Attachment B

Carbon Credits (Carbon Farming Initiative - Beef Cattle Herd Management) Methodology Determination 2014

OVERVIEW OF CALCULATIONS

1. Background

a) Section 12 of the draft *Carbon Credits (Carbon Farming Initiative-Beef Cattle Herd Management) Methodology Determination 2014 (the draft Determination)* requires that proponents calculate the net abatement amount for each year in the reporting period using the Herd Management Calculator. The Herd Management Calculator includes all the calculations required to determine the net abatement amount in accordance with the draft Determination and its use is mandatory.

This document explains the equations implemented in the Herd Management Calculator.

2. Emissions Abatement Calculation under the draft Determination

a) Emissions Intensity Reference Period

The draft Determination provides rules for calculating abatement as the difference between the project and the baseline emissions. The calculation of baseline emissions is founded on the baseline year as the herd in the project reporting year with the same numbers and composition being managed under the same environmental conditions as the project reporting year herd but with an intensity of emissions (total herd emissions per kilogram (kg) liveweight sold) which reflects business as usual management. Emissions intensity is calculated in an emissions intensity reference period for five years preceding registration of the offsets project or five out of seven preceding years where adequate data to comply with the requirements of the Herd Management Calculator (based on the equations below), is not available. This approach is used to avoid crediting for inter-year climatic variation which would affect emissions in the intensity reference period.

The intensity of emissions per kg live weight in the reference period is generated by dividing total intensity reference period emissions by the live weight of all animals of all classes sold for slaughter or export in the reference period.

The total emissions of the emissions intensity reference period year are the sum of:

i. The emission of each class of cattle in the herd for the number of days in that year prior to leaving the herd by death, sale to slaughter/export or sale within Australia for reasons other than slaughter. For animals retained in the herd the annual emission are calculated for 365 days.

ii. The emissions of all animals leaving the herd for a purpose other than death, sale or slaughter from the time of leaving the herd to the end of emission intensity reference period. The emissions calculation for these animals assumes that all animals are adult equivalents from the point of sale until the end of the intensity reference period and have the implied emissions coefficient of table 6.9 of the National Inventory Report (NIR) (currently 72 kg methane per annum, equivalent to 1.8 tonnes CO_2-e).

The average emissions intensity of the five year emissions intensity reference period is multiplied by the liveweight of animals sold for slaughter or export in the project reporting year to estimate baseline emissions. The calculation estimates what emissions would have occurred to produce the project level of live weight sales in the absence of any management change.

b) Crediting Period Emissions

The total project reporting year emissions for each year in the crediting period are calculated using methods consistent with the NIR. They include, as in the emissions intensity reference period, the emissions up to the point of sale for all purposes, plus the emissions of animals sold for purposes other than export or slaughter after the point of sale and up to the end of the crediting period at the adult equivalent implied emissions rate noted above.

The project reporting year emissions are subtracted from the baseline emissions for that year to derive total abatement.

3. Factors to set the emissions intensity reference period emissions in deriving the baseline

Table 1 Emissions intensity reference period categories for pasture fed beef cattle

State$_{(i)}$	**Region $_{(j)}$**	**Season$_{(k)}$**	**Animal class $_{(l)}$**	**Feed (m)**
1 NSW/ACT	j=1 NSW/ACT	1 Spring	1 Bulls > 1 year	1= native grass pasture
2 Tasmania	j=2 Tasmania	2 Summer	2 Bulls < 1 year	
3 Western Australia	j=3a South West	3 Autumn	3 Steers < 1 year	
	j=3b. Pilbara	4 Winter	4 Cows 1 - 2 year	
	j=3c. Kimberley		5 Cows > 2 year	
			6 Cows < 1 year	
4 South Australia	j=4 SA		7 Steers > 1 year	
5 Victoria	j=5 Vic			
6 Queensland	j=6 Qld			
7 Northern Territory	j=7 NT			

a) Geographical Location (State (i) Region (j))

A number of parameters within the calculations are influenced by or can be linked to the geographical location of the livestock. The herd location is verified by the Region (State or part of a

State) in which the herd is located. The parameters relevant to the calculation of enteric CH_4 emissions which are influenced by geographic location are liveweight (LW), liveweight gain (LWG) and dry matter digestibility (DMD) of feed. Crude protein (CP) and DMD content of feed intake are considered in the calculations of CH_4 and N_2O emissions from dung and urine. Stratification by State (i) is required for the draft Determination and is consistent with the NIR.

b) Season (k)

Feed content, LW, LWG and the timing of the addition of supplements are subject to change from season to season.

c) Animal Class (l)

The animal class is required to calculate both the baseline and the project activity to ensure that all emissions can be stratified according to livestock classification. During the project period animals in each class of livestock (breeding females, bulls and progeny) will change in numbers and average live-weight. Accounting for numbers of each class will be calculated through head counts, NLIS waybills, NVD or similar statutory or tax related requirements. The herd book kept to conform to AAS 141 Tier 2 must also account for all of these changes across the animal classes.

d) Feed (m)

In the emissions intensity reference period, all cattle are assumed to have fed on the local native pasture with DMD and CP values as given in the most recent NIR.

4. Emissions sources in the emissions intensity reference period

a) Methane Emissions

Methane emissions for the intensity reference period are calculated using the NIR method as follows:

i. Feed intake, LW and LWG_{ijkl}, drive the emissions per animal (t CO_2e / head) for each class of animals in State 'i', Region 'j', Season 'k' and Class 'l'' within the herd;
ii. The emissions per animal are then multiplied by the average number of animals in the class for the feeding period on each feed supplement to derive total emissions from that class within the herd; and
iii. The total emissions from each class are then summed across all classes to derive total pre project emissions for the entire herd of sale animals for the emissions intensity reference period.

Methane emissions from dung are not calculated. The NIR considers that methane production is likely to be negligible in the manure of range kept livestock due to high temperature, high solar radiation and low humidity environments in Australia which would lead to rapid manure drying. Rapid infestation of scarab (or dung) beetles also reduces potential for anaerobic conditions in rangeland systems suited to methane production.

b) Nitrous oxides from dung and urine

To estimate emissions from dung and urine, the protein concentration of feed intake, milk and NPN (converted to protein equivalent) is multiplied by feed intake and used, with estimates of nitrogen retention and live-weight gain, to estimate net nitrogen excretion. This information is divided by the

actual numbers of animals by class and live-weight using default factors (baseline) or actual data on the herd (project) to estimate nitrogen excretion per head per day as dung and urine.

The excreted nitrogen is regarded as input to soil emissions in accord with NIR methods. Nitrogen excretion as dung and urine are multiplied by the NIR default emissions factors and summed across the total feeding period (days). The calculation is consistent with NIR methods.

Consultation note: The calculation of global warming potential (GWP) for methane (from 21 to 25 CO_2-e) and nitrous oxide (from 310 to 298 CO_2-e) are being updated for the 2015 National Inventory. The values for GWP parameters are indicative and may change prior to finalising the Determination, but the values will be consistent with the National Inventory as updated from time to time.

Also note for grazing cattle the leaching emissions fraction for dung and urine (FracLEACH) is being updated from 0.3% to 0.4%.

5. Stepwise calculation of baseline emissions

Unless otherwise stated the figures in the following equations are from the NIR.

a) Enteric methane

The algorithms used to estimate the baseline feed consumption enteric methane emissions are based on the Australian Government National Greenhouse Gas Inventory (NGGI) method. The equivalent equation numbers from the NIR are listed for transparency.

The draft Determination calculates individual animal enteric emissions and then sums the emissions across the herd. The approach used to estimate individual animal CH_4 production in the intensity reference period (Mt_{ijkl}) reflects the effect of feed quality and quantity on feed consumption and CH_4 emissions. Equations 1 to 3 of the draft determination are used to calculate Mt_{ijkl} (the total daily production of methane per animal).

i. Total dry matter intake in the emissions intensity reference period year t ($DMIt_{PPijkl}$) is calculated relative to live-weight and live-weight gain using the equation of Minson and McDonald (1987):

$DMIt_{PPijkl} = (1.185 + 0.00454Wt_{PPijkl} - 0.0000026Wt_{PPijkl}^2 + 0.315LWGt_{PPijkl})^2 \times MA_{PPijkl=5}$	Equation 1/Derived from 4A.1b_1

Where:

$DMIt_{PPijkl}$ = Total dry matter intake (kg DM $head^{-1}$ day^{-1}) of animals in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t (kg).

Wt_{PPijkl} = Live-weight in kilograms of animals in State (i) region (j), in season (k) for animal class (l) from farm records or appropriate NIR Table 6.B.1., in intensity reference year t.

$LWGt_{PPijkl}$ = Daily live-weight gain of the beef animal (kg $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t. Use NIR table 6.B.2 for the relevant year or farm records.

$MAt_{PPijkl=5}$ = The additional intake for milk production of lactating cows in the intensity reference period year t.

Feed intakes can increase by up to 60% during lactation (ARC 1980). For this study, the intake of all breeding cattle was increased by 30% during the season in which calving occurs and by 10% in the following season based on relationships presented in SCA (1990).

ii. The additional intake for milk production (MA_{ijkl}=5) is calculated as:

$MAt_{PPijkl=5} = (LC_{ijkl=5} \times FA_{ijkl=5}) + ((1-LC_{ijkl=5}) \times 1)$	Equation 2/Derived from (4A.1b_2)

Where:

$MAt_{PPijkl=5}$ = The additional intake for milk production of lactating cows in the intensity reference period year t.

$LC_{ijkl=5}$ = Proportion of Cows >2 lactating. Calculated as number of unweaned calves divided by the number of breeding age cows in feed supplementation period.

$FA_{ijkl=5}$ = Feed adjustment. Further details on feed adjustments can be found in table 6.B.5 from the NIR for the relevant year from table 6.B.5.

iii. The total daily production of methane (Mt_{ijkl}, kg CH4/head/day) is give by Charmley et al. (2014) as:

$Mt_{ijkl} = 21.5 \times DMIt_{PPijkl} /1000$	Equation 3/ derived from 4A.1b_3

Where:

Mt_{ijkl} = The total daily production of methane per animal (kg CH_4/head/day) located in State (i) region (j) during season (k) of each animal class (l) intensity reference year t.

$DMIt_{PPijkl}$ = Total dry matter intake (kg DM $head^{-1}$ day^{-1}) for the herd in State (i) region (j) during season (k) of each animal class (l) for intensity reference year t. A constant of 21.5 is used per Charmley et al 2014.

Consultation note: Equation 3and the parameters for the calculation of the total daily production of methane per animal are being updated for the 2015 National Inventory. The values for parameters in Equation (3) are indicative and may change prior to finalising the Determination, but the values will be consistent with the National Inventory as updated from time to time.

iv. Annual total enteric emissions of CH_4 (t CH_4) for the beef cattle herd in the intensity reference period year (EEB) for are calculated as in Equation 4. Equation 4 ensures that emissions are calculated on a seasonal basis (as the feeding period FSt_{ijkl}).

$EEt_{PP} = (\Sigma_i\Sigma_j\Sigma_k\Sigma_l [FSt_{PPijkl} \times Nt_{ijkl} \times Mt_{ijkl}] \times 10^{-3})$	Equation 4/ derived from 4A.1b_8

Where:

EEt_{PP} = Annual enteric emissions of CH_4 of the beef cattle herd in the intensity reference period (t CH_4).

FSt_{PPijkl} = The feeding period (days) for the herd in the project located in State (i) region (j) during season (k) of each animal class (l) in each intensity reference year t.

Nt_{ijkl} = Head of sale beef cattle located in State (i) region (j) during season (k) of each animal class (l) (head)in each year of the intensity reference year t.

Mt_{ijkl} = The total daily production of methane per animal (M_{ijkl} kg CH_4/head/day) located in State (i) region (j) during season (k) of each animal class (l) intensity reference year t, as calculated in Equation 3.

v. The emissions intensity reference period herd enteric emissions from feed consumption are estimated as follows:

$ECt_{PP} = (EEt_{PP} \times GWP\ CH_4)$	Equation 5/Project based equation

Where:

ECt_{PP} = Annual emissions from feed consumption under the emissions intensity reference year t (t CO_2-e).

EEt_{PP} = Annual CH_4 production for beef cattle managed at pasture in the emissions intensity reference period t (t CH_4).

GWP CH_4 = (t CO2-e.t CH_4^{-1}) global warming potential of CH_4 (current CH_4 = 25) from NGERS Regulations for the intensity reference period years.

a) Nitrous oxide emissions from dung and urine

N_2O emissions from the dung and urine of beef cattle managed at pasture are a function of dry matter digestibility, crude protein and total feed intake.

The algorithms incorporated in the draft Determination (and the Calculator) to calculate N_2O emissions from dung and urine are based on the National Greenhouse Gas Inventory (NGGI) method. The equivalent equation values from the NIR reports are listed for transparency.

The NIR considers that methane production is likely to be negligible in the manure of range kept livestock due to high temperature, high solar radiation and low humidity environments in Australia which would lead to rapid manure drying. Rapid infestation of scarab (or dung) beetles also reduces potential for anaerobic conditions in rangeland systems suited to methane production.

Nitrogen excretion from beef cattle in the intensity reference year is estimated using algorithms to calculate crude protein intake (CPI_{PPijkl}) and amount of nitrogen retention (NRt_{PPijkl}). Using these inputs, nitrogen deposited in the faeces and urine is calculated.

vi. Crude Protein Intake

Total crude protein intake is calculated as the sum of protein intake.

$CPIt_{PPijkl} = (DMIt_{PPijkl} \times CP_{PPijkl}) + (MAt_{PPijkl} \times 0.032)$	Equation 6/Derived from 4B.1b_3

Where:

$CPIt_{PPijkl}$ = Crude protein equivalent intake (from protein in feed (m) Table 1) of the beef cattle in the intensity reference year (kg $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in each year of the intensity reference year t.

$DMIt_{PPijkl}$ = Dry matter intake of cattle in the emissions intensity reference period (kg $head^{-1}$per day) located in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed m (Table 1) in each year of the intensity reference year t, as calculated in Equation 1.

CP_{PPijkl} = Crude protein content of the feed intake expressed as a fraction of cattle located in State (i) region (j) during season (k) for feed m in each year of the intensity reference year using table 6.B.4 from the NIR for the relevant year or default tables for pure or mixed feeds.

MAt_{PPijkl} = The additional intake for milk production of lactating cows in the intensity reference year t.

$CPm_{PPijkl=5}$ = 0.032 the factor for crude protein content of milk produced by lactating animals greater than two years.

vii. Nitrogen retention

The intake of the animals relative to that needed for maintenance (L_{PPijkl}) is calculated as actual intake divided by maintenance intake (i.e. intake of non-lactating animal with live-weight gain is set to zero):

$Lt_{PPijkl} = DMI_{PPijkl} / (1.185 + 0.00454W_{ijkl} - 0.0000026W_{ijkl}^2 + (0.315 \times LWG_{ijkl}))^2$	Equation 7/Derived from 4A.1b_4

Where:

Lt_{PPijkl} = feed intake (kg DMI day^{-1} kg^{-1} LW) of the animals relative to that needed for maintenance (dimensionless) on the proponent's farm which is located in State (i), region (j) during season (k) of each animal class (l) in each intensity reference year in the calculated as actual intake divided by maintenance intake (i.e. intake of non-lactating animal with a zero live weight gain).

DMI_{PPijkl} = total dry matter intake in the pre-project period (kg DM $head^{-1}$ day^{-1}) on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) in each intensity reference year as calculated in Equation 1.

W_{ijkl} = live weight of beef animal in kilograms on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) – if not known use NIR table 6.B.1 for the relevant year.
LWG_{ijkl} = live-weight gain (kg head^{-1} day^{-1}) for each animal class on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) in each year in the intensity reference period- if not known use appropriate NIR table 6.B.2.

The amount of nitrogen retained by the animal (NR_{PPijkl} kg N head^{-1} day^{-1}) is calculated as the amount of nitrogen retained in milk and body tissue. In growing cattle and bulls milk production is zero and is omitted:

$NRt_{PPijkl} = \{\{0.212 - 0.008(Lt_{PPijkl} -2) - [(0.140-0.008(Lt_{PPijkl} - 2)) / (1+\exp(-6(Z_{ijkl} - 0.4)))]\} \times (LWG_{ijkl} \times 0.92)\}/6.25$	Equation 8/Derived from 4B.1b_5

Where:

NRt_{PPijkl} = Amount of nitrogen retained by the body in the intensity reference year t (kg N head^{-1} day^{-1}) of cattle located in State (i) region (j) during season (k) of each animal class (l) in intensity reference year t.

Lt_{PPijkl} = Feed intake (kg DMI day^{-1} kg^{-1} LW) of cattle relative to that needed for maintenance in the intensity reference year (kg head^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in intensity reference period year t as defined in equation 7 above.

Z_{ijkl} = Relative size (live-weight / standard reference weight) of cattle located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference period – use tables 6.B.1 and 6.B.6 from the NIR for the relevant year.

$LWGt_{PPijkl}$ = Live-weight gain (kg day^{-1}) which is located in State (i) region (j) during season (k) of each animal class (l) for each pre project reference year t - use appropriate NIR table 6.B.2.

viii. Nitrogen excreted in the faeces

In accordance with the NIR, nitrogen excreted in the faeces of beef cattle is calculated as the indigestible fraction of the un-degraded protein from paddock feed, NPN, microbial crude protein, milk protein plus the endogenous faecal protein:

$Ft_{PPijkl} = \{0.3(CPIt_{PPijkl} \times (1- [(DMD_{PPijkl} +10) / 100])) + 0.105(ME_{PPijkl} \times DMIt_{PPijkl} \times 0.008) + 0.08\{0.032x\ MAt_{PPijkl=5}\} + (0.0152 \times DMIt_{PPijkl})\} \times 1/6.25$	Equation 9/Derived from 4B.1b_4

Where:

Ft_{PPijkl} = Nitrogen excreted in the faeces (kg N head^{-1} day^{-1}) of the herd located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t.

$CPIt_{PPijkl}$ = Crude protein intake of the beef cattle in the intensity reference year (kg $head^{-1}$ day^{-1} located in State (i) region (j) during season (k) of each animal class (l) in year t as calculated in Equation 6.

DMD_{PPijkl} = Dry matter digestibility of feed intake, expressed as a percentage, in the intensity reference herd based on the diet fed to the beef herd located in State (i) region (j) during season (k) of each animal class (l) in intensity reference year t - use NIR table 6.B.3.

ME_{PPijlk} = Metabolisable energy of feed intake in the intensity reference year t (MJ kg DM^{-1}) by cattle located in State (i), region (j) during season (k) of each animal class (l) in each year - calculated as: 0.1604 DMD_{ijkl} – 1.037 (Minson and McDonald 1987), where DMD_{ijkl} is derived from table 6.B.3 from the NIR for the relevant year.

$DMIt_{PPijkl}$ = Dry matter intake in the intensity reference year t (kg $head^{-1}$per day) for cattle located in State (i) region (j) during season (k) of each animal class (l) in each year as calculated in Equation 1 and 2 of the draft Determination from default factors in Table 6.B.1 and 6.B.2 of the relevant NIR table.

$MAt_{PPijkl=5}$ = The additional intake for milk production of lactating cows in the intensity reference year t.

1/6.25 = Factor for converting crude protein into nitrogen.

ix. Nitrogen excreted in the urine

Nitrogen excreted in the urine (Ut_{PPijkl} kg N $head^{-1}$ day^{-1}) is calculated by subtracting NR_{PPijkl}, F_{PPijkl} and dermal protein loss from the nitrogen intake:

Ut_{PPijkl}= ($CPIt_{PPijkl}$ / 6.25) – NRt_{PPijkl} – Ft_{PPijkl} – [(1.1 x 10^{-4} x $Wt_{ijkl}^{0.75}$) X 1/ 6.25]	Equation 10/Derived from 4B.1b_6

Where:

Ut_{PPijkl} = Nitrogen excreted in the urine by cattle in the intensity reference year (kg N $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in year t.

$CPIt_{PPijkl}$ = Crude protein intake of the beef cattle in the intensity reference year (kg $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in year t as calculated in Equation 6.

NRt_{PPijkl} = Amount of nitrogen retained by the body of cattle in the intensity reference year (kg N $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in each year t as calculated in Equation 7.

Ft_{PPijkl} = Nitrogen excreted in the faeces of cattle in the intensity reference year (kg N $head^{-1}$ day^{-1}) located in State (i) region (j) during season (k) of each animal class (l) in year t as calculated in Equation 8.

Wt_{ijkl} = Live-weight in kilograms of cattle located in State (i) region (j) in season (k) for animal class (l) from farm records or appropriate NIR Table 6.B.1 in intensity reference year t. The power 0.75 is used to derive metabolic body weight (weight of metabolically active tissue to be maintained).

x. The total annual faecal (AFt_{PP}, t N) nitrogen is calculated as:

$AFt_{PPijkl} = (\Sigma_i\Sigma_j\Sigma_k\Sigma_l\ (FSt_{PPijkl} \times Nt_{PPijkl} \times Ft_{PPijkl}) \times 10^{-3})$	Equation 11/Derived from 4B. 1b_7a

Where:

AFt_{PPijkl} = Total annual faecal nitrogen excreted on the soil in the intensity reference year t for all feed types (in tonnes of N)

FSt_{PPijkl} = The feeding period (days) for all livestock classes in the herd located in State (i) region (j) during season (k) of each animal class (l) in each intensity reference year t.

Nt_{PPijkl} = Head of beef cattle located in State (i) region (j) during season (k) of each animal class (l) in each intensity reference year t (head).

Ft_{PPijkl} = Nitrogen excreted in the faeces in the emissions intensity reference period (kg $head^{-1}$ day^{-1}) by cattle is located in State (i) region (j) during season (k) of each animal class (l) in emissions intensity reference year t as calculated in Equation 9.

xi. The total annual urinary nitrogen (AUt_{PPijkl} t.N) is calculated as:

$AUt_{PPijkl} = (\Sigma_i\ \Sigma_j\ \Sigma_k\Sigma_l\ (FSt_{PPijkl} \times Nt_{PPijkl} \times U_{PPijkl}) \times 10^{-3})$	Equation 12/Derived from 4B.1b_7b

Where:

AUt_{PPijkl} = Annual urinary nitrogen in the intensity reference period (t) of cattle located in State (i) region (j) during season (k) (k) of each animal class (l) in each intensity reference year t (in tonnes of N).

FSt_{PPijkl} = The feed supplementation period (days) for the supplemented herd in the project located in State (i) region (j) during season (k) of each animal class in each intensity reference year t.

Nt_{PPijkl} = Head of beef cattle located in State (i) region (j) during season (k) of each animal class (l) in emissions reference year t (head).

U_{PPijkl} = Nitrogen excreted in the urine (kg N $head^{-1}$ day^{-1}) by cattle located in State (i) region (j) during season (k) of each animal class (l) in each intensity reference year t as calculated in Equation 9.

c) Nitrous Oxide Emissions from Agricultural Soils

Under the Australian National Greenhouse Accounts reporting system, nitrous oxide from faeces and urine is treated as a soil emission as a result of the metabolism of nitrogen from these sources after

entering the soil rather than a direct emission source as is the case for enteric methane. Loss occurs as:

- direct nitrous oxide evolution,

- re-deposition of volatilised ammonia and subsequent loss as nitrous oxide (indirect emissions), and.

- losses from leaching and runoff.

i. Annual direct nitrous oxide production is calculated as:

$EAt_{PP} = \sum_i \sum_j \sum_k (AFt_{PPijk} \times EF \times CF\ N_2O) + (AUt_{PPijk} \times EF \times CF\ N_2O)$	Equation 13/Derived from 4D2_3

Where:

EAt_{PP} = Annual direct soil emissions from N_2O in animal waste deposited on the paddock in the intensity reference year t (t N_2O).

AFt_{PPijk} = Faecal nitrogen excreted onto the soil in intensity reference year t as calculated in Equation 10 (in tonnes N).

EF = Emission factor (t N_2O-N (t N deposited)$^{-1}$), equivalent to 0.005 for faeces and 0.004 for urine as used in NIR 2012 (4D2_3).

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

AUt_{PPijk} = Urinary nitrogen excreted onto the soil in the intensity reference year t (t N), as calculated in Equation 12.

ii. The mass of animal waste volatilised is calculated as follows:

$MAWt_{PPijkl} = (AEt_{PPijkl} \times FracGASM)$	Equation 14/Derived from 4D3_2

Where:

$MAWt_{PPijkl}$ = Mass of animal waste volatilised (tN) of cattle located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t.

AEt_{PPijkl} = Mass of nitrogen excreted calculated as the sum of faecal (AFt_{PPijkl}, Equation 10) and urinary (AUt_{PPijkl}, Equation 17) nitrogen of cattle located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t.

FracGASM = The fraction of N volatilised from pasture (no manure management systems are involved) located in State (i) region (j) during season (k) of each animal class (l). A value of 0.2 is used from NIR Table 6.32.

iii. Annual N2O production from atmospheric deposition is calculated as:

$EADt_{PPijk} = \Sigma_i \Sigma_j \Sigma_k (MAWt_{PPijk} \times EF \times CF\ N_2O)$	Equation 15/Derived from 4D3_5

Where:

$EADt_{PPijk}$ = Annual emissions from atmospheric deposition in the intensity reference period t (t N_2O).

$MAWt_{PPijkl}$ = Mass of N volatilised (t N), from atmospheric deposition from manure and urine of cattle located in State (i) region (j) during season (k) in the intensity reference year t as calculated in Equation 14.

EF = Emissions factor (t N_2O-N t N^{-1}) IPCC default emission factor of 0.01 (not country specific).

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

iv. The mass of animal waste N deposited on soils that is lost through leaching and runoff is calculated as:

$NLRt_{PPijkl} = (AFt_{PPijkl} + AUt_{PPijkl}) \times FracWET \times FracLEACH$	Equation 16/Derived from 4D3_7

Where:

$NLRt_{PPijkl}$ = Annual mass of animal waste N lost through leaching and runoff (tN) from cattle located in State (i) region (j) during season (k) of each animal class (l) in each year of the intensity reference year t.

AFt_{PPijkl} = Annual faecal nitrogen excreted onto the soil (t N) from cattle located in State (i) region (j) during season (k) of each animal class (l) in each year of the intensity reference year t as calculated in Equation 11.

AUt_{PPijkl} = Annual mass of urinary N excreted to soils (t N) from cattle by cattle located in State (i) region (j) during season (k) of each animal class (l) in the intensity reference year t - as calculated in Equation 12.

FracWET = Fraction of N in animal waste available for leaching and runoff. Use appropriate NIR Table 6.J.2.

FracLEACH = 0.4 (t N t applied^{-1}) IPCC default fraction of N lost through leaching and runoff.

v. Annual nitrous oxide production from leaching and runoff is calculated as:

$ELRt_{PPijkl} = \Sigma_i \Sigma_j \Sigma_k (NLRt_{PPijk} \times EF \times CF\ N_2O)$	Equation 17/Derived from 4D3_9

Where:

$ELRt_{PPijkl}$ = Annual emissions from leaching and runoff (t N_2O).

$NLRt_{PPijk}$ = Annual mass of N lost through leaching and runoff (t N) which is located in State (i) region (j) during season (k) in the intensity reference year t.

EF = 0.0075 (t N_2O-N t N^{-1}) - IPCC default emission factor of 0.01.

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

vi. The total emissions of nitrous oxide from agricultural soils can then be calculated as follows:

$EDUt_{PP}$ N_2O = (EAt_{PP} + $EADt_{PP}$ + $ELRt_{PP}$) x GWP N_2O	Equation 18/Project based equation

Where:

$EDUt_{PP}$ N_2O = Total N_2O emissions from dung and urine deposited on soil in the intensity reference year t (t CO_2-e).

EAt_{PP} = Annual direct soil emissions from N_2O in animal waste deposited in the intensity reference year t (t N_2O) as calculated from Equation 13.

$EADt_{PP}$ = Annual indirect emissions from atmospheric deposition in the intensity reference year t (t N_2O) as calculated in Equation 15.

$ELRt_{PP}$ = Annual indirect emissions from leaching and runoff in the intensity reference year t (t N_2O) as calculated in Equation 17

GWP N_2O = (kg CO_2-e.kg N_2O^{-1}) global warming potential of N_2O (currently 298) from the NGERS Regulations for the emissions intensity reference years.

b) Total intensity reference period emissions

i. Average annual intensity reference emissions are estimated as the enteric CH_4 emissions from feed consumption and N_2O emissions from dung and urine of the beef cattle managed at pasture averaged over the five to seven year emissions intensity reference period plus the emissions of cattle as adult equivalents sold for purposes other than slaughter or export at the NIR implied emissions rate until the end of the intensity reference period:

EFt_{PP} = (($EFCt_{PP}$ + $EDUt_{PP}$) + ($AENSt_{PP}$ x IEF/365 x ED_{PP} x GWP CH_4))X 10^{-3}	Equation 19/Project based equation

Where:

EFt_{PP} = Total emissions under the intensity reference period for each intensity reference year t. (t CO_2-e).

$EFCt_{PP}$ = Emissions from feed consumption in all intensity reference years (t CO_2-e), as calculated in Equation 5.

$EDUt_{PP}$ N_2O = N_2O emissions from dung and urine in all intensity reference years (t CO_2-e) from Equation 18.

$AENSt_{PP}$ = Total number of cattle of all classes sold for purposes other than export or slaughter in intensity reference period years t.

IEF = Implied emissions factor for beef cattle in Australia (NIR Table 6.9 as updated from time to time). Currently 72 kg methane per head per year.

ED_{PP} = Emissions days between date of sale and date of end of the emissions intensity reference period.

GWP CH_4 = (kg CO_2-e.kg CH_4^{-1}) global warming potential of CH_4 (current CH_4 = 25) from NGERS Regulations.

ii. Intensity Reference Period - Emissions Intensity of liveweight sales for export or slaughter.

The intensity of emissions associated with sale of animals of all classes to slaughter or export is based on the total annual intensity reference period emissions divided by the sum of the liveweight of all animals of all classes sold to slaughter or export:

$EIt_{PP} = EFt_{PP}/LWSt_{PPijk}$	Equation 20/Project based equation

Where:

EIt_{PP} = Emissions intensity of live weight sold during the emissions intensity year t (t CO_2-e.t $LWSt_{PPijk}^{-1}$).

Et_{PP} = Total emissions (t CO_2-e) for the intensity reference year t from Equation 19.

$LWSt_{PPijk}$ = Liveweight sold for export or slaughter in the emissions intensity reference year for State (i) region (j) during season (k) in intensity reference period year t in tonnes.

iii. Average emissions intensity for the intensity reference period is calculated as:

$EI_{PP} = \sum t=5..7\ EIt_{PP}/T$	Equation 21/Project based equation

Where:

EI_{PP} = Average emissions intensity of live weight sold for the five-year emissions intensity reference period (in t CO_2 e/t LWS).

EIt_{PP} = Emissions intensity of live weight sold for the emissions intensity year t.

T = Emissions intensity reference period duration of seven years prior to project commencement unless seven years data is not available from tax or other records, in which case the duration is a minimum 5 years but with all available years reported.

e) Total baseline emissions in the project reporting year

i. Total baseline emissions are calculated by multiplying average intensity reference period emissions intensity of beef production by liveweight sold to slaughter or export calculated as :

$EBt = EI_{PP} \times LWSt_{Pk}$	Equation 22/Project based equation

Where:

EBt = Total baseline emissions of methane from enteric fermentation and nitrous oxide from dung and urine (t CO_2-e) in the emission intensity reference years t.

EI_{PP} = Emissions intensity in the pre project period (in t CO_2 e/t LWS).

$LWSt_{Pk}$ = Live weight of all animals sold to slaughter or export in all seasons in the project reporting year t.

6. Factors to set the Project Activity

The proponent must use the Herd Management Calculator to estimate baseline and project emissions at the commencement of the project or a later version if updated. It is a requirement of the draft Determination that the same version of the Calculator is used to calculate baseline and project emissions in the year of reporting.

The Calculator is owned and operated by the Department of the Environment (DOE). From time to time when new accredited data becomes available, the DOE will update the Calculator consistent with the integrity standards and the NIR Inventory.

Table 2: Project Categories for pasture fed beef cattle

State$_{(i)}$	**Region $_{(j)}$**	**Season$_{(k)}$**	**Animal class $_{(l)}$**	**Feed Supplement (m)**
1 NSW/ACT	j=1 NSW	1 Spring	1 Bulls > 1 year	1= Improved pasture
2 Tasmania	j=2 Tasmania	2 Summer	2 Bulls < 1 year	2= Grain
3 Western Australia	j=3a South West	3 Autumn	3 Steers < 1 year	3= Mixed grain
	j=3b. Pilbara	4 Winter	4 Cows 1 - 2 year	4= Silage
	j=3c. Kimberley		5 Cows > 2 year	5= Hay
			6 Cows < 1 year	6= Crop
4 South Australia	j=4 SA		7 Steers > 1 year	7= Cottonseed
5 Victoria	j=5 Vic			8= Leucaena
6 Queensland	j=6 Qld			
7 Northern Territory	j=7 NT			

e) Geographical Location by State(i) and Region(j)

A number of parameters within the calculations are influenced by or can be linked to the geographical location of the livestock. There are nine regions provided in the Herd Management Calculator corresponding to the NIR regional delineation. The parameters relevant to the calculation of enteric CH_4 emissions are live-weight, live-weight gain and dry matter digestibility of feed intake. Crude protein, dry matter digestibility content of feed intake is considered in the calculations of CH_4 and N_2O emissions from dung and urine. Stratification by State (i) is required for the draft Determination and is consistent with the NGGI estimation approach.

f) Season(k)

Feed content and the timing of the addition of dietary additives are subject to change from season to season. Refer to the Seasonal Feed Quality Data Tables of the Herd Management Calculator for data on seasonal feed content.

g) Animal Class(l)

The animal class is required to calculate both the baseline and the project activity to ensure that all emissions can be stratified according to livestock classification. During the project the different classes of livestock (heifers and steers) will change in their numbers and average live weight. Accounting for numbers of each class will be achieved through head counts of the herd, NLIS waybills, NVD, tax records or similar statutory requirements. The herd book kept to conform to AAS 141 Tier 2 will also account for all of these changes across the animal classes.

h) Supplement (m)

Supplement type is required to calculate the project period animal intake and methane emissions from the feed supplement DMD and nitrogen balance of the animal and resulting soil emissions of nitrous oxide from crude protein content. The feeding period difference between the project and baseline is the key driver of emissions reduction and represents the outcome of feed quality improvements on live weight gain rate. The draft Determination for use of feed supplements in the project but it is assumed that feeding in the emissions intensity reference period will not have included supplements.

7. Emissions sources in the Project Reporting period

a) Methane Emissions

The project methane emissions are calculated under the draft Determination by subtracting the reduction in methane emissions as a result of supplementary feeding of feeds not fed to the baseline herd which results in fewer days on feed before sale from the baseline methane emissions.

The NIR (2011) (Section 6.4.2 p 231), considers methane production as negligible in the manure of range kept livestock due to high temperature, high solar radiation and low humidity environments in Australia which would lead to rapid manure drying. In combination with rapid infestation of scarab (or dung) beetles, there is a low likelihood of anaerobic conditions in rangeland systems.

b) Nitrous Oxide Emissions

Nitrous oxide emissions is estimated in accordance with the NIR approach as for the baseline with the exception that the crude protein intake can comprise native and improved pasture, grains of various supplements and mixtures of the two. To avoid errors in calculating the proportion of intake consumed from various feeds the feed quality parameters are averaged for the feed supplements in the default tables in the Herd Management Calculator. It is assumed that NPN supplements are fed to both the baseline and the project herds as part of routine management and their contribution to nitrous oxide emissions is the same in baseline and project.

8. Stepwise calculation of Project Emissions and Removals

a) Enteric methane

The algorithms used to estimate project feed consumption enteric methane emissions are based on the Australian Government National Greenhouse Gas Inventory (NGGI) method. The equivalent equation numbers from the NIR are listed for transparency.

The draft determination calculates individual animal enteric emissions and then sums the emissions across the herd. The approach used to estimate individual animal CH_4 production in the emissions intensity reference period (Mt_{PPijkl}) reflects the effect of range pasture feed quality and quantity on feed consumption and CH_4 emissions. Equations in the draft Determination are, similarly used to calculate M_{Pijklm} (the total daily production of methane per animal) on a range of default feed supplements, including range pasture, in the project reporting year.

i. Total dry matter intake in the project reporting year t ($DMIt_{Pijklm}$) is calculated relative to live-weight and live-weight gain using the equation of Minson and McDonald (1987):

$DMIt_{Pijklm} = (1.185 + 0.00454Wt_{Pijklm} - 0.0000026Wt_{Pijklm}^2 + 0.315LWGt_{pijklm})^2 \times MAt_{PPijkl=5}$	Equation 23 /Derived from 4A.1b_1

Where:

$DMIt_{Pijklm}$ = Total dry matter intake in the project reporting year (kg DM $head^{-1}$ day^{-1}) of cattle located in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t (kg).

Wt_{Pijklm} = Live-weight in kilograms of animals in project reporting year t on the property located in State (i) region (j), in season (k) for animal class (l) whilst feeding on feed supplement (m) from farm records or appropriate NIR Table 6.B.1.In the project it is assumed that the live weight of the sale animals is the average of the sale weight and the weight at the last weighing before supplementation. In most cases in Northern Australia that will be the most recent annual muster.

$LWGt_{Pijklm}$ = Daily live-weight gain of the project beef animal in kg $head^{-1}$ day^{-1} located in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) for each

year in the project period. This is calculated from proponent farm records as the difference in weight between musters divided by the number of days between musters.

$MAt_{PPijkl=5}$ = The additional intake for milk production of lactating cows in the intensity reference period year t.

ii. The additional intake for milk production (MA_{ijkl}=5) is calculated as:

$MAt_{ijkl=5m} = (LC_{ijkl=5} \times FA_{ijkl=5}) + ((1-LC_{ijkl=5}) \times 1)$	Equation 24 /derived from (4A.1b_2)

Where:

$MAt_{ijk\,l\,=\,5m}$ = Additional intake for milk production of lactating cows in the project reporting year t.

$LC_{ijkl=5}$ = Proportion of Cows >2 lactating. This is calculated as number of unweaned calves divided by number of breeding age cows in feed supplementation period.

$FA_{ijkl=5}$ = Feed adjustment. Further details on feed adjustments can be found in table 6.B.5 from the NIR for the relevant year from Table 6.B.5.

iii. The total daily production of methane (Mt_{ijkl}, kg CH4/head/day) is give by Charmley et al. (2014) as:

$Mt_{ijklm} = 21.5 \times DMIt_{PPijklm} /1000$	Equation 25/ derived from 3A.1b_3

Where:

Mt_{ijklm} = Total daily production of methane per animal (M_{ijkl} kg CH_4/head/day) located in State (i) region (j) during season (k) of each animal class (l) in the project reporting year t.

$DMIt_{PPijklm}$ = Total dry matter intake (kg DM $head^{-1}$ day^{-1}) for the herd in State (i) region (j) during season (k) of each animal class (l) for project reporting year t.

Consultation note: The parameters for gross energy intake that is yielded as methane are being updated for the 2015 National Inventory. The values for parameters in Equation (3) are indicative and may change prior to finalising the Determination, but the values will be consistent with the National Inventory as updated from time to time.

iv. Annual total enteric emissions of CH_4 (t CH_4) for the beef cattle herd in the project reporting year (EEt_P) for the project reporting year are calculated as:

$EEt_P = (\Sigma_i\Sigma_j\Sigma_k\Sigma_l\Sigma_m\,[FSt_{Pijklm} \times Nt_{Pijkml} \times Mt_{Pijklm}] \times 10^{-3})$	Equation 26/ derived from 4A.1b_8

Where:

EEt_P = Annual enteric emissions of CH_4 of the beef cattle herd in the project reporting year t (t CH_4).

FSt_{Pijklm} = The feeding period (days) for the herd in the project located in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t for feeds 1 to 8.

Nt_{Pijklm} = Head of beef cattle located in State (i) region (j) during season (k) of each animal class (l) (head)in the project reporting year t.

Mt_{Pijklm} = The total daily production in the project of methane per animal (M_{ijklm}, kg CH_4/head/day located in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in the project reporting year t, as calculated in Equation 3.

v. The project enteric emissions from feed consumption are estimated as follows:

$ECt_P = (EEt_P \times GWP\ CH_4)$	Equation 27/Project based equation

Where:

ECt_P = Annual emissions from feed consumption under the project reporting year t (t CO_2-e).

EEt_P = Annual CH_4 production for beef cattle managed at pasture under the project reporting year t (t CH_4).

GWP CH_4 = (kg CO_2-e.kg CH_4^{-1}) global warming potential of CH_4 (current CH_4 = 25) from the NGERS Regulations for the relevant reporting year.

a) Nitrous Oxide emissions from dung and urine

N_2O emissions from beef cattle managed at pasture are a function of dry matter digestibility and intake and crude protein concentration. The algorithms incorporated in the Herd Management Calculator estimate N_2O emissions from dung and urine which are based on the NIR method. The equivalent equation numbers from the NIR reports are listed for transparency. The estimation of nitrous oxide emissions is based on DMI adjusted for incremental intake for milk production and consumption in cows and unweaned calves (see Equation 23).

Nitrogen excretion from beef cattle in the project reporting year is estimated using algorithms to calculate crude protein (CPI_{Pijk}) intake and animal storage (NR_{Pijk}). Using these inputs nitrogen deposited in the faeces and urine is calculated.

i. Total crude protein intake is calculated as follows to allow for the combined input of pasture and supplement protein in the project compared to the baseline (refer to Equation 1 for calculation of DMI prior to calculating CPI):

$CPIt_{Pijklm} = DMIt_{Pijklm} \times CPt_{Pijklm} + (MAt_{Pijk)} \times 0.032)$	Equation 28/Derived from 4B.1b_3

Where:

$CPIt_{Pijklm}$ = Crude protein intake of the beef cattle in the project reporting year t (kg $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t – Use NIR table 6.B.4 of the relevant year.

$DMIt_{Pijklm}$ = Dry matter intake of cattle (kg $head^{-1}$) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t as calculated in Equation 23.

CPt_{Pijklm} = Crude protein content of the feed intake expressed as a fraction in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t. Use NIR table 6.B.4 of the relevant year.

MAt_{Pijkl} = The additional intake for milk production of lactating cows in project reporting year t.

ii. In accordance with the NGGI approach, nitrogen excreted in the faeces is calculated as the indigestible fraction of the un-degraded protein from solid feed and the microbial crude protein plus the endogenous faecal protein:

$Ft_{Pijklm} = \{0.3(CPIt_{Pijklm} \times (1- [(DMDt_{Pijklm} +10) / 100])) + 0.105(ME_{Pijklm} \times DMIt_{Pijklm} \times 0.008) + (0.0152 \times DMI_{Pijklm})\} / 6.25$	Equation 29/Derived from 4B.1b_4

Where:

Ft_{Pijklm} = Nitrogen excreted in the faeces of cattle (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t using Equation 28.

$CPIt_{Pijklm}$ = Crude protein intake of the beef cattle (kg $head^{-1}day^{-1}$) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

$DMDt_{Pijklm}$ = Average dry matter digestibility based on the supplements fed to the beef herd in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t - Use the NIR table 6.B.3 of the relevant year expressed as a percentage.

ME_{Pijlkm} = Metabolisable energy of feed (MJ kg DM^{-1}) in State (i) region (j) during season (k) when feeding on feed (m) in reporting year t calculated as: $0.1604DMDt_{Pijklm}$ – 1.037 (Minson and McDonald 1987) from Table 6.B.3.

$DMIt_{Pijklm}$ = Dry matter intake of cattle (kg head per day^{1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

1/6.25 = Factor for converting crude protein into nitrogen.

Nitrogen Retention

The intake of the animals relative to that needed for maintenance (L_{PPijkl}) is calculated as actual intake divided by maintenance intake (i.e. intake of non-lactating animal with live-weight gain is set to zero):

$Lt_{Pijkl} = DMI_{Pijkl} / (1.185 + 0.00454W_{ijkl} – 0.0000026W_{ijkl}^2 + (0.315 \times LWG_{ijkl}))^2$	Equation 30/Derived from 4A.1b_4

Where:

Lt_{Pijkl} = feed intake (kg DMI day^{-1} kg^{-1} LW) of the animals relative to that needed for maintenance (dimensionless) on the proponent's farm which is located in State (i), region (j) during season (k) of each animal class (l) in each project reporting year calculated as actual intake divided by maintenance intake (i.e. intake of non-lactating animal with a zero live weight gain).

DMI_{Pijkl} = total dry matter intake in the pre-project period (kg DM $head^{-1}$ day^{-1}) on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) in each project reporting year as calculated in Equation 23.

W_{ijkl} = live weight of beef animal in kilograms on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) – if not known use NIR table 6.B.1 for the relevant year.

LWG_{ijkl} = live-weight gain (kg $head^{-1}$ day^{-1}) for each animal class on the proponent's farm which is located in State (i) region (j) during season (k) of each animal class (l) in each year in the intensity reference period- if not known use appropriate NIR table 6.B.2.

iii. The amount of nitrogen retained by the body (NR_{Pijklm} kg N head-1 day-1) in the project reporting year t is calculated as the amount of nitrogen retained in milk and body tissue:

$NRt_{Pijklm} = \{\{0.212-0.008(L_{Pijklm} - 2) - [(0.140-0.008(L_{Pijklm} - 2)) / (1+\exp(-6(Z_{ijklm} - 0.4)))]\} \times (LWGt_{ijklm} \times 0.92)\}/6.25$	Equation 31/Derived from 4B.1b_5

Where:

NRt_{Pijklm} = Amount of nitrogen retained by the body of cattle (kg $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in the project reporting year t

L_{Pijklm} = Intake relative to that needed for maintenance of cattle kg $head^{-1}$) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in the project reporting year t.

Z_{ijklm} = Relative size (live-weight / standard reference weight) of cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in each project reporting year – if not known use appropriate NIR tables 6.B.1 and 6.B.6.

$LWGt_{ijklm}$ = Live-weight gain (kg day^{-1}) of cattle in State (i) region (j) during season (k) of each animal class (l) when feeding on feed (m) in the project reporting year t –use appropriate NIR table 6.B.2.

The intake of the animals relative to that needed for maintenance (L_{PPijkl}) is calculated as actual intake divided by maintenance intake (i.e. intake of non-lactating animal with live-weight gain is set to zero):

iv. The total annual faecal (AFtp, N) nitrogen is calculated as:

$AFt_{Pijklm} = \Sigma_i\Sigma_j\Sigma_k\Sigma_l\Sigma_m(FSt_{ijklm} \times Nt_{Pijklm} \times F_{Pijklm}) \times 10^{-3}$	Equation 32/Derived from 4B.1b_7a

Where:

AFt_{Pijklm} = Total annual faecal nitrogen excreted by cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in the reporting year (t N).

FSt_{ijklm} = Feed supplementation period of cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t (t N).

Nt_{Pijklm} = Head of cattle fed in State (i) region (j) during season (k) of each class (l) whilst feeding on feed supplement (m) in project reporting year t (head).

F_{Pijklm} = Nitrogen excreted in the faeces of cattle (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

v. Nitrogen excreted in the urine (Ut_{Pijklm} l in kg N head-1 day-1) is calculated by subtracting NR_{Pijkl} , Ft_{Pijkl} and dermal protein loss from the nitrogen intake:

$Ut_{Pijklm} = (CPIt_{Pijklm} / 6.25) – NRt_{Pijklm} – Ft_{Pijklm} – [(1.1 \times 10^{-4} \times W_{ijklm}^{0.75}) / 6.25]$	Equation 33/Derived from 4B.1b_6

Where:

Ut_{Pijklm} = Nitrogen excreted in the urine of cattle (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

$CPIt_{Pijklm}$ = Crude protein intake of cattle (kg $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t as calculated in Equation 28.

NRt_{Pijklm} = Amount of nitrogen retained by the body of cattle (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t as calculated in Equation 30.

Ft_{Pijklm} = Nitrogen excreted in the faeces of cattle (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t as calculated in Equation 29.

W_{ijklm} = Live-weight in kilograms of cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t from farm records or use NIR table 6.B.1 of the relevant year.

vi. The total annual urinary nitrogen (AUt_{pijklm}) is calculated as:

$AUt_{Pijklm} = \Sigma_i \Sigma_j \Sigma_k \Sigma_l \Sigma_m (FSt_{Pijklm} \times Nt_{Pijklm} \times Ut_{Pijklm}) \times 10^{-3}$	Equation 34/Derived from 4B.1b_7b

Where:

AUt_{Pijklm} = Urinary nitrogen excreted onto the soil (t N) in State (i) region (j) during season (k) of each animal class (l) when feeding on feed (m) in project reporting year t.

FSt_{Pijklm} = Feeding period of cattle of animals in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in reporting year t.

Nt_{Pijklm} = Head of supplemented beef cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

Ut_{Pijklm} = Nitrogen excreted in the urine of animals (kg N $head^{-1}$ day^{-1}) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t from Equation 31.

b) Nitrous Oxide Emissions from Agricultural Soils

Using the NIR approach, nitrous oxide emissions from animals at pasture are considered to be soil emissions and are calculated according to NIR (2011) Section 6.6.2.2.

Annual direct nitrous oxide production is calculated as:

$EAt_P = ((AFt_{Pijklm} \times EF \times CF\ N_2O) + (AUt_{Pijklm} \times EF \times CF\ N_2O))$	Equation 35/Derived from 4D2_3

Where:

EAt_P = Annual emissions from animal waste deposited on the paddock in the project reporting year t (t N_2O).

AFt_{Pijklm} = Faecal nitrogen excreted onto the soil by cattle located in State(i), Region (j), Season (k) animal class (l) whilst feeding on feed supplement (m) in the project reporting year t (t N) from Equation 31.

EF = Emission factor (t N_2O-N (t N deposited)$^{-1}$), equivalent to 0.005 for faeces and 0.004 for urine (NIR, 2011).

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

AUt_{Pijklm} = Urinary nitrogen excreted onto the soil(t N) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t from Equation 33.

i. Nitrous oxide emissions from atmospheric deposition are estimated based on the mass of animal waste volatilised is calculated for manure deposited on pasture as:

$MAWt_{Pijklm} = (AEt_{Pijklm} \times FracGASM)$	Equation 36/Derived from 4D3_2

Where:

$MAWt_{Pijklm}$ = Mass of nitrogen from animal waste volatilised (t N) of cattle in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

AEt_{Pijklm} = Mass of nitrogen excreted from dung and urine calculated as the sum of faecal (AFt_P Equation 31) and urinary (AUt_{Pijklm}, Equation 32) nitrogen (t N) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

FracGASM = Fraction of N volatilised in pasture systems given as a default of 0.2 in NIR (2011).

ii. Annual N_2O production from atmospheric deposition is calculated as:

$EADt_P = \Sigma_i \Sigma_j \Sigma_k (MAWt_{Pijklm} \times EF \times CF\ N_2O)$	Equation 37/Derived from 4D3_5

Where:

$EADt_P$ = Annual emissions from atmospheric deposition in the project reporting year t (t N_2O).

$MAWt_{Pijklm}$ = Mass of nitrogen from animal waste volatilised (t N) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

EF = Emissions factor (t N_2O-N t N^{-1}) IPCC default emission factor of 0.01 (NIR, 2010).

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

iii. The mass of animal waste N deposited on soils that is lost through leaching and runoff is calculated as:

$NLRt_{Pijklm} = (AUt_{Pijklm} + AFt_{Pijklm}) \times FracWET \times FracLEACH$	Equation 38/ Derived from 4D3_7

Where:

$NLRt_{PijIkm}$ = Mass of animal waste N lost through leaching and runoff (t N) in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

AUt_{Pijklm} = Mass of urinary N excreted to soils (t N) in State (i) region (j) during season (k) of each animal class (l) in project reporting year t as calculated in Equation 33.

AFt_{Pijklm} = Mass of faecal N excreted to soils in each project reporting year as calculated in Equation 30 in State (i) region (j) during season (k) of each animal class (l) whilst feeding on feed supplement (m) in project reporting year t.

FracWET = Fraction of N available for leaching and runoff from animal waste from free range beef cattle. Use Appendix table 6.J.2 NIR (2011).

FracLEACH = 0.4 (t N/t applied) IPCC default fraction of N lost through leaching and runoff.

iv. Annual nitrous oxide production from leaching and runoff is calculated as:

$ELRt_P = \Sigma_i \Sigma_j \Sigma_k (NLRt_{Pijklm} \times EF_{lr} \times CF\ N_2O)$	Equation 39/Derived from 4D3_9

Where:

$ELRt_P$ = Annual emissions from leaching and runoff (t N_2O) in project reporting year t

$NLRt_{Pijklm}$ = Mass of N lost through leaching and runoff (t N) in State (i) region (j) during season (k) of each animal class (l) in project reporting year t whilst feeding on feed supplement (m).

EF_{lr} = 0.0125 (t N2 O-N t N^{-1}), (NIR 2011 Equation 4D2 _ 3).

CF N_2O = 44/28 factor to convert elemental mass of N_2O to molecular mass.

v. The total emissions of nitrous oxide from agricultural soils can then be calculated as follows:

$EDUt_PN_2O = (EAt_P + EADt_P + ELRt_P) \times GWP\ N_2O$	Equation 40/Project based equation

Where:

$EDUt_P\ N_2O$ = Total N_2O emissions from dung/urine in the reporting year t (t CO_2-e).

EA_P = Annual N_2O production from animals in the project reporting year t (t N_2O) as calculated in Equation 34.

$EADt_P$ = Annual emissions from atmospheric deposition in the project reporting year t (t N_2O) as calculated in Equation 36.

$ELRt_P$ = Annual emissions from leaching and runoff in the project reporting year t (t N_2O) as calculated in Equation 38.

GWP N_2O = (kg CO^2-e.kg CH_4^{-1}).global warming potential of N_2O (currently 298) from the NGERS Regulations of the relevant reporting year.

c) Total Project Emissions

i. Project reporting year emissions are subsequently estimated as the enteric CH_4 emissions from feed consumption and CH_4 and N_2O emissions from dung and urine:

$Et_P = (ECt_P + EDUt_P\ N_20) + (\sum_{t=1..7} AENSt_P \times IEF/365 \times ED_P \times$	Equation 41 (Project based equation)

GWP CH_4) x 10^{-3}	

Where:

Et_P = Sum of the emissions in the project reporting year t (t CO_2-e).

$EFCt_P$ = Emissions from feed consumption in the reporting year t (t CO_2-e) as calculated in Equation 27.

$EDUt_P$ N_20 = Emissions from dung and urine in the project reporting year t (t CO_2-e) as calculated in Equation 39.

$AENSt_P$ = Total number of cattle of all classes sold for purposes other than export or slaughter in project reporting year t.

IEF = Implied annual emissions factor for beef cattle in Australia (NIR Table 6.9 as updated from time to time). Currently 72 kg methane per head per year.

ED_P = Emissions days between date of sale for purposes other than export or slaughter and date of end of crediting period.

GWP CH_4 = (kg CO^2-e.kg CH_4^{-1}) global warming potential of CH_4 (current CH_4 = 25) from NGERS Regulations for crediting period years.

ii. Abatement of greenhouse gases in the draft Determination is calculated as the difference in emissions between baseline and project for two sources of emissions, methane and nitrous oxide.

The calculation methodologies presented here serve to complete the following equation for calculating the net greenhouse gas abatement in the project reporting year as the difference between total emissions in the project reporting year and total emissions in the baseline reporting year from both feed consumption and dung and urine deposition:

E_{net} = EBt-Etp	Equation 42/Project derived equation

Where:

E_{net} = Total net greenhouse gas abatement in the project reporting year (t CO_2-e).

EBt = Total baseline emissions of methane from enteric fermentation and nitrous oxide from dung and urine (t CO2-e) calculated using Equation 22.

Etp = Total project emissions of methane from enteric fermentation and nitrous oxide from dung and urine (t CO2-e) in project year t calculated using Equation 40.