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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

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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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 group

Emissions are estimated based on groups of cattle with similar intake requirements and lengths of stay on the feed pad. The emissions are summed across each group 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 can 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.

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:

$$E_{enteric} = \sum_{j} \left(D_j \times Me_j \times N_j\right) \times 10^{-3}$$

Where

D_j = duration of stay of each cattle group (days)

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

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

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

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

Where

I_j = dry matter intake of cattle group (j) (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.

Question Reference 3.1:

It is expected that dry matter intake data would be readily available for feedlot cattle. Should farm-specific data be required for intake under Method 1?

Is farm-specific data on the ether extract (EE) and neutral detergent fibre (NDF) content of the ration also readily available? If so should farm-specific data for these parameters also be required under Method 1?

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 group (j).
Data source	Farm stock records
Quality assurance / quality control considerations	All animals purchased or sold in the reporting period must be included. Number of cattle reported can be cross checked with stocking density allowances for system size. If value is significantly higher or lower than expected stocking density, this value can be flagged as possibly erroneous. Check the class of animals on farm align with reported products from farm.

Data / Parameter	D_j
Data unit	days
Description	Duration of stay for each cattle group (j)
Data source	Farm stock records; system type records or purchase and sales can be evaluated to determine average length of stay
Quality assurance / quality control considerations	Check if length of stay aligns with duration of stay expected for the default feedlot cattle classes in Table 12.1.2.1 in Chapter 12 Appendix

Data / Parameter	Ij
Data unit	kg DM/head/day
Description	Average dry matter intake per head per day of each group of cattle.
Data source	Farm records of dry matter content of total mixed ration (TMR), and daily feed and feed waste weights for each group 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 group
Quality assurance / quality control considerations	This input can be compared this input to inventory defaults for the relevant cattle class. If significantly higher or lower than inventory defaults check farm records to ensure correct data entry.

3.1.2.2 Data (Method 1 and 2 Options)

Question Reference 3.2:

Are there specific tools or industry guidance that could be referenced to support feedlot producers to calculate NDF and EE and apply Method 2?

Data / Parameter	NDF_j
Data unit	per cent
Description	Average neutral detergent fibre as a percentage of feed intake for each feedlot cattle group. National default data based on length of stay is available if neutral detergent fibre of TMR for a group is not known.
Method 1 data source	Table A5.5.3.2 National Inventory Report Volume 2 [2]
Method 1 value	See Table 12.1.2.3 in Chapter 12 Appendix. Select the default value appropriate to the length of stay for the group of cattle
Method 2 data source	Farm records of neutral detergent fibre of TMR for each cattle group. 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. [*See **Question Reference 3.1** regarding input to support for this calculation*]
Quality assurance / quality control considerations	If Method 2 data is used compare this input to inventory defaults for the relevant cattle class. If significantly higher or lower than inventory defaults check farm records to ensure correct data entry.

Data / Parameter	EE_j
Data unit	per cent
Description	Ether extract as a percentage of intake (Ij) feedlot cattle classes (duration of stay)
Method 1 data source	Table A5.5.3.2, National Inventory Report, Volume 2 [2]
Method 1 value	See Table 12.1.2.3 in Chapter 12 Appendix. Select the default value appropriate to the length of stay for the group of cattle
Method 2 data source	Farm records of ether extract of TMR for each cattle group 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. [*See **Question Reference 3.1** regarding input to support for this calculation*]
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian NIR.

3.2 Beef - Pasture, Rangeland, 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 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 (I) 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 1.4.6).

Beef Cattle Classes (k)	Beef Cattle Subclass (l) [(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

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:

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

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

Me_{jkl} = daily production of enteric methane (kg CH_4/head/day)

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

(2) Daily production of enteric methane Me_{jkl} based on Charmley et al. (2015) [3] is calculated as:

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

Where

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

(3) Feed intake I_{jkl}, based on Minson and McDonald (1987) [4], is calculated as:

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

Where

W_{jkl} = liveweight (kg)

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

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

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

Question Reference 3.3

The current Guidance assumes beef cows do not calve until at least 2 years of age.

Should the Guidance allow for the possibility of calving in 1-2 year old replacement heifers?

(4) Additional intake for milk production is calculated in the season of calving and the season after calving as:

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

Where

$LC_{jk=5}$ = proportion of cows > 2 years (k=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 $LC_{jk=5} = 0$

$FA_{jk=5}$ = feed adjustment value for cows > 2 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 ($LC_{jk=5}$) 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 equations 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).

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	All animals purchased, sold or born in the reporting period are assumed to be reported. Number of cattle reported can be cross checked with stocking density allowances for farm size. If value is significantly higher or lower than expected stocking density, flag as possibly erroneous.

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 can be based on scanning numbers where available. If scanning results are not available weaning numbers can 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 can be cross checked with scanning and/or weaning records If scanning or weaning results are not recorded proportion of cows > 2 years can be cross checked from number of cows and calves in the reporting period.

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
Method 1 value	91.25 as the default time period which is seasonal
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	Purchase and sale records (invoices) can be used for data assurance and control of entered values. Recorded stock counts can also be used for quality assurance of entered values.

Question Reference 3.4

Method 1 applies default state or regional-level liveweights and liveweight gain values for grazing beef cattle sourced from the National Inventory Report (NIR).

Are there industry datasets available which could provide a more accurate representation of these parameters by region or breed that could be considered as alternative defaults?

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	Table A5.5.2.1 National Inventory Report Volume 2 [2]
Method 1 value	See Table 12.1.1.1 & 12.1.1.2 in Chapter 12 Appendix 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	Purchase and sale weight records (invoices) can be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records can 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 autumn calving ensure default weights reflect this with lowest weigh 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.

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	Table A5.5.2.2 National Inventory Report Volume 2 [2]
Method 1 value	See Table 12.1.1.3 & 12.1.1.4 in Chapter 12 Appendix 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	Compare to NIR default values with entered values to flag potential data entry errors. Purchase and sale weight records (invoices) can be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records can 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.

3.2.2.3 Constants

Data / Parameter	$FA_{ijkl=5}$
Data unit	fraction
Description	Feed adjustment value for cows > 2 years lactating
Data source	Table A5.5.2.5 National Inventory Report Volume 2 [2]
Value	See Table 12.1.1.7 in Chapter 12 Appendix 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 NIR.

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, <1year 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 can be taken from the appropriate beef pasture, range and paddock defaults (see Section 3.2 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:

$$E_{enteric} = \sum_j \Big(\big(N_{j=1,2,4,6} \times M_{j=1,2,4} \times D_{j=1,2,4}\big) + \big(N_{j=3,5} \times M_{j=3,5} \times D_{j=3,5}\big) + \big(N_{j=3,5} \times MPW_{ENTERIC,j=3,5} \times D_{j=3,5}\big) \Big)$$

Where

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

Me_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) Daily production of enteric methane M_j (kgCH_4/head/day) based on Charmley et al. (2015) [3] is calculated as:

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

Where

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

(3) Feed intake I_j (kg DM/head/day) based on Minson and McDonald (1987) [4] 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) 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) If milk production data is collected in quantities of milk solids rather than litres of milk, then milk solids can be converted to litres as [5]:

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

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) Metabolisability of the diet qm_j based on Minson and McDonald (1987) [4] 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.

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	All animals purchased or sold in the reporting period are assumed to be reported. 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 can be cross checked with stocking density allowances for system size. If value is significantly higher or lower than expected stocking density, flagged as possibly erroneous. Check the class of animals on farm align with 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	Average farm milk sales records and average number of milking cows overt the reporting period can be used to calculate the daily milk production. The average amount of milk sold per day (in litres) can 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 the data table for MS_j below.
Quality assurance / quality control considerations	Ensure farm source data isn't significantly different when compared to NIR state-based values indicating potential data entry error. State-based values can be found in Table 12.1.3.9 in Chapter 12 Appendix. Ensure alignment with the latest version of the Australian NIR. If milk production can be verified 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 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) can 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 should be computed into MP_j (using values for FC_j and PC_j) and compared to NIR state-based values indicating potential data entry error. State-based values can be found in Table 12.1.3.9 in Chapter 12 Appendix. Ensure alignment with the latest version of the Australian NIR. If milk production can be verified through milking parlour software and corroborated via milk collection receipts. Users providing values of MS_j must also provide values for FC_j and PC_j.

3.3.2.2 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 can 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.

Question Reference 3.5.

Method 1 currently provides default liveweights for milking cows and heifers sourced from the Australian Dairy Carbon Calculator tool. Liveweight gain and standard reference weights for all dairy classes, as well as liveweights for bulls, are based on the default from the national inventory.

Are there any other industry datasets available that provide breed-specific liveweight, standard reference weight and liveweight gain for dairy cattle which could be used for Method 1 defaults ?

Data / Parameter	W_j
Data unit	kg
Description	Liveweight of each class of stock
Method 1 data source	Table A5.5.1.1 National Inventory Report, Volume 2 [2] and the Australia Dairy Carbon Calculator 2025 [5]
Method 1 value	See Table 12.1.3.1 and Table 12.1.3.2 in Chapter 12 Appendix. 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	Ensure farm source data isn’t significantly different when compared to NIR default values indicating potential data entry error. Checking purchase and sale weight records against entered values can be used for data assurance and control.

Data / Parameter	LWG_j
Data unit	kg/head/day
Description	Liveweight gain of each class of stock
Method 1 data source	Table 5.5.1.2 National Inventory Report, Volume 2 [2]
Method 1 value	See Table 12.1.3.3 in Chapter 12 Appendix. 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	Ensure farm source data isn’t significantly different when compared to NIR default values indicating potential data entry error. Additional checks of farm source data are within expected ranges. Typical liveweight gain for various heifers are [5]: • 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 can be used for data assurance and control.

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 [2].
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 can be used. The ADCC, 2025 [5] 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 NIR 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. The ADCC, 2025 [5] provides ranges of DMD for different forage of non-forage supplements.

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 [5]
Method 1 value	4.0
Method 2 data source	Farm-specific values for FC_j can be used, where farmers have records specific to the milk production of the reporting period.
Quality assurance / quality control considerations	Farm-specific values of FC_j should be computed into MP_j (using values for MS_j and PC_j) and compared to NIR state-based values indicating potential data entry error. State-based values can be found in Table 12.1.3.9 in Chapter 12 Appendix. Ensure alignment with the latest version of the Australian NIR.

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 [5]
Method 1 value	3.3
Method 2 data source	Farm-specific values for PC_j can be used, where farmers have records specific to the milk production of the reporting period.
Quality assurance / quality control considerations	Farm-specific values of PC_j should be computed into MP_j (using values for MS_j and FC_j) and compared to NIR state-based values indicating potential data entry error. State-based values can be found in Table 12.1.3.9 in Chapter 12 Appendix. Ensure alignment with the latest version of the Australian NIR.

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	Table A5.5.1.5, National Inventory Report, Volume 2 [2]
Value	See Table 12.1.3.8 in Chapter 12 Appendix. Select the appropriate default value for cattle class
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian NIR.

Data / Parameter	MR_j
Data unit	fraction
Description	Increase in metabolic rate when producing milk
Data source	National Inventory Report, Volume 1 [6]
Value	See Table 12.1.3.9 in Chapter 12 Appendix Select appropriate value based on animal class
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian NIR

Data / Parameter	NE
Data unit	MJ net energy/kg milk
Description	Net energy required for milk production
Data source	National Inventory Report, Volume 1 [6]
Value	3.054
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian NIR

Data / Parameter	GEC
Data unit	MJ/kgDM
Description	Gross energy content of feed dry matter
Data source	National Inventory Report, Volume 1 [6]
Value	18.4
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian NIR

Data / Parameter	k
Data unit	fraction
Description	Efficiency of use of metabolizable energy for milk production
Data source	National Inventory Report, Volume 1 [6]
Value	0.60
Quality assurance / quality control considerations	Ensure alignment with the latest version of the Australian NIR

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 Section 1.4.6).

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)

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:

$$E_{enteric} = \sum_{j} \sum_{k} (N_{jk} \times Me_{ijk} \times D_j) \times 10^{-3}$$

Where

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

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

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

Where

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

(3) 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) Potential intake PI_{jk} (kg DM/head/day) based on AFRC (1990) [8] is calculated:

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

Where

W_{jk} = liveweight (kg). Default values applied under Method 1

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

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

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

Where

DMD_{jk} = dry matter digestibility of feed (per cent). Default values applied under Method 1

(6) Relative feed intake RI_{ijk} expressed as a fraction based on White et al. (1983) [9] is calculated as:

$$RI_{jk} = 1 - \mathrm{e}^{-2\left(DMA_{jk}\right)^2}$$

Where

DMA_{jk} = dry matter availability (t/ha). Default values applied under Method 1

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

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

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.

Question Reference 3.6.
The current equation for estimating the proportion of ewes and maidens lactating is based on SB-GAF calculations which restricts the lamb marking rate to <100% to prevent a situation where more than 100% of the breeding flock is assumed to be lactating.

Are there suggestions on how this calculation could be improved? Would farmers have access to data that would allow them to directly enter the proportion of breeding flock that is lactating? Should a wet-dry rate be added as Method 2?

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

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

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}, DMD_{jk}, DMA_{jk} is required for the selected time-period (i.e. seasonal, monthly or other).

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.

Question Reference 3.7.

Dry matter digestibility (DMD) is known to be difficult to measure, and the calculation of sheep intake is relatively insensitive to this parameter.

Should the requirement for farm-specific dry matter digestibility (DMD) in Method 2 be changed from a ‘shall’ to a ‘may’, allowing more flexibility in achieving Method 2?

3.4.2 Data/Parameters

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	All animals purchased or sold in the reporting period must be reported. Number of sheep reported can be cross checked with stocking density allowances for system size. If value is significantly higher or lower than expected stocking density, flagged as possibly erroneous. Check the class of animals on farm marry up with expected enterprise on farm. For example, self-replacing systems vs purchased breeder or trading systems.

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 can also be used to approximate the number of ewes and maidens lactating at this time.
Quality assurance / quality control considerations	Lambing rate can 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 can be cross checked from number ewes, maidens and lambs reported in herd flow model.

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 NIR 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 can be used to cross check numbers entered. Lambing percentage can also be considered against the number of ewes, lambs and maidens reported in herd flow model to sense check reported lamb marking rate.

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
Method 1 value	91.25 as the default time period is seasonal
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)

Quality assurance / quality control considerations	Purchase and sale records (invoices) can be used for data assurance and control of entered values. Recorded stock counts can also be used for quality assurance of entered values.

Question Reference 3.8.

Method 1 currently applies default state-level liveweight values for sheep sourced from the NIR.

Are there industry datasets available that could provide a more accurate representation of liveweights by regions, breed or production system, that could be considered as alternative defaults?

Data / Parameter	W_{jk}
Data unit	kg
Description	Average liveweight of livestock per sheep class
Method 1 data source	National Inventory Report Volume 2, Table A5.5.4.1 [2]
Method 1 value	See Table 12.1.4.1 in Chapter 12 Appendix
Method 2 data source	Farm stock records and herd flow model (see Chapter 1 Section 1.9)
Quality assurance / quality control considerations	Compare to NIR default values with entered values to flag potential data entry errors. Purchase and sale weight records (invoices) can be used for data assurance and control of entered values. Dated print out, screen shot, or photo of scale unit records can also be used for quality assurance of entered values.

Data / Parameter	DMD_{jk}
Data unit	Per cent
Description	Dry matter digestibility of feed
Method 1 data source	National Inventory Report Volume 2, Table A5.5.4.2 [2]
Method 1 value	See Table 12.1.4.2 in Chapter 12 Appendix
Method 2 data source	Farm records - user input values for each season and class of stock. Noting that if farm specific DMD can be used for some classes or seasons if known and inventory defaults for other unknown classes of stock.
Quality assurance / quality control considerations	Compare to NIR default values with Method 2 values to flag potential data entry errors

Question Reference 3.9.

Method 1 currently applies default state-level dry matter availability for feed (DMA) values for sheep sourced from the NIR. Are there industry datasets available that could provide a more accurate representation that could be considered as alternative defaults?

It is recommended that farm specific DMA be used if possible. Are the methods or tools available, such as the MLA Feed Demand Calculator, that could be referenced to support famers to estimate DMA?

Data / Parameter	DMA_{jk}
Data unit	t/ha
Description	Dry matter availability of feed
Method 1 data source	National Inventory Report Volume 2, Table A5.5.4.3 [2] 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 1 value	See Table 12.1.4.3 in Chapter 12 Appendix
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 can be applied to the sheep classes and time periods when this feeding is taking place and DMA is known.
Quality assurance / quality control considerations	Compare to NIR default values with Method 2 values to flag potential data entry errors

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 [6]
Value	1.3
Quality assurance / quality control considerations	Ensure the most recently available published data is used in alignment with the Australian NIR.

3.5 References

[1] A. K. Almeida, J. P. McMeniman, M. R. V. der Saag, and F. C. Cowley, "Evaluation of methane prediction equations for Australian feedlot cattle fed barley and wheat-based diets," *Anim. Prod. Sci.*, vol. 65, no. 5, Mar. 2025, doi: 10.1071/AN24212.

[2] Department of Climate Change, Energy, the Environment and Water, "National Inventory Report 2023, Volume II." Australian Government, 2023. [Online]. Available: https://www.dcceew.gov.au/sites/default/files/documents/national-inventory-report-2023-volume-2.pdf

[3] E. Charmley *et al.*, "A universal equation to predict methane production of forage-fed cattle in Australia," *Animal Production Science*, vol. 53, no. 3, pp. 169–180, Dec. 2015.

[4] D. J. Minson and C. K. McDonald, "Estimating Forage Intake from the Growth of Beef Cattle," *Tropical Grasslands*, vol. 21, no. 3, Sept. 1987, [Online]. Available: chrome-extension://dbchgeokljmcmdjbpfiaagmjdkohknec/content-script/index.html?file=https%253A%252F%252Fwww.tropicalgrasslands.info%252Fpublic%252Fjournals%252F4%252FHistoric%252FTropical%252520Grasslands%252520Journal%252520archive%252FPDFs%252FVol_21_1987%252FVol_21_03_87_pp116_122.pdf

[5] KM Christie-Whitehead and Dairy Australia, "Australian Dairy Carbon Calculator," Tasmanian Institute of Agriculture; Dairy Australia, Launceston, Tasmania; Melbourne, Victoria, Feb. 2025. [Online]. Available: https://www.dairyaustralia.com.au/en/climate-and-environment/greenhouse-gas-emissions/australian-dairy-carbon-calculator

[6] Department of Climate Change, Energy, the Environment and Water, "National Inventory Report 2023, Volume I." Australian Government, 2023. [Online]. Available: https://www.dcceew.gov.au/sites/default/files/documents/national-inventory-report-2023-volume-1.pdf

[7] S. M. Howden, D. H. White, and P. J. Bowman, "Managing sheep grazing systems in southern Australia to minimise greenhouse gas emissions: adaptation of an existing simulation model," *Ecological Modelling*, vol. 86, no. 2, pp. 201–206, May 1996, doi: 10.1016/0304-3800(95)00052-6.

[8] AFRC, "Technical Committee on Responses to Nutrients, Report Number 5, Nutritive Requirements of Ruminant Animals: Energy," *Nutrition abstracts & reviews, series B*, vol. 62, no. 12, pp. 729–804, 1992.

[9] D. H. White, P. J. Bowman, F. H. W. Morley, W. R. McManus, and S. J. Filan, "A simulation model of a breeding ewe flock," *Agricultural Systems*, vol. 10, pp. 149–189, 1983, doi: 10:1016/0308-521X(83)90067-7.