Final report

Red meat greenhouse gas emissions update 2023

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Abstract

This report provides updated estimates of emissions attributable to the Australian red meat industry based on the 2023 Australian National Greenhouse Gas Inventory. The report presents greenhouse gas emissions for beef cattle, sheep meat and goats in 2023, and recalculates emissions from 2005-2022 using current inventory data.

In 2023, net greenhouse gas emissions from the red meat industry were 45.8 Mt CO_2-equivalents representing a 70% decrease compared with the reference year of 2005 when total emissions were 154 Mt CO_2-equivalents. This decrease is primarily due to a reduction in clearing of forest and sparse woody vegetation, and an increase in vegetation growth and carbon storage.

The majority of emissions in 2023 are associated with enteric methane produced by grazing beef cattle. These are partially offset by emissions removals within grazing landscapes, with land grazed by livestock currently an emissions sink.

Executive summary

Background

Understanding the sources of, and changes in, greenhouse gas emissions from red meat production is important to help the red meat industry achieve its sustainability goals. In a previous project (B.CCH.7714), a method was developed to quantify greenhouse gas emissions from red meat production based on data from the Australian National Greenhouse Gas Inventory. This current project provides an updated estimate of emissions from red meat production in Australia from 2005 to 2023.

Objectives

- Calculate greenhouse gas emissions from the Australian red meat industry using data from the 2023 Australian National Inventory (GWP100, AR5 values), including:
    - sources of emissions
    - contribution to total national emissions
    - emissions by commodity; cattle, sheep meat and goats
    - emissions by sector; farm, feedlot, and processing
- Calculate total greenhouse gas emissions from the Australian red meat industry using GWP20, GTP100, GTP20, direct methane, GWP* and radiative forcing
- Report livestock numbers and red meat production volumes

Methodology

Emissions from Australia's National Greenhouse Accounts 2023 Paris Agreement Inventory were allocated to beef cattle (on pasture and in feedlots), sheep meat and goats based on animal numbers, resource use and processing volumes.

Results/key findings

Emissions from the Australian red meat industry in 2023 were 45.8 Mt CO_2-equivalents. The biggest source of emissions is enteric methane fermentation, particularly from grazing beef cattle. These emissions are partially offset by removals from grazing landscapes.

Net emissions from the red meat industry have decreased by 70% since 2005. These changes are largely due to a reduction in the clearing and reclearing of forest and sparse woody vegetation, and an increase in vegetation growth and carbon storage.

Benefits to industry

Annual reporting enables understanding of the red meat industries net emissions profile and contribution to national emissions, and can inform research and development priorities, as well as other strategic actions.

Future research and recommendations

The report provides recommendations of data that would improve the accuracy of these calculations, and capture improvements in efficiency made on-farm and in feedlots.

Acknowledgements

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1. Background

The Australian red meat industry is a source of greenhouse gas emissions that contribute to climate change. These include emissions from enteric fermentation, the degradation of animal waste, production of feed, land use change and processing of meat. With livestock managed over half the Australian continent (Australian Bureau of Statistics 2024), there is also an opportunity for extensive livestock systems to offset emissions through the storage of carbon in the soils and vegetation that comprise grazing landscapes.

As part of its sustainability goals and contributions to the Australian beef and sheep sustainability frameworks, the red meat industry has been benchmarking its greenhouse gas emissions footprint annually since 2015.

This report provides an update of greenhouse gas emissions (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)) from the Australian red meat sector based on the 2022-23 Paris Agreement Inventory (hereafter referred to as the *National Inventory*) published by Australia's National Greenhouse Accounts (Australian Government 2025a).

2. Objectives

1. Calculate the 100-year Global Warming Potential (GWP100) greenhouse gas footprint of the Australian red meat production for 2023 including:
   a. sources of emissions
   b. contribution to national emissions
   c. emissions by commodity; cattle, sheep meat and goats
   d. emissions by sector; farm, feedlot, and processing
2. Calculate the GWP20, Global Temperature Potential (GTP)100, GTP20, as per previous years' reporting
3. Calculate total red meat sector emissions using direct methane (i.e., tonnes CH_4), GWP* and radiative forcing
4. Report livestock numbers and red meat production volumes

3. Methodology

3.1 Scope of reporting

This report provides an estimate of greenhouse gas emissions attributable to the red meat industry from 2004-05 to 2022-23. The scope of this assessment includes the domestic production and processing of beef cattle, sheep meat and goats. Emissions from dairy cattle[1], buffalo, wool production and wild-harvested animals (i.e., those not included in ABS livestock population data) were not included as part of the red meat sector. Offshore emissions from the transport, production and processing of live animals and red meat products after they left Australia were also excluded.

A chart of accounts is included in Appendix 8.2, but in summary, emissions and removals from the following sources are included:

- Scope 1
  - enteric fermentation
  - manure management
  - agricultural soils, both direct and indirect soil emissions from grazing lands and the fraction of croplands used to support the production of feedlot rations
  - field burning of agricultural (crop and pasture) residues
  - liming and urea applications
  - land use and land use change relating to cropland, grassland and forest available for grazing
- Scope 2 & 3
  - electricity and fuel use on farms, in feedlots and in processing

Specific gaps in this approach are identified in the chart of accounts. Due to data limitations, this analysis does not include scope 2 and 3 emissions associated with domestic transport of livestock, cropland used to produce grain fed to livestock outside of feedlots (e.g., confinement fed sheep), manufacture and transport of feed (e.g., hay and silage), manufacture and transport of fertiliser and other farming inputs, provision of services (e.g., insurance, consultants), capital goods (e.g., sheds, tractors) and waste disposal (e.g., compositing, landfill).

3.2Data sources and allocation of emissions to the red meat industry

The report builds on the methods used in previous reporting periods (Mayberry 2024) and also seeks to align this approach with the Common Approach to Greenhouse Gas Accounting (Sevenster *et al.* 2023). The Common Approach provides aspirational, best-practice guidance for sector-level greenhouse gas accounting and aims to guide improvements in data collection and reporting across Australia's agricultural sectors over time.

Calculations used in this report are based primarily on emissions reported by the Australian National Inventory, supplemented by other data on livestock populations and processing (Table 1). The Paris Agreement Inventory uses GWP100 values from the Fifth Assessment Report (AR5) and reports against the United Nations Framework Convention on Climate Change (UNFCCC) sectors. The Australian Government Department of Climate Change, Energy, the Environment and Water (DCCEEW) review and update activity data and the inventory methodology on an annual basis, and

[1] milking cows, cull dairy cows, replacement heifers, bobby calves/vealers and dairy bulls

changes are applied retrospectively to previous years. Thus, the 2023 National Inventory and this report both supersede previous iterations.

Table 1. Key datasets used in this analysis

Data type	Activity data	How used in calculation	Source
General	Australia's National Greenhouse Accounts Paris Agreement inventory	Base data for calculations	Australia's National Greenhouse Accounts (Australian Government 2025a)
Livestock production	Beef produced	Emissions from processing	ABS Livestock Products, Table 9. Red meat produced – beef (Australian Bureau of Statistics 2025b)
	Sheep meat produced	Meat-wool allocation; emissions from processing	ABS Livestock Products, Table 11. Red meat produced – mutton, Table 12. Red meat produced – lamb (Australian Bureau of Statistics 2025b)
	Number of sheep live exported	Meat-wool allocation	2002-2023 from MLA markets via direct request; 1990-2001 from ABS (Australian Bureau of Statistics 2019)
	Wool yields	Meat-wool allocation	1992-2023 AWI wool yield data (Australian Wool Innovation 2025); 1990-1991 ABS Livestock products, Table 16. Brokers and dealers receivals of taxable wool (Australian Bureau of Statistics 2022)
	Feedlot activity data (number cattle, liveweight gain, days on feed)	Allocation of cropland to feedlot	National Inventory Report (Australian Government 2025d)
	Feed intake by sheep, beef cattle and dairy cattle	Relative grazing pressure of different species	Provided by DCCEEW National Inventory team
	Livestock populations (cattle, sheep, goats, horses, deer, buffalo, donkeys/mules, alpacas, camels)	Relative grazing pressure of different species	National Greenhouse Accounts Activity tables. Livestock National (Australian Government 2025a)
Land and resource use	Area of cropland	Allocation of cropland to feedlot	Area of cropland, Table 6.2.2 (Australian Government 2025c)
	Area of irrigated pasture	Allocation of irrigated pasture emissions to red meat	Water Account, Australia (Australian Bureau of Statistics 2017)
	Lime and urea use on crop and pasture land	Allocation of lime and urea emissions to species	ABS Agricultural resource management practices (Australian Bureau of Statistics 2014)
	LULUCF emissions attributed to grazing	Allocation of LULUCF emissions to beef and sheep meat	National Greenhouse Accounts Activity tables. National Inventory by Economic Sector 2023-Data Tables 11-19A (Australian Government 2025a)

Under the Paris Agreement, emissions are reported for energy, industrial processes, agriculture, land use land use change and forestry (LULUCF) and waste. Most emissions from the red meat industry are from the agriculture and LULUCF sectors, with small contributions from the energy sector. Emissions reported by the National Inventory are allocated to the red meat industry based on animal numbers, feed intake, meat production and resource use as described by Mayberry *et al.* (2018). A broad summary of how emissions are allocated to the red meat industry is provided below, with details related to specific emissions categories in Table 2. For more details on the methods and data used by DCCEEW to calculate emissions, readers are referred to the National Inventory Reports (Australian Government 2025c; Australian Government 2025d).

Allocation of emissions between livestock species

The National Inventory reports emissions associated with livestock activities (enteric methane, manure management and degradation of urine and faeces in the field) for each species, and separates cattle into dairy cattle, beef cattle on pasture and beef cattle in feedlots. All emissions from beef cattle on pasture, beef cattle in feedlots and goats were reported directly from the inventory.

The national sheep flock produces both meat and wool, and emissions were attributed to either commodity using the protein mass allocation method (Wiedemann *et al.* 2015). This method calculates the amount of protein in animal liveweight and wool based on the volume of mutton and lamb produced (Australian Bureau of Statistics 2025b), gross weight of live export sheep (Australian Bureau of Statistics 2019; MLA Marketing team) and greasy wool yields (Australian Bureau of Statistics 2022; Australian Wool Innovation 2025). In 2023, 64% of protein produced by sheep was in meat and 36% in wool. The proportion of protein in meat (i.e., 0.64 in 2023) was applied to total sheep emissions to calculate emissions from sheep meat. Because the amount of meat and wool produced varies between years, this calculation was repeated for each year of data.

While goats also produce multiple commodities, insufficient data is available to disaggregate emissions between goat meat, dairy and fibre production.

Attribution of cropland emissions to red meat

Cropland is used to produce grain fed to cattle in feedlots, with emissions associated with soil tillage, application of fertilisers, degradation of organic matter, fire and land clearing. The area of cropland used to support feedlot cattle production was estimated based on Wiedemann *et al.* (2017), who report average area of cropland per kg liveweight gain for cattle in Australian feedlots. Area of cropland used to produce grain for feedlot cattle was calculated based on the number of cattle in feedlots, days on feed and average daily liveweight gain (Australian Government 2025d). This was divided by the total cropland area (Australian Government 2025c) to provide the proportion of cropland that contributes to feedlot cattle production. This proportion was then applied to all cropland emissions in the inventory (from Agriculture and LULUCF sectors) to estimate cropland emissions attributable to red meat production.

Grain is also fed to grazing livestock in some years and regions. Emissions associated with cropland use from grazing animals were not included in this assessment due to lack of data on supplementation rates. This data gap could be filled through farm surveys, expert consultation or gross margin budgets.

Proportion of grazing lands used for beef, sheep-meat and goat production

Emissions from grazed lands (including pasture and forages sown on cropland), grasslands and forests include emissions from application of fertiliser, degradation of organic matter, fire and land clearing. Grasslands and forest lands can also be a carbon sink, with carbon stored in above and below ground biomass. These emissions are reported by the National Inventory under the Agriculture and LULUCF sectors and are allocated to the red meat industry on a state/territory basis as described below.

Irrigated pasture – direct soil emissions and atmospheric deposition

The proportion of emissions from irrigated pasture (direct soil emissions and atmospheric deposition from fertiliser applied to pasture) allocated to red meat is calculated based on the proportion of irrigated pastureland used by beef cattle and sheep. The Australian Bureau of Statistics previously reported time-series data for the area of irrigated land used for various activities including *dairy production*, *production from meat cattle* and *production from sheep and other livestock* from 2009 until 2016 (Australian Bureau of Statistics 2017). For years where data was available, the proportion of irrigated pastureland used for *production from meat cattle* in each state/territory was applied to the National Inventory emissions from irrigated pastures to calculate beef cattle emissions from irrigated pastures. The same process was used to calculate emissions from sheep grazing irrigated pastures, except that the area of irrigated pasture used for *sheep and other livestock* is not able to be further disaggregated, and the entire area is allocated to sheep, then corrected for co-production of meat and wool as described above. While this may overestimate the area of irrigated pasture used for sheep production, the total emissions from irrigated pastures are small and this has minimal impact on the emissions included in the red meat inventory. Proportions of irrigated pasture used for beef or sheep production in 2009 were applied to earlier years, and proportions of irrigated pasture in 2016 were applied to later years.

Updated data on the area of irrigated pasture used by different livestock would improve this allocation.

Non-irrigated pasture – direct soil emissions and atmospheric deposition

Direct and indirect emissions from non-irrigated pastures (direct soil emissions from pasture residues, direct soil emissions and atmospheric deposition from fertiliser applied to pasture) reported under the Agriculture sector are allocated to the red meat industry based on relative feed intake.

Total pasture intake of grazing animals was estimated as follows. Total feed intake of beef cattle, dairy cattle and sheep was taken from time-series spreadsheets provided by DCCEEW, and it was assumed that beef cattle and sheep consume 100% pasture and that feed intake of dairy cattle is 60% pasture (Dairy Australia 2024; Gollnow *et al.* 2014). Feed intake of goats was estimated using goat population data reported by the National Inventory (Australian Government 2025d), and assuming an average liveweight of 38.5 kg (Australian Government 2025c) and pasture intake of 2% liveweight. Feed intake of other grazing species (horses, deer, buffalo, donkeys/mules, alpacas, camels) was estimated using livestock population data from the National Inventory (Australian Government 2025d), default liveweight values provided by the IPCC (Gavrilova *et al.* 2019) and assuming pasture intake of 2% liveweight.

The proportion of pasture intake for beef cattle, sheep and goats was applied to National Inventory emissions from non-irrigated pastures to calculate emissions attributable to red meat. The proportion of grazing land used for sheep production is corrected for co-production of meat and wool as outlined above.

Leaching emissions from irrigated and non-irrigated pasture

Emissions from leaching are climate dependent, and proportionally much greater on dairy land compared to pastures grazed by beef cattle, sheep and goats (Australian Government 2025d). Following advice from DCCEEW, indirect emissions from N leaching and runoff from pastures were allocated to beef cattle, sheep and goats based on the proportion of indirect leaching emissions from manure for each species.

LULUCF

Emissions from grazing that occur under LULUCF are now reported directly by the National Inventory in the National Inventory by Economic Sector Data Tables (Australian Government 2025a). This includes relevant emissions from grasslands, forest land, cropland and wetlands. The proportion of LULUCF grazing emissions attributed to red meat production were calculated based on relative feed intake of beef cattle, sheep and goats as per the process used for non-irrigated pastures.

Energy use on farm, in-feedlots and in processing

General energy use in feedlots was calculated based on energy required per 1000-head day (Wiedemann *et al.* 2017), number of cattle in feedlots and days on feed (Australian Government 2025d). Energy used for feed milling and delivery was calculated based on energy required per tonne of feed (Wiedemann *et al.* 2017) and feed intake.

On-farm energy use for beef cattle was calculated based on tonnes of dry matter intake (Wiedemann *et al.* 2016) and numbers of animals. On-farm energy use for sheep was calculated based on energy per 1000 ewes joined (Wiedemann *et al.* 2015) and number of breeding ewes, then attributed to either meat or wool production based on the protein mass allocation method described above.

Greenhouse gas emissions from energy use in feedlots and on-farm were calculated based on energy content and emissions factors of electricity, gas, petrol, and diesel (DCCEEW 2022; DCCEEW 2023; DCCEEW 2024; DISER 2021).

Energy use from processing was calculated based on reported emissions per tonne red meat and the proportion of emissions attributed to energy consumption (All Energy Pty Ltd 2021; Ridoutt 2025; Ridoutt *et al.* 2015; Ridoutt and Sikes 2023), and volume of meat produced (Australian Bureau of Statistics 2025b). The method accounts for improvements in processing efficiency captured in the Red Meat Processing Sector Environmental Performance Reviews conducted every 2-5 years.

Table 2. Overview of methods used in the Paris Agreement Inventory (Australian Government 2025c), and the basis of allocation of these emissions to the red meat industry.

Emissions source	Emissions relevant to red meat production	National inventory method	Allocation of emissions to the red meat industry
Agriculture			
Enteric methane	Methane produced as a by-product of digestion by ruminants	Emissions from cattle and sheep are based on estimated dry matter intake of livestock in each season (summer, autumn, winter, spring). Emissions from goats are calculated as using average emissions of 5kg CH_4/head/year.	All emissions from beef cattle feedlot, beef cattle pasture and goats were reported directly from the national inventory. Emissions from sheep were corrected for the co-production of meat and wool. Emissions from all other livestock were excluded.
Manure management	Methane from decomposition of organic matter under anaerobic conditions; N_2O from deposition of N volatilized from manure management systems	Based on estimated manure production and N excreted in faeces and urine	All emissions from beef cattle feedlot, beef cattle pasture and goats were reported directly from the national inventory. Emissions from sheep were corrected for the co-production of meat and wool. Emissions from all other were livestock excluded.
Agricultural soils	Direct and indirect emissions of N_2O from soils following application of fertiliser to crops and pastures, urine and dung deposited by grazing animals, decomposition of crop and pasture residues, mineralisation due to loss of soil carbon, and cultivation of histols.	Based on volume of inorganic or organic fertiliser applied to soil, and volume of faeces and urine excreted by grazing animals	Direct emissions from animal waste applied to soils (beef cattle – feedlot) and direct and indirect emissions from urine and dung from beef cattle and goats were reported directly from the national inventory. Emissions from sheep were corrected for the co-production of meat and wool. Emissions from all other livestock were excluded. Direct and indirect emissions from cropland were included based on the proportion of cropland required to supply grain to feedlots. Direct and indirect emissions from pasture were calculated based on the proportion of pasture used for beef, sheep meat and goat production. The area of pasture used for sheep production was corrected for the co-production of meat and wool.
Field burning of agricultural residues	Methane and N_2O emissions from stubble burning	Based on annual crop production, amount of crop residue remaining after harvest/grazing, fraction of annual crop that is burnt, and burning efficiency.	Emissions were included based on the proportion of cropland required to supply feedlots.

Liming	CO_2 emissions from reaction of carbonates with acids in soil.	Volume of lime and dolomite applied to soils multiplied by default IPCC emissions factors	The proportion of emissions attributed to red meat was calculated based on the proportion of lime and dolomite used for beef and sheep farming compared to other agricultural sectors. Volume of lime used for sheep farming was corrected for the co-production of meat and wool.
Urea application	Loss of CO_2 fixed in urea during the manufacturing process.	Volume of urea applied to soils multiplied by IPCC default emissions factor.	The proportion of emissions attributed to red meat was calculated based on the proportion of urea fertiliser used for beef and sheep farming compared to other agricultural sectors. Volume of urea fertiliser used for sheep farming was corrected for the co-production of meat and wool.
Land use, land use change and forestry			
Forest land	Emissions from burning, land clearing and soils; carbon storage in growth of woody vegetation.	Carbon stock changes and emissions are modelled using the Full Carbon Accounting Model (FullCAM) using spatial data on land use, land clearing, forest planting, natural regeneration and the area, timing of prescribed burns and wildfires, area under grazing and grazing intensity. The modelling accounts for spatial and temporal variations in climate, soil and vegetation.	The National Inventory provides data on total LULUCF emissions attributed to grazing and cropping on a national and state/territory basis. Within each state or territory, emissions from grazing were attributed to beef cattle, sheep or goats based on relative feed intake. The area of grazing land used for sheep production was corrected for the co-production of meat and wool. Emissions from cropping were attributed to beef cattle – feedlot based on the proportion of cropland required to supply grain to feedlots.
Cropland	Emissions from changes in management practices from changes in crop type and land use.		
Grassland	Emissions from changes in fire management, grazing intensity, presence of sparse woody vegetation and land clearing.		
Wetland	Methane emissions from farm dams and ponded pastures		

3.3 Analysis of emissions

Unless otherwise stated, emissions in this report are presented as Mt of CO_2-e per financial year, calculated using GWP100 values from the AR5 report (Table 3). This is consistent with national reporting by the Australian Government, and in line with recommendations from the Common Approach to Greenhouse Gas Accounting (Sevenster *et al.* 2023).

The CO_2-e metric allows comparison between different gases by indicating the amount of energy each gas absorbs relative to CO_2 (Lynch 2019). There are several different CO_2-e metrics that can be expressed over different timescales; usually 20 or 100 years (Table 3). Emissions can also be reported using the GWP* and radiative forcing metrics, which are described in more detail below. These alternative metrics can be used for sensitivity assessments based on their relevance for specific sector objectives (Sevenster *et al.* 2023) but are not currently recommended for primary reporting purposes.

Table 3. Global warming and global temperature potentials used in presentation of emissions results. Values are exclusive of climate-carbon feedbacks (Myhre et al. 2013). Values used in the 2023 Paris Agreement Inventory and this report are highlighted in grey.

	GWP100 AR6[1]	GWP100 AR5	GWP20 AR5	GTP100 AR5	GTP20 AR5
CO_2	1	1	1	1	1
CH_4	27	28	84	4	67
N_2O	273	265	264	234	277

[1] The IPCC Sixth Assessment Report (AR6; (Forster et al. 2021)) uses updated GWP100 values, including the differentiation between CH4 from fossil and non-fossil origins. The fossil GWP value (30) is applied to fossil fuel fugitive emission sources such as coal mining, and industrial processes where the carbon within methane is of fossil origin (Greenhouse Gas Protocol 2024). All other sources of methane emissions, including from the combustion of fossil fuels, use the non-fossil GWP value (27). These values are not yet used in Australia's National Inventory.

Global warming potential; GWP100 and GWP20

GWP is the most widespread CO_2-e and is a measure of how much energy a greenhouse gas traps in the atmosphere over a given time period relative to CO_2. It is calculated by multiplying the volume of each gas by the GWP metric (Table 3).

GWP*

The GWP* climate metric assesses the future warming potential associated with a permanent change in the rate of emission of short-lived greenhouse gases such as CH_4. To quantify the change in rate, emissions need to be assessed over a time interval. The developers of GWP* use a 20-year time interval, arguing that this smooths out short-term fluctuations in emission rates that may not reflect permanent change (Allen *et al.* 2018). The GWP* result for methane was calculated following Smith *et al.* (2021) and using the AR5 GWP100 values in Table 3.

$$Emissions = 1.13\frac{r \cdot H \cdot \Delta E(t)}{\Delta t} + 1.13 \cdot s \cdot E(t)$$

Where:

r = represents the response to changing emission flow or *rates*; 0.75

s = represents the long-term equilibration of emission *stocks*; 0.25

H = time horizon used for GWP calculations; 100 years

ΔE(t) = change in emissions over 20 years, calculated using GWP100

Δt = time period of interest; 20 years

E(t) = emissions in current year, calculated using GWP100

Long-lived greenhouse gases, namely CO_2 and N_2O, were assessed using the conventional GWP100 metric values of 1 and 265 (Myhre *et al.* 2013). Results were reported as CO_2-equivalent emissions by combining the amounts of all three gases.

Global Temperature change Potential; GTP100 and GTP20

The 100-year and 20-year GTP (GTP100 and GTP20, respectively) reports the modelled change in global mean surface temperature at a point in time 100 or 20 years after a pulse emission. GTP is calculated as for GWP, using the AR5 values in Table 3.

Radiative forcing climate footprint

The radiative forcing footprint combines radiative forcing from current year emissions and the radiative forcing from historical emissions remaining in the atmosphere (Ridoutt 2021). Due to their long lifetime, historical emissions of CO_2 and N_2O are highly important as they accumulate over time. Methane emissions have a much shorter atmospheric lifetime and the radiative forcing curve from a pulse emission decays comparatively quickly. The profile of radiative forcing over time informs about whether progress is being made toward radiative forcing stabilisation, which is a requirement for climate stabilization. In this study, the radiative forcing associated with a pulse emission was calculated using parameters and equations reported in Myhre *et al.* (2013). The warming potential of emissions (radiative forcing) is reported as milli watts per square meter (mW/m^2).

3.4 Changes since the last report and anticipated changes to future reporting

Changes to National Inventory methods

In line with their international reporting requirements, DCCEEW reviews and updates the methods and data used to calculate national emissions every year. These revisions improve the accuracy of reported emissions and are applied retrospectively to previous inventories. Changes to the National Inventory that are of relevance to the red meat industry reporting are summarised in Table 4, with planned improvements that may be implemented in future inventory releases also highlighted.

The most important changes in the 2023 report relate to national cattle population data and the equations used to calculate emissions from feedlot cattle.

The 2023 National Inventory uses cattle population data from the ABS (Australian Bureau of Statistics 2025a). The larger cattle population compared to previous years means that emissions associated with beef cattle grazing pasture have increased. There have been no changes to the data on feedlot cattle populations. Updated sheep population data are expected to be released in late 2025 and may be included in the 2024 inventory.

The method used by the National Inventory to calculate enteric methane from feedlot cattle has been updated based on Almeida *et al.* (2025). The new equation is based on measurement studies from beef cattle fed typical Australian feedlot diets. This has resulted in lower enteric methane emissions reported for the feedlot sector compared to previous years. The inventory also uses new data on feed intake and dietary characteristics provided by MLA, which have reduced estimates of emissions from manure management.

Changes to allocation of emissions to the red meat sector

The biggest change in attribution of emissions to the red meat sector in this report is the allocation of LULUCF emissions to the grazing sector. In previous reports, it was assumed that all grasslands were used for grazing by livestock and that approximately 68% of ‘other native forests’ (forest land excluding plantations, harvested forests and protected areas) were available for grazing (Mayberry 2024). The first assumption overestimates the area of grasslands used for livestock production and the accuracy of the second assumption is also low. This year, the National Inventory directly reported LULUCF emissions from cropping, grazing, aquaculture, forestry, conservation and other land uses in the National Inventory by Economic Sector data tables (Australian Government 2025a). This provides a more accurate estimate of emissions from the LULUCF sector attributable to livestock production. However, emissions are not disaggregated into those from different land types and practices such as *grasslands remaining grasslands* or *forest land converted to grassland.* Nor are the emissions for each gas provided. Details on how emissions are allocated is available online from Australian Government (2025b).

Minor improvements have also been made this year in the allocation of grazing land emissions between beef cattle, sheep meat and goats by accounting for the pasture consumption of equids, camelids, deer and buffalo. The impact on total emissions attributed to red meat is small.

Table 4. A summary of relevant changes to national inventory calculations in 2022-23 and planned improvements described in the National Inventory report (Australian Government 2025c).

Source	Changes this year	Planned improvements
Enteric methane	• Updated beef cattle pasture numbers • Updated equation for feedlot cattle	• Review methods and parameters to estimate enteric methane from sheep • Periodic review of feed and animal characteristics • Updated sheep population data from ABS • Review of feedlot cattle activity data
Manure management	• Updated beef cattle pasture numbers • Updated data on feedlot cattle intake and diet characteristics	• Revise method to calculate N_2O emissions from manure mass • Updated sheep population data from ABS
Agricultural soils	• Updated beef cattle pasture numbers (which impacts emissions from urine and dung deposited by grazing animals) • Changes to calculation of leaching area (which impacts indirect soil emissions) • Revisions to soil carbon losses for N mineralisation	• Updated sheep population data from ABS • Improved source data on emissions factors for inorganic fertilisers • Consider disaggregation of emissions factors for urea and non-urea fertilisers
Field burning ag residues	None	None
Liming	None	• Alternative sources of activity data will be investigated
Urea application	None	• Investigate use of country specific emissions factors
Forest land	• Updated climate, forest harvest and fire time series data • Refinements to non-temperate fire model	• Improved calibrations for forest growth and disturbance • Improved methods to measure forest cover change
Cropland	• Updated time series data on climate, fire, crop and grass yields	• Refined spatial allocation of crop species and yields • Improved modelling of below ground debris pool • Improved estimated of tillage impacts • Review of stubble management practices • Improved calibrations for forest growth and disturbance • Improved methods to measure forest cover change
Grassland	• Updated time series data on climate, fire, crop and grass yields • Refinements to non-temperate fire model	• Improvements to FullCAM model to better reflect impact of grazing pressure • Improved resolution of forest change data • Improved calibrations for forest growth and disturbance
Wetlands (farm dams & ponded pasture)	• Updated methods to estimate emissions from other constructed water bodies	• Improvements to reservoir model

4. Results

4.1 Emissions reported using GWP100 values

Total net greenhouse gas emissions attributable to the Australian red meat industry in 2023 were 45.8 Mt CO_2-e, and 10% of national greenhouse gas emissions (Table 5). Since 2005, emissions from the red meat industry have decreased, both in absolute terms (by 70% and 108 Mt CO_2-e), and as a proportion of national emissions. Net emissions from the red meat industry were lowest in 2021 (37 Mt CO_2-e) and have risen in the past two years.

On a species basis, the majority (84%) of emissions attributed to the red meat industry are from beef cattle production (Table 6 and 7), reflecting the large volume of enteric methane produced and area of land used for grazing. This is supported by the dominance of on-farm emissions, compared to those from feedlots and processing (Table 8).

Table 5. Greenhouse gas emissions from the Australian red meat sector. Values are Mt CO_2 equivalents calculated using GWP100 values from the AR5 report.

Source	2005	2020	2021	2022	2023
Agriculture	56.9	51.5	53.6	54.3	57.4
Enteric fermentation	*48.3*	*43.1*	*44.9*	*45.3*	*48.0*
Manure management	*4.24*	*4.07*	*4.16*	*4.20*	*4.39*
Agricultural soils	*3.85*	*3.79*	*3.95*	*4.09*	*4.28*
Field burning of agricultural residues	*0.01*	*0.01*	*0.02*	*0.02*	*0.02*
Liming and urea	*0.42*	*0.58*	*0.62*	*0.64*	*0.67*
Land use, land use change and forestry	93.8	3.82	-19.1	-17.8	-14.2
Energy	3.01	2.61	2.52	2.60	2.62
Farm and feedlot	*1.55*	*1.40*	*1.43*	*1.46*	*1.54*
Processing	*1.46*	*1.21*	*1.09*	*1.14*	*1.08*
Total red meat emissions	***154***	***57.9***	***37.0***	***39.1***	***45.8***
Total national emissions	612	478	440	441	453
Proportion total national emissions (%)	25	12	8	9	10

Table 6. Greenhouse gas emissions from the Australian red meat sector by species in 2023. Values are Mt CO_2 equivalents calculated using GWP100 values from the AR5 report.

Source	Beef cattle	Sheep meat	Goats
Agriculture	46.6	10.7	0.08
Enteric fermentation	*38.9*	*9.08*	*0.06*
Manure management	*3.93*	*0.46*	*<0.01*
Agricultural soils	*3.27*	*1.00*	*0.01*
Field burning of agricultural residues	*0.02*	-	-
Liming and urea	*0.47*	*0.20*	-
Land use, land use change and forestry	-10.1	-4.1	-0.04
Energy	1.91	0.72	-
Total emissions per species	***38.4***	***7.33***	***0.04***
Proportion of red meat emissions (%)	***84***	***16***	***<1***

Table 7. Greenhouse gas emissions from the Australian red meat sector by species. Values are Mt CO_2 equivalents calculated using GWP100 values from the AR5 report.

	2005	2020	2021	2022	2023
Beef	132	49.3	32.7	33.3	38.4
Sheep meat	21.3	8.61	4.3	5.8	7.3
Goats	0.20	0.07	0.03	0.03	0.04

Table 8. Greenhouse gas emissions from the Australian red meat sector by species. Values are Mt CO_2 equivalents calculated using GWP100 values from the AR5 report.

	2005	2020	2021	2022	2023
Farm	150	55.3	34.5	36.5	43.1
Feedlot	1.62	1.46	1.40	1.49	1.57
Processing	1.46	1.21	1.09	1.14	1.08

Across all livestock types, enteric methane fermentation was the major source of emissions in 2023, contributing 48 Mt CO_2-e (Table 5). The majority (79%) of enteric methane emissions are from grazing beef cattle (37.9 Mt CO_2-e, Table 6). Enteric methane emissions from sheep meat are also an important contributor (9.1 Mt CO_2-e), whilst emissions from feedlot cattle (1 Mt CO_2-e) and goats (0.06 Mt CO_2-e) are minor.

The volume of emissions from enteric methane and manure management is directly related to national herd and flock sizes, which have been increasing since 2020 (Table 9).

While total sheep numbers were substantially higher in 2005 compared to 2023, emissions are reported here for the portion associated with sheep meat production. In 2005, 50% of sheep emissions were associated with meat production, and this has risen to 64% in 2023 following an increase in the volume of lambs slaughtered and a decrease in greasy wool production.

The increase in emissions from agricultural soils since 2005 and 2023 is associated with increasing fertiliser use and retention of crop residues (Australian Government 2025c).

Table 9. Livestock numbers and red meat production. Population data is from the National Inventory activity tables (Australian Government 2025a) and livestock products are from Australian Bureau of Statistics (2025b) and (Australian Wool Innovation 2025). Volume of goat meat produced is not reported by the ABS.

	2005	2020	2021	2022	2023
Beef					
Total beef cattle (million head)	26.4	24.2	25.3	25.4	26.7
Beef cattle pasture (million head)	25.6	23.1	24.2	24.2	25.5
Beef cattle feedlot (million annual equivalents[1])	0.82	1.11	1.06	1.19	1.16
Beef produced[2] (million tonnes)	2.13	2.35	1.92	1.87	2.00
Sheep					
Total sheep (million head)	100.7	66.7	71.4	73.8	76.2
Lamb & mutton produced (million tonnes)	0.59	0.69	0.66	0.68	0.78
Wool produced (greasy)	0.48	0.28	0.29	0.31	0.32
Goats					
Total goats (million head)	0.46	0.46	0.46	0.46	0.46

[1] Number of animals adjusted for days on feed; [2] Excluding veal

The biggest change in emissions between 2005 and 2023 has been in the LULUCF category, where net emissions have decreased from 94 Mt CO_2-e to -14 Mt CO_2-e (Table 6). Across the grazing sector this has been driven primarily by a decrease in emissions from the conversion of forest land for grazing and feed production (Appendix 8.3).

While emissions from the LULUCF category were net negative in 2023, there was a small increase in emissions from 2021 and 2022 (Table 6). This is attributed to increased emissions from fires in arid regions and reduced storage of carbon in forests and grasslands, including sparse woody vegetation (Australian Government 2025c).

These results highlight the variability of greenhouse gas emissions between years as the result of seasonal conditions. To account for this, the Common Accounting Framework (Sevenster *et al.* 2023) allows for an accounting period of 2-3 years for sheep and cattle production to reflect the production lag between good or bad seasons and stock numbers (Appendix 8.3).

4.2 Emissions reported using alternative metrics

The Paris Agreement Inventory reports emissions using GWP100 values from the AR5 report, and it is recommended that MLA also use these values in reporting emissions from the red meat industry until the National Inventory adopts the AR6 report GWP100 values.

Emissions from the red meat sector were calculated using alternative climate metrics (Table 3) for the Agriculture category only since DCCEEW does not disaggregate the LULUCF emissions by economic sector emissions by gas type. GWP* values are not available for 2005 as 20 years of data is required for the calculation. These are therefore reported from 2020 onwards.

Across the GWP and GTP metrics, emissions from the Agriculture category are strongly influenced by enteric methane emissions, and therefore animal numbers. Emissions show consistent trends and are similar in 2005 and 2023 for GWP100 (AR5, A56), GWP20, GTP100 and GTP20 (Table 10). Values are higher when a shorter time period is used (e.g., GWP20 compared to GTP100), and the GTP values are lower than GWP. GWP100 emissions calculated using the AR6 values are slightly smaller compared to those calculated using AR5 values because methane emissions are higher than those from carbon dioxide and nitrous oxide.

Table 10. Agriculture greenhouse gas emissions (excluding LULUCF and energy) from the red meat industry expressed using different climate metrics. Values for GWP and GTP are calculated using values from Table 4. GWP values for 2005 were unable to be calculated due to insufficient timeseries data.*

Metric	Unit	2005	2020	2021	2022	2023
GWP100 – AR5	CO_2-e	56.9	51.5	53.6	54.3	57.4
GWP20 – AR5	CO_2-e	162	145	151	153	162
GTP100 – AR5	CO_2-e	11.5	10.9	11.4	11.6	12.2
GTP20 – AR5	CO_2-e	130	117	122	123	130
GWP100 – AR6	CO_2-e	55.1	50.0	52.0	52.7	55.7
GWP*	CO_2-e	NA	-10.8	-1.07	0.19	23.6
Radiative forcing	mW/m^3	3.76	4.74	4.75	4.77	4.82

The GWP* emissions are not available 2005 but increase between 2020 and 2023 in response to the increasing cattle and sheep numbers.

As a short-lived but powerful climate pollutant, continued reductions in CH_4 are important to reduce global warming and supporting targets set by the Global Methane Pledge to reduce global CH_4 emissions by 30% of 2020 levels by 2030. Methane emissions from the Agriculture category of red meat emissions account for 39% of total national CH_4 emissions (Table 11). Most CH_4 emissions from the red meat industry are from enteric CH_4, and there has been a slight increase in total CH_4 emissions from the red meat industry between 2020 and 2023 in response to increasing numbers of both cattle and sheep. Methane emissions from the LULUCF category (unable to be reported here) are mostly from biomass burning (wildfires and controlled burns) with small contributions from flooded pastures and farm dams.

Large scale reductions in CH_4 emissions will require activities that reduce enteric CH_4 production. However, the industry still lacks on- or near-to-market options for direct enteric CH_4 reduction, particularly those suitable for extensive grazing industries where most CH_4 emissions originate (e.g., northern Australian beef systems). Furthermore, methodologies will be required to recognise and account for the impact of novel interventions on direct enteric methane, if these advancements are to be reflected in National Inventory's reporting of the sector.

Table 11. Methane emissions (Mt) from the red meat industry in 2020 and 2023. CO_2 equivalents are calculated using GWP100 values from the AR5 report. Emissions in 2020 are provided as the baseline for comparison in the Global Methane Pledge.

	CH_4		**CO_2-e**	
	2020	2023	2020	2023
Red meat – agriculture emissions	1.67	1.86	46.8	52.1
Total national methane emissions	4.65	4.74	130	133
% total national methane emissions	36	39	36	39

5. Conclusion

5.1 Key findings

- Greenhouse gas emissions attributed to the red meat industry in 2023 were 45.8 M CO_2-e
- Emissions attributed to the red meat industry have decreased by 70% (108 Mt CO_2-e) since 2005
- Enteric methane fermentation remains the largest source of emissions
- Emissions from the industry are balanced by removals from grazing landscapes, with grazing land a net sink for emissions since 2021
- Emissions have increased since 2021 due to a combination of increase in national herd/flock size and emissions from LULUCF
- Storage of carbon in grazing landscapes is sensitive to climatic conditions, and continued progress towards net zero goals will require a reduction in animal emissions, particularly enteric methane

5.2 Benefits to industry

Annual reporting of greenhouse gas emissions from red meat production enables MLA, and the industry more broadly, to identify the main sources of emissions, prioritise areas for further RD&E, and monitor changes over time.

6. Future research and recommendations

The following limitations of the method used to attribute emissions from the National Inventory to the red meat industry have been identified based on the Common Approach to Sector-Level Greenhouse Gas Accounting for Australian Agriculture report (Sevenster *et al.* 2023). Research and funding to address these limitations would increase the accuracy of the red meat industry greenhouse gas footprint.

- Emissions attributable to the red meat industry in this report are incomplete due to data limitations, with specific gaps identified in the chart of accounts in Appendix 8.2. Of the emissions not included, emissions from transport should be prioritized as they are likely to be the largest source of additional emissions.
- Emissions from energy and the area of cropland used to support cattle in feedlots are based on historic life cycle assessments (Wiedemann *et al.* 2017; Wiedemann *et al.* 2016; Wiedemann *et al.* 2015). The efficiency of these systems is likely to have changed since the assessments were completed. More current data would enable these improvements to be captured in reporting of emissions.
- Data on where and how goats are managed is scarce. Better data on goat populations and the volume of goat meat produced would enable more complete reporting of emissions associated with the goat industry.

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8. Appendix

8.1Common acronyms used in this report

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
AR5	IPCC Fifth Assessment Report
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent
GTP	Global Temperature Potential
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land use, land use change and forestry
N_2O	Nitrous oxide
UNFCCC	United Nations Framework Convention on Climate Change

8.2Chart of accounts for red meat greenhouse gas emissions

The following chart of accounts is based on the Common Approach to Sector-Level Greenhouse Gas Accounting for Australian Agriculture (Sevenster *et al.* 2023).

GHG Flux	Category	Source category	Item	Scope	Included in this assessment
Emissions	Agriculture	Enteric fermentation	CH4 emissions from enteric fermentation	1	Yes
		Manure management	CH4 emissions from manure management	1	Yes
			N2O emissions from manure management (direct)	1	Yes
			N2O emissions from manure management, atmospheric deposition (indirect)	1	Yes
			N2O emissions from manure management, leaching and run off (indirect)	1	Yes
		Agricultural Soils (direct)	N2O emissions- fertilisers (inorganic, organic) applied to crop	1	Yes
			N2O emissions- animal waste and sewage sludge applied to crop	1	Yes
			N2O emissions- fertilisers (inorganic, organic) applied to pasture	1	Yes
			N2O emissions- animal waste and sewage sludge applied to pasture	1	Yes
			N2O emissions- urine and dung deposited by grazing animals	1	Yes
			N2O emissions- crop residue (crops and pastures)	1	Yes
			N2O emissions from cultivation of histosols (if relevant)	1	Yes
			N2O emissions- mineralisation due to loss of soil organic carbon from cropland remaining cropland	1	Yes
		Agricultural soils (indirect)	N2O emissions – Deposition	1	Yes
			N2O emissions – Leaching and run off	1	Yes
		Residue burning	CH4 and N2O emissions from field burning of stubble	1	Yes
		Application of lime and urea	CO2 emissions - lime and urea application	1	Yes
	Energy & materials	Inputs for agricultural processes	CO2-e emissions on farm fuel use for pasture management and crop and forage production (for tractors, agricultural aircraft, harvester, etc.)	1	Yes
			CO2-e emissions grid-supplied electricity	2	Yes
			CO2-e emissions grid-supplied electricity (pre-combustion)	3	Yes
			CO2-e emissions for feed produced off farm	3	Partial. Feedlots only
			CO2-e emissions embedded in farm inputs (fertiliser, pesticides, fuel, etc.)	3	No
			CO2-e emissions transport of fuel, fertilisers, pesticides, and other inputs to farm	3	No
			CO2-e emissions-services (insurance, consultants, etc.)	3	No

	LULUCF	Forestland converted to cropland	CO_2 emission due to change in soil carbon	1	Yes
			CO_2 emission due to change in live biomass	1	Yes
			CO_2 emission due to change in dead organic matter	1	Yes
			CO_2-e emissions due to controlled burning	1	Yes
			N_2O emissions- N mineralisation associated with a change in soil organic matter	1	Yes
			N_2O emissions-Leaching and run-off from mineralised N	1	Yes
		Forestland converted to grassland	CO_2 emission due to change in soil carbon	1	Yes
			CO_2 emission due to change in live biomass	1	Yes
			CO_2 emission due to change in dead organic matter	1	Yes
			CO_2-e emissions due to controlled burning	1	Yes
			N_2O emissions- N mineralisation associated with a change in soil organic matter	1	Yes
			N_2O emissions-Leaching and run-off from mineralised N	1	Yes
			CH_4, and N_2O emissions from savanna burning	1	Yes
		Wetlands converted to cropland	CO_2-e emissions wetlands converted to cropland (crops and temporary pasture)	1	Yes
		Wetlands converted to grassland	CO_2-e emissions wetlands converted to grassland (permanent pasture)	1	Yes
		Cropland remaining cropland	CO_2 emission due to change in soil organic carbon (crops and temporary pasture)	1	Yes
		Wetlands remaining wetlands	CH_4 emission from other Constructed Water Bodies (dams)	1	Yes
		Grassland remaining grassland	CO_2 emission due to change in soil organic carbon (permanent pasture)	1	Yes
			CO_2-e emissions -Sparse woody vegetation transition (permanent pasture)	1	Yes
			CO_2-e emissions due to controlled burning (permanent pasture)	1	Yes
			N_2O emissions-N mineralization (direct) (permanent pasture)	1	Yes
			N_2O emissions-N mineralized, leaching and run off (indirect) (permanent pasture)	1	Yes
			CH_4, and N_2O emissions from savanna burning	1	Yes
	Capital goods & services		CO_2-e emissions-capital goods on farm and off-farm storage (equipment, tractor, sheds, harvester, etc.)	3	No
			CO_2-e emissions-capital goods on manufacturing stages (equipment, sheds, chiller, etc.)	3	No
	Waste treatment		CO_2-e emissions from all off-farm solid waste disposal (transport, composting, landfill)	3	No
			CO_2-e emissions from all on-farm solid waste disposal (transport, spreading, composting)	1	No

			CO2-e emissions from all wastewater disposal and treatment during manufacturing	3	No
	Energy & materials	Post farm processing	CO2-e emissions fuel use	3	Partial
			CO2-e emissions electricity use	3	Yes
			CO2-e emissions embedded in fuel used	3	Partial
			CO2-e emissions embedded in electricity supply chain	3	Partial
			CO2-e emissions embedded in material inputs (packaging, ingredients, etc)	3	No
			CO2-e emissions embedded in capital goods	3	No
			CO2-e emissions embedded in services	3	No
Removals	LULUCF	Cropland converted to forestland	CO2 removal due to change in soil organic carbon	1	Yes
			CO2 removal due to change in living biomass	1	Yes
			CO2 removal due to change in dead organic matter	1	Yes
		Grassland converted to forestland	CO2 removal due to change in soil organic carbon	1	Yes
			CO2 removal due to change in living biomass	1	Yes
			CO2 removal due to change in dead organic matter	1	Yes
		Cropland remaining cropland	CO2 removal due to change in soil organic carbon (crops and temporary pasture)	1	Yes
		Grassland remaining grassland	CO2 removal due to change in soil organic carbon (permanent pasture)	1	Yes

8.3 Supporting evidence and additional results

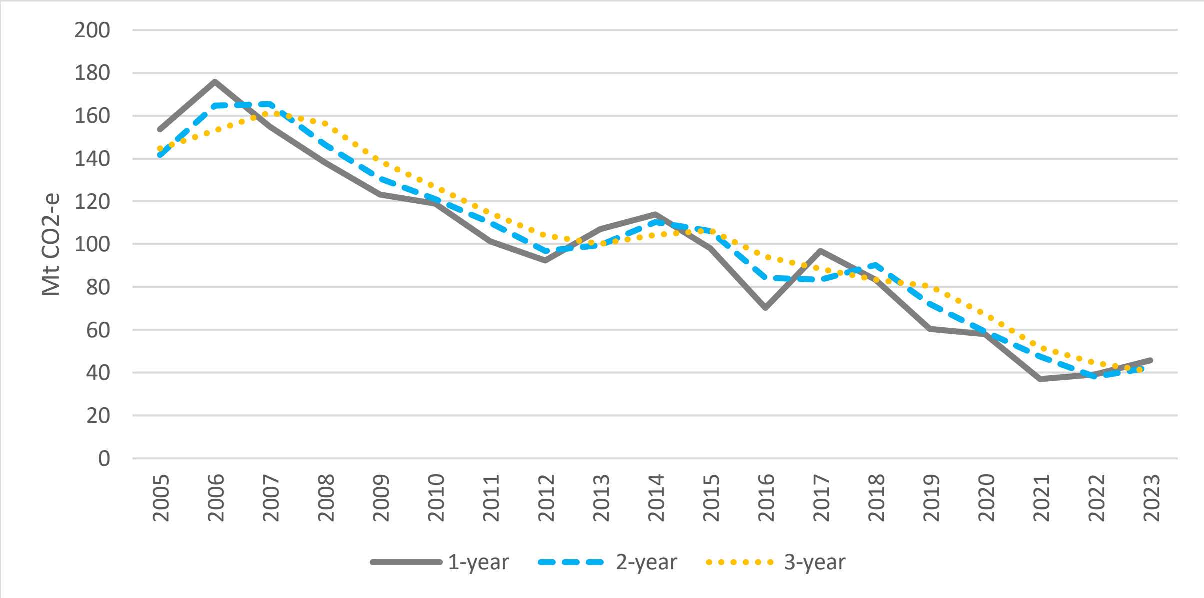

Figure 1. Net greenhouse gas emissions attributed to the red meat industry presented as annual values or 2- and 3-year rolling averages.

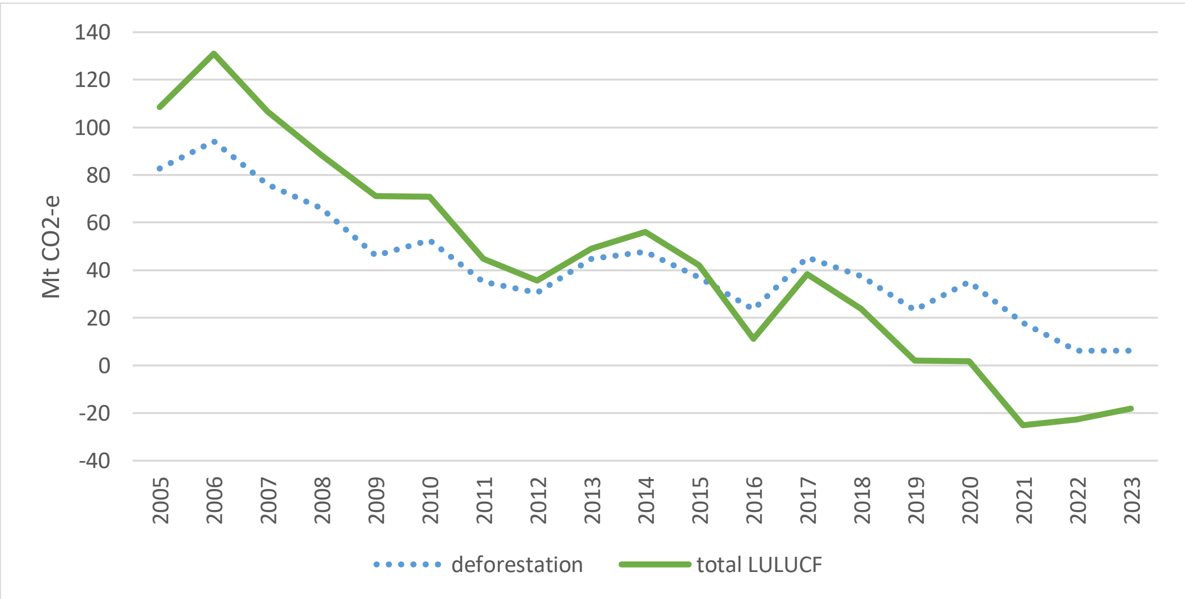

Figure 2. National LULUCF and deforestation emissions from grazing landscapes. Data is from the National Inventory by Economic Sector data tables (Australian Government 2025a) and is for all grazing systems, not just those associated with red meat production.

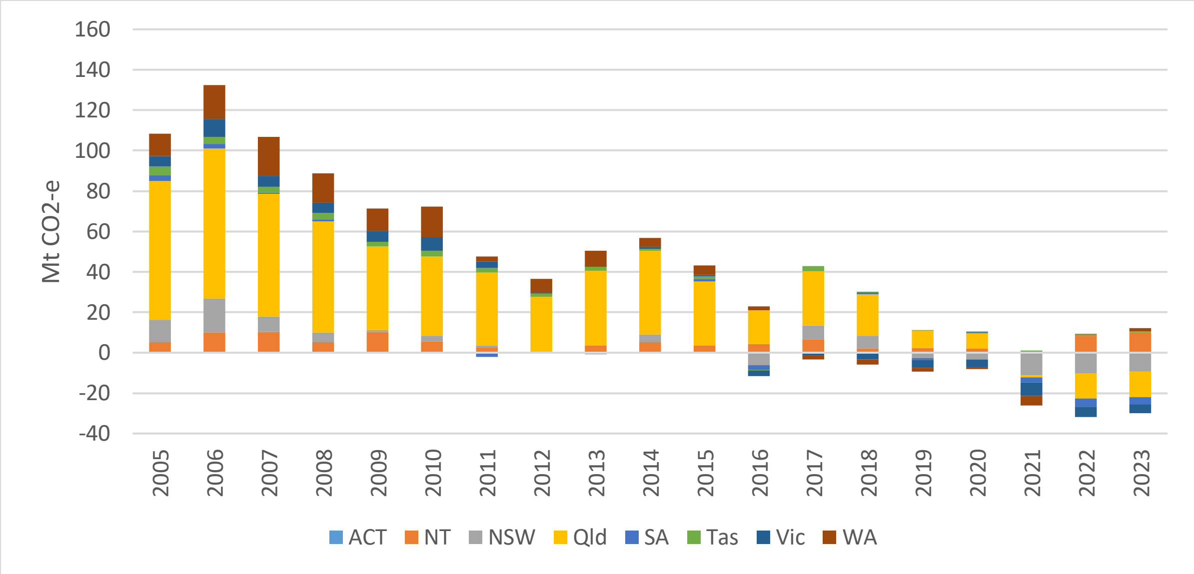

Figure 3. State and territory emissions from LULUCF on grazing lands. Data is from the National Inventory by Economic Sector data tables (Australian Government 2025a) and is for all grazing systems, not just those associated with red meat production.