

# Life cycle assessment of Australian Avocados



---

Undertaken by Lifecycles for Hort Innovation

For Hort Innovation Project – AV23015 Industry-level life cycle assessment (LCA) of Australian avocado production

December 2025

Citation	Reutter, B, Renouf, M. (2025), Life cycle assessment of Australian avocados, Lifecycles, Melbourne, Australia.
About the authors	<p>Lifecycles is a sustainability consultancy based in Melbourne (lifecycles.com.au) specialising in environmental life cycle assessment (LCA) and related services. This includes metrics for sustainability reporting, greenhouse gas (GHG) accounting, environmental product declarations (EPD), GHG emission reduction strategies and targets, among others. Lifecycles has been providing LCA services for more than 20 years for Australian and overseas clients, and is a pioneer of LCA data, training and tool development in Australia.</p> <p>The authors have expertise in LCA of agricultural products and developed the life cycle inventory (LCI) data for Australian agricultural commodities (AusAgLCI) in 2014 [1], led by the Rural Industries Research and Development Corporation (RIRDC), and updated in 2025 in partnership with Agrifutures [2]. They have contributed to many LCA projects related to Australian agricultural and bio-based production, including guidelines for LCA and greenhouse gas emission (GHG) accounting in agriculture, enabling access into markets requiring sustainability credentials, and informing greenhouse gas emission reduction strategies.</p>
Copyright	© 2025 Lifecycles. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of Lifecycles.
Important disclaimer	Lifecycles advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, Lifecycles (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.
Acknowledgements	<p>The authors acknowledge the First Nations people of Australia as the traditional custodians of the lands and waters on which we live, learn and work. We pay our respects to past, present and future Elders of these nations. In particular, we acknowledge the traditional custodians of the lands and waters where Lifecycles' offices are located.</p> <p>This project was funded by Hort Innovation, a not-for-profit research and development corporation for the Australian horticulture industry. Hort Innovation is funded by grower levies, and Australian Government and other industry contributions, in order to invest in research and development, and marketing and trade to help anticipate future challenges and opportunities within the horticultural sector. The authors acknowledge the contribution of the Project Reference Group (PRG), who provided industry insights to guide the scope and outcomes of the project. The authors also acknowledge the avocado growers and distributors who contributed their time and data. The project would not have been possible without their contributions.</p>

---

# Executive summary

This Life Cycle Assessment (LCA) study examined the environmental footprints of Australian avocados, providing the first comprehensive, whole of industry analysis of greenhouse gas (GHG) emissions and climate change impacts, and water use and water scarcity impacts. It was conducted through the Hort Innovation Project AV23015 - "Industry level LCA of Australian avocado production".

The LCA study was conducted in accordance with the International Standards for LCA (ISO 14044) and Carbon Footprint of Products (ISO 14067). Primary activity data was collected and collated from 31 avocado farms, representing 14% of national production across all major growing regions: WA, Tristate, NSW / SE QLD, Central QLD, and Northern QLD.

The functional unit of the LCA was one kilogram of Australian avocados, for both cradle-to-farm gate and cradle-to-market system boundaries, including orchard establishment, on-farm avocado production, primary packaging, cold storage, transport to distribution centre, and ripening.

Impact assessment applied IPCC Global Warming Potentials to convert GHG emission estimates into climate change impact results (carbon footprints), water use assessments to generate Water Footprints, from which water scarcity impact indicators were generated using the AWARE method. The analyses were conducted in SimaPro LCA software and using background data from the Australian Life Cycle Inventory (AusLCI) database and from the international ecoinvent 3.10 database.

## *Carbon Footprint*

The industry-average GHG emission intensity (Carbon Footprint) for Australian avocados was estimated to be 0.64 kg CO<sub>2</sub> eq per kg at farm gate and 0.98 kg CO<sub>2</sub> eq per kg at market. On-farm production contributes 65% of emissions, and post-farm activities contribute the remaining 35% including transport, packaging, cold storage and ripening.

Energy consumption was found to be the dominant source of emissions:

- Diesel and electricity use collectively - 57% of on-farm emissions
- Fertilizer production and nitrous oxide (N<sub>2</sub>O) emission from N-fertiliser application - 31% of on-farm emissions
- Transport - 43% of post-farm emissions
- Packaging - 29% of post-farm emissions

Regional carbon footprints show modest variation (0.60-0.68 kg CO<sub>2</sub> eq/kg at farm gate, a 13% spread), the differences reflecting distinct production characteristics:

- Central QLD production has the lowest footprint (0.60 kg CO<sub>2</sub> eq/kg) due to favourable growing conditions, which reducing energy-intensive inputs
- Western Australia production has highest electricity-related emissions (0.30 kg CO<sub>2</sub> eq/kg, nearly double the national average) due to fossil fuel-dependent grid electricity and deep-bore water extraction
- Northern QLD production has the highest total emissions (0.68 kg CO<sub>2</sub> eq/kg).

## *Water Footprint*

The industry-average water footprint was estimated to be 0.99 m<sup>3</sup> per kg of avocados at farm-gate and at market, with irrigation accounting for 84%. Regional variations are substantial, ranging from 0.49 m<sup>3</sup>/kg in New South Wales to 1.23 m<sup>3</sup>/kg in Central

Queensland, reflecting differences in climate, rainfall patterns, irrigation efficiency, and productivity.

### *Water Scarcity*

The industry-average water scarcity impact result was estimated to be 38.55 m<sup>3</sup> world water equivalent per kilogram (m<sup>3</sup> world water-eq). This metric, which accounts for regional water stress, shows high variation:

- Tristate region: 109.68 m<sup>3</sup> world water-eq /kg
- Central QLD: 39.40 m<sup>3</sup> world water-eq /kg
- New South Wales: 1.15 m<sup>3</sup> world water-eq /kg

These results underscore that Australian avocado production occurs predominantly in water-stressed environments where water consumption has significant environmental consequences.

### *Carbon Footprint Reduction Opportunities*

Scenario analysis evaluated opportunities for reducing GHG emissions:

Most impactful interventions for cradle to farm gate emissions were found to be:

- solar PV electricity: 12% emissions reduction from adoption that replaced 30% of electricity demand,
- yield improvement: 9% emissions reduction from 10% yield improvement,
- fertilizer reduction: 3% emissions reduction from 10% reduction in fertiliser input,
- diesel use efficiency: 2% emissions reduction from 10% reduction in diesel fuel demand.

The analysis demonstrates that meaningful GHG emission reductions should prioritize on-farm interventions, particularly renewable energy adoption and agronomic improvements.

Post-harvest interventions show more modest potential benefits, with 20% solar electricity in facilities achieving ~2% reduction and 20% packaging reduction also achieving ~2% reduction for cradle to market emissions. Packaging optimisation must carefully balance material minimization with product protection, as increased product waste from inadequate packaging can negate emission savings.

### *Strategic Implications*

This study established essential base case environmental performance metrics that will enable the Australian avocado industry to:

- respond to market demands for environmental credentials with credible, comprehensive data,
- prioritize sustainability investments in the most impactful initiatives,
- benchmark performance for ongoing improvement tracking,
- engage stakeholders including retailers, regulators, and consumers with reliable environmental information,
- differentiate Australian avocados as competitively low-carbon food alternative.

The pathway to enhanced sustainability is clear: prioritize renewable energy adoption to address dominant energy-related emissions, optimize agronomic practices with emphasis on fertiliser use, and maintain whole-supply-chain thinking to ensure post-harvest improvements complement production-phase gains. With strategic focus on these interventions, the Australian avocado industry is well-positioned to strengthen its competitive advantage as a sustainable producer in an increasingly environmentally conscious global marketplace.

---

# Contents

<b>1</b>	<b>Introduction</b>	<b>8</b>
<b>2</b>	<b>Method</b>	<b>9</b>
2.1	Life cycle assessment	9
2.2	Goal and scope definition	10
2.3	Industry sample	12
2.4	Inventory	13
2.5	Impact assessment	19
<b>3</b>	<b>Results</b>	<b>21</b>
3.1	Impact assessment	21
3.2	Contribution analysis	21
<b>4</b>	<b>Interpretation</b>	<b>28</b>
4.1	Carbon footprint reduction opportunities	28
4.2	Carbon footprint comparisons	30
4.3	Water footprint and scarcity comparisons	32
<b>5</b>	<b>Conclusions</b>	<b>33</b>
	<b>References</b>	<b>35</b>
	<b>Appendix A – HGAF tool comparison</b>	<b>37</b>
	<b>Appendix B - Background processes</b>	<b>38</b>
	<b>Appendix C – Recycling credits</b>	<b>42</b>

---

---

# Figures

Figure 1 Framework for life cycle assessment.	9
Figure 2 Life cycle stages included in the LCA.	11
Figure 3 Avocado production locations in Australia [8] (green dots) and grower sample locations (yellow circles)	13
Figure 4 Life cycle model of Australian avocado production	14
Figure 3 Contribution analysis of the GHG emissions intensity of Australian avocados per growing region.	22
Figure 4: GHG emissions contribution for Australian avocados with a cradle-to-market system boundary.	23
Figure 5 Total water use per growing region for 1kg of avocados.	27
Figure 6: Water scarcity results, per growing region for 1kg of avocados.	27
Figure 7: Avocados GHG emissions improvements for different system changes compared to the cradle-to-farm gate base case scenario.	29
Figure 8: Avocados GHG emissions changes for different interventions, compared to the cradle-to-market base case scenario.	29
Figure 9 Comparison of GHG emissions intensities of plant-based foods [23].	30
Figure 10 Comparison of GHG emissions intensities of fruits at the farm gate [24].	31

---

# Tables

Table 1 Industry sample.	12
Table 3: Inputs for the establishment phase, relative to full production.	15
Table 2 Most relevant data collected from the industry sample, reported as regional averages.	16
Table 4: Materials for packaging.	18
Table 5: Contribution per region to total Australian production and regions distance to Sydney.	18
Table 6 Data quality assessment framework.	18
Table 7 Indicators and characterisation models used in this LCA.	19
Table 8 Impact assessment results for one kg of Australian avocados at farm gate and at market.	21
Table 9 Carbon footprint contribution and hotspot analysis of Australian avocados at farm gate, climate change results	22
Table 10: Post-farm GHG emissions per KG of avocado.	23
Table 11 Water use and water scarcity results of one kg of Australian Avocados at market.	27
Table 12: LCA literature of avocado and their estimation of GHG emissions for 1kg of product.[33, 34] [35].	32
Table 13 Inventory of key processes used in this Australian Avocados LCA	38

---

# 1

# Introduction

This report presents findings from a Life Cycle Assessment (LCA) study of Australian avocados, conducted under Hort Innovation Project AV23015: "Industry level life cycle assessment (LCA) of Australian avocado production". The study aimed to assess the environmental impact of Australian avocado production to inform the sector's sustainability strategies and individual producer initiatives.

The study directly aligns with Avocado Australia's Strategic Plan 2022-2026 [3] (Industry Priority 4) and the Hort Innovations Avocado Strategic Investment Plan 2022-2026 [4]. It builds on prior environmental investigations commissioned by Hort Innovation [5], and aligns with broader sustainability frameworks established by Hort Innovation [6] and the Australian Fresh Product Alliance [7].

By providing robust LCA-based environmental metrics, this study addresses the growing demand for sustainability data across business operations, reporting requirements, supply chain communications, and customer engagement. Such metrics are becoming essential for market participation and competitive positioning.

The study examined three environmental aspects: climate change impacts from greenhouse gas (GHG) emissions (carbon footprint), total water consumption (water footprint), and water scarcity impacts.

Global recognition of climate change has created expectations for all sectors to reduce GHG emissions. Government policies and industry initiatives are driving emissions reduction requirements throughout food supply chains—from retailers to manufacturers to growers. This LCA study provides the avocado sector with essential data to meet future information requests and compliance requirements.

Water scarcity represents a significant global environmental challenge, particularly in Australia. As agriculture is both dependent on water resources and a major water consumer, understanding water use intensities and scarcity impacts is crucial for sustainable resource management, especially during drought conditions.

While the avocado industry has historically faced limited environmental scrutiny—fresh horticultural products typically demonstrate lower impact intensities than other food categories—all food supply chains now face increasing pressure to measure, monitor, and communicate environmental performance.

The study's findings enable strategic decision-making by identifying the most impactful areas for environmental improvement, establishing performance base cases for future monitoring, and providing credible data for communication with customers, regulators, and other stakeholders. These capabilities position the Australian avocado industry to proactively address sustainability challenges while maintaining productive and profitable operations.

The study was supported by a Project Reference Group (PRG), made up of industry experts, who provided industry insights to guide the scope and outcomes of the project. There was also cross-fertilisation between this project and two other Hort Innovation Projects:

- AV23016 "Developing a strategy for long-term sustainability of avocado production in Australia". The two projects shared the same PRG, and outcomes from this LCA study feed into the sustainability strategy.
- AV22004 "Develop and adapt a benchmarking tool for Australian avocado growers". Some grower data collected by the benchmarking study was incorporated into the industry sample for the LCA study.

# 2 Method

## 2.1 Life cycle assessment

LCA is a methodology for assessing the environmental impact of products by quantifying environmental flows at each stage of a product's life cycle from 'cradle-to-grave'. It quantifies exchanges between the 'environment' and the 'technosphere' (the product system). Exchanges include the extraction of natural resources from the environment and emissions of pollutants to the environment (to air, water and soil).

The framework and principles of LCA are described in the international standard ISO 14044 (International Organization for Standardization, 2006a). The general structure of the LCA framework is shown in Figure 1. Each stage of the LCA interacts with the other stages, making it an iterative process.

- The first stage (goal and scope) describes the goal for the LCA, the system boundaries, the functional unit, and the impact indicators to be assessed.
- The second stage (inventory analysis) builds a model of the product's life cycle, compiles life cycle inventory (LCI) data describing the quantities of inputs (resources) and outputs (emissions / releases) into and out of the process.
- The third stage (impact assessment) converts the inventory data into a set of environmental indicators using impact characterisation factors.
- The final stage (interpretation) analyses the impact assessment results to identify the most important contributors and key variables, via sensitivity analysis.

The LCA methodology underpins greenhouse gas (GHG) accounting methods prescribed in the International Standard for the Carbon Footprint of Products (ISO 14067) and the Greenhouse Gas Protocol.

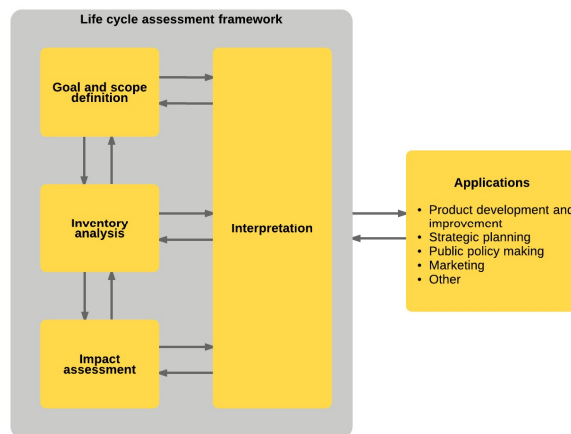


Figure 1 Framework for life cycle assessment.

The LCA study was conducted in accordance with the ISO 14044 Standard for LCA and the ISO14067 Standard for Carbon Footprint of Products.

## 2.2 Goal and scope definition

### 2.2.1 Goal of the LCA

The goal of the LCA is to generate metrics describing the climate change and water use impacts of Australian avocados to inform the sustainability initiatives of growers and strategies of the industry.

The LCA focus on the 'cradle-to-market' stage for avocados to the domestic Australian market, presenting differentiated results for 'cradle-to-farm gate' system boundary.

The intended audiences for this report are those interested in the environmental credentials of Australian Avocados, including but not limited to growers and marketers, agronomists, industry decision-makers and researchers.

### 2.2.2 Definition of the production system

A number of varieties of avocados are grown commercially in Australia, with the main ones being Haas (82%) and Shepard (15%) [8]. Based on the advice of the PRG, the production systems and yields were assumed to be the same for both and not differentiated in the study.

An initial definition of avocado production was built based on literature describing Australian avocado production systems, in particular farm models and gross margin analyses prepared by State Government agricultural departments and extension advisors. These are useful sources of information describing the type and quantities of farming inputs.

To further refine the model to be representative of actual production practices occurring in different regions, case study assessments were conducted for an initial small sample of six (6) growers. The purpose was to understand production practices and identify whether any differentiation by region and / or production practices was necessary. The case study sample aimed to cover the main producing regions and included two (2) growers in Western Australia, two (2) in Bundaberg, QLD, one (1) in Northern QLD and one (1) in Northern NSW.

The case study process involved conducting familiarisation visits to each farm to observe and describe practices, developing a data requirements checklist, collecting the required data from the grower, generating of LCA results for each case study farm, and discussing the results and feasible improvement opportunities.

The learnings from the case studies enabled a model of Australian avocado production to be developed which has the following general features:

- seedlings / plants purchased from specialist nursery and established for 3 years before a productive phase of around 25 years,
- irrigation is required for good yields, with water from a range of sources (farm dams, river, groundwater, irrigation schemes), pumping powered either with diesel or electricity,
- nutrients applied as granular NPKS fertilisers with some trace elements,
- pests controlled with spray application of insecticides and fungicides and some use of biological controls,
- harvested fruit collected loose in large bins with subsequent packaging into cardboard trays, which occurs either on farm or at packhouses elsewhere,
- use of tractors and farm vehicles,

- harvested and packaged avocados transported to centralised storage and ripening facilities and then on to distribution centres (market).

Production methods were found to be similar across the case study sample. Regional differences, influenced by climate, were found to influence differences in energy use for irrigation and yields. This warranted differentiation between the main producing – North QLD, Central QLD, Southern QLD / Northern NSW, Tristate and WA.

The case study process also enabled the development of data requirements list that was used in the data collection for the larger industry sample (see 2.3).

### 2.2.3 System boundary

On the advice of the PRG, the LCA had two system boundaries (Figure 2):

- 'cradle to farm gate', which included nursery production of the avocado plants, the establishment phase, the productive phase, to produce loose avocados at farm gate.
- 'cradle to market', which extended the system boundary to also include post-farm processes of packaging, storage and ripening, and transport to market. Even though packaging can occur on-farm where produced, it was modelled to be part of the post-farm phase.

Also included in the system boundary was the production of all input to these processes (energy, fertilisers, chemicals, etc.) and emissions and waste and emissions outputs from the processes.

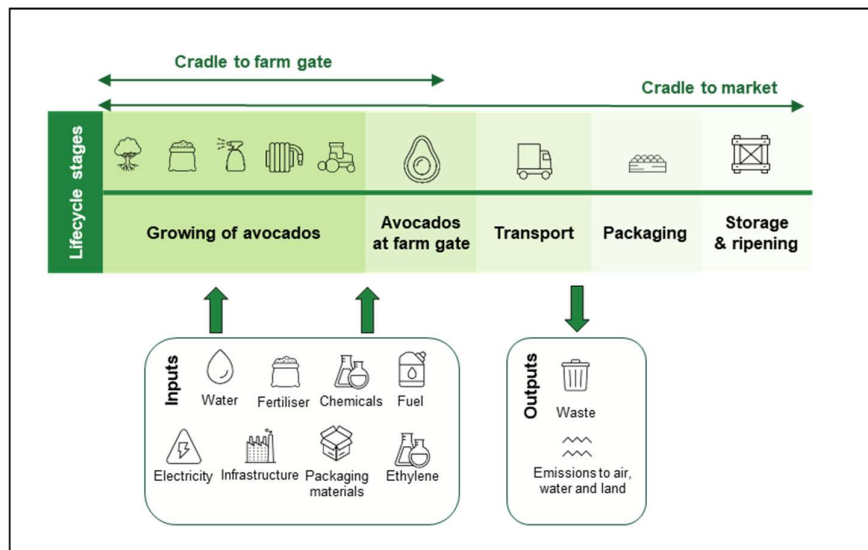


Figure 2 Life cycle stages included in the LCA.

Some inputs and environmental flows were excluded due to being insignificant. Flows can be excluded if they are below the cut-off threshold, which is a contribution of less than 1% to any impact category assessed by the LCA. No flows were deliberately excluded due to this threshold. However, the following minor inputs, which were expected to be well below this threshold, were not considered:

- bee hives and aviculture for pollination, including their transport and inputs were attributed to honey production and not avocado production.
- production of packaging for plant delivery from nurseries
- production of agents used in small quantities including biological control products and growth regulators
- production of and emissions from LPG used on forklifts

- management of municipal waste other than packaging waste for agrochemicals and fruit packaging
- Bins used for harvesting
- Water for packaging operations

Land use change impacts were not accounted, as most farms are already well established beyond the 20-year cutoff for land use change.

#### 2.2.4 Functional unit

The functional unit describes the product delivered by the production system. This study intends to examine the impacts of the production of 1kg of Avocados, from cradle to market. The functional units was:

*“One kilogram (kg) of Australian avocados at farm-gate and at market”*

## 2.3 Industry sample

The industry sample included data from the case study growers mentioned previously (see 2.2.2), plus data collected by the project team from additional growers, and data derived from an industry benchmarking study (Hort Innovations project AV22004). The aim was to generate a sample that adequately represented from the main avocado producing regions:

- North QLD,
- Central QLD,
- Southern QLD and Northern NSW
- Tristate (at junction of VIC, NSW, SA)
- Western Australia

Overall, the industry sample contained data from 31 farms representing 14% of Australian production (Table 1). It is considered that the data provides a good representation of the industry.

Table 1 Industry sample.

Region	No. avocado farms in the sample	Area of farms in the sample (ha)	Production represented by sample	Avocado production for Australia (t/yr) [8]	% of national production represented by sample
North QLD	8	628	4,732	32,342	14.6%
Central QLD	5	545	2,837	25,768	11.0%
Southern QLD and Northern NSW	6	175	1,258	12,507	10.1%
Tristate	4	69	709	14,495	4.9%
Western Australia	8	691	12,092	65,801	18.4%
<b>TOTAL</b>	<b>31</b>	<b>2,108</b>	<b>21,627</b>	<b>150,913</b>	<b>14.3%</b>

Figure 3 Avocado production locations in Australia [8] (green dots) and grower sample locations (yellow circles)



## 2.4 Inventory

### 2.4.1 Life cycle model

A life cycle model for Australian avocado production was developed in the Simapro LCA software V10.2.0.2, and populated with inventory data, derived from collected primary data, quantifying inputs and outputs.

It includes the life cycle phases of on-farm plant establishment, on-farm avocado production and post-farm processes. The foreground process of avocado production, linked to background processes for all the material and energy inputs. The background processes incorporated into the model are detailed in Appendix B, and the recycling allocation in Appendix C.

The model was parameterised, meaning that the inventory values can be adjusted to model different production scenarios and regions.

### 2.4.2 Inventory data collection

The data for plant establishment, on-farm processes and post-farm processes were gathered and collated between August 2024 and June 2025. All data and assumptions were reviewed by PRG members, and also sense-checked against Australian published data.

#### 2.4.2.1 Plant establishment

Nursery plants were assumed to be supplied from to be supplied from a nursery in Northern NSW. Road transport to deliver plants from the nursery to growers was estimated from the amount of plants required to achieve a planting density of 380 plants per ha and a plant weight of 2.5 kg.

An establishment phase of 3-years was assumed, followed by an orchard lifespan of 25 years, based on growers' interviews and PRG input.

Inputs for farm establishment, relative to full production, are shown in Table 2 and were obtained in growers' interviews.

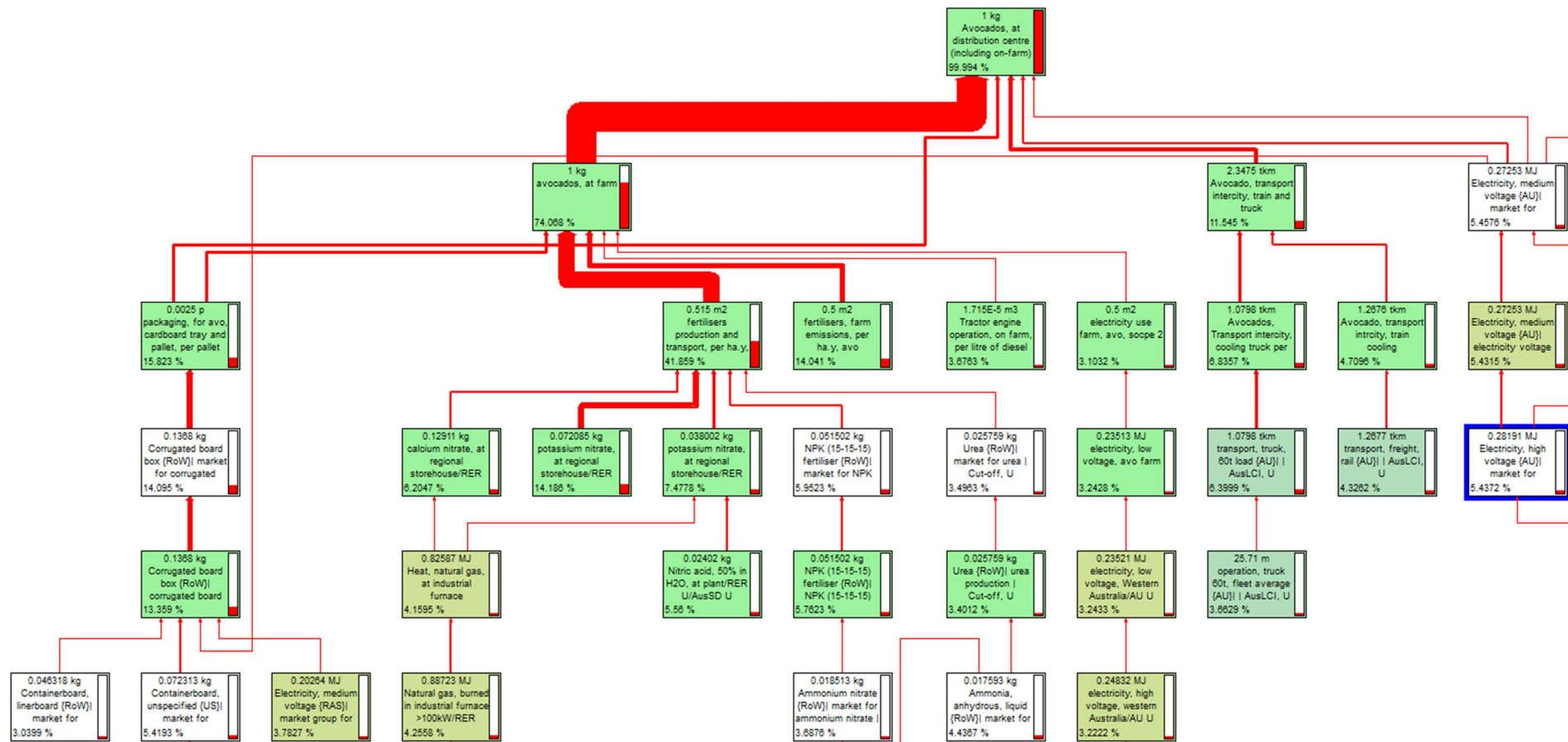


Figure 4 Life cycle model of Australian avocado production

Table 2: Inputs for the establishment phase, relative to full production.

Parameter	Fraction
Diesel	0.4
Electricity	0.3
Petrol	0.1
Fertiliser	0.4
Water	0.25

#### 2.4.2.2 On-farm processes

Data from growers related to on-farm avocado production was collected confidentially under an agreed Data Management Plan.

Given that avocado production can vary from year to year (with “on and off” years and significant weather events), the compiled data aimed to reflect the “most representative year” out of the last five years in consultation with the growers. Most of the data was for 2022-2023 season, but each participant chose what they considered the representative year for their farm.

The most important items of data for on-farm processes are summarised in **Error! Not a valid bookmark self-reference.**, reported as regional averages, to protect confidentiality.

**Electricity:** Impacts are differentiated per state, using AusLCI data base. When photovoltaic electricity is generated on farm and is sold to the grid, then net energy use is assumed (purchased – sold to the grid). The impacts of photovoltaic generation are estimated considering the solar panel array, with a life span of 30 years.

**Irrigation system:** It is assumed that pumps and pipelines have a lifespan of 15 years.

**Agrochemicals:** For pesticides and herbicides, it is assumed that active ingredients are transported from overseas and then mixed and packed in Australia. It is estimated that the active ingredients travel for 2200 km by sea from overseas, and then by road to the nearest city. Agrochemical packaging is considered to be landfilled using world average landfill emissions.

**Water from the environment:** Considers water catchments available in AusLCI data base[9]. Irrigation scheme water losses were also accounted (when relevant), data was obtained from official irrigation scheme sources for each data point. Water use values are within the ranges described in [10]. Specific model assumptions are described below for system inputs and outputs.

**Emissions to air from fertilisers:** Data for calculations obtained from [11], emissions considered:

- Direct emissions of dinitrogen monoxide (N<sub>2</sub>O) from application of inorganic fertilizer.
- Indirect emissions of dinitrogen monoxide (N<sub>2</sub>O) via leaching and runoff. Note that values for leached fertilizers are region-specific.
- Emissions from Lime application
- Emissions from urea application
- Emissions from atmospheric deposition of volatilised fert-N
- Ammonia (NH<sub>3</sub>) emissions from volatilization of applied fertiliser

**On-farm dam evaporation:** Annual farm dam evaporative loss is driven by the dam water surface area and the evaporation rate per unit area. Pan evaporation values

are obtained from the farms nearest meteorological station [12], using the average for the last 15 years.

**Methane emissions from dams:** In alignment with the National Inventory Report 2022 [13, 14], annual total methane emissions from agricultural ponds have been estimated by converting the density of farm dam surface area into cumulative methane emissions (kg CH<sub>4</sub> year<sup>-1</sup> ha<sup>-1</sup>) by re-organising the Boltzmann-Arrhenius relationship and adjusting for local temperature. The methodology is described in [15] as a tier 1, temperature dependant approach. To obtain averages temperatures, monthly minimum and maximum temperature values were obtained from the nearest meteorological station from [12].

Table 3 Most relevant data collected from the industry sample, reported as regional averages.

Parameter name	Unit	Northern QLD	Central QLD	Southern QLD and Northern NSW	Tristate	Western Australia
Yield	kg/ha/y	7,535	6,017	7,190	10,316	17,497
Farm area	Ha	90	136	35	17	87
Water Use	ML/ha/y	6.2	6.3	3.2	11.9	13.2
Fuel Consumption petrol	L/ha	21	115	80	190	132
Fuel Consumption diesel	L/ha	371	251	345	474	422
Solar PV array	kW	21	0	0	50	16
Grid Electricity Use	kWh/ha/y	1,032	998	1,871	1,862	7,953
Fertiliser active ingredients	kg/ha/y	944	425	868	962	1,698
Mulch	kg/ha/y	23	0	0	154	5,199
Gypsum	kg/ha/y	68	22	800	0	1,272
Fungicides active ingredients	kg/ha/y	15.3	0	0.8	8.8	4.7
Herbicides active ingredients	kg/ha/y	1.6	0	0.9	1.7	2.8
Paclbutrazol	kg/ha/y	0.4	0	0	0.6	1.3
Potassium hydroxide	kg/ha/y	9.6	0	0	13.7	32.0
Insecticides active ingredients	kg/ha/y	1.3	4.1	0.2	1.5	0
Glyphosate active ingredients	kg/ha/y	0	15	5	3	0
Irrigations scheme losses	%	0.142	0.096	0.0	0.0	0.0
CH <sub>4</sub> emissions from dams	t CH <sub>4</sub> /ha/yr	0.13	0.12	0.10	0.09	0.09
Dam evaporation rate	mm/day	5.2	4.9	4.2	3.9	8.4
Dam size	m <sup>2</sup>	82,815	19,800	4,000	4,000	40,941
Distance to nearest city	km	80	39	124	80	53

### 2.4.2.3 Post-farm processes

Data related to post-farm processes (packaging, storage, ripening, transport to market) was collected from operators of avocado packhouses, supplemented with information derived literature related to storage and ripening.

**Packing of avocados** involves energy use for packhouse operations, use packaging materials and fugitive gases of refrigeration (see storage for refrigeration assumptions). Packaging materials are described in

Table 4, values are averages from 6 packhouses. Electricity use was estimated as 0.08 kwh/kg fruit, based on production-weighted average from three Australian packhouses and is in the same order of magnitude that values reported in literature [16]. To ensure confidentiality no individual packhouse data is presented.

Table 4: Materials for packaging.

Input	Value
Avodos per pallet (kg)	800
Trays per pallet (n)	144
Mass per tray (kg)	0.4
Cardboard corners per pallet (kg)	6
Plastic wrap per pallet (kg)	0.375
Number of times pallets are reused [17]	10

**Storage** was assumed to be for 14 days (data from Hort Innovation project AV22011) at a temperature of 5-7°C, electricity needs are based on literature [16] and modified based on temperature and storage time. Fugitive gases from refrigeration consider 50% R448A and 50% R449A , with a average annual leakage rate of 2.2% [18] and a requirement of rounded up to 0.3kg of refrigerant/kW of cooling capacity.

**Transport** assumed to deliver packed avocados to the Sydney market. Assumed distance travel per kg of avocado to Sydney market: 2347 km. Table 5 provide values used to estimate distance. All inter-city transport is assumed to be done by refrigerated truck, the only exception being transport from Perth to Sydney which is modelled at 100% by train (PRG provided information).

**Ripening** uses ethylene in ripening chamber (0.0874 g ethylene/kg fruit) and electricity (0.0322 kWh/kg fruit) [19].

Table 5: Contribution per region to total Australian production and regions distance to Sydney.

Growing region	WA	Tristate	CNSW	SEQLD	Central QLD	North QLD
% Australian Production (2023-24 seasons) [20]	33	9	6	5	20	27
Distance to Sydney (km)	3844	1137	519	732	1276	2421

### 2.4.3 Data quality

The quality of the inventory data was assessed as a requirement of the ISO Standard. The key data quality criteria were related to reliability, and temporal, geographic and technological representation (Table 6).

As the inventory was based on primary data from the industry sample, data quality in terms of temporal, geographic and technological coverage criteria was rated as very good.

Table 6 Data quality assessment framework.

	Poor	Fair	Good	Very good
<b>Reliability</b>	Non-qualified estimate	Qualified estimate	Modelled data	Primary measured data
<b>Temporal coverage</b>	From past production >10 years old	From past production >5 years old and less than 10 years old	From past production >2 years old and less than 5 years old	From current production data <2 years old
<b>Geographical coverage</b>	From distinctly dissimilar region	From global average	From similar region	From region of interest
<b>Technology coverage</b>	From old or dissimilar technology	Generic technology average	From technology specific to region	From actual technology used

## 2.5 Impact assessment

The impact assessment stage converts the inventory data into indicators of environmental impact using impact characterisation factors. Impact assessment was conducted in the SimaPro® LCA software v10.2.0.2, for the following impact categories of interest, detailed of which are provided in Table 7:

- climate change impact (Carbon Footprint)
- water consumed (Water Footprint)
- water scarcity impacts (Water Scarcity)

Table 7 Indicators and characterisation models used in this LCA.

Impact indicator	Description	Characterisation model
<b>Carbon footprint</b> (climate change impact)	Climate change is driven by increased concentrations of greenhouse gases (GHG) in the atmosphere that traps heat leading to higher global temperatures. Gases are principally carbon dioxide (CO <sub>2</sub> ) from fossil fuels, methane (CH <sub>4</sub> ), and nitrous oxide (N <sub>2</sub> O).  Climate change impacts are estimated based on the radiative forcing potential of GHGs, represented as Global Warming Potential (GWP) relative to the reference gas, carbon dioxide.  Expressed in kg CO <sub>2</sub> eq / kg product.	IPCC 2021  International Panel on Climate Change model for characterising the GWP of GHGs over a 100-year timeframe (GWP 100).
<b>Water footprint</b> (Water consumed)	Consumptive use of blue water over the life cycle of the product. Blue water refers to water extracted from the environment as a direct result of the production system such that it is no longer available for other anthropogenic or environmental uses. It includes water drawn from reservoirs (surface waters, dams, groundwater, etc.), water evaporation from dams, etc.	ISO 14046  International Standard for Water Footprints
<b>Water scarcity</b> (Impact of water consumed)	Water scarcity considers the water remaining in a watershed, after the demand of humans and aquatic ecosystems has been met. The calculations of the water scarcity indicator multiply the quantity of water used by the water scarcity factor for the region, to generate a deprivation-weighted water consumption value.  Expressed in m <sup>3</sup> world water-eq.	AWARE  Available WATER REMAINING as recommended by UNEP, 2016 with added Australian catchments.

### 2.5.1 Carbon Footprint (climate change)

The metric that represents climate change impacts represents the GHG emissions intensity per unit of product (CO<sub>2</sub> eq / kg product) but is commonly referred to as the 'carbon footprint' and is described as such in this report.

The greenhouse gases (GHG) accounted for as part of the climate change impact assessment in this study included all gases that contribute to radiative forcing, as described by the International Panel on Climate Changes (IPCC). The main gases are carbon dioxide (CO<sub>2</sub>) from fossil fuel sources, methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), and refrigerant gases. The methods and factors used to calculate GHG emissions were consistent with those used in Australia's National Inventory Report (NIR) [14].

Nitrous oxide (N<sub>2</sub>O) is an important GHG for most agricultural crops and is calculated using N<sub>2</sub>O emissions factors (EF) from the NIR. The N<sub>2</sub>O EF for horticulture in the NIR currently is 0.0065 kg N<sub>2</sub>O-N/kg N-applied, inferring that 0.65% of N applied is lost to atmosphere as N<sub>2</sub>O. This is a one size fits all value for all horticultural crops and may not be a good representation of N<sub>2</sub>O emissions from the protected cropping systems used for avocado production. A literature review and consultation with researchers aimed to identify any N<sub>2</sub>O EFs specific to avocado, but none was identified. Therefore, the generic NIR horticulture EF was used in the absence of an avocado-specific value.

Greenhouse gas (GHG) accounts typically do not count biogenic CO<sub>2</sub> emissions and removals, associated with biological materials and considered part of the natural carbon cycles. For example, the carbon taken up in the vegetation of avocado trees is a biogenic CO<sub>2</sub> removal and is assumed to be re-emitted to atmosphere as a biogenic CO<sub>2</sub> emission when the plant dies and decomposes and when avocados are eaten. These biogenic removals and emissions are assumed to cancel each other out. Biogenic CO<sub>2</sub> removals are only counted as carbon sequestration if they are fixed in plant vegetation or derived products for at least 100 years, which is not the case for avocado production, and so removals were not considered.

## 2.5.2 Water footprint and water scarcity

Two metrics related to water use were reported – water consumed (referred to as the Water Footprint) and the impact of water consumed (Water Scarcity indicator).

Water Footprint is well known as the physical quantity of blue water extracted from the environment over the life cycle of a product. It does not represent the impacts of water use but is a useful metric that familiar to audiences of the results.

Water Scarcity is an indicator increasing used to represent the impacts of water consumption, calculated using characterisation factors that account for regional water availability and demand.

Water scarcity impact indicators are less familiar to audiences of these results compared to water footprints. The international consensus method for water scarcity is the AWARE method, which generate a water scarcity impact indicator using regional water stress factors that represent the relative water stress of the region where the water is drawn from. Water stress is based on regional water availability determined by precipitation runoff and groundwater infiltration rates, and water demand from anthropogenic activities and ecosystem requirements.

The reporting unit represents a volume of water consumption adjusted to reflect the potential to deprive other users (humans or ecosystems) of water, relative to the global average water consumption. The unit is cubic meters of world water equivalent (m<sup>3</sup> world water-eq)

This approach considers the marginal impact of additional water consumption within each catchment's existing water stress context. Characterization factors range from 0.1 m<sup>3</sup>-equivalent per m<sup>3</sup> actual consumption in water-abundant regions with minimal competing demands, to 100 m<sup>3</sup>-equivalent per m<sup>3</sup> in severely water-stressed catchments where human and environmental flow requirements substantially exceed renewable water resources.

# 3 Results

## 3.1 Impact assessment

The industry average carbon footprints for Australian avocados were calculated to be 0.64 kg CO<sub>2</sub> eq / kg at farm gate and 0.98 kg CO<sub>2</sub> eq / kg at market (Table 8). The contribution of post-farm activities to the total at-market footprint is around 35% percent. The sources of GHG emissions and their contributions to the total carbon footprint are analysed in Section **Error! Reference source not found.**

The industry average water footprint for Australian avocados was calculated to be 0.99 m<sup>3</sup> per kg of avocados at farm gate and at market. The contribution of the post-farm processes to the total is negligible compared to the on-farm contribution. The contributors to water use and their relative contributions to water scarcity are analysed in Section **Error! Reference source not found.**

The industry average water scarcity impact for Australian avocados was calculated to be 38.55 m<sup>3</sup> world water-eq per kg at farm gate and at market. Consistent with the water footprint, the post-farm stage does not contribute significantly to the total. Regional water scarcity characterisation factors represent a significant determinant of the footprint. The water scarcity methodology and regional factor analysis are detailed in Section 3.2.3.

Table 8 Impact assessment results for one kg of Australian avocados at farm gate and at market.

Impact category	Unit	Avocados at farm gate	Avocados at market
<b>Carbon footprint</b> (Climate change impact)	kg CO <sub>2</sub> eq / kg	0.64	0.98
<b>Water footprint</b> (Water consumed)	m <sup>3</sup> used / kg	0.99	0.99
<b>Water scarcity</b> (impact of water consumed)	m <sup>3</sup> world water-eq / kg	38.55	38.55

## 3.2 Contribution analysis

### 3.2.1 Carbon Footprint (climate change)

#### 3.2.1.1 Cradle to farm gate impacts

The carbon footprint contribution analysis for avocados (Table 9 and Figure 5) shows that energy and fertiliser use dominate, with three hot spots: diesel use, electricity use and fertiliser use, which is typical for agricultural crops.

Energy use accounts for 57% of the total carbon footprint, including diesel and electricity use. Diesel powers mechanical operations (tractors, pumps for irrigation, and transport vehicles) and electricity typically powers irrigation systems and refrigerated storage. Electricity represents the largest single emissions source across all regions, accounting for 33% of total emissions. Diesel production and consumption is the second major contributor, accounting for 20% of the footprint.

Table 9 Carbon footprint contribution and hotspot analysis of Australian avocados at farm gate, climate change results

Process	Scope	NQLD	CQLD	NSW	TRI	WA	Australia
Fertiliser nitrous oxide emissions	Scope 1	0.07	0.05	0.06	0.07	0.11	0.08
Dam methane emissions	Scope 1	0.05	0.01	0.00	0.01	0.01	0.02
Petrol combustion	Scope 1	0.01	0.05	0.02	0.04	0.02	0.02
Diesel combustion	Scope 1	0.14	0.11	0.13	0.13	0.07	0.10
Electricity production	Scope 2	0.12	0.15	0.21	0.14	0.29	0.21
Irrigation infrastructure	Scope 3	0.01	0.01	0.01	0.00	0.00	0.00
Fertilisers production	Scope 3	0.18	0.10	0.13	0.14	0.08	0.11
Agrochemical production	Scope 3	0.04	0.05	0.02	0.03	0.01	0.03
Petrol production	Scope 3	0.00	0.01	0.01	0.01	0.00	0.00
Diesel production	Scope 3	0.04	0.03	0.04	0.04	0.02	0.03
Electricity transmission and Solar PV infrastructure	Scope 3	0.00	0.00	0.00	0.02	0.00	0.00
Establishment (amortised)		0.04	0.02	0.03	0.04	0.02	0.03
<b>TOTAL</b>		<b>0.68</b>	<b>0.60</b>	<b>0.65</b>	<b>0.67</b>	<b>0.63</b>	<b>0.64</b>
<b>Total Scope 1</b>		0.27	0.23	0.23	0.26	0.21	0.23
<b>Total scope 2</b>		0.13	0.15	0.21	0.15	0.30	0.22
<b>Total scope 3</b>		0.28	0.21	0.21	0.25	0.12	0.19

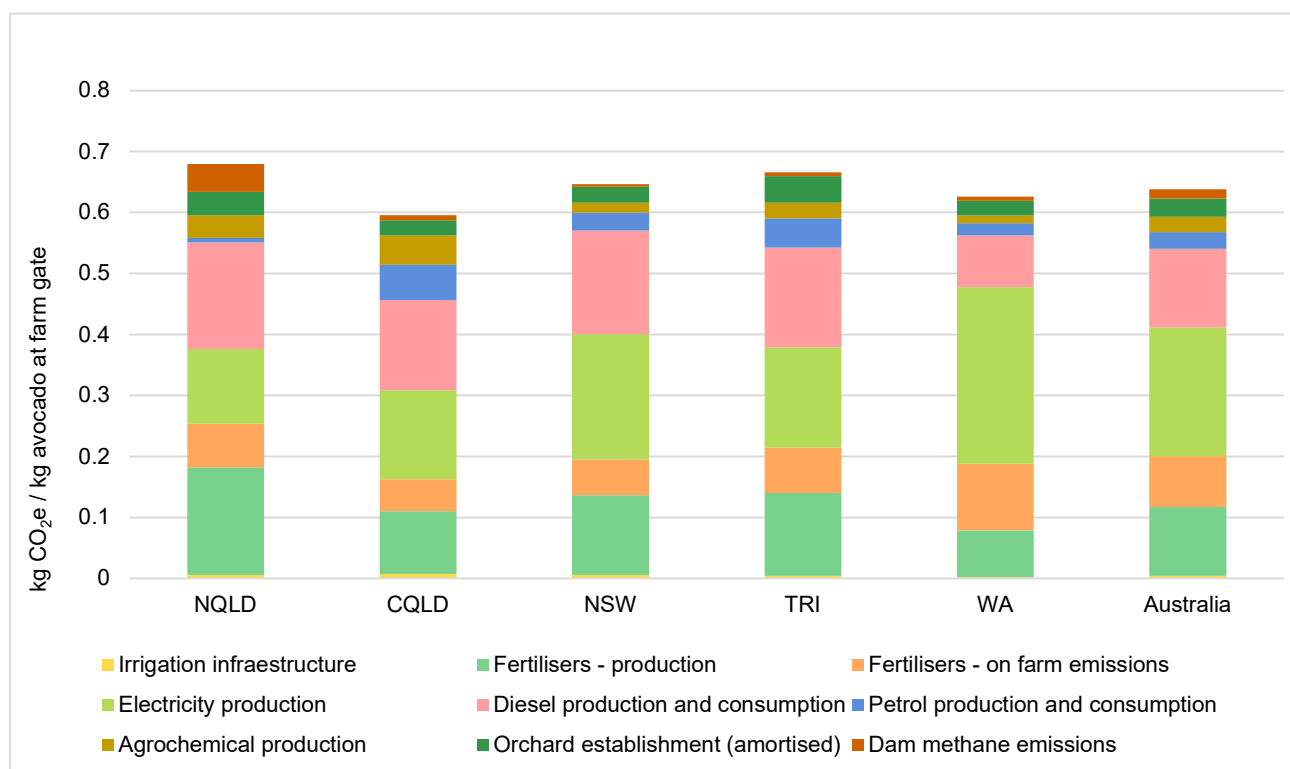


Figure 5 Contribution analysis of the GHG emissions intensity for Australian avocados at farm gate, per growing region.

Fertiliser-related emissions are due to both fertiliser production and on-farm emissions of nitrous oxide (N<sub>2</sub>O) from N-fertiliser application, together representing 31% of the total carbon footprint. Fertiliser production accounts for 18% of emissions, representing the embodied emissions from manufacturing nitrogen, phosphorus, and potassium fertilizers. On-farm N<sub>2</sub>O, emitted when a fraction of applied N is converted from ammonia to N<sub>2</sub>O in the soil, contributes 13%.

The remaining categories (irrigation infrastructure, agrochemical production, orchard establishment and dam methane emissions) collectively contribute less than 12% of the carbon footprint.

The Australian average carbon footprint is 0.64 kg CO<sub>2</sub> eq / kg avocado, and ranges between 0.60 kg CO<sub>2</sub> eq / kg in Central Queensland and 0.68 kg CO<sub>2</sub> eq / kg in Northern Queensland. This is a regional variation of only 13%.

Variations between regions reflects differences in electricity demand for irrigation (driven by water demand which is determined by the regional climate) as well as the carbon intensity of regional electricity grids supplying the electricity (observed by the higher electricity emissions for WA).

The results in Table 9 also show emission sources broken down based on their Scope 1, Scope 2 and Scope 3 categorisation. About one third of emissions are Scope 1 meaning they are generated directly at the farm. One third are Scope 3 related to electricity generation. The remaining one third are Scope 3, related to the production of material inputs.

### 3.2.1.2 Cradle to market

The carbon footprint of Australian avocado at market is 0.98 kg CO<sub>2</sub> eq / kg, with on-farm activities contributing 65% and post-farm operations adding 35% (Figure 6). On-farm production is the dominant contributor, but post-farm processes are significant. Energy is the main source of emissions post-farm for transport and electricity.

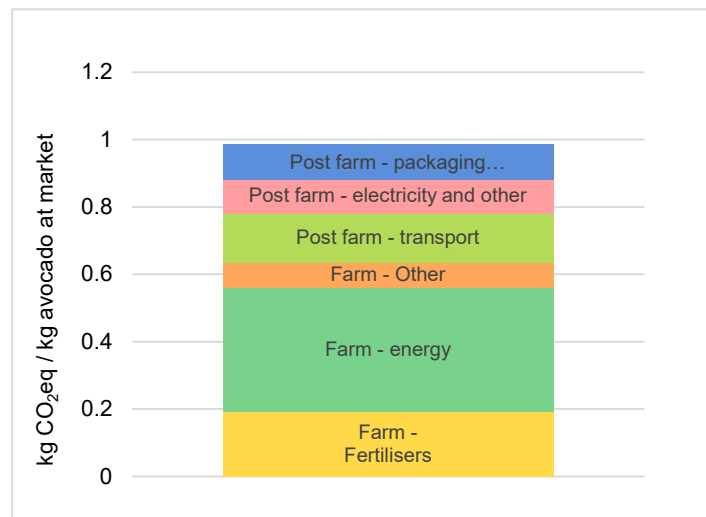


Figure 6: Contribution analysis of the GHG emissions intensity for Australian average avocados at market.

Table 10: Post-farm GHG emission sources.

Source	kg CO <sub>2</sub> eq / kg
Transport	0.147
Packaging and storage - Electricity	0.086
Packaging materials	0.101
Ripening – Ethylene and electricity	0.011
Storage - Refrigerant	0.001
<b>Total</b>	<b>0.347</b>

For the post-farm emission sources (Table 10), the transport of avocados from farm to market, via storage / ripening, is the largest contributor accounting (43%), followed by the manufacture of cardboard packaging materials (29%), then electricity for refrigerated storage and for packaging operations (23%). Ripening and refrigerant gas emissions make the lowest contribution.

The farm-gate carbon footprint varies from 0.60 kg CO<sub>2</sub> eq / kg in Central Queensland to 0.68 kg CO<sub>2</sub> eq / kg in Northern Queensland, a difference of 13%. The post-farm emissions of 0.35 kg CO<sub>2</sub> eq / kg are additional to all regions equally, meaning that even the most efficient production region still incur this post-farm addition. The post-farm phase, therefore, acts as an equaliser across the Australian avocado industry, diminishing the competitive advantage that more efficient production regions might otherwise hold in terms of carbon footprint performance.

### 3.2.2 Water footprint

The water footprint contribution analysis for avocados (

Table 11 and Figure 7) shows that irrigation dominates, being 84% of the total, which is typical for agricultural crops.

The Australian average water footprint was estimated to be 0.99 m<sup>3</sup> per kilogram of avocados, both at farm-gate and at market, since the post-farm contribution to is relatively insignificant. It ranges between 0.49 m<sup>3</sup>/kg in NSW to 1.22/1.23 m<sup>3</sup>/kg in Tristate and Central QLD regions. The variations reflect differences in water demand due to evapotranspiration rates, soil water-holding capacity and irrigation efficiency.

Evaporation from dams is the next largest contributor to the water footprint at 0.10 m<sup>3</sup>/kg nationally (10% of total water use).

### 3.2.3 Water scarcity

While total water consumption provides one measure of water use efficiency, the water scarcity impact indicator provides a more nuanced picture of the impact of water use by accounting for the water stress in the region where it is drawn from.

The Australian average water scarcity impact was estimated to be 38.55 m<sup>3</sup> world water eq / kg avocado (

Table 11 and Figure 8), but masks important regional variations that reveals water stress challenges.

The Tristate region was estimated to have the highest water scarcity impact at 109.68 m<sup>3</sup> world water eq./kg, nearly three times the national average and significantly higher than any other region. This is a combination of high irrigation demand of 1.15 m<sup>3</sup>/kg, as well as a high-water index.

Central Queensland has the second-highest water scarcity impact at 39.40 m<sup>3</sup> world water eq./kg, marginally above the national average despite having the second-highest absolute water consumption at 1.23 m<sup>3</sup>/kg.

New South Wales stands out as having the lowest impact by both metrics, with the lowest absolute water consumption (0.49 m<sup>3</sup>/kg) and the lowest water scarcity footprint (1.15 m<sup>3</sup> world water eq./kg)—97% lower than the national average. This reflects both low irrigation requirements (0.45 m<sup>3</sup>/kg) and production in an area with relatively abundant water resources, resulting in a water scarcity impact from irrigation of only 0.92 m<sup>3</sup> world water eq./kg. NSW's achievement demonstrates that avocado production can be conducted with minimal water stress impact when favourable rainfall patterns, soil conditions, and water availability align.

Table 11 Water footprint and water scarcity results of one kg of Australian Avocados at market.

Process	Total water use (m <sup>3</sup> /kg avocado)						Water scarcity (m <sup>3</sup> world water eq./kg avocado)					
	NQLD	CQLD	NSW	TRI	WA	Aus	NQLD	CQLD	NSW	TRI	WA	Aus
Irrigation	0.82	1.05	0.45	1.15	0.76	0.83	26.28	33.57	0.92	103.41	26.46	32.91
Evaporation from Irrigation schemes	0.08	0.10	0.00	0.00	0.00	0.03	2.43	3.22	0.00	0.00	0.00	1.07
Farm dam evaporation	0.23	0.04	0.02	0.03	0.08	0.10	7.42	1.38	0.05	2.92	2.87	3.36
Farm - establishment	0.03	0.03	0.01	0.04	0.02	0.03	0.81	1.02	0.03	3.13	0.81	1.00
Farm - Other	0.01	0.00	0.00	0.01	0.00	0.00	0.27	0.22	0.15	0.22	0.18	0.21
Post-farm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Total</b>	<b>1.16</b>	<b>1.23</b>	<b>0.49</b>	<b>1.22</b>	<b>0.87</b>	<b>0.99</b>	<b>37.21</b>	<b>39.40</b>	<b>1.15</b>	<b>109.68</b>	<b>30.31</b>	<b>38.55</b>

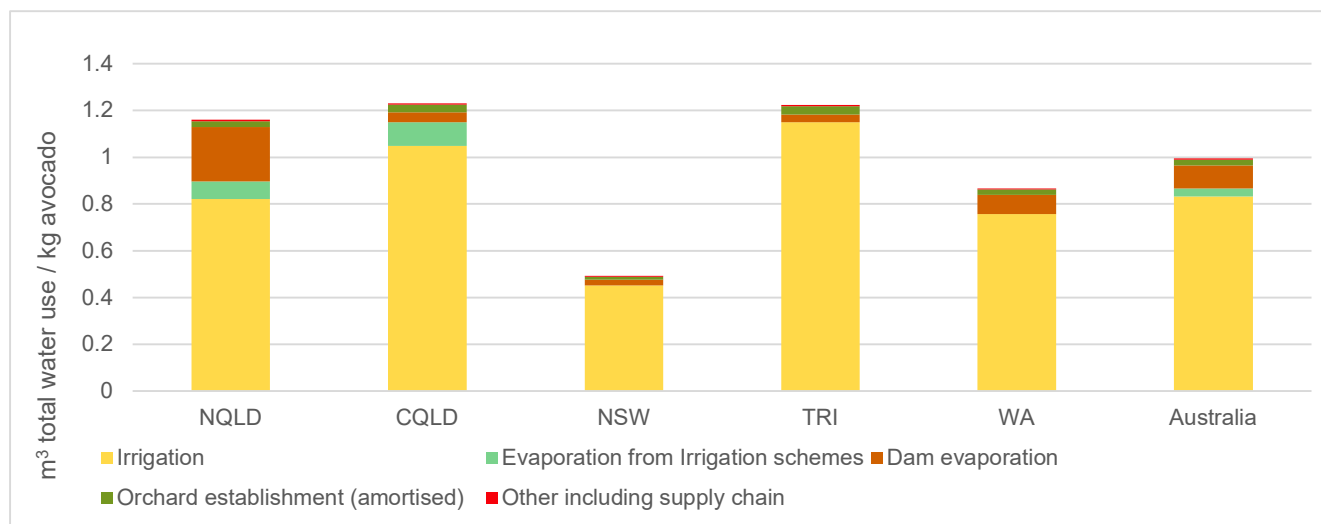


Figure 7 Contribution analysis of water footprint for Australian avocados, per growing region

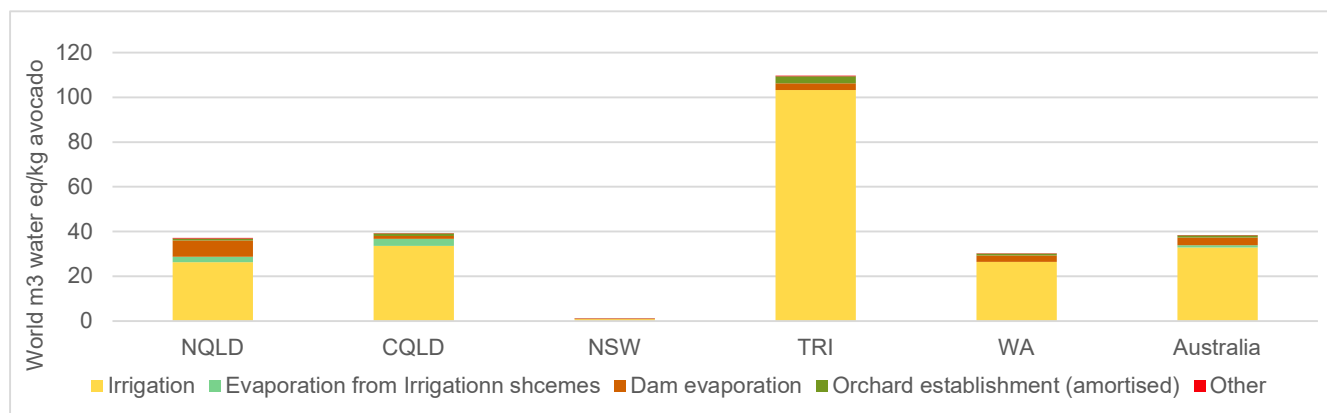


Figure 8: Contribution analysis of water scarcity impacts for Australian avocados, per growing region

---

# 4 Interpretation

## 4.1 Carbon footprint reduction opportunities

The hotspots identified from the LCA study point to potential interventions to reduce the environmental impacts of on-farm production and post-farm processes. Figure 9 and Figure 10 show the estimated percentage reductions in carbon footprint, relative to the base case, from the following identified initiatives.

### On-farm production

- **30% on-farm electricity grid from solar:** Transitioning 30% of grid electricity to solar power delivers the most substantial emissions reduction, achieving 12% improvement relative to base case. This significant benefit reflects the carbon-intensive nature of grid electricity combined with substantial energy requirements for irrigation, pumping and on-farm operations.
- **10% yield increase:** Improving yields by 10% delivers 9% emissions reduction, representing the second-highest impact intervention. By producing more fruit per unit of input (fertiliser, diesel, water, land use), the carbon intensity per kilogram of product decreases substantially. Yield improvements highlight that agronomic excellence is a powerful carbon reduction strategy.
- **10% less fertiliser use:** Reducing fertiliser application by 10% achieves 3% emissions reduction. While modest compared to other interventions, this addresses one of the most emission-intensive inputs. Nitrogen fertilisers are particularly carbon-intensive both in their manufacture and through nitrous oxide emissions following field application. This scenario suggests opportunities for more efficient fertiliser management through precision application and soil testing without compromising productivity, and while reducing costs.
- **10% diesel reduction:** A 10% reduction in diesel fuel use delivers approximately 2% emissions reduction. The two major users of on-farm diesel are tractor operations and irrigation pumps. A reduction of 15% of diesel use at the farm level has been reported when good tractor use and maintenance are implemented [22], and efficient irrigation can reduce the energy input requirements.

### Post-farm processes

- **20% switch to solar electricity:** Transitioning 20% of post-harvest facility electricity to solar power delivers approximately 2% benefit. This demonstrates that post-harvest energy use represents a smaller proportion of total supply chain emissions compared to on-farm production, reflecting that packing and distribution energy requirements are proportionally smaller than cumulative emissions from the production phase.
- **20% less cardboard packaging:** Reducing cardboard packaging by 20% shows 2% benefit. This confirms that embodied emissions in the avocado fruit itself far exceed the emissions associated with cardboard packaging materials.
- When reducing cardboard packaging by 20% combined with 5% product waste, results show a negative impact of approximately -3% (representing an increase in emissions intensity). This reflects the trade-off between packaging reduction and product protection. Less protective packaging may lead to increased product loss, and since the embodied emissions in the avocado fruit itself far exceed the

emissions from cardboard packaging, any increase in waste negates packaging savings. This highlights the critical importance of optimising packaging for product protection rather than simply minimising packaging materials.

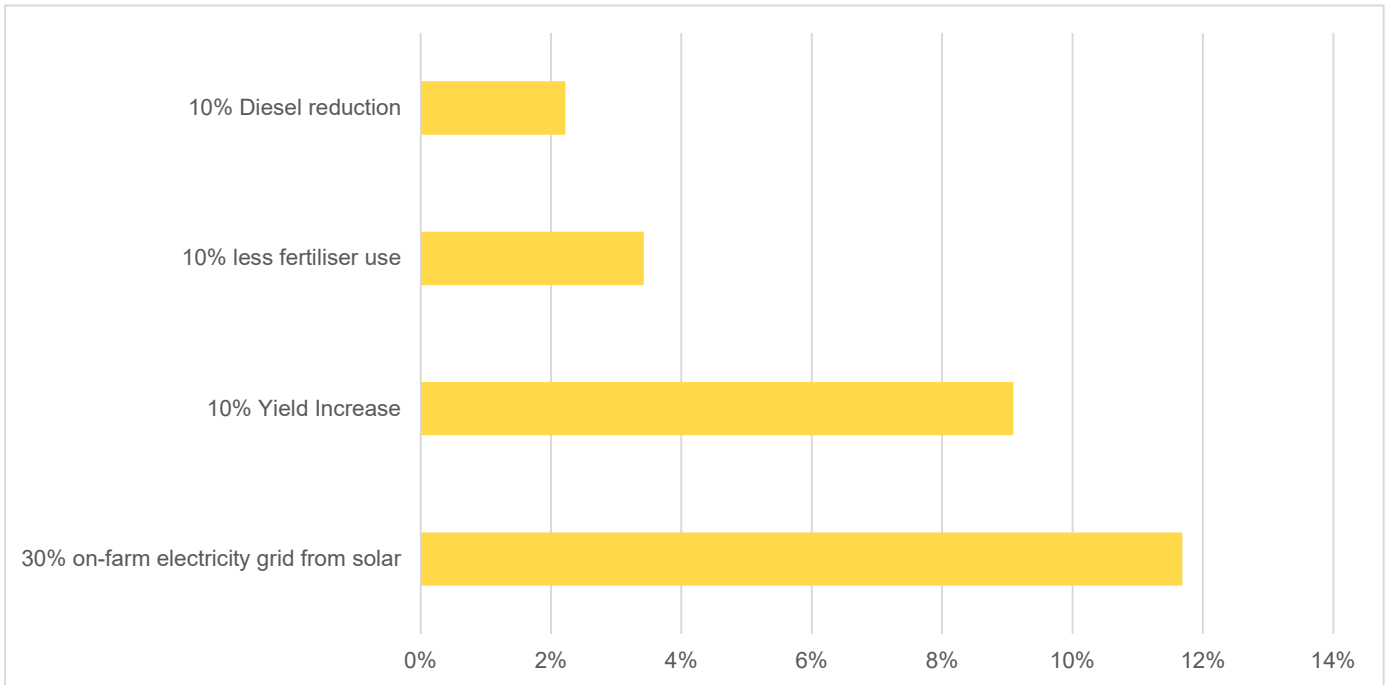


Figure 9: Percentage reductions in farm gate carbon footprint from system changes compared to base case

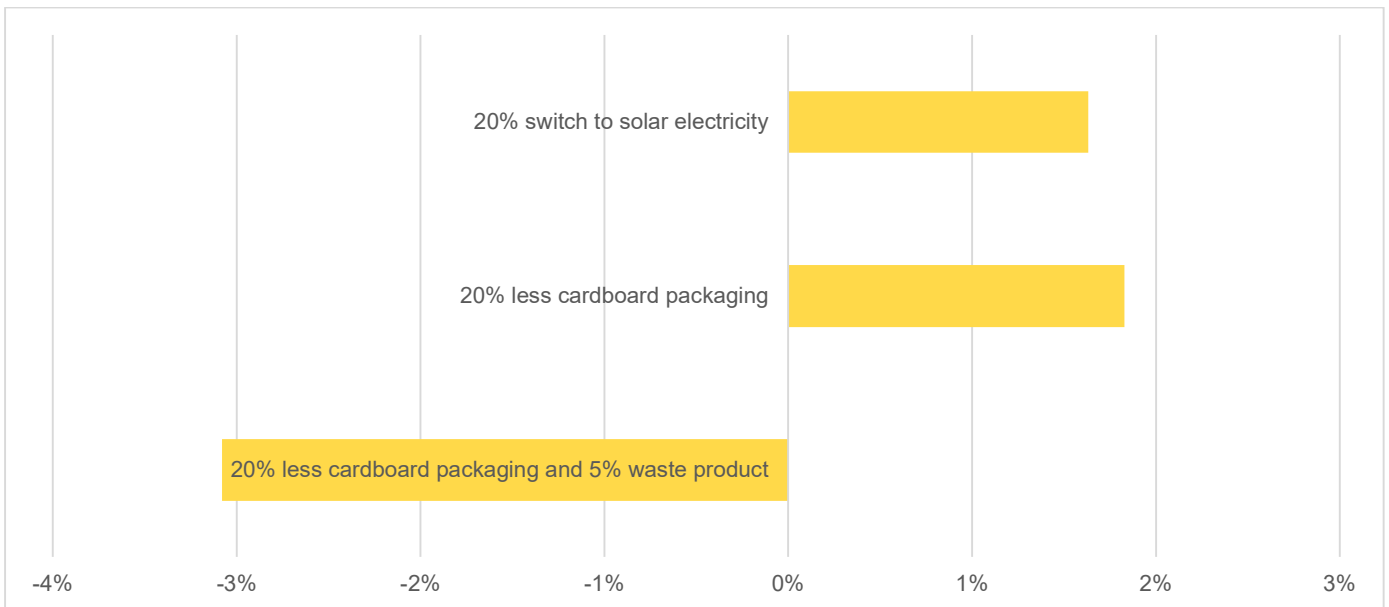


Figure 10: Percentage reductions in at market carbon footprint from system changes compared to base case

## 4.2 Carbon footprint comparisons

### 4.2.1 Fruit production in the broader food system context

Fruit products generally have relatively low carbon footprints compared to most other food types [23]. As shown in the comparative analysis in Figure 11, beef and lamb production dominate the high end of the emissions spectrum, with footprints exceeding 20 kg CO<sub>2</sub> eq / kg and extending to 40 kg CO<sub>2</sub> eq / kg or higher. Cheese production ranges from approximately 10-20 kg CO<sub>2</sub> eq / kg, while poultry and pork demonstrate lower but still substantial footprints around 5-10 kg CO<sub>2</sub> eq / kg. Plant-based proteins like pulses and legumes typically range from 1-3 kg CO<sub>2</sub> eq / kg.

In contrast, most fruits and vegetables cluster at the lower end of the emissions spectrum, generally below 2 kg CO<sub>2</sub> eq / kg. Within this context, Australian avocados at farm gate (0.64 kg CO<sub>2</sub> eq / kg) sit comfortably within the low-impact category of plant-based foods. The carbon footprint is comparable to many staple vegetables and significantly lower than animal proteins, reinforcing the environmental advantages of plant-forward diets.

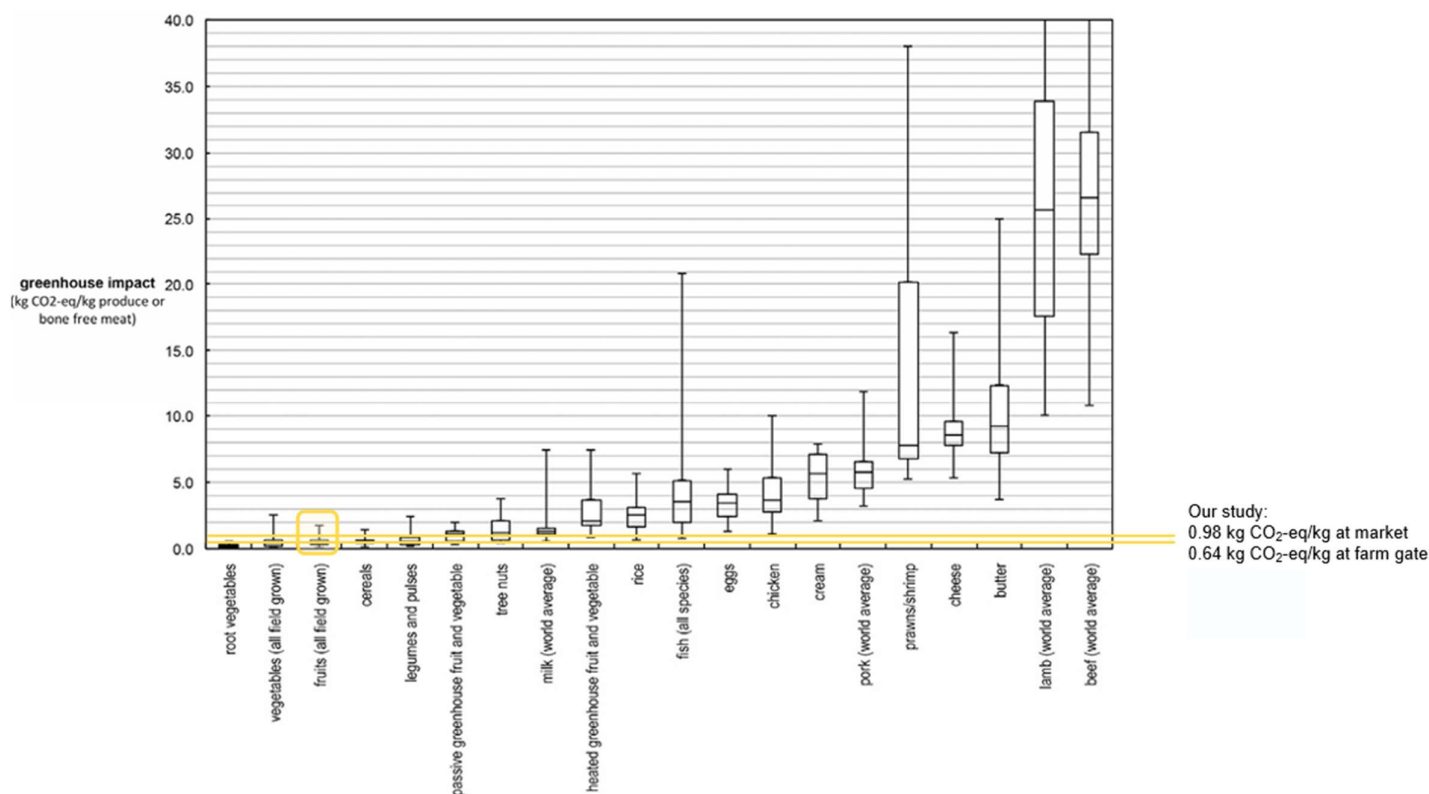


Figure 11 Comparison of GHG emissions intensities of plant-based foods [23].

### 4.2.2 Avocados compared to other fruits

Compared to other fruits, Australian avocados at farm gate (0.64 kg CO<sub>2</sub> eq / kg) are mid-range [24] (Figure 12). Citrus fruits (lemons, oranges, mandarins) cluster at the lower end around 0.2-0.4 kg CO<sub>2</sub> eq / kg, reflecting their relatively extensive production systems and lower input intensity. Pome fruits like apples and pears show similar low footprints, typically between 0.2-0.5 kg CO<sub>2</sub> eq / kg.

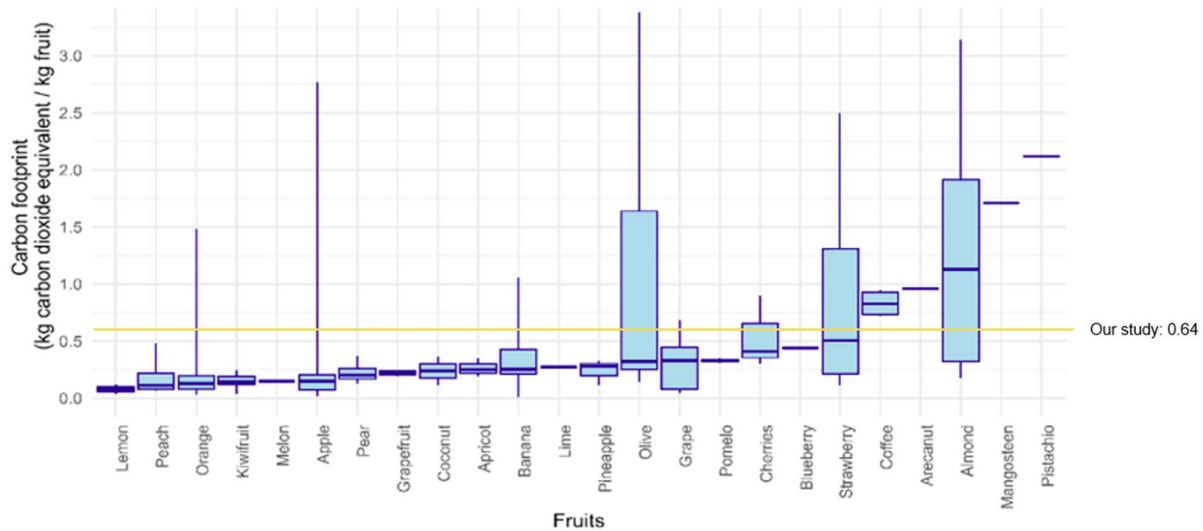


Figure 12 Comparison of GHG emissions intensities of fruits at the farm gate [24].

#### 4.2.3 Australian avocados compared to other global producing regions

Australian avocado at farm gate (0.64 kg CO<sub>2</sub> eq / kg) are mid-range of results published from international studies using comparable system boundaries. Several production regions demonstrate lower farm-gate footprints: Colombian systems report 0.2-0.6 kg CO<sub>2</sub> eq / kg [25][26], New Zealand shows 0.43 kg CO<sub>2</sub> eq / kg [27], Peru reports 0.5 kg CO<sub>2</sub> eq / kg [28], California demonstrates 0.45 kg CO<sub>2</sub> eq / kg [29], and Mexican organic and conventional systems range from 0.41-0.54 kg CO<sub>2</sub> eq / kg [30]. These lower values likely reflect specific regional advantages, including favourable climatic conditions reducing irrigation energy requirements, lower grid electricity carbon intensity or reduced input intensity.

For at-market results, where post-harvest handling, packaging, storage, and distribution are included, Australian avocados at market (0.98 kg CO<sub>2</sub> eq / kg) demonstrate competitive performance, particularly for domestic supply chains. Transportation distances and supply chain complexity influence the carbon footprints, particularly for globally traded fruit.

Exported Peruvian avocados at port (1.09 kg CO<sub>2</sub> eq / kg) [31], and studies of avocados from multiple countries studies supplying avocados to overseas markets report 1.3 kg CO<sub>2</sub> eq / kg for Chilean, Israeli, Peruvian, Spanish, and South African fruit delivered to market [32] and 2.4 kg CO<sub>2</sub> eq / kg when delivered to UK consumers [16].

Australian avocados at domestic market have a lower footprint than these international supply chains, demonstrating that domestic production for domestic consumption provides clear advantages globally traded fruit.

It is important to note that direct comparisons across studies must be made cautiously due to methodological variations, including differences in system boundaries (cradle-to-farm gate versus cradle-to-market versus cradle-to-consumer), temporal scope of data collection, allocation methods for multi-product systems, and specific impact assessment methodologies employed. Despite these caveats, the general positioning suggests Australian avocado growers are competitive from a carbon perspective, and with continued adoption of interventions such as solar energy, yield optimisation, and precision fertiliser management, have clear opportunities to maintain or strengthen their position as relatively low-carbon producers in the increasingly environmentally conscious global fresh produce market.

Table 12: LCA literature of avocado and their estimation of GHG emissions for 1kg of product.[33, 34] [35].

Citation	Type of resource	Area of Avocado Production	System boundaries	GHG emissions kg CO2 eq / kg
Majundar (2024)	Journal Paper	New Zealand	Orchard stage	0.43
Astier et al. (2014)	Journal Paper	Central Mexico	Orchard stage	0.41 (organic) 0.54 (conventional)
Bartl et al. (2012)	Journal Paper	Peru	Orchard stage	0.5
Bell et al. (2018)	Journal Paper	California	Orchard stage	0.45
Graefe et al. (2013)	Journal Paper	Colombia	Orchard stage	0.2
Solarte-Toro et al. (2022)	Journal Paper	Colombia	Orchard stage	0.6
Frankowska et al. (2019)	Journal Paper	Peru, Chile, Israel, South Africa, Spain	Orchard to market	2.4
D'abbadie & Akbari (2023)	Report	Australia	Orchard to the domestic market	0.32
Bendotti Avocado (2021)	Public Disclosure Statement	Australia	Orchard to domestic/international markets	0.62
Carbon Neutral Avocados (2021)	Public Disclosure Statement	Australia	Orchard to domestic/international markets	1.23
Stoessel et al. (2012)	Journal Paper	Chile, Israel, Peru, Spain, South Africa	Orchard to market	1.3
Esteve-Llorens et al. (2022)	Journal Paper	Peru	Orchard to port of export	1.09

#### 4.2.1 Comparison with other assessment tools

Some horticulture businesses have adopted the Greenhouse Accounting Framework for Horticulture (H-GAF tool) [36] as recommended by the Australian Fresh Product Alliance [37]. The H-GAF tool is also underpinned by LCA methodology, but accounts for narrower scope of emissions than those accounted for in this LCA study (see Appendix A). Therefore, results generated from the H-GAF tool are expected to be different to those generated by this study.

## 4.3 Water footprint and scarcity comparisons

The estimated water footprint estimated for Australian avocados (0.99 m<sup>3</sup>/kg) is moderate water consumption compared to multiple comparative studies that have consistently identified avocados as having high water use impacts relative to other food products [16, 29, 32]. Water use must be interpreted considering the regional water stress, which is the value of the water scarcity indicator also quantified in this study.

The water scarcity indicator estimated for Australian avocados in this study (38.55 m<sup>3</sup> world water-eq / kg) is substantially higher than reported water scarcity reported for New Zealand's avocado, of up to 0.75 m<sup>3</sup> world water-eq / kg [27]. The higher Australian value reflects the recognised water scarcity challenges in Australia, where the same volumetric water use has dramatically greater environmental consequences due to competition for limited water resources.

---

# 5 Conclusions

This study represents the first comprehensive environmental impact analysis for Australian avocados. The study generated carbon and water indicators for avocados at farm-gate and at market from all major Australian growing regions, based on data representing 14% of national production. It established useful baseline metrics for industry sustainability planning.

Australian avocados were found to have a greenhouse gas emissions intensity (carbon footprint) of 0.64 kg CO<sub>2</sub> eq per kilogram at the farm gate, increasing to 0.98 kg CO<sub>2</sub> eq per kilogram at market, which includes post-farm activities. On-farm activities contributing 65% and post-harvest operations 35% to total emissions. Total consumptive water use (water footprint) was estimated to be 0.99 m<sup>3</sup> per kilogram, while the water scarcity impact indicator can be as high as 38.55 m<sup>3</sup> world water-eq per kilogram, reflecting the water-stressed conditions for key Australian production.

Regional analysis demonstrates some geographical variations in environmental impacts. Western Australia exhibits the highest electricity-related emissions due to grid carbon intensity and deep-bore water extraction requirements, while Central Queensland achieves the lowest overall carbon footprint at 0.60 kg CO<sub>2</sub> eq/kg, benefiting from favourable growing conditions. Water scarcity impacts vary significantly, with the Tristate region recording 109.68 m<sup>3</sup> world water-eq / kg—nearly three times the national average—while New South Wales demonstrates exceptional water efficiency at just 1.15 m<sup>3</sup> world water-eq / kg.

The contribution analysis identifies energy use as the dominant emission source, with diesel and electricity collectively accounting for 57% of on-farm emissions. Fertiliser-related impacts, encompassing both production and field emissions, represent 31% of the carbon footprint. In the post-farm phase, transport emerges as the largest contributor at 43% of downstream emissions, followed by packaging materials at 29% and cold storage electricity at 23%.

An analysis of potential initiatives for emissions reduction identified several practical pathways. Transitioning on-farm electricity to 30% solar generation could reduce greenhouse gas emissions by approximately 12%—the single most impactful intervention available to growers. Yield improvements of 10% could decrease footprints by 9%, while 10% fertiliser reduction and diesel optimisation could achieve 3% and 2% reductions respectively. Notably, the analysis demonstrates that packaging reduction strategies must carefully balance material minimisation with product protection, as inadequate packaging leading to even modest increases in product waste can negate packaging-related emission savings.

International comparisons position Australian avocado production competitively within the global context. The farm gate footprint falls within the range of international studies, comparable to production systems in Peru, California, and Mexico, though higher than New Zealand's 0.43 kg CO<sub>2</sub> eq/kg. The cradle-to-market result demonstrates clear advantages over long-distance imported fruit, with studies reporting 1.3 kg CO<sub>2</sub> eq / kg for Chilean, Israeli, Peruvian, Spanish, and South African exports and 2.4 kg CO<sub>2</sub> eq / kg for fruit delivered to UK consumers. This positioning highlights the environmental value of domestic production for domestic consumption while maintaining competitive performance against regional supply chains.

From a broader food system perspective, avocados demonstrate favourable environmental performance relative to animal-based proteins, aligning with the generally low carbon footprint characteristic of fresh produce. However, water scarcity results underscore the importance of regional context in environmental assessment. The substantial water scarcity impacts observed in Australian

production reflect genuine water stress challenges that distinguish this crop from production in less water-constrained regions such as New Zealand.

This research establishes essential baseline data for the Australian avocado industry's sustainability initiatives by identifying clear priorities for environmental improvement. The metrics generated enable the sector to respond to increasing market demands for environmental credentials, inform strategic investments in renewable energy and agronomic optimisation, and guide policy development supporting more sustainable production practices. The comprehensive nature of this assessment provides a foundation for ongoing monitoring of industry environmental performance and evaluation of improvement initiatives as they are implemented across the sector.

The analysis reveals that meaningful carbon footprint reduction should prioritise on-farm interventions, particularly renewable energy adoption and agronomic improvements that enhance productivity. Solar electricity transition offers the greatest single-point reduction opportunity, while yield improvements provide significant benefits through enhanced system efficiency. The packaging analysis demonstrates that carbon reduction strategies must be holistic and evidence-based, as interventions that appear beneficial may have unintended consequences when product protection is compromised. For the avocado industry, the pathway to substantial emissions reduction lies predominantly in production-phase optimisation and renewable energy transition.

---

# References

1. Eady, S., et al., *AusAgLCI - A Life Cycle Inventory database for Australian agriculture. Project Report*. 2014, Australian Government Rural Industries Research and Development Corporation: Canberra.
2. Renouf, M.A., et al., *Equipping Australian agriculture with LCA-based sustainability metrics. Final Report for LCAgMetrics Project (PRO-017538)*. 2025, Prepared by Lifecycles for Agrifutures.
3. Avocados Australia, *Avocados Australia Strategic Plan. 2022-2026 Industry Priorities*. 2022, Avocados Australia.
4. Innovation, H., *Avocado Strategic Investment Plan 2022-2026*. 2021, Hort Innovation.
5. Connelly, D., *Australian avocados.. green by nature? An environmental stocktake of the Australian avocado industry. HAL project AV08001*. 2009, Prepared for Horticulture Australia.
6. Hort Innovation, *Australian-Grown Horticulture Sustainability Framework 2023/24*. 2023, Hort Innovation Australia Limited.
7. AFPA, *Environmental Sustainability Brief*. 2023, Australian Fresh Produce Alliance.
8. Hort Innovation, *Australian Horticulture Statistics Handbook 2023/24 All Fruit - Overview*. 2024.
9. Bontinck, P.-A., et al., *Recalculating Australian water scarcity characterisation factors using the AWARE method*. *The International Journal of Life Cycle Assessment*, 2021. **26**(8): p. 1687-1701.
10. Newett, S.B.C.E.F., *Australian Avocado Irrigation Review 2020 - 2021*, Hort Innovation, Editor. 2021: Australia.
11. Commonwealth of Australia, *National Inventory Report 2022 Volume 1*. 2024: Canberra.
12. Queensland Government, *SIL0 - Australian climate data from 1889 to yesterday*. 2024.
13. Commonwealth of Australia, *National Inventory Report 2023 Volume 2*. 2025, Department of Climate Change, the Environment and Water: Canberra.
14. Commonwealth of Australia, *National Inventory Report 2023 Volume 1*. 2025, Department of Climate Change, the Environment and Water: Canberra.
15. Malerba, M.E., N. Wright, and P.I. Macreadie *A Continental-Scale Assessment of Density, Size, Distribution and Historical Trends of Farm Dams Using Deep Learning Convolutional Neural Networks*. *Remote Sensing*, 2021. **13**, DOI: 10.3390/rs13020319.
16. Frankowska, A., H.K. Jeswani, and A. Azapagic, *Life cycle environmental impacts of fruits consumption in the UK*. *Journal of Environmental Management*, 2019. **248**: p. 109111.
17. Australian-boxes, a.c. *The benefits of recycling old wooden pallets*. 2024; Available from: <https://www.abccrates.com.au/why-should-we-recycle-wooden-pallets/#:~:text=If%20maintained%20properly%20and%20carefully,be%20disposed%20of%20%E2%80%93%20ideally%20recycled>.
18. Dewerson, P.B.M.M.G., *Cold Hard Facts 2022*. 2022, Department of Climate Change, Energy, the Environment and Water, Australian Government.
19. Pedreschi, R., et al., *Impact of postharvest ripening strategies on 'Hass' avocado fatty acid profiles*. *South African Journal of Botany*, 2016. **103**: p. 32-35.
20. Hort Innovation, *Australian Horticulture Statistics Handbook 2023/24 All Fruit*. 2024.
21. DCCEEW, *Australian National Greenhouse Accounts Factors*. 2024, Department of Climate Change, Energy, the Environment and Water.

22. Government, N., *Energy efficiency and farm vehicles*, D.o.p. Industries, Editor. 2021.
23. Clune, S., E. Crossin, and K. Verghese, *Systematic review of greenhouse gas emissions for different fresh food categories*. *Journal of Cleaner Production*, 2017. **140**: p. 766-783.
24. Subedi, S., B. Dent, and R. Adhikari, *The carbon footprint of fruits: A systematic review from a life cycle perspective*. *Sustainable Production and Consumption*, 2024. **52**: p. 12-28.
25. Graefe, S., J. Tapasco, and A. Gonzalez, *Resource use and GHGe missions of eight tropical fruit species cultivated in Colombia*. *EDP Science*, 2012. **68**(4): p. 303-314.
26. Solarte-Toro, J.C., M. Ortiz-Sanchez, and C.A. Cardona Alzate, *Environmental life cycle assessment (E-LCA) and social impact assessment (SIA) of small-scale biorefineries implemented in rural zones: the avocado (Persea Americana var. Americana) case in Colombia*. *Environmental Science and Pollution Research*, 2023. **30**(4): p. 8790-8808.
27. Majumdar, S. and S.J. McLaren, *Towards use of life cycle–based indicators to support continuous improvement in the environmental performance of avocado orchards in New Zealand*. *The International Journal of Life Cycle Assessment*, 2024. **29**(2): p. 192-217.
28. Bartl, K., F. Verones, and S. Hellweg, *Life Cycle Assessment Based Evaluation of Regional Impacts from Agricultural Production at the Peruvian Coast*. *Environmental Science & Technology*, 2012. **46**(18): p. 9872-9880.
29. Bell, E.M., J.R. Stokes-Draut, and A. Horvath, *Environmental evaluation of high-value agricultural produce with diverse water sources: case study from Southern California*. *Environmental Research Letters*, 2018. **13**(2): p. 025007.
30. Astier, M., et al., *Energy balance and greenhouse gas emissions in organic and conventional avocado orchards in Mexico*. *Ecological Indicators*, 2014. **43**: p. 281-287.
31. Esteve-Llorens, X., et al., *Environmental footprint of critical agro-export products in the Peruvian hyper-arid coast: A case study for green asparagus and avocado*. *Science of The Total Environment*, 2022. **818**: p. 151686.
32. Stoessel, F., et al., *Life Cycle Inventory and Carbon and Water FoodPrint of Fruits and Vegetables: Application to a Swiss Retailer*. *Environmental Science & Technology*, 2012. **46**(6): p. 3253-3262.
33. Avocado, B., *Product certification FY 2021–2022 projected*. 2021, Public Disclosure Statement.
34. d’Abbadie, C. and S. Akbari, *WA Avocado Life Cycle Analysis (LCA)*. 2023, Department of Primary Industries and Regional Development and the State of Western Australia.
35. Avocados, C.N., *Carbon neutral avocados product certification 2021–2022 projected*. 2021.
36. Eckard, R.J., *Horticulture Greenhouse Accounting Framework. Project No UM10778 - Update*. 2012.
37. AFPA, *Common Greenhouse Gas Accounting Framework for the Australian Fresh Produce Industry*. 2023, Prepared by Sustenance Asia for AFPA.
38. ALCAS, *Australian Life Cycle Inventory Database (AusLCI) Version 2.43*, A.L.C.A. Society, Editor. 2024: Melbourne.
39. Weidema, B.P., et al., *Overview and methodology. Data quality guideline for the ecoinvent database version 3. Ecoinvent Report 1(v3.10)*. 2023, The ecoinvent Centre: St. Gallen.
40. WRI and WBCSD, *Product Life Cycle Accounting and Reporting Standard*. 2011, World Resources Institute and World Business Council for Sustainable Development.

# Appendix A – HGAF tool comparison

## Comparison of this project method with HGAF tool recommended by the AFPA GHG Framework

✓ = consistent; ✓+ = consistent plus extras; - not consistent but complementary; ✗ = not consistent

	This report	AFPA GHG Framework	Consistency of RB22001 relative to HGAF tool
Representation	- Averages for avocado from an industry sample	- Individual businesses - Aggregated across AFPA member organisations	-
Functional unit reported	GHG emissions intensity - kg CO <sub>2</sub> eq / kg product	GHG emissions intensity - kg CO <sub>2</sub> eq / kg product GHG emissions account - t CO <sub>2</sub> eq / year	✓
System boundary	Cradle to market	Cradle to first point of sale (delivered to wholesaler)	✓+
Operational boundary	Scopes 1,2,3	HGAF tool Scopes 1,2,3 AFPA reporting Scope 1,2 (Scope 3 later)	✓
Environmental aspects assessed	GHG emissions Water / water scarcity	GHG emissions	✓+
GHG coverage	Comprehensive account of GHG emission sources, including all Scope 3 emissions	Scope 1 and 2 emissions captured by National Inventory Report (NIR) and some Scope 3 emissions	✓+
Scope 1,2 emissions	Estimated using: - NIR algorithms, assumptions - NIR emission factors (EF)	Estimated using: - NIR algorithms, assumptions - NIR emission factors (EF)	✓
Scope 3 emissions	Estimated using best available life cycle inventory (LCI) data from ecoinvent and AusLCI	Estimated using various published papers (potentially outdated)	✗
Reporting standard	ISO14044 ISO14067	GHG Protocol	✗

# Appendix B - Background processes

While hundreds of background processes contribute to the analysis, the most important processes are described here, particularly those affecting the results or those that have been modified from the original source to better represent the inputs to this assessment.

Australian energy use, waste treatment processes and truck data are all based on the AusLCI database [38]. All global background data is taken from the ecoinvent 3.10 allocation recycling cut-off model [39].

Table 13 Inventory of key processes used in this Australian Avocados LCA

Process/Flow	Database	Comment
<b>Pesticides, herbicides and insecticides</b>		
Insecticides, at regional storehouse/RER U/AusSD U	AusLCI V2	
Herbicides, at regional storehouse/RER U/AusSD U	AusLCI V2	
Fungicides, at regional storehouse/RER U/AusSD U	AusLCI V2	
Glyphosate, at regional storehouse/RER U/AusSD U	AusLCI V2	
Paclobutrazol  market for paclobutrazol   Cut-off, U	Ecoinvent 3.10	
Potassium hydroxide, at regional storage/kg/RER	AusLCI V2	
<b>Fertilisers</b>		
Potassium nitrate, [AU]  market for potassium nitrate   AusLCI, U	AusLCI V2	
Calcium nitrate, [AU]  market for calcium nitrate   AusLCI, U	AusLCI V2	
Magnesium sulfate [GLO]  market for magnesium sulfate   Cut-off, U	AusLCI V2	
Potassium nitrate, [AU]  market for potassium nitrate   AusLCI, U	AusLCI V2	Proxy for MKP
Monoammonium phosphate, [AU]  market for monoammonium phosphate   AusLCI, U	AusLCI V2	
Potassium sulfate, [AU]  market for potassium sulfate   AusLCI, U	AusLCI V2	
Ammonium nitrate, [AU]  market for ammonium nitrate   AusLCI, U	AusLCI V2	
Nitric acid, without water, in 50% solution state [RoW]  market for nitric acid, without water, in 50% solution state   Cut-off, U	Ecoinvent 3.10	

Process/Flow	Database	Comment
Phosphoric acid, fertiliser grade, without water, in 70% solution state [RoW] market for phosphoric acid, fertiliser grade, without water, in 70% solution state   Cut-off, U	Ecoinvent 3.10	
Ammonium sulfate, at regional storehouse/RER U/adapted/AU S	AusLCI V2	
Iron sulfate [GLO] market for   Cut-off, U	Ecoinvent 3.10	Proxy for iron chelate
NPK (15-15-15) fertiliser [RoW] market for NPK (15-15-15) fertiliser   Cut-off, U	Ecoinvent 3.10	
Packaging, for fertilisers [GLO] market for packaging, for fertilisers   Cut-off, U	Ecoinvent 3.10	Fertiliser packaging
Boric oxide, at plant/GLO U/AusSD U	AusLCI V2	
Gypsum, mineral, at mine/CH U/AusSD U	AusLCI V2	
Zinc sulphide, ZnS, at plant/RER U/AusSD U	AusLCI V2	
Copper sulfate  market for copper sulfate   Cut-off, U	Ecoinvent 3.10	
Urea [RoW] market for urea   Cut-off, U	Ecoinvent 3.10	
Lime, from carbonation, at regional storehouse/CH U/AusSD U	AusLCI V2	
<b>Nitrogen emissions to air/water</b>		
nitrous oxide emissions – dinitrogen monoxide emissions to air	Elementary flow	Direct N2O emissions from applied inorganic fertiliser N - NGGI 2022 Indirect N2O emissions from redeposited NH3-N and NOx-N from the volatilisation of applied fertiliser N - NGGI 2022 Indirect N2O emissions from N lost through runoff and leaching - NGGI 2022
ammonia emissions – ammonia, AU emissions to air	Elementary flow	Ammonia (NH3) emissions from volatilisation of applied fertiliser N - NGGI 2022
Nitrate compounds - emissions to water	Elementary flow	Nitrate emissions to water
<b>Packaging</b>		
Packaging, for pesticides  market for packaging, for pesticides   Cut-off, U	Ecoinvent 3.10	Packaging for Pesticides
Packaging, for fertilisers or pesticides  packaging production for solid fertiliser or pesticide, per kilogram of packed product   Cut-off, U	Ecoinvent 3.10	Packaging for fertilisers
Corrugated board box [GLO] market for corrugated board box   Cut-off, U	Ecoinvent 3.10	Packaging, for Avocados, cardboard tray
Core board [GLO] market for core board   Cut-off	Ecoinvent 3.10	Pallet cardboard corners
Polyethylene linear low density granulate [GLO] market for polyethylene, linear low density, granulate \ Cut-off, U	Ecoinvent 3.10	Pallet protection
Extrusion plastic film  market for extrusion plastic film   Cut-off	Ecoinvent 3.10	Pallet protection

Process/Flow	Database	Comment
EUR-flat pallet  market for EUR-flat pallet   Cut-off	Ecoinvent 3.10	Pallet
<b>Water use</b>		
water pump, irrigation, 25kg [AU]]   AusLCI, U	AusLCI V2	
Drip irrigation system, production, per ha/AU U	AusLCI V2	
water, river, at farm, by Australian catchment	Elementary flow	Irrigation – river water, regionalised by Australian catchment of use
water, unspecified natural origin, at farm, by Australian catchment	Elementary flow	Irrigation – dam and well water, regionalised by Australian catchment of use
<b>Transport</b>		
transport, truck, 60t load [AU]]   AusLCI, U	AusLCI V2	Transport of avocados to Sydney by truck
Operation, reefer, cooling [GLO]] market for operation, reefer, cooling   Cut-off, U	Ecoinvent 3.10	Refrigerated transport of avocados
transport, freight, rail [AU]]   AusLCI, U	AusLCI V2	Transport of avocados to Sydney by train
transport, truck, 16 to 28t, fleet average [AU]]   AusLCI, U	AusLCI V2	Transport of packaging materials
transport, truck, 40t, fleet average [AU]]   AusLCI, U	AusLCI V2	Fertiliser transport
transport, truck, 28t, fleet average [AU]]   AusLCI, U	AusLCI V2	Fertiliser and agrochemical transport
Transport, freight, sea, container ship  market for transport, freight, sea, container ship   Cut-off, U	Ecoinvent 3.10	Fertiliser and agrochemical transport
Transport, freight, lorry 16-32 metric ton, EURO4  market for transport, freight, lorry 16-32 metric ton, EURO4   Cut-off, U	Ecoinvent 3.10	Fertiliser and agrochemical transport
Tractor operation, per litre diesel consumed	AusLCI V2	
<b>Fuel/electricity use</b>		
Photovoltaic slanted-roof installation, 3kWp, multi-Si, panel, mounted, on roof [RoW]] photovoltaic slanted-roof installation, 3kWp, multi-Si, panel, mounted, on roof   Cut-off, S	Ecoinvent 3.10	Solar panel Assumed 30 year lifetime, to match Ecoinvent
Electricity, low voltage [AU]] electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel, mounted   Cut-off, U	Ecoinvent 3.10	Solar energy
electricity, low voltage [AU]] market for electricity, low voltage   AusLCI, U	AusLCI V2	Electricity use – regionalised by state
Gasoline, combusted in equipment/US U	USLCI	
Tractor engine operation, on farm, per litre of diesel consumed/AU U	AusLCI V2	
<b>Other</b>		
Ethylene   market for ethylene   Cut-off	Ecoinvent 3.10	Ethylene for ripening
Heat pump, brine-water, 10kW [GLO]] market for heat pump, brine-water, 10kW   Cut-off, U	AusLCI V2	Cool rooms pumps

Process/Flow	Database	Comment
Tetrafluoroethane, R134a [GLO]  market for tetrafluoroethane, R134a   Cut-off, U	AusLCI V2	Refrigerant gasses for coolrooms

---

# Appendix C – Recycling credits

In this LCA the main allocation issue relates to the allocation of the recycling credit between the product system which generates the tray and the product system which utilises the recycled material as secondary material input.

The GHG protocol for product carbon footprints [40] suggest two options for dealing with recycling credits. The first (for strong recycling markets) is the 0/100 method which provides 100% of the credit to the recycling at the end of a product life. The second is the 100/0 method where 100% of the benefit of recycling is applied to the secondary product - this is for weak recycling markets where new products made from recycled content need to be specified (i.e. there is a larger supply of recycled material than demand for products made of the recycled material).

The 100/0 method has been applied in this LCA for relevant materials (cardboard boxes). This means that the use of cardboard boxes, made from recycled content, receives the full benefit from the recycling (i.e. benefits from displacing virgin paper pulp). As the full benefit from recycling has been applied, recycling this cardboard box at its end-of-life does not provide any further benefit.