Input specifications for He Waka Eke Noa reporting methods

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1. Background

The He Waka Eke Noa Emissions Reporting workgroup recently considered three types of reporting methods for the mandatory reporting under a farm-level pricing mechanism by 2024. The three methods are (1) simple, (2) intermediate and (3) detail. Each of these were briefly described in the 'He Waka Eke Noa Emission Reporting Working Draft' as follows:

1. Simple

   Key inputs only, e.g., livestock numbers, amount of nitrogen fertiliser applied, sequestration (as recommended by Sequestration workstream); annual time step; NZ specific average emissions factors, e.g., by class of stock, type of nitrogen fertiliser, type of forest; no mitigations.

2. Intermediate

   More detailed inputs, e.g., livestock production; monthly time step; NZ specific average emissions factors; e.g., maintenance and milk production or liveweight; basic mitigations, e.g. efficiency accounted for.

3. Detailed

   Multiple farm-specific inputs, e.g., livestock numbers, class, age, performance (milk solids, liveweight), and diet; monthly time step; use of NZ-specific emissions factors and farm-specific data to estimate dry matter intake; inclusion of full range of approved mitigations and sequestration methods, with potential for inclusion of additional approved mitigation and sequestration opportunities.

Before the Emissions Reporting workgroup can align existing models/tools with each of these three methods or developing a new tool to meet a specific method, the workgroup agreed further information and expansion of the input specifications of each method is required.

2. Approach

AgResearch scientists familiar with greenhouse gas (GHG) emissions inventory methodologies and farm-scale greenhouse gas reporting met to discuss the following:-

- Identify the key sources of greenhouse gas emissions to be captured in the methods
- For each key source, describe the required Output per method
- Provide details of the required Inputs to ensure each required Output could be achieved at the degree of detail considered satisfactory for the method
- For each key greenhouse gas source and each of the three reporting methods, align current and future greenhouse gas mitigation options
- Ensure required Inputs were able to capture the current and future mitigation options.

This information was developed following discussions between the authors and reference to documents describing greenhouse gas accounting methodologies (de Klein et al. 2019; Journeaux et al. 2021; Pickering et al. 2020; Vibart et al. 2021). The New Zealand agricultural greenhouse gas inventory provided a useful reference point for developing the input specifications for the three methods, as it can be considered as an intermediate method for livestock-based emissions (Fig. 1).

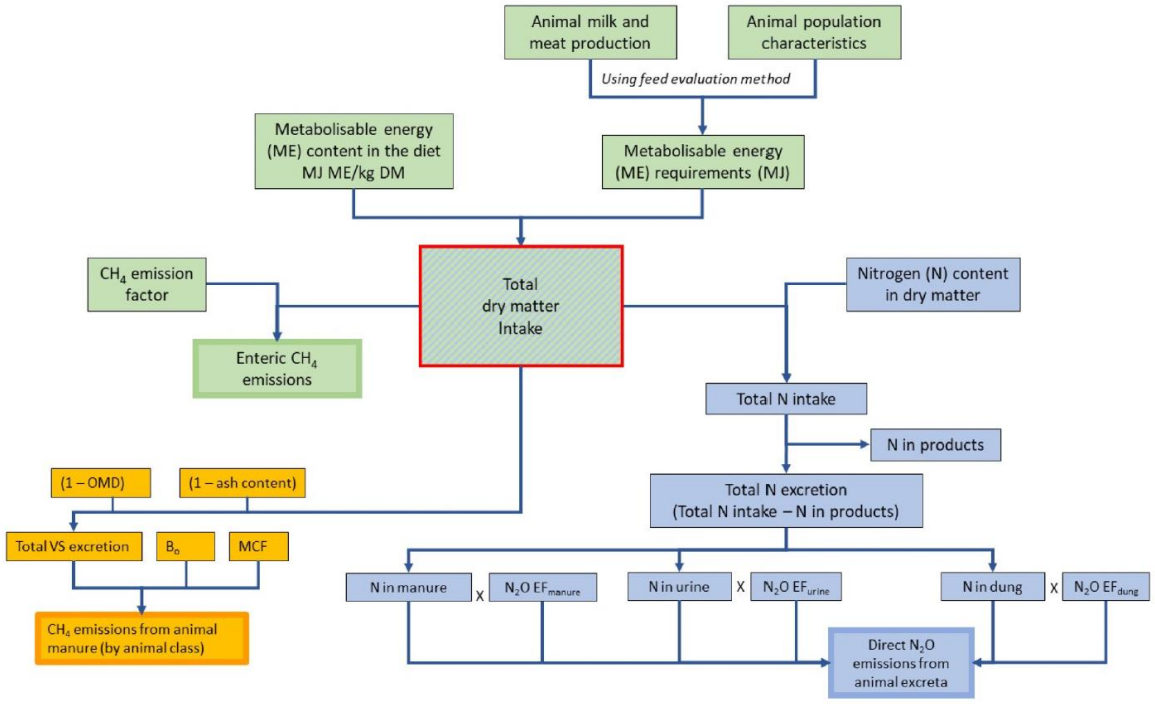

Fig. 1. Schematic overview of the approach adopted by the New Zealand agricultural greenhouse gas inventory for estimating methane (CH_4) and nitrous oxide (N_2O) emissions from livestock production systems. Green boxes refer to enteric CH_4, orange boxes to manure CH_4, and blue boxes to N_2O. ME=metabolisable energy; MJ=mega joules; OMD=organic matter digestibility; VS=volatile solids; B_0=maximum CH_4 producing capacity of manure; MCF=CH_4 conversion factor; EF=emission factor. The efficiency of use of feed energy and protein modulate these fluxes. (source: Vibart et al. 2021).

Input specifications for each key GHG source are provided in Section 3 as a series of tables, describing one source per table. Each table follows the same structure, with key features described below:

- **Method Component**: Output, Input or Mitigation information per Method
  - **Outputs**: outputs provided for each GHG source
  - **Inputs**: vary according to the GHG source, and according to the information required to achieve the stated Output
  - **Mitigations**: type of mitigations that can be used for each GHG source for simple, intermediate and detailed methods
- **Source of input information:**
  - **User** = individual operating the tool/model
  - **Database** = input obtained from information databases used by the tool/model
  - **Engine** = input/parameters estimated from equations/emission factors used by the tool/model.
- **Simple method**: Represents a basic method for estimating farm-scale GHG emissions. Could be considered as aligning with IPCC Tier 1 or simpler.
- **Intermediate method**: Represents a method that allows limited flexibility in representing farming practices that influence GHG emissions. Can capture some mitigation options. For many GHG sources, this method often aligns with New Zealand's agricultural inventory methodology.
- **Detailed method**: Represents a method that allows substantial flexibility in farming practices that influence GHG emissions. Can capture many mitigation options. For many GHG sources, this method often aligns with the more complex type of farm-scale GHG foot-printing models.
- **Notes**: points of clarification and assumptions

The He Waka Eke Noa Sequestration group are in the process of developing methods for capturing carbon (C) storage, therefore the specifications for emission reporting methods detailed in the current report may need to be aligned with C sequestration methods.

3. Input Specifications per Greenhouse Gas source

3.1 Ruminants: Enteric CH_4

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		Enteric CH_4 based on average emission per head of livestock	Enteric CH_4 based on animal physiological status and level of farm production, and assumes a static ME content of diet	Enteric CH_4 based on animal physiological status and level of farm production, feed type and month	
Inputs					
Number of animals	User	Total number by species (weighted annual average)	Animal numbers split by category (body weight, species and physiological status (i.e. maintenance vs lactation vs. growth))	Animal numbers split by category (body weight, body weight changes, species, age and physiological status (i.e. maintenance vs lactation vs. growth))	For simple, weighted annual average assumes a breeding female rearing a default number of offspring, no trading stock
Feed type eaten	User	Not required	Not required	Feed type per animal category	
Animal reproductive data	User	Not required	Lambing and calving percentage	Breeding date, pregnancy date, lambing percentage, culling date	

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Animal production	User	Not required	Milk, meat and wool production per animal type and category	Milk, meat and wool production per animal type and category	
Feed information	Database	Not required	Weighted annual average feed quality (DM, ME, N content)	Monthly feed quality (DM, ME/digestibility, N content) of pasture and supplements	
Time step	Engine	Annual	Annual	Month	
Underlying calculations/ defaults	Engine/ Database	Default CH_4 emissions per head of livestock type	Animal ME requirements from feeding standards (typically CSIRO 2007, 2012); default single diet DMI per animal type; default CH_4 emissions per DMI per animal type; default reproductive data and lactation length	Animal ME requirements from feeding standards (typically CSIRO 2007, 2012); DMI per feed type (driven by DM digestibility, ME and N of feed); default CH_4 emissions per kg DMI per feed type	
Mitigations					
Mitigations - current				Low CH_4 forages: Adjusted default for CH_4 EF per kg DMI	
Mitigations - future proofing				Low CH_4 sheep, cattle: Adjusted default for CH_4 EF per kg DMI*	

* Includes CH_4 vaccines and inhibitors. Breeding values (BV) for low CH_4 sheep integrate the effect of low CH_4 per kg DMI and increased feed efficiency (less DMI per unit of production). The proposed method for capturing low CH_4 sheep in GHG calculations is to convert BV to an adjusted CH_4 emitted per DMI; in future, BV may be separated into an adjusted CH_4 and increased feed efficiency.

3.2 Agricultural Soils – Urine: N_2O

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		N_2O emissions from urine deposition based on average emission per animal species.	N_2O emissions from urine deposition based on urine-N excreted following pasture grazing; grazing on different slope classes.	N_2O emissions from urine deposition based on urine-N excreted following diet of pasture/ forage crops/supplements; grazing on different slope classes. Soil type and climate information (*).	* Soil and climate also affect N_2O EF and if algorithms are developed detailed method could include this
Inputs					
Number of animals	User	Total number by species (weighted annual average)	Animal number split by category (body weight, species and physiological status (i.e., maintenance vs lactation vs. growth))	Animal number split by category (body weight, body weight changes, species, age and physiological status (i.e. maintenance vs lactation vs. growth)) including time off paddock	
Farm location	User	Not required	Not required	Required (*)	*If the method includes an algorithm for estimating EF based on soil and climate
Topography	User	Not required (assumes flat)	Area of farm in different slope classes (flat/low	Area of farm in different slope classes (flat/low slope; medium/steep slopes)	

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
			slope; medium/steep slopes)		
Feed type eaten	User	Not required	Not required	Feed type per animal category	
Animal production	User	Not required	Milk, meat and wool production per animal type and category	Milk, meat and wool production per animal type and category	
Time step	Engine	Annual	Annual	Month	
Spatial scale	Engine	Farm	Farm	Block	
Soil data per block	Database	Not required	Not required	Required (*) Depends on prediction algorithm but could include e.g. organic C, bulk density, clay content.	* If the method includes an algorithm for estimating EF based on soil and climate
Climate data per farm	Database	Not required	Not required	Required (*) Depends on prediction algorithm but could include e.g. monthly rainfall	* If the method includes an algorithm for estimating EF based on soil and climate
Feed information	Database	Not required	Weighted annual average feed quality (DM, ME, N content) (fixed values)	Monthly feed quality (DM, ME/digestibility, N content) of pasture and supplements	
Underlying calculations/ defaults	Engine/ Database	Default annual implied N_2O	Excreta-N excretion based on DMI, N content and N removed in	Excreta-N excretion based on DMI, dietary crude protein, and N in products. DMI per feed type	Indirect N_2O emissions occur following N

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
		emission per head of livestock type	products. DMI driven by DM digestibility or ME requirement (see enteric CH_4); default N in products (milk, meat and wool); Excreta-N split between urine and dung based on default dietary N; Default proportion of Urine-N to manure management system and soil; Default annual direct and indirect N_2O emission per urine-N excreted	driven by DM digestibility or ME requirement (see enteric CH_4); default N in products (milk, meat and wool); Excreta-N split between urine and dung based on dietary N; Proportion of Urine-N to manure management system and applied to soil based on 'time off paddock'; Default annual direct and indirect N_2O emission per urine-N excreted per forage type; nutrient transfer model to distributing urine-N across slope classes	leaching and ammonia volatilisation
Mitigations					
Mitigations - current				Low N_2O forages: Adjusted monthly N excretion per animal type, age and sex; Adjusted monthly N leach	
Mitigations - future proofing			Nitrification inhibitors: Adjusted default for N_2O EF and N leaching	Nitrification inhibitors: Adjusted default for N_2O EF and N leaching per forage type: Adjusted monthly N leaching. Low N_2O cattle: Adjusted monthly N excretion	

3.3 Agricultural Soils – Dung: N_2O

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		N_2O emissions from dung deposition based on average emission per animal species.	N_2O emissions from dung deposition based on dung-N excreted following pasture grazing	N_2O emissions from dung deposition based on dung-N excreted following diet of pasture/ forage crops/supplements	
Inputs					
Number of animals	User	Total number by species (weighted annual average)	Animal number split by category (body weight, species and physiological status (i.e. maintenance vs lactation vs. growth))	Animal number split by category (body weight, body weight changes, species, age and physiological status (i.e. maintenance vs lactation vs. growth)) including time off paddock	
Feed type eaten	User	Not required	Not required	Feed type per animal category	
Animal production	User	Not required	Milk, meat and wool production per animal type and category	Milk, meat and wool production per animal type and category	
Time step	Engine	Annual	Annual	Month	
Spatial scale	Engine	Farm	Farm	Block	
Soil data per block	Database	Not required	Not required	Not required	

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Climate data per farm	Database	Not required	Not required	Not required	
Topography	Engine	Not requires	Not required	Not required	
Underlying calculations/ defaults	Engine/ Database	Default annual implied (direct and indirect) N_2O emission per head of livestock type	Excreta-N excretion based on DMI, N content and N removed in products. DMI driven by DM digestibility or ME requirement (see enteric CH_4); default N in products (milk, meat and wool); Excreta-N split between urine and dung based on default dietary N; Default proportion of Dung-N to manure management system and soil; Default annual direct and indirect N_2O emission per dung-N excreted	Excreta-N excretion based on DMI, dietary crude protein, and N in products. DMI per feed type driven by DM digestibility or ME requirement (see enteric CH_4); default N in products (milk, meat and wool); Excreta-N split between urine and dung based on dietary N; Proportion of Dung-N to manure management system and soil; Default annual direct and indirect N_2O emission per dung-N excreted per forage type	Indirect N_2O emissions occur following N leaching and ammonia volatilisation
Mitigations					
Mitigations - future proofing			Nitrification inhibitors: Adjusted default for N_2O EF	Nitrification inhibitors: Adjusted default for N_2O EF	

3.4 Manure storage: CH_4

Method component	Source of input information	Method: Simple	Intermediate	Detailed
Output		Total CH_4 emissions from stored effluent	Total CH_4 emissions from stored effluent	Total CH_4 emissions from stored manures (effluent, solid manure, slurry) including time off paddock
Inputs				
Number of animals	User	Total number by species (weighted annual average)	Total number by species (weighted annual average)	Animal number split by category (body weight, species, age and physiological status (i.e. maintenance vs lactation vs. growth)) including time off paddock
Feed type eaten	User	Not required	Not required	Feed type per animal category
Type and use of manure management system	User	Not required	Not required	Effluent, solid manure, slurry storage
Time step	Engine	Annual	Annual	Month
Spatial scale	Engine	Farm	Farm	Farm
Feed information	Database	Not required	Not required	Feed quality (DM, ME/digestibility) of pasture and supplements
Underlying calculations/ defaults	Engine/ Database	Default effluent volume per animal; default CH_4 emission per m^3 effluent stored (annualised)	Default effluent volume per animal class; default CH_4 emission per m^3 effluent	DMI per feed type driven by DM digestibility or ME requirements (see enteric CH_4); default volatile solids (VS) from ash content, organic matter digestibility of feed types; default CH_4

Method component	Source of input information	Method: Simple	Intermediate	Detailed
			stored for a typical period of time (annualised)	emission of effluent/solid manure/slurry VS based on default Bo and methane conversion factor (MCF); Duration of storage (months)
Mitigations				
Mitigations - future proofing			CH_4 flaring to CO_2; CH_4 biogas harnessing for energy source: Adjusted default for amount of CH_4 emitted.	CH_4 flaring to CO_2; CH_4 biogas harnessing for energy source: Adjusted default for amount of CH_4 emitted.

3.5 Manure storage: N_2O

Method component	Source of input information	Method: Simple	Intermediate	Detailed
Output		Total N_2O emissions from stored effluent	Total N_2O emissions from stored effluent	Total N_2O emissions from stored manures (effluent, solid manure, slurry) based on excreta production
Inputs				
Number of animals	User	Total number by species (weighted annual average)	Total number by species (weighted annual average)	Animal number split by category (body weight, species, age and physiological status (i.e. maintenance vs lactation vs. growth)) including time off paddock
Feed type eaten	User	Not required	Not required	Feed type per animal category
Animal production	User	Not required	Milk, meat and wool production per animal type and category	Milk, meat and wool production per animal type and category
Type and use of manure management system	User	Not required	Not required	Effluent, solid manure, slurry storage
Time step	Engine	Annual	Annual	Month
Spatial scale	Engine	Farm	Farm	Farm
Feed information	Database	Not required	Not required	Feed quality (DM, ME/digestibility, N content) of pasture and supplements

Method component	Source of input information	Method: Simple	Intermediate	Detailed
Underlying calculations/ defaults	Engine/ Database	Default effluent volume per animal; default implied (direct and indirect) N_2O emission per m^3 effluent stored for a typical period of time (annualised)	Default effluent volume per animal class; default N content of effluent; separate default direct and indirect N_2O emission per N-effluent stored for a typical period of time (annualised)	Excreta-N excretion based on DMI, dietary crude protein, and N in products. DMI per feed type driven by DM digestibility or ME requirements (see enteric CH_4); default N in products (milk, meat and wool); Excreta-N split between urine and dung based on dietary N; Proportion of Urine-N and Dung-N to manure management system (effluent, solid manure, slurry) based on grazing time; Default annual direct and indirect N_2O emission per N-effluent/solid manure/slurry stored per week; Duration of storage (months).
Mitigations				
Mitigations - future proofing			Covered stores: Adjusted default for indirect (ammonia) loss	Covered stores: Adjusted default for indirect (ammonia) loss

3.6 Agricultural Soils – Manure application: N_2O

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		Total N_2O emissions from effluent application	Total N_2O emissions from effluent application	N_2O emissions split by manure type (effluent, solid manure, slurry)	
Inputs					
Type of manure applied to land	User	Not required	Not required	Effluent, solid manure, slurry	
Manure application method	User	Not required (surface assumed)	Not required (surface assumed)	Surface or incorporation	Incorporation of manure reduces NH_3 volatilisation: relevant for cropping
Time step	Engine	Annual	Annual	Month	
Spatial scale	Engine	Farm	Farm	Block	
Underlying calculations/ defaults	Engine/ Database	Default effluent volume per animal; default N content of effluent; default implied (direct and indirect) N_2O EF per kg effluent-N	Default effluent volume per animal class; default N content of effluent; default EF (separate direct and indirect N_2O) per kg effluent-N	N content of manure types calculated from N in manure storage, allowing for N processes (N transformation, emission) during storage; default EF (separate direct and indirect N_2O) per kg N per manure type	Indirect N_2O emissions occur following N leaching and ammonia volatilisation

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Mitigations					
Mitigations - future proofing			Nitrification inhibitors: Adjusted default for N_2O EF and N leaching	Nitrification inhibitors: Adjusted default for N_2O EF and N leaching	

3.7 Agricultural Soils – N fertiliser: N_2O

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		Total N_2O emissions from total synthetic N use	N_2O emissions split by fertiliser type	N_2O emissions split by fertiliser type, summed across months and blocks	Detailed: if soil type and climate included, may be able to predict N_2O EF in future
Inputs					
Fertiliser Type	User	Total synthetic N (product tonnage) split into urea and non-urea	Total synthetic N (product tonnage) split into urea, non-urea, urea + urease inhibitor	Total synthetic N (product tonnage) split into urea, non-urea, urea + urease inhibitor	Detailed: captures different EF (direct N_2O) or FracGASF (indirect N_2O) values for the three fertiliser types
Application method	User	Surface assumed	Surface or incorporation	Surface or incorporation	Incorporation of urea reduces NH_3 volatilisation: relevant for cropping
Location	User	Not required	Not required	Required (*)	* If the method includes an algorithm for estimating fertiliser EF based on soil and climate in near future
Time step	Engine	Annual	Annual	Monthly	
Spatial scale	Engine	Farm	Farm	Block	

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Soil data per block	Database	Not required	Not required	Required (*) Depends on prediction algorithm but could include e.g. organic C, bulk density, clay content.	* If the method includes an algorithm for estimating fertiliser EF based on soil and climate
Climate data per farm	Database	Not required	Not required	Required (*) Depends on prediction algorithm but could include e.g. monthly rainfall	* If the method includes an algorithm for estimating fertiliser EF based on soil and climate
Underlying calculations/ defaults	Engine/ Database	Default N per fertiliser type; Implied emission factor captures direct and indirect N_2O into single value, per tonne fertiliser type	Default N per fertiliser type; default EF (separate direct and indirect N_2O) per kg N as urea and non-urea	Default N per fertiliser type; default EF (separate direct and indirect N_2O) per kg N as urea and non-urea	Indirect N_2O emissions occur following N leaching and ammonia volatilisation
Mitigations					
Mitigations - current			Urea + urease inhibitor; Fertiliser incorporation: Adjusted default for indirect (ammonia) loss	Urea + urease inhibitor; Fertiliser incorporation: Adjusted default for indirect (ammonia) loss	
Mitigations - future proofing			Nitrification inhibitors: Adjusted default for N_2O EF and N leaching	Nitrification inhibitors: Adjusted default for N_2O EF and N leaching	

3.8 Urea Fertiliser application: CO_2 from urea application to land

Method component	Source of input information	Method: Simple	Intermediate	Detailed	Notes
Output		Total CO_2 emissions from urea use	Total CO_2 emissions from urea use	Total CO_2 emissions from urea use	No difference between methods for this source, given it is a minor source
Inputs					
Fertiliser Type	User	Total Urea (product tonnage)	Total Urea (product tonnage)	Total Urea (product tonnage)	
Time step	Engine	Annual	Annual	Annual	
Spatial scale	Engine	Farm	Farm	Farm	
Application method	Engine	Surface assumed	Surface assumed	Surface assumed	
Underlying calculations/ defaults	Engine/ Database	CO_2 EF per tonne urea	CO_2 EF per tonne urea	CO_2 EF per tonne urea	

3.9 Summary of User Input data

Method component	Method: Simple	Intermediate (required on annual basis)	Detailed (required on monthly basis)	Notes
Number of animals	Total number by species (weighted annual average)	Animal numbers split by category (body weight, species and physiological status (i.e. maintenance vs lactation vs. growth))	Monthly animal number split by category (body weight, body weight changes, species, age and physiological status (i.e. maintenance vs lactation vs. growth)) including time off paddock	For simple, weighted annual average assumes a breeding female rearing a default number of offspring, no trading stock
Feed type eaten	Not required	Not required	Feed type per animal category	
Animal reproductive data	Not required	Lambing and calving percentage	Breeding date, pregnancy date, lambing percentage, culling date	
Animal production	Not required	Milk, meat and wool production per animal type and category	Milk, meat and wool production per animal type and category	
Farm location	Not required	Not required	Required (*)	*If the method includes an algorithm for estimating N_2O EF for urine and/or fertiliser based on soil and climate
Topography	Not required (assumes flat)	Area of farm in different slope classes (flat/low slope; medium/steep slopes)	Area of farm in different slope classes (flat/low slope; medium/steep slopes)	
Type of manure applied to land	Not required	Not required	Effluent, solid manure, slurry storage	

Method component	Method: Simple	Intermediate (required on annual basis)	Detailed (required on monthly basis)	Notes
Manure application method	Not required (surface assumed)	Not required (surface assumed)	Surface or incorporation	Incorporation of manure reduces NH_3 volatilisation: relevant for cropping
Fertiliser type	Total synthetic N (product tonnage) split into urea and non-urea	Total synthetic N (product tonnage) split into urea, non-urea, urea + urease inhibitor	Monthly total synthetic N (product tonnage) split into urea, non-urea, urea + urease inhibitor	Detailed: captures different EF (direct N_2O) or FracGASF (indirect N_2O) values for the three fertiliser types
Fertiliser application method	Surface assumed	Surface or incorporation	Surface or incorporation	Incorporation of urea reduces NH_3 volatilisation: relevant for cropping

3.10 Summary of Mitigations captured (relevant to Intermediate and Detailed only)

Mitigation availability	Intermediate	Detailed
Current		
		Low CH_4 forages: Adjusted default for CH_4 EF per kg DMI
		Low N_2O forages: Adjusted monthly N excretion per animal type, age and sex; Adjusted monthly N leach
	Urea + urease inhibitor; Fertiliser incorporation: Adjusted default for indirect (ammonia) loss	Urea + urease inhibitor; Fertiliser incorporation: Adjusted default for indirect (ammonia) loss
Future proofing		
		Low CH_4 sheep, cattle: Adjusted default for CH_4 EF per kg DMI*
		Low N_2O cattle: Adjusted monthly N excretion
	Nitrification inhibitors: Adjusted default N_2O EF and annual N leaching for urine, dung, manure application and N fertiliser	Nitrification inhibitors: Adjusted default N_2O EF and monthly N leaching for urine and dung per forage type; and for manure application and N fertiliser
	Effluent ponds: CH_4 flaring to CO_2; CH_4 biogas harnessing for energy source: Adjusted default for amount of CH_4 emitted.	Effluent ponds: CH_4 flaring to CO_2; CH_4 biogas harnessing for energy source: Adjusted default for amount of CH_4 emitted.
	Covered manure stores: Adjusted default for indirect (ammonia) loss	Covered manure stores: Adjusted default for indirect (ammonia) loss

* Includes CH_4 vaccines and inhibitors. Breeding values (BV) for low CH_4 sheep integrate the effect of low CH_4 per kg DMI and increased feed efficiency (less DMI per unit of production). The proposed method for capturing low CH_4 sheep in GHG calculations is to convert BV to an adjusted CH_4 emitted per DMI; in future, BV may be separated into an adjusted CH_4 and increased feed efficiency

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