Australian Dairy Carbon Calculator

Manual

Version 5

Section 5 only - ADCC

November 2022

A herd of cows in a field

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Logo, company name

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We would also like to thank Agriculture Victoria for allowing the reproduction of Figure 1 (adapted with updated GWPs for this manual).

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.

Over time, the calculator has been maintained and upgraded within projects funded by the Australian Federal Government Department of Agriculture, Fisheries and Forestry, Dairy Australia, Meat & Livestock Australia, and Australian Wool Innovation. Version 5 of ADCC was funded by Dairy Australia. We acknowledge funding from all above-mentioned agencies to allow the development and upgrading of the calculator as required to meet the most current guidelines.

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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 Australian Dairy Carbon Calculator theme (section 5), along with the Glossary and commonly used acronyms (section 2), full listing of resources, appropriate references and appendices (sections 8-10). 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. Note the Table and Figure numbers in this section match those of the full manual; they have not recommenced as Table or Figure 1.

# 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 |

# Australian Dairy Carbon Calculator (ADCC)

The ADCC, and its predecessor, the Dairy Greenhouse gas Abatement Strategies (DGAS) calculator, is based on the most currently available Australian NGGI methodology (Australian Government, 2022). In many ways, ADCC is very similar to the University of Melbourne’s Greenhouse Accounting Framework (D-GAF; <http://www.piccc.org.au/resources/Tools>) calculator, and the carbon calculator within Dairy Australia’s DairyBase (<https://www.dairyaustralia.com.au/farm-business/dairybase/getting-started#.Yfyihd9BwnI>). There is also a DairyBase in New Zealand, so when you google DairyBase looking for the Australian version, make sure you are selecting the correct website, located on Dairy Australia’s website.

All three Australian dairy GHG calculators are built using the same NGGI methodology, it’s essentially the ‘same machine under the hood’. While previously there were some differences between the calculators, resulting in differing GHG emissions results, many of those differences have now been resolved. For example, D-GAF previously did not estimate pre-farm embedded emissions associated with key farm inputs such as grain, fodder, and fertiliser. At the time of writing this manual, D-GAF has not allocated a proportion of GHG emissions to meat production; all emissions were attributed to milk production. D-GAF also employs an EI based on milksolids, as opposed to FPCM.

One key difference between the three calculators is that ADCC allows users to explore a range of abatement options to reduce on-farm GHG emissions (see the Carbon Offset Scenario Tool (COST) in section 7, located in a separate document on the Dairy Australia website). ADCC also allows users to compare the effect of the changing NGGI methodology on baseline farm emissions. For example, for the farm example used in sections 5 and 6, the 1990 methodology results were 3,242 t CO2e/annum, increasing slightly to 3,289 t CO2e/annum with the 2015 methodology, increasing substantially to 3,582 t CO2e/annum with the 2022 methodology. This is an important insight, as the change in GHG emissions here was solely a result of changing methodology, as opposed to any change in farm practices. Therefore, it’s important when reporting either net GHG emission or EI, that the methodology used is also outlined, so that you are comparing ‘apples with apples’, not ‘apples with oranges’.

It is also important to note that ADCC and DairyBase may still lead to slightly different results, due to rounding up/down numbers, determining annual stock numbers, diet quality etc. Likewise, as mentioned above, D-GAF allocates all GHG emissions to milk production, so the estimated result will be greater than those of ADCC or DairyBase. Once you have determined a calculator to use, it is important to remain using this same calculator. This means that results can be compared over several years of assessment for the same farm, or to compare results between farms.

## Where can I access ADCC from?

The ADCC is an excel spreadsheet on the Dairy Australia website, and can be downloaded at <https://www.dairyaustralia.com.au/resource-repository/2020/07/09/australian-dairy-carbon-calculator-website#.YyfTfXZBxaR>. The file should automatically download, and then you can save this to your computer. Once downloaded, you no longer require access to the Dairy Australia website to use the calculator.

## Introduction

The data needed to undertake an assessment of farm GHG emissions will come from a range of sources, such as milk production data from your milk factory, herd book data for the number of heifers, receipts from electricity or fertiliser suppliers, stock agent for stock sales data, accountant etc.

Feedback from users of the calculator has indicated it takes around 1-2 hours to complete an assessment, assuming you have most of this information at hand. The task will take longer if you need to gather all the information from a range of sources. Part of this time is spent becoming familiar with each question and discerning the required level of detail.

When you first open ADCC, you will see many tabs/data sheets (Figure 5). The first is the Introduction, and this sheet gives you an overview of the calculator, including a description of how to manage the Abatement strategies (COST) worksheets. Some worksheets are hidden (e.g. data for generating the graphs, and emission factors for GWPs) to protect them from being altered.

A picture containing graphical user interface

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**Figure 5.**A screenshot of the first few tabs/worksheets in ADCC.

At the bottom left-hand side of the Introduction sheet, there’s a list of changes made to the current version of the calculator, relative to version 4.

We have purposely protected each sheet to maintain integrity of the equations. We have also hidden all the ‘working’ components of each sheet. If you wish to unprotect worksheet(s) to view the working components, locate the ‘Review’ tab in excel, click on ‘Protect Sheet’, and type in the password Dairy\_DGAS (case sensitive). You can then unhide the rows to access the working calculation area. Only unprotect the worksheet(s) if you are confident that you won’t alter any of the equations.

## Baseline farm data entry

The “Baseline farm” sheet is where you will spend most of your time when using the calculator; its where you enter all the data for the assessment year. When you open ADCC, and progress to the “Baseline farm” sheet for the first time, all cells will be blank. We have created an “Example baseline farm” sheet to illustrate a typical farm (same as used in sections 5 and 6 in this manual) as a reference point to understand the data entry required.

Many of the headings or questions asked will have a note in the form of a red triangle in the top right corner. If you place your mouse over the cell where the heading/question is, a note will appear, giving additional information. For example, when you hover your cursor over the Milking Cows heading, the message in Figure 6 appears.

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**Figure 6.** Screenshot of the Milking Cows help message.

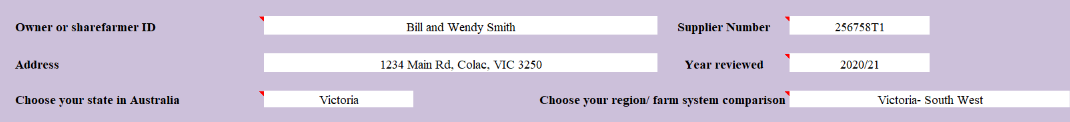
In most instances, you will need to enter data in each of the white cells. Some white cells require numbers, while others will have a drop-down list. You need to select the most suitable option for your farm assessment. Note: the cell with the drop-down list for when calves are sold is purple as opposed to white.

The only exceptions where you may not need to enter data into white cells for the baseline farm are:

* If you enter fertiliser using the ‘tonnes of element per annum’ option rather than the ‘kg of element per ha per annum’ option (see *Step five*),
* Whet the answer is zero such as you didn’t purchase any supplementary feed for each feed type (see *Step seven*),
* When you do not have trees established on farm to estimate their rate of carbon sequestration (see *Step eight*), or
* When you are using the default state-based factors and fractions for manure management (see *Step nine*).

*Step one: Farmer details*

Start at the top, working your way across and down the sheet. Figure 7 is a screenshot of the farmer’s details. Selecting your state within Australia is critical to determining how the manure (dung and urine) is handled on farm. Choosing your region/farm system comparison is important as ADCC uses this selection to ascertain which region to use when graphing the typical averages bar chart (see Results in section 5.4). Users can select either their region (Victoria, New South Wales, and Queensland broken down into several regions), their state, Australia-wide, or their level of grain feeding. Only the state and region/farm system comparison is used within the calculator, all other data is purely for identification.



**Figure 7.** Farmer details section on the “Baseline farm” sheet. This farm is in Victoria, to estimate waste emissions, and the results graph will compare this farm with the Victoria- South West average.

*Step two: Livestock numbers, liveweights, and sales data*

Livestock numbers

The largest source of on-farm GHG emissions is enteric CH4. Therefore, entering accurate stock numbers is critical for an accurate assessment. Milking cows number also includes dry cows for the year of assessment. For example, a 360 spring calving herd is the same as a year-round calving herd that milks ~ 300 cows daily and has ~ 60 dry cows present at any time of the year or a split-calving herd with 200 cows calving in spring and 160 cows calving in autumn. Any cow milked for a minimum of two months should be accounted for, even if they were culled prior to the rest of the herd being dried off.

All other stock classes are determined by the average number present over the full 12-month period. For example, displayed in Figure 8, we retained 125 Heifers < 1 yr of age. We also had 125 Heifers > 1 yr of age but after pregnancy testing at 18 months of age, there were 10 non-pregnant heifers. In this example, there was 125 heifers for 6 months (12-18 months of age), and 115 heifers for 6 months (18-24 months of age), thus the annual average was 120 heifers. The 10 non-pregnant heifers were sold at 425 kg liveweight. We retained 100 bull calves (Other stock < 1 yr of age) which were fattened for 12 months before selling at 400 kg liveweight. We also sold 4 bulls at 600 kg, and 115 cull cows at 550 kg liveweight.

If you retained 100 steers each year until they are 24 months of age before selling, then in addition to having 100 steers in the Other stock < 1 yr age class, you also have 100 steers in the Other stock > 1 yr age class. However, if these 100 steers were sold at 21 months of age instead of 24, then you would have 100 steers for 9 months, and 0 steers for 3 months, equivalent to 75 head for the full 12 month assessment (i.e. 100 steers x 9 months + 0 steers x 3 months = 900 steers / 12 months = 75 steers). If you retain your steers for longer than 24 months, you will have one group of steers > 1 yr age, and another group of steers > 2 years of age. For example, you have 100 steers present for the full 12 months (12 to 24 months), and then have another cohort of 100 steers present for 2 months (24 to 26 months), as they are sold at 26 months of age. This would be equivalent to 117 steers present across the 12-month assessment (i.e. 100 1-2 yr old steers x 12 months + 100 2- 3 yr old steers x 2 months = 1400 steers / 12 months = 117 steers).

Liveweight and liveweight gain

Liveweight is the average liveweight for each stock class over the 12-month period. For Heifers < 1 yr and Heifers > 1 yr, it is generally their liveweight at 6 months and 18 months of age. For ‘Other stock’ in each age group, it will be the average weight for the period they are present on the farm within each stock class. For example, steers were 300 kg at 12 months of age, and sold at 450 kg at 18 months of age, so their average liveweight for Other stock > 1 yr of age would be 375 kg. Milking cow liveweight gain is blanked out. Over the duration of 12 months, the weight they lose in early lactation is regained over the balance of their lactation and dry period. Bull liveweight gain is also blanked out as they are unlikely to gain much weight over a 12 month period.

Liveweight gain is the average weight gain per day over the assessment year. Heifers will gain between around 0.6 and 0.75 kg/day, although steers are likely to have a higher daily liveweight gain. An easy way to estimate liveweight gain might be to work out their liveweight at the end of the 12 months, subtract from this their liveweight at birth, and divide by 365 days. For example, heifers were born at 40 kg, and at 12 months of age were 250 kg, so they put on 210 kg over 365 days, equivalent to 0.6 kg/day. Likewise, the steers put on 150 kg over 6 months, gaining 0.83 kg/day. If the animals are not present for the full 12 months, still determine the difference between the start and end of the assessment and divide by the number of days present. For example, steers put on 100 kg over 75 days equates to 1.33 kg/day.

Stock sales

A new feature of ADCC version 5 is identifying when surplus animals (non-replacement heifers and bull calves) are sold. There is a drop-down list to the right-hand side of the Calves heading in the Livestock dynamics section. If you sell these non-replacement animals soon after birth (i.e. 1-3 weeks post birth), select ‘*Calve sold soon after birth’*. If you retain them until post-weaning before selling, select ‘*Calves sold post-weaning’*. In Figure 8, the non-replacement calves were sold post-weaning. If you sell some calves soon after birth, while others post-weaning, determine the average liveweight across both groups of calves. For example, retain 95 heifer calves until they are weaned before selling at 100 kg but sell 120 bull calves at 45 kg, this would be equivalent to selling 215 calves at ~ 70 kg. Although more calves are sold at birth, total liveweight sold was greater with the heifer calves vs bull calves, so select ‘*Calves sold post-weaning’* from the drop-down list. If you retained some non-replacement animals post-weaning (e.g. raise heifers to 15 months of age for the export market), these need to be included in the appropriate Other stock < 1 yr age and Other stock > 1 yr age classes.

ADCC also now asks questions related to total liveweight sold from all stock classes. This helps to determine net GHG emissions attributed to meat and milk production, and thus the EI of milk and meat. In Figure 8, we sold 115 cull cows at 550 kg, 10 18 month old empty heifers at 425 kg, 4 mature bulls at 600 kg, 100 steers at 400 kg, and 215 calves post-weaning at 105 kg. Thus total meat sold off the farm was 132 tonnes liveweight.

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Graphical user interface

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**Figure 8.** The livestock numbers section for the “Baseline farm” sheet (note this section of data entry has been broken down into three images to make it easier to read the text).

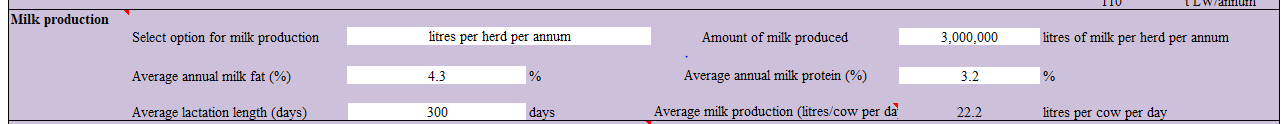
*Step three: Milk production*

There is a drop-down list to select how to enter milk production data:

* litres per herd per annum, or
* kg milksolids per her per annum.

Select the option you wish to use, then enter total milk production, average fat%, and protein%, with these percentages entered as whole numbers to one decimal point. This is schematically shown in Figure 9, with 4.3 typed in the white cell for fat%. Do not type in 0.043 or 4.3% as this will result in an error in FPCM estimations. Also enter the herd’s average lactation length (days), for instance most cows are milked for 300-305 days before drying off. If you implement extended lactations, with cows milked for longer than 365 days, enter 365 into the white cell. This reflects how long the cows have been milked for that year of assessment. A error message will appear if you try to enter a number greater than 365.

ADCC will then estimate daily cow milk production, based on cow numbers, total milk production, and average lactation length. In this example, the average milk production was 22.2 litres per cow per day (circled section in Figure 9). Check to ensure the average milk production per day is reasonable. If not, check data entry and amend as required.





**Figure 9.** Annual milk production section for the “Baseline farm” sheet (note this data entry section has been broken down into two images to make it easier to read the text).

*Step four: Average diet intakes and quality*

The ADCC needs relatively accurate diet digestibility (DMD) and crude protein (CP) data to estimate CH4 and N2O emissions. The easiest way to enter data here is to enter all the supplementary feed intakes (kg DM/day), taking into consideration wastage (i.e. ~ 1-2% for grain/concentrates, possibly up to 15% for silage and hay fed in the paddock), and quality. Click on the link in the green box on the left-hand side of this section if you are unsure of the feed quality information for each supplementary feed (circled in red in Figure 10 below). This action will lead you to a new sheet within ADCC, where there is a table of feeds, and their corresponding feed quality ranges to use as estimates. The feed quality sheet can also help you convert megajoules of energy (ME; MJ/kg dry matter) to DMD%. Additionally, the feed quality sheet can also help to determine the average feed quality for each feed type if you feed more than one. For example, feeding 2 kg of wheat with a CP of 12%, and 1 kg of lupins with a CP of 32%, equates to 3 kg of grain with a CP of 19.3%.

Once you have entered all supplementary feed, and their corresponding DMD and CP%, enter the average annual pasture DMD and CP%. If you have no idea of your pasture DMD and CP%, we suggest you enter 75 and 20, respectively, as these are the defaults used within the NGGI methodology, based on research by Christie *et al.* (2012).

ADCC estimates the potential total diet intake based on average annual milk production and diet DMD%. Daily intake is shown in italics on the left-hand side of the diet intakes and quality section, just above the red circle in Figure 10. If the amount of pasture consumed is not known, you can subtract the total amount of supplementary feed from this total intake to determine pasture intake. To illustrate on this farm example, ADCC estimated the cows required 17 kg DM/cow to produce 22.2 litres/day for 300 days. The milkers were fed 2.5 kg DM per day as grain/concentrate, and 1.5 kg DM per day as silage after wastage was taken into consideration. Therefore ADCC estimated the cows would require 13 kg DM of pasture per day. In Figure 10, we increased this slightly, 14 kg DM/day from pasture, which resulted in a diet of 18 kg DM/day, at 76.0% DMD, and 18.6% CP. Note: this section is only determining the overall diet DMD and CP% of the milker diet which is then also used for the dry period for the milking cow. While it is noted that dry cow diets are generally lower in quality, the sensitivity of feed quality on overall GHG emissions is relatively low. Thus, having two feed qualities, one during the lactation phase, and one during the non-lactating phase, is unnecessary. Daily intakes, including the dry period, to estimate GHG emissions (e.g. enteric CH4 emissions) are estimated using other data, such as milk production and liveweights.

ADCC also requires the feed quality for all other stock classes. We have not distinguished between stock classes here. If unsure of the feed quality, use the defaults of 75% DMD and 20% CP as these are implemented in the NGGI methodology, as per Christie *et al.* (2012).

Graphical user interface, text, application

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**Figure 10.** Milker average intakes and feed quality section for the “Baseline farm” system.

*Step five: Fertiliser inputs*

Fertiliser inputs are used to estimate N2O emissions from the application of fertilisers, CO2 emissions from lime and urea, and the pre-farm embedded Scope 3 emissions from the manufacturing of these fertilisers. To keep it simple, ADCC only mentions lime, but if you are also applying dolomite to pastures and/or crops, include this amount as you would for lime.

ADCC gives you two options for entering fertiliser input data from a drop-down list:

* tonnes of element per annum (e.g. 15 t of N/annum or 3.5 t of P/annum), or
* kg of element per hectare per annum (e.g. 225 kg N/ha.annum, 125 kg P/ha.annum).

Whichever option is selected, you need to use this for all fertiliser data entry. We are also asking for either tonnes or kg of element (i.e. N or P), not per product (i.e. urea or single superphosphate). If you do not know the percentage of element(s) in each product (e.g. urea is 46% N), then use the help option by clicking on the ‘Click here to work out fertiliser rates’ cell (highlighted by a red circle in Figure 11). This will take you to a new worksheet to help estimate total tonnes of element per annum from a range of fertilisers, including entering your own blends.

If you select *‘tonnes of element per annum’*, you only enter data on the right-hand side of this section (Figure 11). In this example, we applied 55 t N/annum to pastures across the whole farm (remember to include your outblock/runoff block), 10 t P/annum, 3 t K/annum, 3 t S/annum, and 150 t lime/annum. We also need to determine the percentage of N fertiliser that is urea for the CO2 released when applied to pastures and crops. In Figure 11, 95% of the 55 t of N was from urea, with the balance 5% of N included in di-ammonium phosphate (DAP). All other non-urea N fertilisers (e.g. SOA, DAP, MAP) do not release CO2 when applied to pastures and crops as atmospheric CO2 was not incorporated into these fertilisers when manufactured.

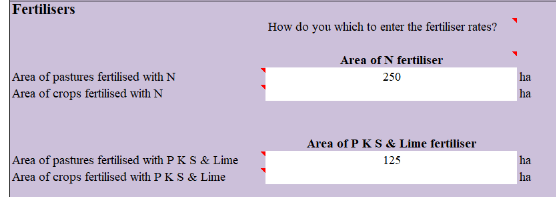
Graphical user interface, application

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**Figure 11.** Fertiliser inputs when selecting the tonnes of element per annum option.

If you select *‘kg of element per hectare per annum’* from the drop-down list, you need to fill in the whole *Fertilisers* section (Figure 12). You will need to determine the area of pasture fertilised with N, the rate of N, and the percentage of total N fertiliser from urea. This step needs to be repeated for P, K, S, and Lime. It becomes a bit harder with this option if you have different areas for each nutrient. In this instance, it may be easier to multiply each element by the area applied and enter this as tonnes of element per annum. In shown in Figure 12 below, 220 kg N/ha was applied to 250 ha of pastures, with urea being 95% of the total N fertiliser applied. In addition, 125 ha of pastures had 80 kg P, 24 kg K, 24 kg S, and 1,200 kg lime per hectare applied, which is the same amounts as shown in Figure 11.

Graphical user interface, application

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**Figure 12.** Fertiliser inputs when selecting the kg of element per hectare per annum option (note this data entry section has been broken down into two images to make it easier to read the text).

*Step six: Energy consumption*

Electricity consumption

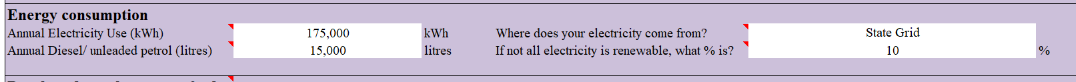
Enter your total electricity consumption for the dairy shed, irrigation, water supply, fences, workshop, calf shed etc. We don’t need the power for your private home or those of your employees. Use the drop-down list to select the source as either:

* state grid, or
* 100% renewable.

If a proportion of your electricity is from renewable sources, such as your supplier guarantees a percentage is from renewable sources, select ‘*State Grid’*, enter the total amount of electricity purchased, and the percentage from renewables. For example, my supplier guarantees that 10% is from renewables. If you consumed 175,000 kWh of electricity in the 12 month period, 90% would have a carbon footprint, based on the state grid emission factor, and the balance 10% from renewables will have a zero carbon footprint (Figure 13).

If you generate some electricity on farm through renewables (e.g. solar panels on the dairy), you need to firstly work out how much you purchased from the grid but then subtract any surplus electricity you fed back into the grid. For example, you purchased 100,000 kWh, and while you generated 60,000 kWh on farm through solar panels, 20,000 kWh of this was fed back into the grid. Thus, the amount of ‘purchased’ grid electricity was 80,000 kWh (i.e. 100,000 kWh purchased minus the surplus 20,000 kWh fed back into the grid). Enter 80,000 kWh in the Annual Electricity use cell, select ‘*State Grid’*, but ensure you enter 0 in the % of electricity from renewables cell to reflect the net amount purchased from the grid.

Alternatively, your farm consumed 140,000 kWh (i.e. 100,000 kWh purchased plus 60,000 kWh generated on farm minus 20,000 kWh fed back into the grid). Now you still need to work out what percentage of this 140,000 kWh was from renewables by dividing on farm generated electricity by total electricity consumed, thus 60,000 kWh divided by 140,000 kWh = 43% of the electricity consumed on farm was from renewable generation. The result is that 140,000 kWh x 57% (i.e. 1- 43% consumed on farm) = 80,000 kWh from non-renewables. This second method becomes messy, can be prone to error, and results in the same total emissions from state-grid electricity as the first method.



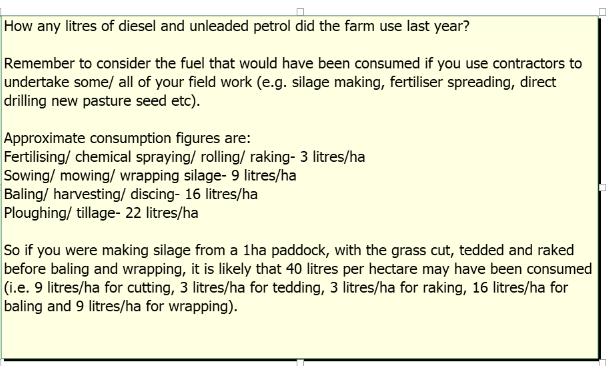


**Figure 13.** Electricity consumption, source (State Grid) and percentage from renewable sources (10%), along with fuel consumption (note this section of data entry has been broken down into two images to make it easier to read the text).

Diesel consumption

Enter the amount of diesel/unleaded petrol consumed per annum across the farm. Many dairy farms use contractors for some/all field work such as fertiliser spreading, silage making, paddock renovation etc. It is important to try and estimate how much fuel they may use with these operations, as these activities are part of your farm business. When you hover over the Annual Diesel/unleaded petrol text, there is a help message with estimates of consumption per hectare (Figure 14).

An example may be that a farmer used a contractor to fertilise 100ha, 3 times per year, so 100ha x 3 times/annum x 3 litres of diesel/ha = 900 litres of diesel. Another example is that 50 hectares was cut, tedded, raked, baled, and wrapped as silage. Thus, 50ha x 9 litres for mowing, 50ha x 3 litres for tedding, 50ha x 3 litres for raking, 50ha x 16 litres for baling and 50ha x 9 litres for silage wrapping = 2,000 litres of diesel. If an activity is not listed in the help message, identify a similar activity, remembering that the harder a tractor needs to work, the more fuel consumed per hectare.



**Figure 14.** Approximation of the amount of diesel consumed per hectare for typical paddock operations.

*Step seven: Purchased supplementary feed*

Enter the amount of purchased supplementary feed for the year of analysis. If you have two have two businesses, a dairy farm and a cropping farm and the emissions for the cropping farm is included in the dairy emissions (e.g. fuel and fertilisers), this does not constitute purchased supplementary feed, as the emissions have already been included. However, if the emissions of the cropping farm are not included in the dairy farm emission estimates, enter the amounts of supplementary feed ‘purchased’ from the cropping farm. This ensures that the emissions for amount of product coming from the cropping farm are accounted for.

The amount of feed purchased is multiplied by an emission factor to estimate the pre-farm embedded Scope 3 emissions associated with the production of these feeds. In the example below, the farm purchased 200 t DM of pasture hay, and 700 t DM of grain/concentrates (Figure 15). Suppose you purchased a large amount of supplementary feed towards the end of the assessment year. In this case, you could consider transferring this purchase to the following year of assessment to better reflect when that purchased feed was consumed on farm.

Graphical user interface, application

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**Figure 15.** Screenshot of a component of the purchased supplementary feed inputs (note some of the purchased supplements are not shown in this screenshot).

*Step eight: Carbon sequestration in trees*

ADCC gives you three options for determining the amount of carbon sequestered in trees on the farm. These are:

* No estimation of carbon sequestration,
* Based on data entered here, or
* Carbon sequestered using other tools

The first option is the default option when opening up ADCC, which results in zero carbon sequestration in trees.

The second option (*Based on data entered here*) requires you to select the appropriate answer from a series of drop-down lists:

* Region of Australia (the number of options available will depend on state selected at the start of the assessment, e.g. Victoria is divided into six regions),
* Type of trees planted (four to six options for each region),
* Soil type (two options)

You then need to enter the area of trees (hectares), and the average age of the trees (in whole years). In the Figure 16 example below, there was 15ha of 15 year old mixed species, planted on a Red Duplex soil in South West VIC. Most regions are relative distinct in terms of selecting the region within the state. However, the three Victorian regions of the Mallee, Northern, and North East may be a little bit harder to select, especially if the farm is close to a regional boundary. We have added a few examples of towns within each region. These can be found by hovering over the Choose your region in Australia text. If unsure, select one region, review the results, then select the other region, and review those results. The amount of carbon sequestered can be substantially lower in the Mallee vs the other two regions. Notice that while there are two soil types for each region, the amount of carbon sequestered in trees remains relatively similar for both. Therefore, selecting the correct soil type is less critical than region or tree species.

The tree species list differs from previous versions of ADCC, and only contains a few options. If your species is not present, select a similar option or the default Mixed species (Environmental Plantings) which is a blend of native trees, shrubs, and understory vegetation endemic to your region. Make sure you start from the top, and work down the sheet, as excel needs to know the region of Australia to then determine the type of trees and soil type option available for that region. Working up the sheet will result in either errors or zero carbon sequestration results.

Graphical user interface, application

Description automatically generated

**Figure 16.** Screenshot of the data entry when selecting the estimation is Based on data entered here.

If you select the third option of ‘*Carbon sequestered using other tools’* from the drop-down list, a new cell will appear asking for the amount of carbon sequestered (t CO2e/ha) using other tools (Figure 17). For instance, you may use the FullCAM model (<https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam>) or the LOOC-C online tool (<https://looc-c.farm/>) to determine the likely amount of CO2e sequestered on your farm with your tree species. In that case, you will only enter the amount of CO2 sequestered, and the area of trees planted; all other cells can remain blank (e.g. age of trees in Figure 17). In the below example, LOOC-C estimated that the 15ha of trees sequestered 6.5 t CO2e/ha.annum. **NOTE** other calculators may report the change in carbon as t C/ha.annum (e.g. FullCAM). To convert from tonnes of C to tonnes of CO2e, multiply the tonnes of C by 3.67 (e.g. 5 t C/ha = 18.35 t CO2e/ha).

Graphical user interface, application, icon

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**Figure 17.** Screenshot of the data needed to be entered if you select to estimate the Carbon sequestered using other tools option from the first drop-down list.

The estimation of carbon sequestered using ADCC is only indicative, it cannot be used as a surrogate for participating in carbon credit schemes such as the Federal Government’s *Reforestation by Environmental or Mallee Plantings-FullCAM methodology*, or non-government schemes.

You could use Carbon sequestration in trees as a surrogate for soil carbon sequestration. For example, you have soil tests to confirm that your farm’s soil carbon stocks have increased from 95.0 t C/ha to 95.2 t C/ha over the last 12 months. The net change in soil carbon stocks is a soil carbon flux of 0.2 t C/ha.annum. It is the annual carbon flux we need to include here, not carbon stocks. Select ‘*Carbon sequestered using other tools’* from the drop-down list, enter the amount of carbon sequestered/ha.annum, keeping in mind that you need to convert from t C/ha to t CO2e/ha, and the area of the farm in the Area of trees cell. For example, my 100 ha farm sequestered 73.3 t CO2e, based on 0.2 t C/ha.annum x 3.67 to convert from t C to t CO2e x 100ha.

*Step nine: Manure management*

The NGGI methodology uses a range of previous information, such as Dairy Australia’s Natural Resource Management surveys, to determine the amount of manure (dung and urine) deposited and handled by several manure management systems (MMSs). Around 80-85% of all manure is assumed to be deposited onto pastures or crops as the animals are grazing. The balance is divided between an anaerobic pond/lagoon system, a sump dispersal system, drains to the paddock, and solid storage. The more anaerobic a manure system is (e.g. pond/lagoon systems), the more CH4 is produced. Users decide if they wish to estimate their GHG emissions from a drop-down list:

* Default state-based factors and fractions, or
* User-defined factors and fractions

If you select the first ‘*Default state-based’* option, ADCC will populate the next few rows, illustrating how much manure will be assumed to go to each MMS (Figure 18). Most manure is allocated to pastures, then the lagoon system, with small amounts to the other three systems. This is the average for the whole state, so even though you may only have the first two options, there are other farms with other MMS options, such as the sump dispersal system, based on Dairy Australia’s surveys. For most farms, the state-based fractions will be relatively accurate for your farm system, reflecting cows are off pastures for 3-4 hours per day for milking.

However, if your milking herd spends substantially extended periods away from grazing paddocks and crops, either during moving to/from the dairy, retained on a feedpad system for supplementary feeding (i.e. partial mixed ration farms) or housed (TMR farms), you should explore the implications of how your manure is handled (Figure 18). This is done by selecting ‘*User-defined factors and fractions’* from the drop-down list. Then you are required to answer a series of questions to determine how long the milking herd is at the dairy, how the dairy manure is handled, how long the milking herd is on a feedlot, and how the feedlot manure is handled. There are plenty of help messages for this section, which can be accessed by hovering over each question.

In some circumstances, heifers might also be retained off paddocks, such as in TMR farms. In these instances, ADCC also needs to estimate the time these animals are on hard surfaces where their manure is collected. ADCC uses this same data for steers and bulls if this second ‘*User-defined factors and fractions’* option is selected. Note here that we are not concerned with heifers being occasionally through yards for routine herd health operations; only if the heifers are retained off paddocks for a significant period throughout the year.

Figure 18 is an example of entering data to determine how the manure is handled when entering your own farm management data. The cows are either moving to/from the dairy or in the dairy for 4 hours per day for 300 days per annum. ADCC assumes all the manure is flushed to a pond/lagoon system, unless the user enters the percentage of waste flushed and then drained to the paddock and/or spread daily from a sump/dispersal system. In this example, we also assumed there was some form of pre-treatment (selected from the appropriate drop-down list), with a solids-trap in place to collect some of the solids (default is 20% collected). The milkers then spent 2 hours per day for 300 days per annum on a feedlot, where the manure was scrapped and stockpiled. ADCC has calculated that 11% of the milkers’ manure is handled via a lagoon system (manure from the dairy), and 9.6% of their manure is handled as solid storage (solids trapped from the dairy before entering the lagoon plus the manure from the feedlot). The balance of the manure is deposited on pastures during grazing. In this example, all other stock remain grazing year-round, so 100% was allocated to pastures.

Users then can quickly revert back to selecting the ‘*Default state-based fractions and factors’* to explore the difference in results when using one option compared to the other. Farmers considering using a feedpad to manage supplementary feeding options could use this to understand the implications of changing feeding practices on total farm GHG emissions.

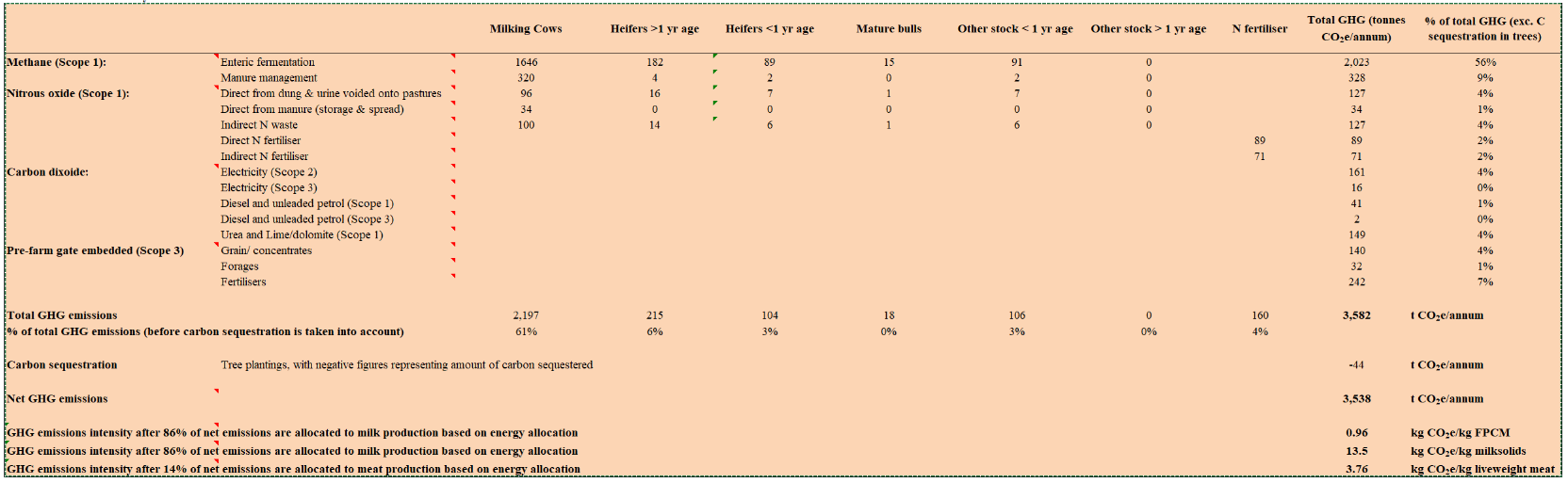
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**Figure 18.** A screenshot of a farm where the milking herd spends some time on a feedlot, so have used the option of exploring the farm-specific manure management practices.

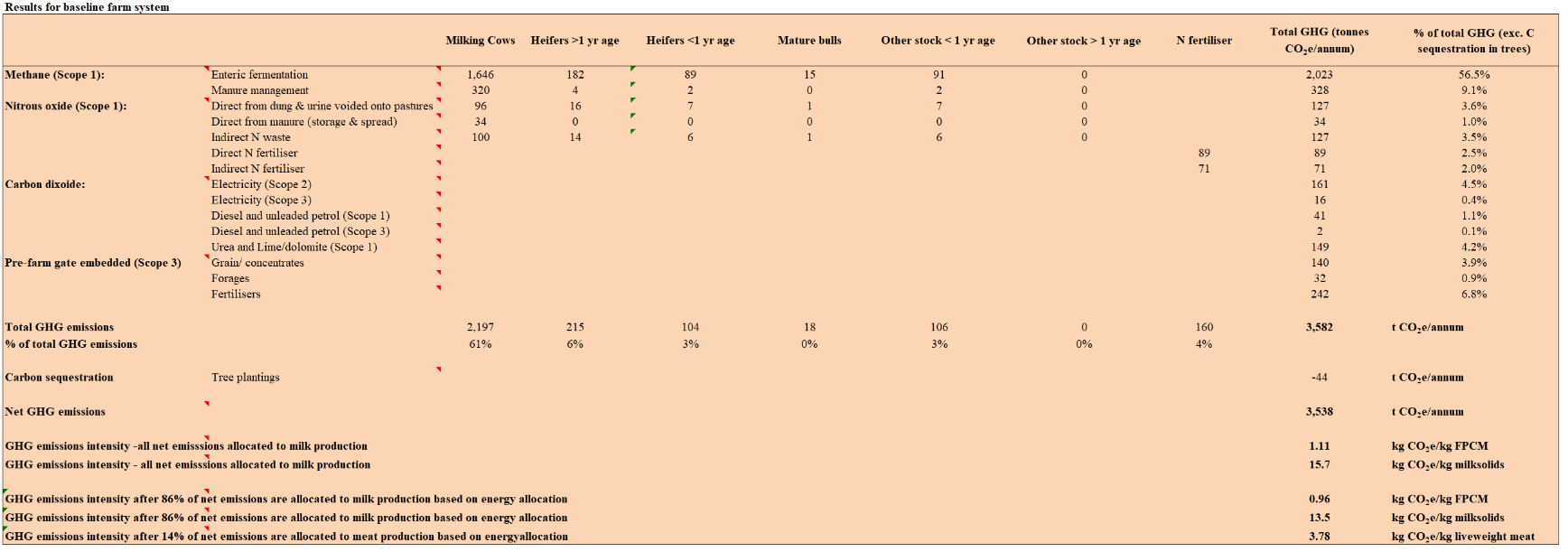
## Baseline farm results explanation

Once all the data is entered, users can view the results. As shown below (Figure 19), we entered fertiliser based on tonnes of element per annum (Figure 11), estimated trees on farm based on data entered here (Figure 16), and used the default state-based factors and fractions for manure management. Total GHG emissions were 3,582 t CO2e. However, as there were trees on farm sequestering 44 t CO2e/annum (shown as -44 t CO2/annum to reflect carbon sequestration), the resultant net emissions were 3,538 t CO2e/annum. Approx. 86% of net GHG emissions were allocated to milk production (shown in the text towards the bottom-left corner of the screenshot), with the balance 14% attributed to meat production. Milk EI was estimated at 0.96 kg CO2e/kg FPCM or 13.5 kg CO2e/kg MS, while meat EI was estimated at 3.76 kg CO2e/kg liveweight (Figure 19).



**Figure 19.** Screenshot illustrating the results for the whole farm (segmented below for easier reading)**.**

Results are presented as total GHG emissions for each stock class, along with direct and indirect N fertiliser emissions. Figure 20 shows the breakdown of emission for the milking herd, mostly CH4, with enteric fermentation at 1,646 t CO2e, and manure management at 320 t CO2e. The milking herd was responsible for 2,197 t CO2e, equivalent to 61% of total farm GHG emissions. Emissions for the Heifers > 1 yr age were significantly lower, at 215 t CO2e/annum, representing 6% of total farm GHG emissions.



**Figure 20.** Screenshot illustrating the milking cows and heifers > 1 year of age total greenhouse gas emissions.

Users can also see the breakdown across each source. For example, CH4 from enteric fermentation across the whole herd totalled 2,023 t CO2e, equivalent to 56% of total farm GHG emissions (Figure 21). The second largest source was CH4 from manure management, mainly associated with the manure while in effluent ponds, at 9% of total farm GHG emissions. Purchased fertilisers was the third largest source at 7% of total farm GHG emissions, while all other sources were < 5% of total GHG emissions (Figure 21).

Table

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**Figure 21.** Screenshot illustrating the total farm GHG emissions and percentage of total farm greenhouse gas emissions for each source (note some columns have been hidden to illustrate this).

Net GHG emission (i.e. total emissions minus carbon sequestered in trees) are divided by milk production to allow comparison between years or farms. In this example approx. 86% of GHG emissions are attributed to milk production, using an adapted method based on the that described by IDF (2022). Therefore, EI was 0.96 kg CO2e/kg FPCM or 13.5 kg CO2e/kg milk, while meat EI was 3.76 kg CO2e/kg liveweight (Figure 22). If users wanted to compare their EIs to historical data, where net emissions were fully allocated to milk production, divide milk EI by the % allocated to milk. For example, 0.96 kg CO2e/kg FPCM divided by 86% allocated to milk equals an EI of 1.11 kg CO2e/kg FPCM if 100% of emissions were allocated to milk production.

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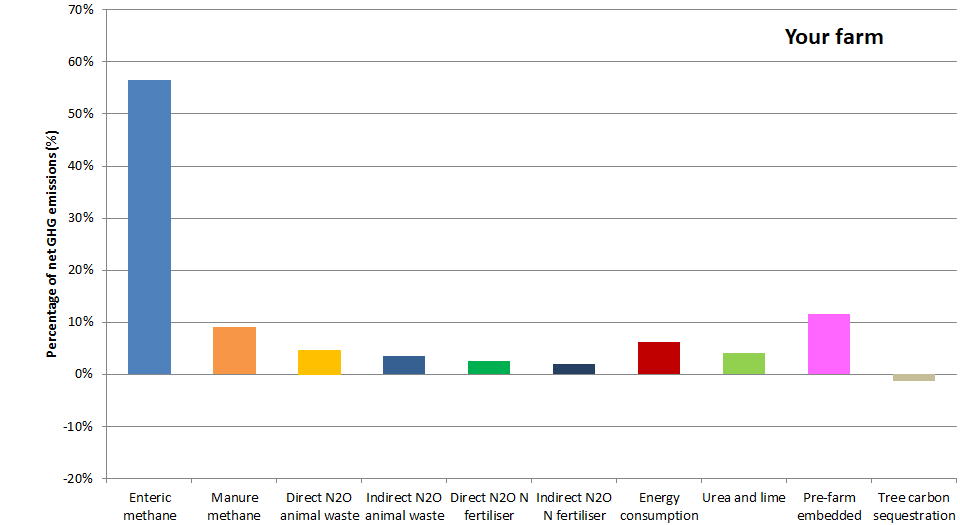
**Figure 22.** Screenshot illustrating the emissions intensity of milk and meat production when a proportion of emissions are allocated to meat (note some columns have been hidden to illustrate this).

Results are also presented graphically, detailing the percentage of emissions for each source, along with carbon sequestered in trees for the farm being assessed and for a typical farm, South West Victoria in this example (Figure 23). In the example below, the graphs have been presented vertically here due to the size of the graphs. Around 56% of the farm’s net GHG emissions was enteric CH4, compared to around 58% for the typical average farm (dark blue columns). In contrast, urea and lime emissions (lime green columns) are double for the farm examined here, at 4% compared to 2% for the typical farm (Figure 23). Appendix 2 contains the percentage of emissions from each source for the typical farm comparison.

If EI for the farm is outside an expected range of between 0.6 and 1.2 kg CO2e/kg FPCM or between 8 and 18 kg CO2e/kg milksolids, check data entry to ascertain if there is any noticeable data entry errors. If the farm has large areas of trees on farm, net EIs could be lower than this range. Allocation of emissions to meat will further reduce milk EI. However, the level of reduction cannot be indicated here as some farms might only have 10-15% of emissions allocated to meat (i.e. small amount of meat leaving the farm, for example when all non-replacement animals are sold at one week of age) while others may have 40-50% of emissions allocated to meat (i.e. retain all non-replacement animals to fatten before selling to processors).

Analysing the graphs may also help with ascertaining if there are any data entry errors. For example, if your farm’s energy consumption was 40% of net GHG emissions, this is significantly different to the typical farm, averaging 5-10%. Therefore, check data entry for electricity and fuel consumption. Minor errors in data entry are more difficult to ascertain as the result might still fall within typical ranges.

We have provided typical averages based on several years of data from Dairy Australia’s DairyBase program, using the Dairy Farm Monitor Project (DFMP) and Queensland Dairy Accounting Scheme (QDAS) datasets (approx. 1,775 datasets from 2015-16 to 2020-21 inclusive). The user needs to select their region, at the top of the worksheet, so ADCC can populate the Typical averages graph. Alternatively, users can compare their results to other regions or against the Australia-wide average. We have also included a comparison of the farm system, based on the level of grain feeding. Users can select either low grain feeding (< 1 t DM/cow.lactation), medium grain feeding (1-2 t DM/cow.lactation) or high grain feeding (> 2 t DM/cow.lactation). These numbers are also presented in Appendix 2.



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**Figure 23.** Screenshot of the percentage of the total greenhouse gas emissions and carbon sequestered in trees for the farm being assessed compared to a typical average.

## Previous methodology comparison

Over time, as new knowledge from scientific research emerges, the NGGI methodology is updated. Examples of this have been changes to the Australian enteric CH4 equation or changes to global GWPs for CH4 and N2O. The Australian NGGI methodology was developed in 1990, and since then there has been two major updates, in 2017 (ADCC version 4), and more recently in 2022 (current ADCC version 5). Within ADCC, we have retained these two older methodologies, facilitating users to compare the same farm input data across all three NGGI methodologies. By entering data into the “Baseline farm” sheet, this populates and estimates the 1990 and 2017 methodology comparisons.

For the example farm used predominantly throughout this manual, after considering the amount of carbon sequestered in trees, and using the new method of estimating carbon sequestration in trees, net GHG emissions was 3,198 t CO2e/annum with the 1990 methodology. Emissions increased to 3,245 t CO2e/annum with the 2017 methodology, and further still to 3,538 t CO2e/annum with the 2022 methodology. Likewise, EI has also increased over time as milk production has remained the same.

The biggest contributor to the rise in net GHG emissions over time has been the increase in GWP of CH4. In 1990, the NGGI methodology adopted the GWP of 21 (based on SAR), increasing to 25 in 2017 (based on AR4) and further again in 2022 to 28 (based on AR5) (Myhre *et al.* 2013). At the same time, the GWP for N2O has declined from 310 to 298, and now to 265 (Myhre *et al.* 2013). Inclusion of CO2 from urea and lime have been included for the first time with the 2022 methodology. Other emission factors have also altered over time, although these changes have had minimal impact on total GHG emissions. Given that the largest source of GHG emissions is enteric CH4, any change in the GWP can substantially impact net GHG emissions.

When comparing results, it is important to understand which methodology is being used, especially the GWPs, and whether a proportion of emissions have been allocated to meat. If so, which allocation method (i.e. mass, economic, systems expansion, or energy as implemented in ADCC) was used to estimate GHG emissions. Otherwise, you may be comparing 1990 results with no meat GHG allocation with 2022 results with a meat GHG allocation.

## What’s different between versions 4 and 5 of ADCC?

There have been a series of updates/amendments between ADCC versions 4 and 5. These include:

* Updated methodology, taking into consideration changes in the GWP of CH4 and N2O in line with the IPCC (2014) AR5 guidelines,
* Alterations to some of the emission factors related to estimating N2O emissions,
* Alterations to the emission factors for supplementary feeds and fertilisers,
* Separation of results into Scope 1, Scope 2, and Scope 3 sources,
* Inclusion of the CO2 emissions associated with the breakdown of urea and lime fertiliser when applied to pastures and crops,
* An explanation of each emission source is included as a note in the results table,
* Two ‘Other stock’ classes (< 1 yr of age and > 1 yr of age). This will combine all non-replacement heifers and steers with young bulls that are retained on farm to facilitate the growth in dairy beef from within the industry,
* Estimation of the amount of meat sold from livestock,
* Inclusion of the CO2 emitted with the spreading of urea and lime onto pastures and crops,
* Allocation of a proportion of GHG emissions to meat based on an updated methodology developed by the International Dairy Federation (2022), based on the energy requirements of milk and meat (see Appendix 1 for the example baseline farm developed for this manual)
* Milk EI, based on 100% of emissions allocated to milk, is no longer reported. This decision was reached given dairy farms also produce meat (cull cows, non-replacement calves, fattened steers etc). ADCC now allocates a proportion of net GHG emissions to milk and meat based on the energy requirements to produce each in accordance with the IDF (2022) methodology. See Appendix 1 for a working example,
* Typical farm emissions comparison based on the results of the DFMP and QDAS 2015/16 to 2020/21 years (total of 1,275 datasets) for each region or farm system (see section 7, Benchmarking in a separate document on the Dairy Australia website),
* Tree carbon sequestration estimations based on FullCAM outputs as per other carbon calculators (e.g. SB-GAF), and now regionally specific rather than based on average annual rainfall,
* When developing COST within ADCC version 4, we included a potential income that might be derived if the EI of milk production decreased with the implementation of an abatement strategy, even if net GHG emissions increased. Over time, the focus has moved away from a reduction in EI, towards reducing absolute net GHG emissions. Thus, reporting any change in EI, and potential income derived from this change, is no longer relevant. Thus, all references to this have been removed along with rearrangement of the graphs for each abatement strategy explored,
* Inclusion of the password to unprotect sheets, located in the Introduction tab at the bottom of the list of changes (Dairy\_DGAS).

## What are some of the limitations of ADCC?

The estimations in ADCC rely on accurate farm data, “rubbish in” equals “rubbish out”. The calculator’s most sensitive number is the milking herd size. Each additional milking cow can be responsible for 4-5 t CO2e/annum. Accurate annual milk production for the whole herd is also important as it is one of the major determinants of daily intake and, therefore, daily enteric CH4 emissions.

The GHG emission estimates are relatively static, and thus for some estimates, farm management can have a diminished impact on results. For example, each tonne of N fertiliser applied results in ~ 3 t CO2e from direct and indirect N2O emissions. The calculator does not distinguish whether the total amount was applied once per annum or smaller, more frequent applications. Clearly the risk of losing N to the environment (especially leaching and volatilisation) is greater if applied as 2-3 larger applications vs several smaller applications where the pastures can take up most of the N applied. Likewise, some soils are more conducive to leaching, and thus higher indirect N2O losses. The NGGI equations have taken a national approach to estimate N2O losses.

The enteric CH4 equation is based on daily DM intake, which is driven by milk production, liveweight, and diet DMD%. The equations assume an increase in milk production results from an increase in daily DM intake. Therefore, the calculator does not consider any improvement in feed conversion efficiency/residual feed intake of the animal. For example, two cows eat the same diet, have the same liveweight, and produce the same amount of milk per day. One cow consumes 15 kg DM/day while the other consumes 16 kg DM/day. The first cow has a lower residual feed intake for the same level of milk production. The calculator will estimate that because both cows produce the same amount of milk, their intakes are assumed to be the same, and therefore both cows produce the same amount of CH4 per day.

Several supplementary feeds may reduce enteric CH4 production. For example, feeding a source of high dietary fat can reduce enteric CH4 by 3.5% for each 1% increase in overall diet fat content (see Sections 6.4 and 6.5). Another example is a comparison made by Moate *et al.* (2017), finding dairy cattle fed wheat produced significantly less enteric CH4 than if they were fed either barley or maize grain. The baseline farm estimation does not take the diet’s fat content, or the grain type into consideration. All diets are assumed to produce 20.7 grams of CH4 per kg of DMI (Charmley *et al.* 2016).

Similarly, there are pasture species that contain condensed tannins (e.g. Birdsfoot trefoil (*Lotus corniculatus*), sulla (*Hedysarum coronarium*), and plantain (*Plantago lanceolota*) (Min *et al.* 2020; Simon *et al.* 2019)). These species, to varying degrees, can reduce enteric CH4 production. In addition, some of these species can also reduce N2O emissions through the binding of proteins, increasing the deposition of N into dung vs urine. Suppose if the DMD and CP% of the diet with these species is comparative to perennial ryegrass/white clover pastures, and thus milk production per cow also remains the same. In that case, ADCC cannot estimate any reduction in GHG emissions with the alternative pasture species.

The calculator does not estimate soil carbon due to the difficulty of accurate estimates due to spatial and temporal variability. However, on the assumption that the user has either measured data for changes in soil C, or data from other tools such as FullCAM, it is possible to include this data by substituting tree carbon with soil carbon using the “Carbon sequestered using other tools” option (see Figure 17).

Tree carbon sequestration is based on a regional average for a limited number of tree species. The inclusion of tree carbon sequestration is for illustrative purposes, giving a reasonable estimate. If farmers are keen to better understand the potential to sequester carbon in trees on their farm, we suggest they seek this information from other tools, such as LOOC-C (<https://looc-c.farm/>), FullCAM (<https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam>), or from specialist tree carbon service providers.

d here).

# 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>

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Christie KM, Gourley CJP, Rawnsley RP, Eckard RJ, Awty IM (2012) Whole-farm systems analysis of Australian dairy farm greenhouse gas emissions. *Animal Production Science* **52**, 998-1011.

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/>

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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.

Moate PJ, Williams SRO, Jacobs JL, Hannah MC, Beauchemin KA, Eckard RJ, Wales WJ (2017) Wheat is more potent than corn or barley for dietary mitigation of enteric methane emissions from dairy cows. *Journal of Dairy Science* **100**, 7139-7153.

Myhre G, Shindell D, Bréon F-M, Collins W, Fuglestvedt J, Huang J, Koch D, Lamarque J-F, Lee D, Mendoza B, Nakajima T, Robock A, Stephens G, Takemura T, Zhang H (2013) Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.‐K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. Adapted in <https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf>

Simon PL, de Klein CAM, Worth W, Rutherford AJ, Dieckow J (2019) The efficacy of Plantago lanceolata for mitigating nitrous oxide emissions from cattle urine patches. *The Science of the Total Environment* **691**, 430-441.

# Appendices

***Appendix 1***

At the time of developing ADCC version 5, and this accompanying manual, along with upgrading the carbon calculator within DairyBase, it became clear the International Dairy Federation (IDF, 2022) were embarking on upgrading the method of estimating the allocation of GHG emissions to milk and meat. Previous versions of the Australian calculators had allocated all GHG emissions to milk. Given the aim to maintain as many similarities as possible between these two calculators in addition to the IDF methodology, a method of estimating milk and meat net emissions, and emissions intensity was devised to best align with DairyBase, with this method reproduced for ADCC.

*Step 1:*

Total liveweight sold is estimate by multiplying the number of animals sold by their liveweight at point of sale. For the baseline farm, 115 culled cows @ 550kg = 63,250 kg, 215 calves sold post-weaning @ 105 kg = 22,575 kg, 10 rising 2 year old heifers @ 425 kg, 4 bulls @ 600 kg = 6,650 kg, and 100 Other livestock < 1 year of age @ 400 kg = 40,000kg. Meat sales totalled 132,475 kg.

|  |  |  |
| --- | --- | --- |
| **Livestock class** | **Number of stock sold and liveweight (kg)** | **Total LW per stock class** |
| Culled cows | 115 @ 550kg | 63,250 |
| Calves sold at birth | 0 | 0 |
| Calves sold post-weaning | 215 @ 105kg | 22,575 |
| Fattened dairy livestock (heifers and bulls) | 10@ 425kg,  4@ 600kg | 6,650 |
| Fattened Other livestock | 100@ 400kg | 40,000 |
| Total LW |  | 132,475 |

*Step 2:*

Total energy demand for meat is estimated by multiplying the total liveweight of meat for each stock class by the energy required for each kg of liveweight. For example, for culled cows, multiply 63,250 kg LW by 15.0 MJ/kg LW to attribute 948,750 MJ energy to cull culls. Energy attributed to Other Livestock (440,000 MJ) was deemed to automatically be attributed to meat production, as this represents where they retain non-replacement heifers and steers for the dairy beef market. The total energy demand for dairy livestock meat for each stock class was divided by dairy meat total energy demand. For example, the culled cows have an energy demand of 948,750 MJ out of a total of 1,360,525 MJ, representing 70% of total dairy meat energy demand attributed to culled cows. Likewise, a similar process is undertaken for all other dairy meat stock classes. For culled cows, 948,750 MJ out of 1,800,525 MJ represents 53% of total energy demand from all livestock meat. The same process is undertaken for all other stock classes.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Livestock class** | **Number of stock sold and liveweight (kg)** | **Total LW per stock class** | **Energy factor (MJ/kg LW) per stock class** | **Total energy demand to dairy livestock meat** | **% of total meat energy demand from dairy meat** | **Total energy demand to all livestock meat** | **% of total meat energy demand from all livestock meat** |
| Culled cows | 115 @ 550kg | 63,250 | 15.0 | 948,750 | 70 | 948,750 | 53 |
| Calves sold at birth | 0 | 0 | 27.5 | 0 |  | 0 | 0 |
| Calves sold post-weaning | 215 @ 105kg | 22,575 | 15.0 | 338,625 | 25 | 338,625 | 19 |
| Fattened dairy livestock (heifers and bulls) | 10@ 425kg,  4@ 600kg | 6,650 | 11.0 | 73,150 | 5 | 73,150 | 4 |
| Fattened Other livestock | 100@ 400kg | 40,000 | 11.0 |  |  | 440,000 | 24 |
| Total LW |  | 132,475 |  |  |  |  |  |
| Energy demand for meat |  |  |  | 1,360,525 |  | 1,800,525 |  |

*Step 3:*

Estimate the energy attributed to milk production by multiplying total FPCM by 3.1. For the baseline farm, this represents 9,855,833 MJ/annum. Add this to meat energy to determine total energy demand for dairy livestock meat (11,216,358 MJ/annum), and energy demand to all livestock meat (11,656,358 MJ/annum). Then divide energy demand for milk by total energy demand to dairy livestock meat to determine the % of energy attributed to milk. In this example, milk energy is 88% of total milk + dairy meat (i.e. 9,855,822 MJ / 11,216,358 MJ = 88%), while energy demand for milk, as a proportion of all milk + meat energy demand, is 85% (i.e. 9,855,833 MJ / 11,656,358 MJ = 85%).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Livestock class** | **Number of stock sold and liveweight (kg)** | **Total LW per stock class** | **Energy factor (MJ/kg LW) per stock class** | **Total energy demand to dairy livestock meat** | **% of total meat energy demand from dairy meat** | **Total energy demand to all livestock meat** | **% of total meat energy demand from all livestock meat** |
| Culled cows | 115 @ 550kg | 63,250 | 15.0 | 948,750 | 70 | 948,750 | 53 |
| Calves sold at birth | 0 | 0 | 27.5 | 0 |  | 0 | 0 |
| Calves sold post-weaning | 215 @ 105kg | 22,575 | 15.0 | 338,625 | 25 | 338,625 | 19 |
| Fattened dairy livestock (heifers and bulls) | 10@ 425kg,  4@ 600kg | 6,650 | 11.0 | 73,150 | 5 | 73,150 | 4 |
| Fattened Other livestock | 100@ 400kg | 40,000 | 11.0 |  |  | 440,000 | 24 |
| Total LW |  | 132,475 |  |  |  |  |  |
| Energy demand for meat |  |  |  | 1,360,525 |  | 1,800,525 |  |
| Energy demand for milk |  |  |  | 9,855,833 |  | 9,855,833 |  |
| Total energy demand for milk and meat |  |  |  | 11,216,358 |  | 11,656,358 |  |
| % total energy to milk |  |  |  | 88% |  | 85% |  |

*Step four:*

The IDF methodology (2022) refers to systems separation, where GHG emissions that can be solely attributed to the dairy or to meat production should be appropriately allocated. Given the difficulty of separating the GHG emissions from a dairy system from a dairy-beef system, we have devised a method of allocating each source of GHG emissions. ADCC attributes all electricity and pre-farm gate embedded emissions from concentrates and forages to the milk production (348 t CO2e/annum in this example). This is based on the assumption that most electricity is either consumed in the dairy shed or for irrigating pastures fed to dairy cows. Likewise, most concentrates are fed to the milking herd compared to raising other livestock for the dairy-beef market.

All GHG emissions from the milking herd, replacement heifers and bulls (2,533 t CO2e/annum in this example) were multiplied by the proportion of total energy to milk, i.e. 88% in this example, thus attributing 2,226 t CO2e/annum to milk production, with the balance 12% (307 t CO2e/annum) attributed to meat production to reflect culled cows, sold replacements etc.

All GHG emission from Other Livestock (106 t CO2e/annum) was attributed to meat production.

General farm emissions (N fertilisers, urea, and lime CO2e emissions, pre-farm embedded emissions from fertilisers, emission from fuel, and carbon sequestered in trees), totalling 550 t CO2e/annum in this example, could not be separated between milk production and meat production. A proportion of these emissions were attributed to milk production, based on the proportion of milk energy to total milk and meat energy, i.e. 85% in this example, thus 483 t CO2e/annum, with the balance 15% of general farm GHG emissions (67 t CO2e/annum) attributed to meat production.

Therefore, milk production was allocated 3,039 t CO2e (i.e. sum of 2,226 t CO2 from the milking herd related livestock, 348 t CO2e from electricity and concentrates, and 483 t CO2e from general farm emissions) while meat production was allocated the balance 498 t CO2e (i.e. sum of 106 t CO2e from Other livestock, balance of 307 t CO2e from dairy herd related livestock, and balance of 67 t CO2e from general farm GHG emissions). Milk and meat production GHG emissions were then divided by total GHG emissions to determine the percentage of emissions allocated to milk and meat, at 86% and 14%, respectively.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Livestock class** | **Number of stock sold and liveweight (kg)** | **Total LW per stock class** | **Energy factor (MJ/kg LW) per stock class** | **Total energy demand to dairy livestock meat** | **% of total meat energy demand from dairy meat** | **Total energy demand to all livestock meat** | **% of total meat energy demand from all livestock meat** | **GHG emissions**  **(t CO2e/annum)** |
| Culled cows | 115 @ 550kg | 63,250 | 15.0 | 948,750 | 70 | 948,750 | 53 |  |
| Calves sold at birth | 0 | 0 | 27.5 | 0 |  | 0 | 0 |  |
| Calves sold post-weaning | 215 @ 105kg | 22,575 | 15.0 | 338,625 | 25 | 338,625 | 19 |  |
| Fattened dairy livestock (heifers and bulls) | 10@ 425kg,  4@ 600kg | 6,650 | 11.0 | 73,150 | 5 | 73,150 | 4 |  |
| Fattened Other livestock | 100@ 400kg | 40,000 | 11.0 |  |  | 440,000 | 24 |  |
| Total LW |  | 132,475 |  |  |  |  |  |  |
| Energy demand for meat |  |  |  | 1,360,525 |  | 1,800,525 |  |  |
| Energy demand for milk |  |  |  | 9,855,833 |  | 9,855,833 |  |  |
| Total energy demand for milk and meat |  |  |  | 11,216,358 |  | 11,656,358 |  |  |
| % total energy to milk |  |  |  | 88% |  | 85% |  |  |
| Milk only emissions |  |  |  |  |  |  |  | 348 |
| Meat only emissions |  |  |  |  |  |  |  | 106 |
| Dairy livestock emissions  (milk/meat breakdown) |  |  |  |  |  |  |  | 2,533  (2,226/307) |
| General farm emissions  (milk/meat breakdown) |  |  |  |  |  |  |  | 550  (483/67) |
| Total emissions |  |  |  |  |  |  |  | 3,538 |
| Total milk GHG emissions |  |  |  |  |  |  |  | 3,039 |
| Total meat GHG emissions |  |  |  |  |  |  |  | 498 |
| % total CO2 allocated milk |  |  |  |  |  |  |  | 86% |
| % total CO2 allocated meat |  |  |  |  |  |  |  | 14% |

*Step 5:*

Milk allocated GHG emissions were then divided by total milk production to estimate the EI for milk production. In this example, 3,039 t CO2e was divided by 3179.3 t FPCM, resulting in an EI of 0.96 kg CO2e/kg FPCM. Total meat allocated GHG emissions were then divided by total meat produced to estimate the EI of meat production. In this example, 498 t CO2e was divided by 132.475 t liveweight, for an EI of 3.76 kg CO2e/kg liveweight.

While not visible to users of ADCC, there is a further series of steps to estimate the EI of meat production for each stock class. The emissions for each stock class is then calculated as dairy livestock GHG emissions x (1- total energy demand to dairy livestock meat %) x (% of total energy demand for meat from dairy meat + general farm GHG emissions) x (1- Total energy demand to all livestock meat %) x % of total energy demand for meat from all livestock meat.

In this example above, the tonnes of CO2 allocated to cull cows was 2,533 t CO2e x (1-88%) x 70% + 550 t CO2e x (1-85%) x 53%, equivalent to 259 t CO2e. This was then converted into kg of CO2e, and then divided by total kg of meat from cull cows (63,250 kg), to estimate an EI of 4.1 kg CO2e/kg LW. The same process is undertaken for all other stock classes. For this example, the EI was 4.1 kg CO2e/kg LW for weaned calves, 3.0 kg CO2e/kg LW for fattened dairy livestock, and 3.2 kg CO2e/kg LW for fattened Other livestock. This illustrates that while the overall meat EI was 3.8 kg CO2e/kg LW, there was variation between stock classes. The total GHG emissions to milk production is also divided by total milksolids production to estimate a milksolids EI for ADCC.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Total emissions**  **(t CO2e/annum)** | **Total product**  **(t FPCM)** | **EI milk**  **(kg CO2e/kg FPCM** | **Total product**  **(t LW)** | **EI meat**  **(kg CO2e/kg LW)** |
| Milk | 3,039 | 3,179.3 | 0.96 |  |  |
| Meat | 498 |  |  | 132.5 | 3.8 |
| Culled cows | 259 |  |  | 63.3 | 4.1 |
| Calves at birth | 0 |  |  | 0 | 0 |
| Calves weaned | 92 |  |  | 22.6 | 4.1 |
| Fattened dairy livestock | 20 |  |  | 6.7 | 3.0 |
| Fattened other livestock | 127 |  |  | 40 | 3.2 |

***Appendix 2***

Typical regional, state, country-wide, and level of grain feeding percentage of GHG emissions, based on several years of DairyBase data (Dairy Farm Monitor Project and Queensland Dairy Accounting Scheme from 2015-16 to 2021-22). Note that with the upgrade of ADCC/DairyBase with respect to tree carbon sequestration, we were unable to generate a percentage of net emissions attributed to carbon sequestered in trees.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source/sink GHG emissions** | **Australia-wide** | **Victoria** | **VIC- Gippsland** | **VIC- Northern** | **VIC-**  **South West** | **New South Wales** | **NSW-**  **North** | **NSW-**  **South** |
| Enteric CH4 | 60% | 60% | 60% | 61% | 58% | 58% | 56% | 59% |
| Waste CH4 | 9% | 10% | 10% | 10% | 9% | 10% | 9% | 11% |
| N2O direct grazing | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% |
| N2O Manure storage & spread | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| N2O Indirect N waste | 2% | 2% | 2% | 1% | 2% | 2% | 2% | 2% |
| N2O Direct N fertiliser | 3% | 3% | 3% | 3% | 3% | 3% | 3% | 3% |
| N2O Indirect N fertiliser | 2% | 2% | 2% | 1% | 2% | 2% | 2% | 1% |
| Electricity | 4% | 5% | 4% | 5% | 5% | 6% | 7% | 5% |
| Fuel | 2% | 2% | 1% | 2% | 2% | 2% | 2% | 2% |
| Urea & Lime | 2% | 2% | 2% | 1% | 2% | 2% | 2% | 1% |
| Concentrates | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 6% |
| Fodder | 1% | 1% | 1% | 3% | 1% | 1% | 1% | 2% |
| Fertiliser | 5% | 5% | 6% | 3% | 6% | 5% | 6% | 4% |
| Trees | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

***Appendix 2 cont.***

Typical regional, state, country-wide, and level of grain feeding percentage of GHG emissions, based on several years of DairyBase data (Dairy Farm Monitor Project and Queensland Dairy Accounting Scheme from 2015-16 to 2021-22). Note that with the upgrade of ADCC/DairyBase with respect to tree carbon sequestration, we were unable to generate a percentage of net emissions attributed to carbon sequestered in trees.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Source/sink GHG emissions** | **Queensland** | **QLD-**  **North** | **QLD-**  **South** | **South Australia** | **Tasmania** | **Western Australia** | **Low grain1** | **Med grain1** | **High grain1** |
| Enteric CH4 | 60% | 61% | 60% | 61% | 66% | 60% | 64% | 60% | 59% |
| Waste CH4 | 9% | 9% | 9% | 10% | 8% | 8% | 9% | 9% | 9% |
| N2O direct grazing | 3% | 3% | 3% | 3% | 4% | 3% | 4% | 3% | 3% |
| N2O Manure storage & spread | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% | 1% |
| N2O Indirect N waste | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% | 2% |
| N2O Direct N fertiliser | 3% | 4% | 3% | 3% | 4% | 3% | 4% | 3% | 3% |
| N2O Indirect N fertiliser | 1% | 1% | 1% | 1% | 2% | 2% | 1% | 2% | 1% |
| Electricity | 4% | 4% | 4% | 3% | 1% | 3% | 3% | 5% | 4% |
| Fuel | 2% | 2% | 2% | 3% | 1% | 2% | 2% | 2% | 2% |
| Urea & Lime | 2% | 2% | 1% | 1% | 2% | 2% | 2% | 2% | 1% |
| Concentrates | 6% | 5% | 6% | 5% | 4% | 6% | 3% | 4% | 6% |
| Fodder | 1% | 1% | 1% | 2% | 1% | 1% | 1% | 1% | 1% |
| Fertiliser | 5% | 5% | 4% | 5% | 6% | 6% | 5% | 6% | 5% |
| Trees | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |

1 Low grain feeding = < 1 tonne DM/cow.lactation, medium grain feeding = 1-2 tonnes DM/cow.lactation, high grain feeding = > 2 tonnes DM/cow.lactation.