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A Guide to Carbon Footprint Assessment for South Australian Livestock Production Systems

AgExcellence ALLIANCE

National Landcare Program

LANDSCAPE SOUTH AUSTRALIA NORTHERN AND YORKE

LANDSCAPE SOUTH AUSTRALIA MURRAYLANDS AND RIVERLAND

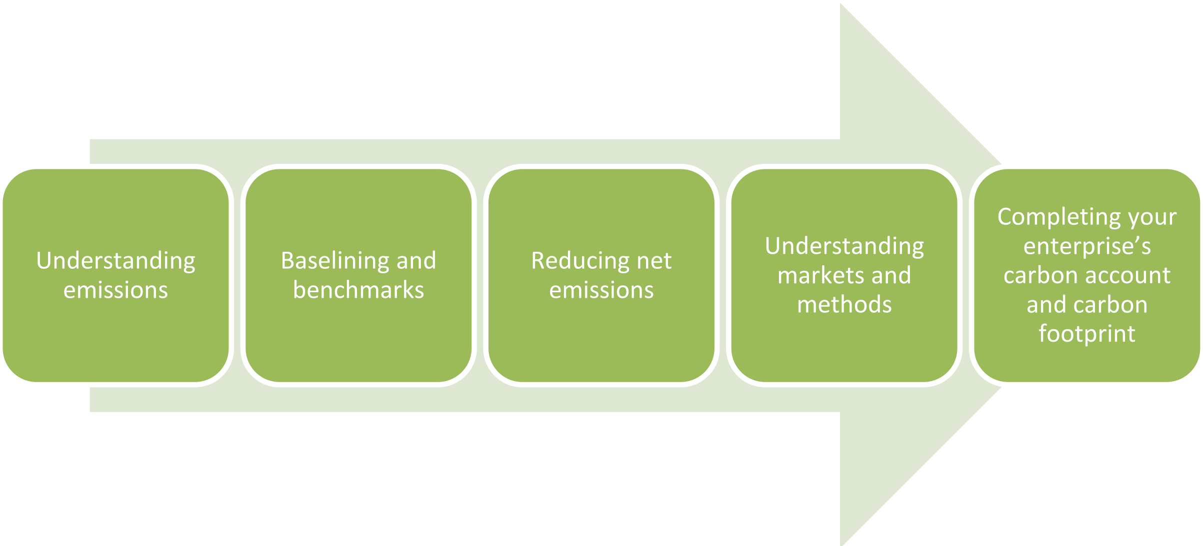
INTEGRITY AG & Environment

Introduction

This technical manual is based on the outcomes and feedback from a study conducted for the Department of Primary Industries and Regions (PIRSA) and a series of pilot carbon accounting workshops run in early 2022 in South Australia with Ag Excellence Alliance (Ag Ex). This manual provides background information on carbon accounting and explains how to undertake a simplified carbon account for livestock operations.

The guideline follows the process of understanding and quantifying carbon impacts and moving towards emission reduction. The steps are as follows (and these represent the section headings of this guideline):

1. *Understanding emissions*
2. *Baselining and benchmarks*
3. *Reducing net emissions*
4. *Understanding markets and methods*
5. *Completing your enterprise's carbon account and carbon footprint*



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1 Understanding agricultural GHGs

Greenhouse gases (GHGs) contribute to climate change by trapping radiant heat energy within the atmosphere, leading to global warming[1]. Each gas has a different Global Warming Potential (GWP), a measure of cumulative radiative forcing (the long-term contribution of a particular gas to global warming)[2]. GWP_{100} is the global metric for assessing the average contribution to global warming over the next 100 years and is reported in carbon dioxide equivalents (CO_2-e). Most global GHG emissions come from burning fossil fuels, releasing carbon dioxide (CO_2)[1]. That is why CO_2-e is used, as it enables all different GHGs to be compared in terms of their effect on global warming. The GWP_{100} values and how these have changed over time are shown in Table 1. The last column, labelled "AR 5", shows the values in use when this guideline was published.

Table 1. Global warming potential (GWP) of the major greenhouse gases, showing the changing values over time

Chemical Name	Chemical Formula	GWP values for a 100-year time horizon		
		Second Assessment Report (SAR) – used prior to 2015	Fourth Assessment Report (AR4) – used from 2015 to 2019	**Fifth Assessment Report (AR5) – current value used**
Carbon Dioxide	CO_2	1	1	**1**
Methane	CH_4	21	25	**28**
Nitrous Oxide	N_2O	310	298	**265**

While it is referred to as 'carbon accounting' for ease, these accounts also include nitrous oxide (N_2O), methane (CH_4) and other emissions and, therefore, would be more accurately termed 'GHG accounting'. In this guide, the two terms are considered synonymous. These other gases are important in agriculture, and the Australian Government's *National GHG Inventory* (also known as the National Inventory Report or NIR) also includes additional gases such as sulphur hexafluoride (SF_6) and other hydrofluorocarbons and perfluorocarbons, but these are released at negligible levels at most farms.

Agricultural systems are built around a carbon cycle. Plants take up carbon from the atmosphere, and it is released when plant material 'senesces' (ages) and breaks down in the soil or is consumed. Only the 'net change' of biogenic carbon is reported in carbon accounting because only fluctuations in long-term carbon storage pools are treated as influencing global warming. Short term cycling of CO_2 is excluded because it is rapidly taken up from the atmosphere and released again, having no long-term impact on climate change.

Long-term changes in carbon pools, including soil stored carbon and carbon in plants, refer to changes occurring over decades. While not strictly defined, generally storing carbon for > 25 years is needed to be considered a ‘permanent’ change, and this timeframe is used as the minimum in carbon markets. A long-term increase in carbon within soil or vegetation is called carbon sequestration. It is included on the deduction side of a carbon account (a negative emission represents removal from the atmosphere). If carbon is lost from these pools, it is added to the emission side of a carbon account.

Carbon stock changes in soil and vegetation that occur in typical agricultural management are referred to as changes in Land Use (LU) emissions. When land use is permanently changed, such as changing from pasture to cropping or visa-versa, it is referred to as a Land Use Change (LUC).

Changes in carbon stocks can be quite difficult and expensive to measure. A change for any given year is measured by finding the difference between stocks at the beginning and end of the year (or over several years) and can be modelled based on management records. In many cases, the carbon account is simplified to assume "no change" in soil and vegetation carbon, which is often an acceptable assumption for relatively stable production systems. This guide covers modelling options for changes in vegetation carbon (see section 5.3).

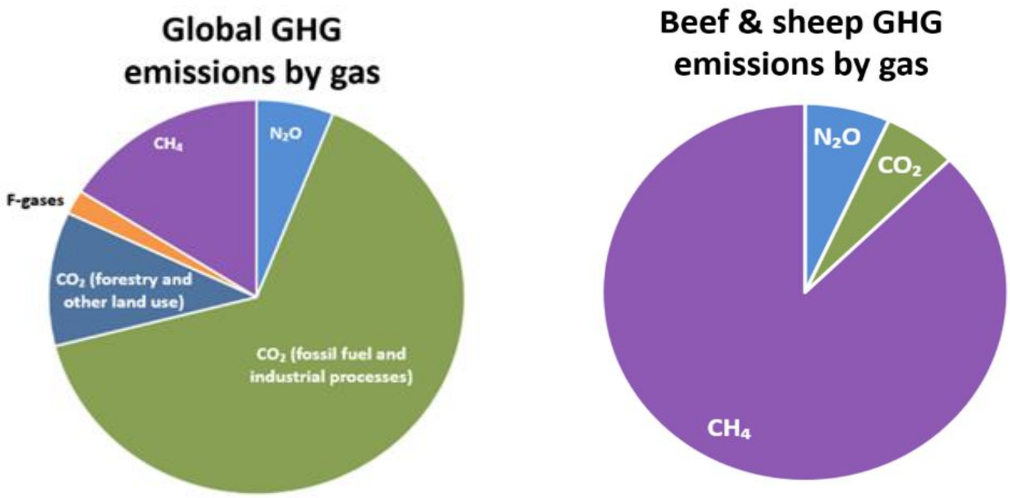

Figure 1. Global GHG emissions and ruminant livestock enterprise GHG emissions by gas[3]

While methane is the most prominent GHG emission from the livestock industry, there is debate over the right accounting system for methane compared to other gases. Methane mainly arises from ruminant digestion in cattle and sheep enterprises (Figure 1 and Figure 2).

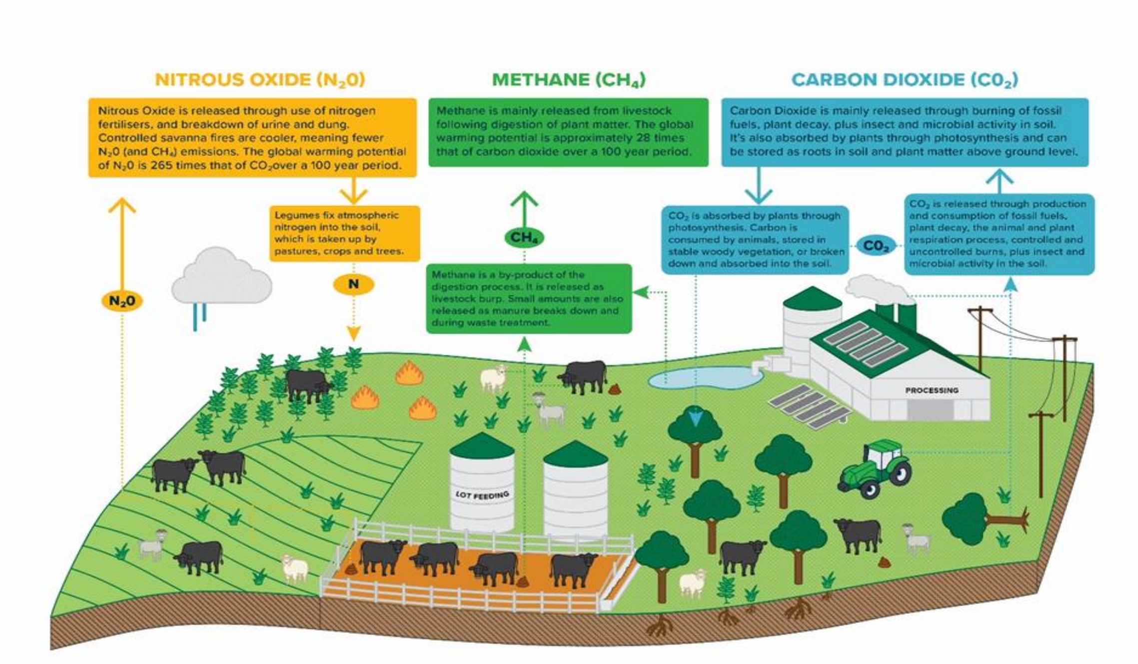

Figure 2. Sources and sinks of major GHG emissions[4]

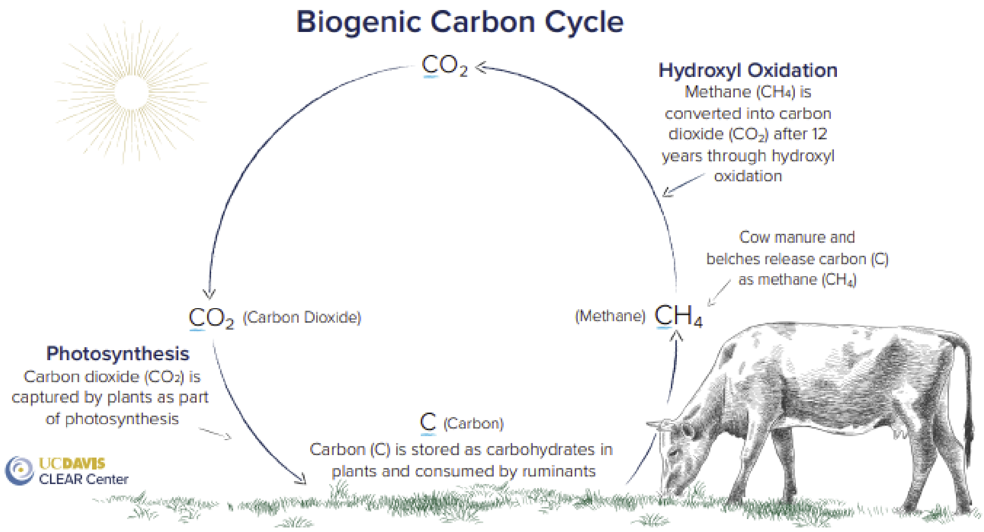

Figure 3. The biogenic carbon cycle: methane and livestock (UC Davis) [5]

As shown in Figure 3, methane emitted by ruminants such as cattle and sheep is recycled into carbon in plants and soil, which is part of the biogenic carbon cycle. Methane breaks down into carbon dioxide (CO_2) and water after 12 years; grass then absorbs the CO_2 through photosynthesis, ruminants eat the grass and the cycle continues[6]. While methane does break down over time, it has a substantial warming impact in the atmosphere while it is present. A stable herd and flock (numbers not changing) will result in stable methane levels in the atmosphere. This has a warming impact, but it is not increasing over time as is the case with other gases such as CO_2. While the only way to stop having further warming impacts on the climate is to have zero CO_2 emissions, it only requires **stable methane** emissions to have no additional warming impact on the climate[5]. New accounting metrics, such as GWP* or radiative forcing, have shown the Australian sheep industry is 'climate neutral' [7,8], meaning it is currently producing no additional impact on warming. Having noted this, it is still necessary for the industry to reduce emissions to decrease its current impact on climate change.

While scientists are reconsidering how methane is compared to other gases when calculating global warming impacts, the carbon accounting practices outlined in this guide reflect current practices required by the Australian Government and all carbon accounting systems worldwide. These systems use the GWP_{100} method which is the global benchmark at present.

1.1 Emission boundaries

A carbon account must be established with a clear, stated boundary defining what is included and excluded. For an agricultural enterprise, a typical 'boundary' is the area under the operational control of the business, which may include leased land. This boundary includes scope 1 and 2 emission sources (described below). Additionally, upstream scope 3 emissions (described below) are included and reported separately in an enterprise carbon account.

A carbon footprint is most commonly used to describe the product leaving the farm (i.e. the product carbon footprint). By definition (ISO 14067), a carbon footprint is the sum of GHG emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment (LCA), using the single impact category of climate change.

These guidelines cover both an enterprise carbon account and the carbon footprint of products leaving the farm. For clarity, when describing the carbon footprint of a farm, it includes all impacts from the "cradle" to the point at which products leave the farm. These impacts are typically reported relative to a "reference flow" of product leaving the farm (for example, for a kilogram of liveweight). This reporting method enables benchmarking against other businesses and products because it is independent of the scale or type of enterprise.

It is standard practice in carbon accounting for businesses to report emissions using different classifications, depending on where they arise and how they relate to the business. According to the GHG Protocol, these are termed emission 'scopes'[2]. Standards developed by the GHG Protocol govern the reporting and accounting of these GHG emissions.

According to the GHG Protocol, emissions are defined into three scopes:

- **Scope one**: direct GHG emissions from sources owned or controlled by the company.
- **Scope two**: GHG emissions from the generation of purchased electricity consumed by the company.
- **Scope three**: emissions are a consequence of the company's activities but occur from sources not owned or controlled by the company. In this guide, only upstream scope 3 emissions are considered. *NOTE: Examples of scope three activities are those arising from the extraction and production of purchased materials, the transportation of purchased fuels, and the use of sold products and services. These can be further broken down into upstream and downstream sources, as shown in Figure 4.*

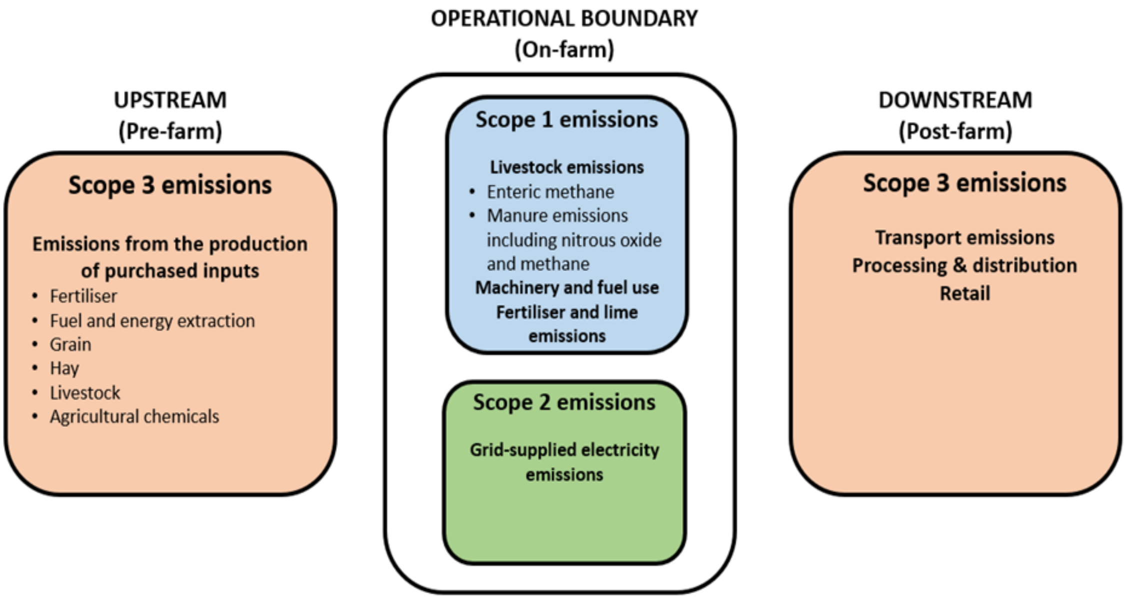

Figure 4. Examples of scope 1, 2 and 3 emissions for a livestock operation

1.2 Key elements of carbon footprint assessment

A carbon footprint assessment involves modelling farm data to determine the emissions profile of a farm operation and can be thought of simply with the following equation:

Carbon footprint = emissions – carbon sequestration

It is a measure of the net emissions of an entity, though as described in later sections, carbon sequestration may be zero from some sources and may not need to be calculated to complete a carbon footprint.

It is important to understand the differrence between a carbon footprint and the concept of carbon neutrality. Carbon neutrality can be thought of in simple terms with the following equation:

Carbon neutral = carbon footprint (+ offsets) = 0

If the carbon footprint of an entity shows zero emissions, that entity can be considered carbon neutral.

The role of carbon offset credits complicates these simple calculations. Offsets are a way of trading carbon between businesses (see section 4.2). In a market facing carbon neutral assessment (see section 4.1), offsets sold to other entities are deducted from the sellers' carbon footprint. On the other hand, carbon neutrality may be achieved by purchasing additional carbon offset credits from another entity.

1.2.1 Assessing emissions

A carbon footprint assessment reports the emissions across the operational boundary, including scopes 1, 2 and 3. These are often broken down across primary sources of emissions to identify 'hotspots' for further action. Figure 5 provides an example of a simple hotspot analysis for an example farming operation based on the PIRSA research station in Turretfield, South Australia, and it shows the calculator's output. To create a complete carbon footprint, soil carbon and carbon in native regeneration can also be added (described below).

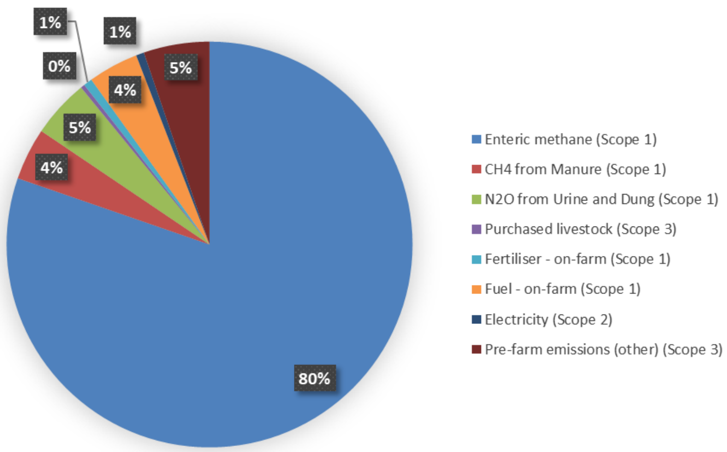

Figure 5. Emissions profile of an example sheep farming operation at a PIRSA research station at Turretfield, South Australia [9]

Calculating emissions is done by multiplying inputs with emission factors. Examples of common, simple emission factors for some product types are listed in Table 2 and Table 3. These values are subject to change over time and are an example only. Emissions from the livestock (enteric methane, manure emissions) are much more complicated to calculate. The methods used to calculate these are embedded in the calculators, and more detail can be found in the National Inventory Report (see section 5.3.2, pg. 308-12, section 5.3.3, pg. 313-4, section 5.4.1, pg. 320-6 and section 5.4.5, pg. 330-331[10]).

Purchased livestock also have scope 3 embedded emissions equivalent to the total emissions generated on the farm that bred and raised the animal prior to sale.

Table 2. Emissions factors for common energy inputs

Input	Scope 1	Scope 2	Scope 3	Total
Diesel (kg CO2-e / L)	2.71	-	0.14	2.85
Petrol (kg CO2-e / L)	2.32	-	0.12	2.44
SA electricity (kg CO2-e / kWh)	-	0.3	0.07	0.36

Emission factors for common energy inputs in 2021 [11]

Table 3. Example emissions factors for embedded emissions of some common farm products

Inputs	Unit	Example GHG per unit (kg CO_2-e)
Urea	t	933[1]
SSP	t	216[2]
Lime application	t	3.1[3]

[1] *Cradle-to-NZ port for urea produced in the Middle East* [12]
[2] *Cradle-to-manufacturing-plant-gate in NZ* [12].
[3] *Crushed limestone rock production* [13].

1.2.2 Assessing carbon in native vegetation

Trees can sequester large amounts of CO_2 from the atmosphere that can be used to offset GHG emissions from agricultural operations. Planting trees or regenerating native forests to offset emissions is a long-term solution as it takes several years to establish trees and achieve the carbon storage benefits. Vegetation offers additional benefits such as increased biodiversity and erosion and salinity control.

Higher carbon sequestration rates occur in younger trees, however, mature trees and forested areas continue to sequester carbon over their lifetime at a very slow rate[14]. An indicative carbon sequestration potential of existing native vegetation can be estimated with simple tools such as FullCAM and LOOC-C programs (see section 5.3).

1.2.3 Assessing carbon in soils

Small variations in soil carbon can lead to large carbon sequestration potential[15]. Understanding soil carbon and the factors that cause it to change is a big learning area. Some useful materials have been provided in the "future reading" section. Here the basics are considered.

Australian soils are generally very low in soil organic carbon (SOC), with agricultural soils typically ranging from 0.4-4% SOC[16]. Without organic matter inputs to the soil, there is typically a 2-3% reduction in soil organic matter per year[17]. Even with continued inputs, microbes respire a significant portion of the carbon input as CO_2, meaning that good management is needed to maintain soil carbon levels. Increasing soil carbon levels requires more carbon to be added, or less carbon to be lost from the soil carbon balance. This generally requires a change in management to practices that support increases in soil carbon (see section 3.2).

The only reliable way at present to include carbon change in a carbon account is to baseline soil carbon levels and re-test periodically (for example, every 3-5 years). The change is measured as the difference between the two testing periods. Costs associated with a robust soil carbon testing program can be a significant barrier to adoption for many producers because soil carbon is often variable across a paddock and a large number of tests are needed to be confident in measuring a change in the level.

Before conducting soil carbon testing, consideration should be given to the desired output. If testing is being done for your own purposes to indicate soil health and carbon levels, following good practice for agronomic testing may be adequate. It is beneficial to include bulk density testing and test to a depth of 30cm (at a minimum). It is also helpful to map fixed testing points (GPS locations that can be returned at another time) to reduce variability.

If the testing is being done to develop carbon credits (Australian Carbon Credit Units), a project must first be registered with the Clean Energy Regulator (CER) and baselining must be done according to the method requirements for this program. This is quite an involved process and may require professional assistance. For further information about the ERF, see section 4.

2 Baselining and benchmarks

A recent study with PIRSA on a research and extension sheep farm at Turretfield, SA, found emission intensities of 25.8 kg CO_2-e per kg wool and 9.6 kg CO_2-e per kg liveweight[9]. This study was conducted in a single location only and may not reflect broader regions. Studies of prime lamb production[18] have shown a range of emission intensities from 6.2 to 7.5 kg CO_2-e per kg liveweight sold (Figure 6). This was higher for Merino systems, which showed a range of 7.4 to 8.8 kg CO_2-e per kg liveweight sold (Figure 6).

A study of Merino wool producers[19] found a carbon footprint of 26.1 kg CO_2-e per kg greasy wool as the regional average of the SA Southern Pastoral Zone which was also very similar to the wheat-sheep zone in WA. (Figure 7).

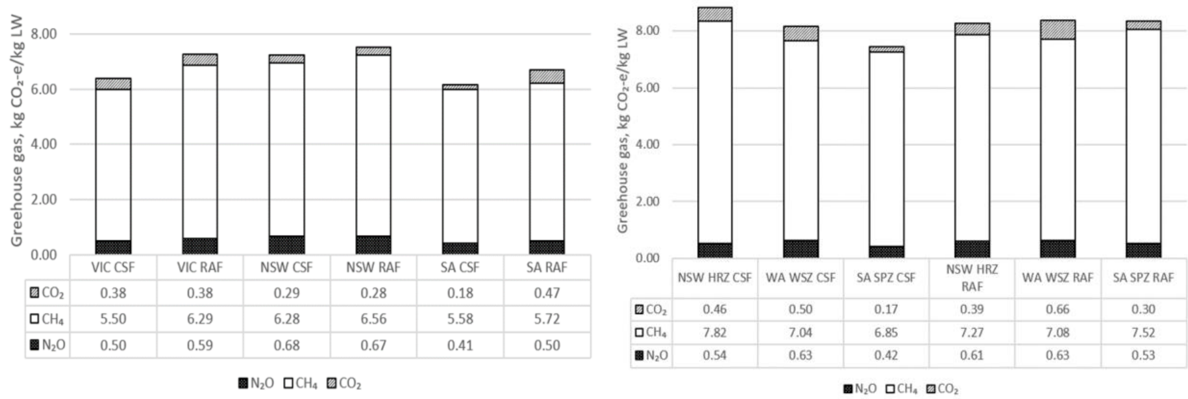

Figure 6. GHG emissions intensity of sheep meat production showing prime lamb systems[18] (left) and Merino systems[19] (right). Results are shown for case study farms (CSF) and regional average farms (RAF) in different regions across Australia (figures updated to use AR5 GWP$_{100}$ values).

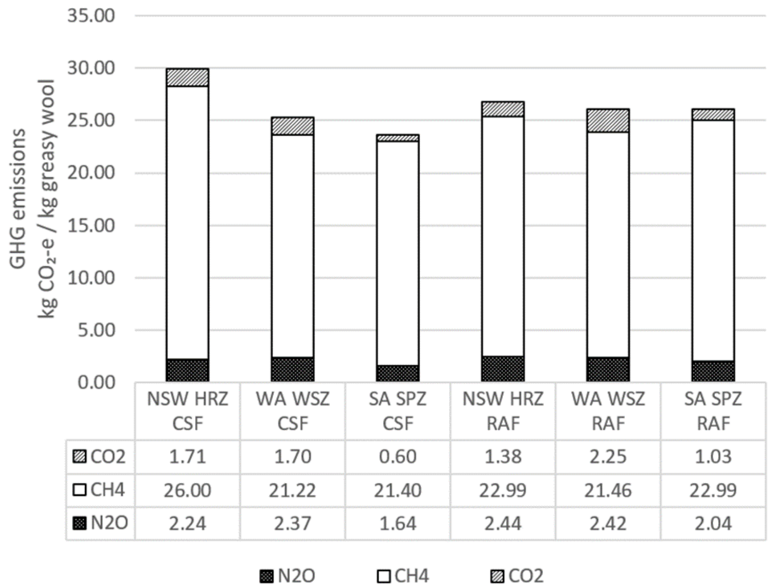

Figure 7. GHG emissions intensity of wool production for case study farms (CSF) and regional average farms (RAF) in different wool production regions of Australia (figures updated to use AR5 GWP$_{100}$ values) [19]

3 Reducing net emissions

Producers can become carbon neutral by reducing emissions and increasing carbon storage in vegetation and/or soil carbon. If branding a product as carbon neutral, it is also possible to purchase carbon credits to offset emissions. The Federal Government's Climate Active carbon neutral certification requires scopes 1, 2 and 3 emissions (full carbon footprint) to be included in an assessment of carbon neutrality for a product, and offsets must equal emissions.

The Australian Red Meat Industry's Carbon Neutral by 2030 target stipulates that the red meat and livestock industry aims to achieve net zero GHG emissions by 2030. The 'Carbon Neutral by 2030 Roadmap' maps out a pathway by reducing emissions from grazing management, lot feeding and processing, and increasing in carbon storage in soils and vegetation [4].

3.1 Reducing carbon emissions

GHG emissions in grazing enterprises can be reduced by implementing improved management practices that reduce emissions and methane mitigating technologies. Reducing emissions in Australian livestock operations should typically focus on methane, the most significant contributor to emissions. There are a number of options currently available or in development that could reduce total methane emissions and/or reduce methane emissions intensity (Figure 8).

Increased herd or flock productivity can reduce total GHG emissions and intensity and improve overall productivity. Productivity improvements include increased weaning/marking rates, increased growth rates from weaning to processing, breeding for improved feed conversion efficiency, joining heifers/ewes at an earlier age, and reducing overall number while maintaining output (through increased weaning/marking rates and an associated reduction in breeder numbers)[20]. Improving weight for age through increased grain and supplementary feeding and improved pasture utilisation can also drive lower emissions intensity (kg CO_2-e per kg LW sold).

Methane mitigating feed additives and pastures are showing significant potential to address the challenge of methane from ruminant animals in the future. Currently available supplements include fats and oils in the diet and nitrates where suitable. High efficacy products such as Bovaer (3-NOP) and Red Asparagopsis seaweed are currently in development and showing promise to mitigate substantial methane emissions in controlled environments. Bovaer is nearing commercialisation, with Red Asparagopsis currently undergoing numerous trials to determine effectiveness and ability to scale production. Feed additives are likely to provide beneficial outcomes within intensive feeding systems over the next several years, however, research is still being conducted to determine how to scale this to extensive and grazing systems.

Several species of pastures have anti-methanogenic properties, including Leucaena, Desmanthus, Biserulla, Eremophila, and Birdsfoot trefoil. The sub-tropical species Desmanthus and Leucaena have received the most attention to date and are not suited to South Australian conditions, however, Birdsfoot trefoil and Biserulla are suited to many grazing regions in Southern Australia[20]. Using perennial pastures may also have the added benefit of contributing positively to soil organic carbon levels when implemented on previously degraded soils[21].

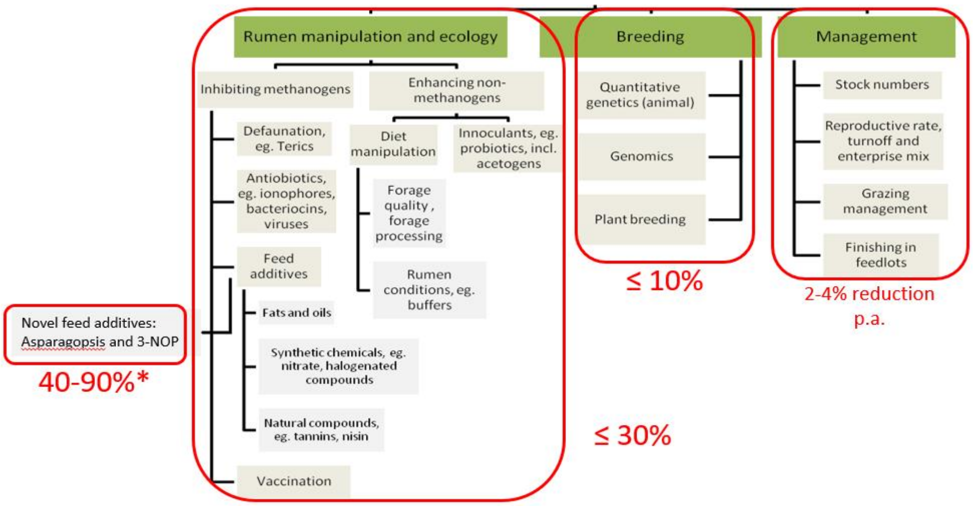

Figure 8. Enteric methane mitigation options for a grazing enterprise (adapted from [22])

3.2 Storing carbon

Achieving carbon neutrality requires increased carbon storage in soil and/or vegetation, as emissions reduction strategies cannot achieve a zero-emissions profile in isolation. In livestock enterprises, soil carbon storage may provide an opportunity to reduce net emissions.

Soil carbon increase is a function of the quantity of carbon added to the soil and how much is retained. Practices such as applying amendments (e.g. organic manure), incorporating perennial and improved pastures, and other soil improvement practices can increase soil carbon across large areas.

Carbon levels generally stop increasing and reach an equilibrium over time, with the upper limit generally determined by climatic conditions and soil type[23,24] (Figure 9). There may be greater potential for carbon sequestration in previously degraded soils than soil that has already been under best management practices for some years. Previous management practices may have caused carbon losses, allowing the opportunity to reverse these losses and build carbon back towards an attainable carbon level. The main contributors to carbon loss in agricultural soils are direct losses through soil erosion, indirect losses through organic matter decomposition influenced by climate (e.g. rainfall and temperature) and soil disturbance, such as tillage[25].

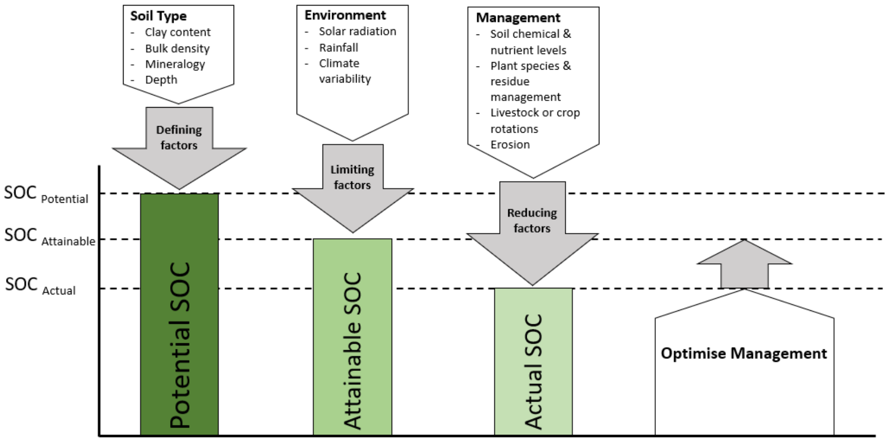

Figure 9. A representation of the factors influencing potential, attainable and actual SOC and change expected from altered management practices [26]

Changes in soil carbon can be estimated based on soil factors and regional knowledge, and paired sites between different management systems can provide insight.

The greatest opportunities for SA's agricultural zones exist in areas of higher rainfall, however, all livestock districts have at least a small potential to increase SOC compared to existing baselines, as shown in Figure 10 and Figure 11. Carbon credits from increased soil carbon will need to be generated if seeking to include soil carbon increases in a branded carbon neutral program.

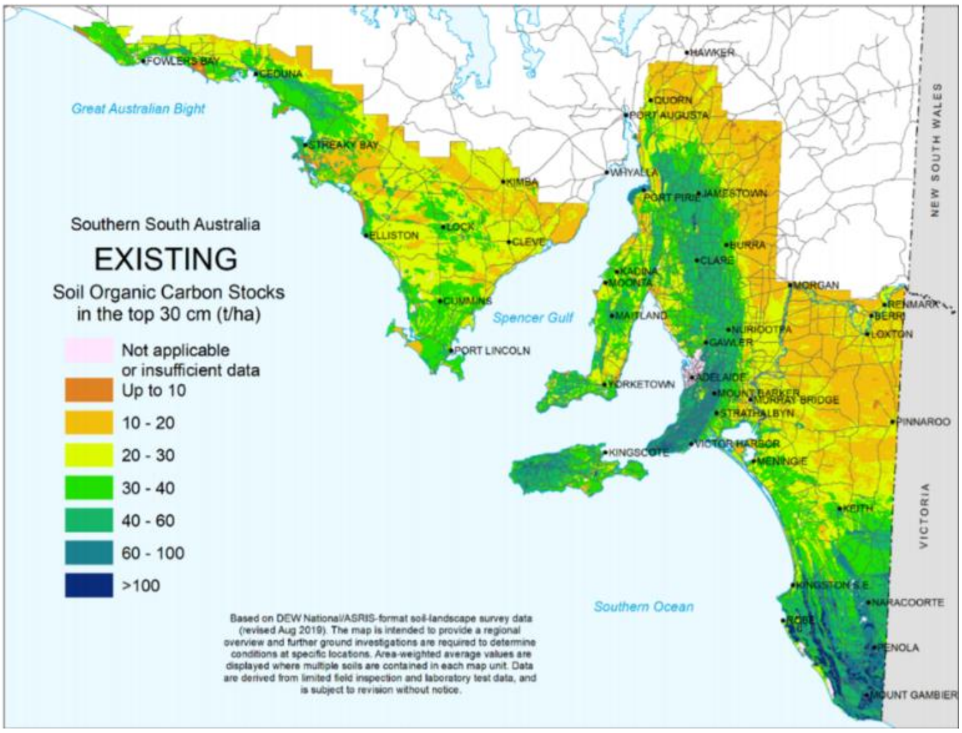

Figure 10. Existing surface SOC 1990-2000 [27]

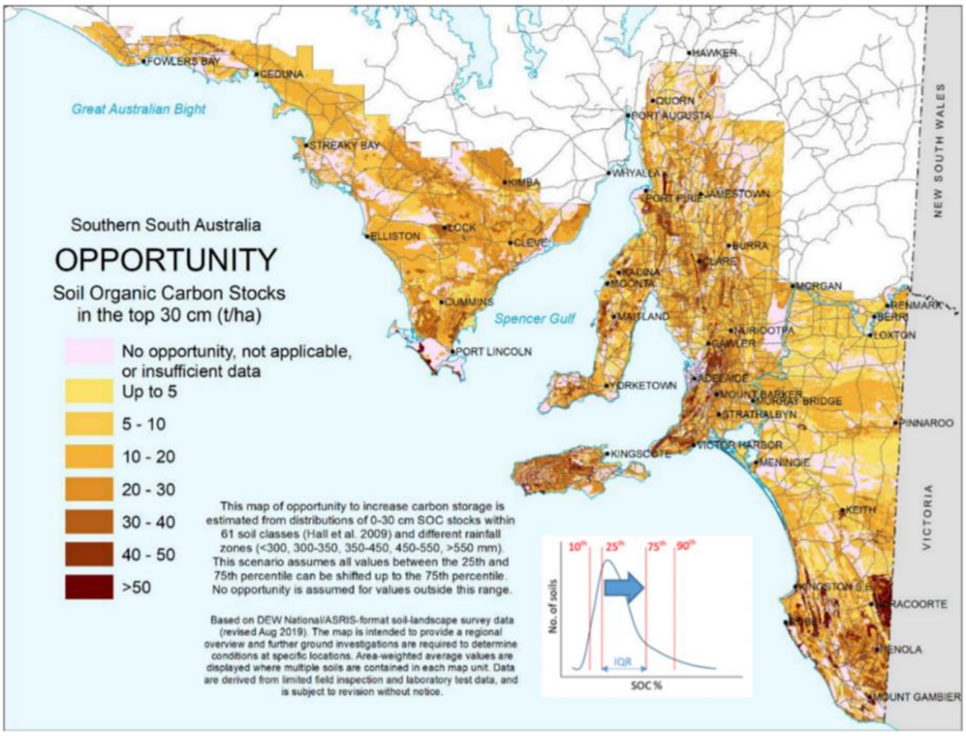

Figure 11. Opportunity for surface soil OC % - all values between the 25th and 75th percentile can be shifted to the 75th percentile [27]

Vegetation carbon storage may provide further opportunities to reduce emissions. Carbon storage opportunities such as native vegetation plantings or regeneration of native forests may be possible within livestock operations through options such as the use of marginal or unused land or implementing belt plantings. Existing established native vegetation is not eligible to be counted towards formal Climate Active certification, however, this may change in the future.

4 Understanding markets and methods

4.1 Climate Active certification process

One way to claim carbon neutrality in the marketplace is by engaging with the Climate Active program. Climate Active is managed by the Australian Government Department of Industry, Science, Energy and Resources (DISER). Climate Active certifies businesses, products and services that have credibly reached a state of carbon neutrality by measuring, reducing, and offsetting their carbon emissions. A business must meet the Climate Active Carbon Neutral Standard requirements to be certified and receive Climate Active accreditation (for a product or as an organisation).

The standard requires the calculation of a carbon footprint prior to offsetting emissions through the purchase of approved carbon credits or the retirement of existing carbon offset credits owned by the entity (see Figure 12).

Climate Active's certification also requires an independent third party to verify the carbon footprint and offset measures. Livestock producers must meet ongoing certification and reporting requirements (e.g. annual reporting) to use the Climate Active trademark on their products.

To include carbon sequestration in soil or via native regeneration of vegetation, a farm must generate certified carbon offset credits and then retire these against their carbon neutral certification. It is not possible to generate carbon credits, sell them to another entity, and then claim the same carbon credits against the farm's carbon neutral certification. This practice would result in double-counting of abatement.

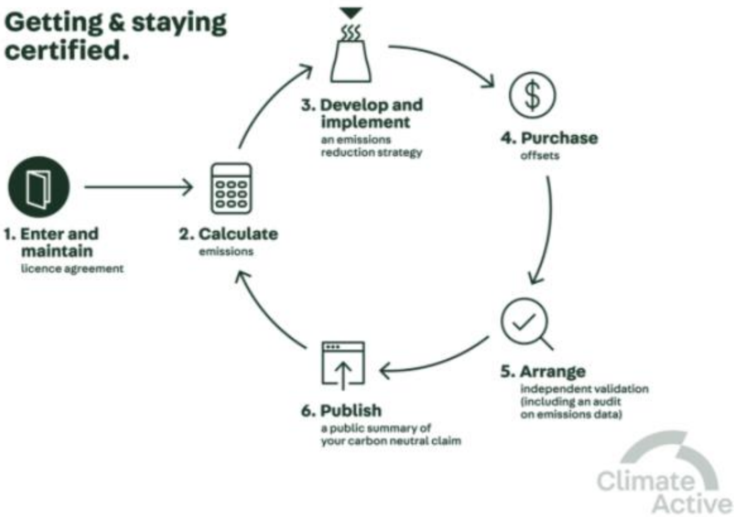

Figure 12. Climate Active Carbon Neutral project flow chart

4.2 Emissions Reduction Fund (ERF)

The Emissions Reduction Fund is a voluntary program that provides financial incentives for companies to adopt approved methodologies to reduce their GHG emissions. Methodology determinations (methods) under the ERF are the rules for estimating emission reductions to ensure they are valid strategies used in addition to normal operational procedures.

Projects are focused on one of two streams: avoiding emissions, which is focused on reducing the emissions that would have transpired had the project not occurred, such as covered ponds, burning methane gas and ceasing ongoing tree clearing events; and storing or sequestering carbon, such as storing carbon in vegetation through tree plantings or regenerating native forest, or storing carbon in soil through undertaking actions that improve the organic carbon content of the soil. Projects yield Australian Carbon Credit Units (ACCUs), with one ACCU being the equivalent of 1 tonne of carbon dioxide equivalent (1t CO_2-e) either prevented from being emitted (avoidance) or being stored (sequestered) in vegetation or soil. Earned ACCUs can be sold to organisations looking to offset their carbon footprint or meet emissions reduction obligations, or the Federal Government through the Clean Energy Regulator (Figure 13).

Signing up for a sequestration project requires committing to a permanence obligation, meaning the carbon stored by a project must be maintained for the chosen period, either 100 or 25 years. Management of vegetation and practices that increase soil carbon sequestration must be maintained over this period. Navigating the carbon project requirements generally requires professional assistance from a project developer or consultant. Carbon yield and project scale typically need to be reasonably large to cover project costs.

In addition to the ERF, secondary offset or voluntary markets exist where alternative forms of carbon credits can be traded, such as Verified Carbon Units (VCUs) and Voluntary Emission Reductions (VERs).

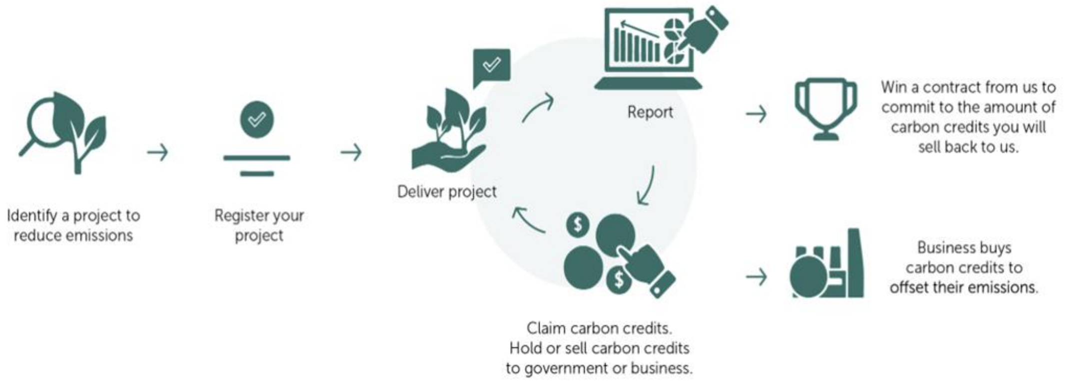

Figure 13. ERF project flow chart

5 Completing your enterprise carbon account and carbon footprint

In completing an enterprise carbon account and carbon footprint, the first question is, "What is the purpose of this carbon account/footprint?".

There are three common purposes (requiring different levels of effort): an internal baseline for indicative purposes, a baseline for public release or an audited carbon footprint for market purposes. Note that the guidelines in this document suit purpose 1 below, and some description is given for more detailed purposes.

Purpose 1: Internal business carbon baseline assessment. For many businesses, carbon is a new consideration in the business. The best first step is often an **internal business carbon baseline assessment** for company use only to define impact hotspots and to act as a general guide for the level of emissions. This assessment can be done reasonably easily in many cases with little guidance. However, any calculator is only as useful as the data used to generate results. The old saying holds: "garbage in, garbage out". Many unrealistic results have been generated by users' missing necessary inputs or "making up" the input values. If the purpose is to get a general estimate for indicative purposes, with results within 30-40% of an in-depth carbon account, this can often be done fairly quickly with average numbers that are quick to collate.

While this is a good start, it won't give a result that can be transferred for purposes 2 or 3 without further work to ensure the data inputs are verifiable and methods suit the requirements.

Purpose 2: The second purpose is a **formal business carbon baseline for public release**. This assessment is typically done for investors (including banks) or supply chain partners. A publicly released carbon account should be done to clear standards to have credibility. If a particular stakeholder has requested the carbon account, the first step is to ask if they list specific requirements and follow these. Some industries are in the process of developing sector-specific guidelines which can be used, but these vary in their level of detail and purpose. For instance, many may have been developed for purpose 1 because they may not use a clear, auditable method.

Good general practice is to comply with the National GHG Inventory for agricultural emissions, the GHG Protocol business accounting and Agricultural guidance, and/or ISO 14064 for carbon accounting. For product carbon footprints, ISO 14067 is the global standard. In late 2022, Climate Active plan to release specific guidance for agricultural businesses, which is useful, particularly if intending to move to a market reporting assessment. All input data should be accurate, verifiable, and sourced from farm records to achieve this.

The assessment should be done to a standard that could be audited, though an audit may not be necessary depending on the requirements of the external stakeholders you plan to share the carbon account with. In most cases, professional carbon accounting and/or auditing skills are required to ensure this is done correctly, particularly to set up the account in the baseline year and to work through business-specific assumptions.

Purpose 3: Audited carbon account or carbon footprint. The highest requirement is an audited carbon account or product carbon footprint. This is required for market-based programs (ERF, Climate Active) where the account is being used to make specific claims around the business or product. Audited accounts must meet an audit standard and have verified data sources to enable an audit to be conducted. This process is often significantly more work than purpose 2, and costs to complete this form of assessment may be high. It is usually only done where there is a clear demand or opportunity for such a process.

Once the purpose has been established, you can move on to generating the carbon account. As noted, this guidance has been produced for purpose 1, to develop an **internal business carbon baseline assessment.**

5.1 Livestock GHG accounting tool (SB-GAF)

Producers can create carbon accounts for their farms using publicly available online tools. One such tool is the Sheep and Beef Greenhouse Accounting Framework (SB-GAF). Below is an explanation of how to use the SB-GAF tool, which can be downloaded from https://piccc.org.au/resources/Tools.html.

5.2 Data you will need

The following data is needed to determine your carbon account with the SB-GAF tool. The required information may be available from your farm tax records, farm management records, or your memory. This includes:

- **Livestock inventory**: births, deaths, purchases, sales, weights and liveweight gain (LWG), weaning rates and reproductive status of animals.
- **Farm inputs**: fertilisers, purchased animal feed, fuel, electricity and other purchases.
- **Tree planting:** area planted to trees(ha), species and planting date (to determine age).

The SB-GAF tool is limited to sheep and beef production systems. Other enterprises operating on-farm, such as cash cropping, require a different tool. The tool can be used to create a carbon account for any year where data are available. We suggest selecting a recent and "representative" year for the farm, where farm inputs and outputs are not highly variable compared to average yearly inputs and outputs, and setting this as the baseline year.

The following section briefly outlines the steps required to populate the tool. There is also a six-minute online video to help explain how to input beef cattle data into SB-GAF (available online at: integrityag.net.au/beefcarboninformationrequest). This video can also be used as a guide for inputting sheep data as the data input pages for beef and sheep are relatively similar.

5.2.1 Step one: Data input – Beef/sheep

After downloading the SB-GAF spreadsheet from the PICCC website, toggle between the *Data input – beef* sheet and *Data input- sheep* sheet as needed using the tabs at the bottom of the screen. The following instructions have been adapted from the MLA carbon accounting manual [20], which is useful reading if you want further information on the topic. At the top of the sheets, add the farm name and use the drop-down menu options to select the farm's region in Australia. Use the drop-down menu to indicate whether the farm is north of the Tropic of Capricorn. Next, refer to the map on the right of the sheet to determine if your farm is in the orange zone and use the drop-down menu to indicate accordingly.

The livestock inventory is separated between breeder and owner bred cattle and traded cattle for beef. For sheep, it is separated between breeding flock and traded sheep.

Input steps:

- **Livestock numbers:** Input livestock numbers for each livestock category as an average for each season, which accounts for stock losses, sales and purchases. Traded cattle need to be entered into the 'traded cattle' category.
- **Live weight (LW):** Input average LW (kg/head) of each livestock category for each season. If you do not know LW, it can be calculated from the LWG (if known) to create an average weight for each season. When entering the LW of calves/lambs, do not enter the birthweight as an average across the season is required for their LW. In the instance of calves born in the middle of spring, in columns for 'steers < 1' & 'heifers < 1', the average weight for the season would be calculated by adding the birthweight to the growth rate multiplied by half the days in the season.
- **Live weight gain (LWG):** Input the estimated average daily LWG (kg/head/day), and check that it matches the LW entered in the section above. If LW is known across two seasons, these can be used to calculate LWG. Find the difference in weight between the two seasons (amount of growth) and divide this by the number of days in the season to give you growth per day.

		Bulls >1	Steers <1	Steers 1-2	Steers >2	Cows >2	Heifers<1	Heifers 1-2
Livestock Numbers	Spring	8	82			211	82	37
	Summer	8	82			209	82	37
	Autumn	8	82			208	82	37
	Winter	8				175	37	37
	Average	8	82			201	71	37
Liveweight	Spring	800	81			475	81	318
	Summer	800	172			489	167	373
	Autumn	800	245			513	236	423
	Winter	800				529	277	464
	Average	800	166			501	190	394
Liveweight gain (LWG)	Spring	0.00	1.00			0.00	1.00	0.60
	Summer	0.00	1.00			0.30	0.90	0.60
	Autumn	0.00	0.60			0.24	0.60	0.50
	Winter	0.00				0.10	0.30	0.40
	Average	0.00	0.87			0.16	0.70	0.53

Figure 14. First section of Data input – beef sheet with example data

Scroll down to input data into the 'purchase inventory' pane and fill it in as follows:

- **No. head purchased:** total number of livestock purchased for each category over the year.
- **Purchase weight (LW/hd):** average LW (kg/head) when purchased.

Open the *data input - beef sheet* and select 'region where most cattle purchased' for the breeding herd and traded cattle from the drop-down list. Enter '% of cattle purchased from this location.' Check that these numbers add up to 100%. Enter the '% of sheep purchased' as either Merino or cross-bred on the sheep data input page.

Continue scrolling down to the 'sale inventory' and fill it in as follows:

- **No. head sold:** total number of livestock sold in each category over the year.
- **Sale weight (LW/h):** average LW (kg/head) when sold.

Once the purchase and sale inventory panes have been populated, the 'LWG (traded cattle)'/'LWG (traded sheep)' section should automatically populate. No action is required here.

For the *Data input – sheep* sheet, continue scrolling down to the 'wool' section and complete the following:

- For each category, enter the total 'number shorn' and the 'wool shorn kg/hd' (to reflect wool shorn from wool produced on the farm over the past 12 months, i.e. gross wool production). If sheep are purchased with substantial wool, this wool should be removed. If sheep are sold with substantial wool, this should be added.
- 'Greasy wool production (kg/yr)' automatically populates based on the data entered in the cells above.
- Enter 'clean wool yield' as a %.

Number shorn		26		314	1309		340	655
Wool shorn kg/head		5.5		2.5	3.5		2	2
Greasy wool production (kg/yr)		143	0	785	4581.5	0	680	1310
Clean wool yield		65		65	65		70	70
Clean Wool (t/year)		0.09	0.00	0.51	2.98	0.00	0.48	0.92
Carbon content of Wool	45.2							

Figure 15. Wool section of Data input – sheep sheet with example data

For the 'percentage of cows calving/ewes lambing section', complete the following:

Enter the calving/lambing rate, calculated by dividing the number of calves/lambs born by the number of cows or ewes exposed to the bull, or ram, the previous joining season. If there is more than one calving/lambing event in a season, ensure the total value matches the annual calving or lambing rate. This should be a percentage.

For the 'purchased inputs' and 'energy and fuel' panes, you need to enter the input corresponding to the purple parameters on the left, taking note of the units in the purple to the right. This includes fertiliser, soil additives, electricity, fuel, grain, cottonseed, and hay details. Be sure to include on-road fuel used in business-related travel. For the grain, cottonseed, and hay inputs, be sure to split these values into the proportion used for either cattle and/or sheep where relevant. If the parameter value is zero, insert a 0 into the corresponding cell. The savanna burning section is only of relevance to enterprises in northern Australia.

Purchase inventory		Bulls >1	Steers <1	Steers 1-2	Steers >2
No. head purchased		2			
Purchase weight (LW/hd)		800			
Live weight / category		1600	0	0	0
		Breeding herd	Trade		
Region where majority of cattle		nth QLD	nth QLD		
% of cattle purchased from this location		0%	100%		
Sale inventory					
No. head sold		2	82		
Sale weight (LW/hd)		800	272		
Live weight / category		1,600.0	22,304.0	0.0	0.0
LWG (trade cattle)					
kg/hd					
kg/category					
Percentage of cows calving	Spring	78%			
	Summer	0%			
	Autumn	0%			
	Winter	0%			
	Total	78%			
		Dryland		Irrigated	
Urea Fertiliser Pasture (enter as tonnes of urea)			0		0
Urea Fertiliser Crops (used for grazing cattle - tonnes urea)			0		0
Other N fertiliser (enter value as tonnes of N)					
Total Nitrogen			0		0
Single Superphosphate					
Limestone applied to soils	Total for farm				
	Fraction	1			
Energy and Fuel					
Electricity Source		State Grid			
Annual Diesel Consumption (for cattle enterprise)		3500			
Annual Petrol Consumption (for cattle enterprise)		1800			
Annual Electricity Use (for cattle enterprise)		2000			
Grain Purchased for Cattle Feed (all grains)					
Cotton Seed Purchased for Cattle Feed		30			
Hay Purchased for Cattle Feed					
Glyphosate					
Herbicides/pesticides					

Figure 16. Second section of Data input – beef sheet with example data

5.2.2 Step two: Data input – Planted trees

To determine carbon from vegetation for an **internal business carbon baseline assessment,** the *Data input – vegetation* sheet (Figure 17) can be completed from top to bottom as items within certain drop-down boxes are dependent on previous options selected. Fill in the drop-down boxes, in order, for State, Region, Species of Tree, and Soil Type. Then fill in the data for Area of Trees (ha), Age of Trees (years) and Allocation % to beef or sheep operations.

Vegetation	State	SA	
	Region	Pastoral	
	Species of Tree	Mixed species (Environmental Plantings)	
	Soil Type	Cracking Clays	
	Area of Trees	10	ha
	Age of Trees	15	years
	Allocation to beef	100%	
	Allocation to sheep	0%	

Figure 17. Data input – vegetation sheet with example data

Not all tree species are available for modelling through this tool, and the results are indicative only. Additionally, see section 5.3 below.

5.3 Other vegetation carbon sequestration methods

The SB-GAF tool calculates potential annual carbon sequestration in native trees. Another tool, LOOC-C, is available for calculating potential vegetation carbon sequestration resulting from running an ERF project on the land. The LOOC-C tool can be accessed from https://looc-c.farm/. Click on "Explore your options" to use the tool and enter your property details. The first step to using LOOC-C is to select a project area on the map provided, using the "Area tool" at the top left of the map. Answer the questions on the webpage below the map and click next to receive an assessment of your property for available ERF methods, including potential vegetation carbon sequestration rates for applicable methods.

For a more accurate estimate of the carbon sequestered in trees, skilled users may choose the Full Carbon Accounting Model (FullCAM). FullCAM can provide a robust estimate of sequestration when used as described in the FullCAM guidelines of an Emissions Reduction Fund (ERF) method. There are easy-to-follow FullCAM guidelines written for environmental plantings, the regeneration of native vegetation, and forestry plantations. The correct sequestration calculation requires reference to the 'calculations' section of the matching ERF Determination. This may be as simple as summing carbon sequestered in above- and below-ground biomass (plus coarse woody debris) or as complex as modelling the contrast between 'baseline' and 'project' scenarios. FullCAM is free to use and is available, along with links to the ERF methods, as mentioned above, from the Australian Government website: https://www.industry.gov.au/data-and-publications/full-carbon-accounting-model-fullcam.

5.4 Soil organic carbon sequestration

For an **internal business carbon baseline assessment,** it is possible to calculate carbon sequestration potential in soil and include this in the carbon account. This requires a soil testing program, including a baseline and subsequent testing rounds. Sequestration is determined by the difference between each sampling period, often 3-5 years.

To calculate SOC, you need to know your soil's SOC % and bulk density by analysing soil samples taken at a specific depth. If SOC % is known, the carbon stored in the soil can be calculated by following the approach in Equation 1. The standard depth for soil carbon sampling is 0 – 30 cm. Accounting for bulk density is important for adjusting carbon levels to an equivalent soil mass[25]. Changes in bulk density over a soil sampling interval may occur with soil compaction and needs to be captured.

Soil organic carbon can vary throughout a property, such as different management practices and history, season, time in the year, and varying soil types. To improve the accuracy of SOC determinations, advice should be sought from a suitably qualified practitioner familiar with the requirements of baselining soil carbon. A representative number of samples across the focus area should be collected. Note that there are many more requirements around soil sampling that must be followed to generate carbon credits under the ERF soil carbon method, and users must refer to these guidelines if the purpose is to develop a soil carbon project to generate carbon credits.

Equation 1. Soil organic carbon baseline and change equation

$$\boldsymbol{Tonnes\ carbon\ per\ hectare} = \boldsymbol{SOC}\ (\%) \times \boldsymbol{bulk\ density}\ (\boldsymbol{g\ per\ cm^3}) \times \boldsymbol{depth}\ (\boldsymbol{cm})$$

For example, the total tonnes of carbon per hectare of soil with a SOC of 1.2 % and a bulk density of 1.3 g cm^{-3} sampled to a depth of 30 cm can be determined as follows:

$$1.2 \times 1.3 \times 30 = 46.8\ tonnes\ of\ carbon\ per\ hectare$$

If SOC % after a subsequent sampling event increased by 0.1% to 1.3%, the total tonnes of carbon per hectare would be:

$$1.3 \times 1.3 \times 30 = 50.7\ tonnes\ of\ carbon\ per\ hectare$$

This equation amounts to an increase of 3.9 tonnes of carbon per hectare, equivalent to 14.3 tonnes of CO_2-e per hectare. It shows a very large increase in carbon, despite the small change in carbon percentage. Results should be interpreted with caution because season and sampling variability or a change of laboratories can all result in changes in reported soil carbon levels that may be false or may be reversed in subsequent years. As a guide, the ERF method does not allow baselining in drought conditions (because this provides a below long-term average baseline) and discounts the first reported change in soil carbon by 50% until a clear improvement trend has been established.

5.5 Data summary

Upon completion of data entry into the *Data input – beef*, *Data input – sheep* and *Data input – vegetation* sheets, the *Data summary* sheet is populated with your farm's emissions results (Figure 18). Your farm's emissions are broken down in the *Data summary* sheet into Scope 1, 2 and 3 emissions, carbon sequestration in tree plantings, net farm emissions, and emissions intensity.

Beef & Sheep Greenhouse Accounting Tool

Outputs	eef t CO_2e/farm	eep t CO2e/farm	otal t CO2e/farm
Scope 1 Emissions			
CO_2 - Fuel	0.00	8.57	8.57
CO_2 - Lime	0.00	0.00	0.00
CO_2 - Urea	0.00	0.00	0.00
CH_4 - Fuel	0.00	0.00	0.00
CH_4 - Enteric	0.00	528.13	528.13
CH_4 - Manure Management	0.00	28.61	28.61
CH_4 - Savannah Burning	0.00		0.00
N_2O - Fertiliser	0.00	0.00	0.00
N_2O - Urine and Dung	0.00	27.02	27.02
N_2O - Atmospheric Deposition	0.00	2.84	2.84
N_2O - Leaching and Runoff	0.00	0.00	0.00
N_2O - Savannah Burning	0.00		0.00
N_2O - Fuel	0.00	0.06	0.06
Scope 1 Total	**0**	**595**	**595**
Scope 2 Emissions			
Electricity	0.00	6.73	7
Scope 2 Total	**0**	**7**	**7**
Scope 3 Emissions			
Fertiliser	0.00	2.81	2.81
Purchased feed	0.00	15.00	15.00
Herbicides/pesticides	0.00	0.00	0.00
Electricity	0.00	0.66	0.66
Fuel	0.00	0.44	0.44
Lime	0.00	0.00	0.00
Purchased livestock	0.00	0.00	0.00
Livestock on agistment			
Scope 3 Total	**0**	**19**	**19**
Carbon Sequestration			
Carbon sequestration in trees	-31.82	-17.43	-49.25
Net Farm Emissions	**-32**	**603**	**572**
Emissions intensity			
Sheep meat (breeding herd) excl. sequestrati	**7.3**		kg CO2-e / kg LW
Sheep meat (breeding herd) inc. sequestratio	**7.1**		kg CO2-e / kg LW
Wool excl. sequestration	**26.8**		kg CO2-e / kg greasy
Wool inc. sequestration	**26.0**		kg CO2-e / kg greasy
Beef excl. sequestration			kg CO2-e / kg LW
Beef inc. sequestration			kg CO2-e / kg LW

Summary	CO2e/farm
CO_2	22
CH_4	557
N_2O	33

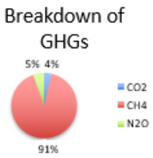

Figure 18. Data summary sheet with example data

On this page, a hotspot analysis of the main emissions sources is visually displayed in a pie chart, shown in Figure 19. In the SB-GAF tool, the hotspots are manure, purchased livestock, urine and dung, indirect N_2O, fuel, savannah burning, electricity, other pre-farm, and enteric methane.

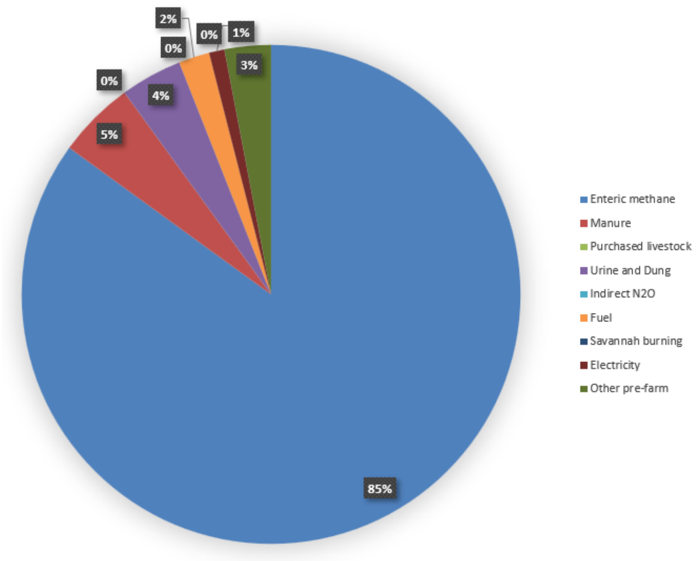

Figure 19. Pie chart of Hotspot Analysis in Data summary sheet with example data

Combining the outputs from the GAF calculator with a potential change in vegetation and soil carbon enables the formulation of a net emissions value. Utilising this understanding and tailoring emission reduction options to an operation enables an operation to determine potential carbon improvements to the overall carbon account and emissions intensity profile. The calculator can be used as needed and can also be used to test management changes to indicate the different emission outcomes.

5.6 Calculator limitations

The SB-GAF tool only includes major scope 3 emission sources, and the results don't provide a complete carbon footprint. For example, pre-farm and off-farm emission sources such as employee commutes, transport of farm inputs, production externalities from input manufacturing and downstream emissions are not accounted for. Scope 3 emissions are an important part of a carbon account and must be reported under certain standards. These tools do not currently allow for calculating carbon sequestration in soils.

If you wish to conduct carbon accounting for a formal process (reporting to markets or stakeholders), data inputs must be verified, and in that case, a more comprehensive list of scope 3 emissions may need to be collected depending on the boundary for the assessment.

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