Australian Dairy Carbon Calculator

Manual

Version 5

Sections 1 to 4 - Carbon accounting

November 2022

A herd of cows in a field

Description automatically generated with medium confidence

Logo, company name

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The original Australian Dairy Carbon Calculator (ADCC), previously known as the Dairy Greenhouse gas Abatement Strategies (DGAS) calculator, was developed in the late 2000’s with funding from Dairy Australia and the Australian Government Department of Agriculture, Fisheries and Forestry.

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# Australian Dairy Carbon Calculator Manual

The Australian Dairy Carbon Calculator manual contains four theme areas:

* Carbon accounting (sections 1-4),
* Australian Dairy Carbon Calculator (section 5),
* Benchmarking of Dairy Farm Monitor Project data (section 6), and
* GHG adaptation options explored in the Carbon Offset Scenario Tool (section 7)

This version of the manual only contains the carbon accounting theme (sections 1-4), along with the full listing of resources and appropriate references (sections 8 and 9). If you wish to access all or some of the other sections of the ADCC manual, you can find these on the Dairy Australia website.

# Glossary and commonly used acronyms

|  |  |
| --- | --- |
|  |  |
| 3-NOP | 3-nitrooxypropanol trading as Bovaer® |
| Abatement | Strategy to reduce net GHG emissions |
| ADCC | Australian Dairy Carbon Calculator |
| Allocation | Dairy farms produce milk and meat. ADCC allocates net GHG emissions, based on an energy allocation method, to milk and meat |
| Anthropogenic | GHG emissions caused or influenced by people, either directly or indirectly |
| AR4 | IPCC Fourth Assessment Report |
| AR5 | IPCC Fifth Assessment Report |
| Benchmarking | Comparing the performance of the enterprise against the rest of the industry |
| Carbon accounting | The process used to qualify greenhouse gas (GHG) emissions of an enterprise |
| Carbon flux | The change in carbon stocks stored in sinks over a duration, usually a yearly basis |
| Carbon footprint | Quantification of the GHG emissions emitted directly or indirectly by an individual, company, or product |
| Carbon negative/carbon positive | Condition in which net carbon dioxide equivalent emissions are negative and positive, respectively. However, these terms can be ambiguous and are sometimes used inconsistently. Therefore, the dairy industry is moving away from the use of these terms and referring to a farm as remaining either an emitter of emissions (i.e. has not attained carbon neutrality/net zero), as net zero (all emissions offset by carbon sequestration), or a beyond net zero (sequestering more carbon than emitting) |
| Carbon neutrality | Net-zero GHG emissions |
| Carbon sequestration | The process whereby carbon dioxide is removed from the atmosphere and stored in carbon sinks such as soils and vegetation |
| Carbon sink | A reservoir that absorbs carbon dioxide from the atmosphere. Natural carbon sinks include plants, soils, and oceans |
| Carbon stocks | Carbon stocks refers to the quantity of carbon that has been sequestered from the atmosphere and is stored in a carbon sink |
| CFI | Carbon Farming Initiative; the original Federal government voluntary carbon credit scheme, later replaced with the ERF and subsequently the CSF |
| CH4 | Methane |
| CO2 | Carbon dioxide |
| CO2e | Carbon dioxide equivalents (CO2e) are a unit used to compare emissions from different GHGs based on their global warming potential (GWP) over a specific timeframe, typically 100 years (GWP100) |
| COST | Carbon Offset Scenario Tool, a series of mitigation options embedded within ADCC |
| CP | Crude protein |
| CSF | Climate Solutions Fund; the Australian Government’s most recent voluntary carbon credit scheme, formerly known as the CFI and subsequently the ERF |
| DFMP | Dairy Farm Monitor Project |
| DGAS | Dairy Greenhouse gas Abatement Strategies calculator, the original name for ADCC |
| Direct N2O | Nitrous oxide lost to the environment from deposition of urine, dung, effluent, and nitrogen-based fertilisers (see indirect N2O) |
| DM | Weight of feed after all moisture is removed |
| DMD | Dry matter digestibility |
| DMI | Dry matter intake is the amount of moisture-free feed an animal consumes, usually referred to on a daily basis |
| EF | Emission factor |
| Emissions intensity | Emissions intensity (EI) is a metric based on the net GHG emissions relative to the output (e.g. kg of fat and protein corrected milk or kg liveweight). EIs allow for comparison and benchmarking between farms of different sizes and production levels |
| Energy allocation | ADCC allocated GHG emissions based on the total energy attributed to milk production versus meat production |
| Enteric methane | Enteric methane is produced through enteric fermentation when plant material is broken down in the rumen and is a by-product of this digestive process. Methane is released primarily through belching and exhalation |
| ERF | Emissions Reduction Fund is the Australian Government’s second voluntary carbon credit scheme, formerly known as the CFI and then later replaced with the CSF |
| FPCM | Fat and protein-corrected milk is a kg of milk standardised to 4.0% fat and 3.3% protein to allow comparison of milk with varying fat and protein percentages |
| GHGs | Greenhouse gases are gases that absorb and emit radiant energy. The main GHGs associated with agriculture are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) |
| Global temperature potential | Global Temperature Potential (GTP) is an alternative to GWP100 to report the warming potential of methane, based on the change in global mean surface temperature, usually on a yearly time-step |
| Global warming potential | Global warming potential (GWP) is a measure of cumulative radiative forcing, which aims to quantify the long-term contribution of a GHG to global warming. Each GHG has a specific GWP value, and this is relative to a specific timeframe |
| GWP100 | Global warming potential based on a 100-year time horizon |
| IPCC | Intergovernmental Panel on Climate Change, established in 1988 to provide scientific information on anthropogenic climate change, including the impacts, risks, and possible response options |
| Indirect N2O | A proportion of the nitrogen applied to soils via animal urine, dung, and effluent, or as nitrogen-based fertilisers, can be lost to the environment as volatilised ammonia or leaching/runoff nitrate. Over time, this nitrogen is redeposited onto soils in rainfall (volatilised N) or deposited into water courses (leached/runoff N). A proportion of this redeposited nitrogen will be transformed into nitrous oxide through the processes of nitrification and denitrification |
| K | Potassium |
| LW | Liveweight of an animal, usually reported as kgs |
| LWG | Liveweight gain of an animal, usually reported as kg/day |
| Manure | Manure is used in this manual when referring to the sum of urine and dung. At times, waste is also used as an alternative term for manure. Unless stipulated, manure refers to the sum of urine and dung deposition |
| Manure management system | Manure management system (MMS) refers to the method of handling animal manure. MMSs for dairy include directly voided onto pastures during grazing, pond/lagoons, sump/dispersal, drains to paddock daily, and solid storage |
| Methane conversion factor | Methane conversion factor (MCF) defines the proportion of methane-producing potential of each manure management system. Pond/lagoons have a higher MCF than other storage systems |
| Methane | Methane (CH4) is a GHG that is 28 times more potent than carbon dioxide over a 100-year timeframe, based on the IPCC AR5 report. Methane is released to the environment via the digestion process (enteric CH4) and with manure management (waste CH4) |
| N | Nitrogen |
| Net emissions | Total GHG emissions minus carbon sequestered in carbon sinks (trees and/or soils) |
| NGGI | The National GHG Inventory accounts for, and estimates, Australia’s GHG emissions and sinks |
| NGER | National Greenhouse and Energy Reporting |
| NH4 | Ammonium |
| Nitrous oxide | Nitrous oxide (N2O) is a GHG that is 265 times more potent than carbon dioxide, based on the IPCC AR5 report. N2O is released to the environment when micro-organisms in the soil act on the nitrogen applied to the soil, whether that N is deposited via animal urine, dung, effluent or nitrogen-based fertilisers |
| N2O | Nitrous oxide |
| NO3 | Nitrate |
| P | Phosphorus |
| Pre-farm embedded emissions | GHG emissions associated with the production/manufacturing of key farm inputs such as grain, fodder, and fertiliser. In ADCC, pre-farm embedded emissions do not include the emissions associated with the transportation of these inputs from the point of production to the farm gate, due to the difficulty in establishing distances travelled for grain, fodder, and/or fertilisers |
| S | Sulphur |
| SAR | IPCC Second Assessment Report |
| Scope | Standard practice is to report GHG emissions using different classifications depending on where they arise from, and how they relate to the business. These are termed emission ‘scopes’ |
| Scope 1 emissions | Direct GHG emissions from sources that are owned or controlled by the business. For dairy farms, this refers to emissions from on-farm methane and nitrous oxide, along with carbon dioxide emissions from the consumption of fuel |
| Scope 2 emissions | GHG emissions from the generation of purchased electricity consumed by the business |
| Scope 3 emissions | GHG emissions that are a consequence of the activities of the business, but that occur from sources not owned or controlled by the business. For dairy farms, these are GHG emissions from the production of key farm inputs (i.e. pre-farm embedded emissions), extraction/refinement of fuel, and indirect loss of electricity through transmission and distribution in the grid |
| Waste | Waste is used in this manual when referring to the sum of urine and dung. At times, manure is used as an alternative term for waste. Unless stipulated, waste means the sum of urine and dung deposition |

# Introduction

There is no doubt that human-induced climate change is occurring, and that greenhouse gases (GHGs) are contributing to this global warming. Many companies, governments, and industries have either established or are establishing targets to reduce GHG emissions, with many targeting carbon neutrality or net-zero emissions by 2050. The current Australian Federal government has set a target of 43% reduction of GHG emissions by 2030, and net zero by 2050, relative to the 2005 baseline (<https://www.dcceew.gov.au/about/news/australia-submits-new-emissions-target-to-unfccc>). Australian agriculture is facing increased consumer and community pressure to reduce emissions, while maintaining /improving productivity to remain profitable. The Australian dairy industry set a target of reducing GHG emissions intensity (EI) by 30% across whole of industry (farm and manufacturing) by 2030[[1]](#footnote-2) as part of the Dairy Industry Sustainability Framework (Dairy Australia, 2021).

The cost of direct measurement of on-farm GHG emissions is expensive, time-consuming, and requires specialised equipment. Annual GHG emissions generated by dairy production, and other farm-related operations critical to the success of dairying, can be estimated by undertaking a ‘carbon account’. Accounting allows producers to ascertain their current farm GHG emissions. It can also help them identify hot-spots within the farm boundary so they can better understand how to reduce their carbon footprint.

Greenhouse gases essentially represent lost ‘energy’ from the farm system. For example, reducing enteric CH4 has the potential to retain this energy within the animal, which may result in an increase in milk production and/or liveweight gain. Likewise, excess applications of N fertiliser, beyond that required by pastures, can potentially be lost to the environment through leaching, volatilisation, and N2O emissions. Reducing GHGs can yield a range of other benefits both within and beyond the farm gate, such as:

* increased productivity and long-term sustainability
* improved social licence to farm
* improved access to emerging markets for low carbon/net zero products

The Australian dairy industry is committed to reducing its carbon footprint, and tools such as ADCC are critical to help producers firstly ascertain their baseline GHG emissions, and secondly, determine areas of improvement that can be undertaken on farm. This manual provides guidance in the use of the ADCC, including detailed information on how to complete a carbon account for dairy production, and highlights opportunities for reducing GHG emissions through a range of abatement strategies (COST within ADCC). This manual also included benchmarking results from the Dairy Farm Monitor Project datasets within DairyBase. The Dairy Australia website (<https://www.dairyaustralia.com.au/land-water-and-climate>) also contains a range of resources to help farmers manage their land, water, and climate to improve farm production and profitability. Good farm management practices will generally result in a reduction in GHG emissions per unit of milk and meat production. However, it is critical that farmers also explore aspects of the farm business that can be improved, to directly reduce net farm GHG emissions.

# Carbon accounting

## Major greenhouse gases

Greenhouse gases reported under the Australian Federal Government’s *National Greenhouse Gas Inventory* (commonly referred to as NGGI; Australian Government, 2022) include:

* carbon dioxide (CO2)
* methane (CH4)
* nitrous oxide (N2O)
* sulphur hexafluoride (SF6)
* other hydrofluorocarbons and perfluorocarbons

The main emissions from agricultural production are CO2, CH4 and N2O (Figure 1; reproduced with modifications courtesy of Agriculture Victoria). Greenhouse gas emissions are measured in CO2 equivalents (CO2e) to allow for comparison in terms of the potency of each gas, as each has a different capacity to contribute to global warming. Methanehas a potency, or global warming potential (GWP), of 28 times that of CO2, when reported on a 100-year timeframe (GWP100). In contrast, N2O has a GWP100 of 265 times that of CO2.

It is well recognised that limitations may exist to the GWP100 method, particularly around how CH4 is handled (IPCC 2014; Lynch *et al*. 2020). Methane breaks down into biogenic CO2 and water vapour after around 10–14 years. The warming effect of CH4 during these years is significantly higher, at around 80+ times more potent than CO2 over the shorter timeframe. Accounting for the warming effect over a much longer period (100 years) may be problematic if this breakdown factor is not accounted for. Several other metrics have been proposed including Global Temperature Potential (GTP) (IPCC 2014) and GWP\* (Lynch *et al*. 2020), and these report lower impacts for CH4 under specific scenarios.

In the future, new methods, such as GTP, may gain more traction and become standard international practice. However, for the purposes of ADCC and this manual, the standard GWP100 have been applied. We note that these GWP100 values are periodically updated in response to new science, and the values here align with the Australian Government inventory, as of July 2022.



**Figure 1.** Sources of major dairy farm greenhouse gas emissions (Courtesy of Agriculture Victoria (2022), adapted with updated GWPs).

## Methane

Enteric CH4 is a by-product of ruminant digestion and mainly occurs in the rumen, and to a lesser extent, the large intestine. Cellulose and starches are broken down into volatile fatty acids through microbial activity (methanogenic bacteria), releasing hydrogen, which combines with CO2 to form CH4. Enteric CH4 results in the loss of 5-10% of gross energy intake, energy that could otherwise be used to increase productivity (e.g. increase milk production for cows or increase daily liveweight gain for young stock). The Australian NGGI methodology estimates enteric CH4 production as 20.7 g CH4/kg dry matter intake (DMI; Charmley *et al*. 2016), equivalent to ~ 3.8 t CO2e/annum, assuming each cow eats 20 kg DM/day while lactating, and 8 kg DM/day while dry.

Methane is also lost to the environment from waste/manure (dung and urine deposition) when stored in anaerobic (absence of oxygen) conditions, such as lagoon/pond systems. Waste CH4 emissions in Australia are relatively low. Most dung and urine are deposited onto pastures as animals are grazing, compared to housed systems in Europe and North America. ADCC uses state-based data to ascertain what proportion of waste is handled via five manure management systems (MMS). These are:

* deposited onto pasture while grazing,
* anaerobic pond/lagoon system,
* sump dispersal system,
* drains/spread to the paddock daily, and
* solid storage.

The default in ADCC is that between 80 and 85% of the milking herds’ waste is deposited onto pastures (proportion varies between states). The remaining 15-20% is deposited at the dairy shed. This residual waste is then divided between the four remaining manure management systems, with the proportion of manure to each system varying between states. Each manure management system has a varying methane conversion factor (MCF), with the risk of CH4 loss from pond/lagoon systems substantially greater than all other systems. With the dairy industry increasingly relying on feedpads to deliver partial or total mixed rations to the milking herd, ADCC also allows users to explore how their farm’s waste is handled under these feeding regimes, to give a more accurate reflection of waste CH4 emissions.

## Nitrous oxide

Nitrous oxide emissions arise from waste excretion (urine and dung) and nitrogen (N)-based fertiliser applications (e.g. urea, diammonium phosphate (DAP), sulphate of ammonia (SoA)). Emissions of N2O are largely a result of two soil microbial processes, nitrification, and denitrification. Nitrification is an aerobic process that oxidises ammonium (NH4+) to nitrate (NO3-), with denitrification of N2O produced as a by-product. Denitrification is also an anaerobic process that reduces nitrate into dinitrogen (N2), with N2O an obligatory intermediate (de Klein and Eckard, 2008). A simplified N cycle of a grazed dairy pasture is shown in Figure 2, illustrating the points in the N cycle where nitrification and denitrification occurs.

Factors that significantly affect the production of N2O from animal waste and fertilisers are temperature, water-filled pore space (WFPS), level of organic carbon, soil pH, and soil NO3 (Whitehead 1995). Soil NO3 levels and soil aeration (WFPS) have been identified as the most likely key factors affecting N2O emissions from grazing systems (Eckard *et al*. 2010). In addition to direct losses of N2O as described above, a proportion of N lost to the environment through leaching and/or runoff of NO3 and ammonia (NH3) volatilisation. When these sources of N are redeposited on land, the N cycle begins again, resulting in a proportion of this N lost as indirect N2O emissions.

Timeline

Description automatically generated

**Figure 2.** Simplified nitrogen cycle of a grazed dairy pasture (Source: Dairy Australia Fert$mart Nitrogen Pocket Guide).

## Carbon dioxide

Carbon dioxide emissions on dairy farms come from a range of sources. These include burning fossil fuels for electricity sourced from the grid, and fuel for farm vehicles and equipment. Urea manufacturing removes CO2 from the atmosphere. When applied to pastures and crops, this CO2 is released back into the atmosphere. Lime undergoes a similar process as urea, releasing CO2 to the atmosphere when applied to pastures and crops. Carbon dioxide emissions (mainly CO2 but also smaller amounts of CH4 and/or N2O) arise from the manufacturing and transporting of key farm inputs, such as fertilisers and feeds. Soils also respire CO2 as organic matter (pastures, roots etc) breaks down. Carbon dioxide is also sequestered (stored) in soils through building soil organic matter and in the growth of vegetation, such as trees and shrubs. The CO2 from on-farm electricity and diesel consumption, the production/manufacturing of supplementary feeds and fertiliser, and the breakdown of urea and lime are all estimated in ADCC. The emissions associated with the transportation of key farm inputs are not included. This is due to large variation in the distances that key inputs may need to travel from the point of production or manufacturing to the farm gate. ADCC also does not estimate soil net CO2 respiration. However, users can decide if they wish to estimate soil/tree carbon sequestration to offset a proportion of their GHG emissions.

## Carbon accounting and carbon footprinting

Measuring GHG emissions on farm is time-consuming, complex, and expensive. As such, GHG emissions are often modelled using well-validated equations from the most current scientific research relevant to a region. These finding are then incorporated into methodologies (i.e. NGGI) to estimate GHG emissions and carbon sequestration. An example of this is the equation to estimate enteric CH4, based on the research of Charmley *et al*. (2016). Their meta-analysis study reviewed research trials undertaken throughout Australia that used open-circuit respiration chambers to measure enteric CH4 emissions. For example, Agriculture Victoria’s Ellinbank dairy research facility is considered the ‘Gold-Star’ for measuring enteric CH4 emissions. Any results from diets that were considered to inhibit the reduction in enteric CH4 (e.g. high in dietary fat or tannins) were omitted from the meta-analysis. This resulted in > 1,000 datapoints to develop the NGGI relationship between intake and CH4 production, at 20.7 g CH4/kg DMI (Charmley *et al*. 2016).

A **carbon account** represents the net GHG emissions (i.e. total GHG emissions minus carbon sequestration) and is generally reported on an annual timeframe, as t CO2e/annum. While useful, a carbon account does not allow for comparison between different farm sizes or production levels.

A **carbon footprint**, commonly known as emissions intensity or EI,represents the net GHG emissions per unit of product over 12 months, such as kg CO2e per kg milksolids (MS) or kg CO2e per kg of fat and protein-corrected milk (FPCM). Most milk EIs use an equation to standardise milk production based on fat and protein content. The ADCC tool uses FPCM, based on the International Dairy Federation guidelines of standardising milk to 4.0% fat and 3.3% protein (IDF, 2022). In addition, EI is also estimated in ADCC by dividing net GHG emissions by kg of milksolids. EI allows the comparison of a farm’s GHG emissions over time, accounting for changes in production, herd size etc. Alternatively, EI’s enables the comparison of a farm’s GHG emissions with other farms within the region, other regions of Australia, or even globally[[2]](#footnote-3).

Dairy farms produce several products, not just milk, but also meat with cull cows, non-replacement heifers and bull calves/steers. The dairy industry is increasingly retaining more calves on farm, especially bull calves. Thus, it is important that **allocation** of net GHG emissions is attributed to both milk and meat production. There are a range of allocation methods available (e.g. economics, protein, systems expansion; Flysjö *et al*. (2011); Kyttä *et al.* (2022)). In ADCC, we use an energy allocation method where net emissions are attributed to both milk and meat based on the known relationships between net energy requirements for lactation and growth, and the production of milk and meat (IDF, 2022 following Thoma and Nemecek (2020)). See Appendix 1 for a complete explanation of how GHG emissions are allocated to milk vs meat).

When comparing results between farms, it is also important to understand the allocation method used, as EI will alter between methods. For example, Flysjö *et al*. (2011) found that the EI for a New Zealand case study farm was 1.00 kg CO2e/kg energy-corrected milk when 100% of emissions were allocated to milk. However, EI could be as low as 0.63 CO2e/kg energy-corrected milk when using a systems expansion GHG allocation.

When estimating a carbon account or footprint, it is important to also define the **system boundary**. In most instances, the system boundary encompasses all GHG emissions arising within the operational and organisational boundary of the farm enterprise. Therefore, this includes on-farm emissions associated with milk production (e.g. enteric CH4 emissions from livestock), feed production (e.g. N2O emissions from fertiliser inputs), and manure management (e.g. CH4 and N2O emissions from dung and urine). It also includes emissions associated with key inputs, commonly known as pre-farm embed emissions. These include supplementary feed, and manufactured fertilisers. In addition, emissions associated with off-farm generated electricity and diesel are included. Dairy farms may agist their replacement heifers, and sometimes even dry cows, with another farm business (i.e. we are not referring to a runoff/outblock here but a separate farm that the current farm owner has no control over). It is important to note that even though these animals are not within the physical boundary of the farm, they are part of the operational boundary of the dairy farm enterprise. Therefore, these animals must be included in the carbon account.

In most instances, the carbon account or footprint often concludes at the farm gate, commonly termed ‘cradle to gate’. The reason is that, at this point, the farmer no longer has control of the milk they produce. Emissions associated with transporting raw milk for processing, milk processing, delivering of product(s) to the consumer, and wastage at the consumer level is beyond the farmer’s control. Studies such as Life Cycle Assessments (LCAs) include both on-farm emissions and those emissions through the supply chain, from processing through to the consumer (termed cradle to grave).

## Scope emissions breakdown

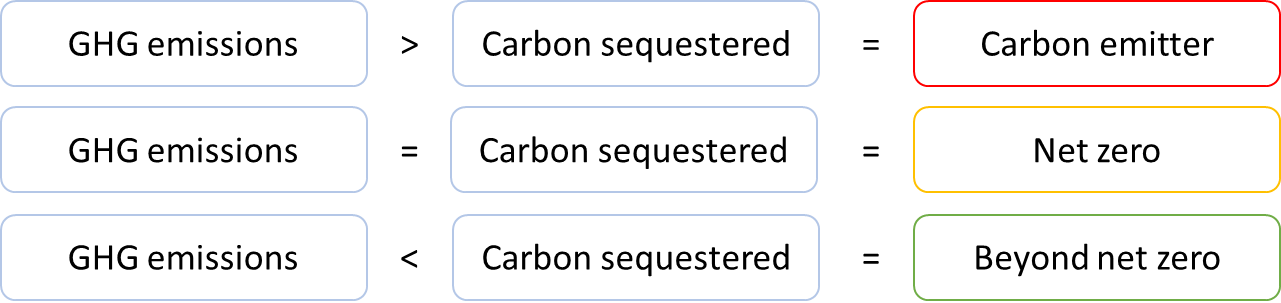
Greenhouse gas emissions are often defined according to where and when they occur. Direct GHG emissions are those from sources owned or controlled by the farmer. Indirect GHG emissions are those that are a consequence of the activities of the farm but occur at sources owned or controlled by another business (Note we are not referring to indirect N2O emissions here, which are Scope 1 emissions). Ranganathan *et al.* (2004) developed three scopes to help delineate direct and indirect GHG emissions:

**Scope 1** GHG emissions are direct emissions under the control of the farmer, such as enteric and waste CH4 emissions, N2O emissions from animal waste and N-based fertilisers, CO2 emissions from lime and urea applications on farm, as well as CO2 emissions from the consumption of fuel in farm vehicles and machinery.

**Scope 2** GHG emissions are the CO2 emissions associated with the generation of purchased electricity consumed on farm. These are also considered direct emissions as a farmer could reduce their electricity consumption, or install renewable energy on farm, to reduce consumption of fossil-derived electricity.

**Scope 3** GHG emissions are indirect emissions when they are associated with the farm but occur off-farm. These include the CO2e emissions associated with the production of key-farm inputs, such as grain and fodder, fertilisers, and soil ameliorants (lime). Scope 3 also includes emissions associated with the extraction and manufacturing of fuel, in addition to the indirect loss of electricity during transmission and distribution in the power grid. For example, a dairy farmer has no direct control over the management decisions of a cropping farm, e.g. N fertiliser inputs. But they can make the decision as to whether to buy from a farm that can illustrate that their grain’s EI is lower than that of a neighbouring farm, due to lower N fertiliser inputs.

A carbon footprint requires all three Scope emissions to be included and is frequently required for carbon neutral certification under systems such as the Federal Government’s *Climate Active* program ([www.climateactive.org.au](http://www.climateactive.org.au)). Carbon neutrality or net zero occurs when total GHG emissions (sum of all three Scope emission) equals the amount of carbon sequestered in soils, and/or tree vegetation plus any carbon offset credits purchased and relinquished by the farm business for the year of assessment. Note that a net zero carbon footprint does not necessarily mean absolute zero GHG emissions. A farm could still be a high emitter of GHGs but be net zero if the amount of carbon sequestered on-farm plus purchased offsets either equals GHGs emitted (i.e. carbon neutral/net-zero) or outweighs GHG emissions (beyond net zero) (Figure 3).



**Figure 3.** A farm remains a carbon emitter (red outcome) when GHG emissions are greater than carbon sequestered. A farm is carbon neutral/net zero (orange outcome) when the amount of carbon sequestered is equal to GHG emissions. The best outcome is when the amount of carbon sequestered is greater than GHGs emitted as the farm is now beyond net zero (green outcome).

## Commonly asked questions

While not extensive, here are some commonly asked questions related to undertaking assessments of dairy GHG emissions.

*Why do you count feed inputs, such as grain and fertiliser inputs, as part of the dairy farm’s carbon footprint? Is this not double counting the emissions?*

When the Australian government estimates national GHG emissions each year, the emissions from dairy supplementary feeds such as grain and fodder is only counted once, on the farm where it is produced. The emissions associated with urea production is attributed to the country where the urea is manufactured.

However, when we scale GHG estimations down to the farm-scale, it should be noted that the GHG emissions attributed to the dairy farm is the sum of direct emissions, those from sources owned or controlled by the farmer (Scope 1 and 2), and indirect emissions, those as a consequence of the activities of the farm but occur at sources owned or controlled by another business (Scope 3).

Farmers can make a choice to feed less grain and rely more on home-grown pastures and forages. Similarly, farmers can choose to increase the legume content of their pasture as opposed to applying N fertiliser to increase pasture production. Either option would reduce their Scope 3 GHG emissions and thus their net GHG emissions.

*Why do I not get credited for the carbon I sequester in pastures and crops?*

If the carbon sequestered in pastures and crops was permanently stored, farmers could be credited for the carbon stored in these feeds. However, pastures and crops are either grazed directly, or conserved and fed out to livestock at a later stage. Thus, a proportion of the carbon in the forages is converted into CH4 in the rumen and released into the atmosphere. The biogenic carbon is constantly being recycled through photosynthesis and digestion by ruminants. Only options that permanently remove carbon from the atmosphere, either in tree vegetation, or with building soil carbon, can qualify for carbon credits.

*Why do we account for CH4 gas (a short-term GHG) the same as we do CO2 and N2O (long-term GHGs)?*

The IPCC, when developing guidelines for countries to estimate their GHGs, compared all three gases over a 100-year timeframe. The half-life of CH4 is around 10-12 years, compared to 100+ years for the other two gases. Over a much shorter timeframe, the GWP of CH4 is significantly higher (~ 84 times more potent than CO2). A tonne of CH4 emitted today will break down into CO2 and water vapour in 10-12 years. Several other metrics have been proposed, including Global Temperature Potential (GTP) (IPCC, 2014) and GWP\* (Lynch *et al.* 2020), to better capture the higher GWP of CH4 over its lifetime as opposed to 100 years. Until the IPCC and UNFCCC (United Nations Framework Convention on Climate Change) determine a different metric, the Australian NGGI will remain using 100-year timeframes for all three gases.

Figure 4 illustrates the result of either increasing, maintaining, or reducing CO2 and CH4 emissions on global warming over time. So if we (globally) can stabilise CH4 production, the tonne produced today replaces the tonne produced 10-12 years ago, thus the net change in CH4 emissions and global warming attributed to CH4 will flatline (middle set of graphs). In contrast, even if we were to stabilise CO2 production today, the tonne of CO2 produced today builds on the tonne produced yesterday.

Many of the largest dairy exporting countries (NZ, USA, EU) reached an agreement at COP26 in 2021 to reduce CH4 emissions by 30% by 2030. It must be noted at the time, the then Australian coalition government did not sign this agreement (<https://www.abc.net.au/news/2021-11-03/australia-refuses-to-join-global-pledge-to-cut-methane-emissions/100589510>, accessed March 2022). This may change in the future with the current Labor government. While much of the initial focus will occur within the fossil fuel and waste management sectors, agriculture will also need to implement policies to reduce CH4 production.

To slow down global warming, it is imperative that net production of all GHGs are eliminated (right-hand side graphs in Figure 4). This does not mean that production of GHGs must cease, we may never get a net zero GHG-emitting cow. Our future needs to be reflect where residual GHGs are offset with an equal, or preferably greater, rates of carbon sequestration in trees and soils, so that net emissions are zero/beyond zero.

Diagram

Description automatically generated

**Figure 4.** Illustration of the effect of rising, constant or falling carbon dioxide and methane emissions on global warming over time (Source: <https://clear.ucdavis.edu/explainers/why-methane-cattle-warms-climate-differently-co2-fossil-fuels>, accessed March 2022).

# Resources

*General resources not listed below in abatement/mitigation option reviews*

Agriculture Victoria (2022) Soil Carbon Snapshot <https://agriculture.vic.gov.au/__data/assets/pdf_file/0006/857607/Soil-Carbon-Snapshot-updated-May-2022.pdf>

Dairy Australia’s Land, Water, and Climate website <https://www.dairyaustralia.com.au/land-water-and-climate>

Dairy Australia reducing emissions website <https://www.dairy.com.au/sustainability/reducing-environmental-impact/reducing-emissions>

Dairy Australia Fert$mart manual <https://www.dairy.com.au/sustainability/reducing-environmental-impact/reducing-emissions>

Fert$mart Nitrogen Guidelines: Best management practice <https://www.dairyaustralia.com.au/resource-repository/2021/06/24/fert$mart-nitrogen-guidelines---best-management-practice#.YfH1tepBwnI>

Fert$mart Nitrogen Pocket Guide <https://www.dairyaustralia.com.au/resource-repository/2021/06/24/fert$mart-nitrogen-pocket-guide#.YfH1ROpBwnI>

Moss, A. (2020) Database of nutrient content of Australian feed ingredients. <https://agrifutures.com.au/wp-content/uploads/2020/09/20-078.pdf>

*Abatement option reviews*

There are many reviews of abatement options for ruminant livestock, therefore the listing below is not exhaustive.

Beauchemin KA, Ungerfeld EM, Eckard RJ, Wang M (2020) Review: Fifty years of research on rumen methanogenesis: lessons learned and future challenges for mitigation. *Animal* **14:S1**, s2-s16. <https://www.cambridge.org/core/journals/animal/article/review-fifty-years-of-research-on-rumen-methanogenesis-lessons-learned-and-future-challenges-for-mitigation/8F7537B81CBDA633F48663C1ACF33036>

Black JL, Davison TM, Box I (2021) Methane emissions from ruminants in Australia: Mitigation potential and applicability of mitigation strategies. *Animals* **11**, 951. <https://www.mdpi.com/2076-2615/11/4/951>

Eckard RJ, Clarke H (2018) Potential solutions to the major greenhouse-gas issues facing Australasian dairy farming. *Animal Production Science* **60**, 10-15. <https://www.publish.csiro.au/AN/AN18574>

Eckard RJ, Grainger C, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production – a review. *Livestock Science* **130**, 47-56. <https://www.sciencedirect.com/science/article/pii/S1871141310000739>

Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, Falcucci A, Tempio G (2013) Tackling climate change through livestock- A global assessment of emissions and mitigation opportunities. (Food and Agriculture Organization of the United Nations (FAO): Rome, Italy). <https://www.fao.org/3/a0701e/a0701e.pdf>

Harrison MT, Cullen BR, Mayberry DE, Cowie AL, Bilotto F, Badgery WB, Liu K, Davison T, Christie KM, Muleke A, Eckard RJ (2021) Carbon myopia: The urgent need for integrated social, economic and environmental action in the livestock sector. *Global Change Biology* **27**, 5726-5761. <https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15816>

Hristov AN, Oh J, Lee C, Meinen R, Montes F, Ott T, Firkins J, Rotz A, Dell C, Adesogan A, Yang W, Tricarico J, Kebreab E, Waghorn G, Dijkstra J, Oosting S (2013) Mitigation of greenhouse gas emissions in livestock production- A review of technical options for non-CO2 emissions. <https://www.fao.org/publications/card/en/c/87178c51-d4d1-515d-9d0e-b5a6937fa631/>

Hristov AN, Oh J, Firkins JL, Dijkstra J, Kebreab E, Waghorn G, Makkar HPS, Adesogan AT, Yang W, Lee C, Gerber PJ, Henderson B, Tricarico JM (2013) SPECIAL TOPICS- Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane operations. *Journal of Animal Science* **91**, 5045-5069. <https://academic.oup.com/jas/article/91/11/5045/4731308>

Hristov AN, Ott T, Tricarico JM, Rotz A, Waghorn G, Adesogan A, Dijkstra J, Montes F, Oh J, Kebreab E, Oosting SJ, Gerber PJ, Henderson B, Makkar HPS, Firkins JL (2013) SPECIAL TOPICS- Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options. *Journal of Animal Science* **91**, 5095-5113. <https://academic.oup.com/jas/article/91/11/5095/4731330>

Llonch P, Haskell MJ, Dewhurst RJ, Turner SP (2017) Review: current available strategies to mitigate greenhouse gas emission in livestock systems: an animal welfare perspective. *Animal* **11**, 272-284. <https://www.cambridge.org/core/services/aop-cambridge-core/content/view/2C1E6F2AA8B6608B9B5C49544EEB26F4/S1751731116001440a.pdf/current-available-strategies-to-mitigate-greenhouse-gas-emissions-in-livestock-systems-an-animal-welfare-perspective.pdf>

Min BR, Solaiman S, Waldrip HM, Parker D, Todd RW, Brauer D (2020) Dietary mitigation of enteric methane emissions from ruminants: A review of plant tannin mitigation options. *Animal Nutrition* **6**, 231-246. <https://reader.elsevier.com/reader/sd/pii/S2405654520300706?token=4113F5241001D734B17EB067E8A665DA98A9B4DB00CF0D2264E4708B879AEFB550EC7EDC61A4FB66DF7A5B40D61D2A2E&originRegion=us-east-1&originCreation=20220318052754>

Montes F, Meinen R, Dell C, Rotz A, Hristov AN, Oh J, Waghorn G, Gerber PJ, Henderson B, Makkar HPS, Dijkstra J (2013) SPECIAL TOPICS – Mitigation of methane and nitrous oxide emissions from animal operations: II. A review of manure management mitigation options. *Journal of Animal Science* **91**, 5070-5094. <https://academic.oup.com/jas/article/91/11/5070/4731316>

# References

Agriculture Victoria (2022) Greenhouse gas cycles in agriculture. Available at <https://agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/greenhouse-gas-cycles-in-agriculture>

Australian Government (2022) National Inventory Report 2020: The Australian Government Submission to the United Nations Framework Convention on Climate Change. Available at <https://www.industry.gov.au/data-and-publications/national-inventory-reports>

Charmley E, Williams SRO, Moate PJ, Hegarty RS, Herd RM, Oddy VH, Reyenga P, Staunton KM, Anderson A, Hannah MC (2016) A Universal equation for predicting methane production of forage-fed cattle in Australia. *Animal Production Science* **56**, 169-180.

Dairy Australia (2020) Fert$mart Nitrogen Pocket Guide. Available at <https://www.dairyaustralia.com.au/resource-repository/2021/06/24/fert$mart-nitrogen-pocket-guide#.YfH1ROpBwnI>

Dairy Australia (2021) Australian Dairy Industry Sustainability Report 2020. Available at <https://www.dairy.com.au/sustainability/australian-dairy-sustainability-framework>

de Klein CAM, Eckard RJ (2008) Targeted technologies for nitrous oxide abatement from animal agriculture. *Australian Journal of Experimental Agriculture* **48**, 14-20.

Eckard RJ, Grainger C, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production – a review. *Livestock Science* **130**, 47-56.

Flysjö A, Cederberg C, Henriksson M, Ledgard S (2011) How does co-product handling affect the carbon footprint of milk? Case study of milk production in New Zealand and Sweden. *International Journal of Life Cycle Assessment* **16**, 420-430.

IDF (2022) The IDF global Carbon Footprint standard for the dairy section. Bulletin of the IDF No. 520/2022. (International Dairy Federation: Brussels, Belgium). Available at <https://fil-idf.org/>

IPCC (2014). IPCC Fifth Assessment Synthesis Report-Climate Change 2014 Synthesis Report. In *IPCC Fifth Assessment Synthesis Report-Climate Change 2014 Synthesis Report*. Available at <https://www.ipcc.ch/assessment-report/ar5/>

Kyttä V, Roitto M, Astaptsev A, Saarinen M, Tuomisto Hl (2022) Review and exert survey of allocation methods used in life cycle assessment of milk and beef. *The International Journal of Life Cycle Assessment* **27**, 191-204.

Lynch J, Cain M, Pierrehumbert R, Allen M (2020) Demonstrating GWP\*: A Means of Reporting Warming-Equivalent Emissions That Captures the Contrasting Impacts of Short- and Long-Lived Climate Pollutants. *Environmental Research Letters* **15,** 044023.

Ranganathan J, Bhatia P (2004) The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition). Available at <https://www.researchgate.net/publication/258261856_The_Greenhouse_Gas_Protocol_a_Corporate_Accounting_and_Reporting_Standard_Revised_Edition>

Thoma G, Nemecek T (2020) Allocation between milk and meat in dairy LCA: critical discussion of the IDF’s standard methodology. In ‘Proceedings of the 12th International Conference on Life Cycle Assessment of Food’, LCA Food 2020, pp 83-89, Berlin, Germany.

Whitehead DC (1995) Grassland nitrogen. (CAB International: Wallingford, UK).

1. 2015-16 baseline year [↑](#footnote-ref-2)
2. Assuming same GWPs and standardisation of milk production [↑](#footnote-ref-3)