are housed most of the time select the system best describes the land which surrounds the housed area. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

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Data / Parameter	$FracGASM_m$
Data unit	(kg NH_3–N + NO_x–N)/kg N
Description	Fraction of N volatilised from each MMS
Data source	See Appendix Table A.1.3.7
Value	Select the appropriate value based on the MMS in place.
Quality assurance / quality control considerations	Ensure the most recently available published data is used.

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Data / Parameter	$Frac_{LEACH\_MS}$
Data unit	fraction
Description	Fraction of nitrogen lost through leaching and runoff for solid storage MMS only
Data source	National Inventory Report Vol 1 [9]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

4.4 Sheep

This module covers the estimation of methane and nitrous oxide that result from sheep manure management. Figure 4.6 summarises the emission sources from the manure of sheep. There are two components to methane emission estimates –manure excreted directly onto pasture, rangeland and paddock (PRP), and manure that runs-off into natural water sources and farm dams. There are no nitrous oxide emissions from manure management for manure excreted to PRP, however emissions from the soil occur from the metabolism of the deposited urine and faeces, and indirectly through atmospheric deposition and leaching and runoff.

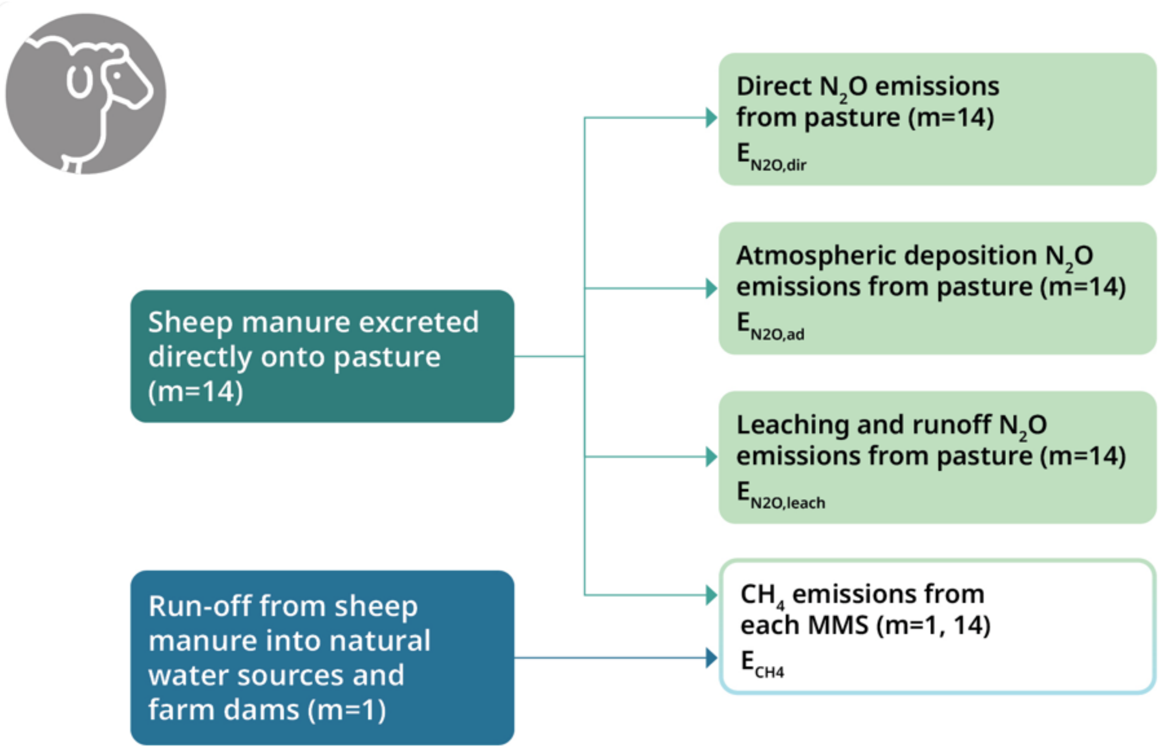

Figure 4.6: Emissions that result from sheep manure

The following subscripts are used in this module:

Subscript	Meaning
i	Temperature zone
j	time-period
k	Sheep Class
m	Manure management system (MMS)

Emissions are estimated based on age and sex classes of sheep, time of the year and manure management system. The temperature zone will affect the selection of appropriate emissions factors. The emissions are summed across each class, manure management system and time-period spent on farm during the reporting period.

The classes of sheep on the farm (‘sheep input class’) will depend on the diversity of the farming operation. These classes need to be mapped back to default categories (‘sheep class k’) to allow the use of default inventory values under Method 1

The time-period selected will depend on availability of stock numbers and liveweight and liveweight gain data (see Herd Flow modelling guidance in Section 1.3.7).

Sheep Class *k*	Possible Sheep Input Class
1 = Rams	Rams
2 = Wethers	Wethers
3 = Maiden ewes	Maiden ewes (1-2 years) intended for breeding
4 = Breeding ewes	Breeding ewes
5 = Other ewes	Other ewes
6 = Lambs and hoggets	Ewe lambs (<1 year)
	Wether lambs (<1 year)
	Ram lambs (<1 year)

The only relevant manure management systems (m) for grazing beef are PRP (m=14) and anaerobic lagoons (m=1). Where farmers have unfenced natural water sources and farm dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these water sources.

4.4.1 Estimation methodology

4.4.1.1 Method 1 — Manure Methane Sheep

(1) Total annual methane production from manure management for sheep E_{CH4} ($kgCH_4$) is calculated as:

$$E_{CH4} = \sum_j \sum_k \sum_m (N_{jk} \times M_{jkm} \times D_j) \times 10^{-3}$$

Where N_{jk} = number of sheep in each time-period and input class (head)

M_{jkm} = daily methane produced from the manure in each time-period, sheep class and MMS ($kgCH_4$/head/day)

D_j= number of days in each time-period (days). This is 91.25 days under Method 1 as the default time-period is a season

(2) In equation (1) methane produced from the manure of sheep M_{jk} ($kgCH_4$/head/day) is calculated as:

$$M_{jkm} = VS_{jk} \times B_O \times MMS_m \times MCF_{im} \times \rho$$

Where VS_{jk} = volatile solid production in each time-period and class(kg/head/day)

B_O = emissions potential (m^3 CH_4/kgVS)

MMS_m = fraction of waste in each manure management system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied

ρ = density of methane (kg/m^3)

The primary manure management system (MMS) for sheep is pasture range and paddock (m=14). Where natural water sources, such as farm dams, are present the anaerobic lagoon (m=1) MMS is used to estimate the run-off of manure into these water sources. Where farmers can demonstrate animals are on bore or reticulated water systems, where water is provided in troughs (i.e., no unfenced natural water sources), then the only relevant MMS to be considered shall be pasture range and paddock (m=14).

(3) In equation (2) volatile solid production from sheep VS_{jk} (kg/head/day) is calculated as:

$$VS_{jk} = \left(I_{jk} \times \left(\left(1 - DMD_{jk}\right) + \left(0.04 \times I_{jk}\right)\right)\right) \times (1 - A)$$

Where I_{ijk} = dry matter intake as calculated in Chapter 3 Section 3.4.1 (kgDM/head/day)

DMD_{ijk} = dry matter digestibility expressed as a fraction. Default values applied under Method 1

A = ash content of feed intake

4.4.1.2 Method 2 — Manure Methane Sheep

Method 2 is the same as Method 1 except that under equations 4.4.1.1 (3) feed intake I_{jkl} is estimated as per section 3.4.1.2 for the selected time-period (i.e. seasonal, monthly or other) and farm specific data is required for MCF_{im}. Farm specific data is may also be applied for DMD_{jk}.

Under Method 2 the selected time-period and associated L_j used in equation 4.4.1.1 (1) may be a season (L_j= 91.25 days), month (L_j=28-31 day depending on month) or a specific number of days in a month or season if the entry and exit from farm of a specific cohort of animals is being estimated

4.4.1.3 Method 1 — Soil Direct N2O Sheep

(1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of urine and dung $E_{N2O,dir}$ (t N_2O) are calculated as:

$$E_{N2O,dir} = AE \times EF_{PRP} \times C_{N2O} \times 10^{-3}$$

Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

EF_{PRP}= emission factor for nitrous oxide from urine and dung deposited to soil (kg N_2O-N/kg N deposited)

C_{N2O}= factor to convert elemental mass of nitrous oxide to molecular mass

(2) In equation (1) total nitrogen excreted to pasture, range, and paddock AE (kg N) is calculated as:

$$AE = \sum_j \sum_k (N_{jk} \times NE_{jk} \times D_j)$$

Where N_{jk} = number of sheep in each time-period and input class (head)

NE_{jk} = nitrogen excreted in each time-period and by each class (kg N/head/day)

D_j= number of days in each time-period (days). This is 91.25 days under Method 1 as the default time-period is a season

(3) In equation (1) nitrogen excreted NE_{jk} (kg N/head/day) is calculated as:

$$NE_{jk} = \left(CPI_{jk} \div 6.25\right) - NR_{jk}$$

Where CPI_{jk} = crude protein intake (kg/head/day)

NR_{jk} = amount of nitrogen retained by the body (kg N/head/day)

(4) In equation (3) Crude protein intake CPI_{ijk} (kg/head/day) of sheep is calculated as:

$$CPI_{jk} = \left(I_{jk} \times CP_{jk}\right) + (0.045 \times MC_{jk=6})$$

Where CP_{jk} = crude protein content of feed intake expressed as a fraction. Under

Method 1, default values are applied

(5) In equation (4) milk intake for sheep $MC_{jk=6}$ (kg/head/day) is calculated as:

$$MC_{jk=6} = 1.6 \times PL_{jk=6}$$

Where 1.6 = milk production for time-period lambs are born (kg/head/day).

$PL_{jk=6}$ = proportion of lambs born in the time-period

(6) In equation (3) the amount of nitrogen retained by the body NR_{jk} (kg N/head/day) is calculated as:

$$NR_{ijk} = \left\{ \left(0.045 \times MP_{jk=3,4}\right) + \left(WP_k \times 0.84\right) + \left\{ EBG_{jk} \times \left[\left(212 - 4 \times \left(\frac{EBG_{jk} \times 1000}{4 \times SRW_k{}^{0.75}} - 1\right)\right) - \frac{\left(140 - 4 \times \left(\frac{EBG_{jk} \times 1000}{4 \times SRW_k{}^{0.75}} - 1\right)\right)}{1 + e^{-6(Z_{jk} - 0.4)}} \right] \right\} \times 10^{-3} \right\} \div 6.25$$

Where $MP_{jk=3,4}$= milk production (kg/head/day)

WP_k = clean wool production (kg/head/day)

EBG_{jk} = empty body gain (kg)

SRW_k = standard reference weight (kg)

Z_{jk} = relative size

(7) In equation (6) milk production of sheep $MP_{jk=3,4}$(kg/head/day) is calculated as:

$$MP_{jk=3,4} = LE_{jk=3,4} \times 1.6$$

Where $LE_{jk=3,4}$ = proportion of ewes lactating each season or time period as calculated in Chapter 3 Section 3.4.1

1.6 = milk production for the season the lambs are born in (kg/head/day)

For sheep classes other than breeding ewes and maidens, milk production should be set to zero, i.e., $MP_{jk=1,2,5,6} = 0$ and in non-breeding seasons milk production should be set to zero for all sheep classes.

(8) In equation (6) clean wool production WP_k (kg/head/day) is calculated as:

$$WP_k = \frac{GW_k \times Y_k}{365}$$

Where GW_k = greasy wool production per sheep class (kg/head)

Y_k = average clean wool yield per sheep class (fraction)

365 = number of days in a year

(9) In equation (6) The empty body gain EBG_{jk} (kg) is calculated as:

$$EBG_{jk} = LWG_{jk} \times 0.92$$

Where LWG_{jk} = liveweight gain (kg). Under Method 1, default values are applied.

(10) In equation (6) the relative size of the sheep Z_{jk} is calculated as:

$$Z_{jk} = \frac{W_{jk}}{SRW_k}$$

Where W_{jk} = liveweight (kg). Under Method 1, default values are applied.

4.4.1.4 Method 2 — Soil Direct N2O Sheep

Method 2 is the same as Method 1 except that under equation 4.4.1.3 (4) feed intake I_{jkl} is estimated as per section 3.2.1.2 and farm specific data is required for the selected time-period (i.e. seasonal, monthly or other) for W_{jk} (Eq 4.4.1.3 (10)), LWG_{jk} (Eq 4.4.1.3 (9)). Farm specific data may also be applied for CP_{jk} (Eq 4.4.1.3 (4)).

Under Method 2 the selected time-period and associated L_j used in equation 4.4.1.3 (2) may be a season (D_j= 91.25 days), month (D_j=28-31 day depending on month) or a specific number of days in a month or season if the entry and exit from farm of a specific cohort of animals is being estimated

4.4.1.5 Method 1 — Soil Atmospheric Deposition N2O Sheep

(1) Annual atmospheric deposition emissions from urine and dung deposited on pasture $ES_{N2O,ad}$ (t N_2O) is calculated as:

$$E_{N2O,ad} = M_{vol} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on pasture (kg N)

EF_{N2O} = nitrous oxide emission factor for atmospheric deposition (kg N_2O-N/kg N)

C_{N2O}= factor to convert elemental mass of nitrous oxide to molecular mass

(2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

$$M_{vol} = AE \times FracGASMsoil$$

Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

$FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces deposited on pasture ((kg NH_3–N + NO_x–N)/kg N)

4.4.1.6 Method 2 — Soil Atmospheric Deposition N2O Sheep

There is no Method 2 quantification option for this emission source.

4.4.1.7 Method 1 — Soil Leaching and Runoff N2O Sheep

(1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N2O,leach}$ (t N_2O) are calculated as:

$$ES_{N2O,leach} = M_{leach} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

EF_{leach} = emission factor for leaching and run off (kg N_2O-N/kg N)

C_{N2O}= factor to convert elemental mass of nitrous oxide to molecular mass

(2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} (kg N) is calculated as:

$$M_{leach} = AE \times FracWet \times FracLEACH$$

Where AE = total mass of nitrogen excreted on PRP by sheep (kg N)

$FracWet$ = fraction of N that is available for leaching and runoff

$FracLEACH$ = fraction of all N that is lost through leaching and runoff

4.4.1.8 Method 2 — Soil Leaching and Runoff N2O Sheep

There is no Method 2 quantification option for this emission source.

4.4.2 Data/Parameters

4.4.2.1 Input Data (Required)

Data / Parameter	N_{jk}
Data unit	head
Description	Number of sheep in each time-period and class
Data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Number of sheep reported may be cross checked with average stocking density for farm size and system (if known). The animal class proportions may be cross checked with those expected in the farm's type of operationFor example, self-replacing systems vs purchased breeder or trading systems.

Data / Parameter	GW_k
Data unit	kg/head
Description	Average greasy wool fleece weight for each sheep class
Data source	Farm source data – based on average wool fleece weight for each class. If not known this can be calculated from the total greasy weight sold divided by the number of head in each class shorn. .
Quality assurance / quality control considerations	Invoices from wool sales may be used to cross check the weight of wool sold in the reporting period. The average fleece weight may be considered in the context of the farming operation and breed of sheep farmed. Industry averages may be used to sense check average fleece weights for different breeds and age classes.

Data / Parameter	Y_k
Data unit	fraction
Description	Average clean wool yield for each sheep class
Data source	Farm source data – based on wool testing results at point of sale for the clean wool percentage for each class. If only total greasy and total clean weights are known the fraction of clean may be calculated as: $Y = \frac{cleanweight}{greasyweight}$ For more accurate estimation, it is recommended this value is calculated for ewes and lambs separately and applied to each class appropriately.
Quality assurance / quality control considerations	Invoices from wool sales may be used to cross check the percent clean wool sold in the reporting period. The clean wool yield may be considered in the context of the farming operation and breed of sheep farmed. Industry averages may be used to sense check average fleece weights for different breeds and age classes.

4.4.2.2 Data (Method 1 and 2 Options)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each sheep input class
Method 1 data source	National Inventory Report Volume 1 [1]
Method 1 value	91.25 as the default time period is seasonal.
Method 2 data source	Farm stock records; system type records or purchase and sales may be evaluated to determine average duration of each sheep input class (see Chapter 1 Section 1.9 for more details on herd flow modelling)
Quality assurance / quality control considerations	Ensure that if animals are on the farm all year round the duration of stay is 365 days Ensure that if animals are only born part way through the reporting period their duration of stay reflect this. If Method 1 is used inputs should be entered seasonally throughout the calculations. Purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values. Recorded stock counts may also be used for quality assurance of entered values.

1076

Data / Parameter	DMD_{jk}
Data unit	fraction
Description	Dry matter digestibility of feed
Method 1 data source	See Appendix Table A.1.4.2
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records - user input values for each season and class of stock. Noting that if farm specific DMD may be used for some classes or seasons if known and inventory defaults for other unknown classes of stock.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1077

Data / Parameter	CP_{jk}
Data unit	fraction
Description	Crude protein content of feed
Method 1 data source	See Appendix Table A.1.4.4
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records - user input values for each season and class of stock. Noting that if farm specific CP may be used for some classes or seasons if known and inventory defaults for other unknown classes of stock.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 is used farm source data may be cross checked against Method 1 default values.

1078

Data / Parameter	LWG_{jk}
Data unit	kg
Description	Liveweight gain per time period and sheep class
Method 1 data source	See Appendix Table A.1.4.5
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Purchase and sale weight records (invoices) may be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values. It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. that default liveweight gain reflects when stock are expected to be growing more due to feed quality and availability.

Data / Parameter	W_{jk}
Data unit	kg
Description	Liveweight of livestock per time period and sheep class
Method 1 data source	See Appendix Table A.1.4.1
Method 1 value	Select the appropriate default value for location of sheep, sheep class and season
Method 2 data source	Farm records and see herd flow model see Chapter 1 Section 1.9
Quality assurance / quality control considerations	Purchase and sale weight records (invoices) may be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records may also be used for quality assurance of entered values. It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. if lambing in spring ensure default weights reflect this with lowest weigh value applied in spring for stock <1 year and/or that default weights reflect when stock are expected to be at the lightest and heaviest due to feed availability and quality.

Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.4.8
Method 1 value	Choose default based on State and MMS.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

4.4.2.3 Constants

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential
Data source	IPCC (2019), Chapter 10 [3]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	MMS_m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	See Appendix Table A.1.4.7
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS_m values shall be selected based on State and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and $MMS_{m=14}$ = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

Data / Parameter	*p*
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	*A*
Data unit	fraction
Description	Fractional ash content of feed intake.
Data source	National Inventory Report, Volume 1 [1]
Value	0.08
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

\Data / Parameter	SRW_k
Data unit	kg
Description	Standard reference weight
Data source	See Appendix Table A.1.4.6
Value	Select appropriate default value for location of sheep and sheep class
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	EF_{PRP}
Data unit	kg N_2O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	Please see Appendix Table A.2.2.2.
Value	The appropriate EF_{PRP} shall be selected by using the IPCC values for EF_{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	EF_{N2O}
Data unit	kg N_2O-N/kg N
Description	Nitrous oxide emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the sheep are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

1092

Data / Parameter	FracGASMsoil
Data unit	(kg NH_3–N + NO_x–N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1093

Data / Parameter	FracLEACH
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

1094

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [9, p. 1]
Value	0.011
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

4.5 Swine

This module covers the estimation of methane and nitrous oxide that results from the manure management of swine. Figure 4.7 summarises the emission sources associated with the manure from swine. The allocation of waste to different manure management system is dependent of the type of housing system (e.g. conventions, deep litter or outdoor/free range) and whether there is a primary and secondary treatment of the manure. Emissions associated with manure from management systems that is subsequently applied to soils are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser module.

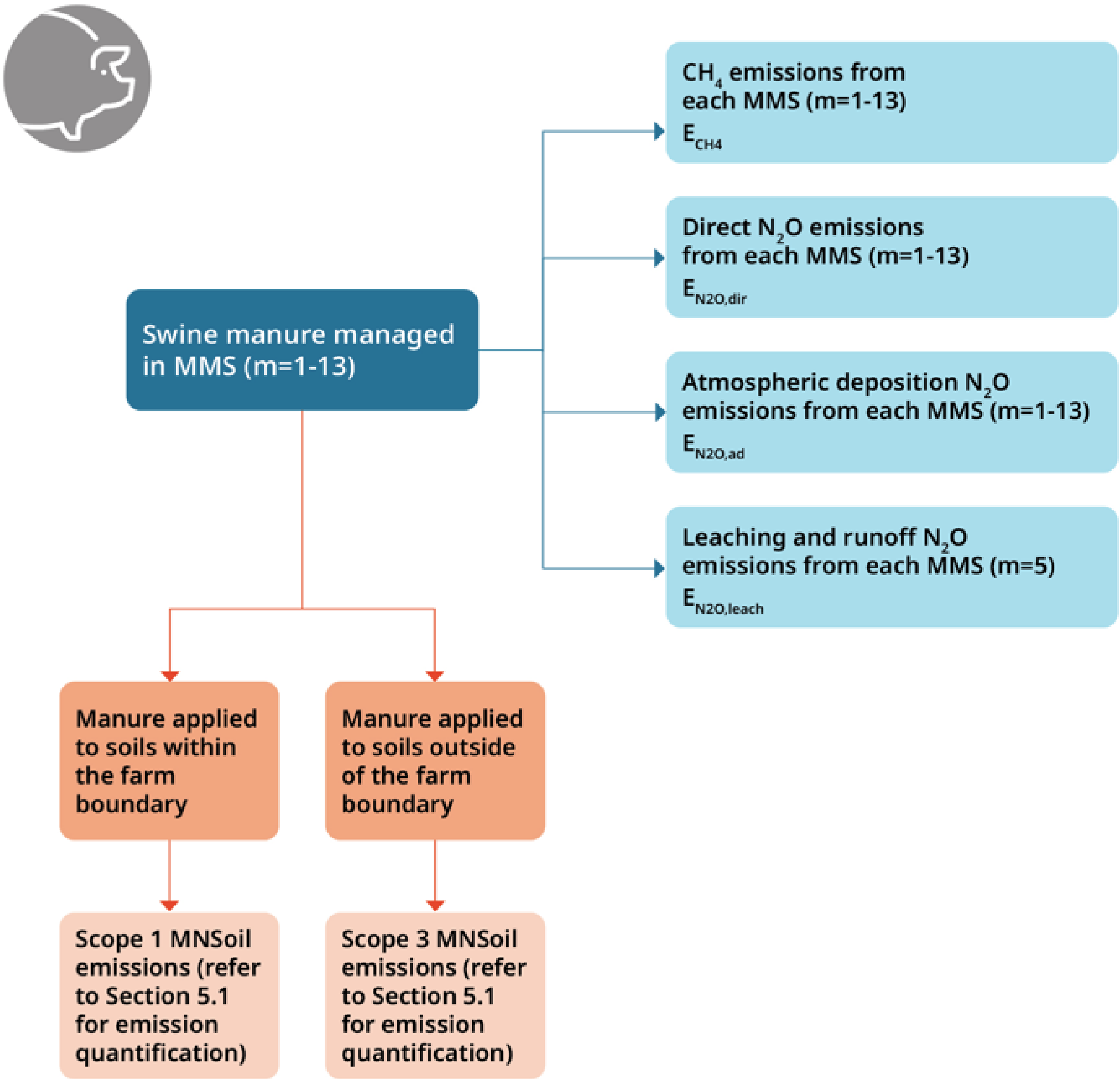

Figure 4.7: Summary of emissions sources associated with manure management in swine systems

The following subscripts are used in this module:

Subscript	Meaning
i	Temperature zone

j	Swine class
m	Manure management system (MMS)
T	Treatment stage

Emissions will be summed across each class within the swine system during the reporting period to enable the accounting of emissions based on age classes of swine with different intake requirements and time spent on farm within the reporting period.

The classes of pigs on the farm ('Swine input class') will depend on the diversity of the farming operation. These input classes need to be mapped back to NGGI default categories to allow the use of default inventory values (if required) e.g.,

Swine Class j	Possible Swine Input Class
1 = Boars	Boars
2 = Sows	Sows
3 = Gilts	Gilts
4 = Others	Suckers
	Weaners
	Growers
	Slaughter pigs

In Australia most swine farming systems include housing and a manure management system (MMS). While outdoor or free-range housing allows pigs to be outdoors at all times, the manure deposited in outdoor systems is treated as a dry lot rather than pasture range and paddock. The manure produced by farmed swine may pass through multiple treatment stages. The manure management system (m) for primary treatment stage (T=1) and secondary treatment stage (T=2) will need to be selected. In conventional housing there is the option of separating solids before manure enters the primary system. The allocation of waste to the different primary systems needs to be adjusted for solid separation. The separated solids are currently assumed to treated through solid storage. The following MMS are currently included in the National Inventory Report:

Manure Management System (MMS) m
1 = Anaerobic lagoon
4 = Solid storage
5 = Dry lot (outdoor/free range)
7 = Digester/Covered lagoon
8 = Deep litter
9 = Pit storage (short hydraulic retention tank (HRT) < 1 month)

13 = Direct application to soil

Figure 4.8 outlines how swine manure is assumed to transferred between primary and secondary treatments in the National Inventory Report. For farm-level estimation the fraction of manure transferred shall be allocated to relevant primary and secondary treatment stage based on the MMSs used on farm.

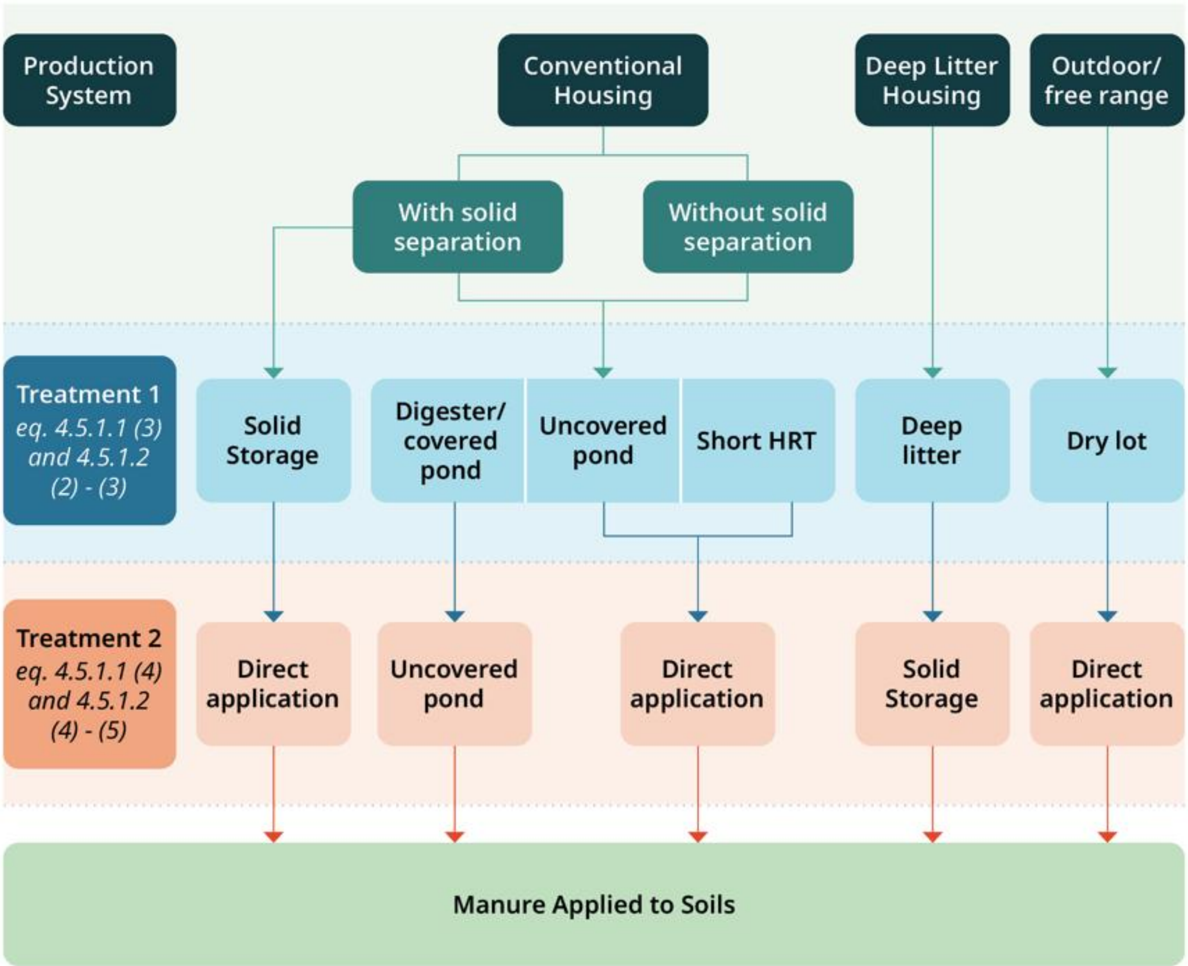

Figure 4.8 Example of the possible different stages of manure management in different swine production systems from the Australian National Inventory Report [1].

Question Reference 4.1.

Current guidance provides MMS options aligned with National Inventory Report and Greenhouse Gas Accounting Framework options. Are there other MMS in use in piggeries? For example, are separated solids treated in systems other than solid storage?

Question Reference 4.2.

Outdoor and free-range housing is treated as a dry lot in the National Inventory Report, rather than pasture, range and paddock, due to the relatively high concentration of waste. It is assumed that the manure is subsequently removed from the outdoor pen and is eventually applied to soils (within or outside the farm boundary). Is this assumption correct or does this waste remain in the outdoor pen?

4.5.1 Estimation methodology

4.5.1.1 Method 1 – Manure Methane Swine

(1) Total annual methane emissions from manure management E_{CH4} (t CH_4) is calculated as:

$$E_{CH4} = \sum_j \sum_m \sum_T (D_{jmT} \times M_{jmT} \times N_{jmT}) \times 10^{-3}$$

Where D_j = length of stay of each class of swine (days)

M_j = methane production from manure in each swine class, MMS, and treatment stage (kg CH_4/head/day)

N_j = numbers of swine in each class (head)

Pre-treatment and Treatment stage 1 (primary system)

(2) In equation (1) production of methane in treatment stage 1 MMS $M_{jm\,T=1}$ (kg CH_4/head/day) is calculated as:

$$M_{jm\,T=1} = VS_j \times FVS_{jm\,T=1} \times MCF_{im} \times B_O \times \rho$$

Where VS_j = volatile solid production from swine in each class (kg VS/head/day). Under Method 1 default values are applied

$FVS_{jm\,T=1}$ = the fraction of volatile solids in each primary system,

MCF_{im} = methane conversion factor for temperate zone and system. Under Method 1, the default State temperate zone is applied

B_O = emissions potential (m^3 CH_4/kg VS)

ρ = density of methane (kg/m^3)

(3) In equation (2) the fraction of volatile solids in each primary system $FVS_{jm\,T=1}$ other than solid storage (m=4) is calculated as:

$$FVS_{jm\,T=1} = MMS_{jm\,T=1} \times (1 - SS_m)$$

Where SS_m = fraction of volatile solids separated to solid storage for each MMS

$MMS_{jm\,T=1}$ = fraction of manure to each primary MMS for each class prior to solid separation

(4) In equation (3) the fraction of volatile solids in solid storage, $MMS_{jm=4\,T=1}$ is calculated as:

$$FVS_{jm=4\,T=1} = MMS_{jm=4\,T=1} + (MMS_{jm=1,7,9\,T=1} \times SS_m)$$

Note: Where solid separation systems are applied, the separated solids are currently assumed to treated through solid storage.

Note: Where manure is treated in a series of uncovered anaerobic ponds (commonly two or three ponds used in a series) these may be treated as a single primary system. If different systems are used, such as a covered anaerobic primary pond followed by an uncovered secondary pond, the secondary system emissions shall be estimated.

Treatment stage 2 (secondary system)

(5) In equation (1) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg CH_4/head/day) is calculated as:

$$M_{ijmT=2} = VST_j \times B_O \times MMS_{jmT=2} \times MCF_{im} \times \rho$$

Where $MMS_{jmT=2}$= fraction of manure in each secondary system

$VST_{jmT=2}$ = volatile solids transferred from the primary system (kg VS/head/day)

(6) In equation (5) volatile solids transferred to treatment stage 2 MMS $VST_{jm\,T=2}$ (kg VS/head/day) is calculated as:

$$VST_{ijmT=2} = VS_j \times FVS_{jmT=1} \times (1 - VSL_{mT=1})$$

Where $VSL_{mT=1}$ = fraction of volatile solids lost during storage in the primary system.

4.5.1.2 Method 2 – Manure Methane Swine

Method 2 is the same as Method 1 except that under equations 4.5.1.1 (3) – (7) farm specific data for VS_j, SS_j and the temperature zone for $MCF_{im=1}$. is required.

4.5.1.3 Method 1 – Manure Direct N2O Swine

(1) The total annual direct nitrous oxide emissions from manure management systems $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = \sum_j \sum_m \sum_T (MN_{jmT} \times EF_{jm} \times C_{N2O}) \times 10^{-3}$$

Where MN_{jmT} = nitrogen per swine class, MMS and treatment stage (kg N_2O)

EF_{jm} = nitrous oxide emission factor for MMS (kg N_2O-N/kg N)

C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

Pre-treatment and Treatment stage 1 (primary system)

(2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jm\,T=1}$ (kg N_2O) is calculated as:

$$MN_{jm\,T=1} = AE_j \times FN_{jm\,T=1}$$

Where AE_j = total nitrogen excreted by each swine class (kg N)

FN_j = fraction of nitrogen in each primary MMS system (kg N)

(3) In equation (2) the fraction of nitrogen in each primary system $FN_{jm\,T=1}$ other than solid storage (m=4) is calculated as:

$$FN_{jm\,T=1} = MMS_{jm\,T=1} \times (1 - SN_m)$$

Where SN_m = fraction of nitrogen separated to solid storage for each MMS

(4) In equation (2) the fraction of nitrogen in solid storage, $FN_{jm=4\,T=1}$ is calculated as:

$$FN_{jm=4\,T=1} = MMS_{jm=4\,T=1} + (MMS_{jm=1,7,9\,T=1} \times SN_m)$$

(5) In equation (1) annual nitrogen excretion AE_j (kg N) from each swine group is calculated as:

$$AE_j = N_j \times NW_j \times D_j$$

Where NW_j = nitrogen produced in swine manure and waste feed in each class (kg N/head/day).

Under Method 1 default values for NW_j are used

Treatment stage 2 (secondary system)

(6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jm\,T=2}$ (kg N_2O) is calculated as:

$$MN_{jm\,T=2} = NT_{jm\,T=2} \times MMS_{jmT=2}$$

Where $NT_{jm\,T=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

Note: if direct application to soil occurs at treatment stage 2 ($MN_{jm=13T=2}$) the nitrogen moves directly to $MNsoil$ calculation (equation 4.5.1.5 (1)) and is not included in direct nitrous oxide from manure management equation (Equation 4.5.1.3 (1)).

(7) In equation (8) nitrogen transferred to treatment stage 2 MMS $NT_{jm\,T=2}$ (kg N) is calculated as:

$$NT_{jm\,T=2} = \left(MN_{jmT=1} \times (1 - FracGASM_{mT=1} - EF_{mT=1})\right)$$

Where $FracGASM_{mT=1}$ = fraction of N volatilised from MMS treatment at stage 1

$EF_{mT=1}$ = Nitrous oxide emission factor for MMS treatment at stage 1

4.5.1.4 Method 2 – Manure Direct N2O Swine

Method 2 is the same as Method 1 except that under equation 4.5.1.3 (3) farm specific data for NW_j is required and farm specific and SN_j are required for equation 4.5.1.3 (2) if relevant to the production system.

4.5.1.1 Method 1 – Manure Atmospheric Deposition Swine

(1) Total annual atmospheric deposition emissions from manure management $E_{N2O,ad}$ (t N_2O) is calculated as:

$$E_{N2O,ad} = (MMS_{ATMOS} \times EF_{N2O} \times C_{N2O}) \times 10^{-3}$$

Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

EF_{N2O} = Nitrous oxide emission factors for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) volatilised nitrogen from MMS MMS_{ATMOS} (kg N) is calculated as:

$$MMS_{ATMOS} = \sum_j \sum_m \sum_T MN_{jmT} \times FracGASM_{mT}$$

Where $FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH_3–N + NO_x–N)/kg N)

Note: in the case of direct application at treatment stage 2 ($MN_{jm=13T=2}$) the nitrogen moves directly to $MNsoil$ calculation (equation 4.5.1.5 (1)) and is not included in the atmospheric deposition from manure management calculation.

4.5.1.2 Method 2 – Manure Atmospheric Deposition Swine

There is no Method 2 quantification option for this emission source

4.5.1.3 Method 1 – Manure Leaching and Runoff N2O Swine

(1) Annual emissions from leaching and run off from each MMS $E_{N2O,leach}$ (t N_2O) is calculated as:

$$E_{N2O,leach} = \sum_j \sum_{m=1-13} (MNLeach_{jm} \times EF_{leach} \times C_{N2O}) \times 10^{-3}$$

Where $MNLeach_{jm}$ = mass of N lost through leaching and runoff from each MMS (kg N)

EF_{leach} = Emission factor for leaching and runoff (kg N2O-N/kg N)

Due to strict environmental controls, $MNLeach_m$ is assumed to be 0 for all MMS other than outdoor piggeries. Therefore, emissions from leaching and run off are only estimated for drylots MMS (m=5). This simplifies the equation to:

$$E_{N2O,leach} = MNLeach_{jm=5} \times EF_{leach} \times C_g \times 10^{-3}$$

This assumption may need to be reconsidered if other MMS are incorporated based on stakeholder feedback.

(2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage systems $MNLeach_{jm=5}$ (kg N) is calculated as:

$$MNLeach_{jm=5} = MN_{jm=5T=1} \times FracWET \times FracLEACH_{MS}$$

Where $FracWET$ = fraction of N available for leaching and runoff.

$FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

4.5.1.4 Method 2 – Manure Leaching and Runoff N2O Swine

There is no Method 2 quantification option for this emission source

4.5.1.5 Manure Applied to Soils

It is assumed that all manure managed through MMS (m=1-13) will eventually be applied to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is transferred to Chapter 5 Section 5.2 to estimate emissions associated with the application of organic fertilisers, including the associated atmospheric deposition, and leaching and run-off emissions.

This manure may be applied to soils within the boundary of the piggery or may be sent off-site and applied to another farming system or enterprise. Where manure is applied to soils within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions from shall be estimated and reported as Scope 1 emissions. Where the manure is used outside the direct emissions boundary the emissions from shall be estimated and reported as Scope 3 emissions, $MNSoil_{scope3}$, under Scope 3 Category 5 – waste generated in operations (see Chapter 13).

(1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is calculated as:

$$MNSoil_{scope1} = \sum_j \sum_m (MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) - MNLeach_{jm=5}) \times PF$$

Where $EF_{mT=2}$ = nitrous oxide emission factor for each MMS at treatment stage 2 (kg N_2O-N/kg N)

PF = fraction of manure applied to soil within the piggery boundary

Note: where direct application occurs at treatment stage 2 ($MN_{jm=13T=2}$), $EF_{jm=13T=2}$ and $FracGASM_{jm=13T=2}$ are set to zero.

(2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is calculated as:

$$MNSoil_{scope3} = \sum_{j} \sum_{m} (MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) - - MNLeach_{jm=5}) \times (1 - PF)$$

> The current approach assumes that the manure used off-site within a different farm enterprise, *if not sold,* is considered a residue from the farm, rather than a co-product. The CRF definitions and guidance for product allocation are still under review and this approach will be updated to align with the final CRF definitions and guidance. Please refer to Section 10 of CRF for more guidance on allocation and to provide feedback on allocation approaches.

4.5.2 Data/Parameters

4.5.2.1 Input Data (Required)

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each swine class within the annual period assessed
Data source	Farm stock records; system type records or purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay of each class. Breeding stock that are kept year-round shall be assumed to be on the farm for 365 days.
Quality assurance / quality control considerations	For those classes with stays of less than 365 days purchase and sale records (invoices), and National Vendor Declarations or NLID transfer records may be used for data assurance and control of entered values. Recorded stock counts may also be used for quality assurance of entered values. The class of swine on farm align can be cross checked with reported products from farm.

Data / Parameter	N_j
Data unit	head
Description	Number of swine in each class
Data source	Farm stock records; system type records, purchase and sales records and National Vendor Declarations or NLID transfer records may be evaluated to determine average length of stay of each class. Breeding stock that are kept year-round shall be assumed to be on the farm for 365 days.
Quality assurance / quality control considerations	Number of swine reported may be cross checked with stocking density allowances for system size (if known). The class of swine on farm may be cross checked against reported production system (breeder vs trader) and products from farm.

Question Reference 4.3.

If there is more than one MMS per feedlot will the farmer need support in calculating the percent manure distributed to each system? Is PigBal the best tool to support this?

Data / Parameter	$MMS_{jmT=1}$
Data unit	Fraction
Description	Fraction of manure in each primary MMS
Data source	Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based consistently on either weight or volume of manure. If treatment is different for different swine groups this may also be recorded per swine group. For each production system there are different primary MMS options. The options estimated in the National Inventory Report are: Conventional housing: • Uncovered pond (m=1) • Digester/covered pond (m=7) • Short HRT (m=9) • Solid storage (m=4) – associated with solid separation Deep litter housing: • Deep litter (m=8) Outdoor/free range: • Drylot (m=5) If a different MMS is applied which is not listed for swine the most closely aligned MMS should be identified.
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=1}$ values should equal one. If only one primary MMS is used to treat manure, then $MMS_{jmT=1}$ should equal 1.

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Data / Parameter	$MMS_{jmT=2}$
Data unit	Fraction
Description	Fraction of manure from primary system in each secondary manure management system
Data source	Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). This fraction should be based on either weight or volume of manure. If treatment is different for different swine groups this may also be recorded per swine group. The options estimated in the National Inventory Report are: • Solid storage • Direct application • Uncovered pond If a different MMS is applied which is not listed for swine the most closely aligned MMS should be identified.
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=2}$ values should equal one. If there is only one available secondary MMS then $MMS_{jmT=2}$ should be equal to 1.

1330

Data / Parameter	PF
Data unit	fraction
Description	Fraction of manure applied to soil within the farm boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	If all of manure is not applied to soil within the farm boundary ensure it is appropriately tracked what proportion is sold to other entities. If it is not known what proportion is sold to other entities assume all manure is applied within in the farm boundary until better data can be collected.

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4.5.2.2 Data (Method 1 and 2 Options)

Data / Parameter	SS_j
Data unit	Fraction
Description	Fraction of volatile solids separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SS_j = 0.25 If solid separation does not occur SS_j = 0
Method 2 data source	User specified input as to what fraction of volatile solids is screened before flowing in to primary MMS. PigBal [11] may be used to support the estimation of this fraction based on the options effluent pre-treatment.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data is used Table 10 in the PigBal [11] manual may be used to check the typical percentages of solids and nutrients removed from raw piggery effluent by a range of pre-treatment systems. The value entered and type of pre-treatment specified may be compared to the values in the PigBal manual.

Data / Parameter	VS_j
Data unit	kg/head/day
Description	Volatile solids produced in swine manure and waste feed in each class
Method 1 data source	See Appendix Table A.1.6.1
Method 1 value	Select the appropriate value based on animal class and year.
Method 2 data source	PigBal [11] may be used to calculate daily production of volatile solids per swine class by entering animal characteristics, feed intakes, diet composition and wastage rates.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

Data / Parameter	MCF_{im}
Data unit	fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.6.4
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.6.4 and A.1.8.1 for data source information).

Data / Parameter	SN_j
Data unit	Fraction
Description	Fraction of nitrogen separated by pre-treatment of manure
Method 1 data source	National Inventory Report Volume 2 [4]
Method 1 value	If solid separation occurs SN_j = 0.25 If solid separation does not occur SN_j = 0
Method 2 data source	User specified input as to what fraction of nitrogen is screened before flowing in to primary MMS. PigBal [11] may be used to support the estimation of this fraction based on the options effluent pre-treatment.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report. If Method 2 data is used Table 10 in the PigBal manual [11] may be used to check the typical percentages of solids and nutrients removed from raw piggery effluent by a range of pre-treatment systems. The value entered and type of pre-treatment specified may be compared to the values in the PigBal manual.

Data / Parameter	NW_j
Data unit	kgN/head/day
Description	Nitrogen waste production per pig and swine class per day including both animal waste and feed waste
Method 1 data source	See Appendix Table A.1.6.1
Method 1 value	Select the appropriate value based on animal class and year,
Method 2 data source	PigBal [11] may be used to calculate the nitrogen waste produced per swine class per head per day This is calculated by mass balance, as the difference between the amount in the ingested feed and the amount retained by the animal as live weight gain and the nitrogen in the waste feed.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used in alignment with the Australian National Inventory Report.. If Method 2 is used farm source data may be cross checked against Method 1 default values.

4.5.2.3 Constant

Data / Parameter	$VSL_{mT=2}$
Data unit	Fraction
Description	Fraction of volatile solids lost during storage in the primary system.
Data source	National Inventory Report Volume 2 [4]
Value	There are only two production systems where losses are assumed when manure is transferred from a primary system to a secondary system and these each transfer a different fraction of manure. Conventional housing: • VSL = 0.75 from digester/covered pond (m= 7) Deep litter housing: • VSL = 0.05 from deep litter (m=8) In all other cases VSL = 0
Quality assurance / quality control considerations	N/A.

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	0.19
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	p
Data unit	kg/m^3
Description	Density of methane.
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass.
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	EF_{mT}
Data unit	kgN_2O-N/kgN
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.6.3
Value	Select appropriate default values based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	$FracGASM_{mT}$
Data unit	(kg NH_3–N + NO_x–N)/kgN
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.6.2
Value	Select appropriate default values based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1347

Data / Parameter	EF_{N2O}
Data unit	kgN_2O-N/kgN
Description	Nitrous oxide emission factors for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Select the value based on the production system which most accurate described the land surrounding the piggery. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is used in alignment with the Australian National Inventory Report.

1348

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

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Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define temperature zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

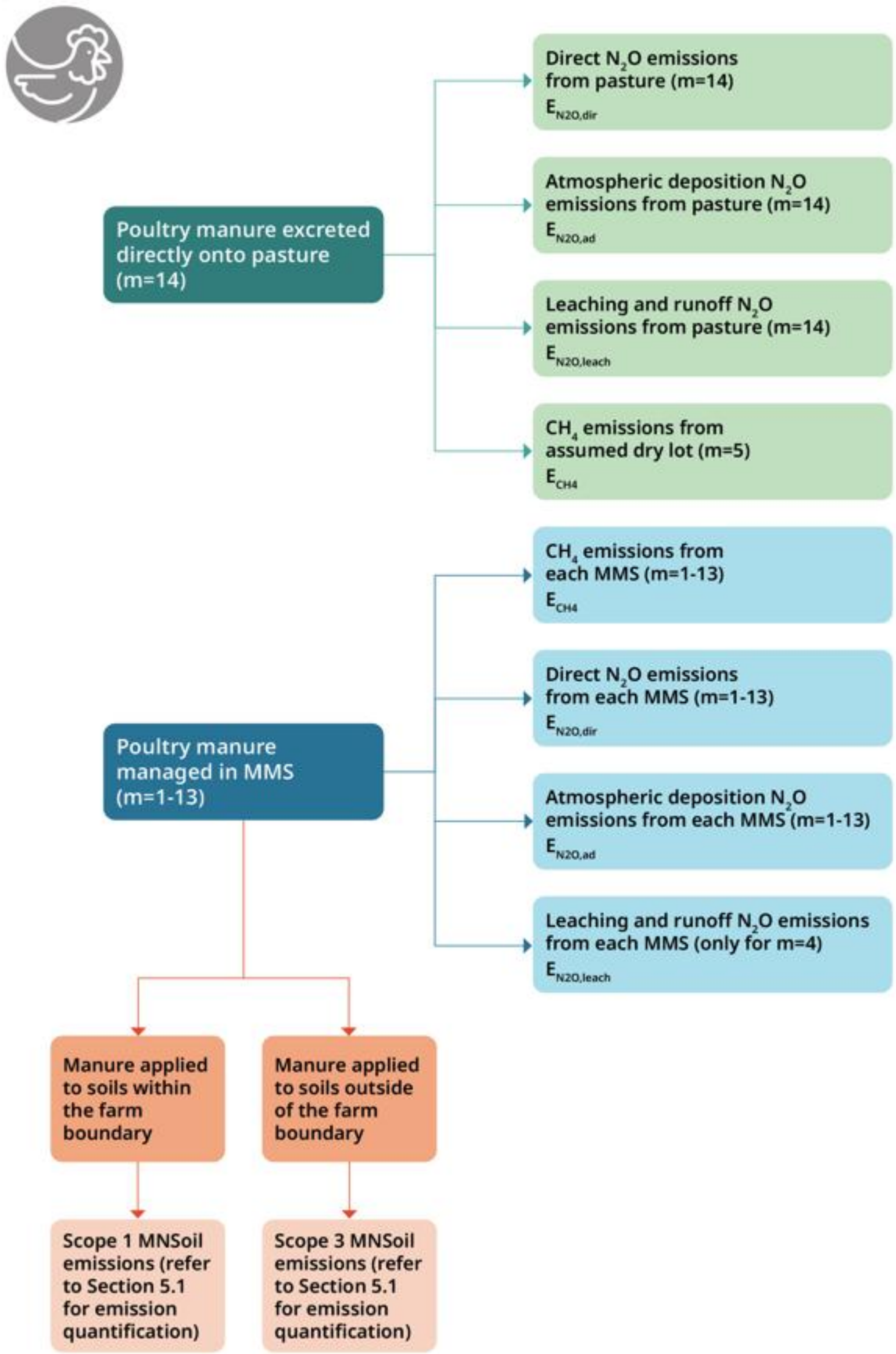
1351

Data / Parameter	$FracLEACH_{MS}$
Data unit	fraction
Description	Fraction of nitrogen lost through leaching and runoff for solid storage MMS only
Data source	National Inventory Report Vol 1 [1]
Value	0.02
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1352

4.6 Poultry

This module covers the quantification of greenhouse gas emission that results from manure management of poultry. Figure 4.9 summarises the resultant emissions from the manure management of poultry. The fraction of waste allocated to different manure management system is dependent of the type of housing system (e.g. housing with or without litter/bedding or free range) and whether there is primary and secondary treatment of the manure. Emissions associated with manure from management systems that is subsequently applied to soils as a secondary treatment are covered in the organic fertiliser section in Chapter 5 Section 5.1 Fertiliser module.



1362

1363 Figure 4.9: Emissions that result from manure management of poultry

1364 The following subscripts are used in this module:

Subscript	Meaning
i	Temperature Zone
j	Poultry Class
k	Poultry Subclass
m	Manure management system
T	Treatment stage

Emissions are estimated based on the class of poultry and the manure management system. The emissions are summed across each poultry class and subclass within the farming operation during the reporting period. These classes and subclasses may be broken down further into different input classes to facilitate tracking of different lengths of stay, housing, or management approaches. Input classes may be labelled as numbers e.g. Group 1, Group 2, Group 3 or given relevant names based on housing or management approach or age for data entry purposes.

These input classes need to be mapped back to the default categories to allow the use of default inventory values (if required) e.g.,

Poultry Class (j)	Poultry Subclass (k)	Possible Input Classes
1 = Layer	1 = Layer	Cage
		Barn
		Free Range
2 = Meat	2a = Meat Chicken Growers	Group 1 depletion 50%
		Group 1 depletion 100%
		Group 2 depletion 50%
		Group 2 depletion 100%
	2b = Meat Chicken Breeders	Breeders
	2c = Other	Other

Manure from poultry farms may pass through multiple manure management systems (m). Free range systems will include both a shelter and an outdoor range component. The outdoor range component is assumed to have similar methane emissions to a dry lot. Additionally, the temperature zone (i) the poultry farm is operating in is needed to inform the methane conversion factor applied. The following are common MMS used for poultry:

Manure Management System (MMS) m
Primary Systems (T=1)
10 = Poultry manure with litter
11a = Poultry manure without litter with belt manure removal
11b = Poultry manure without litter with manure stored in house
14 = Pasture range and paddock
Secondary Systems (T=2)
4 = Solid Storage
6 = Composting (passive windrow)
7 = Digestor/Covered Lagoon
8 = Deep Litter
12 = Direct processing into pelletized fertilizer
13 = Direct application to soils

Question Reference 4.4.

Current guidance provides MMS options aligned with National Inventory Report and Greenhouse Gas Accounting Framework options. What other MMS are in use in poultry houses in both primary and secondary treatment stages?

4.6.1 Estimation methodology

4.6.1.1 Method 1 – Manure Methane Poultry

(1) Total annual methane emissions from manure management E_{CH4} (t CH_4) is calculated as:

$$E_{CH4} = \sum_{j}\sum_{k}\sum_{m}\sum_{T}\left(D_{jk} \times M_{jkmT} \times N_{jk}\right) \times 10^{-3}$$

Where D_{jk} = duration of stay of each class and subclass of poultry (days)

M_{jk} = methane production from manure per class, subclass, MMS, and treatment stage (kg CH_4/bird/day)

N_{jk} = numbers of poultry in each class and subclass (bird)

Treatment stage 1 (primary system)

(2) In equation (1) production of methane in treatment stage 1 MMS $M_{ijm\,T=1}$ (kg CH_4/bird/day) is calculated as:

$$M_{jkm\,T=1} = VS_{jk} \times Bo_j \times MMS_{jm\,T=1} \times MCF_{im} \times \rho$$

Where VS_{jk} = volatile solid production poultry classes (kg VS/bird/day)

Bo_j = emissions potential per class (m^3 CH_4/kg VS)

$MMS_{jm\,T=1}$ = the fraction of manure in each primary system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied.

ρ = density of methane (kg/m^3)

Treatment stage 2 (secondary system)

(3) In equation (1) production of methane in each treatment stage 2 MMS $M_{ijmT=2}$ (kg CH_4/bird/day) is calculated as:

$$M_{jkmT=2} = VST_{jk} \times B_O \times MMS_{jmT=2} \times MCF_{im} \times \rho$$

Where VST_{jm} = fraction of volatile solids transferred to treatment stage 2 MMS (kg VS/bird/day)

$MMS_{jmT=2}$ = the fraction of manure in each secondary system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied

Note: there is no secondary system for manure on pasture, range and paddock (M=14)

(4) In equation (3) volatile solids transferred to treatment stage 2 MMS $VST_{jm\,T=2}$ (kg VS/bird/day) is calculated as:

$$VST_{ijmT=2} = VS_{jk} \times MMS_{jmT=1} \times (1 - VSL_{mT=1})$$

Where $VSL_{mT=1}$ = fraction of volatile solids lost during storage in the primary system.

(5) In equation (4) volatile solid production VS_j (kg/bird/day) is calculated as:

$$VS_{jk} = I_{jk} \times (1 - DMD_{jk}) \times (1 - A_j)$$

Where I_{jk} = dry matter intake for each class and subclass (kg DM/bird/day).

DMD_{jk} = dry matter digestibility for each class and subclass (fraction).

A_j = ash content of manure for each class and subclass (fraction)

Under Method 1, default I_{jk} and DMD_{jk} values are applied.

Question Reference 4.5.

It is understood that mortalities and/or spent hens may be managed through manure management systems. The addition of spent hens and/or mortalities to manure management systems will increase the VS within the system. Are there known values for VS of mortalities and/or spent hens? Or MCF appropriate for the decomposition of this material? How else could this be quantified other than the National Greenhouse Accounts Factors waste factors in Chapter 13?

4.6.1.2 Method 2 – Manure Methane Poultry

Method 2 is the same as Method 1 except that under equations 4.6.1.1 (3) – (5) farm specific data I_{jk} and DMD_{jk} are required and for temperature zone is required for MCF_{im}.

> **Question Reference 4.6.**
>
> Current guidance provides default options for intake and dry matter digestibility (DMD) aligned with National Inventory Report. However, as emissions estimates are sensitive to these variables should farm-specific intake and DMD be required data for Method 1? Alternatively, should intake be required while defaults are provided for DMD?

4.6.1.3 Method 1 – Manure Direct N2O Poultry

(1) The total annual direct nitrous oxide emissions from manure management systems $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = \sum_j \sum_k \sum_m \sum_T (MN_{jkmT} \times EF_{jm} \times C_{N2O}) \times 10^{-3}$$

Where MN_{jkmT} = nitrogen per poultry class, subclass, MMS and treatment stage (kg N_2O)

EF_{jm} = nitrous oxide emission factor for MMS (kg N_2O-N/kg N)

C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

Treatment stage 1 (primary system)

(2) In equation (1) nitrogen in the treatment stage 1 MMS $MN_{jkmT=1}$ (kg N_2O) is calculated as:

$$MN_{jkm\,T=1} = AE_{jk} \times MMS_{jm\,T=1}$$

Where AE_{jk} = total nitrogen excreted by each poultry class and subclass (kg N)

> **Question Reference 4.7.**
>
> It is understood that mortalities and/or spent hens may be managed through manure management systems. The addition of mortalities to manure management systems will increase the N content within the system. Are there known values for N content of mortalities and/or spent hens? How else could the decomposition of this material be quantified other than the National Greenhouse Account Factors waste factors in Chapter 13?

(3) In equation (2) annual nitrogen excretion AE_{jk} (kg N) from is calculated as:

$$AE_{jk} = N_{jk} \times NE_{jk} \times D_{jk}$$

Where NE_{jk} = nitrogen excretion (kg N/bird/day)

(4) In equation (3) nitrogen excretion NE_j (kg/bird/day) is calculated by:

$$NE_{jk} = NI_{jk} \times (1 - NR_{jk})$$

Where NI_{jk} = nitrogen intake (kg/bird/day)

NR_{jk} = nitrogen retention expressed as a fraction of intake (per cent).

Under Method 1, default NR_{jk} values are applied.

(5) In equation (4) nitrogen intake NI_j (kg/bird/day) of poultry is calculated by:

$$NI_{jk} = I_{jk} \times CP_{jk} \div 6.25$$

Where CP_j = crude protein content of feed (fraction).

6.25 = factor for converting crude protein into nitrogen

Under Method 1, default I_{jk}, and CP_{jk} values are applied.

Treatment stage 2 (secondary system)

(6) In equation (1) nitrogen in each treatment stage 2 MMS $MN_{jm\,T=2}$ (kg N_2O) is calculated as:

$$MN_{jkm\,T=2} = NT_{jkm\,T=2} \times MMS_{mT=2}$$

Where $NT_{jkm\,T=2}$ = nitrogen transferred to secondary treatment MMS (kg N)

Note: if direct application occurs at treatment stage 2 ($MN_{jkm=13T=2}$) the nitrogen moves directly to $MNsoil$ calculation (equation 4.6.1.9 (1)) and is not included in direct nitrous oxide from manure management equation (equation 4.6.1.3 (1)).

(7) In equation (6) nitrogen transferred to treatment stage 2 MMS $NT_{jkmT=2}$ (kg N) is calculated as:

$$NT_{jkm\,T=2} = \left(MN_{jkmT=1} \times (1 - FracGASM_{mT=1} - EF_{mT=1})\right)$$

Where $MN_{jkmT=1}$ = nitrogen in MMS treatment stage 1 (kg N)

$FracGASM_{mT=1}$ = fraction of N volatilised from MMS treatment at stage 1

$EF_{mT=1}$ = Nitrous oxide emission factor for MMS treatment at stage 1

4.6.1.4 Method 2 – Manure Direct N2O Poultry

Method 2 is the same as Method 1 except that under equation 4.6.1.3 (4) - (5) farm specific data for I_j, and CP_j is required.

> **Question Reference 4.8.**
>
> Current guidance provides default options for intake and crude protein (CP) aligned with National Inventory Report. However, as emissions estimates are sensitive to these variables should farm-specific intake and CP be required data for Method 1? Alternatively, should intake be required while defaults are provided for CP?

4.6.1.5 Method 1 – Manure Atmospheric Deposition Poultry

(1) Total annual atmospheric deposition emissions from manure management $E_{N2O,ad}$ (t N_2O) is calculated as:

$$E_{N2O,ad} = (MMS_{ATMOS} \times EF_{N2O} \times C_{N2O}) \times 10^{-3}$$

Where MMS_{ATMOS} = mass of N volatilised from MMS (kg N)

EF_{N2O} = Nitrous oxide emission factors for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) volatilised nitrogen from MMS MMS_{ATMOS} (kg N) is calculated as:

$$MMS_{ATMOS} = \sum_j \sum_k \sum_m \sum_T MN_{jkmT} \times FracGASM_{mT}$$

Where MN_{jmT} = nitrogen in each treatment stage MMS (kg N) (excluding $MN_{ijm=13T=2}$)

$FracGASM_{mT}$ = fraction of N volatilised in each MMS ((kg NH_3–N + NO_x–N)/kg N)

Note: in the case of direct application at treatment stage 2 the nitrogen ($MN_{jkm=13T=2}$) moves directly to $MNsoil$ calculation (equation 4.5.1.5 (1)) and is not included in the atmospheric deposition from manure management calculation.

4.6.1.6 Method 2 – Manure Atmospheric Deposition Poultry

There is no Method 2 quantification option for this emission source

4.6.1.7 Method 1 – Manure Leaching and Runoff N2O Poultry

(1) Annual emissions from leaching and run off from each MMS $E_{N2O,leach}$ (t N_2O) is calculated as:

$$E_{N2O,leach} = \sum_j \sum_k \sum_{m=1-13} (MNLeach_{jkm} \times EF_{leach} \times C_{N2O}) \times 10^{-3}$$

Where $MNLEach_{jkm}$ = mass of N lost through leaching and runoff from each MMS (kg N)

EF_{leach} = Emission factor for leaching and runoff (kg N2O-N/kg N)

$MNLeach_{m}$is assumed to be 0 for all MMS except free range operations manure excreted on pasture in free range operations and manure and manure stockpiles. Leaching from emissions from the pasture component (m=14) is estimated in the manure applied to soils equations (Section 4.6.1.10 - 4.6.1.15). Therefore, emissions from leaching and run off are only estimated for solid storage stockpiles MMS (m=4). This simplifies the equation to:

$$E_{N2O,leach} = MNLeach_{jkm=4} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Question Reference 4.9.

Current guidance assuming leaching and runoff can only occur from poultry manure excreted on pasture, range and paddock or from solid storage stockpiles. Is there any existing research indicating leaching and run off could occur from other secondary treatment such as composting systems?

(2) In equation (1) the mass of nitrogen lost to leaching and runoff from solid storage systems $MNLeach_{jm=5}$ (kg N) is calculated as:

$$MNLeach_{jm=4} = MN_{jkm=4T=1} \times FracWET \times FracLEACH_{MS}$$

Where $FracWET$ = fraction of N available for leaching and runoff.

$FracLEACH_{MS}$ = fraction of N lost through leaching and runoff

4.6.1.8 Method 2 - Manure Leaching and Runoff N2O Poultry

There is no Method 2 quantification option for this emission source

4.6.1.9 Manure Applied to Soils

It is assumed that all manure managed through an MMS (m=1-13) will eventually be applied to soils. The mass of nitrogen applied to soils is calculated here and then this $MNSoil$ value is transferred to Chapter 5 Section 5.2 to estimate emissions associated with the application of organic fertilisers, including the associated atmospheric deposition, and leaching and run-off emissions.

This manure may be applied to soils within the boundary of the poultry farm or may be sold and applied to another enterprise. Where manure is applied to soils within the boundary of the farming enterprise $MNSoil_{scope1}$, the emissions shall be estimated and reported as Scope 1 emissions. Where the manure is used with in the direct emissions boundary of other entities the emissions from shall be estimated and reported as Scope 3 emissions $MNSoil_{scope3}$, under Scope 3 Category 5 – waste generated in operations (see Chapter 13).

(1) The mass of nitrogen applied to soils for scope 1 emissions $MNSoil_{scope1}$ (kg N) is calculated as:

$$MNSoil_{scope1} = \sum_{j} \sum_{m} (MN_{jm\,T=2} \times (1 - EF_{jm=1-13} - FracGASM_{jm-1-13}) - M_{leach,MMS}) \times PF$$

Where $MN_{jmT=2}$ = mass of N in secondary treatment stage as calculated for manure management (kg N)

$EF_{mT=2}$ = nitrous oxide emission factor for each MMS (kg N_2O-N/kg N)

$FracGASM_{mT=2}$ = fraction of animal waste N volatilised in each MMS ((kg NH_3–N + NO_x–N)/kg N)

PF = fraction of manure applied to soil within the farm boundary

(2) The mass of nitrogen applied to soils for scope 3 emissions $MNSoil_{scope3}$ (kg N) is calculated as:

$$MNSoil_{scope3} = \sum_{j} \sum_{m} \sum_{T} MN_{jmT=2} \times (1 - EF_{mT=2} - FracGASM_{mT=2}) \times (1 - PF)$$

The current approach assumes that the manure used off-site within a different farm enterprise, *if not sold,* is considered residue product from the farm, rather than a co-product. The CRF definitions and guidance for product allocation are still under review and this approach will be updated to align with the final CRF definitions and guidance. For more guidance on allocation and to provide feedback on allocation approaches including poultry industry standards for co-products and allocation please refer to Section 10 of the CRF.

4.6.1.10 Method 1 – Soil Direct N2O Poultry

(1) Direct nitrous oxide emissions $E_{N2O,PRP,dir}$ from poultry manure deposited directly on to pasture at the primary treatment stage are calculated as:

$$EM_{N2O,PRP,dir} = \sum_{j} \sum_{k} (MN_{jkm=14T=1} \times EF_{PRP} \times C_{N2O}) \times 10^{-3}$$

Where $MN_{jkm=14T=1}$ = mass of nitrogen excreted directly on pasture by poultry class and subclass (kgN)

EF_{PRP}= nitrous oxide emissions emission factor for manure deposited on pasture (kgN_2O-N/kgN deposited)

4.6.1.11 Method 2 – Soil Direct N2O Poultry

There is no Method 2 quantification option for this emission source

4.6.1.12 Method 1 – Soil Atmospheric Deposition N2O Poultry

(1) Atmospheric deposition emissions from poultry manure deposited on pasture $E_{N2O,ad}$ (t N_2O) are calculated as:

$$E_{N2O,ad} = M_{vol,m=14} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where $M_{vol,m=14}$ = mass of nitrogen volatilised from manure deposited on pasture (kg N)

EF_{N2O} = emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen volatilised $M_{vol,PRP}$ (kg N) is calculated as:

$$M_{vol,m=14} = \sum_j \sum_k MN_{jkm=14T=1} \times FracGASMsoil$$

Where $FracGASMsoil$ = fraction of nitrogen volatilised from manure deposited on pasture ((kg NH_3-N + NO_x-N)/kg N)

4.6.1.13 Method 2 – Soil Atmospheric Deposition N2O Poultry

There is no Method 2 quantification option for this emission source.

4.6.1.14 Method 1 – Soil Leaching and Runoff N2O Poultry

(1) Leaching and runoff emissions from urine and dung deposited on pasture $ES_{N2O,leach}$ (t N_2O) are calculated as:

$$E_{N2O,leach} = M_{leach.m=14} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Where $M_{leach,m=14}$ = mass of nitrogen lost to leaching and runoff from urine and faeces deposited on pasture (kg N)

EF_{leach} = emission factor for leaching and runoff (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen lost to leaching and runoff $M_{leach,PRP}$ is calculated as:

$$M_{leach,m=14} = \sum_j \sum_k MN_{jkm=14T=1} \times FracWet \times FracLEACH_{MS}$$

Where $FracWet$ = fraction of N available for leaching and runoff.

$FracLEACH_{MS}$ = fraction of N that is lost through leaching and runoff

4.6.1.15 Method 2 – Soil Leaching and Runoff N2O Poultry

There is no Method 2 quantification option for this emission source

4.6.2 Data/Parameters

4.6.2.1 Input Data (Required)

Data / Parameter	N_{jk}
Data unit	birds
Description	Number of poultry in each class j and subclass k
Data source	Farm flock records
Quality assurance / quality control considerations	Number of poultry reported may be cross checked with expected flock numbers for system size and production, if known. The numbers reported with in each input class of animals may be crossed checked with expected enterprise values, if known: for example, number of laying hens vs meat chickens vs breeder.

Data / Parameter	D_{jk}
Data unit	days
Description	Duration of stay for each class and subclass of poultry
Data source	Farm flock records, housing/system records and placement and dispatch documentation may be used to determine average duration of stay for each poultry class and subclass. For broiler chickens records of depletions, or “flock thinning” may be used to ascertain length of stay within each class and subclass of poultry.
Quality assurance / quality control considerations	Ensure average length of stay aligns with duration of stay expected for poultry type, class and subclass. Layers would be expected to be on farm on average for 365 days while broiler chickens will vary depending on production system and when depletions occur.

Question Reference 4.10.

If there is more than one MMS per treatment stage will the farmer need support in calculating the fraction of manure distributed to each system for the MMS input values? Are there existing calculations or tools that should be referenced to support this?

Data / Parameter	$MMS_{jmT=1}$
Data unit	Fraction
Description	Fraction of manure in each primary MMS
Data source	Farmer records as to what fraction each system is used to treat manure based on the available MMS options (m). If treatment is different for different poultry groups this may also be recorded per poultry group. Free range systems will include both a shed and range component. Unless other data is available it shall be assumed that 0.8 of manure in free range system is allocated to the shed (with or without litter) and 0.2 to a drylot MMS system as a pasture substitute [12], [13]. Available primary MMS options include: • Poultry manure with litter • Poultry manure without litter - stored in house • Poultry manure without litter – belt removal • Pasture, range and paddock If a different MMS is applied which is not listed for poultry the most closely aligned MMS should be identified. Please see consultation **Question Reference 4.4** if you know of systems in use which are not captured in the available options
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=1}$ values should equal one. If only one primary MMS is used to treat manure, then $MMS_{jmT=1}$ should equal 1.

Data / Parameter	$MMS_{jmT=2}$
Data unit	Fraction
Description	Fraction of waste from primary system transferring to each secondary manure management system i.e. what fraction of manure goes to what MMS once it has been removed from the house.
Data source	Farmer records as to what fraction of manure flows to each system based on the available MMS options (m). If treatment is different for different poultry groups this may also be recorded per poultry group. If a different MMS is applied which is not listed for poultry the most closely aligned MMS should be identified. Please see consultation **Question Reference 4.4** if you know of systems in use which are not captured in the available options
Quality assurance / quality control considerations	The sum of all $MMS_{jmT=2}$ values should equal one. If there is only one available secondary MMS then $MMS_{jmT=2}$ should be equal to 1.

Data / Parameter	PF
Data unit	Fraction
Description	Fraction of manure from MMS applied to soil within the farm boundary
Data source	Farmer records of manure sales or transport weights compared to total manure treated on farm. When all manure treated in MMS is applied within the entity boundary and none is sold off-site to be used in a different enterprise, then PF = 1.
Quality assurance / quality control considerations	If all manure is not applied to soil within the entity boundary, ensure it is appropriately tracked what proportion is sold to other entities. If it is not known what proportion is sold to other entities assume all manure is applied within the entity boundary until better data can be collected.

4.6.2.2 Data (Method 1 and 2 Options)

Question Reference 4.11.

Are there existing tools or equations you would want included to support the calculation of intake? The Australia Eggs tool has been referenced below but calculation of intake is not visible to users.

Data / Parameter	I_{jk}
Data unit	kg DM/bird/day
Description	Dry matter intake for each class and subclass
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	Farm records relating to daily feed intake for each class or subclass. For rearers and layers the Australian Egg Tool [14] provides a calculation of intake based on total feed delivered to rearers or subclass of layer (cage, barn, free range) and diet characteristics, if known.
Quality assurance / quality control considerations	Intake may be compared to Method 1 defaults for the relevant poultry class. If significantly higher or lower than inventory defaults check farm records to ensure correct data entry.

Data / Parameter	DMD_{jk}
Data unit	fraction
Description	Dry matter digestibility
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	If average DMD for the reporting period of different poultry classes is known based on farm records of feed sources and quality, a farm specific DMD value may be used. For any poultry classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	Compare to inventory defaults, if values are significantly higher or lower data entry error is possible. Where Method 2 data is used conduct checks of farm source data are within expected ranges.

Data / Parameter	CP_j
Data unit	fraction
Description	Crude protein content of feed intake
Method 1 data source	See Appendix Table A.1.7.1
Method 1 value	Select appropriate value based on animal class.
Method 2 data source	Farm records or feed delivery receipt stating crude protein of complete feed for different poultry classes. For any poultry classes where farm records of feed sources and quality are not available, the National Inventory Report default shall be applied.
Quality assurance / quality control considerations	Compare to defaults, if values are significantly higher or lower data entry error is possible. Where Method 2 data is used conduct checks of farm source data are within expected ranges.

Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.7.4
Method 1 value	Choose default based on State and MMS. If MMS in use is not covered by state-based defaults Method 2 shall be applied.
Method 2 data source	Select relevant MCF for MMS and temperature zone from Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report or IPCC Guidelines where appropriate (see Appendix Table A.1.7.4 and A.1.8.1 for data source information).

4.6.2.3 Constant

Data / Parameter	B_0
Data unit	m^3 CH_4/kg VS
Description	Emissions potential.
Data source	IPCC (2019), Chapter 10 [3]
Value	**Layers** = 0.39 **Meat Chickens** = 0.36
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report..

Data / Parameter	ρ
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1663

Data / Parameter	$VSL_{mT=1}$
Data unit	fraction
Description	Fraction of volatile solids lost in the primary system
Data source	National Inventory Report, Volume 2 [4]
Value	**Poultry manure with litter** = 0.15 **Poultry manure without litter - stored in house** = 0.2 **Poultry manure without litter – belt removal** = 0
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1664

Data / Parameter	*A*
Data unit	fraction
Description	Ash content of manure
Data source	See Appendix Table A.1.7.1
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1665

Data / Parameter	EF_{jm}
Data unit	$kgN_2O\text{-}N/kgN$
Description	Nitrous oxide emission factor for each MMS.
Data source	See Appendix Table A.1.7.3
Value	Select appropriate value based on manure management system.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1666

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1667

Data / Parameter	NR_{jk}
Data unit	per cent
Description	Nitrogen retention expressed as a per cent of intake
Data source	See Appendix Table A.1.7.1
Value	Select appropriate value based on animal class.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

Data / Parameter	$FracGASM_{mT}$
Data unit	(kg NH_3–N + NO_x–N)/kgN
Description	Fraction of N volatilized in each MMS.
Data source	See Appendix Table A.1.7.2
Value	Apply the FracGASM that best represents the MMS in each treatment stage.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report..
Data / Parameter	EF_{N2O}
Data unit	kgN_2O-N/kgN
Description	Nitrous oxide emission factors for atmospheric deposition
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Select the value based on the production system which most accurately describes the land surrounding the housing area. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the rainfall zone the enterprise is located in
Quality assurance / quality control considerations	Ensure the most recently available emissions factors is selected in alignment with the production system-based emissions factors reported in the Australian National Inventory Report.

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [10]
Value	0.011

Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report..

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8.2 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

Data / Parameter	$FracLEACH_{MS}$
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Inventory Report, Volume 1 [1]
Value	0.02
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

4.7 Other Livestock

This module covers the estimation of methane and nitrous oxide that result from other livestock manure management. Other livestock are assumed to be range-kept livestock with manure deposition occurring in a dispersed fashion on pasture, range or paddock (PRP).

The following subscripts are used in this module:

Subscript	Meaning
i	Temperature Zone
j	Other livestock type

Emissions are estimated based on type of animal and the manure management system. The temperature zone will affect the selection of appropriate emissions factors. The emissions are summed across manure management systems.

The other livestock types on the farm will depend on the diversity of the farming operation. The classes of different other livestock types need to be mapped back to default categories ('Other Livestock Types (j)') to allow the use of default values under Method 1.

Other livestock types j	Possible input classes
1 = Buffalo	Bulls
	Cows
	Steers
	Calves
2 = Goats	Bucks/Billy
	Wethers
	Maiden breeding does/nannies
	Breeding does/nannies
	Other
	Kids
3 = Deer	Bucks
	Breeding Does
	Other Does
	Fawn
4 = Camels	Camels
5 = Alpacas	Alpacas
6 = Horses	Horses
7 = Mules/asses	Mules/asses
8 = Emus/ostriches	Emus/Ostriches

The only relevant manure management systems (m) for other livestock are PRP (m=14) and anaerobic lagoons (m=1). Where farms have unfenced natural water sources and farm dams, anaerobic lagoons are used as a proxy to estimate the runoff of manure into these water sources. Figure 4.10 summarises the emission sources associated with the manure of other livestock.

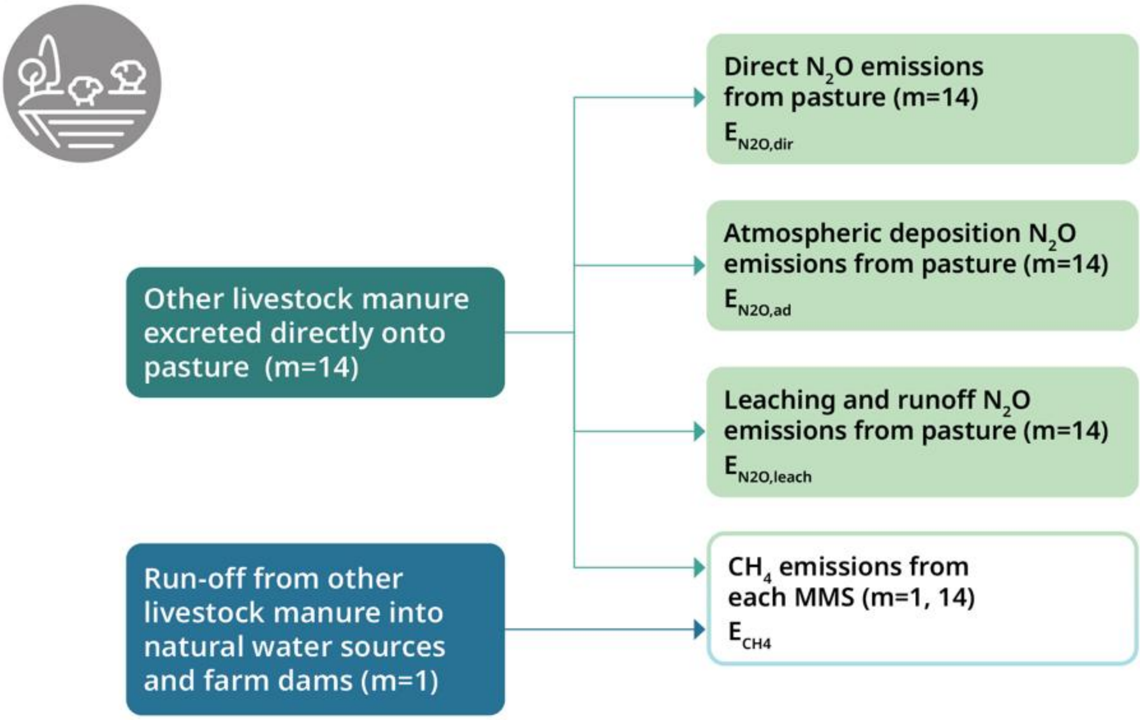


Figure 4.10: Emissions that result from manure of other livestock on pasture, rangeland and paddock

4.7.1 Estimation methodology

4.7.1.1 Method 1 – Manure Methane Other Livestock

(1) Total annual methane production from manure management of other livestock E_{CH4} (t CH_4) is calculated as:

$$E_{CH4} = \sum_j \sum_m (N_j \times M_{jm} \times 365) \times 10^{-3}$$

Where N_j = average annual of livestock per livestock type j (head)

M_{jm} = annual methane production (kg CH_4/head/day)

(2) In equation (1) annual methane production from manure management M_{jm} (kg CH_4/head/day) is calculated as:

$$M_{jm} = VS_j \times B_O \times MMS_m \times MCF_{im} \times \rho$$

Where VS_j = volatile solid production (kg/head/day)

B_O = emissions potential (m^3 CH_4/kgVS)

MMS_m = fraction of waste in each manure management system

MCF_{im} = methane conversion factor for temperature zone and MMS. Under Method 1, the default state temperature zone is applied.

ρ = density of methane (kg/m^3)

The primary manure management system (MMS) for other livestock is pasture range and paddock (m=14). Where natural water sources, such as farm dams, are present the anaerobic lagoon (m=1) MMS is used to estimate the run-off of manure into these water sources. Where farmers can demonstrate animals are on bore or reticulated water systems, where water is provided in troughs (i.e., no unfenced natural water sources), then the only relevant MMS to be considered shall be pasture range and paddock (m=14).

The assumption regarding run-off into farm dams is under review and may change in future. Until new assumption confirmed by DCCEEW the allocation to MMS for unfenced water sources is aligned with the current National Inventory Report approach. A new method for estimating VS production will be implement in the next National Inventory Report and has been reflected here.

4.7.1.2 Method 2 – Manure Methane Other Livestock

Method 2 is the same as Method 1, except a temperature zone specific value for MCF_{im} is applied in equation 4.7.1.1 (2).

4.7.1.3 Method 1 – Soil Direct N2O Other Livestock

(1) Total annual direct nitrous oxide emissions from agricultural soils from deposition of urine and dung to pasture $E_{N2O,dir}$ (t N_2O) is calculated as:

$$E_{N2O,dir} = AE \times EF_{PRP} \times C_{N2O} \times 10^{-3}$$

Where AE = annual nitrogen excreted by each livestock type (kg N/year)

EF_{PRP} = emission factor for nitrous oxide from urine and dung deposited to soil (kg N_2O-N/kg N deposited)

C_{N2O} = factor to convert elemental mass of nitrous oxide to molecular mass

(2) In equation (1) total nitrogen excreted to pasture, range and paddock AE (kg N/year) is calculated as:

$$AE = \sum_j (N_j \times NE_j \times 365)$$

Where NE_j = Nitrogen excreted by each livestock type (kg N/head/day)

4.7.1.4 Method 2 – Soil Direct N2O Other Livestock

There is no Method 2 quantification option for this emissions source.

4.7.1.5 Method 1 – Soil Atmospheric Deposition N2O Other Livestock

(1) Atmospheric deposition emissions from urine and dung deposited on pasture $E_{N2O,ad}$ (t N_2O) are calculated as:

$$E_{N2O,ad} = M_{vol} \times EF_{N2O} \times C_{N2O} \times 10^{-3}$$

Where M_{vol} = mass of nitrogen volatilised from urine and faeces deposited on pasture (kg N)

EF_{N2O} = emission factor for atmospheric deposition (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen volatilised M_{vol} (kg N) is calculated as:

$$M_{vol} = AE \times FracGASMsoil$$

Where $FracGASMsoil$ = fraction of nitrogen volatilised from urine and faeces deposited on pasture ((kg NH_3–N + NO_x–N)/kg N)

4.7.1.6 Method 2 – Soil Atmospheric Deposition N2O Other Livestock

There is no Method 2 quantification option for this emission source

4.7.1.7 Method 1 – Soil Leaching and Runoff N2O Other Livestock

(1) Leaching and runoff emissions from urine and dung deposited on pasture $E_{N2O,leach}$ (t N_2O) are calculated as:

$$E_{N2O,leach} = M_{leach} \times EF_{leach} \times C_{N2O} \times 10^{-3}$$

Where M_{leach} = mass of nitrogen lost to leaching and runoff (kg N)

EF_{leach} = emission factor for leaching and runoff (kg N_2O-N/kg N)

(2) In equation (1) the mass of nitrogen lost to leaching and runoff M_{leach} is calculated as:

$$M_{leach} = AE \times FracWet \times FracLEACH$$

Where $FracWet$ = fraction of N available for leaching and runoff.

$FracLEACH$ = fraction of all N that is lost through leaching and runoff

4.7.1.8 Method 2 – Soil Leaching and Runoff N2O Other Livestock

There is no Method 2 quantification option for this emission source

4.7.2 Data/Parameters

4.7.2.1 Input Data (Required)

Data / Parameter	N_j
Data unit	head
Description	Average annual numbers of other livestock per other livestock type j
Data source	Farm stock records – Method assumes animals are on farm for 365 days. If there are changes in livestock numbers throughout the year an average annual number should be calculated based on animal movements i.e. for systems with multiple subclasses where numbers of animals on farm varies between these subclasses throughout the year purchase/birth and sales/deaths records may be used to estimate an annual average number of livestock over a month or season. These numbers may then be averaged to estimate the annual average number of livestock on the farm.
Quality assurance / quality control considerations	All animals purchased or sold in the reporting period are assumed to be reported. Number of other livestock reported may be cross checked with stocking density allowances for system size. The type of animals on farm may be crossed check against reported products from farm.

4.7.2.2 Data (Method 1 and 2 Options)

Data / Parameter	MCF_{im}
Data unit	Fraction
Description	Methane conversion factor for temperature zone and system.
Method 1 data source	See Appendix Table A.1.5.6
Method 1 value	Choose default based on State and MMS.
Method 2 data source	Select relevant MCF for MMS and temperature zone see Appendix Table A.1.8.1. See Chapter 1 Section 1.8.2 for guidance on selecting appropriate temperature zone.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

4.7.2.3 Constants

Data / Parameter	VS_j
Data unit	kg VS/head/year
Description	Volatile solids produced for other livestock type j
Data source	See Appendix Table A.1.5.2
Value	Select the appropriate livestock type.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

DCCEEW is investigating the provision of more granular spatial mapping of MMS for method 2 option.

Data / Parameter	MMS_m
Data unit	fraction
Description	Fraction of waste in each MMS
Data source	National Inventory Report, Volume 1 [1]
Value	Where a producer cannot demonstrate water bodies are stock excluded MMS_m values shall be selected based on State, Region and MMS. If animals are on bore or reticulated water systems where water is provided in troughs (i.e. no unfenced natural water sources) then all waste should be allocated to pasture range and paddock and $MMS_{m=14}$ = 1.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report. High resolution aerial imagery may be used to cross check that water sources are stock excluded.

Data / Parameter	C_{N2O}
Data unit	fraction
Description	Factor to convert elemental mass of nitrous oxide to molecular mass
Data source	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Chapter 5: Agriculture [7]
Value	1.57
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1787

Data / Parameter	*p*
Data unit	kg/m^3
Description	Density of methane
Data source	National Greenhouse and Energy Reporting (Measurement) Determination 2008 [5]
Value	0.6784
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1788

Data / Parameter	EF_{PRP}
Data unit	kg N_2O-N/kg N
Description	Emission factor for urine and dung deposited on pasture, range or paddock
Data source	See Appendix Table A.2.2.2.
Value	The appropriate EF_{PRP} may be selected by using the IPCC values for EF_{PRP} specific to the climate zone in which the farm is located. Refer to Chapter 1 Section 1.8.2 for guidance on how to determine the climate zone the enterprise is located in.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report.

1789

Data / Parameter	NE_j
Data unit	kg N_2O/head/year
Description	Nitrogen excreted per livestock type
Data source	See Appendix Table A.1.5.3
Value	Select the appropriate livestock type.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1790

Data / Parameter	EF_{N2O}
Data unit	kg N_2O-N/kg N
Description	Emission factor for atmospheric deposition.
Data source	See Appendix Table A.2.2.1
Value	This is the same emissions factor as used for direct nitrous oxide emissions from inorganic fertilisers. Apply the EF that best represent the production system

	In some farm systems animals may graze on crops. Apply the inorganic fertiliser EF that best representing how the animals are grazed for the majority of the year or calculate a weighted average if the number of days on each grazing system is known. For non-irrigated cropping systems, the emission factor varies depending on whether the agricultural system is in a high rainfall or low rainfall zone. Refer to Chapter 1 Section 1.8 for guidance on determining the relevant rainfall zone.
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian National Inventory Report

Data / Parameter	FracWET
Data unit	Fraction
Description	Fraction of nitrogen that is available for leaching and runoff
Data source	National Inventory Report Volume 1 [1]
Value	To determine whether the entity is located in an area where leaching occurs refer to Chapter 1 Section 1.8 on how to determine whether the enterprise is located in a leaching zone. Where it is determined that leaching does occur, FracWET = 1 Where it is determined that leaching does not occur, FracWET = 0
Quality assurance / quality control considerations	Farm title data may be checked to ensure spatial farm boundaries used to define leaching zone are correct. Other inputs such as electricity or fuel of irrigation purposes may be used to highlight if pastures are irrigated and therefore leaching will be occurring.

Data / Parameter	FracGASMsoil
Data unit	(kg NH_3–N + NO_x–N)/kg N
Description	Fraction of nitrogen volatilised from urine and faeces deposited on pasture
Data source	IPCC 2019, Volume 4, Chapter 11, Table 11.3 [8]
Value	0.21
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1795

Data / Parameter	FracLEACH
Data unit	fraction
Description	Fraction of N that is lost through leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [1]
Value	0.24
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Greenhouse Gas Inventory.

1796

Data / Parameter	EF_{leach}
Data unit	kg N_2O-N/kg N
Description	Emission factor for leaching and runoff
Data source	National Greenhouse Gas Inventory Volume 1 [1]
Value	0.011
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

1797

4.8 References

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