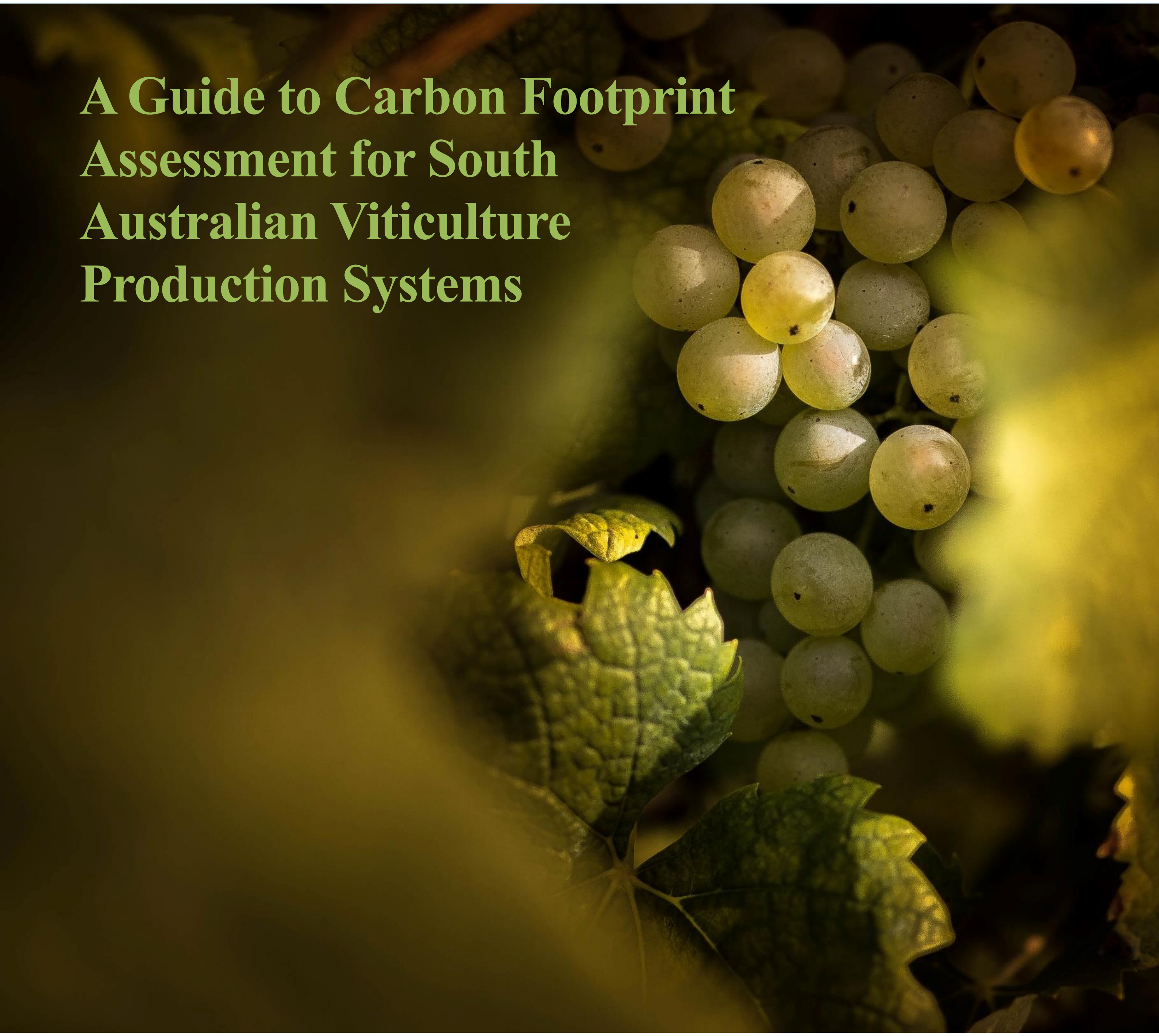
# A Guide to Carbon Footprint Assessment for South Australian Viticulture Production Systems

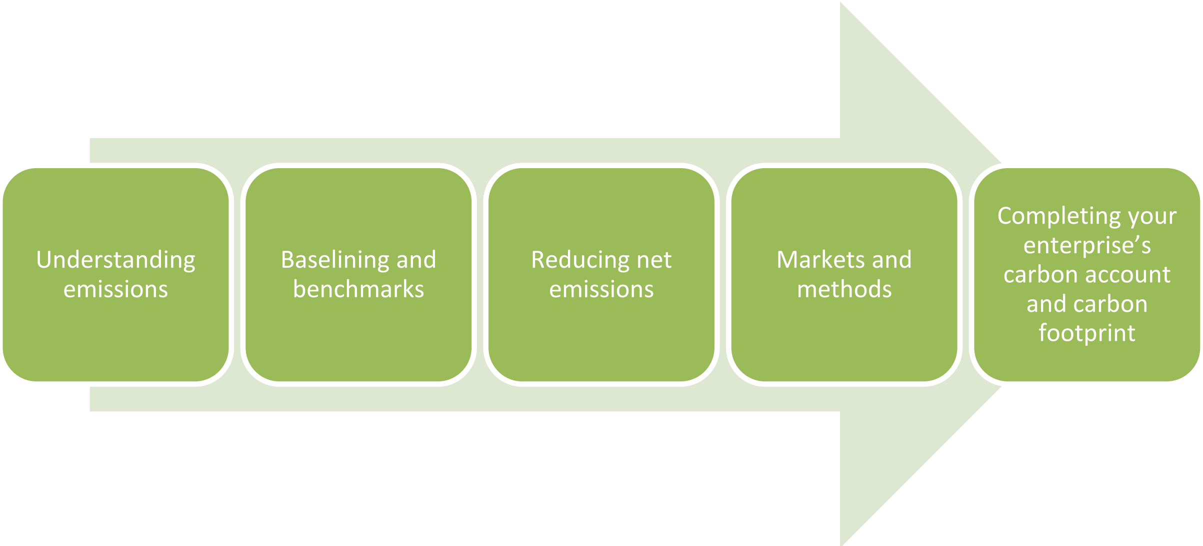


# Introduction

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 viticulture 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. *Markets and methods*
5. *Completing your enterprise's carbon account and carbon footprint*

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# 1 Understanding emissions

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).

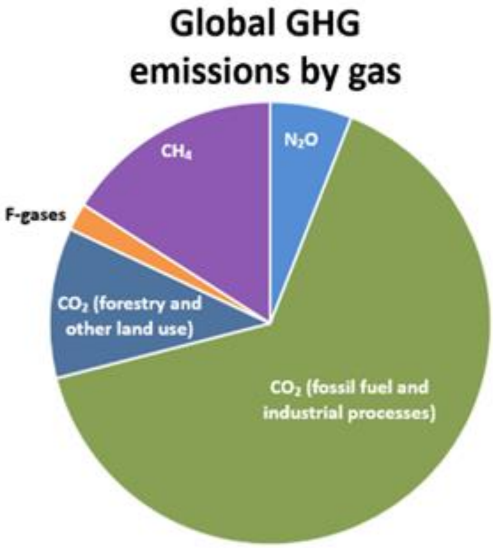


*Figure 1. Global GHG emissions by gas*[3]

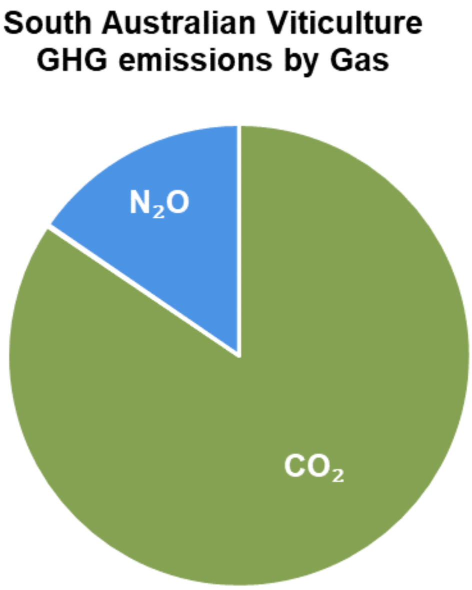


*Figure 2. South Australian Viticulture GHG emissions by Gas*

## 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 (see Figure 3). For clarity, when describing the carbon footprint, 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 tonne of grapes). 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 1**: direct GHG emissions from sources owned or controlled by the company.
- **Scope 2**: GHG emissions from the generation of purchased electricity consumed by the company.
- **Scope 3**: 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 3.*

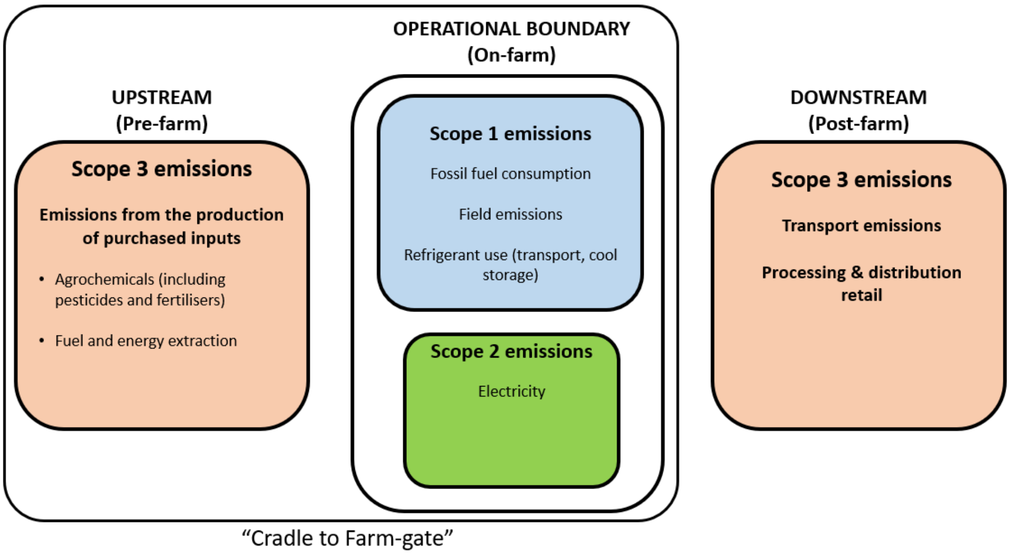


***Figure 3. Examples of scope 1, 2 and 3 emissions for a viticultural operation***

## 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 4 provides a simple hotspot analysis for an example farming operation based on the PIRSA research station in Loxton, South Australia, showing the calculator's output. To create a complete carbon footprint, soil carbon and carbon in native regeneration can also be added (described below)

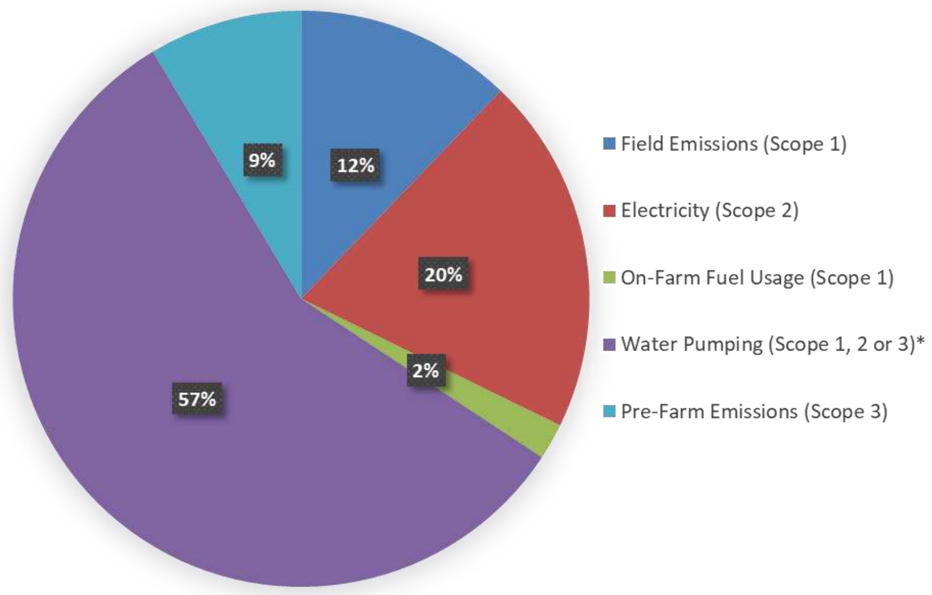


***Figure 4. Emissions profile of an example grape-growing operation at a PIRSA research station at Loxton, South Australia*** [4]

** Water pumping could be scope 1, 2 or 3 depending on where and how the power generation for pumping occurs (e.g. scope 1 for on-farm diesel pumps, scope 2 for on-farm electric-powered pumps, or scope 3 for water supplied to the farm under pressure through infrastructure such as a central irrigation system).*

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. Field emissions and indirect nitrous oxide 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 5.6.2, pg 345-6, section 5.6.3, pg 346-7, section 5.6.9, pg 352-3 and section 5.6.10, pg 353-5[5])

***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* [6]

*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* |
| SSP | T | 216# |
| Lime application | t | 3.13^ |

* *Cradle-to-NZ port for urea produced in the Middle East* [7].
\# *Cradle-to-manufacturing-plant-gate in NZ* [7].
^ *Crushed limestone rock production* [8].

### 1.2.2 Assessing carbon in grapevines

Horticultural woody biomass crops such as trees and grape vines benefit from storing carbon in biomass and potentially soil throughout their lifecycle. In grapevines, carbon is stored in the vine trunk and cordons while they are still growing. However, pruning operations limit the amount of carbon stored in woody tissue. Annual carbon storage in vines varies with vine age. Research on vines up to 25-30 years shows that vine trunks continue to increase in diameter and store carbon as they age[9,10]. Annual carbon sequestration in older vines can be equal to or greater than in young vines[10].

Further research is required to determine the extent of carbon sequestration in grapevines beyond 30 years. According to the NIR, the sequestration of carbon in biomass of perennial woody crops may be included in emissions and sequestration assessments up to maturity, however, no allowance is made post-maturity and coefficients for grape vines are not provided in the NIR. Taking basic measurements of a vine can assist with determining the carbon stored within permanent biomass.

Carbon may also be stored in the soil through carbon added from the decomposition of plant roots, litter and prunings (Figure 5), and this is discussed in section 1.2.4.

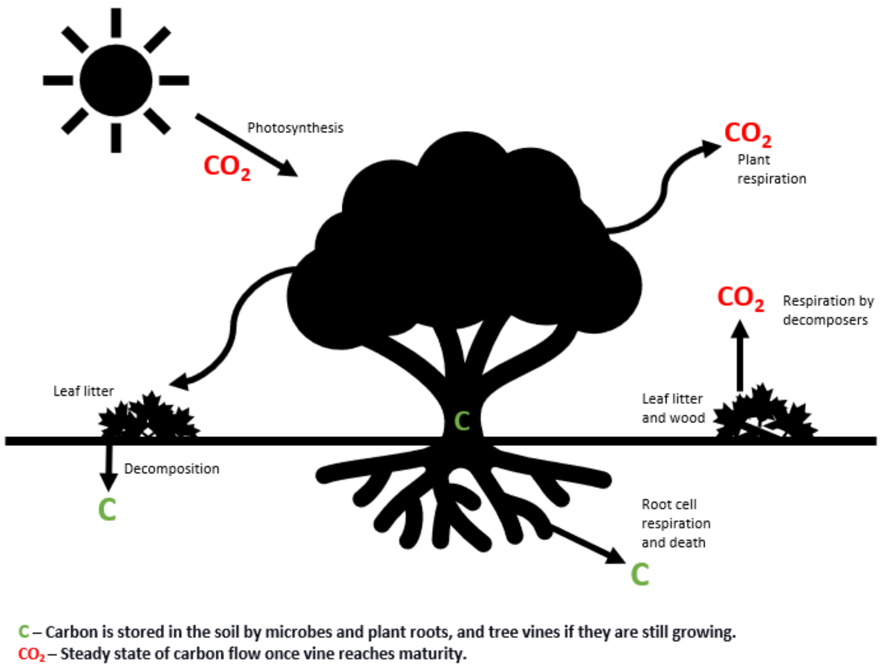


*Figure 5. Major carbon flows within a typical vine-growing system*

### 1.2.3 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 to offset emissions is only a long-term solution. 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[11]. 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).

### 1.2.4 Assessing carbon in soils

Small variations in soil carbon can lead to large carbon sequestration potential[12]. 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[13]. Soil carbon increase is a function of the quantity of carbon added to the soil and how much is retained. Without organic matter inputs to the soil, there is typically a 2-3% reduction in soil organic matter per year[14]. 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

Grape-growing is typically a smaller contributor to the overall life cycle impacts of the wine supply chain, with Abbott *et al.* (2016) reporting 15% of emissions being contributed from the grape-growing phase (the remainder is typically from transport, winemaking, and packaging of wine in glass bottles). Most of the emissions from vineyards arise from fuel or electricity use, while winery emissions are mostly produced by electricity (Figure 6).

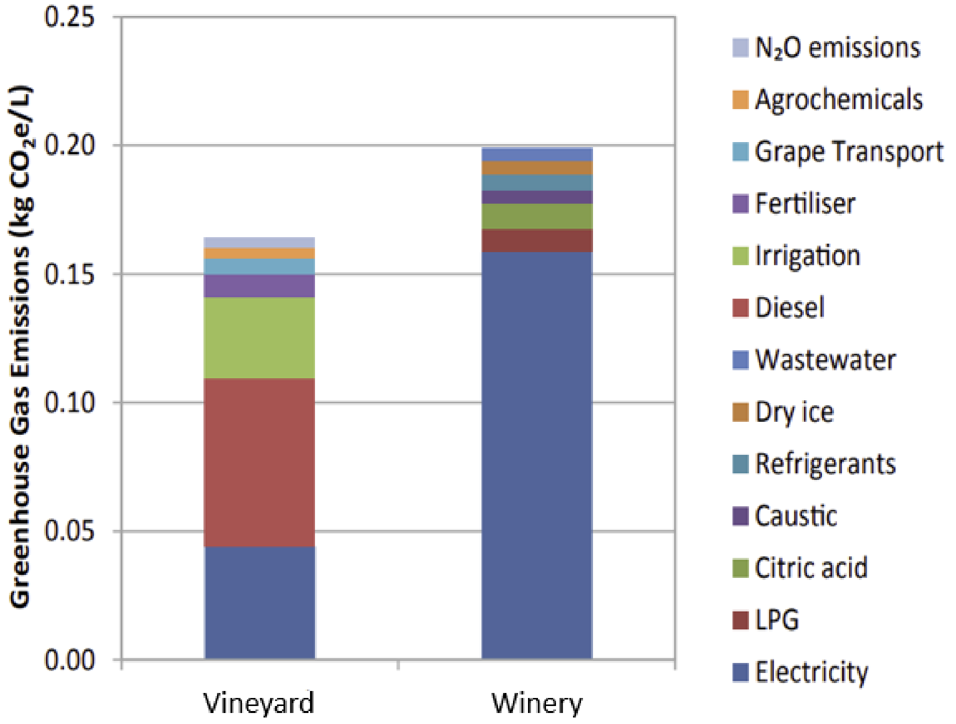


***Figure 6. The GHG emissions profile of a vineyard and winery*** [19]

A recent study with PIRSA on a research and extension horticultural farm at Loxton, SA, found emissions intensities of 248, 239 and 307 kg $CO_2$-e t yield$^{-1}$ for Chardonnay, Shiraz and Cabernet Sauvignon grapes, respectively [4]. This study was conducted in a single location only and may not reflect broader regions. More broadly, a recent Landcare extension program across southern Australia found significant variation across producers surveyed, with a range of 19 – 900 kg $CO_2$-e t yield$^{-1}$ identified, highlighting the significant variability possible within Australia alone, based on specific location and ongoing management practices. The range in emissions intensities across 9 SA farms participating in a workshop as part of the current project was 19 – 842 kg $CO_2$-e t yield$^{-1}$, with a median of 318 kg $CO_2$-e t yield$^{-1}$.

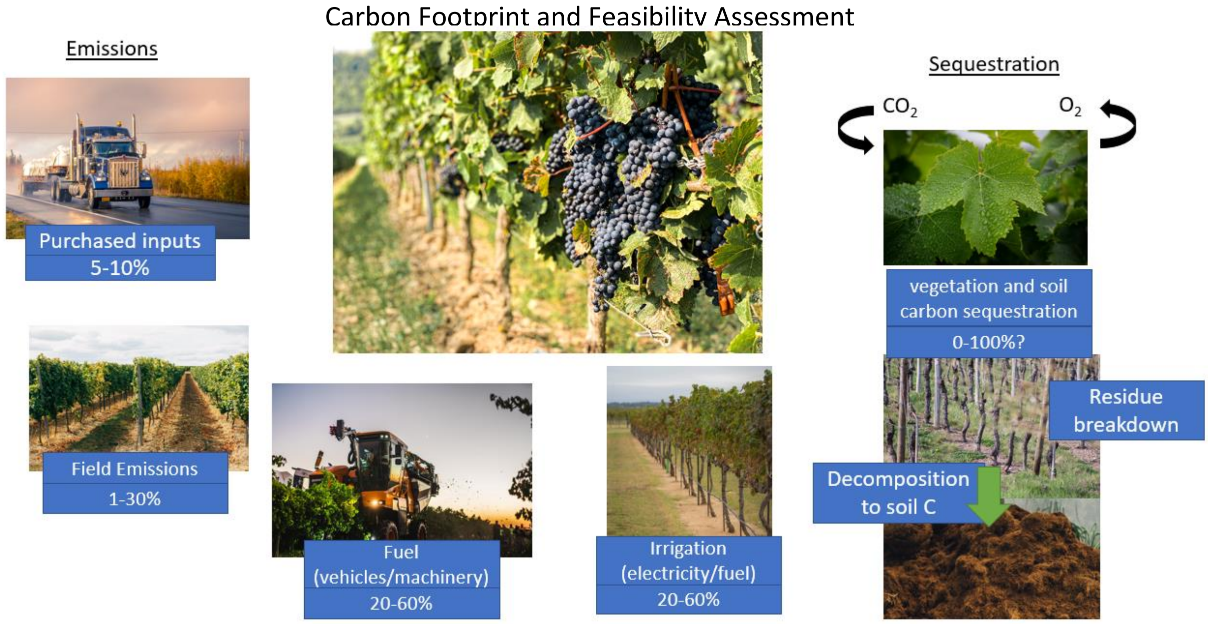


***Figure 7. Typical emission profiles seen in a vineyard, highlighting the ranges that can occur depending on enterprise practices and environmental constraints***

For comparison, a review of multiple international studies (including regions in Italy, California and Cyprus)[20–22] found a range of emissions intensities from 203 kg $CO_2$-e t yield$^{-1}$ to 846 kg $CO_2$-e t yield$^{-1}$. These ranges are highly variable, influenced by harvesting practices, crop type and yield volumes, environmental suitability (such as rainfall and soil characteristics), and management practices.

# 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 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 offacnsets must equal emissions.

## 3.1 Reducing carbon emissions

Reducing emissions in Australian grape-growing operations should typically focus on optimising inputs, primarily electricity use, fuel use, water use, and purchased inputs (such as nitrogen fertilisers, herbicides, and pesticides) relative to yield developing options to use less emission-intensive inputs.

The highest emissions are typically for electricity or fuel to pump irrigation water. Improved water use efficiency (WUE) through optimisation activities is the largest area for potential improvement and has benefits for water savings and costs. Likewise, reducing fuel use by optimising pumping efficiency or machinery utilisation enables further energy reductions. An alternative, or complementary, approach to reducing electricity and irrigation energy emissions is to supplement electricity with renewable energy instead of grid electricity. This could be achieved by implementing solar electricity and battery storage on-site or through utilising green energy programs such as 'Greenpower' to reduce typical grid electricity use with renewable energy projects, which would reduce the attributable carbon footprint of the operation. The cost-effectiveness and technology availability of these options remains a limitation for these options at present.

## 3.2 Storing carbon

Achieving carbon neutrality requires carbon storage in soil and/or vegetation, as emissions reduction strategies cannot achieve a zero-emissions profile in isolation. In viticultural enterprises, soil carbon storage may provide an opportunity to reduce net emissions. While there are multiple factors in the potential of soil carbon increases at a location, many practices that are undertaken in best-practice management of vineyards also produce increases in soil carbon, such as mulching and reapplying prunings, maintaining vines over decades prior to removal, the utilisation of cover cropping, the application of organic amendments such as compost or animal manure, and irrigation.

Carbon levels generally stop increasing and reach an equilibrium over time, with the upper limit generally determined by climatic conditions and soil type[16,17] (Figure 8). There may be greater potential for carbon sequestration in previously degraded soils than in soils that have 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[15].

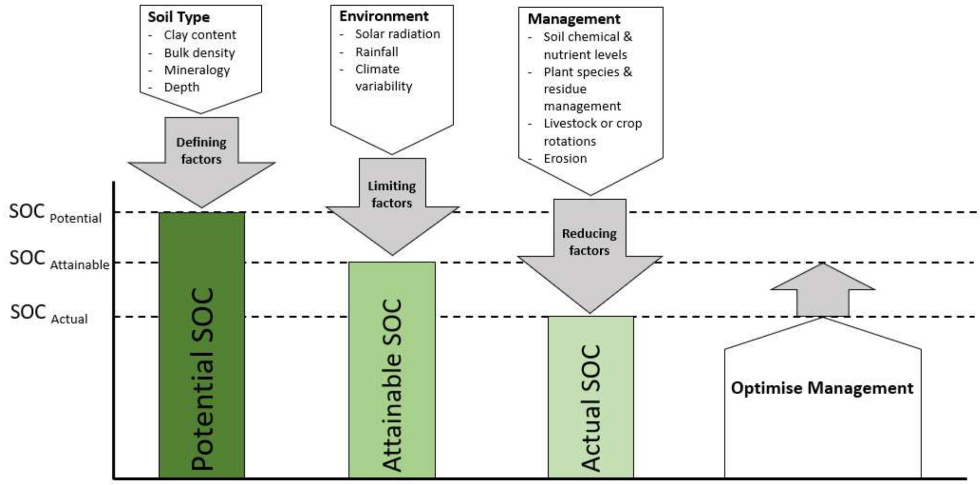


***Figure 8. A representation of the factors influencing potential, attainable and actual SOC and change expected from altered management practices*** [18]

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 grape-growing districts have at least a small potential to increase SOC compared to existing baselines, as shown in Figure 9 and Figure 10. Carbon credits from increased soil carbon need to be generated if considering a branded carbon neutral program.

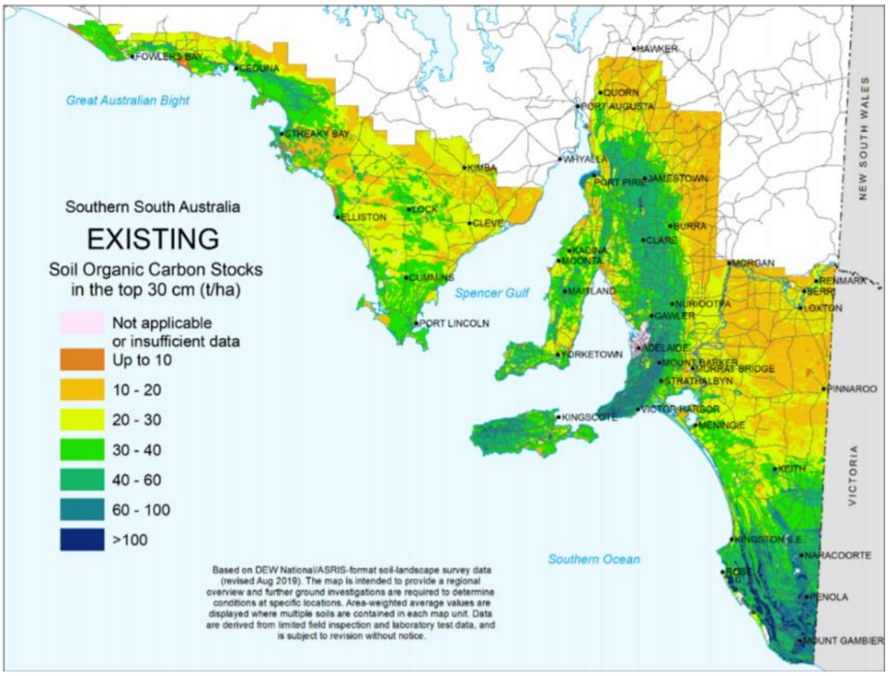


***Figure 9. Existing surface SOC 1990-2000***[23]

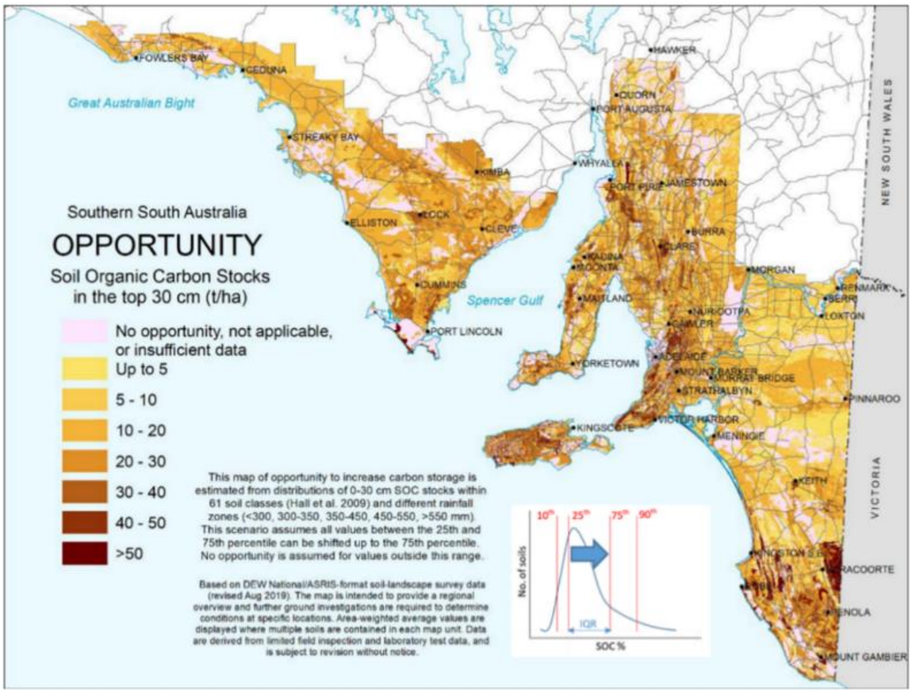


*Figure 10. Opportunity for surface soil OC % - all values between the 25th and 75th percentile can be shifted to the 75th percentile*[23]

Vegetation carbon storage may provide further opportunities to reduce net emissions. Currently, no methods under the ERF allow ACCUs to be earned through carbon stored in horticultural trees/crops, and therefore the carbon in vines is not able to be counted towards Climate Active carbon neutral programs.

Recently surveyed farming operations indicated the potential carbon storage achieved in the vineyards could be in the order of 0.6 and 6.6 t $CO_2$-e per hectare per year. Sequestration per hectare is dependent on the number of vines, with higher sequestration rates corresponding to higher planting density. Net carbon sequestration in vines older than 30 years is uncertain and may be zero in older fines or decline with age. Other carbon storage opportunities such as native vegetation plantings or regeneration may exist within viticultural operations. Because sequestration potential can be substantial compared to emissions, further work to understand carbon sequestration in vines and establish calculation approaches acceptable for carbon accounting is required.

# 4 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 11).

Climate Active's certification also requires an independent third party to verify the carbon footprint and offset measures. Viticultural 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 native 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.

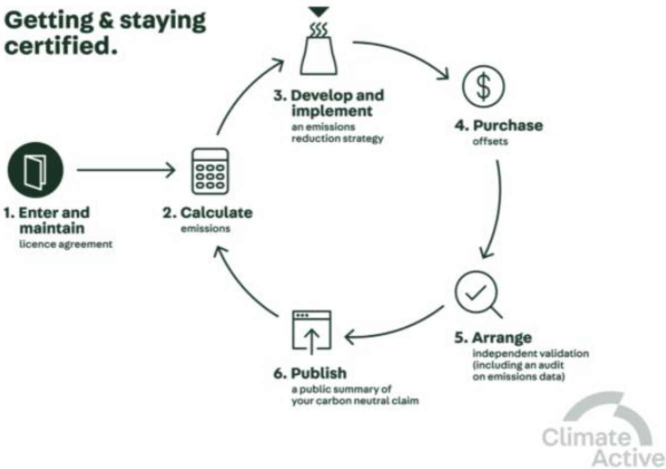


*Figure 11. Climate Active Carbon Neutral project flow chart*

## 4.2 Emissions Reduction Fund (ERF)

The ERF 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 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 soil. Projects yield Australian Carbon Credit Units (ACCUs), with one ACCU being the equivalent of 1 tonne of carbon dioxide equivalent (1 t $CO_2$-e) either prevented from being emitted (avoidance) or by 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 to the Federal Government through the Clean Energy Regulator (Figure 12).

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.

Importantly, no current methods under the ERF allow ACCUs to be earned through carbon stored in vines, but soil carbon may represent an opportunity for larger entities.

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).

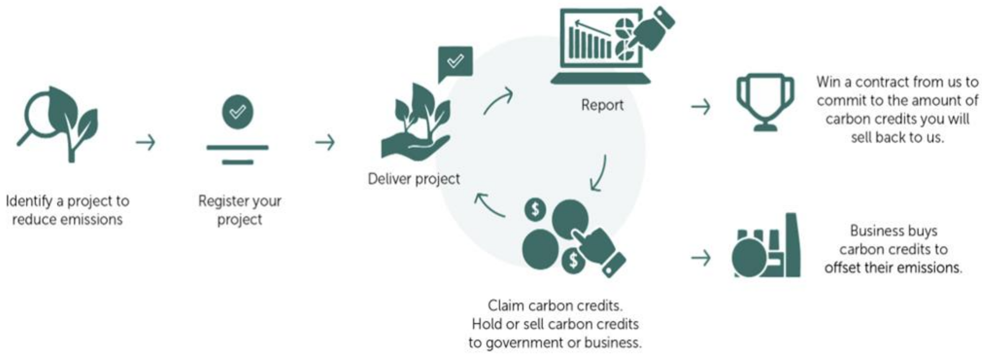


*Figure 12. ERF project flow chart*

# 5 Completing your own 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.

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 Carbon accounting calculators

Producers can create a carbon account for their farms using publicly available online tools. Three tools currently available for calculating emissions from viticulture are the Horticulture Greenhouse Accounting Framework (H-GAF), Australian Wine Carbon Calculator and HortCarbonInfo tools. Here we discuss the H-GAF tool, which can be downloaded at 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 H-GAF tool:

- **Farm inputs:** fertilisers, lime, pesticides, fuel and electricity.
- **Tree planting:** area planted to trees (ha), species and planting date (to determine age).
- **General crop and farm information:** crop yield, area cropped, and the fraction of burnt crop residues.

The H-GAF tool is limited to horticulture crops. Other enterprises operating on-farm, such as sheep grazing vineyard inter-rows, require different tools. The tool can be used to create a carbon account for any year where data are available. We suggest selecting a recent, "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.

### 5.2.1 Step one: Data input – Crops

Each data item listed in the *Data input – crops* sheet (Figure 13) is required to calculate the farm's total emissions, except for the "Farm Name" on the first row of the sheet. Enter the region and electricity source for a single farm. Select the crop type from the dropdown boxes under "Farm cropping details". By looking at the map next to the data input cells, identify whether the crop is within the orange zone on the map and enter the correct zone. When entering nitrogen fertiliser use, enter the total amount of nitrogen applied (kg N/ha), including nitrogen in urea and any other source. You also need to enter the total amount of urea applied (kg urea/ha) in the next cell down. Under "General Herbicide/Pesticide use", enter the total kg of the active ingredient in pesticides applied that is not glyphosate, as glyphosate is added in the following row.

| | | | | | |
|---|---|---|---|---|---|
| **Enter your farm data** | Farm Name | **Joe Bloggs's** | | | |
| Choose your region in Australia | SA | | | | |
| Electricity Source | State Grid | | | | |
| **Farm cropping details** | Perennial Hort | Annual Hort | Hops | Pulses | |
| Is the crop in orange zone? (Ref Map. 1) | No | No | No | No | |
| Is the crop irrigated? | Yes | Yes | No | No | |
| Average crop yield | 3.00 | 0.00 | 0.00 | 0.00 | t/ha |
| Area sown | 20 | 0 | 0 | 0 | ha/farm |
| Nitrogen Fertiliser Use | 20 | 0 | 0 | 0 | kg N/ha |
| Urea Application (included in the above) | 0 | 0 | 0 | 0 | kg Urea /ha |
| Single Superphosphate | 0 | 0 | 0 | 0 | kg/ha |
| Mass of Lime Applied | 0 | 0 | 0 | 0 | kg/ha |
| Fraction of Lime as limestone vs dolomite | 1.00 | 1.00 | 1.00 | 0.00 | Limestone/dolomite |
| Fraction of the annual production of crop that is burnt (F) | 0.00 | 0.00 | 0.00 | 0.00 | ha/total crop ha |
| Annual Diesel Consumption | 2000 | 0 | 0 | 0 | litres/year |
| Annual Petrol Use | 0 | 0 | 0 | 0 | litres/year |
| Annual Electricity Use | 5000 | | | | KWh |
| Allocation to crop | 100% | 0% | 0% | 0% | % |
| General Herbicide/Pesticide use | 4 | 0 | 0 | 0 | kg total |
| Glyphosphate use | 20 | 0 | 0 | 0 | kg total |

*Figure 13. Data input – crops 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 14) can be completed from top to bottom as items within certain dropdown boxes are dependent on previous options selected. Fill in the dropdown boxes 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 each crop entered on the Data input – crops sheet.

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

| | | | | |
|---|---|---|---|---|
| **Vegetation** | State | | SA | |
| | Region | | South East | |
| | Species of Tree | | Mixed species (Environmental Plantings) | |
| | Soil Type | | Duplex Soils | |
| | Area of Trees | | 3 | ha |
| | Age of Trees | | 15 | years |
| | Allocation to crop | Perennial Hort | 60% | |
| | Allocation to crop | Annual Hort | 40% | |
| | Allocation to crop | Hops | 0% | |
| | Allocation to crop | Pulses | 0% | |

*Figure 14. Data input – vegetation sheet with example data*

## 5.3 Other vegetation carbon sequestration methods

The H-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 provides 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 Grapevine carbon sequestration

For an **internal business carbon baseline assessment,** it is possible to calculate carbon sequestration potential in grape vines and include this in the carbon account. Multiple allometric approaches exist in international literature for estimating carbon sequestered in woody biomass. One of the simplest for grape vines is that used by Goward and Whitty 2014, which treats vine trunks and cordons as 'cylinders'. The following equations can estimate the total carbon sequestered in vines.

***Equation 1***

$$Volume\ (cm^3) = Area\ (cm^2) \times Length\ (cm)$$
$$= \pi r^2 \times l$$

Where *r* is the trunk or cordon radius in cm and *l* is the trunk or cordon length in cm for calculating trunk or cordon volume, respectively.

***Equation 2***

$$Cordon\ radius\ (cm) = (2.5cm + (0.25cm\ \times (vine\ age - 5)) \div 2)$$

Where vine age is in years.

***Equation 3***

$$Aboveground\ biomass\ (kg) = Total\ vine\ volume\ (cm^3)\ \times Wood\ density\ (g/cm^3)\ \div\ 1000$$
$$= Total\ vine\ volume\ \times 0.95\ \div\ 1000$$

***Equation 4***

$$Whole\ vine\ biomass\ (kg) = Aboveground\ biomass\ \div\ 0.7$$

***Equation 5***

$$Total\ carbon\ content\ (kg) = Whole\ vine\ biomass\ \times carbon\ content\ fraction$$
$$= \boldsymbol{Whole\ vine\ biomass\ \times 0.45}$$

***Equation 6***

$$Total\ CO_2\ (t) = Total\ carbon\ content\ \times 3.67 \div 1000$$

## 5.5 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 reported by measuring the soil carbon at the beginning and end of a sampling period (often 3-5 years) and calculating the difference.

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 7. 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[15]. 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 due to various factors, such as different management practices and history, season, time in the year, and varying soil types. To improve the accuracy of SOC determination, 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 many more requirements around soil sampling must be followed to generate carbon credits under the ERF soil carbon method. Users must refer to these guidelines if the purpose is to develop a soil carbon project to generate carbon credits.

***Equation 7. Soil organic 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.

## 5.6 Data summary

Upon completion of data entry into the *Data input – crops* and *Data input – vegetation* sheets, the *Data summary* sheet is populated with your farm's emissions results (Figure 15). 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.

**Horticulture Greenhouse Accounting Tool**

| Crop | Perennial Hort | Annual Hort | Hops | Pulses | Total | Summary | t CO2e/farm |
|---|---|---|---|---|---|---|---|
| **Outputs** | t $CO_2$e/farm | t $CO_2$e/farm | t $CO_2$e/farm | t $CO_2$e/farm | t CO2e/farm | | |
| **Scope 1 Emissions (on-farm)** | | | | | | | |
| $CO_2$ - Fuel | 5.40 | 0.00 | 0.00 | 0.00 | 5.40 | $CO_2$ | 6 |
| $CO_2$ - Lime | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | $CH_4$ | 0 |
| $CO_2$ - Urea | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | $N_2O$ | 7 |
| $CH_4$ - Field burning | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| $CH_4$ - Fuel | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | | |
| $N_2O$ - Fertiliser | 1.42 | 0.00 | 0.00 | 0.00 | 1.42 | | |
| $N_2O$ - Atmospheric Deposition | 0.16 | 0.00 | 0.00 | 0.00 | 0.16 | | |
| $N_2O$ - Field Burning | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| $N_2O$ - Crop Residues | 3.74 | 0.00 | 0.00 | 0.00 | 3.74 | | |
| $N_2O$ - Leaching and Runoff | 1.43 | 0.00 | 0.00 | 0.00 | 1.43 | | |
| $N_2O$ - Fuel | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 | | |
| **Scope 1 Total** | **12** | **0** | **0** | **0** | **12** | | |
| **Scope 2 Emissions (off-farm)** | | | | | | | |
| Electricity | 2.2 | 0 | 0 | 0 | 2.2 | | |
| **Scope 2 Total** | 2.2 | 0 | 0 | 0 | 2.2 | | |
| **Scope 3 Emissions (pre-farm)** | | | | | | | |
| Fertiliser (urea + Superphosphate) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| Herbicides/pesticides | 0.08 | 0.00 | 0.00 | 0.00 | 0.08 | | |
| Electricity | 0.5 | 0 | 0 | 0 | 0.5 | | |
| Fuel | 0.28 | 0.00 | 0.00 | 0.00 | 0.28 | | |
| Lime | 0 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| **Scope 3 Total** | **1** | **0** | **0** | **0** | **1** | | |
| **Carbon Sequestration** | | | | | | | |
| Carbon sequestration in trees | -61.52 | -41.02 | 0.00 | 0.00 | -102.54 | | |
| **Net Farm Emissions** | **-46** | **-41** | **0** | **0** | **-87** | | |
| **Emissions intensity** | **-0.02** | **#DIV/0!** | **#DIV/0!** | **#DIV/0!** | **t CO2-e/t crop** | | |

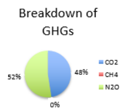


*Figure 15. Data summary sheet with example data*

To the right of the tabulated emissions breakdown, a hotspot analysis of the main emissions sources is visually displayed in a pie chart (Figure 16). In the H-GAF tool, the hotspots are Fuel, Electricity, Fertiliser, Crop Residues, Indirect $N_2O$ and Pre-farm emissions.

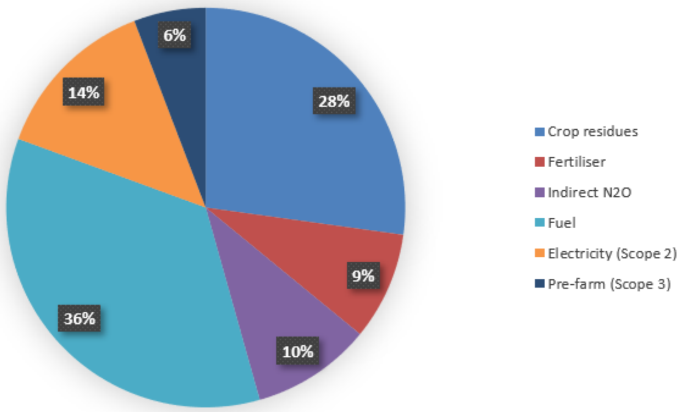


*Figure 16. Pie chart of Hotspot Analysis in Data summary sheet with example data*

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. For example, implementing a program to reduce tractor passes by 30% would potentially reduce fuel by 30%, enabling a deduction of 30% of the fuel carbon emissions from the overall account. The calculator can be used as needed and can also be used to test management changes to indicate the different emission outcomes.

## 5.7 Calculator limitations

Due to the complex nature of carbon accounting, the available calculators have different limitations that vary depending on the chosen tool. No one tool is ideal, and none can currently meet the needs for formal carbon accounts without additional information.

Here are some points to note. Firstly, check which version you have. Factors change regularly, especially for electricity and occasionally for GWP values, and methods are periodically updated. A calculator that is 3 years old is out-of-date.

Second, check the purpose. You can calculate an enterprise carbon account focused on scope 1 and 2 emissions, but it's difficult to benchmark performance against other businesses with these results, and you can't report a product carbon footprint. Most of the available tools are variable in their handling of scope 3 emissions and give indicative results at best.

The Australian Wine Carbon Calculator does not allow for calculating scope 3 emissions. Some scope 3 emissions are calculated in the H-GAF tool, including emissions from the production of purchased inputs; however, other scope 3 emissions are not calculated (e.g. transport of purchased inputs, employee commuting, waste, downstream emissions, some fertiliser related emissions and some herbicide/pesticide inputs). Scope 3 emissions are an important part of a carbon account and must be reported in accordance with certain standards. These tools do not currently allow for calculating carbon sequestration in soils or horticultural crops.

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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