Strengthening the sustainability of Rubus berry production

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Public summary

Escalating climate change impacts and environmental degradation have positioned environmental stewardship as a critical priority for Australian agricultural sectors. The agricultural industry faces increasing regulatory requirements and market incentives to demonstrate measurable reductions in environmental footprints, particularly greenhouse gas emissions. To address this imperative within the berry sector, this project conducted a comprehensive life cycle assessment (LCA) of Australian raspberry and blackberry production systems, generating evidence-based insights for targeted environmental performance improvements.

The research directly advances Outcome 2 of the Berry Industry Strategy, specifically supporting the objective to "develop a long-term sustainability program that includes a set of values, practices and communication activities that support a well-respected and sustainable berry industry." Project deliverables encompass technical and summary reports documenting LCA findings for Australian Rubus production, analysis of greenhouse gas mitigation pathways, a standardized data collection protocol for growers, and comprehensive industry communication initiatives.

Life cycle assessment is an internationally accepted methodology for quantifying environmental impacts across complete product life cycles, from raw material extraction through end-of-life disposal. This assessment incorporated primary data from 13 production sites representing 36% of national Australian production, which was processed through SimaPro LCA software to generate comprehensive environmental impact profiles.

The analysis determined carbon intensities of 2.2 kg CO2eq kg^{-1} for packaged raspberries and 1.6 kg CO2eq kg^{-1} for blackberries at farm gate. While both crops utilize comparable production inputs, differential fruit yields represent the primary driver of carbon intensity variation between them. Four emission hotspots dominate the carbon footprint: on-farm energy consumption, packaging systems (encompassing plastic punnets and cardboard secondary packaging), protected cropping infrastructure (trellis and tunnel systems), and fertilizer manufacturing and application.

Water impact assessment revealed water scarcity footprints of 4.0 m^3 H2O-equivalent deprived kg^{-1} for raspberries and 0.8 m^3 H2O-equivalent deprived kg^{-1} for blackberries. Direct water consumption totaled 0.4 m^3 kg^{-1} for raspberries and 0.2 m^3 kg^{-1} for blackberries. Irrigation systems emerged as the predominant contributor to both total water consumption and regional water scarcity impacts.

The assessment identified significant barriers to farm-level environmental data collection, which constrain grower capacity to perform LCA. In response, the project developed a comprehensive data collection guide that explains LCA methodology and provides guidance for agricultural data gathering. Extensive industry engagement activities facilitated knowledge transfer and stakeholder participation, including two feature articles in "Berries Australia" magazine, a technical presentation at Berry Quest 2025, and two dedicated industry workshops. Continuous collaboration with the project reference group ensured stakeholder feedback integration throughout the research development process.

Keywords

Raspberries, blueberries, life cycle assessment, carbon footprint, water footprint, sustainability.

Introduction

Environmental sustainability is transitioning from an aspirational goal to an operational requirement across Australian agricultural sectors. Contemporary agricultural enterprises must navigate evolving regulatory frameworks and sustainability policies while demonstrating measurable environmental stewardship through systematic monitoring and improvement programs.

Greenhouse gas emission reduction represents a particularly critical focus area, with both regulatory mandates and market incentives driving agricultural transition toward lower-emission production systems. Government and industry commitments to net-zero carbon targets have established clear trajectories for sectoral emission reductions, necessitating robust measurement methodologies to track progress and verify improvements. Life cycle assessment provides an internationally recognized scientific framework for comprehensive environmental performance evaluation, forming the methodological foundation for credible carbon footprinting initiatives.

This project delivers a foundational LCA study for Australian raspberry and blackberry production, establishing the scientific baseline required for evidence-based environmental initiatives and performance monitoring within the berry sector. Beyond generating reliable carbon and water footprint metrics for Australian Rubus production, the assessment identifies emission hotspots and provides strategic insights for targeted environmental improvements, enabling the industry to prioritize the most impactful intervention strategies for greenhouse gas reduction.

The research process revealed significant operational challenges in farm-level data collection, which currently constrains grower capacity for independent environmental assessment. To address this barrier, the project developed comprehensive data collection guidance that demystifies LCA methodology while providing practical protocols for systematic agricultural data acquisition. This resource enables individual producers to implement their own environmental assessments and contribute to sector-wide sustainability monitoring.

Extensive stakeholder engagement facilitated knowledge transfer through multiple communication channels, including two dedicated grower workshops that presented research findings and fostered industry dialogue on implementation strategies. These engagement activities ensure research outcomes translate into practical applications across the production community.

The project directly advances Outcome 2 of the Berry Industry Strategy, which mandates development of "a long-term sustainability program that includes a set of values, practices and communication activities that support a well-respected and sustainable berry industry." This research provides the scientific foundation and practical tools necessary for comprehensive industry sustainability program implementation, positioning the Australian berry sector to meet evolving environmental requirements while maintaining competitive market positioning.

Methodology

LCA methodology

LCA is a methodology for assessing the full 'cradle-to-grave' environmental benefits of products and processes by assessing environmental flows (i.e. impacts) at each stage of the life cycle. LCA aims to include all important environmental impacts for the product system being studied. In doing so, LCA seeks to avoid shifting impacts from one life cycle stage to another or from one environmental impact to another. *Appendix A: Life cycle assessment of Australian raspberries and blackberries* provides full methodology details.

The LCA was conducted according to the International Standards for Life Cycle Assessment and Carbon Footprints [1], which accounts for all impacts in the product life cycle (including all scope 1, scope 2 and scope 3 emissions). The analysis was performed for GHG, water scarcity and total water use.

System Boundaries: The production system considered was at the farm gate, this includes all inputs required for the production of Rubus up to the farm gate (Figure 1).

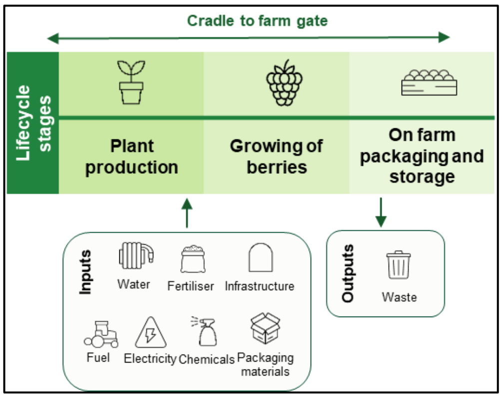

Figure 1: System boundary of the study

Data: Farm data was collected during 2024 and early 2025, from 13 farms, representing a total of 36% of Australian production. The sample included 8 production sites for raspberries and 5 for blackberries. In total, 9 sites were located in QLD/NSW and 4 in VIC/Tas. Background data was sourced primarily from AUSLCA v2, with some ecoinvent processes.

Software: A parametrised LCA model was built using the Simapro LCA software. Variations in production types/regions were captured in the model through the parametrisation of productive inputs, and their subsequent differentiated results.

Impact assessment categories and characterisation models: Climate change and water scarcity were the impact categories analysed, Table 1 provides details. Results are also presented for Total water use, though this is not an environmental indicator, rather, it describes the physical quantity of water as an input. This was included following Project Reference Group (PRG) suggestions.

Table 1 Impact assessment categories and characterisation models

Indicator	Description	Characterisation model
Climate change	Radiative forcing as Global Warming Potential (GWP100) Expressed in kg CO_2 eq. This is governed by the increased concentrations of gases in the atmosphere that trap heat and lead to higher global temperatures. Gases are principally carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).	(IPCC 2021) IPCC model based on 100-year timeframe
Water scarcity	User deprivation potential. Expressed in m^3 H_2O deprived. Represents the relative Available WAter REmaining (AWARE) per area in a watershed, after the demand of humans and aquatic ecosystems has been met. The calculations are based on deprivation-weighted water consumption numbers.	(AWARE) Available WAter REmaining as recommended by UNEP, 2016 with added Australian catchments

Project Management

Following the inception meeting conducted with Hort Innovation (on 25/01/2024), a project reference group (PRG) was established as the main sounding board for the project development. The PRG was composed of 5 members, representing Hort Innovation, the berry industry association and 3 producers. The PRG met virtually 5 times during the project and offered guidance mainly on project scope, growers' involvement and results interpretation, all of which was incorporated into the project. Details of the PRG meetings can be found in *Appendix D - confidential: PRG meetings presentations and minutes*.

Results and discussion

LCA Results

Carbon footprint analysis established emission intensities of 2.2 kg CO2eq kg^{-1} for Australian raspberries and 1.7 kg CO2eq kg^{-1} for blackberries at farm gate. Despite comparable production systems and input requirements, blackberries demonstrate a 23% lower carbon intensity attributed to superior fruit yields per unit area. These findings align with published values for international Rubus production [2-4], and exhibit consistency with emission intensities reported for protected cropping and greenhouse horticultural systems [5].

Water scarcity impact assessment yielded 4.0 m^3 H2O-equivalent deprived kg^{-1} for raspberries and 0.8 m^3 H2O-equivalent deprived kg^{-1} for blackberries, with corresponding direct water consumption of 0.4 m^3 kg^{-1} and 0.2 m^3 kg^{-1} respectively. Irrigation systems constitute the predominant driver of both absolute water consumption and regional scarcity impacts. Water scarcity footprints demonstrate strong regional dependence on local hydrological conditions, with Australian production areas experiencing elevated water stress exhibiting proportionally higher scarcity impact values.

Four primary emission sources dominate the carbon footprint profile for both raspberry and blackberry production (Figure 2): crop protection infrastructure materials including tunnels and trellis systems, packaging components comprising plastic punnets and cardboard containers, on-farm energy consumption through electricity and diesel fuel usage, and fertilizer production and field application processes. Secondary emission sources including pesticide manufacturing, irrigation infrastructure, and refrigerant fugitive emissions contribute minimally to total greenhouse gas emissions and are consolidated within the 'other' category in (Figure 2).

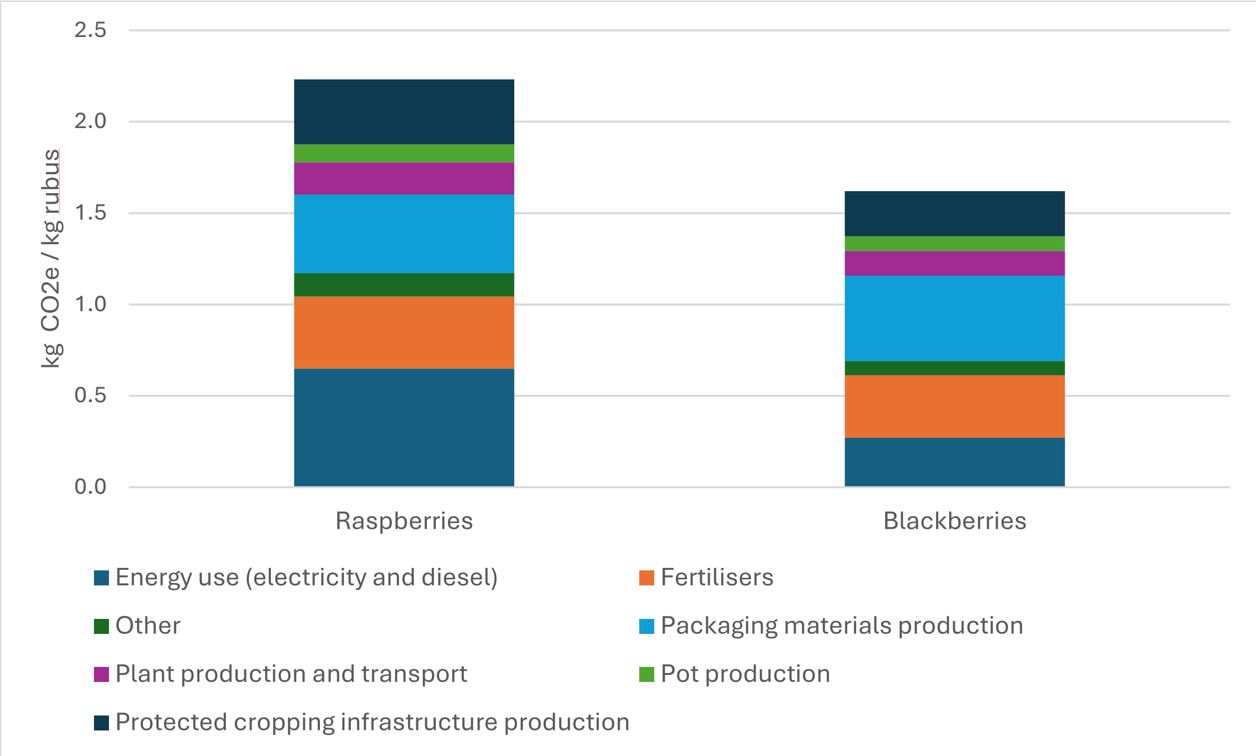

Figure 2: GHG emissions of raspberry and blackberry per kilogram fruit at farm gate

Regional Carbon Footprint Analysis

Raspberry production shows significant geographic variation, with northern regions (Southeast Queensland and Northern New South Wales) averaging 2.5 kg CO2eq kg^{-1} compared to 2.0 kg CO2eq kg^{-1} in southern regions (Victoria and Tasmania). This 20% differential primarily reflects regional yield differences and irrigation energy demands. Sample limitations precluded regional analysis for blackberry production.

Carbon Emission Reduction Strategies

The carbon footprint profile enables strategic identification of emission reduction opportunities. Sensitivity analysis quantified potential greenhouse gas reductions from system modifications relative to baseline scenarios (Figure 3). While focused on raspberry systems, findings apply equally to blackberry operations, providing evidence-based prioritization of mitigation initiatives.

Energy System Optimization: On-farm energy consumption represents the highest-impact intervention opportunity. Existing photovoltaic installations across Rubus operations have demonstrated substantial reductions. Complete transition to solar electricity could achieve a 12% reduction in average emissions—the most effective single mitigation strategy identified. Fleet electrification provides additional benefits, with 50% vehicle conversion to electric alternatives generating approximately 3% carbon footprint reduction.

Productivity Enhancement: Production efficiency improvements directly reduce emission intensity through optimized input utilization. A 10% yield increase achieves a 7% carbon footprint reduction, with the non-linear relationship reflecting packaging requirements independent of production volume.

Packaging System Innovation: Packaging materials require targeted intervention, with primary punnets accounting for 60% of packaging-related emissions and cardboard contributing the remainder. Reducing packaging intensity by 30% per unit generates a 5% carbon footprint reduction through increased fruit density per container, lightweight materials, or lower-emission alternatives. Reusable plastic crates could replace single-use cardboard systems.

Maximizing recycled content in punnets provides immediate benefits, representing an accessible intervention for operations not yet adopting sustainable packaging practices.

Fertilizer Management: Fertilizer emissions originate from energy-intensive manufacturing and direct nitrous oxide field emissions. A 10% reduction in application rates yields approximately 2% carbon footprint reduction, achievable through precision application technologies or improved nutrient retention strategies.

Infrastructure Asset Management: Extending crop protection infrastructure service life by 20% (from 4 to 5 years) reduces total emissions by 3%, emphasizing the importance of durable materials and maintenance programs.

Detailed results are documented in Appendix A: Life cycle assessment of Australian raspberries and blackberries.

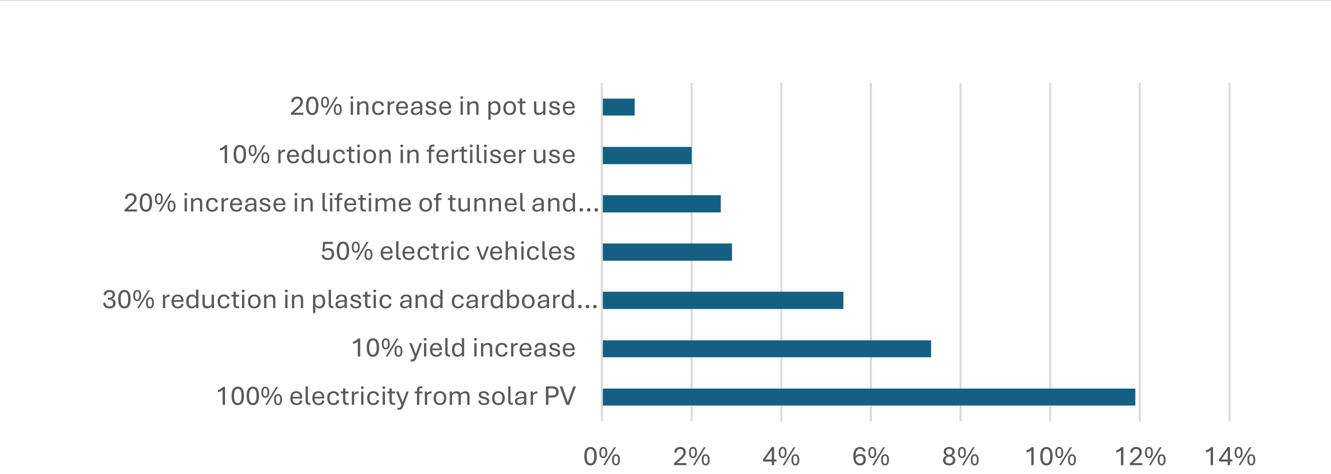

Figure 3. Estimated percentage reduction in GHG emissions, relative to the average, from adoption of practice change scenarios

Outputs

Table 2. Output summary

Output	Description	Detail
Individual growers LCA results (case studies)	Reports for individual farms with their carbon and water footprints and GHG mitigation opportunities.	Reports have been provided to all farms that contributed data. They are presented in *Appendix E Confidential: Individual farm LCA results.* These reports are confidential and has been submitted to the appropriate Hort Innovation R&D manager
Industry-scale LCA results	Rubus Industry LCA report containing average carbon and water footprints and insights for the industry sustainability strategy.	A full technical report has been produced, it has been provided to PRG members, Berries Australia and Hort Innovation. It is available in *Appendix A: Life cycle assessment of Australian raspberries and blackberries.* The report and the plain English summary should be made public, so the general public can benefit from its contents.
Workshop outcomes	Workshops aiming to communicate and discuss environmental insights gained by the project.	Two workshops were held on 19/08/2025 and 21/08/2025. They communicated project results to growers and industry members and provided an instance to discuss possible GHG mitigation strategies for Rubus production. Slide deck, attendance list and satisfaction survey are available in *Appendix C: Rubus industry LCA results communication*
Prototype MS-Excel GHG tool	Calculator for grower self-assessment of carbon footprint	At PRG#2 it was raised the concern of the usefulness of creating a GHG self-assessment tool for growers, given the already existing H-GAF tool being promoted by Aus Fresh Produce Alliance's. Later discussions defined that a "data collection resource" that provides guidance on what data to collect to conduct an LCA will be more useful to growers and the industry. Therefore, the project has delivered the required data collection resource. Available in *Appendix B: Rubus industry LCA data collection resource.* It is recommended that this resource is made public so industry members can

		benefit from it.
Communication pieces	*Activities and publications to communicate the project and its outcomes.*	The project produced 2 articles and 3 presentations: • Australian Berry Journal, Autumn 2024 edition: “Strengthening the sustainability of Rubus production (RB22001)” • Australian Berry Journal, summer 2025 edition: “Opportunities for reducing carbon footprint emissions of Australian Rubus” (submitted not yet published). • BerryQuest 2025 conference presentation • Two results presentations for growers Project held on 19/08/2025 and 21/08/2025. Evidence is presented in *Appendix C: Rubus industry LCA results communication.*

Outcomes

Table 3. Outcome summary

Outcome	**Alignment to fund outcome, strategy and KPI**	**Description**	**Evidence**
Baseline and benchmark LCA results: Knowledge of the industry's environmental performance.	Outcome 2: Strategy 7 - Develop a long-term sustainability program that includes a set of values, practices and communication activities that support a well-respected and sustainable berry industry KPI: Increased level of sustainability of the berry sector	The LCA results provide science-based evidence to evaluate sustainability strategies that are efficient and effective.	A full technical report has been produced: *Appendix A: Life cycle assessment of Australian raspberries and blackberries* *Two results presentation workshops were made:* See *Appendix C: Rubus industry LCA results communication*, which includes a satisfaction survey of the workshops.
Interpretation of LCA results to enable the development of a sustainability strategy	As above	The interpretation of the LCA results, identifying hot-spots, is an initial step for the development of a sustainability strategy, allowing for industry members to have an increased understanding of the potential environmental impacts and develop future strategies for mitigation.	Growers that attended the workshop to show results were engaged and provided positive comments on the usefulness of the results. See *Appendix C: Rubus industry LCA results communication*, which includes a satisfaction survey of the workshops.
Resources for ongoing self-assessment	As Above	A data collection guide was produced, in which growers can find guidance on how to obtain and sort data to perform LCA analysis of their farms.	Data collection guide has been generated. *Appendix B: Rubus industry LCA data collection resource*

Monitoring and evaluation

Table 4. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project achieved its expected outcomes? *Has the project developed a set of LCA-based environmental metrics that meet the needs of growers and industry associations?* *Has the project generated insights about the environmental credentials of the industry that provide a foundation for a sustainability strategy?* *Has the project left the industry with resources that allow them to update and track their carbon footprint moving forward?*	The project has achieved all its expected outcomes: - It has developed LCA-based environmental metrics for the Rubus industry (*Appendix A)* - It has provided insights about the environmental credentials of the industry and an analysis of sustainability opportunities (*Appendix A*) - A data gathering guide for growers was generated, so they can update their carbon footprint estimations through existing online tools (*Appendix B: Rubus industry LCA data collection resource*).	To allow LCA practitioners to easily access the inventory data generated in this project, it could be uploaded as part of the AusLCI data set.
How relevant was the project to the needs of intended beneficiaries? *Were the environmental metrics and interpretations of the LCA results presented in ways that intended beneficiaries (growers, industry associations) could use them for their intended purposes (reporting, stakeholder engagement, and planning a sustainability strategy and promoting environmental improvement priorities).*	The data generated was relevant to the intended beneficiaries: - The PRG provided guidance on the environmental metrics to present as a result of the project. With this, the "total water use" measurement was included. - The two online workshops were successful, and growers' feedback was positive. See *Appendix C: Rubus industry LCA results communication* - The PRG provided positive feedback about the project outputs.	At specific times of the year, growers are time poor; this should be considered to scheduling workshops and data collection efforts accordingly.
3. How well have intended beneficiaries been engaged in the project? *Have intended beneficiaries (growers, industry associations) been informed about project outcomes through the communication plan?* *Have key stakeholders who can influence the quality of the project's outcomes been engaged in the project (growers, industry associations, also horticulturist advisors, other service providers, policy makers, researchers).*	The project executed the communication plan, and the intended beneficiaries have been properly engaged through a variety of ways: - Industry magazine articles: 2 articles has been produced for the Australian berry journal. One on the Autumn 2024 edition and one for the Summer 2025 one. - Berry Quest conference 2025 presentation: Presentation by Dr. Renouf on 27 February 2025. - End-of-project workshops: Two workshops have been held to communicate and discuss results, on 19 and 21 of August 2025. - PRG membership: 5 meetings have been held, providing a vast	The project had a slow start related to growers' involvement in providing data. From this experience, different lessons can be obtained: - PRG establishment and involvement are fundamental. - Timing for approaching farmers has to be considered. - Farm visits are the most effective way to get growers' involvement, but the initial contact needs to be made from an

	opportunity for industry members to discuss project outcomes and suggest data interpretation improvements.	industry member. - Industry-wide surveys for data gathering are not appropriate.
4. To what extent were engagement processes appropriate to the target audience/s of the project? *Have there been a variety of ways for intended beneficiaries to hear about the project's outcomes (face-to-face workshops, online discussions, online information, technical documents, social media).* *Have there been a variety of ways for key stakeholders to engage with the process (face-to-face case study farm visits, telephone, online meetings, review of technical documents, social media).*	The process of getting stakeholder engagement has been appropriate and comprehensive, adjusting timings and formats to better suit the audience. Industry association has helped with the dissemination of information through industry members' e-mails, newsletters and printed magazines. Interviews for data gathering have been face-to-face, online and phone and via e-mail exchange.	Future data gathering efforts should use a Word format to gather data from growers rather than an Excel file.
What efforts did the project make to improve efficiency?	To increase the efficiency of farm visits: - Data gathering sheets were distributed to growers previously, so they could better prepare. - After a couple of itinerations with growers, data requirements were reduced, so growers' time was used more efficiently. - Farm visits were scheduled so that researchers visit more than one farm each trip.	

Recommendations

Grower Recommendations

To reduce Rubus carbon footprints, growers should prioritize the following strategies:

Yield Optimization:

- Maximize productivity with existing inputs through reduced field losses and developing value chains for second-grade fruit
- Any yield improvement directly reduces per-kilogram carbon intensity

Energy Management:

- Expand solar panel installations to minimize grid electricity dependence
- Transition to electric vehicles for on-farm operations
- Implement energy efficiency measures including pump optimization, irrigation system upgrades, and preventive equipment maintenance

Packaging Efficiency:

- Optimize fruit-to-packaging ratios through:
  - Increased product per container
  - Lightweight packaging materials
  - Reusable packaging systems
- Maximize recycled content in plastic punnets
- Minimize in-field packaging losses from wind damage and handling inefficiencies

Fertilizer Management:

- Align fertilizer applications with crop nutrient requirements
- Reduce nutrient losses through improved pot drainage management
- Implement drainage collection systems to recycle lost nutrients

Infrastructure Longevity:

- Select durable tunnel plastics to extend operational lifespan and reduce replacement frequency
- Source materials with recycled content where available
- Maximize reuse of trellis components across operational cycles

Systematic greenhouse gas tracking requires comprehensive recording of production inputs and outputs. A specialized data collection guide has been developed to support grower implementation of these monitoring practices.

LCA Practitioner Guidance

Project findings emphasize the substantial contribution of production infrastructure (tunnels) and packaging systems to Rubus carbon footprints. LCA practitioners must ensure comprehensive accounting of tunnel infrastructure and packaging materials to achieve accurate environmental assessments.

Industry Development Recommendations

Hort Innovation should:

- Integrate environmental sustainability priorities identified through this research into strategic industry development planning
- Collaborate with Berries Australia to ensure public accessibility of project-generated data
- To ensure data sets generated by this project are available for future LCA endeavours of the Rubus industry, it is recommended that the inventory data is uploaded to AusLCI database.
- Liaise with Agriculture Innovation Australia (AIA) in relation to learning from this project to improve the Environmental Accounting Platform tool for horticulture.

These recommendations ensure research outcomes translate into measurable industry improvements while establishing infrastructure for continued environmental performance monitoring and assessment.

Refereed scientific publications

Non

References

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Intellectual property

No project IP or commercialisation to report

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