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 3: Enteric Methane

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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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3 Scope 1 – Enteric Fermentation

3.1 Beef Feedlot

This module covers the estimation of methane emission from enteric fermentation for feedlot beef cattle.

The following subscripts are used in this module:

Subscript	Meaning
j	Cattle lot

Emissions are estimated based on lots of cattle with similar intake requirements and lengths of stay on the feed pad. The emissions are summed across each lot within the feedlot operation during the reporting period.

The number of lots 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. Lots may be labelled as numbers e.g. Lot 1, Lot 2, Lot 3 or given relevant names based on age or breed of group e.g. R2 Wagyu, R3 Angus, R3 Mixed for data entry purposes.

3.1.1 Estimation methodology

3.1.1.1 Method 1 — Enteric Beef Feedlot

(1) Total annual methane production from enteric fermentation in feedlot beef cattle $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \left(D_j \times M_j \times N_j\right) \times 10^{-3}$$

Where D_j = duration of stay of each cattle lot (days)

M_j = daily methane production (kg CH_4/head/day)

N_j = numbers of feedlot cattle in each cattle lot (head)

(2) In equation (1) daily production of enteric methane M_j (kg CH_4/head/day) based on Almeida et al. (2025) [1] is calculated as:

$$M_j = \left(5.11 \times I_j - 4.00 \times EE_j + 2.26 \times NDF_j\right) \times 10^{-3}$$

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

EE_j = ether extract as a percentage of I_j (per cent)

NDF_j = neutral detergent fibre as a percentage of I_j (per cent)

Under Method 1, default I_j, EE_j and NDF_j values are applied.

3.1.1.2 Method 2 — Enteric Beef Feedlot

Method 2 is the same as Method 1 except that under equation 3.1.1.1 (2) farm specific data for I_j, EE_j and NDF_j is required.

3.1.2 Data/Parameters

3.1.2.1 Input Data (Required)

Data / Parameter	N_j
Data unit	head
Description	Number of beef cattle in each lot (j).
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 shall be included. 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	D_j
Data unit	days
Description	Duration of stay for each cattle lot (j)
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.
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.

92 3.1.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	lj
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 to Method 1 defaults for the relevant cattle class.

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Data / Parameter	NDF_j
Data unit	percentage of dry matter intake (l_j)
Description	Average neutral detergent fibre as a percentage of feed intake (l_j) for each cattle lot. National default data based on length of stay is available if neutral detergent fibre of TMR for a lot is not known.
Method 1 data source	See Appendix Table A.1.1.3.
Method 1 value	Select the default value appropriate to the length of stay for the lot of cattle.
Method 2 data source	Farm records of neutral detergent fibre of TMR for each cattle lot. TMR may change over the duration of the stay therefore a weighted average of neutral detergent fibre should be calculated based on the composition of feed throughout the stay.
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	EE_j
Data unit	percentage of dry matter intake (I_j)
Description	Ether extract as a percentage of intake (I_j) for each cattle lot
Method 1 data source	See Appendix Table A.1.1.3.
Method 1 value	Select the default value appropriate to the length of stay for the lot of cattle.
Method 2 data source	Farm records of ether extract of TMR for each cattle lot. TMR may change over the duration of the stay therefore a weighted average of ether extract should be calculated based on the composition of feed throughout the stay.
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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3.2 Beef Pasture, Range, and Paddock

This module covers the estimation of methane emission from enteric fermentation for beef cattle on pasture, rangeland or paddock.

The following subscripts are used in this module:

Subscript	Meaning
j	Time-period (e.g season or month)
k	Beef cattle class
l	Beef cattle subclass

Emissions are estimated based on age and sex classes of cattle and time of the year reflecting different intake requirements. The emissions are summed across each class (and subclass) and time-period spent on farm during the reporting period.

The time-period selected will depend on availability of stock numbers and liveweight and liveweight gain data (see Herd Flow modelling guidance in Chapter 1 Section 1.9).

The classes of cattle on the farm ('Beef cattle input class') will depend on the diversity of the farming operation and the data records available. 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.

Beef cattle classes (k)	Beef cattle subclass (l) [(a)]	Example beef cattle input classes
1 = Bulls < 1 year	1 = Bulls < 1 year	Bulls < 1 year
2 = Bulls > 1 year	2 = Bulls > 1 year	Bulls 1-2 year
		Bulls 2-3 year
		Bulls >3 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 breeding
		Cows 1-2 years other
5 = Cows > 2 years	5a = Cows 2-3 years	Cows 2-3 years breeding
		Cows 2-3 years other
	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

3.2.1 Estimation Methodology

3.2.1.1 Method 1 — Enteric Beef Grazing

(1) Total annual methane production from enteric fermentation in grazing beef cattle $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \sum_k \sum_l (D_j \times M_{jkl} \times N_{jkl}) \times 10^{-3}$$

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

M_{jkl} = daily production of enteric methane in each time-period, class and sub class (kg CH_4/head/day)

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

(2) In equation (1) daily production of enteric methane M_{jkl} based on Charmley et al. (2015) [2] is calculated as:

$$M_{jkl} = 20.7 \times I_{jkl} \times 10^{-3}$$

Where I_{jkl} = dry matter intake (kg DM/head/day)

(3) In equation (2) feed intake I_{jkl}, based on Minson and McDonald (1987) [3], is calculated as:

$$I_{jkl} = \left(1.185 + 0.00454 \times W_{jkl} - 0.0000026 \times W_{jkl}{}^2 + 0.315 \times LWG_{jkl}\right)^2 \times MA_{jk=4,5}$$

Where W_{jkl} = liveweight (kg)

LWG_{jkl} = live weight gain (kg/head/day)

$MA_{jk=4,5}$ = additional intake for milk production in cows >2 years (kg/head/day) noting that for all other cattle classes $MA_{jk=1,2,3,6,7}$ = 1

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

Dry matter intake I_{jkl} may also be specified in equation (2) as a Method 2 approach.

(4) In equation (3) additional intake for milk production is calculated in the season of calving and the season after calving as:

$$MA_{jk=4,5} = \left(LC_{jk=4,5} \times FA_{jk=4,5}\right) + \left(1 - LC_{jk=4,5}\right)$$

Where $LC_{jk=4,5}$ = proportion of cows > 1 years (k=4,5) in calf in the season of calving. Applied to calving season and the season immediately after calving expressed as a fraction noting that for all other seasons $LC_{jk=4,5} = 0$

$FA_{jk=4,5}$ = feed adjustment value for cows > 1 years lactating for the season of calving and the season immediately after calving expressed as a fraction

For farms with multiple calving seasons, the proportion of cows > 2 years in calf ($LC_{jk=4,5}$) should be reported separately for each season.

3.2.1.2 METHOD 2 — ENTERIC BEEF GRAZING

Method 2 is the same as Method 1 except that under equation 3.2.1.1 (3) farm specific data for W_{jkl}, LWG_{jkl} is required for the selected time-period (i.e. seasonal, monthly or other). Alternatively, dry matter intake I_{jkl} may be specified in equation 3.2.1.1 (2) as a Method 1 approach.

Under Method 2 the selected time-period and associated D_j used in equation 3.2.1.1 (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

3.2.2 Data/Parameters

3.2.2.1 Input Data (Required)

Data / Parameter	N_{jkl}
Data unit	head
Description	Number of pasture beef cattle per time-period, and input class.
Data source	Farm stock records – see herd flow modelling in 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
Description	Proportion of cows > 2 years in calf in the season of calving. This is used as a proxy for cows >2 lactating.
Data source	Farm records: Proportion of cows > 2 in calf 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	Proportion of cows > 2 years in calf may be cross checked with scanning and/or weaning records. 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.

160 3.2.2.2 DATA (METHOD 1 AND 2 OPTIONS)

Data / Parameter	D_j
Data unit	days
Description	Number of days in each time period animals in each class (j) are on the farm.
Method 1 data source	National Inventory Report Volume 1 [5].
Method 1 value	91.25 as the default time period which 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 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	I_{jkl}
Data unit	kgDM/head/day
Description	Average dry matter intake of beef pasture cattle per time-period, class, and sub-class.
Method 1 data source	Equation 3.1.1.1 (3).
Method 1 value	Calculated based on liveweight and liveweight gain.
Method 2 data source	Farm stock records of dry matter intake.
Quality assurance / quality control considerations	Method 2 values may be sense checked against production data and system to ensure they are appropriate e.g. that intake reflects when stock are expected to be growing more due to feed quality and availability.

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Data / Parameter	W_{jkl}
Data unit	kg
Description	Average liveweight of beef pasture cattle per time-period, class, and sub-class.
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 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.

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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.1.2.3 & A.1.2.4.
Method 1 value	Select the appropriate default value for location of cattle 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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165 3.2.2.3 CONSTANTS

Data / Parameter	$FA_{ijkl=5}$
Data unit	fraction
Description	Feed adjustment value for cows > 2 years lactating.
Data source	See Appendix Table A.1.2.7.
Value	Select appropriate value based on cattle breed. For farms with multiple calving seasons, the feed adjustment value should be applied to the cows calving in each season and immediate season after calving as appropriate. 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.
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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3.3 Dairy

This module covers the estimation of methane emission from enteric fermentation for dairy cattle.

The following subscripts are used in this module:

Subscript	Meaning
j	Dairy cattle class

Emissions are estimated based on the age and sex classes, reflecting different intake requirements. The emissions are summed across each class and time spent on farm within 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 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 4.2 for more detail).

3.3.1 Estimation methodology

3.3.1.1 Method 1 — Enteric Dairy Cattle

(1) Total annual methane production from enteric fermentation in dairy cattle $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \left(\left(N_{j=1,2,4} \times M_{j=1,2,4} \times D_{j=1,2,4} \right) + \left(N_{j=3,5} \times M_{j=3,5} \times D_{j=3,5} \right) + \left(N_{j=3,5} \times MPW_{ENTERIC,j=3,5} \times D_{j=3,5} \right) \right) \times 10^{-3}$$

Where N_j = number of dairy cattle in each class (head)

M_j = daily enteric methane production (kg CH_4/head/day)

$MPW_{ENTERIC,j=3,5}$= daily methane production for 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

The approach assumes that until dairy calves are fully weaned calves primarily consume milk or milk replacer, pellets and hay, which results in lower emissions.

(2) In equation (1) the daily production of enteric methane M_j (kg CH_4/head/day) based on Charmley et al. (2015) [2] is calculated as:

$$M_j = 20.7 \times I_j \times 10^{-3}$$

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

(3) In equation (2) feed intake I_j (kg DM/head/day) based on Minson and McDonald (1987) [3] is calculated as:

$$I_j = \left(1.185 + 0.00454 \times W_j - 0.0000026 \times W_j^2 + 0.315 \times LWG_j\right)^2 \times MR_j + MI_j$$

Where W_j = liveweight (kg)

LWG_j = liveweight gain (kg/head/day)

MR_j = increase in metabolic rate when producing milk expressed as a fraction

MI_j = additional intake required for milk production (kg DM/head/day)

Under Method 1, default W_j and LWG_j values are applied.

(4) In equation (3) the additional intake required for milk production MI_j (kg DM/head/day) is calculated by:

$$MI_j = \frac{MP_j \times 1.03 \times NE}{GEC \times k \times qm_j}$$

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

NE = net energy (MJ net energy/kg milk)

GEC = gross energy content (MJ/kgDM)

k = efficiency of use of metabolizable energy for milk production expressed as a fraction

qm_j = metabolisability of the diet expressed as a fraction

1.03 = conversion from litres to kg

(5) In equation (4), if milk production data is collected in quantities of milk solids rather than litres of milk, then milk solids may be converted to litres as [4]:

$$MP_j = \frac{MS_j}{0.01 \times (FC_j + PC_j)}$$

Where MS_j = daily production of milk solids (kg MS/head/day)

FC_j = fat content in fat and protein corrected milk (per cent)

PC_j = protein content in fat and protein corrected milk (per cent)

(6) In equation (4), metabolisability of the diet qm_j based on Minson and McDonald (1987) [3] is calculated as:

$$qm_j = 0.795 \times (DMD_j \times 100) - 0.0014$$

Where DMD_j = dry matter digestibility expressed as a fraction

3.3.1.2 Method 2 — Enteric Dairy Cattle

Method 2 is the same as Method 1 except that under equation 3.3.1.1 (3) farm specific data for W_j, LWG_j is required. Under equation 3.3.1.1 (5) – (6) farm specific data may be used for FC_j, PC_j and DMD_j.

3.3.2 Data/Parameters

3.3.2.1 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 records of daily milk production. The daily milk production should include the milk feed to calves. The average farm milk sales records, the average volume of milk feed to calves, and average number of milking cows over the reporting period may be used to calculate the daily milk production. If milk production records are in terms of milk solids rather than litres of milk, refer to the data table for MS_j below.
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 may be found in Appendix Table A.1.3.9.Milk production may be reviewed through milking parlour software and corroborated via milk collection receipts.

Data / Parameter	MS_j
Data unit	kgMS/head/day
Description	Daily milk solids production per milking cow.
Data source	Only required for annual emissions estimation where MP_j is not known. Farm milk sales records and number of milking cows. The average amount of milk sold per day (in kg of milk solids) may be divided by the average number of milking cows on the farm to calculated the daily milk production per milking cow.
Quality assurance / quality control considerations	Farm source values of MS_j may be computed into MP_j (using values for FC_j and PC_j) and compared to National Inventory Report state-based values to check for data entry errors and/or milk production values may be reviewed through milking parlour software and corroborated via milk collection receipts. Users providing values of MS_j shall also provide values for FC_j and PC_j.

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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 [5].
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 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. If Method 2 is used consider if input classes of animals are on the farm all year round 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.

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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 default value for cattle 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 1 default 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.

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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 various heifers are [4]: • 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.

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Data / Parameter	DMD_j
Data unit	fraction
Description	Dry matter digestibility.
Method 1 data source	Table A5.5.1.4, National Inventory Report, Volume 2 [6].
Method 1 value	0.75
Method 2 data source	If average DMD for the reporting period of different livestock classes is known based on farm records of feed sources and quality, a farm-specific DMD value may be used. The ADCC, 2025 [4] provides support on how to calculate DMD 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 [4] provides ranges of DMD for different forage of non-forage supplements which may alternatively be used to review entered data.

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Data / Parameter	FC_j
Data unit	per cent
Description	Fat content in fat and protein corrected milk (only needed if milk production data is provided in the form of milk solids, MS_j, rather than litres, MP_j).
Method 1 data source	Australian Dairy Carbon Calculator [4].
Method 1 value	4.0.
Method 2 data source	Farm-specific values for FC_j may be used, where farmers have records specific to the milk production of the reporting period.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used. If Method 2 is used calculated values of MP_j (using values for FC_j and PC_j) and cross checked against to National Inventory Report state-based values and/or milk production values may be reviewed through milking parlour software and corroborated via milk collection receipts.

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Data / Parameter	PC_j
Data unit	per cent
Description	Protein content in fat and protein corrected milk (only needed if milk production data is provided in the form of milk solids, MS_j, rather than litres, MP_j).
Method 1 data source	Australian Dairy Carbon Calculator [4].
Method 1 value	3.3.
Method 2 data source	Farm-specific values for PC_j may be used, where farmers have records specific to the milk production of the reporting period.
Quality assurance / quality control considerations	If Method 1 is used ensure the most recently available published data is used. If Method 2 is used calculated values of MP_j (using values for FC_j and PC_j) and cross checked against National Inventory Report state-based values and/or milk production values may be reviewed through milking parlour software and corroborated via milk collection receipts.

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254 #### 3.3.2.3 CONSTANTS

Data / Parameter	$MPW_{ENTERIC,j=3,5}$
Data unit	kg CH_4/head/day
Description	Methane production for pre-weaned heifer and bull calves (less than 12 months old).
Data source	See Appendix Table A.1.3.5.
Value	Select the appropriate default value for cattle class.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

255

Data / Parameter	MR_j
Data unit	fraction
Description	Increase in metabolic rate when producing milk.
Data source	See Appendix Table A.1.3.9.
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..

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Data / Parameter	NE
Data unit	MJ net energy/kg milk.
Description	Net energy required for milk production.
Data source	National Inventory Report, Volume 1 [5].
Value	3.054.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

258

Data / Parameter	GEC
Data unit	MJ/kgDM
Description	Gross energy content of feed dry matter.
Data source	National Inventory Report, Volume 1 [5].
Value	18.4.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

259

Data / Parameter	k
Data unit	fraction
Description	Efficiency of use of metabolizable energy for milk production.
Data source	National Inventory Report, Volume 1 [5].
Value	0.60.
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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3.4 Sheep

This module covers the estimation of methane emissions from enteric fermentation for sheep.

The following subscripts are used in this module:

Subscript	Meaning
j	Time-period (e.g season or month)
k	Sheep Class

Emissions are estimated based on age and sex classes of sheep and time of the year reflecting different intake requirements. The emissions are summed across each class 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 the default categories ('sheep class k') 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 Chapter 1 Section 1.9).

Sheep Class *k*	Possible Sheep Input Class
1 = Rams	Rams
2 = Wethers	Wethers
3 = Maiden ewes	Maiden ewes (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)

3.4.1 Estimation Methodology

3.4.1.1 Method 1 — Enteric Sheep

(1) Total annual methane production from enteric fermentation in sheep $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \sum_k (N_{jk} \times M_{ijk} \times D_j) \times 10^{-3}$$

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

M_{jk} = daily methane production (kg CH_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) daily production of enteric methane M_{jk} (kg CH_4/head/day) based on Howden et al. (1994) [7] is calculated as:

$$M_{ijk} = (I_{jk} \times 0.0188) + 0.00158$$

Where I_{jk} = daily feed intake (kg DM/head/day)

(3) In equation (2) feed intake per head per day I_{jk} (kg DM/head/day) is calculated as:

$$I_{jk} = PI_{jk} \times RI_{jk} \times MA_{k=3,4}$$

Where PI_{jk} = potential intake (kg DM/head/day)

RI_{jk} = relative intake expressed as a fraction

$MA_{k=3,4}$ = additional intake for milk production expressed as a fraction

(4) In equation (3) potential intake PI_{jk} (kg DM/head/day) is calculated as:

$$PI_{jk} = \left(104.7 \times qm_{jk} + 0.307 \times W_{jk} - 15\right) \times W_{jk}^{0.75} \times 10^{-3}$$

Where W_{jk} = liveweight (kg).

qm_{jk} = metabolizability of the diet expressed as a fraction

Under Method 1, default W_{jk} is applied.

(5) In equation (4) metabolizability of the diet qm_{jk} based on Minson and McDonald (1987) [3] is calculated as:

$$qm_{jk} = \left(0.795 \times DMD_{jk}\right) - 0.0014$$

Where DMD_{jk} = dry matter digestibility of feed (per cent).

Under Method 1, default DMD_{jk} is applied.

(6) In equation (3) relative feed intake RI_{ijk} expressed as a fraction based on White et al. (1983) [8] is calculated as:

$$RI_{jk} = 1 - e^{-2(DMA_{jk})^2}$$

Where DMA_{jk} = dry matter availability (t/ha).

Under Method 1, default DMA_{jk} is applied.

(7) In equation (3) additional intake for milk production in breeding ewes and maidens $MA_{jk=3,4}$ is calculated as:

$$MA_{jk=3,4} = (LE_{jk=3,4} \times FA_{k=3,4}) + (1 - LE_{jk=3,4})$$

Where $LE_{jk=3,4}$ = proportion of ewes and maidens lactating expressed as fraction

$FA_{k=3,4}$ = feed adjustment value expresses as fraction

Additional intake for milk production for non-lactating sheep $MA_{jk=1,2,5,6}$ should be set to 1.

(8) In equation (7) proportion of ewes and maidens lactating $LE_{jk=3,4}$ is calculated as:

$$LE_{jk=3,4} = \frac{LR_{jk=3,4} \times \min(LMR_{jk=3,4}, 100)}{100}$$

Where $LR_{jk=3,4}$ = lambing rate of ewes and maidens (per cent)

$LMR_{jk=3,4}$ = lamb marking rate per ewe mated (per cent)

The lamb marking percentage may not exceed 100%, so that no more than 100% of the breeding flock can be lactating at one time.

For farms with multiple lambing events, the lambing rate and lamb marking percentage should be reported separately for each season or time period and the proportion of ewes and maidens lactating in that season or time period calculated appropriately.

3.4.1.2 Method 2 — Enteric Sheep

Method 2 is the same as Method 1 except that under equations 3.4.1.1 (3) – (6) farm specific data for W_{jkl} required for the selected time-period (i.e. seasonal, monthly or other) and farm specific DMD_{jk} and DMA_{jk} may also be applied.

Under Method 2 the selected time-period and associated D_j used in equation 3.4.1.1 (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.

339 ### 3.4.2 Data/Parameters

340 #### 3.4.2.1 Input Data (Required)

Data / Parameter	N_{jk}
Data unit	head
Description	Number of sheep in each class k.
Data source	Farm records and 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 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.

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Data / Parameter	$LR_{jk=3,4}$
Data unit	per cent
Description	Number of ewes and maidens lambing in the season as a proportion of the total number of ewes and maidens carried in the season.
Data source	Farm records: lambing rate should be based on weaning numbers. The percentage of ewes carrying a lamb at weaning and percentage of maidens carrying lamb at weaning should be reported separately where available. If weaning results are not available docking or tailing or scanning numbers may also be used to approximate the number of ewes and maidens lactating at this time.
Quality assurance / quality control considerations	Lambing rate may be cross checked with weaning records i.e. percentage of ewes and maidens carrying a lamb at weaning. If weaning results are not known lambing rate may be cross checked from number ewes, maidens and lambs reported in herd flow model.

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343

Data / Parameter	$LMR_{jk=3,4}$
Data unit	per cent
Description	Lamb marking rate for ewes and maidens in each lambing season or time period.
Data source	Farm records: lamb marking rate should be calculated by number of lambs marked per ewe mated. Currently the National Inventory Report does not take into consideration the extra energy requirements for ewes carrying multiple lambs so the lamb marking percentage is capped at 100%, i.e. where lamb marking rate is > 100%, LMS will equal 100% in the calculations.
Quality assurance / quality control considerations	Records of docking/tailing or weaning results may be used to cross check numbers entered. Lambing percentage may also be considered against the number of ewes, lambs and maidens reported in herd flow model to sense check reported lamb marking rate.

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345 #### 3.4.2.2 Data (Method 1 and 2 Options)

Data / Parameter	D_j
Data unit	days
Description	Number of days in each time period animals in each class (j) are on the farm.
Method 1 data source	National Inventory Report Volume 1 [5].
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.

346

Data / Parameter	W_{jk}
Data unit	kg
Description	Average liveweight of livestock per sheep class.
Method 1 data source	See Appendix Table A.1.4.1.
Method 1 value	Select the appropriate default value based on sheep class and state.
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9).
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. It is recommended Method 1 default values are sense checked against production data and system to ensure they are appropriate e.g. ensure lambing season default weights reflect this with lowest weigh value applied in the season of lambing 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 farm source data may be cross checked against Method 1 default 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.

347

Data / Parameter	DMD_{jk}
Data unit	Per cent
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 based on sheep class and state.
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.

348

Data / Parameter	DMA_{jk}
Data unit	t/ha
Description	Dry matter availability of feed.
Method 1 data source	See Appendix Table A.1.4.3.
Method 1 value	Select the appropriate default value based on sheep class and state. It should be noted that the intake calculations are impacted by the feed availability if it falls below 1.63 tonnes/ha. If containment feeding or supplemental feed is used during times of lower feed availability the inventory defaults will not be representative of this. It is recommended feed availability is entered as a farm specific parameter, if possible, to capture on farm feeding practices.
Method 2 data source	Farm specific DMA calculated based on available pasture growth and supplementary feed provided. During periods of containment feeding, if DMA can be calculated more readily due to control of intake, this may be applied to the sheep classes and time periods when this feeding is taking place and DMA is known.
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.

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350 ### 3.4.2.3 CONSTANTS

Data / Parameter	$FA_{k=3,4}$
Data unit	fraction
Description	Feed adjustment value.
Data source	National Inventory Report, Volume 1 [5].
Value	1.3.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

351

3.5 Swine

This module covers the estimation of methane that results from enteric fermentation production for swine.

The following subscripts are used in this module:

Subscript	Meaning
j	Swine class

Emissions are estimated based on age and sex classes of swine reflecting different intake requirements. The emissions are summed across each class and time-period spent on farm during the reporting period.

The classes of swine on the farm ('Swine input class') will depend on the diversity of the farming operation. These classes need to be mapped back to default categories ('Swine Class (j)) to allow the use of default intake values under Method 1.

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

3.5.1 Estimation methodology

3.5.1.1 METHOD 1 – ENTERIC SWINE

(1) Total annual methane production from enteric fermentation in swine $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \left(N_j \times M_j \times D_j\right) \times 10^{-3}$$

Where N_j = numbers of swine of each class (head)

M_j = methane production (kg CH_4/head/day)

D_j = the average number of days on farm for each swine class (days)

(2) In equation (1) the total daily production of enteric methane of swine M_j (kg CH_4/head/day) is calculated as:

374 $$M_j = \frac{\left(I_j \times 18.6 \times 0.007 \right)}{F}$$

375 Where I_j = daily feed ingested by each swine class (kg /head/day)

376 18.6 = gross energy (GE) content of feed (MJ GE/kg feed)

377 0.007 = fraction of GE intake converted to methane by swine

378 F = megajoules per kilogram of methane (MJ/kg CH_4)

379 Under Method 1, default I_j values are applied

380

381 ### 3.5.1.2 METHOD 2 – ENTERIC SWINE

382 Method 2 is the same as Method 1 except that under equations 3.5.1.1 (2) farm specific data
383 for I_j is required.

384

385

3.5.2 Data/Parameters

3.5.2.1 Input Data (Required)

Data / Parameter	N_j
Data unit	head
Description	Numbers of swine of each class (j).
Data source	Farm stock records.
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 check against reported production system (breeder vs. trader) and products from farm.

Data / Parameter	D_j
Data unit	days
Description	Average number of days on farm for each swine class (j).
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	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.

3.5.2.2 Data (Method 1 and 2 Options)

Question Reference 3.1.

Guidance currently directs farmers to PigBal for support calculating fed ingested weights. Are there other supporting tools or other industry guidance that could be referenced here to support the use of this higher method data? Additionally, for free range producers are there any default datasets for intake or tools to support the calculation of this as National Inventory Report defaults are based off intensive industries data?

Data / Parameter	Ij
Data unit	kg/head/day
Description	Average feed intake per head class of swine.
Method 1 data source	Table A5.5.5.2 National Inventory Report Volume 2 [6].
Method 1 value	See Table A.1.6.1 in A1 Appendix.
Method 2 data source	Farm records relating to daily feed and feed waste weights for each class. PigBal [9] may be utilized to support the calculation annual feed fed per head to different classes of swine. It should be noted that feeding weights may change over time therefore an average should be calculated based on the amount of feed throughout time period reported for the swine class.
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 swine class.

3.5.2.3 Constant

Data / Parameter	F
Data unit	MJ/kg CH_4
Description	Megajoules per kilogram of methane.
Data source	National Inventory Report Volume 1 [5].
Value	55.22.
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian National Inventory Report.

3.6 Other Livestock

This module covers the estimation of methane emissions from enteric fermentation of other livestock.

The following subscripts are used in this module:

Subscript	Meaning
j	Type of other livestock

Emissions are estimated based on type of animals. 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

3.6.1 Estimation methodology

3.6.1.1 Method 1 – Enteric Other Livestock

(1) Total annual methane production from enteric fermentation in other livestock $E_{enteric}$ (t CH_4) is calculated as:

$$E_{enteric} = \sum_j \left(N_j \times M_j\right) \times 10^{-3}$$

Where N_j = number of livestock of each livestock type j (head)

M_j = enteric fermentation emission factor (kg CH_4/head/year)

3.6.1.2 Method 2 – Enteric Other Livestock

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

3.6.2 Data/Parameters

3.6.2.1 Input Data (Required)

Data / Parameter	N_j
Data unit	head
Description	Average annual numbers of each other livestock type j.
Data source	Farm stock records noting that the enteric fermentation factor applies assumes animals are on farm all year. If there are changes in livestock numbers throughout the year an average number of each other livestock class should be calculated based on animal movements to calculated the average numbers of livestock on farm for the reporting year.
Quality assurance / quality control considerations	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.

3.6.2.2 Data (Method 1 and 2 Options)

There are no Method 2 data for this quantification approach.

3.6.2.3 Constant

Data / Parameter	M_j
Data unit	kg CH_4/head/year
Description	Enteric fermentation emission factor for each other livestock type j.
Data source	See Appendix Table A.1.5.1
Value	Select appropriate value based on livestock type.
Quality assurance / quality control considerations	Ensure the most recently available published data are used in alignment with the Australian National Inventory Report.

3.7 References

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