Options for improved waste management

Current practices and opportunities for improved pre-farm gate waste management in agriculture, fisheries and forestry

by Isabel Axiö, Donna Lucas, Dr Anne-Maree Boland, Clinton Muller, Kat Heinrich and Matt Allan

AgriFutures® National Challenges and Opportunities

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in agriculture, fisheries and forestry

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AgriFutures®
National Challenges and Opportunities

Foreword

Australia's agriculture, fisheries and forestry sector is making inroads to reduce its waste footprint and align with *Australia's National Waste Policy*. Investment in a range of projects as part of AgriFutures Australia's *Pre-Farm Gate Waste Program* has delivered insight to inform strategies and investment across rural industries, and set a baseline for future data collection to support waste management activities.

The sector generates a significant amount of waste and by-products. Management of theses waste streams involves a range of practices, from stockpiling, landfilling, burning and burial to reuse, recycling and recovery. Being able to participate in the latter options is constrained by access to services, distance to markets and high cost relative to other disposal methods. However, there are many improvements that can provide environmental benefits for growers, fishers and foresters, as well as improve efficiency and resilience.

This report details current waste management activities and captures existing or emerging options that have been changing, or can change, management of waste for the better. The report presents the findings from an options analysis and includes (1) an assessment of four preferred options to manage specific waste challenges and insights on the barriers, risks, costs and opportunities for implementation; and (2) a SWOT analysis of an additional 60 options that provides direction and ideas for many other avenues that can be investigated, trialled or implemented.

The four options examined in depth are:

- Replacing copper chrome arsenate-treated posts used extensively in viticulture with either steel posts, untreated timber posts encased in recycled plastic or wood-plastic composite posts.
- Whole crop purchasing to reduce on-farm food waste and overproduction.
- Using certified soil biodegradable plastic mulches in horticulture and nursery production.
- Establishing reception facilities that accept unwanted fishing gear and assessing opportunities to recycle nets, ropes and gear.

The research identified Australian primary producers are committed to better managing their waste, including taking part in innovative programs that promote avoidance, reuse and recycling options – the desire and appetite to adopt improved practices is evident. However, there exist several critical barriers to implementing improved practices, including added costs and extra time, logistical challenges associated with collecting and transporting waste, access to and capacity of recycling and upcycling options, waste material contamination, and inconsistent waste management legislation between states.

This report has been produced as part of AgriFutures Australia's investment in pre-farm gate waste research, which supports our priority of identifying, understanding and responding to national challenges and opportunities impacting Australian rural industries. Most of AgriFutures Australia's publications are available for viewing, free download or purchase online at www.agrifutures.com.au.

Michael Beer
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About the authors

This report was authored by RMCG team members in collaboration with Rawtec. RMCG is a multi-disciplinary consultancy specialising in the environment, agriculture and communities. RMCG's waste and resource recovery team works with its community engagement specialists to integrate understanding of waste management into the policies, community expectations and education required for a successful circular economy.

Acknowledgement of Country

The authors acknowledge the Traditional Owners of the Country we work on throughout Australia, and recognise their continuing connection to land, waters and culture. We pay our respects to their Elders past, present and emerging, and the Elders of other Aboriginal and Torres Strait Islander communities. Moreover, we express gratitude for the knowledge and insight Traditional Owners and other Aboriginal and Torres Strait Islander people contribute to our shared work.

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Abbreviations

Abbreviation	Definition
ABA	Australian Bioplastics Association
AORA	Australian Organic Recycling Association
CCA	copper chrome arsenate
DCCEEW	Department of Climate Change, Energy, the Environment and Water
EOL	end-of-life
EPR	extended producer responsibility
FRDC	Fisheries Research and Development Corporation
GHG	greenhouse gas
NFF	National Farmers' Federation
RDC	Research and Development Corporation
SFWA	Stop Food Waste Australia
UTS	University of Technology Sydney
WCP	whole crop purchasing
WMRR	Waste Management and Resource Recovery Association of Australia
WRIQ	Waste Recycling Industry Queensland

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Overview and methodology

Australia's primary industries, including agriculture, fisheries and forestry, generate a significant amount of waste and by-products. Management of theses waste streams involves a range of practices, from stockpiling, landfilling, burning and burial to reuse, recycling and recovery.

Being able to participate in the latter options is constrained by access to services, distance to markets and high cost relative to other disposal methods. However, there are many improvements that can provide environmental benefits for growers, fishers and foresters, as well as improve efficiency and resilience.

This options analysis project researched current waste management activities and captured existing or emerging options that have been changing, or can change, management of waste for the better. This report presents the findings from the options analysis and includes (1) an assessment of four preferred options and insights on the barriers, risks, costs and opportunities for implementation; and (2) a SWOT analysis of an additional 60 options that provides direction and ideas for many other avenues that can be investigated, trialled or implemented.

Current landscape mapping	Conducted 47 interviews and a targeted internal workshop to understand the challenges, opportunities, barriers, risks and benefits.
Longlist and consolidation	Developed a longlist with 70-plus options/ideas based on an internal workshop (December 2021), targeted research and interviews. Removed duplicates and irrelevant items to reduce the list to 64 options.
SWOT analysis	Assessed the feasibility and impact, and the strengths, weaknesses, opportunities and threats, associated with each of the 64 options.
Preliminary shortlist	Shortlisted 14 options based on criteria.
Review of preliminary shortlist	Sought input on the preferred options from select members of the project group (16 people), and then from clients and industry participants (15 people), via workshops.
Preferred options assessments	Selected four options that scored high on the criteria, that were in the workshops, and that represented different waste streams and industries.

Figure ES1. Overview of methodology

Current practices

Agriculture

Agricultural organic wastes include animal waste, sludges, green waste, product loss and harvest residues. Organic residues and animal manures from intensive livestock operations are often composted or mulched and used on farm. Harvest residues and product loss are often fed to animals or left in the field without being used for a higher value (i.e. upcycling or composted). However, material left in the field is used as a soil amendment.

Plastic waste is the primary waste issue for most agriculture industries. Plastic wastes include mulch and poly tunnel films, piping and irrigation, nets and mesh, bagging and twine, and storage, trays and labels. Some plastics are recycled, mainly through coordinated programs. Many plastics are likely burned or buried onsite. Other plastics are landfilled in mixed waste collections.

Workshop wastes include a range of materials, with their types highly dependent on the production system. These wastes include fencing wire, treated timber posts, tyres, batteries, oils, machinery and other inert and hazardous waste. Material is often stockpiled in and around physical workshops.

Fisheries and aquaculture

Plastic is widely used and products are often a composite of several types of plastic, and sometimes include metal or other components. The material can be damaged (physically and by UV) and contaminated by organic materials. Netting, ropes, buoys, bollards, cages, baskets, pontoons and feed bags are some of the plastic products used.

Organic waste from fisheries and aquaculture includes mortalities, viscera, blood water and shell. Most of this is composted or land spread through controlled measures. Shell is often landfilled.

Treated timber posts are a problematic workshop waste used in oyster growing. Steel framing for aquaculture and fisheries equipment is used but often reused and/or recycled through a range of scrap recyclers.

Forestry

The key plastics used that generate waste pre-farm gate include marking tape (for marking harvest, thinning, new prospecting areas and routes) and seedling protectors (corflute and netting). These are most often left *in situ*.

There are significant organic harvest residues left in the forest after harvest. These residues protect the soil after harvest. Some of these residues are aggregated and collected for compost, some are piled up in the coupes and some are burned depending on the forestry and harvest system used.

Drivers, barriers and opportunities

Drivers

The key drivers for positive change in waste management expressed by industries were:

1. **Environmental** – personal consciousness and desire to care for the land; alignment with industry sustainability frameworks; environmental responsibility; benefits of organic amendments to soil health; move to zero carbon; desire for a circular economy.
2. **Financial** – cost efficiency; efficient use of resources/materials; replacement of resources (e.g. fertilisers); prohibitive cost of disposal; increasing the value of secondary materials.
3. **Social** – licence to operate; responsible neighbours; meeting community expectations; considering materials as a resource rather than a waste.
4. **Business** – access to specific markets (local and export) through supplier and quality assurance programs; meeting consumer expectations; responding to retailer requirements.
5. **Regulatory** – legislation for waste management.

Barriers and opportunities

Despite the willingness for change, there are several critical barriers to implementing improved practices to manage waste that industry has identified, including:

- **Logistics** – logistical challenges exist associated with aggregation, collection and transport, particularly in isolated regions.
- **Capacity** – access to and capacity of recycling and upcycling options is limited.
- **Alternatives** – there are few existing options for end uses with established markets.
- **Contamination** – contaminated waste materials cannot be recycled.
- **Costs and time** – there are added costs and extra time associated with alternative practices, and a perception there is no financial benefit.
- **Convenience** – producers have difficulty dealing with waste materials and there are few on-farm pick-up services.
- **Awareness** – there is a lack of information and knowledge as to available waste management options.
- **Regulation** – waste management legislation is inconsistent between states.
- **Monitoring** – there is a lack of data available for tracing the flow of material.
- **Local solutions** – market concentration means there is a lack of local suppliers, regional recycling facilities and community-based solutions.

Four preferred options

Treated timber posts

There is widespread use of copper chrome arsenate (CCA) posts in the Australian viticulture industry and other agricultural industries. CCA posts contain toxic materials and when burned or improperly disposed can impact human and animal health, as well as water, air and soil quality. CCA posts cannot currently be recycled and must be sent to landfill at their end-of-life.

Galvanised steel posts are the most cost-effective and practical of three alternatives assessed. When considering whole-of-life costs (but not discounted cash flow) over a 30-year cycle, steel is cheaper than CCA by about $50 per hectare. Steel posts are significantly cheaper to dispose at their end-of-life than CCA posts, assuming they can be recycled as scrap steel. Steel posts can vary in strength and price depending on the product design and the price of steel.

A major barrier of the alternatives is the high upfront costs compared with CCA posts, and the perceived risk of not performing as well as CCA posts.

Key recommendation: Introduce a circular business model for supply of posts. This could involve farmers/vineyard operators leasing posts rather than buying them, and the supplier being responsible for post installation, maintenance, replacement and end-of-life management. This model would help producers overcome the barriers of high upfront cost and the perceived risk of posts not fulfilling farming requirements.

Whole crop purchasing

Whole crop purchasing (WCP) can help reduce on-farm food waste and overproduction. It involves retailers/wholesalers committing to buying an entire crop from a grower, instead of accepting and rejecting units based on quality specifications or tonnages set by retailer contracts (noting that an estimate of volume and thus hectares to be grown is expected). Under WCP, a greater proportion of crop yields may be directed to the fresh market or hospitality and food service markets. Any crop fractions that are unsuitable for these markets have the potential to be upcycled into new food products or sent to another value-adding process (e.g. made into animal feed).

Crops potentially suited to a WCP arrangement include those that have strict aesthetic standards, seasonal gluts, a short shelf life, and/or are susceptible to pest and disease impacts and/or physical damage. Bananas, carrots, potatoes, cauliflowers, broccolis and fresh market tomatoes that are field grown are suitable for such an arrangement, as are other crops that have one or more of the above characteristics.

The potential benefits of a WCP arrangement to the Australian banana industry were evaluated. The assessment estimated the industry could unlock an additional $75.2 million of revenue from the sale of lower-grade bananas, with an average banana plantation (32 hectares) receiving additional net revenue of $34,000 per year under these arrangements. Retailers/wholesalers also stand to benefit from WCP by producing new products that generate revenue, strengthening relationships with their growers, reducing their scope 3 greenhouse gas (GHG) emissions and demonstrating extended producer responsibility to their customers.

Key recommendations:

1. Create a map showing target crops and volumes, overlayed with potential existing markets for crops (including existing upcycling facilities), to identify the key locations and target crops to begin with under WCP arrangements.
2. Develop a trial business case in collaboration with the Australian banana industry, key retailers/wholesalers and Stop Food Waste Australia.
3. Establish an expression of interest (EOI) process to identify growers and retailers/wholesalers interested in trialling WCP arrangements for the identified locations and target crops.

Certified soil biodegradable mulch

Plastic mulch is commonly used on Australian crops, such as tomatoes, capsicums, zucchinis, strawberries and nursery production, to retain moisture, suppress weeds and retain fumigation in the soil. Growers need to remove the plastic mulch at the end of each crop cycle, which takes time and involves a cost. Any plastic that isn't collected fragments into microplastics, which can contaminate the soil.

Alternative field mulches that do not require removal at the end of the crop cycle have been available since the early 2000s. Certified field mulches conform with ISO 23517, which requires the product to biodegrade in the soil, leaving organic material and no microplastics. This mulch is known as 'certified soil biodegradable mulch' and is different from plastic mulches that break down into microplastics (even if they are termed 'biodegradable', 'oxodegradable' or 'photodegradable'). The Australasian Bioplastics Association (ABA) has launched a verification program for these products, to the requirements of ISO 23517:2021 *Plastics – Soil biodegradable materials for mulch films for use in agriculture and horticulture.*

This assessment suggests the whole-of-life cost of soil biodegradable mulch is slightly higher ($200 per hectare, or 9% higher) than plastic mulch. This assumes the purchase price of soil biodegradable mulch is double that of plastic mulch. However, sensitivity analysis shows soil biodegradable mulch would be cost competitive if the purchase price was only 80% higher than plastic mulch, or the removal and disposal cost for conventional plastic mulch was 23% higher.

Key recommendation: Support greater uptake of certified soil biodegradable mulch, including by establishing demonstration sites to confirm the economics, logistics and risks of the option, and offering rebates and/or loans to minimise the upfront cost for growers transitioning to certified soil biodegradable mulch.

Plastic use in commercial fisheries and aquaculture

A wide range of gear types and plastic material is used in fisheries and aquaculture. Plastic products are often composed of a mix of plastics, or are mixed with other materials (metal/timber), and at their end-of-life are often contaminated by organic material and worn by use. This type of plastic is considered low value by recyclers.

The locations where plastic waste is generated, namely ports and aquaculture farms, are often a significant distance from recycling markets, and processor capacity local to the port/farm can be limited. This increases the cost of transporting plastic materials to processors.

This assessment has outlined the steps to take to identify improved plastic material management solutions. These steps include:

1. Identify plastic materials and locations
2. Consider material characteristics
3. Assess potential options
4. Develop a business case
5. Pilot option/s
6. Implement solution.

Further, details for an assessment approach (steps 1-3) have been described. The analysis includes:

- A list of plastic wastes by industry, the types of materials and the key challenges for recycling these.
- Factors that must be considered and addressed to facilitate recovery. These include plastic quality, physical product characteristics (size, weight, form), volume and seasonality of waste generation, and requirements for pre-treatment.
- Consideration of costs, infrastructure requirements, logistics, contamination standards, labour, recycling capacity and markets for products.
- A framework for considering recovery and recycling that takes a hierarchical approach and illustrates pathways for materials to be avoided, recycled or managed appropriately.

Key recommendations:

1. Develop a business case for extended producer responsibility (EPR).
2. Conduct a fisheries and aquaculture plastic data collection project to estimate the volume, nature and locations of plastic generated and stockpiled annually.
3. Work with priority fisheries and aquaculture sectors or ports to develop a business case(s) for infrastructure upgrades.
4. Pilot infrastructure upgrades (e.g. reception facilities) at a case study site (e.g. port).

Other options

In addition to the four case studies, this report presents 60 other options in a list, along with more detail in a SWOT analysis table (Appendix E). These options cover a range of opportunities across waste streams (organic, plastic, workshop) and industries.

Introduction

Australia's primary industries, including agriculture, fisheries and forestry, generate a significant amount of waste and by-products. Management of theses waste streams involves a range of practices, from stockpiling, landfilling, burning and burial to reuse, recycling and recovery.

Being able to participate in the latter options is constrained by access to services, distance to markets and high cost relative to other disposal methods. However, there are many improvements that can provide environmental benefits for growers, fishers and foresters, as well as improve efficiency and resilience.

In December 2020, RMCG completed a scoping study for AgriFutures Australia. The scoping study informed the development of AgriFutures Australia's *Pre-Farm Gate Waste Program*, and in 2021 five projects were funded under the Program. These included:

- *Pre-farm gate waste management – data collection for agriculture, fisheries and forestry waste* (waste data collection, PRO-013257)
- *Options for improved waste management* (options analysis, PRO-015119)
- *Agriculture, Fisheries and Forestry National Waste and Resource Recovery Roadmap* (the Roadmap, PRO-015140)
- *Towards circular material futures: Development of innovative solutions to recycling and re-purposing existing pre-farm gate waste* (PRO-015081)
- *Revaluing workshop waste* (PRO-133332).

This engagement highlighted a desire within rural industries to improve waste and resource management, and industry support to facilitate this. Further, as the *Agriculture, Fisheries and Forestry National Waste and Resource Recovery Roadmap* (Boland *et al.*, 2022) (the Roadmap) identified, there is a need to change behaviour, increase knowledge, develop partnerships and target research and development.

This report captures the process and results of the options analysis project, which involved researching current waste management activities and capturing existing or emerging options that have been changing, or can change, management of waste for the better.

The report includes: (1) the methodology used; (2) a description of current waste management practices; (3) an assessment of four preferred options, with insights on the barriers, risks, costs and opportunities for implementation; and (4) a SWOT analysis of an additional 60 options to provide direction and ideas for many other avenues that can be investigated, trialled or implemented.

Project objectives and scope

The objectives of the project were to:

- **Identify the gaps** – ascertain what needs to change for the sectors to achieve sustainable waste management and resource recovery, and analyse the economic, environmental and social risks and benefits of implementing possible solutions. These include redesigning material use to avoid waste; increasing reuse and extending product life; and improving management of end-of-use material.
- **Identify practical solutions** for pre-farm gate waste reduction and recovery implementation.
- **Identify risks and benefits** of adopting changed practices, and consider these when analysing the feasibility of options.
- **Present a report** that facilitates the implementation of solutions for the agriculture, fisheries and forestry industries to improve pre-farm gate waste management.

The project scope included:

- **Pre-farm gate waste**, defined as waste generated in primary production businesses up to the point of and including harvest, prior to product leaving the farm or fishing vessel. This may include some on-farm packing, e.g. vegetable packing sheds, but excludes processing, e.g. vegetable processing, fish processing, log (forestry) processing and milling.
- **Three categories of waste – plastic, organic and workshop**. Each category includes sub-categories of material that in turn can include very specific material types. For example, within the organic waste category, the project scope includes pre-farm gate 'product loss'.

For definitions or clarification of the scope, see *Pre-farm gate waste management: Guidelines for waste data collection* (Lucas *et al.*, 2022).

Current practices

Agriculture

Agriculture generates significant volumes of organic, plastic and workshop waste. However, the amount, types and use and disposal practices vary and depend on the enterprise, the location, the manager's attitude and experience, available options, and cost.

Organic wastes include animal waste, sludges, green waste, product loss and harvest residues. Organic residues and animal manures from intensive livestock operations are often composted or mulched and used on farm. Harvest residues and product loss are often fed to animals or left in the field without being used for a higher value (i.e. upcycling or composted). For farmers, organic waste, particularly residues, are not considered a waste as they are managed on farm as animal feed or a soil amendment. Unharvested produce is considered product loss and does not reach the market due to market specifications, impacts of climate, labour problems or collapse of market price. This is a significant issue in many horticulture industries.

Plastic waste is the primary waste issue for most agriculture industries. Plastic wastes include mulch and poly tunnel films, piping and irrigation, nets and mesh, bagging and twine, and storage, trays and labels. Some plastics, for example poly irrigation pipe or plastic mesh bags, are recycled, mainly through coordinated programs such as drumMUSTER or location-specific initiatives. There are significant stockpiles of plastic waste, including irrigation piping, plastic mulch and silage, throughout the country. Many plastics are likely burned or buried onsite. Other plastics are landfilled in mixed waste collections.

Workshop wastes include a range of materials, with their types highly dependent on the production system. These wastes include fencing wire, treated timber posts, tyres, batteries, oils, machinery and other inert and hazardous waste. Material is often stockpiled in and around physical workshops. Scrap metal is probably the most recycled material, either reused on farm or recycled through a regional collection service. Oil is often recycled through a local council site or re-used on farm. Some workshop waste is generated and managed by contractors, and therefore not handled pre-farm gate, and thus is out of scope for this project.

Fisheries and aquaculture

Most fisheries operations occur in oceans and estuaries, apart from a very small proportion of land-based aquaculture.

Plastic is widely used and products are often a composite of several types of plastic, and sometimes include metal or other components. The material can be damaged (physically and by UV) and contaminated by organic materials. Netting, ropes, buoys, bollards, cages, baskets, pontoons and feed bags are some of the plastic products used. Some individual fishing and aquaculture businesses have established recycling programs for specific plastic products. Significant research and development between specific users (fisheries), manufacturers (of plastic) and recyclers has been completed to enable material, including feedbags, cages and netting, to be recycled. However, most plastics are landfilled or stockpiled.

Organic waste from fisheries and aquaculture includes mortalities, viscera, blood water and shell. Most of this is composted or land spread through controlled measures. Shell is often landfilled.

Treated timber posts are a problematic workshop waste used in oyster growing. Steel framing for aquaculture and fisheries equipment is used but often reused and/or recycled through a range of scrap recyclers.

Forestry

Many forestry services are delivered by contractors, who plant, spray, maintain and harvest crops. The waste is often generated at their workshops, which are offsite. Waste products may include plastic drums, other input containers, machinery, tyres and used oils.

The key plastics used that generate waste pre-farm gate include marking tape (for marking harvest, thinning, new prospecting areas and routes) and seedling protectors (corflute and netting). These are most often left *in situ*.

There are significant organic harvest residues left in the forest after harvest. These residues protect the soil after harvest. Some of these residues are aggregated and collected for compost, some are piled up in the coupes and some are burned depending on the forestry and harvest system used. For example, if logs are harvested and taken to a central point for trimming and loading, the residue is centralised. Most organic residues are left *in situ* for beneficial reuse and thus are outside the scope of this project.

Drivers, barriers and opportunities

Drivers

Australian primary producers are committed to better managing their waste, including taking part in innovative programs that promote avoidance, reuse and recycling options. The desire and appetite to adopt improved practices is evident, but there is often a gap in the settings (knowledge, coordination, incentives, regulation) and practical alternatives to facilitate this change at scale.

The key drivers for positive change in waste management expressed by industries were:

1. **Environmental** – personal consciousness and desire to care for the land; alignment with industry sustainability frameworks; environmental responsibility; benefits of organic amendments to soil health; move to zero carbon; desire for a circular economy.
2. **Financial** – cost efficiency; efficient use of resources/materials; replacement of resources (e.g. fertilisers); prohibitive cost of disposal; increasing the value of secondary materials.
3. **Social** – licence to operate; responsible neighbours; meeting community expectations; considering materials as a resource rather than a waste.
4. **Business** – access to specific markets (local and export) through supplier and quality assurance programs; meeting consumer expectations; responding to retailer requirements.
5. **Regulatory** – legislation for waste management.

Barriers and opportunities

Despite the willingness for change, there are several critical barriers to implementing improved practices to manage waste that industry has identified, including:

- **Logistics** – logistical challenges exist associated with aggregation, collection and transport, particularly in isolated regions.
- **Capacity** – access to and capacity of recycling and upcycling options is limited.
- **Alternatives** – there are few existing options for end uses with established markets.
- **Contamination** – contaminated waste materials cannot be recycled.
- **Costs and time** – there are added costs and extra time associated with alternative practices, and a perception there is no financial benefit.
- **Convenience** – producers have difficulty dealing with waste materials and there are few on-farm pick-up services.
- **Awareness** – there is a lack of information and knowledge as to available waste management options.
- **Regulation** – waste management legislation is inconsistent between states.
- **Monitoring** – there is a lack of data available for tracing the flow of material.
- **Local solutions** – market concentration means there is a lack of local suppliers, regional recycling facilities and community-based solutions.

Methodology

Overview

This project aims to increase adoption of existing waste avoidance and diversion practices. The objectives were to:

- Identify gaps and ascertain what needs to change for the sectors to achieve sustainable waste management and resource recovery, and analyse the economic, environmental and social risks and benefits of implementing possible solutions.
- Identify practical solutions for pre-farm gate waste reduction and recovery implementation.
- Identify risks and benefits of adopting changed practices, and consider these when analysing the feasibility of options.
- Develop recommendations that facilitate implementation of solutions for the agriculture, fisheries and forestry industries to improve pre-farm gate waste management.

The project methodology is summarised in Figure 1, with additional detail provided in the following sections.

Current landscape mapping	Conducted 47 interviews and a targeted internal workshop to understand the challenges, opportunities, barriers, risks and benefits.
Longlist and consolidation	Developed a longlist with 70-plus options/ideas based on an internal workshop (December 2021), targeted research and interviews. Removed duplicates and irrelevant items to reduce the list to 64 options.
SWOT analysis	Assessed the feasibility and impact, and the strengths, weaknesses, opportunities and threats, associated with each of the 64 options.
Preliminary shortlist	Shortlisted 14 options based on criteria.
Review of preliminary shortlist	Sought input on the preferred options from select members of the project group (16 people), and then from clients and industry participants (15 people), via workshops.
Preferred options assessments	Selected four options that scored high on the criteria, that were in the workshops, and that represented different waste streams and industries.

Figure 1. Overview of methodology

Current landscape mapping

An internal workshop was held on 16 November 2021 to capture unpublished industry knowledge about waste management, including current challenges and barriers, and emerging opportunities or innovations (including the risks and benefits of implementing change for those who generate the waste). The workshop was attended by 16 participants, including agricultural experts from RMCG, subcontractors and organisations delivering related projects for AgriFutures Australia.

In addition, extensive consultation was undertaken with primary industry and waste industry stakeholders. Interviews focused on gaining insights and information relevant to all three RMCG *Pre-Farm Gate Waste Program* projects (waste data collection, options analysis and roadmap development). Interviewees were asked about their current practices; challenges, barriers, risks and opportunities for change; and knowledge of ideas/options being trialled or practised.

Interviewees included representatives from Research and Development Corporations (RDCs), including Hort Innovation and Fisheries Research and Development Corporation (FRDC), and peak bodies, e.g., the Waste Management and Resource Recovery Association of Australia (WMRR), National Farmers' Federation (NFF) and AUSVEG. Interviewees also included individual farmers, researchers, recycling and process providers, and state government staff.

Longlist and consolidation

A longlist of options was created through collating ideas from the internal workshop, industry interviews, the project team and subcontractors, as well as associated projects (DCCEEW's *National Non-Packaging Agricultural Plastic Stewardship Scheme*, UTS's plastic innovation project) and desktop research.

The project team (Rawtec and RMCG) assessed the longlist and grouped/combined similar options. Options were also assessed for fit with the project scope, with 11 being removed. A total of 64 potential options were taken to the analysis stage.

SWOT analysis

Each of the 64 options were assessed against a range of characteristics:

General characteristics

- Description and examples (with links to reports and webpages)
- Industry scope (relevance to one or many industries or sectors)
- Waste category (organic, plastic and/or workshop)
- Waste hierarchy (where in the waste hierarchy is the option effective? i.e. avoid, reuse, recycle).

Factors/characteristics affecting potential feasibility

- Technology type (known, available or cutting-edge)
- Implementation timeline (short, medium or long term)
- Complexity (low, medium or high)
- Incentive for farmers (disincentive, no incentive or incentive associated with implementation)
- Capital and operating cost of option technology (low, medium or high).

Factors/characteristics for potential impact

- Volume available (low, medium or high)
- Applicable industries (one, some or many industries)
- Environmental benefit (low, medium or high)
- Economic impact (negative, negligible or net positive)
- Waste management hierarchy designation (avoid, reduce, reuse, recycle, recovery or dispose).

These characteristics were summarised as strengths, weaknesses, opportunities and threats, and used to inform selection of the options for shortlisting.

Preliminary shortlist

The shortlisting process was undertaken by the project team and considered:

- Overall rating of factors affecting potential feasibility (low, medium, high)
- Overall rating of potential impact (low, medium, high)
- Strength and weaknesses
- Opportunities and threats
- Whether initiatives or other projects exist or are in a progressed development stage – e.g. drumMUSTER, pig feed investigation project (Fight Food Waste CRC), *National Non-Packaging Agricultural Plastic Stewardship Scheme* (DCCEEW), nurseries pots recycling (Greenlife), silage stewardship (Dairy Australia), *Designing optimal solutions for workshop waste* (Murrang Earth Sciences), UTS's plastic innovation project, *Development of a national waste management strategy for primary industries* (RMCG)
- Whether initiatives could realistically be assessed within the scope of this project
- Whether the option would have impact across sectors and across waste streams.

The 64 options were assessed for shortlisting using the labels 'No' and 'Yes' as follows:

- 14 options were shortlisted (i.e. labelled 'Yes'). These were assessed as having a large potential positive impact on a large volume of waste and/or a large number of industries.
- 50 options were not shortlisted (i.e. labelled 'No'). These were assessed as having a small potential impact on a very small volume of waste and/or a small number of industries, or are being addressed by other projects.

Review of preliminary shortlist

Two workshops were held to gain input on the 14 shortlisted options and facilitate an informed selection of preferred options for further assessment. All workshop participants were provided with the longlist of options to provide context for the shortlisted options.

The workshops presented the analysis approach and the 14 options by stream (i.e. organic, plastic, workshop). A facilitated discussion and further consideration post the workshop enabled participants to identify their top three options.

The first internal workshop was attended by 16 people – 15 from RMCG, Rawtec, Lotic Consulting, Murrang Earth Sciences, University of Technology Sydney and Equilibrium, plus product stewardship consultant Ed George. The second industry-facing workshop was attended by 15 people from AgriFutures Australia, Australian Organic Recycling Association (AORA), Solving Plastic Waste CRC, Waste Recycling Industry Queensland (WRIQ), Australian Bioplastics Association (ABA), CSIRO, Stop Food Waste Australia (SFWA), VegNet/Enviroveg, Hort Innovation, Fisheries Research and Development Corporation (FRDC), National Farmers' Federation (NFF), Mallee Landcare Network and Fishwell Consulting.

Four options that represented a cross-section of industries and waste streams were selected.

Assessment of preferred options

Although the approaches used to assess the four preferred options were different, each captured the benefits and risks, and provided information about the cost and feasibility characteristics for implementation. The development of each option involved working closely with relevant stakeholders to ensure the data attributes were accurate and the results of the analysis useful to the industry/industries.

The approaches used to assess each option are described in the following section (Findings).

Findings

1 Treated timber posts

Summary

There is widespread use of copper chrome arsenate (CCA posts in the Australian viticulture industry and other agricultural industries. CCA posts contain toxic materials and when burned or improperly disposed can impact human and animal health, as well as water, air and soil quality. CCA posts cannot currently be recycled and must be sent to landfill at their end-of-life.

This option evaluates three alternatives to CCA posts in vineyards: galvanised steel, untreated timber encased in recycled plastic and wood-plastic composite. It identifies the whole-of-life costs of each alternative, their benefits and barriers preventing their uptake.

Galvanised steel posts are the most cost effective and practical of the alternatives. When considering whole-of-life costs (but not discounted cash flow) over a 30-year cycle, steel is cheaper than CCA by about $50 per hectare. Steel posts are significantly cheaper to dispose at their end-of-life than CCA assuming they can be recycled as scrap steel. Steel posts can vary in strength and price depending on the product design and the price of steel.

A major barrier of the alternatives is their high upfront cost compared with CCA posts and the perceived risk they don't perform as well as CCA posts.

As an example, a 10 ha vineyard moving from CCA posts to a recyclable alternative would reduce waste to landfill by 250 m^3 (enough to fill more than two buses).

CCA posts contain hazardous materials and are expensive to dispose at their end-of-life, with landfill the only current disposal option. Many farmers stockpile posts on farm prior to disposal or reuse them, e.g. as fence posts.

CCA posts are also challenging to remove after bushfires. Post-bushfire work in South Australia indicates the cost to remove and dispose CCA posts burnt to ash is about $30 per post. If the post is damaged but not completely burnt, the cost is about $5.80 per post.[1]

There is an opportunity to move to a circular business model for supply, maintenance and recycling of posts. This could involve farmers/vineyard operators leasing posts rather than buying them, and the supplier being responsible for post installation, maintenance, replacement and end-of-life management. This model would help producers overcome the barriers of high upfront cost and the perceived risk of posts not fulfilling farming requirements.

[1] Cost estimates are based on work completed by Rawtec costing the impact of bushfires.

Background

Treated timber is commonly used as a trellis for grapevines and orchard fruit trees, netting structures, and fence posts. There are several treated timber options designed for different applications and weather conditions, and to withstand pressure from pests or fungi.

Conventional CCA posts

CCA timber, also called 'green posts', is a common type of treated timber. Another common treatment is creosote. CCA contains a water-based heavy metal mixture that includes arsenic, chromium and copper. CCA posts are common in viticulture, used by an estimated 65% of Australian vineyards (AWRI, 2019), although this figure varies by region. This project has focused on CCA posts in vineyards given their high-volume use.

CCA posts are also frequently used in fruit growing, livestock and aquaculture. Many of the attributes/ discussion points below are relevant to all industries. However, post specifications, uses and barriers to change in other industries were not investigated as part of this project.

CCA posts are challenging to dispose at their end-of-life. They should not be burned, meaning landfill is the only option for disposal but is expensive. As a result, stockpiling is common. Stockpiling CCA-treated timber may increase the potential for leachate to contaminate soils and groundwater (EPA SA, 2016). When wet, CCA-treated timber can produce a leachate that contains the heavy metals arsenic, chromium and copper.

Alternatives to CCA posts

The opportunity exists for the viticulture industry to shift from CCA posts to alternative types of posts. Alternative posts will ideally be easier to recycle or reuse at their end-of-life. There are many different posts either in use or being trialled in Australian vineyards, including:

- Metal options, including 'star picket'-style posts, round posts and galvanised steel posts. An estimated 12% of vineyards in Australia use metal posts (AWRI, 2019).
- Untreated timber posts encased in recycled plastic (plastic can be from recycled vineyard plastic waste, such as that used for irrigation).
- Wood-plastic composite posts made from recycled sawdust and recycled plastic extruded together as a post.
- Other types of treated timber posts, such as creosote. An estimated 20% of vineyards in Australia have creosote-treated posts (AWRI, 2019).
- Steel posts with recycled plastic exterior.
- Recycled plastic posts.

Some vineyards use a combination, for example one metal post for every two to three CCA posts, or metal posts with CCA strainer posts. Other vineyards affix metal posts to broken CCA posts to prolong the life of CCA posts and to minimise waste (Rural News Group, 2017). There are many good practices happening in the industry, with vineyards trialling alternative posts and/or reusing posts where possible to minimise environmental impact.

CCA posts remain common as the upfront cost per post is lower than most alternatives. Vineyard operators may not consider or know CCA post removal and disposal costs, nor factor these in when buying the posts. There is opportunity to better understand the whole-of-life costs of CCA posts compared with the alternatives, including disposal costs.

Cost comparison of CCA and alternative posts

Assessment approach

The whole-of-life cost of CCA posts was assessed considering the upfront purchase cost, installation cost, failure rate, disposal cost at end-of-life, and replacement cost. Three alternatives were analysed: (1) galvanised steel posts; (2) untreated timber posts encased in recycled plastic; and (3) wood-plastic composite posts.

Other alternatives mentioned above were not included as initial research indicated they could not perform to the same standard as CCA posts, or they have some form of treatment with hazardous material (and we prioritised non-treated post options).

Appendix A includes a list of assumptions used for the assessment.

Whole-of-life cost comparison

The whole-of-life costs (but not full lifecycle analysis) of CCA posts and the three alternatives were compared. The analysis considered the average cost per year over 30 years without applying discounted cash flow.

Treated timber posts

1

The average whole-of-life cost per hectare over 30 years is lowest for steel posts at $1,450, compared with CCA posts at $1,500, untreated timber posts encased in recycled plastic at $1,750 and wood-plastic composite posts at $2,130 (Figure 2).

The assessment of costs broken down into cost items (purchase, installation and EOL disposal) shows disposal cost is greatest for CCA posts ($294 per hectare). However, purchase cost is lowest ($775 per hectare compared with the alternatives at more than $1,100 per hectare). CCA has the lowest upfront cost (purchase and installation) at about $1,200 per hectare compared with the alternatives, at $1,400 per hectare and above.

The low upfront cost for CCA posts makes them an attractive option for vineyard operators, given cash flow limitations at establishment. End-of-life costs for steel posts are very low as they are easier/quicker to remove and cheaper to transport, and because the producer can receive cash when recycling the product.

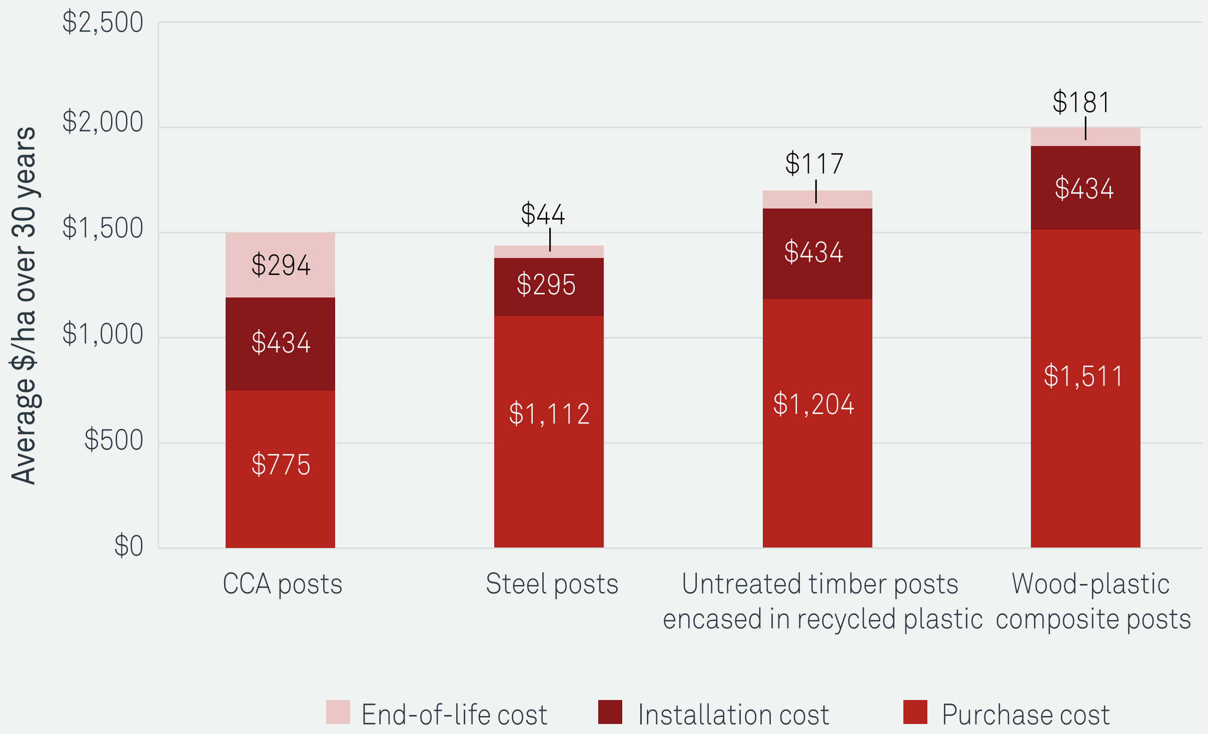

Figure 2. Average whole-of-life cost per hectare over 30 years for each post type, broken down by cost item. Note: Cost not based on discounted cash flow. Does not include costs for clips and strainer posts. Based on an average of 650 posts installed per hectare of vineyard.

Costs of CCA posts following a bushfire

CCA posts are challenging to remove after bushfires. Post-bushfire work in South Australia indicates the cost to remove and dispose CCA posts burnt to ash is about $3,000 per tonne, or $30 per post. This is much higher than the cost to remove a non-burnt post, and does not include potential environmental damage to the soil and groundwater caused by the burnt post. If faced with a bushfire, the cost of CCA posts is more expensive than all alternatives.

Discounted cash flow comparison

Appendix A includes detail of a discounted cash flow analysis. Incorporating the discounted cash flow analysis into the assessment suggests the cost of CCA posts over a 30-year cycle is lower than the alternatives. This finding is different to that above, as discounted cash flow was not considered because the cost at year 0 for a 10 ha vineyard is significantly lower for CCA posts ($122,000) than the alternatives (between $150,000 and $200,000). Therefore, a vineyard operator who chooses CCA posts has more cash available at the start compared with an operator who chooses an alternative type of post, and this cash could be invested elsewhere.

Sensitivity analysis on key variables (not considering discounted cash flow)

Appendix A includes detail of a sensitivity analysis that assessed the impact of changing upfront cost and/or installation cost on the average cost per hectare over 30 years (not considering discounted cash flow). For upfront costs:

- Steel can increase to almost $20 per post (model currently assumes $19 per post) before CCA becomes the lower whole-of-life cost option.
- Untreated timber encased in recycled plastic must reduce to between $14 and $15 per post (current assumption is $18.60) to have a lower whole-of-life cost than CCA posts.
- Wood-plastic composite must reduce to between $13 and $14 per post (current assumption is $23.40) to have a lower whole-of-life cost than CCA posts.
- The current assumption for CCA is $12 per post not including installation.

Currently, CCA posts installation is assumed to be $6.70 per post not including disposal of an old post. As such:

- If installation of steel posts increased from the currently assumed $5 per post to $6 per post, they have a similar whole-of-life cost to CCA posts.
- Installation cost of untreated timber posts encased in recycled plastic needs to decrease to $2.75 per post to have a similar whole-of-life cost to CCA.
- Installation cost of wood-plastic composite posts could decrease to $0 per post and the whole-of-life cost would remain higher than CCA posts.

Sensitivities on disposal costs per tonne and transport costs per tonne were also explored. These had minimal impact on the whole-of-life cost analysis.

Benefits

Changing from CCA posts to alternative posts provides a range of benefits not captured in the financial data, including:

- Savings in landfill space and/or space at an average vineyard if stockpiling CCA posts – an average vineyard is estimated to generate 245 m^3 of CCA posts over 30 years, enough to fill more than two buses.[2]
- Reduced costs and risks associated with bushfires due to the clean-up of ash from burned CCA timber.
- Supporting Australia's transition towards a circular economy as alternatives (particularly steel and untreated timber encased in recycled plastic) are designed to be recycled (see notes below).
- Quicker installation time (for steel), reducing cost but also allowing time for other jobs when setting up the vineyard.
- Creating demand for recycled plastics (alternatives 2 and 3). Steel may have some recycled steel in the posts, but this is difficult to determine.

[2] Based on 1,290 posts being disposed per hectare over 30 years and each post being 0.019 m^3, equating to 24 m^3 per hectare of posts, which over 10 hectares is 245 m^3 over 30 years. We have assumed a bus is 120 m^3.

Treated timber posts

1

Barriers, drawbacks and risks

Major barriers to transitioning to the alternatives include:

- Higher upfront cost
- Disposal costs of treated timber at its end-of-life
- Potential risk of using an alternative product that may not perform as well as CCA posts
- Uncertainty about breakage percentages/weak points of alternative products
- A perception there is no cost to dispose CCA posts as they get stockpiled, despite ongoing stockpiling being an unsustainable option.

There are also some drawbacks and risks to consider for the alternatives, including:

Steel

- Some steel posts are manufactured overseas (e.g. New Zealand), therefore few local jobs will be generated unless all manufacturing is brought onshore.
- It is not possible to put nails in steel, although self-drilling screws can be used. This makes steel less adaptable in circumstances where wiring changes are required (noting there is reduced cost as having pre-drilled holes for clips and trellis reduces cost).
- Steel can bend or rust, which can lead to it breaking. This is very dependent on the type of product and its size/strength. Larger or stronger steel posts have reduced risk of breaking.
- The price of steel can fluctuate, impacting the price of posts.
- There is some variability in price and performance/strength of steel posts.

Untreated timber coated in recycled plastic

- Such posts may need to be replaced when there is a crack in the plastic coating. The product will degrade rapidly in these circumstances.
- Such posts may require machinery adjustments prior to installation, as care is required so as not to split the coating.
- If the ground is very hard or rocky, the installation technique will need adjusting so as not to break the casing.
- To reduce the cost of posts, the timber is narrower than that used for CCA posts, which may compromise its strength.
- The product is relatively new.

Wood-plastic composite

- There are few examples of the product in use.
- There are cheaper options available (narrower posts, posts with holes in the centre), but these have high failure rates as they don't meet specifications.
- It can be challenging to recycle products with blended materials such as wood-plastic composite posts. Producers will need to check with the manufacturer regarding the recycling options at their end-of-life.

Other considerations

The perceived risk of alternative posts not performing to the required standard is high. There are examples of vineyards installing thousands of alternative posts, particularly untreated timber encased in recycled plastic and wood-plastic composite, that have had high failure rates. This risk can be reduced by suppliers better understanding soil types and conditions where the posts will be installed, better understanding the machinery that will be used to install the posts, and ensuring posts meet specifications (and charging accordingly), rather than reducing the size or quality of the post to meet a budget.

Performance of alternative posts can vary. Consultation revealed mixed views of the alternatives, with some vineyard managers preferring one option over another. There are examples of where an alternative was successfully installed at one vineyard, but had a high failure rate at another vineyard.

Recommendations

To address barriers and encourage greater use of alternative posts, producers, industry and post suppliers should adopt the following initiatives and opportunities:

1. Investigate grants, loans and/or rebates for additional upfront purchase.
2. Introduce a circular business model for supply of posts. This could involve farmers/vineyard operators leasing posts rather than buying them, and the supplier being responsible for post installation, maintenance, replacement and end-of-life management. This model would help producers overcome the barriers of high upfront cost and the perceived risk of posts not fulfilling farming requirements.
3. Explore the opportunity to ban producers from purchasing and using traditional CCA timber products when establishing a new vineyard or replacing CCA posts, providing adequate lead time (e.g. from 2026 onwards).
4. Engage with businesses that are major consumers of traditional CCA timber products to promote the use of alternative environmentally sustainable products.
5. Introduce a mandatory product stewardship scheme for posts at their end-of-life. This could involve a takeback scheme for discarded posts where the manufacturer is responsible for disposal/recycling.
6. Demonstrate different posts (e.g. two rows of steel, two rows of untreated timber encased in recycled plastic, two rows of wood-plastic composite, two rows of CCA, and repeat) and assess how they perform over a period of time.
7. Link in with other projects investigating alternatives to CCA posts to continue building the business case.

2 Whole crop purchasing

Summary

Whole crop purchasing (WCP) can help reduce on-farm food waste and overproduction. It involves retailers/wholesalers committing to buying an entire crop from a grower, instead of accepting and rejecting units based on quality specifications or tonnages set by retailer contracts (noting that an estimate of volume and thus hectares to be grown is expected). Under WCP, a greater proportion of crop yields may be directed to the fresh market or hospitality and food service markets. Any crop fractions that are unsuitable for these markets have the potential to be upcycled into new food products or sent to another value-adding process (e.g. made into animal feed). WCP arrangements are in place overseas (e.g. Tesco in the UK) and are being trialled in Australia by Open Food Network (OFN). Temporary agreements were also introduced in 2020-21 when the impact of COVID-19 resulted in a shortfall of fresh fruit and vegetables in Australian supermarkets.

Crops potentially suited to a WCP arrangement include those that have strict aesthetic standards, seasonal gluts, a short shelf life, and/or are susceptible to pest and disease impacts and/or physical damage. Bananas, carrots, potatoes, cauliflowers, broccolis and fresh market tomatoes that are field grown are suitable for such an arrangement, as are other crops that have one or more of the above characteristics.

The potential benefits of a WCP arrangement to the Australian banana industry were evaluated. The assessment estimated the industry could unlock an additional $75.2 million of revenue from the sale of lower-grade bananas, with an average banana plantation (32 hectares) receiving additional net revenue of $34,000 per year under these arrangements. Retailers/wholesalers also stand to benefit from WCP by producing new products that generate revenue, strengthening relationships with their growers, reducing their scope 3 greenhouse gas (GHG) emissions and demonstrating extended producer responsibility to their customers.

WCP arrangements have the potential to increase the sustainability and profitability of the Australian food system. However, the scale of the benefits and how they are distributed depends on how the arrangements are structured. WCP contracts should be established to incentivise growers to produce high-quality produce, and should stipulate a fair price for the picking and packing of the additional crop fractions.

Third-party organisations (e.g. food manufacturers) can play an important role in WCP arrangements by upcycling or value-adding produce that isn't suitable for fresh retail or hospitality. These partnerships will take time to develop. Retailers/wholesalers can also consider using lower-grade crop fractions as ingredients in their home-brand products.

The following actions would help progress this opportunity:

1. Create a map showing target crops and volumes, overlayed with potential existing markets for crops (including existing upcycling facilities), to identify the key locations and target crops to begin with under WCP arrangements.
2. Develop a trial business case in collaboration with the Australian banana industry, key retailers/wholesalers and Stop Food Waste Australia.
3. Establish an EOI process to identify growers and retailers/wholesalers interested in trialling WCP arrangements for the identified locations and target crops.
4. Share lessons from WCP arrangement trials (including those being undertaken by OFN) to inform future design of WCP arrangements.
5. Industry bodies/relevant agencies develop WCP sample contract arrangements that help reduce waste and overproduction, and deliver benefits to the grower, retailer/wholesaler and any other parties involved.

Background

About 18-22% of Australia's fruit and vegetable produce is lost during primary production in field or processing/packaging (Ambiel *et al.*, 2019). The reasons for these losses include disease, seasonal changes, overproduction to meet supply agreements, supply chain interruptions and quality specifications from retailers and wholesalers. However, Rogers *et al.* (2013) found the main reasons related to not meeting quality specifications. These specifications can change based on supply, seasonal demand and changing consumer preferences, leading to significant nutritional, environmental and economic losses (White *et al.*, 2010).

The opportunity

Whole crop purchasing (WCP) is an agreement between a producer and a retailer/wholesaler whereby the whole crop is purchased, and thus harvested. WCP is instead of the retailer/wholesaler accepting and rejecting units based on quality specifications or tonnages set by retailer contracts (although some form of estimated tonnage would still be required). WCP pushes the reasonability of maximising out-of-specification produce onto the retailer/wholesaler, which can sell it in fresh retail, upcycle it into a new product or send it to animal feed or another destination. The grower would still need to manage the crop to ensure good quality.

WCP can be supported through partnerships. For example, retailers/wholesalers can partner with food processors and manufacturers, food rescue organisations, animal feed producers and other organisations to maximise the value of product they cannot sell via their retail outlets.

The following case studies provide examples of WCP activities.

Morrisons supermarket chain

Morrisons supermarket chain in the United Kingdom buys whole crops from farmers. Potatoes are one example product. Instead of asking a third party to sort and package the crop based on its appearance, Morrisons sells small potatoes as "Baby Roasters", while extremely small potatoes go to animal feed. Skin blemishes and oddly shaped potatoes are sold in value packs. Through this initiative, Morrisons uses 20% more potato crops than other supermarkets. (Morrisons, 2011).

A similar initiative to WCP is used for fresh meat. Rather than purchasing the cut of meat, Morrisons purchases the full live animal and processes it using its vertically integrated abattoirs. The supermarket chain has more control over its supply chain waste as a consequence (Morrisons, 2011).

The company also partnered with community food network FareShare in 2010 to repurpose the rest of its supply chain food waste. FareShare is a non-profit network of food charities and redistributors across the UK that seeks to reduce food poverty and food waste.

Whole crop purchasing

2

Open Food Network Australia – Whole Crop Purchasing project

Open Food Network Australia explored how to reduce and design out on-farm food waste in Victoria through its Whole Crop Purchasing project. Project partners were Farmer Incubator and Social Traders.

The aim of the Whole Crop Purchasing project was to reduce on-farm food waste and improve farm profits by facilitating relationships between growers and buyers, and in turn help find markets for produce that would not normally meet buyer standards. Such relationships create secure markets for farmers, helping them forecast demand and address any shortfalls they may experience.

Preliminary findings from the project and background research include:

- The project increased the amount of crops/produce purchased and reduced on-farm food waste for participating farmers.
- Working towards more sales of a crop is an important goal in reducing on-farm food waste, rather than only focusing on, or aiming for, a whole crop purchase (WCP) outcome.
- Building relationships between farmers and multiple, separate buyers can be beneficial and effective in enabling sale of a whole crop.
- Open Food Network has helped mitigate risk for participating growers by facilitating a marketplace where multiple buyers can purchase different parts of the same crop.
- Clear purchasing agreements with multiple parties or between all parties need to be established (these can be the same or different agreements).
- Scale, values alignment and price are critical factors when facilitating and brokering relationships between growers and buyers.
- WCP agreements must be context-specific, align with different growers' needs, including the type of produce and scale of production, and include timeframes that both the grower and buyer can work with to prevent the food becoming waste
- Before a WCP contract is rolled out, a trusted, formal relationship needs to be established, as the current market is flexible and often works with short timeframes. Memorandum of understanding (MoU) agreements have been a useful initial mechanism to build such relationships. These set out a clearly defined governance structure and outline the roles, responsibilities and specifications each party will adhere to.

The project has been a successful trial of a values-based procurement service that addresses on-farm food waste, with one grower reporting they sold 95% of their crop through the project.

A public report was released in late 2022 detailing project findings and next steps.

The Whole Crop Purchasing project was supported by the Victorian Government's Recycling Victoria Innovation Fund as part of the Circular Economy Business Innovation Centre.

Key potential crops

Crops potentially suited to WCP arrangements include:

- Crops with **seasonal production**, with supply peaks that need active marketing to ensure produce is sold
- Crops with a **short shelf life**, where any interruption in the supply chain leading to long periods of storage will result in large volumes of waste
- Crops that are **susceptible to pest and disease impacts and/or physical damage**
- Crops that face **stringent quality standards for cosmetic appearance**
- Crops where non-first-grade-quality product has **real potential to be sold at fresh markets or turned into other food products**.

In Australia, these include carrots, potatoes, bananas, cauliflowers, broccolis and fresh market tomatoes that are field grown, as well as other crops that have one of more the above characteristics. These crops also have high food loss (in-field plus packing shed loss) and large total tonnages produced in Australia. The estimated total loss with the potential to be diverted through WCP is provided in Table 1.

Table 1. **Australian crops with high food loss and potential to apply whole crop purchasing to reduce waste.**

Commodity	Production (tonnes/year)[3]	Locations produced	Current estimated loss (%)[4]	Current estimated loss (tonnes/year)
Carrots (excluding processing)	315,000	WA, Victoria, Tasmania, SA, Queensland	34%	107,000
Potatoes (excluding processing)	452,000	SA, Tasmania, Victoria, NSW	23%	104,000
Field-grown fresh market tomatoes	96,000	Queensland	34%	33,000
Bananas	400,000	Queensland	25%	100,000
Cauliflower (excluding processing)	78,000	Victoria, Queensland, NSW, WA, Tasmania	36%	28,000
Broccoli (excluding processing)	76,000	Victoria, Queensland, WA	23%	17,000
			Total	**389,000**

Potential markets for produce

Through WCP agreements, retailers/wholesalers can direct produce to its highest value based on its grade and available markets (see Figure 3):

- Top-grade produce would continue to be sold in fresh retail markets (e.g. in fruit and vegetable aisles of supermarkets). Retailers may choose to relax their aesthetic standards to sell additional volumes of produce through fresh retail markets, perhaps at a reduced price.
- Lower-grade produce could be sold to the hospitality and foodservice market, for example through value packs or on the Yume Food platform.
- Surplus produce may be donated to food relief charities for distribution to people in need.
- Any produce that is unsuitable for sale in the fresh retail or foodservice markets may be upcycled into a new product, for example baked goods, pickled, juice, flour, powder or pasta sauce; fermented into alcohol; or sent for another value-adding process, for example insect protein or as an ingredient in pet food.

[3] Horticulture Innovation Australia, 2021.

[4] Lucas *et al.*, 2022. Note: Current estimated loss includes in-field plus packing shed loss.

Whole crop purchasing

2

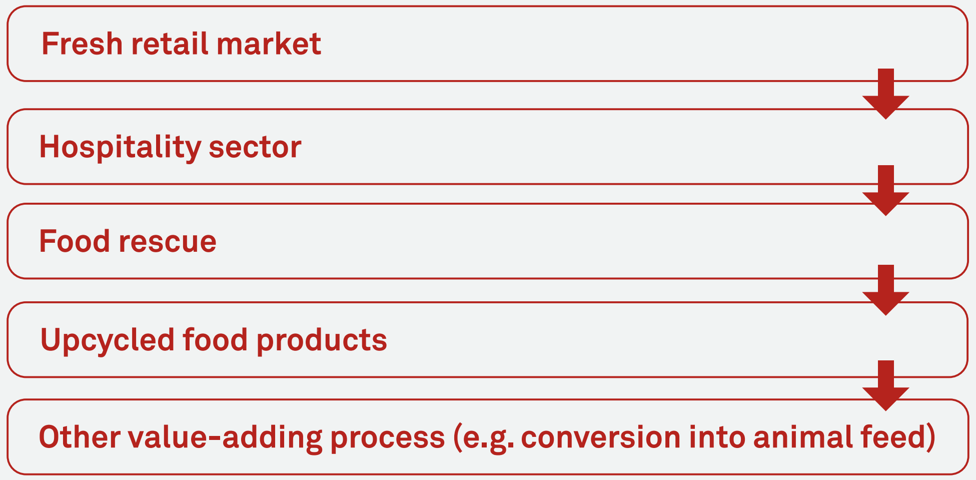

Figure 3. Potential markets for crops under a whole crop purchasing agreement from highest to lowest value.

Cost analysis of whole crop purchasing

Overview

WCP involves additional on-farm costs, including harvesting the lower-grade crops (for produce that is harvested by hand and graded in the field, e.g. market field-grown tomatoes, cauliflowers[5]), packing the produce (e.g. in bins/crates), storing the produce (e.g. in coolstores), and sending material to end uses (e.g. to an upcycling facility). Additional revenue can be attracted through the sale of the additional produce to end markets.

Opportunity for whole crop purchasing for bananas

An estimated 78,000 tonnes per year of bananas across Australia do not meet quality standards. This includes:

- 8,000 tonnes that are rejected because they do not meet aesthetic standards (e.g. are undersized, have skin blemishes)
- 70,000 tonnes that are rejected due to not meeting other quality standards (e.g. knife cuts). These bananas are edible at time of packing but may not be suitable for the fresh market as the damage may result in the product rotting when it reaches supermarket shelves.

Growers typically mulch rejected bananas onsite and spread them on their land. Markets are emerging for growers to send their rejected bananas to upcycling facilities that use them in products, such as banana flour and pet food. WCP agreements between banana growers and retailers/wholesalers would unlock further opportunities to generate revenue from rejected bananas. These include:

- Retailers/wholesalers relaxing their aesthetic standards to allow imperfect bananas to be sold to the fresh market.
- Retailers/wholesalers setting up partnerships with upcycling facilities to convert lower-grade bananas into new products.

These initiatives involve additional on-farm costs to pack and send the lower-grade bananas to end markets.

[5] Growers producing crops that are mechanically harvested and then graded in packing sheds would not face extra costs for growing or harvesting the produce.

Assessment approach

Appendix B includes detailed data and assumptions underpinning this analysis.[6] The findings illustrate the potential costs and benefits of WCP arrangements. The values should not be used to establish WCP; growers and wholesales/retailers need to calculate these on a case-by-case basis. The estimated prices do not take into account how increased supply (in the short to medium term) would affect prices received by growers.

Costs for sending imperfect bananas to fresh retail

Growers would need to receive a minimum of $0.91 per kilogram to cover additional costs (including a margin) for packing and sending cosmetically imperfect bananas to the fresh retail market.

Costs for recovering lower-grade bananas for upcycling

Growers would need to receive a minimum of $0.87 per kilogram to cover additional costs (including a margin) for packing and sending bananas to markets for upcycling. This figure is lower than that for sending to fresh retail as the bananas would be packed into crates/bins and sent directly to upcycling facilities, rather than packed for fresh retail.

Overall impacts of WCP

Through WCP arrangements, the Australian banana industry could unlock an additional $75.2 million of revenue by selling lower-grade bananas. A banana plantation of 32 hectares could receive additional net revenue (after costs) of $34,000 per year under these arrangements. The success of this initiative depends on retailer participation and available markets with customers willing to pay for the produce.

Benefits

WCP arrangements can benefit:

- **The environment** through reduced food waste volumes and upcycling of lower-grade produce into new products, which would displace increased demand for conventional produce and the land and inputs required to produce this. The environment would also benefit from reduced overproduction (Spray, 2013) and reduced demand for fertiliser, water, land and other resources used to grow food that would otherwise be wasted. WCP arrangements also help lower greenhouse gas emissions associated with producing food and can enable growers to rest fields and rotate crops.
- **Growers** through more economical use of inputs and turning lower-grade product from 'waste' into revenue, thereby increasing profitability and diversifying market access.
- **Retailers/wholesalers** as they would have new products that generate new revenue streams, stronger relationships with growers, reduced scope 3 GHG emissions, demonstration of extended producer responsibility, and the ability to respond to customer and consumer concerns about food waste.
- **Consumers** as they would have more options to buy 'wonky' or aesthetically imperfect fruit and vegetables at lower prices. This can assist in relieving cost-of-living pressures for many Australians and providing them with a nutritious diet.[7]
- **Food rescue organisations** through increased donations of surplus produce that would otherwise be wasted. Food donors may be able to receive tax incentives for donations if proposed tax reforms are introduced (Fight Food Waste CRC, n.d.)
- **The broader economy** through new value-adding activities (e.g. developing upcycled products) that have the potential to generate additional income and local employment.

[6] Disclaimer: The information contained within this document is based upon sources, experimentation and methodology that at the time of preparing this document were believed to be reasonably reliable, and the accuracy of this information subsequent to this date may not necessarily be valid. This information is not to be relied upon or extrapolated beyond its intended purpose.

[7] In 2022, KPMG, on behalf of the Fruit and Vegetable Consortium, surveyed 1,000 households about their vegetable consumption, with 72% of respondents stating they are eating less vegetables because of increased produce costs (KPMG, 2022).

Whole crop purchasing

2

Drawbacks and risks

Achieving benefits depends on how the WCP agreements are structured. Risks and mitigation measures associated with WCP are summarised in Table 2.

Other considerations include:

- A WCP arrangement is a partnership between the producer and the retailer/wholesaler. Communication and commitment to a long-term deal is key for both parties to thrive under the agreement.
- A WCP arrangement may need involvement from a third and fourth party to manage out-of-specification produce without producing waste.
- Vertical integration may be required from the retailer/wholesaler if third-party partners can't be found for the WCP. This may be a positive/point of difference for the retailer/wholesaler.
- Producers may need to alter their production cycles or crops to better meet the retailer/wholesaler needs.

Table 2. Risks and mitigation measures associated with whole crop purchasing.

Risk	Mitigation measure
Growers are no longer incentivised to produce high-quality produce because retailers/wholesalers have committed to buying the whole crop.	WCP arrangements include differential pricing based on product grade. Retailer/wholesaler commits to buying the whole crop but pays differential pricing depending on the product grade (i.e. pays more for first-grade produce than other grades). Retailer/wholesaler enters into agreements with growers who produce high-quality produce.
Growers are not paid 'fairly' for produce and/or the high value of first-grade produce is cannibalised by the lower value of other grades.	WCP arrangements pay growers a 'fair' price for each product grade (i.e. higher for first grade). This price should cover additional costs (including a margin) incurred by the grower to harvest, pack, store and send additional fractions to end markets as agreed in the WCP, for example the cost of picking low-grade fruit, packing it in a bin/crate and sending it to an upcycling facility. Depending on the WCP arrangement, the retailer/wholesaler may choose to organise transport (instead of the grower) where it can lower costs. This may be achieved through large-scale transport contracts and/or by improving economies of scale through organising transport for multiple growers in a region. WCP arrangements should include rise and fall clauses to allow for price adjustments (e.g. to input prices) based on CPI or other relevant indices.
There are limited markets for lower-grade produce.	WCP arrangements to be introduced over time targeting crops where there are viable markets for lower-grade produce.
Growers receive lower prices as a result of oversupply.	This is expected to be a short-term risk only. Over time, growers can reallocate resources to producing other crops and/or growing produce for export markets. There is potential for peak industry groups to investigate sources of financial assistance in the transitional period.

Recommendations

To progress implementation of whole crop purchasing, producers, industry and wholesalers/retailers should adopt the following recommendations:

1. Create a map showing target crops and volumes, overlayed with potential existing markets for crops (including existing upcycling facilities), to identify the key locations and target crops to begin with under WCP arrangements.
2. Develop a trial business case in collaboration with the Australian banana industry, key retailers/wholesalers and Stop Food Waste Australia.
3. Establish an EOI process to identify growers and retailers/wholesalers interested in trialling WCP arrangements for the identified locations and target crops.
4. Share lessons from WCP arrangement trials (including those being undertaken by OFN) to inform future design of WCP arrangements.
5. Industry bodies/relevant agencies develop WCP sample contract arrangements that help reduce waste and overproduction, and deliver benefits to the grower, retailer/wholesaler and any other parties involved.

3 Certified soil biodegradable plastics

Summary

Plastic mulch is commonly used on Australian crops, such as tomatoes, capsicums, zucchinis and strawberries, and in nursery production to retain moisture, suppress weeds and retain fumigation in the soil. Growers need to remove the plastic mulch at the end of each crop cycle, which takes time and involves a cost. Any plastic that isn't collected fragments into microplastics, which can contaminate the soil.

Alternative field mulches that do not require removal at the end of the crop cycle have been available since the early 2000s. Certified field mulches conform with ISO 23517, which requires the product to biodegrade in the soil, leaving organic material and no microplastics. This mulch is known as 'certified soil biodegradable mulch' and is different from plastic mulches that break down into microplastics (even if they are termed 'biodegradable', 'oxodegradable' or 'photodegradable'). The Australasian Bioplastics Association (ABA) has launched a verification program for these products, to the requirements of ISO 23517:2021 Plastics – *Soil biodegradable materials for mulch films for use in agriculture and horticulture.*

As the soil biodegradable mulches biodegrade into the soil, there is no removal and disposal cost. Although the upfront cost for this product can be 70-300% higher than the cost of plastic mulch, significant savings are achieved at disposal. The whole-of-life cost is therefore more important to consider than the upfront cost.

The whole-of-life costs for traditional plastic mulch and certified soil biodegradable mulch were assessed, considering removal and disposal costs for the plastic mulch at its end-of-life. Assuming the upfront cost of certified soil biodegradable mulch is double that of plastic mulch, the analysis suggests its whole-of-life cost is slightly higher ($200 per hectare, or 9% higher) than that for plastic mulch.

If the upfront cost of certified soil biodegradable mulch was 80% higher than plastic mulch, or if removal and disposal cost for conventional plastic mulch was 23% higher, the whole-of-life cost for certified soil biodegradable mulch would be lower than that for plastic mulch.

There are a range of other benefits from, but also barriers to, using certified soil biodegradable mulch. Opportunities to support greater uptake of certified soil biodegradable mulch include creating demonstration sites to confirm the economics, logistics and risks of the option, and offering rebates and/or loans to minimise the upfront cost for growers transitioning to certified soil biodegradable mulch.

Certified soil biodegradable mulch films should not be used with fumigation, as fumigation requires totally impermeable film (TIF) or virtually impermeable film (VIF). Follow product labels and seek advice on the use of plastic films for fumigation.

Background

Field mulch is used worldwide in agriculture and horticulture. Field mulch is applied around crop plants to suppress weeds, increase yield, maintain soil temperature and/or improve water retention (thereby reducing the need for irrigation). Field mulch results in improved crop quality and quantity, and reduces the use of plant protection products, including herbicides. Horticultural crops that benefit from field mulch include field-grown vegetables, berries and nursery production.

There are various products and types of field mulch in use on farms. These broadly fit into two categories: **conventional polyethylene plastic mulch** (including fumigation films) and **certified soil biodegradable mulch**.

Plastic films that are used for fumigation are designed specifically for that purpose, as they need to be impermeable.

Conventional polyethylene plastic mulch

Conventional polyethylene plastic mulch is usually polyethylene-based (DAWE, 2021). It is mostly used for a single crop-growing cycle (usually annual) but is sometimes reused for two or three cycles. At the end of its use, it must be removed from fields. The removal and disposal cost is significant considering labour and equipment/fuel use, space for aggregation, transport for disposal and landfill cost. Disposal to landfill is the most practical option given there are often contaminants (soil, plant material) in the mulch that make it very challenging to recycle. As landfill is expensive, growers sometimes manage the material onsite through stockpiling, burying and/or burning practices. Burning conventional polyethylene plastic mulch creates a number of air pollutants that are harmful to the environment and human health. These include soot, solid residue ash, black carbon, and toxic pollutants like dioxins and mercury (Verma *et al.* 2016). These by-products have global warming potential (GWP); black carbon has 5,000 times greater GWP than carbon dioxide (CO_2) (Reyna-Bensusan *et al.*, 2019). There is currently no method to account for this environmental burden and the cost associated with the practice, while important, is not included in this whole-of-life assessment.

Ongoing use of plastic mulch can have significant environmental and production impacts, such as generation of microplastics, loss of topsoil (when removing the mulch), decreased soil quality, reduced germination of seeds, and harm to soil invertebrates (Qi *et al.*, 2020; Ji *et al.*, 2021; Boots *et al.*, 2019; Maheash *et al.*, 2022). China's National Development and Reform Commission has responded to soil health issues caused by microplastics by forbidding the production and sale of plastic mulch that is difficult to collect and recycle (Mancl, 2022).

The Australian agriculture industry uses an estimated 7,000 tonnes of plastic mulch per year (Lucas *et al.*, 2022). At an estimated 200 kilograms per hectare, this equates to 35,000 hectares of crop soils covered in plastic each year.

Certified soil biodegradable mulch

Since the early 2000s, there have been products available that fully biodegrade into the soil. These mulch products are certified to ISO 23517 (ISO, n.d) and do not leave microplastics in the soil. They are not designed to be removed at their end-of-life, meaning producers do not have to retrieve the product from the field for disposal or recycling after harvest. Rather, these products can be ploughed back into the soil, biodegrading into CO_2 and microbial biomass due to the actions of the naturally occurring microorganisms present in the soil (Zumstein *et al.*, 2018; Limpus, 2021).[8] These products are not to be confused with those that fragment into smaller pieces of plastic (biodegradable, oxodegradable or photodegradable plastics).

Certified soil biodegradable mulch can be designed to biodegrade in different timeframes (by adjusting their thickness) and tend to biodegrade in 4-12 months. The upfront cost of soil biodegradable field mulch is significantly higher than that of field plastic. However, there are savings achieved at disposal as there is no need to collect, transport and landfill the certified soil biodegradable mulch. These savings may not be considered by growers when purchasing new mulch.

The difference between plastic mulch and certified soil biodegradable mulch

Certified soil biodegradable mulch meets ISO 23517:2021 and will biodegrade into the soil, leaving microbial mass and no microplastics. This is distinct from traditional non-biodegradable polyethylene mulch films and so-called oxodegradable or oxobiodegradable mulch films, which are made from conventional non-biodegradable polyethylene and contain additives that enhance physical disintegration into small plastic fragments that persist in the environment.

[8] Evidence suggests microbes within the soil will consume the soil degradable product within a seasonal timeframe. However, the research was conducted in a lab to replicate best case scenario conditions for microbial digestion. Each farm would present unique climate conditions and this may impact degradation of the product.

Certified soil biodegradable plastics

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Photo 1. Certified soil biodegradable mulch being laid. Photo: Australian Bioplastics Association.

Photo 2. Certified soil biodegradable mulch with establishing crops (beans and zucchinis). Photo: Australian Bioplastics Association.

The opportunity

The opportunity exists to move away from plastic mulch to certified soil biodegradable mulch. Part of this transition requires better understanding the whole-of-life cost and benefits of certified soil biodegradable mulch, and barriers to transition.

Certified soil biodegradable mulch is more ideal for crop cycles of 4-12 months. If the mulch is installed many months before planting or is being reused, it is more susceptible to tearing. Certified soil biodegradable mulch is also not impermeable, so is currently not suited as a fumigation film. Current research shows that plastic mulch is used mainly in vegetable production (field crops such as tomatoes, capsicums and zucchini), in-field strawberry production, and nursery production.

Crops that may be suited to certified soil biodegradable mulch, the locations they are grown in Australia, and the estimated number of hectares under planting are provided in Table 3.

Table 3. Crops suited to certified soil biodegradable mulch, locations they are grown and estimated number of hectares under planting.

Crop	Main location/s	Estimated area (ha) in Australia[9]
Field-grown fresh market tomatoes	Queensland, Victoria	800 ha
Zucchinis	NSW, Victoria, Queensland	41,000 tonnes/year (ha not provided)
Capsicums	Queensland	2,350 ha
Melons	Queensland, NSW, NT, WA	190,000 tonnes/year (ha not provided)
Other vegetables (eggplant, fennel, celery, salad greens, pumpkins)	All	10,000 tonnes/year of eggplant (ha not provided) 1,400 tonnes/year of fennel (ha not provided) 65,000 tonnes/year of celery (ha not provided) 6,000 ha or 139,000 tonnes/year of salad greens, including head lettuce 30,000 tonnes/year of leafy Asian vegetables (ha not provided) 4,600 ha or 116,000 tonnes/year of pumpkins
Field-grown strawberries	Queensland, Victoria	2,300 ha

[9] Horticulture Innovation Australia, 2021. Tonnes produced in Australia per year included where a value for hectares under planting was not available.

Certified soil biodegradable plastics

3

Cost analysis of plastic mulch and certified soil biodegradable mulch

The whole-of-life cost of certified soil biodegradable mulch was assessed against plastic mulch. The assessment was based on various assumptions, outlined in Appendix C, including that the cost of certified soil biodegradable mulch is double that of plastic mulch (purchase price only), and there is no cost for disposal of certified soil biodegradable mulch.

The whole-of-life cost analysis does not account for environmental cost of open-air burning of conventional polyethylene mulch film, or the environmental cost of extra fuel and other transport emissions incurred in removing conventional film from the field and transporting and disposing it at a waste facility. The whole-of-life cost analysis also takes no account of the impact on soil from use of either product, such as the potential loss of topsoil with the removal of conventional plastic film or the impact of accumulation of microplastics.

As described in Figure 4, the whole-of-life net cost for plastic mulch is $2,205 per hectare and for certified soil biodegradable mulch $2,403 per hectare. This is a $200 per hectare difference, or a 9% higher whole-of-life cost for certified soil biodegradable mulch. This difference is due to the upfront cost of certified soil biodegradable mulch, which is substantially higher than plastic mulch. There is no assumed disposal cost for certified soil biodegradable mulch as it can be ploughed back into the soil at the end of the crop cycle. Plastic mulch, on the other hand, must be picked up, collected and sent to landfill. This is estimated to cost $850 per hectare. The environmental cost of plastic mulch is not considered in this assessment.

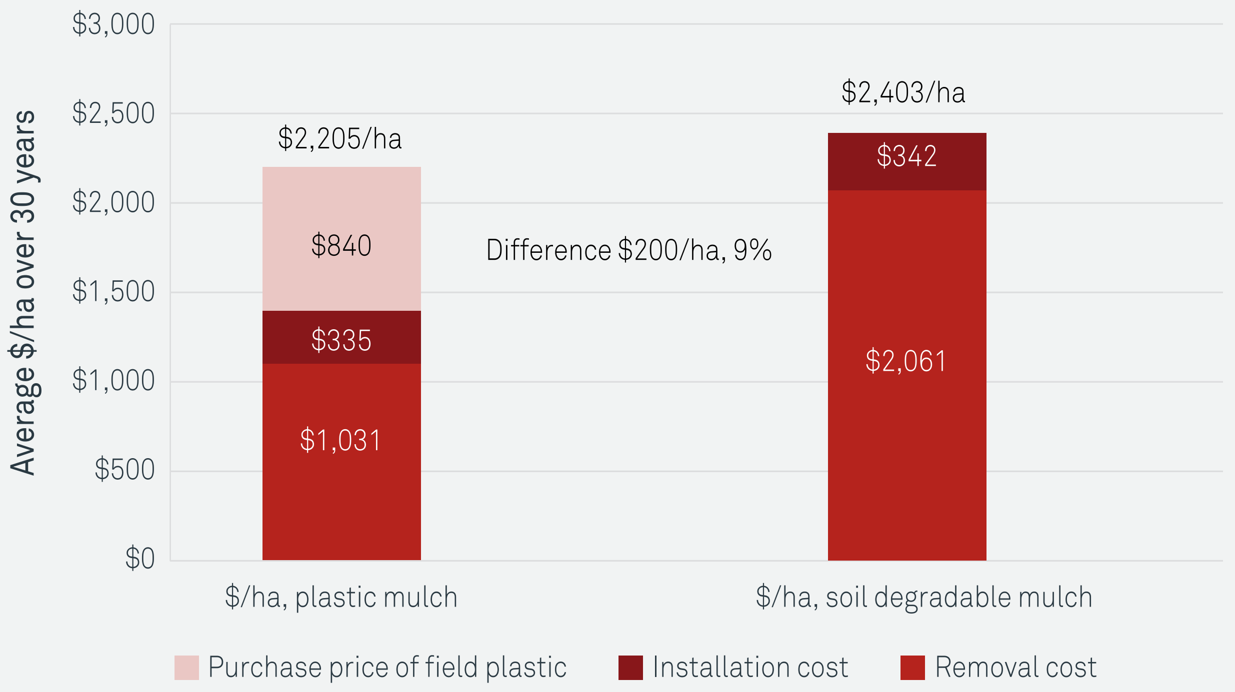

Figure 4. Whole-of-life cost analysis for plastic mulch and certified soil biodegradable mulch.

Sensitivity analysis

A sensitivity analysis was undertaken that explored the impact on net costs if certain assumptions are changed. The sensitivity analysis, detailed in Appendix C, considered upfront and transport cost changes.

Discussions with industry indicated the upfront cost of certified soil biodegradable mulch can range from 70% higher than plastic mulch to three times the cost. Double the cost (100% higher) was assumed in the analysis. However, the sensitivity analysis shows soil biodegradable mulch would be cost competitive if the purchase cost was only 80% higher than plastic mulch, or the removal and disposal cost for conventional plastic mulch was 23% higher.

Benefits

There are a range of non-financial benefits associated with certified soil biodegradable mulch, including:

- **Reduced landfill through saving field plastics from landfill/stockpiling/burning/burying:** Across Australia, there is an estimated 7,000 tonnes per year used across agriculture (Lucas *et al.*, 2022).
- **Improved soil:** By converting to the alternative, the grower is avoiding the potential for microplastics to contaminate the soil, and therefore waterways and vegetation, and increasing carbon in the soil. The alternative also prevents the loss of topsoil associated with the removal of conventional plastic film.
- **Mitigating future risk:** Transitioning to certified soil biodegradable field mulch can reduce the risk of soil and crop growth issues due to microplastics and increased prices of plastic mulch due to changing oil prices.
- **Reduced transport emissions and cost:** As transport to landfill is not required, transport emissions and cost are reduced.
- **Significant labour/time savings:** Installing and removing plastic mulch is estimated to take an additional six hours per hectare compared with the time required to manage certified soil biodegradable mulch.

Drawbacks and risks

Major barriers to transitioning to the certified soil biodegradable mulch are described below.

Upfront cost is high for the alternative and of more importance than whole-of-life cost

The upfront cost of certified soil biodegradable mulch is significantly higher than plastic mulch. As costs for growers continue to rise, they are looking to reduce costs where possible. Even if the whole-of-life costs are similar for certified soil biodegradable mulch, the high upfront cost is a significant disincentive for growers.

Green washing of plastic options

Oxodegradable and photodegradable field plastics are still being confused with the certified soil biodegradable option. Some green washing may be occurring where the plastic alternatives use words such as 'biodegradable' or 'degradable' but the product degrades into small microplastics rather than leaving carbon in the soil. This can lead to a negative perception of certified soil biodegradable mulch if the grower believes the product was a certified product (when this was not the case).

Risk the alternative product won't fit into the farming system

There are some risks taking on alternative products, including potential performance differences, suitability for certain climatic conditions, and cost and time responding to any issues with the new product.

Misaligned expectations on performance throughout the crop cycle

There can be a misalignment in expectations on how long the soil biodegradable product retains its full structural integrity, with the product potentially biodegrading before the end of the crop cycle. The timing of the biodegradation can be adjusted during manufacturing to meet the need of the grower. Some certified soil biodegradable mulch suppliers have questionnaires they provide to growers before a trial to ensure expectations are met from the beginning.

Less flexibility regarding installation timing

Timing of installation is an important consideration, as sometimes growers prefer to install all mulch before consecutive plantings. In this situation, certified soil biodegradable mulch may degrade slightly before the crop is planted and be more susceptible to tearing.

Certified soil biodegradable plastics

Adjusting to the structural integrity of the product

Certified soil biodegradable mulch requires slightly more care to avoid tearing when planting, using machinery or walking around the crop. This is particularly the case if planting occurs after laying the certified soil biodegradable mulch. Growers need to adjust how they treat and use the product to minimise these issues.

Grower perceptions of the true disposal cost for plastic mulch

The grower may opt to stockpile, burn and/or bury plastic mulch at its end-of-life. Perceptions exist among growers that there are no other options, or at least none that are low cost, for disposal of plastic mulch, despite the environmental issues and cost associated with current practices.

Fumigation limitation

Some fumigation products may accelerate the degradation of certified soil biodegradable mulch, and in these cases the product will not work as required. Importantly, there are strict requirements for the type of plastic to be used when using certain fumigants, with soil biodegradable film not appropriate for fumigation purposes.

Other considerations

Other relevant considerations identified during consultation include:

- Certified soil biodegradable mulch has been around for some time, so is not a new product.
- Non-certified products being sold as soil biodegradable mulch have influenced the market for genuine products.
- The high upfront cost of certified soil biodegradable mulch is due to the higher price of input products, i.e. the cost of plant resin (for soil biodegradable film) is greater than the cost of oil (for plastic film). As demand for, and use of, the biodegradable product increases, prices are expected to decrease.
- Factors outside the grower's control can influence the price of both products, such as freight costs and the price of oil (for plastic products).
- If plastic mulch is banned from landfill, there is currently no alternative option for responsible disposal for growers.
- Recycling of plastic mulch is not considered in this assessment as this is currently challenging due to contamination and high transport costs to end markets. Certified soil biodegradable mulch is a better alternative when considering the waste hierarchy.
- In some cases, organic mulch (made from shredded garden organics and timber) may be an appropriate replacement for plastic mulch.

Recommendations

Opportunities and considerations for growers, suppliers, industry and government to facilitate implementation of certified soil biodegradable mulch are listed below.

1. Establish demonstration sites for different crops in different locations to confirm the economics, logistics and practical application in more detail for a range of crops. These locations should have differences in soil health and climate.
2. Consider grants, rebates or loans that can be paid back over time to overcome the barrier of high upfront cost of certificated soil biodegradable mulch.
3. Engage with businesses/farms that are major consumers of plastic mulch to promote the use of certified soil biodegradable mulch.
4. Describe the product limitations and benefits to ensure they are fully understood by growers. This could be via a one-page summary that supports other information provided by potential suppliers when growers inquire about the product.
5. Work with supermarkets that have in place quality assurance standards that stipulate a preference for purchasing crops grown using certified soil biodegradable mulch.

4 Plastic use in commercial wild harvest fisheries and aquaculture

Summary

A wide range of gear types and plastic materials are used in fisheries and aquaculture. **Gear type** refers to the equipment used to harvest a species; for example, fishing pens for offshore caged aquaculture or pelagic net for netting operations. **Plastic material** describe the types of plastic objects used in the whole operation and can include the gear type but also many other materials; for example, fishing net but also buoys, boxes and ropes for a netting operation.

Plastic materials are often composed of mixed plastic or plastic mixed with other materials (metal/timber), and at the end of their life are often contaminated by organic material and worn by use. This type of plastic is considered low value by recyclers.

The locations of plastic waste generation, namely ports and aquaculture farms, are often a significant distance from recycling markets and/or have limited local processor capacity. This increases the cost to transport plastic material to processors.

This assessment outlines the steps to take to identify potential plastic waste solutions. These steps include:

1. Identify plastic materials and locations
2. Consider material characteristics
3. Assess potential options
4. Develop a business case
5. Pilot option/s
6. Implement solution.

Step 1 involves mapping the range of plastic materials used and will provide insight to the composition and challenges with each material group.

Step 2 involves listing and describing the variables to consider for different types of materials, including pre-treatment and aggregation.

Step 3 involves listing and describing the variables to consider for infrastructure, as well as markets, processing capacity and suitable recovery and recycling technology.

The section includes a case study describing the journey taken by the Port Lincoln fisheries community and options for improving recovery and management of plastic waste.

Recommendations include:

- Conduct a fisheries and aquaculture plastic data collection project to estimate the volume, nature and locations of plastic generated and stockpiled annually. This will help identify priority sectors, plastic materials and/or ports.
- Work with priority fisheries and aquaculture sectors or ports to develop a business case(s) for infrastructure upgrades (at ports). This major piece of work would involve assessing technology used for recycling fisheries and aquaculture plastics (research and development); sampling and trialling processing with existing recyclers to determine material presentation requirements and the most sustainable destinations; and collaborating with fisheries/aquaculture groups, local government and industry contractors for solutions to stockpiling and pre-treating plastic.
- Pilot infrastructure upgrades (e.g. reception facilities) at a case study site (e.g. port).
- Develop a business case for an extended producer responsibility (EPR) scheme.
- Investigate and promote plastic circular design options and circular best practice policies.

Background

Plastic materials are used widely across the fisheries and aquaculture industries. The type of material is often related to the gear type used for the fishing activity. For example, the major plastic material for trawling and seine, for offshore caged aquaculture, is nets (from pens). Other plastic materials commonly used, to varying degrees, include ropes, buoys and fish bags, as well as a significant range of specialised items for specific fishing activities.

Gear is often comprised of several types of plastic or plastic mixed with other materials (metal/timber), and at the end of its life is often contaminated by organic material and worn by use. To facilitate recovery of these materials, decontamination, sorting and pre-treatment is often required, which is both labour and cost intensive. The structure of nets, ropes and baskets makes them complex to handle and recycle through mainstream plastic recycling processes. Most fishing waste plastic aggregation occurs at ports, often a significant distance away from existing waste and recycling logistics networks. This adds significantly to transport and logistics costs.

More broadly, in Australia, most plastic generated is currently not recycled. Therefore, recyclers have access to a large volume of plastic and are often highly selective of feedstock accepted. The *Australian Plastics Flows and Fates Study 2019-20* found that of 3.46 million tonnes of plastic consumed in Australia on a per-year basis, only 13.1% is recovered and reprocessed (O'Farrell *et al.*, 2021). Approximately 60% of the recovered material is from packaging sources. Most recovery is also strongly related to two national product stewardship schemes: the Australian Packaging Covenant and the National Television and Computer Recycling Scheme (NTCRS). This highlights that complex plastics from fisheries and aquaculture are competing in a recycling landscape where clean(er) plastic material streams from commercial and household sources are abundant. As such, plastic recyclers tend to seek these cleaner and higher-value streams that are concentrated in urban centres.

In addition, fishers handle a large amount of ocean plastic waste generated by international and national land and sea-based operations. While most of this plastic waste is not generated by Australian fishers, it is often managed by them. This assessment will not focus on ocean plastic but acknowledges where handling and management may be considered in collaboration with fisheries' plastic waste.

This assessment considers the landscape of fisheries and aquaculture, and the characteristics of the plastics used, and outlines practical considerations that will theoretically enable recycling.

Identifying options to recover plastic waste

To identify potential practical and fit-for-purpose solutions for recycling plastic waste across the fisheries and aquaculture, industries, it is important to consider the context of fisheries and aquaculture operations, and the complexity of the operating environment.

This assessment highlights a set of high-level steps to provide guidance on how to identify potential solutions. The six steps are illustrated in Figure 5. This assessment also provides details of factors that need to be considered for steps 1-3 in designing those solutions.

Plastic use in commercial wild harvest fisheries and aquaculture

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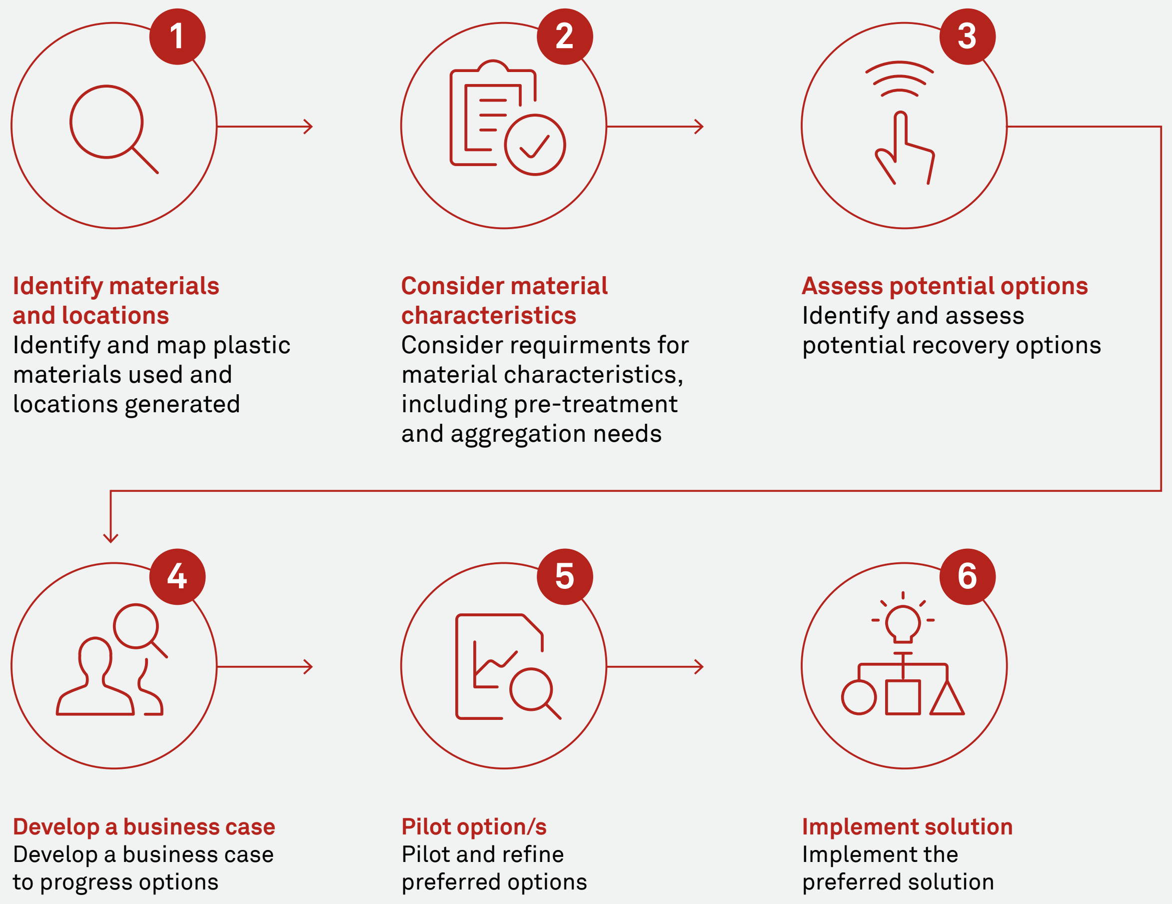

Figure 5. High-level steps to identify and implement potential plastic recovery solutions.

Step 1: Identify materials and locations

Fisheries production by sector and state

There is much variation in operations within wild catch fisheries and aquaculture, and gear and fishing effort is a big determinant of plastic use. However, plastic waste generation is unlikely to be directly related to production. For example, sardines are caught with a concentrated effort by a small number of fishers and in larger quantities. Likewise, salmonoid is farmed in concentrated locations in well-managed systems. Comparatively smaller segments of the industry with a large number of operators in dispersed locations and with low production volumes, such as rock lobster, could have a higher plastic waste generating factor (i.e. more plastics generated per production unit). However, the larger-scale sectors are more likely to have adequate volumes of plastic material to consider for improved management.

Initial analysis of production data (Figure 6) unearthed the following information, which can be used to confirm the target fisheries for further investigation of plastic waste management solutions:

- South Australia has a significant wild harvest fisheries industry (sardines)
- Tasmania has the majority of aquaculture salmonoid operations.
- Wild-caught sardines is a significant commodity
- Wild-caught finfish is a significant commodity (and includes a range of species).

However, this data is by state and therefore does not provide insight into how concentrated the production is by port or region. Some commodities may be concentrated in a particular region or port, while others might be more dispersed and thus have smaller volumes per port.

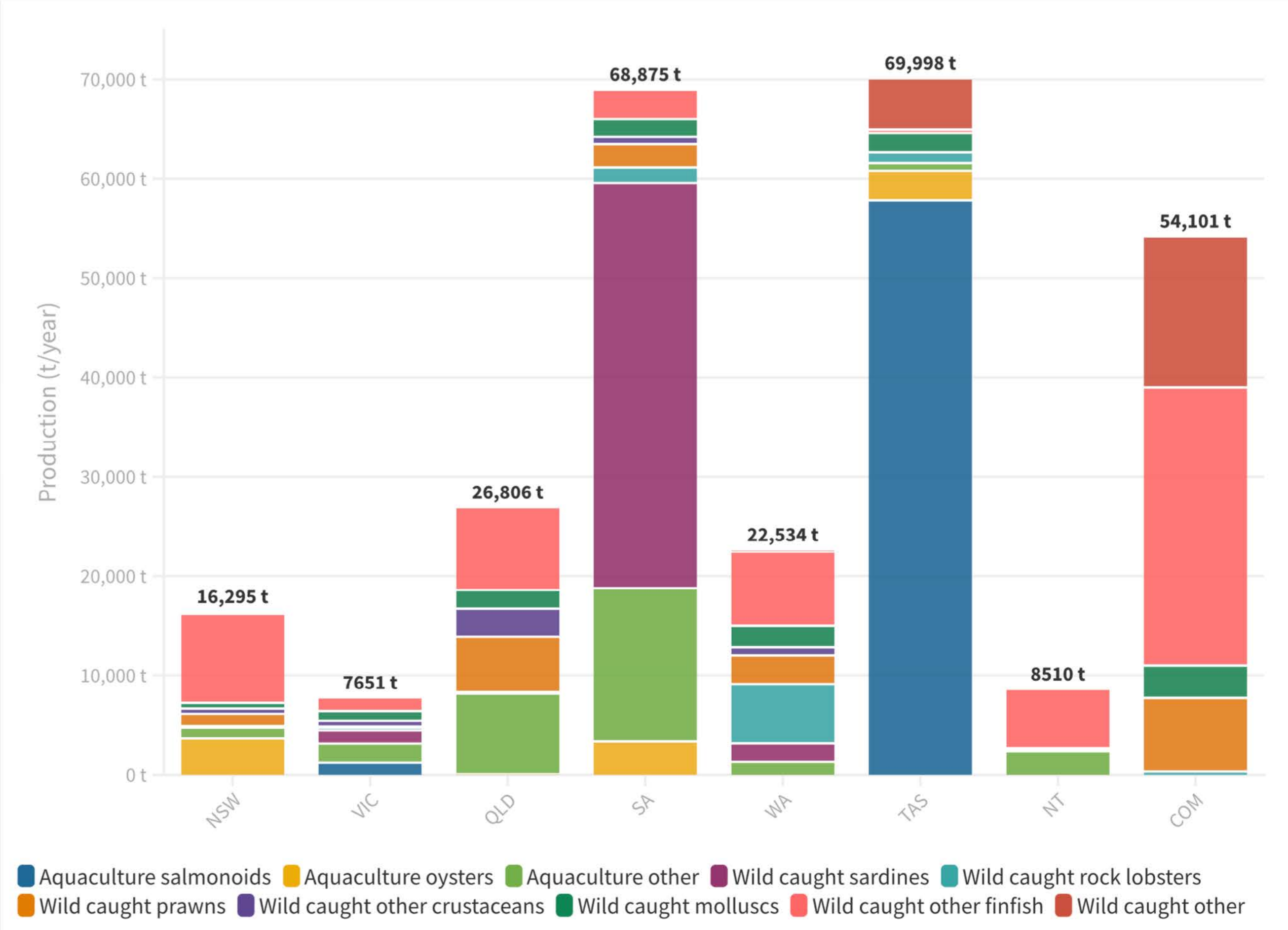

Figure 6. Fisheries and aquaculture production (tonnes) (Steven *et al.*, 2020).

Plastic use in commercial wild harvest fisheries and aquaculture

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Locations of primary landing ports for fisheries

Where primary landing ports for target fisheries are located is another driver that determines the future locations of recycling infrastructures (Figure 7). Australia's fishing industry is regionally based, with catch landing across the Australian coastline. Australia represents one of the largest fishing areas but is a minor producer of fisheries products. This compounds the issues of location and scale when considering opportunities. For example, Australia's major landing port, Port Lincoln, is located more than 680 kilometres from markets in Adelaide.

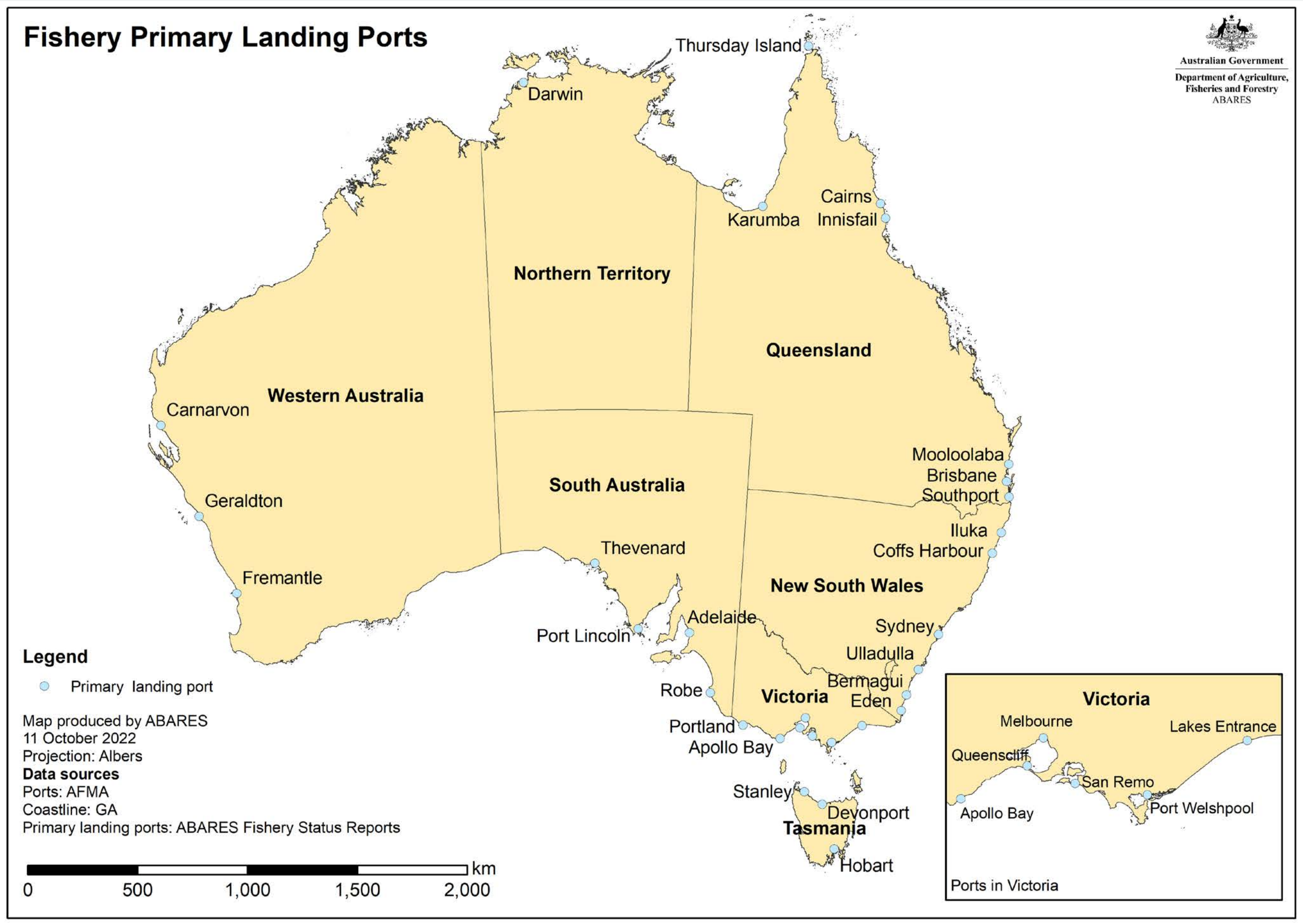

Figure 7. Australia's key landing ports for fisheries (ABARES, 2022). This map is based on Commonwealth fisheries data.

Types of plastic material and composition

Plastic materials can be composed of a range of different polymers, as well as composite polymers. The polymer type, form, volume and material characteristics have implications for possible and viable recycling options. Figure 8 shows the most common plastic material types used in fisheries and aquaculture, as well as how the material is used, the typical polymers that make up the material, and challenges for recycling or recovery.

	Plastic material types					
	Protective film	**Piping and drainage**	**Nets and mesh**	**Bags, twine and ropes**	**Storage, trays and labels**	**Buoys, floats and other**
Common uses	Tank and pond liners Shatter pack plastic film Shrink wrap/film Covers Tarps Shade cloths Algae bags	Feed pipes Water pipes Air lines	Fishing nets Crab and lobster pots Bird netting and rigging Fish pens (netting) Trawl nets Gill nets Pearl oyster panels Catching slat Oyster mesh basket Oyster mesh envelopes	Fishing line Bait box strapping Culture ropes (mussels, oysters) Bags (for bait, tuna, feed) Ropes Product bags	Oyster baskets Storage tanks Culture tanks Tubs Boxes Buckets Tuna mats Compliance tags Drums/ containers	Buoys Floats Collars Jigs
Polymers	Polyvinyl chloride (PVC) High-density polyethylene (HDPE)	Polyethylene terephthalate (PET) Polyvinyl chloride (PVC)	Polyamide nylon (PA) Polypropylene (PP) Polyethylene (PE)	Nylon Polypropylene (PP)	High-density polyethylene (HDPE) Polystyrene (PS) Polycarbonate (PC)	High-density polyethylene (HDPE) Polystyrene (PS) Polycarbonate (PC)
Issues	Composite plastic layers Organic contamination UV degradation	Organic contamination Meta contamination Bulky	Composite plastic layers Other composite material (metal) Organic contamination UV degradation Challenging structure for machinery	Multifilament composite plastics Organic contamination Low-value plastics Challenging structure for machinery	Organic contamination Bulky Low-value plastics	Composite plastic layers Other composite material (metal) Organic contamination UV degradation Low-value plastics

Figure 8. Most common plastic material types used in fisheries and aquaculture, and their uses, indicative polymers and typical challenges.

Plastic use in commercial wild harvest fisheries and aquaculture

Plastic material used in the fisheries and aquaculture sector

The predominant plastic material often relates to the type of gear used. Materials used are mapped to fisheries and aquaculture subsectors in Figure 9. This illustrates that:

- Aquaculture (onshore and offshore) uses the largest range of plastic material types.
- The plastic material types commonly used across subsectors include containers (storage tanks, tubs, boxes, buckets, chemical drums); films (shatter pack, shrink wrap); floats and buoys; rope; and different types of nets used in the offshore aquaculture, trawling, netting and seine sectors (known to be a large waste material stream).

		Offshore longline and rack aquaculture	Offshore caged aquaculture	Onshore aquaculture	Fish trawl and seine	Prawn trawl	Netting	Line fishing	Traps and pots	Dredging	Jigging	Other (incl. hand harvest)
Protective film	Tank and pond liners			●								
	Shatter pack plastic film	●	●	●								
	Shrink wrap/film	●	●	●								
	Covers			●								
	Tarp			●								
	Shade cloth			●								
	Algae bags			●								
P&D*	Feed pipes		●	●								
	Water pipes		●	●					●			
	Airlines		●	●					●			
Nets and mesh	Fishing nets				●	●	●					
	Pots (crabs, lobster)								●			
	Bird netting and rigging		●	●								
	Fish pens (netting)		●	●								
	Trawl nets				●	●						
	Gill nets						●					
	Pearl oyster panels	●										
	Catching slat	●										
	Mesh basket (oyster)	●										
	Mesh envelopes (oyster)	●										
	Fishing lines							●		●		

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		Offshore longline and rack aquaculture	Offshore caged aquaculture	Onshore aquaculture	Fish trawl and seine	Prawn trawl	Netting	Line fishing	Traps and pots	Dredging	Jigging	Other (incl. hand harvest)
Bags, twine and rope	Bait box strapping							●				
	Culture ropes (mussels, oysters)	●										
	Bait bags							●				
	Tuna bags		●									
	Feed bags		●	●								
	Other bags				●	●			●			●
	Ropes	●	●	●	●	●	●	●				●
	Product bags		●	●								
	Oyster bags		●									
	Storage tanks	●	●		●	●	●	●	●		●	●
	Culture tanks				●	●	●	●				
	Tubs	●	●	●	●	●	●	●	●			●
	Boxes	●	●	●	●	●	●	●	●			●
	Buckets	●	●	●	●	●	●	●	●			●
	Tuna mats							●				
	Compliance tags	●			●	●	●	●	●			●
	Drums/containers	●	●	●	●	●	●	●	●			
BF&O*	Buoys	●			●	●	●	●	●			●
	Floats	●	●	●	●	●	●	●	●			●
	Collars		●									
	Jigs											●

*P&D: Piping and drainage
*BF&O: Buoys, floats and others

Figure 9. Plastic material types used by fisheries and aquaculture subsectors.

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Step 2: Consider material characteristics

This step considers the characteristics of the material (quality, physical, volume), including pre-treatment and aggregation requirements. The variables to consider and the fisheries operating context for each of these are described in Table 4.

Table 4. Material characteristics and pre-treatment considerations for designing solutions to fisheries and aquaculture plastic waste.

Variable to consider	Fisheries/aquaculture operating context
Plastic quality Recovered polymer quality will determine the value of the material, amount of sorting required, number of processing steps, best processing technology and whether the polymer has any value for reuse, recycling or energy recovery, or whether it is better landfilled.	**Fishing gear and plastic materials are commonly composed of mixed plastics**. Different polymer types command different values (when mechanically recycled). They also require different levels of processing, e.g. polypropylene ropes require guillotining before shredding. **Fishing gear and plastic materials are often contaminated**. Contamination agents include metals, wood, polystyrene, lead weights, biological contaminants (algae, barnacles, other non-fisheries waste). **Plastic material degrades in the marine environment due to immersion in water, salt and UV light**. Photodegradation occurs via free radical chain reactions initiated by solar UV radiation. Biological degradation is a result of microorganisms in the marine habitat.
Physical product characteristics The size, weight and bulk of materials have implications on handling and logistics.	Moulded or extruded mesh products, such as oyster baskets, can have a low weight-to-bulk ratio, presenting storage and freight challenges. There can be physical handling issues associated with large trawl and seine nets woven in nature due to bulk and weight.
Volume and seasonality of waste generation End-of-season periods tend to generate more waste due to maintenance cycles.	Larger volumes may make reception facilities, pre-sorting and transport viable. Smaller dispersed volumes pose challenges for logistics and therefore potentially have a higher cost. The hub-and-spokes model can work in areas where smaller ports have reasonable connection to larger ports, which then in turn become the collection point or indeed the location of the reception facility. Mobile shredders could aid viability of recovery pathways for some specific material types. Seasonal production can create lumpy supply issues for downstream or onsite processors and collectors.
Requirement for pre-treatment Only materials with a certain (varying) level of contamination will be accepted by recyclers.	Material contaminants are best separated at the source – metals, timber and polystyrene floats, for example, would need to be separated by the fishers. The Icelandic EPR scheme require fishers to separate these elements from nets, including nylon ropes from PP and PE nets (Icelandic Recycling Fund, n.d.) prior to drop off, which increases the value of the material and results in lower pre-processing costs. Collection areas/bins (segregated by material type) would need to be provided at wharves or nearby for fishers to drop contaminants off. Biological contaminants would also need to be removed at the source. This is a key challenge for plastics that stay in the sea, such as oyster baskets and fixed nets. It is often considered this can partially be achieved via shredding. However, an oyster basket shredding trial in 2013 (Rawtec and EconSearch, 2013) recommended the grower removes biological contaminants prior to shredding, which may not be feasible in practice. Larger equipment, such as shredders or balers, would be best located at the aggregation area, which might be the local landfill. Locating these machinery types at the local landfill or a waste contractor would be preferred as licensing would already be in place.

Step 3: Assess potential options

Infrastructure, market and processing capacity considerations

This step considers infrastructure, logistics, technology and markets. The variables to consider, and the fisheries and aquaculture operating context for each of these, are described in Table 5.

Table 5. Infrastructure, market and processing capacity considerations for designing solutions to fisheries and aquaculture plastic waste.

Variable to consider	Fisheries/aquaculture operating context
Cost	There are four areas where cost may be prohibitive to recycling fishing plastic materials: • Infrastructure costs • Freight costs to transport end-of-life fishing gear and materials to a recycling facility • Source separation of different materials and removal of contamination • Gate entry fee to drop end-of-life gear and materials at the receiving facility. Initial set-up costs for collection infrastructure may be significant. These can include site preparation, infrastructure, pre-treatment equipment and handling equipment. High contamination rates (both organic and inorganic) will require some pre-processing/sorting at the source. This adds to cost and requires higher volumes to justify mechanical solutions (such as shredding). Without guaranteed revenue streams ensuring a commercial pay-back, this infrastructure investment will be a barrier for contract collectors. Direct wharf-side collection may be feasible for intensive fishing ports, but costs may not justify the solution for smaller fleets.
Infrastructure	Infrastructure requirements will depend on the characteristics of the material and can include: • Site preparation (shed, slab, services) • Aggregation infrastructure (skips, shipping containers) • Pre-treatment equipment (de-contamination, shredder, balers) • Mechanical handling equipment (forklift, loader). Size reduction (baling or shredding) equipment will be required for plastics aggregation to maximise freight efficiency. Some materials (e.g. oyster baskets) are highly freight inefficient and their size must be reduced onsite. Mechanical handling equipment will be required for heavier materials (e.g. seine nets) and to load bales or bulk bags for transport.
Logistics	Logistics in remote regions are characterised by large distances between smaller generation points (ports) and aggregation points (reception facilities/larger ports), and between aggregation points and processing facilities and end markets. There are few processors/recyclers in regional/rural areas, making logistics more complex as material must be transported to capital cities for sale and processing.
Contamination and standards	Contamination of plastic material will reduce yield, complicate source segregation, increase cycle time for baling and increase transport costs. Quality assurance (QA) standards adopted by processors may lead to load rejection if the contaminant level is deemed too high – so source QA processes will add cost.

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Variable to consider	Fisheries/aquaculture operating context
Labour	Collectors will be required to travel long distances in early scheme stages to collect economic volumes. The associated cost may limit the viability. Also, given shortages in the current labour market (Downham and Litchfield, 2022), competition for skilled operators could create a barrier to retaining skilled operators when considering the potentially unattractive travelling requirements.
Plastic recycling processing capacity	In Australia, current plastic waste generation far exceeds the existing mechanical recycling capacity. This has been further exacerbated by the export ban of mixed plastics (DCCEEW, 2022a), resulting in increased pressure on existing processors and demand for their services. At the time of writing, only four processors[11] have the capability to recycle plastics with any (low) organic matter contamination. This combined capacity is less than 40,000 tonnes per year. This is resulting in low prices and added volatility due to processors being able to 'cherry pick' cleaner material. Cleaner material is quicker to process, which costs the recycler less. The small number of processors means fisheries and plastics operators may have to chase markets, shipping material nationally rather than to their nearest processor, to get the best price. There is currently limited capacity at processors to sort unsegregated plastics. Advanced recycling, the most suitable solution for mixed polymers from fishing nets, is still in the early stages of development in Australia, and processors will charge a gate fee for material. There is more capacity with waste-to-energy solutions, as processors take numerous feedstocks in addition to plastics[12] to create processed engineered fuel briquettes for fuel. All have significant gate fees. Most processors accept shipments of a certain volume (usually a minimum of 20 tonnes per polymer type), which can create storage and shipment issues as less-frequently-used plastics are stockpiled to create a commercial load.
Plastics recyclates market	Processors will pay varying prices for polymer types and grades depending on market demand, creating uncertainty for budgeting scheme costs. Collectors could potentially have to stockpile some polymer types if demand is low, incurring holding costs. Mechanically recycled mixed plastics have a limited market, confined for use in the manufacture of downcycled materials that incorporate composite materials, such as plastic lumber and furniture. The size of this market is small in Australia (less than 15,000 tonnes per year), with ample existing feedstocks. A small or negative price could therefore be expected. Advanced recycling or waste-to-energy solutions are the likely options for mixed plastics but these come with significant gate fees per tonne of waste.
Circular economy	Most commercial fishing materials are imported (primarily from China, India and South Korea). Minimal local manufacturing capability reduces the opportunity for materials to be made back into fishing gear domestically. The only fully circular option is to export recycled polymer feedstock under new export legislation back to the overseas manufacturer.[13] The shortfall in local recycling and remanufacturing capacity, especially for pre-farm gate plastics, could potentially leave an EPR scheme with an expensive collection system but no viable end markets for the plastics. Until robust processing infrastructure and end markets are established, suppliers will see this as a major barrier to scheme establishment.

[11] Polymer Processors, Plastic Forests, Olympic Polymers and Resitech.

[12] ResourceCo plants produce processed engineered fuels from select dry commercial, industrial, mixed construction and demolition materials, including plastics.

[13] Since 1 July 2022, export waste plastics must be sorted into single resin or polymer type and further processed, for example flaked or pelletised; or processed with other materials into processed engineered fuel. See DCCEEW, 2022a.

Variable to consider	Fisheries/aquaculture operating context
Extended producer responsibility (EPR) scheme	The introduction of a levy to fund an EPR scheme may be viewed as a potential anti-competitive cost barrier, exposing participating suppliers to greater price competition from direct imports and free riders. Suppliers are likely to want input into the quantum of a proposed levy and how it would be spent. An independent scheme design and governance structure for product stewardship could potentially leave suppliers with no say in how levy funds are administered. A voluntary EPR scheme can overcome some of the potential barriers. Such a scheme might include a board made up of industry representatives that determines the levy and how funds are spent.

Recovery and recycling technology considerations

This step considers the potential types of technologies and pathways. At a high level, Figure 10 illustrates the concept of recovery potential considering the waste hierarchy and circular economy principles, with the most preferred option shown at the top of the figure.

Pathways for plastic material types used in fisheries and aquaculture, and the materials' potential fates, are illustrated in Figure 11. It is likely the options higher in the hierarchy will take longer to achieve; that is to say that given the current landscape, consolidation and landfilling may be the best option available but as technologies and recycling markets develop, other recovery options could be accessed. Also, as the industries change, it is likely the higher-order options of redesign or circular design concepts are developed.

Design for reuse and recycling
Redesign gear type with the management pathway front of mind; for example, standardising using single polymer and higher-value polymers.

Repair and reuse
Use material types in different configurations to extend their lifespan.

Mechanical recycling
Solution for some single-source polymers, lower carbon footprint, higher plastic value.

Advanced recycling
Solution for mixed plastics, can create naphtha feedstock for new polymers or fuels.

Waste to energy
Too contaminated for recycling options, high calorific value, burnt for energy.

Landfill
Contaminants or plastics unsuitable/cost-prohibitive for the above options, inert when burnt.

Figure 10. Hierarchy of potential plastic waste recovery.

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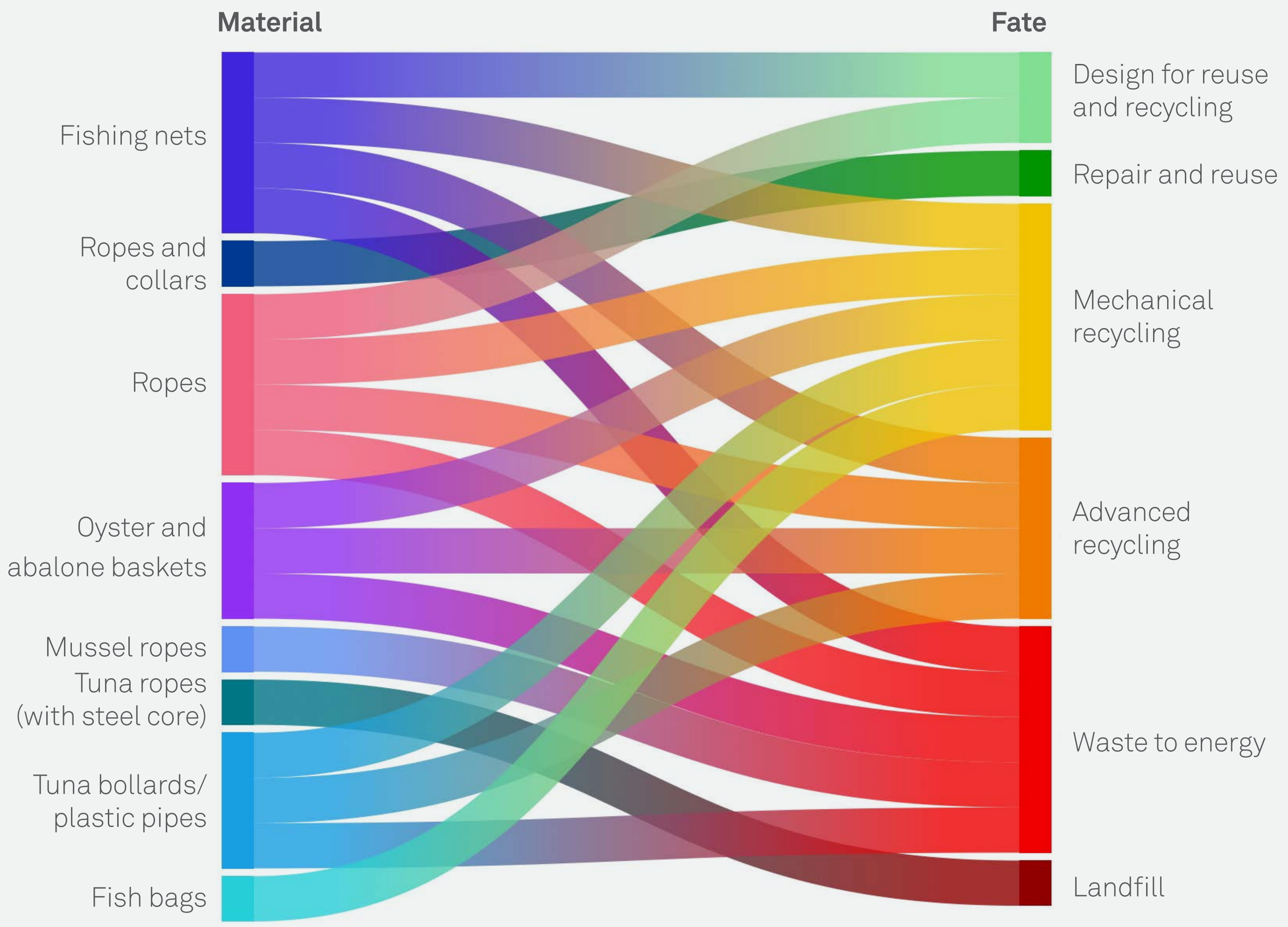

Figure 11. Potential recycling options and/or pathways for plastic material types.[14]

Recommendations

Recommendations for developing a solution to deal with plastic waste in the fisheries and aquaculture sector are:

1. Conduct a commercial fisheries and aquaculture plastic data collection project to estimate the volume, nature (polymer, form, laminates, contamination) and locations of plastic waste generated and stockpiled annually. It is unlikely that annual audits will be practical. One method could be to develop generation factors that can be linked to production and modelled for updates. Alternatively, gear labelling can assist in collecting data, which can then be tracked in a centralised system. The aim of the data capture is to inform identification of priority sectors, plastic materials and/or ports, and to track change.
2. Work with priority sectors or ports to develop a business case(s) for infrastructure upgrades (at ports). This major piece of work would include:

   a. Assessing technologies used for recycling fisheries and aquaculture plastics, considering realistic end markets for recycled polymers and the circularity of products. Consider international examples such as Plastix and Aquafil (Fritts, 2017).

   b. Sampling and trialling processing with existing recyclers to determine material presentation requirements and the most sustainable destinations.

   c. Collaborating regionally with fisheries/aquaculture groups, local government and industry contractors for solutions to stockpiling and pre-treating plastic.
3. Pilot infrastructure upgrades (e.g. reception facilities) at a case study site (e.g. port)
4. Develop a business case for an extended producer responsibility (EPR) scheme that:

   a. Learns from other countries that are more advanced in this area. Iceland has the most advanced fishing EPR scheme, with a fishing nets recovery rate of least 80% (Icelandic Recycling Fund, n.d.) while Canada is halfway through implementing a fisheries EPR program.

   b. Links in with other EPR schemes, e.g. the *National Agricultural Plastics Stewardship Scheme*, to consider shared infrastructure, administrative resources and logistics costs.

   c. Engages fishers in scheme trials to ensure workable solutions are designed that have 'buy in' from the waste generators.

   d. Works with industry groups to create sustainability certification accreditation to encourage participation.

   e. Implements trial collection and processing methodologies.
5. Investigate and promote plastic circular design options, such as:

   a. Redesigning for recycling

   b. Changing the operating model – using assets in a different way, e.g. leasing, where the owner takes materials back at their end-of-life and recycles them

   c. Designing for improved capacity to repair/refurbish and reuse

   d. Manufacturing using recyclates in Australia and sending recycled raw material from Australia overseas to enable the same to happen in other countries.

   e. Seeking information that identifies where products can be manufactured with less variability in plastic polymers.

   f. Developing the market for recycled gear.
6. Monitor recycling market developments, including new locations where material can be turned into processed engineered fuels, and where there is increased mechanical and advanced recycling capacity. The *Recycling Modernisation Fund* investment (DCCEEW, 2022b) will increase capacity.

[14] Thickness of line does not reflect tonnages.

Plastic use in commercial wild harvest fisheries and aquaculture

Port Lincoln case study

At a glance

Port Lincoln is the largest fishing port in Australia, with both a significant commercial fishing boat fleet and a thriving aquaculture industry. Existing plastic waste stockpiles are estimated to be between 2,500-3,000 tonnes and the annual generation of more than 750 tonnes is adding to the issue.

Recycling trials have been undertaken, and are currently operating, in the region, including shredding oyster baskets and granulating PE nets and pipes. These technologies are basic and have not had the capacity or capability to deal with the volume and complexity of plastic in the region.

Recommendations include the development of a robust business case to identify pathways for the volume and complexity of plastic generated. Further, the business case should consider robust recycling processes (including potential overseas markets) and the viable settings required to support resource recovery, such as an EPR scheme.

Focusing on the Eyre Peninsula and Port Lincoln will generate information that can be used for a blueprint approach for Australian ports more broadly.

Introduction

Port Lincoln is the largest fishing port in Australia, with both a significant commercial fishing boat fleet and a thriving aquaculture industry. Port Lincoln is Australia's largest producer of fish and shellfish products. The port is located on the southern end of Eyre Peninsula, which also has six smaller ports (see Table 6). The port has a history of cross-industry collaboration and has conducted research into the type and quantity of plastic waste, as well as research into and trials of waste recovery solutions. This case study highlights the steps for identifying potential solutions at Port Lincoln.

Identifying plastic materials and locations

The Eyre Peninsula hosts a wide range of fisheries and aquaculture industries (Table 6). The ports in the region are listed as they may be important when considering a hub-and-spokes model across the region, i.e. not solely Port Lincoln.

The range of plastic waste generated in Port Lincoln varies by industry, with some industries operating seasonally. Materials are composed of different polymers, often mixed with other materials (e.g. lead weights and timber), and at their end-of-life are often contaminated with organic material (growth). The main types of plastic used by each industry and, where known, the different plastic compositions and annual waste generation are described in Table 7.

In 2016, the project *Review of aquaculture and wild-catch fisheries waste on Eyre Peninsula and options for future waste management* investigated the volumes of plastic waste and opportunities for recycling on the Eyre Peninsula (JCAM, 2016). The project report described the types of plastic generated and stockpiled. Stockpiles at the time included:

- 1,000 tonnes of mixed fishing nets, growing by 100 tonnes per year
- 1,200 tonnes of oyster baskets
- 100 tonnes of abalone baskets
- 12-20 tonnes of tuna bollards and plastic pipe, growing by 1.2-2 tonnes per year
- IBC containers.

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Table 6. Ports and key industries on the Eyre Peninsula.

Eyre Peninsula ports	Commercial fisheries and aquaculture industries
Port Lincoln	**Aquaculture:** Offshore – southern bluefin tuna (SBT), yellowtail kingfish, mussels and *Asparagopsis* (emerging aquaculture sector). Onshore plus offshore – abalone, oysters. **Fisheries:** SBT, Sardine, Spencer Gulf Prawn (SGP), Northern Zone Rock Lobster (NZR), Marine Scalefish Fishery (MSF), Western Zone Abalone (WZA), Great Australian Bight Trawl (GAB) and Gill Hook and Trap (GHT).
East Coast	
Arno Bay	**Aquaculture:** Yellowtail kingfish (hatchery) **Fisheries:** MSF and Blue Crab Fishery (BCF)
Cowell	**Aquaculture:** Oysters **Wild caught:** MSF, SGP and BCF
Whyalla	**Aquaculture:** Yellowtail kingfish **Wild caught**: MSF
West Coast	
Coffin Bay	**Aquaculture:** Oysters (onshore and offshore) **Wild caught:** Sardines, MSF, NZR, WZA, GHT, West Coast Prawn (WCP) and Vongole Fishery (VF)
Elliston	**Aquaculture:** Abalone (offshore) **Wild caught:** MSF, NZR and WZA
Venus Bay	**Fisheries:** VF and WCP
Sceale Bay	**Wild caught:** MSF and WZA
Streaky Bay	**Aquaculture:** Oysters **Wild caught:** MSF, NZR, WZA, GHT and VF
Smoky Bay	**Aquaculture:** Oysters **Wild caught:** MSF, WZA and VF
Ceduna	**Aquaculture:** Oysters **Wild caught:** MSF, WZA, NZR, GAB, GHT and WCP

Table 7. Eyre Peninsula fisheries sectors, plastic materials they use, and the compositions, fates and estimated amounts generated of those materials.

Industry	Plastic waste material	Plastic composition	Current fate	Estimated volume (#)
Tuna	Nets, ropes, shrink wrap, pontoons, pipe	Nets – polyester Ropes – nylon Shrink wrap plastic (LDPE)	Landfilled/ recycling	Nets – 56 tonnes/year Ropes – 700 kg/year Bollards – 1.2-2 tonnes/year
Mussel	Mussel floats, rope, 6 mm ties	Polypropylene	Tuna	Tuna
Sardines	Sardine nets	Braided mesh nylon net, 1.5 mm thick, leaded rope at the bottom, polyethylene float along the top	Stockpiled/ landfilled	10 tonnes/year
Kingfish aquaculture	Ropes, nets, feed bags, stanchions, pen collars	Nets – nylon Rope – polypropylene (60% of the ropes only have a 12-month lifespan) Bags – polyethylene (can be oil contaminated) Stanchions and collars – HDPE	Stockpiled/ landfilled	375 tonnes/year
Oysters	Baskets, clips and risers, dripper tube, bakelite* (inside dripper tube for longline system), buckets and tubs, shipping packaging and liners, poly bags, shrink wrap	Multiple polymers, bakelite*		150-200 tonnes/year (Rawtec and EconSearch, 2013)
Prawn	Nets, ropes, plastic tubs/baskets	Net compositions vary and include polyester, nylon, polyethylene and dyneema	Stockpile/ landfilled Wire rope (recycled)	Nets – 1.95 tonnes/year Codend – 0.39 tonnes/ year Wire rope (12 mm) – 27.3 km/year

Estimated based on industry consultation and JCAM, 2016.
* Bakelite is the common name of polyoxybenzylmethylenglycolanhydride.

Plastic use in commercial wild harvest fisheries and aquaculture

Considerations for designing plastic recovery options

The plastic material types and compositions are many and varied. This makes recovery of plastic material in Port Lincoln complex. Further, the port is not located close to existing recovery and recycling facilities and services, and thus transport and logistic costs are a major barrier.

The ability of the industries that operate in Port Lincoln to participate in comprehensive recovery has been hindered by:

1. Quality and characteristics of the plastic, especially considering the value proposition of fisheries-derived plastic compared with that of clean household/ commercial plastic streams.
2. Lack of existing reception facility and pre-processing infrastructure.
3. Cost associated with transport to markets – Adelaide is more than 680 kilometres away.
4. Available recovery and recycling pathways.

The Port Lincoln community has participated in trials, one example being a mobile plastic shredder targeting oyster basket pre-processing, which made it viable for densified and cleaned plastic to be sent to market. Individual businesses have also sought recycling options for specific material to be transported to Adelaide. However, the lack of pre-processing infrastructure and limited capacity of operators has made continual participation impossible. Many industries are managing stockpiles or alternatively using the local waste facility, where most of the plastic is stockpiled.

Assessing potential options for Port Lincoln

The Port Lincoln fisheries and aquaculture community has identified an opportunity to collaborate across industries. Examples of good stewardship include reusing and repurposing ropes for floats and buoys or collars for use by oyster farms or within agricultural operations. However, as described above, most plastic waste generated does not have a practical or viable pathway.

Establishing a local reception facility that can aggregate and pre-process, and potentially re-manufacture, plastic is considered an important first step to addressing the issue. This could also function as a central location for other ports on the peninsula. A facility, which could be located within the existing waste station or on a new site, could continually, and in an adaptive way, seek the best solution for each plastic.

Shredding of oyster and abalone baskets is an option that has been trialled and is being further investigated. The South Australian Oyster Growers Association (SAOGA) used a mobile shredding unit and cleaned up 40 tonnes of stockpiled oyster baskets in Smoky Bay (SAOGA, 2020). However, several reports suggest this service is currently not available, with SAOGA in discussions with a local entrepreneur to find a process solution to address the issue and create a market.

Granulation and/or shredding is a basic recovery option for plastic pipes and some nets, noting this is unlikely to be a suitable solution for nylon. In August 2022, SABRN Circular opened a proof-of-concept processing plant targeting fisheries and aquaculture plastic (Smith, 2022). SABRN's current technology includes a two-step process: (1) a granulator and (2) a prototype press, which turns the granules into plastic tiles aimed for local markets. This trial technology capacity can process piping (PE) and prawn nets (PE), and has a current capacity of 500 kilograms per day, or approximately 130 tonnes per year. A key focus of this trial has been to de-centralise recovery and manufacturing to the regional areas where the waste is generated. Continual collaboration between the fisheries/aquaculture sector and plastic processors and manufactories with this focus is needed to increase processing capacity and range.

In the short to medium term, landfilling of some complex plastic is likely to be required. However, with a reception facility, the processes for sorting and decontamination could increase recovery potential by improving the viability of sending clean and pre-processed plastics to a market. For example, contamination of plastic nets can make up 20-30% of the weight, and with this contamination removed, local transport viability would increase. A reception facility that aggregates and sorts plastics would also be well-positioned to explore options such as turning complex plastics into a form in that can be used for energy.

An example from a Canadian port seeking a fishing net recycling solution highlights that direct collaboration with overseas plastic recyclers, such as Aquafil and Plastix, is possible, and that recycling technologies for fisheries plastics exist (Fritts, 2017). Initially, only nylon net was aggregated and cleaned before being sent for recycling by Aquafil in Slovenia, but the port cooperative is working on capturing other plastics to send to Plastix in Denmark.

Next steps for Port Lincoln

The Port Lincoln community has worked collaboratively and extensively to identify and consider the landscape of plastic use and opportunities. Further, several options have been explored and trialled. However, the trials completed and underway do not have the capacity to handle the amount or range of plastic material. Further, the market for the recycled plastic is underdeveloped, leaving the options exposed to high risk.

The next step for Port Lincoln is to assess the material types (volumes, composition) and options in more detail. This assessment can be used to inform the development of a business case and implementation plan to increase the capacity of processing in the region. Identifying robust recycling processing and manufacturing options that can handle the quantity and complexity of generated plastic should be the focus. It is likely that this will include some element of an EPR scheme and also centralised or overseas recycling processing.

Port Lincoln is Australia's largest port and the Eyre Peninsula supports significant additional sectors and ports. The industry bodies and businesses that operate across the peninsula are engaged and seeking pathways for change. A process that effectively facilitates change in Port Lincoln could become a blueprint for other ports.

5 Other options

A longlist of options (64) was developed and is described by waste stream. Appendix E provides a more detailed description and a high-level assessment of the strengths, weaknesses, opportunities and threats (SWOT) for each of the longlist options. The options are categorised under 'Organic', 'Plastic' and 'Workshop' waste.

Organic

Option selected for case study

1. Whole crop purchasing

Shortlisted options from the assessment

1. Upcycling vegetable waste into powders
2. Transforming product loss into animal feed using heat treatment or black soldier fly technology
3. Using a mobile laboratory to produce oil, protein and other products from raw fisheries waste
4. Producing clothing and textiles from agricultural waste
5. Freezing and freeze-drying second-grade fruit to be sold in alternative markets instead of disposed
6. Utilising food waste on farms as feed for edible insects
7. Creating compostable shopping bags from waste banana stalks/trees
8. Composting fish waste

Other options not shortlisted

1. Using nanotechnology to improve the properties of compostable packaging made from sugar cane
2. Regenerating reef ecosystems using seafood shells
3. Generating biogas from on-farm vegetable waste
4. Pelletising compost products
5. Feeding product loss to animals
6. Exploring upcycling of product loss into nutritious food options
7. Producing hydrogen fuel and fertilisers from farm waste
8. Growing more resilient crop varieties to reduce inputs
9. Promoting greater industrial symbiosis within the sector through planning
10. Recycling mushroom substrate into compost and casing
11. Using a rotary drum composter in the poultry industry
12. Certifying fisheries that prevent gear loss and operate sustainably
13. Upcycling prawn shells to prawn oil
14. Turning forestry residues into marketable energy products
15. Recycling spent berry coir or using it in compost
16. Using almond waste to produce power, compost and potassium-rich ash for orchards
17. Reducing crop waste using machine learning-driven technology to assist with precision agriculture
18. Establishing co-generation plants for sugarcane
19. Implementing an auditable system requiring sound waste management to certify Australian products as sustainably made

Plastic

Options selected for case study

1. Using certified soil biodegradable plastics
2. Establishing reception facilities that accept unwanted fishing gear and assessing opportunities to recycle nets, ropes and gear

Shortlisted options from the assessment

1. Using sisal, jute or hemp instead of plastic counterparts for plant twine, ties and nets
2. Expanding closed-loop recycling of aquaculture plastics

Other options not shortlisted

1. Establishing a database to report and find ghost nets
2. Collecting and recycling banana bags
3. Exploiting enzymes that depolymerise plastic and enable recycling
4. Leasing reusable pallets and containers
5. Promoting sustainability in the marine industry to improve environmental outcomes and rehabilitate marine habitats
6. Using reusable crates to replace EPS crates for fish
7. Implementing greater standardisation of plastics to improve the viability of recycling
8. Implementing standards requiring minimum thickness of non-biodegradable mulch films to facilitate retrieval
9. Using hydroponics irrigation methods instead of irrigation tape
10. Using recycled-content field plastics in place of virgin plastic products
11. Using organic alternatives to polystyrene for produce packaging
12. Recycling plastic mulch into other products for use on farm
13. Collecting and recycling plant pots
14. Replacing plastic tree guards with compostable guards
15. Using a mobile plastic baler to recycle plastics
16. Establishing an IBC challenge on Twitter
17. Increasing traceability and accountability of plastic film
18. Replacing plastic ear tagging of livestock with AI or injectable transponders
19. Implementing a plastic ear tag deposit return scheme to incentivise famers to collect the waste
20. Incentivising farmers to bring clean waste streams into transfer stations
21. Using compostable pots or meshes instead of plastic tubes/cells for forestry seedlings
22. Requiring fishing gear to be designed to prevent ghost fishing
23. Requiring products to be labelled with their expected effective working life

Workshop

Option selected for case study

1. Shifting to alternatives to treated timber posts

Other options not shortlisted

1. Running campaigns about leasing farm equipment and tools
2. Providing a steel post straightening service
3. Expanding pesticide spraying services to prevent chemicals being stored on farm
4. Increasing the durability of materials and reducing inputs through nanotechnology
5. Promoting the use of integrated pest management to reduce pesticide use
6. Trading obsolete farm machinery and equipment to recover scrap metal
7. Expanding and improving the product stewardship scheme for agricultural drums
8. Reversing logistics and takeback programs to prioritise reuse

Appendix A

Key assumptions

A list of assumptions for each of the alternatives is listed below. It is noted that these may differ depending on the unique situation of the vineyard or the brand of post, among other factors. However, these are what has been assumed for the analysis.

Table 8. Key assumptions for CCA and alternative posts used in comparison analysis.

Area	CCA post	Steel post	Untreated post covered in recycled plastic	Wood-plastic composite post	Notes
Size of post (intermediate post)	2.4 m, 95-130 mm diameter	2.4 m, diameter unknown (4.2 kg is the post weight)	2.4 m, 83 mm diameter	1.8 m, 100 mm diameter	Other sizes are available
Price per post (intermediate post)	$12 per post not including install	$19 per post not including install	$18.65 per post not including install	$23.40 per post not including install	Price will differ depending on the number of posts ordered and the price of steel/timber, among other factors
Installation of new post (intermediate post)	$6.70 if installing the new post without removing the old post	$5 if installing the new post without removing the old post	$6.70 if installing the new post without removing the old post	$6.70 if installing the new post without removing the old post	Assuming posts are for new plantings (i.e. no previous posts to remove)
Posts per hectare (strainer not included in analysis)	650 intermediate posts	650 intermediate posts	650 intermediate posts	650 intermediate posts	Assuming alternatives can be swapped one-for-one with CCA
Average lifespan of posts	30 years	30 years	30 years	30 years	Can vary depending on a range of factors
Average breakages per year	3.5% of stock	2.5% of stock	3.5% of stock	3.5% of stock	Breakage depends on brand and size (thickness)
Cost to remove old post (not including disposal)	$2 per post	$1.50 per post	$2 per post	$2 per post	
Transport and disposal/recycling cost (year 1)	$208.31 per tonne	-$70 per tonne revenue	$100 per tonne	$94.81 per tonne	Transport cost of $80 per tonne assumed for all, and assuming CCA posts can be disposed at landfill
Increase in landfill levy rate per year	5%				Only relevant for the CCA post scenario

Whole-of-life costs – findings when considering discounted cash flow

Vineyard managers/owners make large investments in posts when establishing their vineyards, so it is important to consider opportunity cost. This is done by considering discounted cash flow over a 30-year period, and calculating the net present value of each option. We did this at year 0 and year 30. The results are presented for an average vineyard (estimated at 10 hectares[15]) and per hectare of viticulture. Dollars are presented as costs (negative figures) as there are no savings associated with purchasing posts.

When considering discounted cash flow, the cost to purchase CCA posts over a 30-year cycle is lower than the alternatives (Table 9). This is a different finding from the analysis presented in the main body of this report, which did not consider discounted cash flow. This is because the cost at year 0 is significantly lower for CCA posts ($122,000 to buy CCA posts for a 10-hectare vineyard) than the alternatives (between $150,000 and $200,000). Therefore, a vineyard that chooses CCA posts has more cash available at the start, which could be invested elsewhere, with the potential benefit of this reflected in the figures.

Steel posts remain a strong alternative, with the NPV at year 30 $2,200 higher per hectare than CCA posts. Untreated timber posts encased in recycled plastic are about $5,300 higher per hectare than CCA posts over 30 years, while wood-plastic composite posts are $10,000 higher per hectare.

When these figures are applied to the entire Australian viticulture industry (146,000 hectares) (Wine Australia, 2022), the cost of CCA posts over 30 years is estimated at $2.7 billion, steel posts at $3 billion, untreated timber posts encased in recycled plastic at $3.5 billion and wood-plastic composite posts at $4 billion.

[15] Consultation with the wine industry.

Appendix A

Table 9. Whole-of-life costs considering net present value (considering a discounted rate of 10%) for CCA versus three alternatives.[16]

	Average vineyard (10 hectares)	Per hectare of viticulture	Per hectare of viticulture
Assumed number of posts installed	6,500	650	
	$ (values are negative as posts are a cost to the vineyard)	$ (values are negative as posts are a cost to the vineyard)	$ difference to CCA (higher negative value indicates higher cost than CCA)
Upfront costs in year 0			
CCA	-$122,000	-$12,200	
Steel	-$156,000	-$15,600	-$3,400
Untreated timber encased in recycled plastic	-$165,000	-$16,500	-$4,300
Wood-plastic composite	-$196,000	-$19,600	-$7,400
NPV at year 30			
CCA	-$183,000	-$18,300	
Steel	-$205,000	-$20,500	-$2,200
Untreated timber encased in recycled plastic	-$236,000	-$23,600	-$5,300
Wood-plastic composite	-$283,000	-$28,300	-$10,000

Sensitivity analysis on key variables (not considering discounted cash flow)

We considered two factors in our sensitivity analysis to assess the impact of changing some of the assumed figures on the average cost per hectare over 30 years (not considering discounted cash flow): (1) upfront cost and (2) installation cost.

Table 10 presents the sensitivity analysis on the upfront costs. Of note:

- Steel can increase to a little under $20 per post (model currently assumes $19 per post) before CCA becomes the lower whole-of-life cost option.
- Untreated timber encased in recycled plastic must reduce to between $14 and $15 per post (current assumption is $18.60) to have a lower whole-of-life cost than CCA posts.
- Wood-plastic composite posts must reduce to between $13 and $14 per post (current assumption is $23.40) to have a lower whole-of-life cost than CCA posts.
- The current assumption for CCA posts is $12 per post not including installation.

Table 11 presents the sensitivity analysis of installation costs. Currently, CCA installation is assumed to be $6.70 per post not including disposal of an old post. Of note:

- If the installation cost of steel posts increased from the currently assumed $5 per post to $6 per post, they have a similar whole-of-life cost to CCA posts.
- The installation cost for untreated timber posts encased in recycled plastic needs to decrease to $2.75 per post to have a similar whole-of-life cost to CCA posts.
- The installation cost for wood-plastic composite posts can decrease to $0 per post and the whole-of-life cost would remain higher than CCA posts.

Sensitivities on disposal costs per tonne and transport costs per tonne were also explored. These had minimal impact on the whole-of-life cost analysis.

Table 10. Sensitivity analysis on assumed $/post cost not including installation. Note: CCA is assumed to be $12 per post, or $7,800 per hectare. Negative values (red text) are a net cost.

Steel		Untreated timber encased in recycled plastic		Wood-plastic composite	
Price ($/post)	**Cost difference to CCA ($/ha over 30 years)**	**Price ($/post)**	**Cost difference to CCA ($/ha over 30 years)**	**Price ($/post)**	**Cost difference to CCA ($/ha over 30 years)**
Current – $19	$52	Current – $18.65	-$252	Current – $23.40	-$623
$12	$462	$12	$177	$12	$113
$18	$111	$14	$48	$13	$49
$20	-$6	$15	-$16	$14	-$16
$21	-$65	$16	-$81	$15	-$81
$22	-$123	$17	-$145	$21	-$468

Table 11. Sensitivity analysis on assumed $/post cost for installation. Note: CCA is assumed to be $6.70 per post, or $4,366 per hectare. Negative values (red text) are a net cost.

Steel		Untreated timber encased in recycled plastic		Wood-plastic composite	
Cost $/post install	**Cost difference to CCA ($/ha over 30 years)**	**Cost $/post install**	**Cost difference to CCA ($/ha over 30 years)**	**Cost $/post install**	**Cost difference to CCA ($/ha over 30 years)**
Current – $5.0	$54	Current – $6.7	-$252	Current – $6.7	-$623
$5.5	$25	$2.0	$53	$0.0	-$189
$6.0	-$4	$2.5	$21	$0.5	-$222
$6.5	-$33	$3.0	-$12	$1.0	-$254
$7.0	-$63	$3.5	-$44	$1.5	-$286

[16] These figures are based on several assumptions. Each vineyard is unique and costs would vary depending on the number of posts purchased, location, ease of installation, etc. Timing can also influence price – steel prices can fluctuate and increase the purchase price of steel posts. We recommend receiving quotes to confirm our assumptions. Note that the steel failure rate is 2.5% and CCA 3.5%. We understand the steel failure rate can vary depending on the brand of post and product size/strength. If the failure rate was 1% for steel, the NPV at year 30 would be stronger than CCA.

Appendix B

Key assumptions used in cost analysis

Key assumptions underpinning analysis of whole crop purchasing for bananas are shown in Table 12.

Table 12. Assumptions on production and losses/waste in the Australian banana industry.

Item	Units	Estimate	Sources
Production per hectare	t/ha	40	Calculation
Production per average farm	t/year	1,255	Calculation
Total production in Australia	t/year	414,000	Hort Innovation, 2022
Number of farms	N	330	Calculation
Average loss in shed (as percentage on top of yield)	%	15%	Australian Banana Growers' Council
Loss of bananas in shed	t/year	71,415	Calculation
Mechanical damage	%	18%	Australian Banana Growers' Council
Knife cuts	%	32%	Australian Banana Growers' Council
Cigar end rot (pathogen)	%	1%	Australian Banana Growers' Council
Other insect damage (caterpillar)	%	1%	Australian Banana Growers' Council
Sap	%	5%	Australian Banana Growers' Council
Finger rub	%	16%	Australian Banana Growers' Council
Maturity bronze (physiological)	%	11%	Australian Banana Growers' Council
Neck injury	%	6%	Australian Banana Growers' Council
Point scar (old marks)	%	7%	Australian Banana Growers' Council
Fused fingers (morphological)	%	2%	Australian Banana Growers' Council
Undersized (morphological)	%	1%	Australian Banana Growers' Council
% losses due to aesthetic standards (size, shape)	%	10%	Australian Banana Growers' Council
% losses due to product damage but still edible	%	88%	Australian Banana Growers' Council
% losses – inedible fraction	%	2%	Australian Banana Growers' Council
Total losses due to aesthetic standards (size, shape)	t/year	7,100	Calculation
Total losses due to product damage but still edible	t/year	62,800	Calculation
Total losses – inedible fraction	t/year	1,400	Calculation

Table 13. Financial assumptions for packing and sending cosmetically 'imperfect' bananas to fresh retail markets under a whole crop purchasing arrangement.

Marginal costs for growers	Units	Estimate	Sources
Production	$/kg	N/A	Assumption
Pick	$/kg	N/A	Assumption
Pack	$/kg	$0.37	Hall, 2018
Send	$/kg	$0.26	Hall, 2018
Total cost	$/kg	$0.63	Calculation
Potential income for growers	**Units**	**Estimate**	**Sources**
Margin	%	18%	CDI Pinnacle Management, 2014
Minimum income to make it viable for farmer	$/kg	$0.46	Calculation
Minimum income to make it viable for farmer	$/tonne	$455	Calculation

Table 14. Financial assumptions for packing and sending 'lower-grade, edible' bananas to upcycling or another value-add opportunity under a whole crop purchasing arrangement.

Marginal costs for growers	Units	Estimate	Sources
Production	$/kg	N/A	Assumption
Pick	$/kg	N/A	Assumption
Pack	$/kg	$0.50	Banana grower (packing into crates/bins)
Send	$/kg	$0.10	High-level estimate, transport via Pantec truck
Total cost	$/kg	$0.60	Calculation
Potential income for growers	**Units**	**Estimate**	**Sources**
Margin	%	18%	CDI Pinnacle Management, 2014
Minimum income to make it viable for farmer	$/kg	$0.71	Calculation
Minimum income to make it viable for farmer	$/tonne	$711	Calculation

Appendix C

Key assumptions used in cost analysis

A list of assumptions used in the cost analysis is shown in Table 15.

Table 15. **Assumptions used in the cost analysis.**

Area	Plastic mulch	Certified soil biodegradable mulch	Notes
Thickness	25-40 microns	12-20 microns	Can vary in each product. Will depend on the crop and the location. Certified soil biodegradable mulch is thinner to ensure it breaks down in timely manner.
m² of product used per hectare	7,407 m²	7,407 m²	Assumes 74 rows per 100 m x 100 m block (1.35 m row spacing), with each row 1 m wide and 100 m long.
Roll length (metres)	2,300 m	414,000	Hort Innovation, 2022
Rolls per hectare	3.2	3.2	Based on m² of product used per hectare and roll length and width.
Price per roll not including installation	$320	$640	Assumes certified soil biodegradable mulch is double the price of field plastic. Comments made by industry members indicate this price can vary from 70% more expensive to 200% more expensive.
Subsequent cost per hectare	$1,031	$2,061	Not including installation. Based on the number of rolls per hectare.
Installation cost per hectare	$335	$342	The plastic mulch value assumes one roll takes one hour to install and requires two people at $35 per person per hour plus machinery cost of $34 per hour (total $104 per roll, 3.2 rolls per hectare). The cost for certified soil biodegradable mulch installation is based on it being 2% slower to install.
Removal cost (not including disposal)	$552/ha	$0/ha	No cost for certified soil biodegradable mulch as it does not need to be removed. Value for plastic mulch based on removal taking one person eight hours per hectare and costing $35 per hour plus machinery cost of $34 per hour.
Transport cost	$265/ha	N/A	Transport cost will vary depending on the distance from the farm to landfill. Value assumes a truck is $1,500 and can fit 5.7 hectares of product (based on the grower rolling up the plastic and each roll being 0.6 m³, the truck being 20 m³ so can fit 34 rolls, and assuming there are six rolls of plastic per hectare).
Disposal to landfill	$23/ha	N/A	Based on assumed cost of $122 per tonne (based on most farms being in non-metro areas and paying lower landfill levies) and each hectare leaving 186 kg of plastic mulch at its end-of-life.

Details of sensitivity analysis

A range of sensitivity analyses were conducted on key variables within the model.

Sensitivity one – upfront cost and disposal cost

The two key variables influencing whole-of-life cost are upfront cost and removal cost (including disposal). Table 16 presents a sensitivity check on these two factors, highlighting that, holding all other factors constant, if the upfront cost is reduced from $2,061 to just under $1,900 per hectare, the whole-of-life cost of certified soil biodegradable mulch is lower than plastic mulch. If all other factors are constant, the plastic mulch removal cost would need to increase from $840 per hectare to just under $1,100 per hectare for the whole-of-life cost of certified soil biodegradable mulch to be lower than plastic mulch.

Table 16. **Sensitivity analysis on upfront and removal (including disposal) costs of certified soil biodegradable mulch. Values in the table are the difference in $/ha between the two options. Green represents when the net whole-of-life cost is lower for certified soil biodegradable mulch. Dollar values in bold are current assumed costs.**

		Removal cost of plastic mulch (including disposal), $/ha					
		$600	$700	**$840**	$900	$1,100	$1,300
Upfront cost of certified soil biodegradable mulch not including installation, $/ha	$1,500	$124	$224	$363	$424	$624	$824
	$1,700	-$76	$24	$163	$224	$424	$624
	$1,900	-$276	-$176	-$37	$24	$224	$424
	$2,061	-$437	-$337	**-$198**	-$137	$63	$263
	$2,300	-$676	-$576	-$437	-$376	-$176	$24
	$2,500	-$876	-$776	-$637	-$576	-$376	-$176

Sensitivity two – transport costs

Transport costs to a landfill will vary depending on the location of the farm and the distance from landfill. Transport costs are built into removal costs, assumed to be $265 per hectare. This is based on a single truckload of removed plastic mulch costing $1,500, and this load fitting 5.7 hectares of plastic mulch. Table 17 shows if the cost of transport increased to $2,600 per truckload (about $460 per hectare), the total cost is breakeven compared with plastic mulch.

Table 17. **Sensitivity analysis on the impact of transport costs (cost per truckload) on the net difference between certified soil biodegradable mulch and plastic mulch. Values in red are when the net cost for plastic mulch is lower than for certified soil biodegradable mulch. Dollar value in bold is current assumed cost.**

$/truckload to transport plastic mulch to landfill	Cost difference in $/ha between the two options
$1,500	-$198
$1,700	-$162
$1,900	-$127
$2,100	-$92
$2,300	-$56
$2,500	-$21
$2,700	$14
$2,900	$50

Appendix D

Table 18. SWOT analysis of other options.

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
	Organic options						
	Case study						
1	Whole crop purchasing	Refer to Findings					
	Shortlisted options from the assessment						
2	Upcycling vegetable waste into powders	Transform edible mushroom waste, which is currently downgraded to landscaping, into powder. Demonstrated for broccoli waste and may be expanded to other vegetable types.	Reduce	High-value option/upcycling Meat replacement	Research required Cost of technology		Lack of market Lack of suitable staffing skills
3	Transforming product loss into animal feed using heat treatment or black soldier fly technology	Divert product loss (from farms and packing sheds) and use black soldier flies to convert to protein and fertiliser. Protein outputs can be used as animal feed, displacing conventional feed.	Reduce	Contributes to Australia's target to halve food waste by 2030 Adds value to waste with payment for product loss Scalable technology that displaces conventional animal feed	Lack of incentives for waste generators to separate their surplus produce Other methods are more convenient and cost-effective to manage (e.g. spreading on farm)	Processing facilities in animal production regions Legislation that bans surplus food from landfill/ incineration Circular opportunity for onsite waste processing/ feed production	Potential regulatory barriers (biosecurity) preventing conversion of surplus food into animal feed
4	Using a mobile laboratory to produce oil, protein and other products from raw fisheries waste	Mobile laboratory with factory facilities to transform fresh, raw waste materials from the fisheries industry into marketable products, such as oils, protein-rich fractions and other nutrients.	Reduce	Convenience Upcycling Diversifies income source and products Technology exists and is used overseas	Distance and cost of transport between ports and to markets	Pilot study	Competition in the product market
5	Producing clothing and textiles from agricultural waste	Enable the collection and re-manufacture of agricultural waste (e.g. rice straw, banana plantation waste) to produce textiles.	Reduce	Reduces crop wastage, GHG emissions Reduces crops being grown solely for textiles Farmers get paid for crop waste	Feasibility and implementation issues Quality of textile products Varying quality/quantity of feedstock	Collaboration with textile industry brands to support research	Consumer adoption – cost and quality
6	Freezing and freeze-drying second-grade fruit to be sold in alternative markets instead of disposed	Freeze (or freeze-dry) second-hand fruit rather than dispose, and develop markets for products to show the commercial viability.	Reduce	Contributes to Australia's target to halve food waste by 2030 Low-tech options available and easy to implement Diversifies markets Increases storage capacity for a crop from peak production	Finding/establishing the alternative markets Cost to establish and operate	Regular markets with lower standards (e.g. cosmetics)	Lack of demand or markets

Appendix D

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
7	Utilising food waste on farms as feed for edible insects	Upcycle food waste to be used by insect (e.g. cricket) breeders to produce edible products. Currently, insects for human consumption are not permitted to consume food waste as feed.	Reduce	Simple concept once the right sources of food waste are identified	Some unknowns in terms of which food waste will work best	Collaboration between a farm with waste of interest and an insect farm (for example, co-location)	
8	Creating compostable shopping bags from waste banana stalks/ trees	Use banana plantation stalk/tree waste to produce compostable and recyclable shopping bags.	Recycle	Potential to replace virgin plant material used to make compostable packaging	Additional research required Not commercially viable	Collaboration between researchers and the compostable packaging industry	Alternative plastics market competition
9	Composting fish waste	Divert more marine by-products and fish waste so they can be turned into compost, potting mixes and other gardening products. Assumption is this waste is currently going to landfill.	Recycle	Well-established process that has environmental benefits Demand for compost is high Compost helps with water retention and carbon Fish waste has a significant nutritional profile	Logistics (remote areas, distance from processing) Complexity of the waste – odours and profile (wet) Requires bin infrastructure and collection systems	Combine collection with processing to make it easy for growers/fishers Install bins onsite in strategic locations	Contamination Biosecurity risk of storing, handling and processing fish waste
	Other options not shortlisted						
10	Using nanotechnology to improve the properties of compostable packaging made from sugar cane	Use sugarcane waste to produce packaging and replace single-use plastics by adding nanofibers to sugarcane pulp to improve its mechanical properties.	Avoid	Turns product loss into a valuable product Reduces transport requirements and reliance on imported plant product for compostable packaging	Additional research required Not commercially viable	Collaboration between researchers and the compostable packaging industry	Alternative plastics market competition
11	Regenerating reef ecosystems using seafood shells	Collect and cure used oyster, mussel and scallop shells from packing sheds, and deposit them in reef systems to restore reefs.	Reuse	Uses products from the ocean to restore the ocean	Additional research required Not commercially viable	Collaboration between researchers and the compostable packaging industry	Alternative plastics market competition
12	Generating biogas from on-farm vegetable waste	Produce biogas (methane) on vegetable farms using on-farm vegetable waste via anaerobic digestion (AD). The facility could take waste from the farm and other nearby farms if standards can be met. Biogas would be used to power farm operations.	Recover	AD is a well-established process Potential to offset electricity costs for farmer(s) Generates renewable energy	Relatively high capital cost to build onsite May not be the best use for the waste	Grant funding/clean energy funds	Low renewable energy prices
13	Pelletising compost products	Send organic waste materials to a composter to pelletise the material and sell it as pelletised compost. This product could be used during sowing to enhance plant/ crop growth.	Recycle	Reasonably well-established process that has shown positive results More direct use of compost (targeted at seed) Can be applied using other existing farm machinery Has a low transport cost	Access to a processing facility Cost to the farmer for waste collection	Further trials in a range of industries to demonstrate benefits	Lack of market to purchase pellets
14	Feeding product loss to animals	Turn product loss (from farms and packing sheds) into low-risk, untreated animal feed.	Reduce				

Appendix D

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
15	Exploring upcycling of product loss into nutritious food options	Upcycle food waste currently not meeting specifications or going to animal feed or compost (or left onsite) by developing alternative markets (e.g. pomaces from apple food waste).	Reduce	Potential to receive a return on 'waste' Waste is avoided/becomes a resource Potential to provide more nutritional dietary options		Pilot involving selected streams	Lack of interest in products from consumers
16	Producing hydrogen fuel and fertilisers from farm waste	Encourage collaboration between industry bodies to further develop hydrogen technology (e.g. via technology clusters), with the aim of utilising crop and product loss from farms to produce hydrogen fuel and/or fertilisers.	Recover	Uses organic waste to produce hydrogen and reduce fossil fuels and GHG emissions Reduces the need to import fertilisers Improves the sustainability of fertiliser production	Technology viability still yet to be fully determined		Lack of commercially viability
17	Growing more resilient crop varieties to reduce inputs	Make crops more resilient to disease, pests, climate factors and nutrient deficiencies. Achieving these aims would reduce the volume of inputs needed (e.g. sprays and labour and machinery required to spray) to sustain healthy crops and reduce product loss on farm.	Reduce	Reduces primary factors causing crop wastage	Technology is in early stages of development There is scepticism of genetically modified crops	Changed practices leading to reduced herbicides, pesticides and fertiliser use and costs	Consumer concerns
18	Promoting greater industrial symbiosis within the sector through planning	Promote greater symbiosis in the agricultural sector; for example, by co-locating farms and other services that can supply their by-products as feed to insect breeders (producers).	Avoid	Increases efficiencies in and across the sector Increases viability of a range of avoid and recycling options	Logistics of transitioning to symbiotic models Uncertainty about where to locate	Cross-industry collaboration (e.g. aquatic industry supplying wastewater to crop farmers as fertiliser)	Complexity Disengagement
19	Recycling mushroom substrate into compost and casing	Assuming mushroom substrate is recycled on farm, either compost the substrate or transform it into new casing for use on farm (requires mixing with new products).	Recycle	Simplicity Reduces cost to farmer if paying for compost or fertiliser Can replace virgin materials Reuses product on farm (minimises transport)	Not as desirable as making new products from substrate Farmer may require expert support	Collaboration with berry industry to create a growing substrate	Disease risk
20	Using a rotary drum composter in the poultry industry	Use a rotary drum composter that takes in organic farm animal waste/mortalities (e.g. dead birds and eggs) to produce compost.	Recycle	Makes new product from mortalities Uses small-scale machinery for regional/on-farm processing processing	Onsite equipment requires space on farm Maintenance requirements	Pilot	Alternative options more viable Biosecurity risks
21	Certifying fisheries that prevent gear loss and operate sustainably	Establish a non-profit body that certifies a fishery against sustainability standards.	Avoid	Covers a range of activities Fisheries must minimise operation waste and transform processes to meet standards	Customers do not always notice or care Cost for certification	Apply to other industries	Lack of participation in certification scheme

Appendix D

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
22	Upcycling prawn shells to prawn oil	Upcycle waste from prawn fisheries (prawn shells) into prawn oil for cooking. Potential to expand and include other seafood waste, such as lobster waste.	Reduce	Turns waste into a new product End product has higher value than any recycling option Accessible and efficient due to happening on vessel	Specific industry Relatively new initiative	Collaboration with other industries	
23	Turning forestry residues into marketable energy products	Produce marketable products from forestry harvesting residues, such as plywood, Hardlam or wood pellets. Alternatively, use residues as biomass for energy production or co-generation, or to produce biofuels.	Recover	Clean and reasonably consistent stream Targets certain areas/ locations Generates renewable energy	Complex process Need to demonstrate commercial viability	Onsite processing to minimise transport	Alternative renewable energy sources are more viable
24	Recycling spent berry coir or using it in compost	Use spent berry coir in compost mixtures or as a soil amendment, or recycle it through organic recyclers for reused as a substrate.	Recycle	Simple to roll out to large-scale growers	Plastic casing of some coir product makes de-contamination difficult and microplastic contamination a risk	Onsite composting for those unable to access a composter	Disease and pest management
25	Using almond waste to produce power, compost and potassium-rich ash for orchards	Use combusted almond hull waste to produce power in a co-generation power station. The ash, waste skins and other organic matter can be used to produce compost.	Recover	Case studies in Australia have demonstrated feasibility Potential to offset electricity costs Generates renewable energy	Limited impact Relatively high capital cost	Grant funding/clean energy funds	Low renewable energy prices
26	Reducing crop waste using machine learning-driven technology to assist with precision agriculture	Example from The 77 Lab: [Implement] technology driven by artificial intelligence and machine learning that measures the ripeness of fruit, picks fruit carefully and can replace damaged billets of sugarcane with healthy billets. This serves to prevent crop wastage.	Avoid	Reduces crop wastage Reduces labour intensity for farmers	Emerging solution Reliability/accuracy of the technology High initial investment	Improved feasibility as technology matures Improved reliability	Social issues
27	Establishing co-generation plants for sugarcane	Establish co-generation plants for sugarcane farmers where they can take their bagasse to be used as fuel to produce energy. Energy may be used to power sugar mills, exported or used for other purposes, offsetting fossil fuel consumption.	Recover	Reduces reliance on fossil fuels for energy Prevents bagasse breaking down and releasing GHG emissions Established technology	Cost to establish	Demonstrate success of systems Export bagasse to other areas	Low renewable energy prices
28	Implementing an auditable system requiring sound waste management to certify Australian products as sustainably made	Implement a voluntary system that certifies saleable farmed products as being cultivated using sustainable methods. Include independent audits.	N/A				

Appendix D

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
	Plastic options						
	Case study						
29	Using certified soil biodegradable plastics	Refer to Findings					
30	Establishing reception facilities that accept unwanted fishing gear and assessing opportunities to recycle nets, ropes and gear	Refer to Findings					
	Shortlisted options from the assessment						
31	Using sisal, jute or hemp instead of plastic counterparts for plant twine, ties and nets	Increase the use of compostable twine, ties and nets in place of polypropylene equivalents by incentivising farmers to use them.	Reduce	Uses compostable and renewable materials in place of plastics Convenient as there is no need retrieve plastic after harvest Alternative products are already available Allows for easier recovery of organic material	Alternatives may not be as robust or durable as the plastic equivalents Alternatives may be more expensive Environmental impact is dependent on volumes of plastic available to replace	Explore other alternative materials that could also be manufactured from waste materials	Lack of participation (hard to incentivise)
32	Expanding closed-loop recycling of aquaculture plastics	Expand closed-loop recycling of end-of-life aquaculture products to produce the same aquaculture products.	Recycle	Employs a circular approach, with the collector/processor also manufacturing and supplying aquaculture Collection and recycler motivated to reduce costs Backloading is possible	Logistics of collecting old plastics Relatively new concept in Australia Recycler may only be after certain types of plastics	Target selected items to make it easier for farmers Target higher-value/easier-to-recycle plastic streams first	Contamination (incorrect plastics) Low product quality
	Other options not shortlisted						
33	Establishing a database to report and find ghost nets	Establish a central database to record ghost nets found.	N/A	Data can be used for decision making Relatively low cost	Reactive rather than proactive approach	Use to improve recovery or decrease disposal Identify hot spots	Improper use of system/ missing data leads to poor decisions
34	Collecting and recycling banana bags	Banana growers to participate in an international plastic program whereby projects are issued credits if plastic is collected and recycled.	Recycle	Offers a financial incentive Process includes good data capture Increases sustainability of production Branding opportunities	Reasonably complex for the farmer Has an associated independent auditing cost	Extend to other industries Make the system simpler for farmers	Complexity makes it too difficult
35	Exploiting enzymes that depolymerise plastic and enable recycling	Investigate technology that depolymerises plastics into the constituent monomers, which can then be reused to produce food-grade plastics. This would reduce reliance on fossil fuels to produce virgin plastics and addresses existing plastic waste.	Recycle	Helps with management of hard-to-recycle plastics, including coloured, multi-layer and mixed plastics	Unproven technology Lack of collections sites Many unknowns (cost, location of facilities)	Buy back recycled items	

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	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
36	Leasing reusable pallets and containers	Lease commonly used containers and pallets to operations, preventing purchasing and subsequent waste.	Avoid	Can be applied to any industry Relatively simple Employs a circular approach to material use	Logistics and cost for collecting and maintaining pallets and running the scheme		
37	Promoting sustainability in the marine industry to improve environmental outcomes and rehabilitate marine habitats	Set up marine natural resource management organisations to promote sustainability practices, minimise environmental impact and improve marine ecosystem health.	N/A	Establishes a central location for knowledge and education Harnesses expert knowledge on issues and opportunities for industry	Ability to influence may be limited Effectiveness is hard to measure	Apply concept to farming	Group is set up but is ineffective
38	Using reusable crates to replace EPS crates for fish	Use crates that have smooth inner and outer surfaces and an insulating polyurethane centre to house fish. Such crates would reduce use of conventional EPS crates, reducing environmental issues caused by EPS use. The new crates can be cleaned and reused effectively.	Reuse	Can be applied to any industry Relatively simple	Changing EPS packaging may be challenging Requirements for cleaning processes	Incentivise those currently using EPS crates to change to reusable crates Expand to other industries	
39	Implementing greater standardisation of plastics to improve the viability of recycling	Create standards for common plastics. Work with suppliers to change manufacturing processes.	Recycle	Provides manufacturers with clarity on approved plastics Likely has a lower cost to farmers to recycle	Recycling still an inconvenience	Combine with a product stewardship or collection program	Quality may reduce Could lead to recycling some products that can be reused
40	Implementing standards requiring minimum thickness of non-biodegradable mulch films to facilitate retrieval	Improve ease of retrieving non-biodegradable plastic mulch films from soil (when they have reached their end-of-life) by requiring manufacturers to produce film with a minimum thickness.	N/A	Increases recovery of non-biodegradable mulch films Reduces the potential for plastic to escape into the environment	Increases cost to farmers for mulch film	Apply to any non-compostable plastics	May incentivise poorer-quality plastics
41	Using hydroponics irrigation methods instead of irrigation tape	Increase the use of hydroponics in place of drip irrigation systems.	Avoid	Prevents plastic pollution and the need for collection	High establishment costs Not suitable for all crop types Need to adjust to manage the technology	Educate farmers new to hydroponics	Lack of interest or scepticism from growers
42	Using recycled-content field plastics in place of virgin plastic products	Use recycled-content field plastics rather than newly manufactured products.	Recycle	Supports social licence to operate (especially in more urban/peri-urban areas)	Potentially costs more to purchase recycled-content field plastics		
43	Using organic alternatives to polystyrene for produce packaging	Replace polystyrene packaging with plastic-free organic options.	Reduce	Replaces polystyrene, which is difficult to recycle	Different industries will require different properties	Focus on avoiding waste by replacing polystyrene with long-life reusable packaging	Confusion about packaging and recycling options Compromised product quality from alternative packaging

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
44	Recycling plastic mulch into other products for use on farm	Recycle plastic mulch film into stakes (e.g. for tomato growing) or other plastic products that can be used on farm.	Recycle	Tackles a problematic stream across many industries Provides a direct market for recycled products	Product quality poor and would require a high cost to remove contaminants High transport cost given lightweight product	A product stewardship scheme where old mulch is collected when new mulch is purchased and delivered	
45	Collecting and recycling plant pots	Implement closed-loop recycling to turn plant pots into new plant pots. Establish fixed collection points to gather end-of-life pots.	Recycle	Established process Is a closed-loop scheme – product to product	Requires collection Potential for contamination	Combine with other streams to establish a one-stop drop-off point	Introduction and subsequent contamination of compostable pots
46	Replacing plastic tree guards with compostable guards	Use tree guards that are compostable rather than the conventional plastic guards when planting new trees.	Recycle	Removal of guard may not be required, minimising farmer effort Improves public perception of tree guards and industry	Compostable guards may have reduced product longevity Potentially higher cost		
47	Using a mobile plastic baler to recycle plastics	Establish a mobile plastic baler system that can recycle agricultural plastics. A mobile cleaning system is recommended to accompany the baler to treat highly contaminated plastics	Recycle	Mobile solution for regional settings	Lack of incentives for farmers to bale and recycle their plastics (additional effort and potential costs involved)	Include as part of a product stewardship program	
48	Establishing an IBC challenge on Twitter	Establish a social media challenge asking farmers to show how they have reused their old IBCs for other purposes instead of disposing to landfill.	Reuse	Reuses containers	IBCs may pose an ongoing health/environmental hazard if not cleaned properly Still need to find a method to dispose them at their end-of-life		
49	Increasing traceability and accountability of plastic film	Producers include their logos onto every metre of film so these products can be traced more easily. Also increases manufacturer accountability.	N/A	Makes it easy to communicate with manufacturers and identify opportunities for recycling Incentivises manufacturers to consider product waste	Interest from producers may be low	Combine with other labelling ideas Ensure greater compliance through mandating/ regulating	Lack of uptake from manufacturers
50	Replacing plastic ear tagging of livestock with AI or injectable transponders	Facilitate the implementation of new facial recognition technology to identify livestock to make plastic ear tags redundant. Similarly, injectable transponders may be a solution	Avoid	Avoids plastic waste by making tags redundant Scanning using phone app is convenient Provides richer information	Reliability/accuracy of system Time to establish	Improve reliability of technology to phase out plastic tags Apply to other products	Teething issues in newer technologies
51	Implementing a plastic ear tag deposit return scheme to incentivise famers to collect the waste	Develop a deposit scheme similar to the CDS to collect and recycle plastic ear tags used on farms and livestock.	Recycle	Modelled on a pre-existing and successful initiative (CDS) Incentivises farmers to collect and return found tags Shifts burden of recycling tags to depots	Waste volumes required to make it viable Other opportunities that remove the need for any tags	Pilot to trial viability Expand to other agricultural equipment	Disrupting technologies that make tags redundant

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	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
52	Incentivising farmers to bring clean waste streams into transfer stations	Incentivise farmers to treat their waste prior to recycling (e.g. taking nozzles off piping) to make recycling more efficient and viable.	Recycle	Reasonably simple concept Targets certain streams	High incentives required given the challenge of separating materials and the inconvenience Need to establish a funding option		
53	Using compostable pots or meshes instead of plastic tubes/cells for forestry seedlings	Incentivise the use of compostable pots or meshes for forestry seedlings to replace plastic equivalents.	Avoid	Waste will decompose, which mitigates the need for retrieval Reduces plastic waste and contamination	Cost of compostable pots compared with plastic alternatives Need to remake pots each time	Use wood-derived waste to manufacture pots and protectors	
54	Requiring fishing gear to be designed to prevent ghost fishing	Modify the design of fishing gear so they do not trap marine life when lost ('ghost' equipment). Fit escape panels on traps and use biodegradable fastenings.	N/A	Reduces ghost fishing Proactive rather than reactive initiative	Cost of design and manufacturing is carried to the user	Collaborate with industries to roll out initiative more broadly	
55	Requiring products to be labelled with their expected effective working life	Label silage and greenhouse films with effective working life.	N/A	Relatively simple Incentivises manufacturers to increase working life	Requires cooperation of, and participation by, producers of film	Introduce legislation or standards for labelling Combine with other labelling initiatives	Incorrect/misleading labelling (audits may be needed, adding to the cost)

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	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
	Workshop options						
	Case study						
56	Shifting to alternatives to treated timber posts	Refer to Findings					
	Options not shortlisted						
57	Running campaigns about leasing farm equipment and tools	Run campaigns with agriculture machinery and tool leasers to promote increased leasing. Leasing equipment will reduce the accumulation of workshop waste.	Avoid	Saves upfront purchasing cost and the effort of maintaining and registering tools Decreases the amount of on-farm workshop waste	Leasing companies need to replace obsolete equipment over time Access to leasing companies Inherent wait time for repairs or updates to be made to equipment	Leasing companies update their equipment to the most efficient and clean technology for farmers to utilise Circular economy business models	Lack of available equipment to meet farmers' needs
58	Providing a steel post straightening service	Establish a mobile steel post straightening service. An on-farm service would prevent new posts being purchased and bent posts being discarded.	Reuse	Provides local employment and local solutions Is convenient for the farmer Has a low cost	Potential delays in receiving service	Combine with other services	
59	Expanding pesticide spraying services to prevent chemicals being stored on farm	Provide a pesticide spraying service so farmers do not have to keep pesticides on their properties. Create a registry of service providers and enable farmers to book the service.	Avoid	Reduces accumulation of hazardous waste on farms Avoids excessive use of pesticides Prevents farmers from purchasing and managing their own pesticide supplies	Difficulty linking farmers with service providers Difficulty scheduling the service between different farms Difficulty addressing the needs of different farmers/crops	Promote alternatives to using pesticides Embed principles of circular economy	Farmers not agreeing or wanting to participate (losing autonomy)
60	Increasing the durability of materials and reducing inputs through nanotechnology	Investigate possible nanotechnology solutions for agriculture so there are less inputs (avoiding waste). For example, current research suggests nanotechnology may help improve the efficiency of pesticides (nano pesticides).	Reduce	Improves the efficacy of pesticides and fertilisers through technology, reducing input volumes	Technology still being researched and needs to be proven	Accelerate research into nanotechnology in agriculture	
61	Promoting the use of integrated pest management to reduce pesticide use	Promote increased use of integrated pest management (IPM) practices, which reduce the volumes of pesticides purchased and therefore waste generated.	Reduce	Reduces the number of pesticides purchased and used Replaces pesticides with more natural methods	Level of involvement and complexity of initiative Expert support required Few companies offer the service	Promote the co-benefits of IPM, such as reduced plastic use	Efficacy of IPM Ability to change farming system
62	Trading obsolete farm machinery and equipment to recover scrap metal	Run campaigns with scrap metal collectors to pick up redundant and old machinery and tools from farms.	Recycle	Farmers earn income from scrap metal Incentives for both farmers and collectors to reduce scrap metal waste (symbiosis) Convenient for farmers	Access to sites Capacity of collectors to make the initiative feasible	Create more jobs for collection companies Incentivise farmers to modernise machinery Promote on-farm collection	Lack of participation

	Initiative	Description of initiative	Waste hierarchy position	Strengths	Weaknesses	Opportunities	Threats
63	Expanding and improving the product stewardship scheme for agricultural drums	Expand participation in the drumMUSTER program and improve accessibility (better access to drop-off sites, longer hours of operation).	Recycle	Builds on existing initiative that has nationwide footprint Cost is borne by the producer Ease of participation	Additional cost and logistical considerations to expand access for those in remote locations	Make the initiative mandatory rather than voluntary Increase the refund for collectors	Non-participation of suppliers
64	Reversing logistics and takeback programs to prioritise reuse	Impose an additional price for new products that covers the cost of the manufacturer taking back the item at its end-of-life. The manufacturer can then reuse or recycle the product. The purchaser may also obtain a rebate when the item is returned. The old item could be taken from the farm when it is replaced with the new item.	Reuse	Simplifies the process for farmers Responsibility is shifted to the producer	Concept needs to target specific products Producer needs to change systems and processes to accommodate	Trial on selected products and expand	Cost to service very remote properties Fluctuating commodity prices for recovered materials

References

A Gomez Ltd. (2020). *Food waste inventory – 1st August 2019 to 31st July 2020.* https://www.tescoplc.com/media/756408/a-gomez-final-2020.pdf

Ambiel, C., Adell, A., Sanguansri, P., Krause, D., Gamage, T., Garcia-Flores, R. and Juliano, P. (2019). *Mapping of Australian fruit and vegetable losses pre-retail.* CSIRO. https://doi.org/10.25919/5d28d8ba0fad5

Australian Wine Research Institute. (2019). *AWRI Vineyard & Winery Practices Survey.* https://www.awri.com.au/wp-content/uploads/2019/05/AWRI_Practices_Survey_Final_Report.pdf

Big Dog Pet Foods. (n.d.). *Big Dog Pet Foods.* www.bigdogpetfoods.com

Boots, B., Russell, C. W. and Green, D. S. (2019). Effects of Microplastics in Soil Ecosystems: Above and Below Ground. *Environmental Science & Technology*, 53, 11496-11506. https://doi.org/10.1021/acs.est.9b03304

CDI Pinnacle. (2014). *Banana Enterprise Performance Comparison: Phase 3.* Horticulture Australia Limited. https://www.horticulture.com.au/globalassets/hort-innovation/historic-reports/banana-enterprise-performance-comparison---phase-3-ba11026.pdf

Craig, P. and Watson, M. (2018). *Nutrition across the life stages.* Australian Institute of Health and Welfare. https://www.aihw.gov.au/getmedia/fc5ad42e-08f5-4f9a-9ca4-723cacaa510d/aihw-phe-227.pdf.aspx?inline=true

Department of Agriculture, Water and Environment. (2021). *National Plastics Plan 2021.* https://www.agriculture.gov.au/sites/default/files/documents/national-plastics-plan-2021.pdf

Department of Climate Change, Energy, the Environment and Water. (2022a). *Exports of waste plastic.* https://www.dcceew.gov.au/environment/protection/waste/exports/plastic

Department of Climate Change, Energy, the Environment and Water. (2022b). *Investing in Australia's waste and recycling infrastructure.* https://www.dcceew.gov.au/environment/protection/waste/how-we-manage-waste/recycling-modernisation-fund

Downham, R. and Litchfield, F. (2022). *Labour use in Australian agriculture: Analysis of survey results, 2021-22.* Department of Agriculture, Fisheries and Forestry. https://www.agriculture.gov.au/abares/research-topics/labour

EPA South Australia. (2016). *Copper chromated arsenate (CCA) timber waste—storage and management.* https://www.epa.sa.gov.au/files/7565_guide_cca.pdf

Fight Food Waste CRC. (n.d.) *A case for tax reform to increase food donation by business.* https://fightfoodwastecrc.com.au/project/tax-reform

Fritts, R. (2017). *In the fishing industry, gear recycling is finally catching on.* Ensia. https://ensia.com/features/fishing-gear-recycling/

Hall, H. (2018). *Banana Enterprise Comparison 2016/17.* Hort Innovation. https://www.horticulture.com.au/globalassets/laserfiche/assets/project-reports/ba16009/ba16009---final-report-complete.pdf

Horticulture Innovation Australia. (2022). *Australian Horticulture Statistics Handbook 2020/21 – Fruit.* https://www.horticulture.com.au/contentassets/a68c8934a8bf40b4becdc487bacdb60f/hort-innovation-ahsh-20-21-fruit.pdf

Icelandic Recycling Fund. (n.d.). *The purpose of operating the Icelandic Recycling Fund and collecting recycling fees.* https://www.urvinnslusjodur.is/english

International Organization for Standardization. (n.d.). *23517:2021 Plastics — Soil biodegradable materials for mulch films for use in agriculture and horticulture — Requirements and test methods regarding biodegradation, ecotoxicity and control of constituents.* https://www.iso.org/standard/75894.html

JCAM Creative. (2016). *Review of aquaculture and wild-catch fisheries waste on Eyre Peninsula and options for future waste management.* Report funded by the Australian Government National Landcare Program through the Eyre Peninsula Natural Resources Management Board.

References

Ji, Z., Huang, Y., Feng, Y., Johansen, A., Xue, J., Tremblay, L. A. and Li, Z. (2021). Effects of pristine microplastics and nanoplastics on soil invertebrates: A systematic review and meta-analysis of available data. *Science of The Total Environment*, 788, 147784. https://doi.org/10.1016/j.scitotenv.2021.147784

KPMG. (2022). *Shifting the dial on vegetable consumption*. https://static1.squarespace.com/static/5ddca44a3ac7644d97d9757a/t/633e2e9e396cdd49ccfa3ee9/1665019635620/FVC+Report_Final_041022.pdf

Limpus, S. (2012). *Comparison of biodegradable mulch products to polyethylene in irrigated vegetable, tomato and melon crops*. Horticulture Australia Ltd. https://ausveg.com.au/app/data/technical-insights/docs/130007_MT09068%20Final%20Report%20Complete.pdf

Lucas, D., Axiö, I., Wardley, T., Boland, A.-M., Muller, C. and Larsen, C. (2022). *Pre-farm gate waste management: Baseline waste data for the agriculture, fisheries and forestry sector*. AgriFutures Australia. https://www.agrifutures.com.au/product/pre-farm-gate-waste-management-baseline-waste-data-for-the-agriculture-fisheries-and-forestry-sector

Maheash, P., Chauhan, A. and Warrier, A. (2022). *Plastic Mulching: Microplastics in Agricultural Soils*. Toxics Link. http://toxicslink.org/docs/Plastic%20Mulching.pdf

Mancl, K. (2022). *Microplastics in Soil – Small Size Big Impact on U.S. and Chinese Agriculture*. New Security Beat. https://www.newsecuritybeat.org/2022/04/microplastics-soil-small-size-big-impact-u-s-chinese-agriculture/

Mid West Horticulture Grower Group Inc. (2016). *Trash or Treasure? Repurposing unmarketable fruit produced by the Mid West Horticulture Growers*. https://www.nacc.com.au/wp-content/uploads/2018/10/1812-05-SG2-Trash-or-Treasure-Repurposing-unmarketable-fruit-waste.pdf

Morrisons. (2011). *Morrisons Corporate Responsibility Review 2011*. https://www.scribd.com/document/183648465/Morrisons-Corporate-Responsibility-Review-2011

Mt Uncle Distillery. (n.d.). *Mt Uncle Distillery*. www.mtuncle.com

O'Farrell, K., Harney, F. and Chakma, P. (2021). *Australian Plastics Flows and Fates Study 2019-20*. Department of Agriculture, Water and the Environment. https://www.dcceew.gov.au/sites/default/files/documents/apff-national-report_0.pdf

Qi, R., Jones, D., Li, Z., Liu, Q., and Yan, C. (2020). Behaviour of microplastics and plastic film residues in the soil environment: A critical review. *Science of The Total Environment*, 703, 134722. https://doi.org/10.1016/j.scitotenv.2019.134722

Rawtec and EconSearch. (2013). *Feasibility study into recycling waste plastic oyster baskets in the South Australian oyster industry*. EPA South Australia. https://www.epa.sa.gov.au/files/477882_oyster_basket_study.pdf

Reyna-Bensusan, N., Wilson, D. C., Davy P. M., Fuller, G. W., Fowler, G. D. and Smith, S. R. (2019). Experimental measurements of black carbon emission factors to estimate the global impact of uncontrolled burning of waste. *Atmospheric Environment*, 213, 629-639. https://doi.org/10.1016/j.atmosenv.2019.06.047

RMCG. (2021). *National Agricultural Plastics Stewardship Scheme – Update*. Department of Agriculture, Water and the Environment. https://www.rmcg.com.au/app/uploads/2022/03/DAWE-NPSIF-ag-plastic-waste-update-Jan22-V4-lr2.pdf

Rogers, G. (2013). *Identifying new products, uses and markets for Australian vegetables: A desktop study*. Horticulture Australia Ltd. https://ausveg.com.au/app/data/technical-insights/docs/130052_VG12046.pdf

Rural News Group. (2017). *Re-using broken posts*. https://ruralnewsgroup.co.nz/wine-grower/wg-general-news/re-using-broken-posts

Smith, L. (2022). *SABRN Circular aims to give end-of-life plastics a second chance at Port Lincoln plant*. Port Lincoln Times. https://www.portlincolntimes.com.au/story/7853671/end-of-life-plastics-to-get-a-second-chance-at-new-port-lincoln-plan/

South Australian Oyster Growers Association. (2020). *Industry Update: December 2020*. https://mailchi.mp/52c4f68ce969/oysters-sa-december-industry-update?e=a8923d405e.

Spray, A. (2013). *Action Plan: Securing crop supply through whole crop purchasing*. Product Sustainability Forum. https://docplayer.net/17599009-Action-plan-securing-crop-supply-through-whole-crop-purchasing.html

Steven, A. H., Dylewski, M. and Curtotti, R. (2021). *Australian fisheries and aquaculture statistics 2020*. ABARES. https://doi.org/10.25814/0wzy-re76

The Grocer. (2019). *How Tesco works with suppliers*. https://www.thegrocer.co.uk/promotional-features/how-tesco-works-with-suppliers/596398.article

Verma, R., Vinoda, K. S. Papireddy, M. and Gowda, A. N. S. (2016). Toxic Pollutants from Plastic Waste – A Review. *Procedia Environmental Sciences*, 35, 701-708. https://doi.org/10.1016/j.proenv.2016.07.069

White, A., Gallegos, D. and Hundloe, T. (2010). The impact of fresh produce specifications on the Australian food and nutrition system: a case study of the north Queensland banana industry. *Public Health Nutrition*, 14(8), 1489-1495. http://dx.doi.org/10.1017/S1368980010003046

Wine Australia. (2022). *Australian wine sector at a glance*. https://www.wineaustralia.com/report-downloads/0aad58cc-8c99-4716-95a0-6d9fdce4e118

WRAP. (2017). *Getting more value from surplus and waste*. https://wrapcymru.org.uk/sites/default/files/2020-09/WRAP-fresh-produce-sector-getting-more-value-from-waste-2017.pdf

WRAP. (2022). *Horticulture – Sector Deep Dive* – March 2022 edition. Unpublished.

Yang, G. T. and Bradford, M. A. (2018). Thermal-induced upheaval buckling of concrete pavements incorporating the effects of temperature gradient. *Engineering Structures*, 164, 316-324. https://doi.org/10.1016/j.engstruct.2018.02.002

Zumstein, M. T., Schintlmeister, A., Nelson, T. F., Baumgartner, R., Woebken, D., Wagner, M., Kohler, H. P. E., McNeill, K. and Sander, M. (2018). Biodegradation of synthetic polymers in soils: Tracking carbon into CO_2 and microbial biomass. *Science Advances*, 4(7), eaas9024. https://doi.org/10.1126/sciadv.aas9024

Australia's primary industries, including agriculture, fisheries and forestry, generate a significant amount of waste and by-products. Management of theses waste streams involves a range of practices, from stockpiling, landfilling, burning and burial to reuse, recycling and recovery.

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