Infrastructure Victoria

IV97 – Recycling & Resource Recovery Infrastructure Advice – Resource Recovery & Recycling Infrastructure Analysis

Final Report

FINAL | 10 October 2019

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Contents

List of acronyms

Acronym	Details
AD	Anaerobic digestion
AI	Artificial intelligence
B2B	Business-to-business
BAU	Business as usual
C&D	Construction & demolition waste
C&I	Commercial and industrial waste
CDS	Container deposit scheme
CE	Circular economy
COAG	Council of Australian Governments
DELWP	Department of Environment, Land, Water, and Planning
EfW	Energy from waste
EIS	Environmental Impact Statement
EoW	End of waste
EPA Victoria	Environment Protection Authority Victoria
EU BREF	European Union Best Available Techniques reference documents
e-waste	Electronic waste
FOGO	Food organics and garden organics
FOMO	Fearing of missing out (colloquial, used in a scenario name)
GED	General environmental duty
HDPE	High-density polyethylene
IoT	Internet of Things
IVC	In-vessel composting
LDPE	Low-density polyethylene
LGV	Local Government Victoria
MBT	Mechanical biological treatment
MCA	Multi-criteria analysis
MRF	Materials recycling facilities
MSW	Municipal solid waste
MWRRG	Metropolitan Waste and Resource Recovery Group
NEPMs	National Environment Protection Measures
NSW	New South Wales
PAYT	Pay-as-you-throw
PET	polyethylene terephthalate

Acronym	**Details**
PIW	prescribed industrial waste
PP	Polypropylene
PS	Polystyrene
PVC	polyvinyl chloride
QLD	Queensland
RDF	Refuse-derived fuel
RISP	Recycling Industry Strategic Plan
SA	South Australia
SV	Sustainability Victoria
SWRRIP	State-wide Waste and Resource Recovery Infrastructure Plan
TIA	Transport Integration Act (2010)
VAGO	Victorian Auditor General's Office
VIC	Victoria
WMP	Waste management policy
WRATE	Waste and Resources Assessment Tool for the Environment

Executive summary

This report provides advice on recycling and resource recovery infrastructure in Victoria. It considers the potential for the Victorian Government to support of new infrastructure proposals and attract new business models to Victoria through specific approaches to policy, regulation and market design.

We have developed scenarios to investigate the approaches or infrastructure that the Victorian Government could support to achieve better resource recovery, greenhouse gas emissions reduction and economic outcomes for the state. The scenario approach places recycling and resource recovery infrastructure within a plausible policy and supply chain context and helps decision-makers to understand the relationships between policy, markets and infrastructure development. These supply chain interdependencies are fundamental resolving Victoria’s current waste and recycling challenges.

The descriptions and characteristics for the scenarios developed in this report are:

1. Out of Sorts: Continued investment in current areas of focus for resource recovery initiatives without major policy reform. It involves upgrade of sorting for recyclables, use of low-grade recyclables in infrastructure and continued reliance on landfill disposal of residual waste.

2. Food organics and garden organics (FOGO) FOMO: Recovery of food organics is prioritised with a ban on food waste to landfill and mandatory organics separation for households and food-related businesses. Energy from waste (EfW) is deployed for residual waste.

3. Closing the Floodgates: Waste export is banned by the Australian Government, so domestic recycling is improved and expanded and complemented by a growth in domestic use of recycled products. EfW is deployed for unsaleable recyclables and household waste.

4. Circular Stewards: Victoria’s circular economy policy sees government, industry and the community embracing new, circular business models which prioritise long-term product and material value. Mandatory product stewardship and separation of organics are key features in this scenario.

5. Packaging Crackdown: Australia’s National Packaging Targets and action on ocean plastics pollution drives a focus on recovering and recycling packaging waste and eliminating single-use plastic items.

6. High Energy: Large-scale EfW is deployed using well-proven technologies and industrial sites. A range of residual wastes including household and business waste and unsaleable recyclables are accepted while pay-as-you-throw charging is adopted to curb waste generation.

The characteristics of the scenarios is summarised in Table 1.

Table 1: Summary of scenario characteristics

Intervention components	Scenario Development					
	Out of Sorts (BAU)	**FOGO FOMO**	**Closing the Floodgates**	**Circular Stewards**	**Packaging Crackdown**	**High Energy**
MCA score	**0.47**	**0.62**	**0.60**	**0.65**	**0.52**	**0.58**
Infrastructure investment	**Medium** Focus on dry recyclables sorting to export quality	**High** Focus on organics	**High** Focus on dry recyclables sorting and reprocessing	**High** Focus on circular business models and organics	**Low** Focus on dry recyclables generation and sorting	**Medium** Focus on EfW and PAYT collections
Energy from Waste	**Low**	**High**	**High**	**Low**	**Low**	**High**
Organics separation	**Low**	**High** Mandatory	**Low**	**High** Mandatory	**Moderate** Accepts compostable packaging	**Low** High capture rate in established systems
Dry recyclables recovery	**Medium** Export focus	**Low** Export focus Energy recovery	**High** Domestic reprocessing focus Energy recovery	**Medium** Export focus Avoidance/reuse	**Medium** Export focus Compostable alternatives	**Low** Export focus Energy recovery
CDS in Victoria	**No**	**No**	**No**	**Yes**	**Yes** Includes all glass packaging	**No**
New product stewardship schemes	**No**	**No**	**No**	**Yes** Mandatory	**Yes** Mandatory – packaging only	**Yes** Voluntary

The scenarios were assessed using a standard multi-criteria analysis (MCA) in collaboration with Infrastructure Victoria. The MCA evaluates the scenarios against multiple criteria, which we developed through a workshop with key Infrastructure Victoria representatives and Arup technical specialists. The criteria adopted for the MCA were:

- Household waste services cost.
- Waste management cost.
- Economic uplift.
- Greenhouse gas (GHG) emissions.
- Resource recovery outcomes (using the Circularity Index - see below for explanation).

Arup developed a Circularity Index for the purposes of this assessment, which examines resource recovery outcomes across a range of waste materials and streams. The Circularity Index examines the tonnage of waste directed to each level of the waste hierarchy. This assessment provides a score which reflects the contribution of these material flows to maintaining material value and was included as a criterion in the MCA. These criteria were then weighted using a pairwise comparison, which uses simple ranking of criterion pairs to arrive at final weightings for all five criteria. The results of the MCA are presented in Figure 1 and detailed at length in the report.

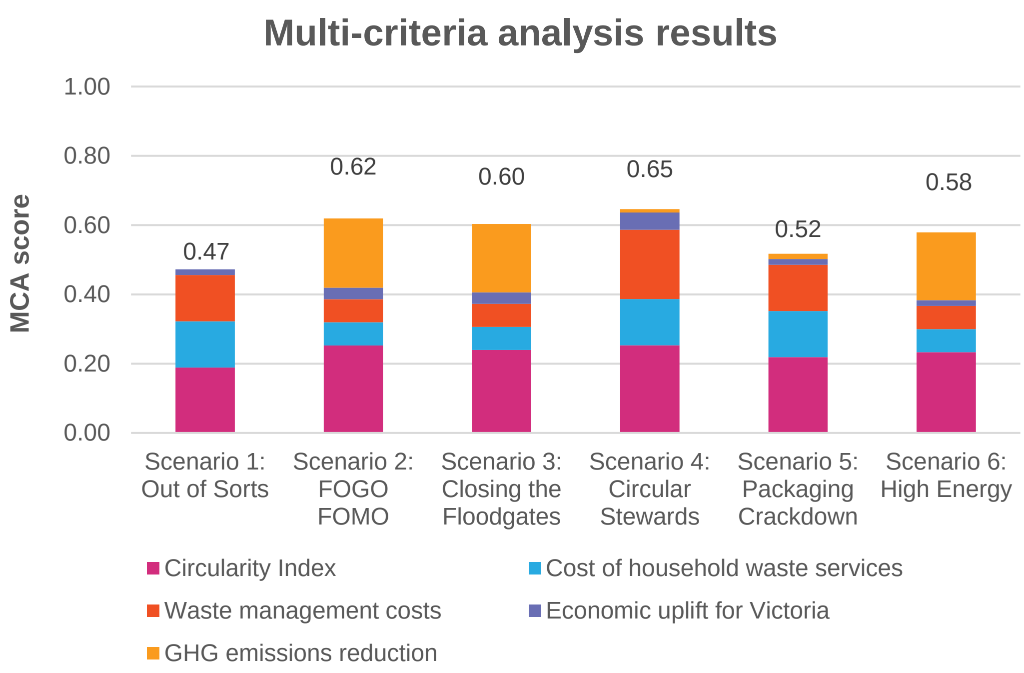

Figure 1: MCA results for the scenarios

The *Circular Stewards* scenario was ranked highest in the MCA process and warrants further development of supporting of policy and regulatory measures, as well as market and infrastructure support. This scenario aligns with the direction set by the Victorian Government's issue paper, *A circular economy for Victoria*, and should be supported by policy expected to be released later this year. It extends the breadth of mandatory product stewardship schemes and oversight and will be supported by the introduction of a container deposit scheme (CDS). This scenario would also require consideration of land use planning for additional organics infrastructure and mandatory source separation of organics by food businesses. The Victorian Government can further enable this scenario by providing support for demonstration precincts/initiatives, business to business engagement, research and development, as well as commercialisation support for new business models and specialised recovery technologies.

FOGO FOMO, Closing the Floodgates and *High Energy* all achieved relatively similar scores. The lack of differentiation between the scenarios is because each one focuses on improving a specific area of resource recovery, either dry recyclables, organics or waste avoidance through pay-as-you-through charging and product stewardship. All three of these scenarios include thermal energy from waste, which diverts the majority of remaining residual material from landfill. This combination of targeted improvements to recycling/waste avoidance and energy recovery from other residual materials results in similar Circularity Index scores.. Energy recovery also drives positive greenhouse gas emissions reduction scores because it avoids methane generation from organics in landfill and provides partially-renewable electricity to offset alternative generation from Victoria's fossil fuel-reliant grid. If pursued, these scenarios can be supported by a range of policy and regulatory measures, as well as infrastructure and market support. These measures are described in Table 2 and Table 3.

Out of Sorts and *Packaging Crackdown* had the lowest scores in the MCA and are therefore not recommended to be pursued (greyed out in the following tables).

Table 2: Policy and regulatory actions to support scenarios

Out of Sorts (not recommended)	**FOGO FOMO**	**Closing the Floodgates**	**Circular Stewards**	**Packaging Crackdown (not recommended)**	**High Energy**
Public education on recycling materials restrictions and recycling outcomes.	Timeline for mandatory organics separation. Energy from Waste policy. Build regulatory capacity for thermal EfW. Waste sector emissions reduction pledge. Public education on waste separation and recycling/resource recovery outcomes. Implementation and compliance on organics landfill ban. Guidance for businesses on mandatory food waste separation. Review of building guidelines to support separate collection of organics.	Develop and phase in import and export restriction policy. Announce mandatory changes to comingled recycling. Land-use planning for new recycling infrastructure. Energy from Waste policy. Build regulatory capacity for thermal EfW. Landfill levy increases. Public messaging on recycling and resource recovery outcomes. Proactive compliance on landfill levy, stockpiling and dumping.	Circular economy policy. Introduce container deposit scheme (CDS). Mandatory product stewardship schemes. Timeline for mandatory organics separation. Land use planning for additional organics infrastructure. Guidance for businesses on mandatory food waste separation. Review of building guidelines to support separate collection of organics. Expand data collection and outcomes monitoring to capture reuse and B2B resource flows.	CDS introduction, national harmonisation and expansion to include all glass packaging. Single use plastic bans. National Packaging Targets implementation – led y APCO with state and federal support. Announce restrictions on non-recyclable packaging. Develop monitoring/compliance capacity. Implement restriction on non-recyclable packaging. Public education on recycling materials restrictions and recycling outcomes. Monitor new materials development and recyclability.	EfW policy. Build regulatory capacity for thermal EfW. Community engagement on thermal EfW. Advice to councils on PAYT models. Landfill levy increases. Product stewardship expansions. Polyvinyl chloride (PVC) packaging ban. Public education on recycling materials restrictions and recycling outcomes. Proactive compliance on landfill levy, stockpiling and dumping. Proactive compliance on landfill levy, stockpiling and dumping.

Table 3: Infrastructure and market actions to support scenarios

Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Funding for materials recycling facilities (MRF) upgrades and processing infrastructure. Continued demonstration and testing of recycled content in construction. Procurement guidelines prioritising recycled content in infrastructure. Procurement of recycled content in infrastructure and commercial/ consumer products. Review landfill airspace and lifetime in light of increased disposal volumes.	Funding for council collection changes. Funding for additional largescale organic processing infrastructure. Feed in tariff of bioenergy. Improved quality specifications for recycled organics. PIW guidelines, product testing and procurement specifications for EfW bottom ash recycling. Research focus on potential emerging contaminants in recovered organics. Commercialisation funding for emerging, high-value organics recovery technologies.	Funding for materials recycling facilities (MRF) upgrades. Funding for recycling infrastructure development and expansion. Funding to councils for mandatory collection change. Transport or infrastructure support for regional areas. Continued demonstration and testing of recycled content in construction. Procurement guidelines prioritising recycled content in infrastructure. PIW guidelines for EfW ash recycling.	Support for demonstration precincts/initiatives. B2B education and support to match and marry businesses. Funding for council collection changes and additional organics processing infrastructure Improved quality specifications and market development for recycled organics Procurement specifications for recycled content, material passports and circular business models. R&D and commercialisation support for new business models and specialised recovery technologies.	MRF upgrades. Expansion of household organics collection. Federal support for MRF, plastic recycling and composting infrastructure related to achieving National Packaging Targets. Technical definitions/ specification of recyclable/ compostable packaging. Consumer and industry education. Procurement guidelines prioritising recycled content in infrastructure, packaging and street furniture. R&D and commercialisation support for new biodegradable packaging/ food grade recycled packaging.	Land use planning for EfW, including support for colocation with industrial heat users. PIW guidelines, product testing and procurement specifications for EfW bottom ash recycling. Transport or infrastructure support for regional areas. R&D and commercialisation support specialised recovery technologies for source-separated wastes (e.g. textiles, e-waste)

1 Introduction

1.1 Project context

The Victoria Government has a longstanding commitment to continuously improving recycling and resource recovery outcomes in Victoria. Through agencies including Sustainability Victoria (SV), the Department of Environment, Land, Water and Planning (DELWP) and Environment Protection Authority Victoria (EPA Victoria), the Victorian Government supports communities and businesses to turn waste into new resources and develop innovations which recover value from new materials, in new ways.

However, recent shocks and challenges have highlighted systematic failures in the waste and recycling sector and undermined public trust in recycling. Currently, parts of Victoria's recycling sector are heavily reliant on global supply chains. This was exposed by import restrictions on contaminated recyclable materials by China and other importing nations, which have led to stockpiling and landfilling of recyclable materials in Victoria. Notably, this was a catalyst for the insolvency of major player, SKM Recycling, in August 2019. Other sectors have stable domestic markets but struggle to expand their current operations due to a mismatch between the material quality expected by end-use markets and the feedstock quality available through current collection systems.

The Victorian Government recognises that decisive action is needed to set Victoria back on a course to sustainable and responsible resource recovery. To this end, the Victorian Government and has asked Infrastructure Victoria for advice on recycling and resource recovery infrastructure in Victoria. Specifically, the Victorian Government is seeking advice on the infrastructure that would be required and the role for government in providing support to:

- Develop Victoria's re-processing sector for recycled material, particularly those that currently rely heavily on overseas markets such as plastics;
- Better enable the use of products containing recycled materials in a variety of Victoria industries, such as manufacturing, construction and agriculture;
- Support an energy from waste sector that prioritises the extraction of recyclable material and recovers energy only from the residual waste that would otherwise be landfilled; and
- Support high levels of resource for organics, particularly food organics.[1]

[1]Infrastructure Victoria, 2019, *Advice on recycling and resource recovery infrastructure in Victoria*, available at: http://www.infrastructurevictoria.com.au/project/advice-on-waste-infrastructure-in-victoria/

1.2 Project objective and approach

Infrastructure Victoria engaged Arup to analyse technologies, associated infrastructure, and required enablers to improve Victoria's recycling and resource recovery. This will contribute to Infrastructure Victoria's advice to the Victoria Government, together with other investigations into policy, economics, governance and interjurisdictional comparisons.

Arup has approached this analysis with an understanding that waste technologies and infrastructure options cannot be developed in isolation from the wider waste and resource recovery supply chain. There are many interdependencies and economic trade-offs which influence how waste is collected, sorted, sold and remanufactured, and the technologies which are used at each stage in the process. Additionally, market conditions and policy settings directly influence the availability of waste streams for recovery and drive commercial decisions about preferred resource recovery technologies.

The advice which Infrastructure Victoria provides to the Victoria Government must be grounded in a supply-chain view of the waste and resource recovery sector. The analysis considered these interdependencies to ensure that technology and infrastructure recommendations are compatible across the supply chain.

Scenarios were used to explore specific infrastructure and technology needs within plausible resource recovery futures for Victoria. This builds on Sustainability Victoria's Resource Recovery Technologies Guide (2018) and Guide to Biological Recovery of Organics (2017) by:

- Updating technical characteristics based on international knowledge and Arup's project experience;
- Focusing on the interdependencies between technology selection at each stage of the resource recovery supply chain, to develop resource recovery scenarios; and
- Applying multi-criteria analysis (MCA) to compare the scenario outcomes

The scenario approach and outcomes-focused analysis provides an understanding of preferred technology and infrastructure options which form a compatible future supply chain due to consistent policy and market drivers.

2 Background

2.1 Global waste context

Globalisation of trade and labour markets have fundamentally shaped resource recovery markets over the past 50 years. Product manufacturing and demand for raw materials is increasingly concentrated in emerging South-East Asian economies, and these markets have previously accepted waste material for recycling from developed nations across the world. The low cost of labour and weak environmental protection regulation supported a global reliance on manual sorting in these waste-importing nations, who upgraded low-quality mixed scrap materials into usable feedstocks for the manufacture of new products.

However, there is increasing pressure on these emerging economies to improve waste management, environmental protection and labour conditions within their own societies. This pressure has led to strict contamination limits on imported scrap materials, initially introduced by China in 2018. Australia's collection and sorting systems for recyclable waste were unable to meet the new contamination limits for various materials, which were effectively banned from import under the new rules. Global material flows shifted to other importing markets, which subsequently introduced their own quality restrictions, and commodity prices for low-quality mixed scrap material collapsed, highlighting the vulnerability of the global recycling system. This market shock has prompted renewed attention among developed countries on economically and environmentally acceptable options for managing recyclable material within national borders. The Basel Convention, to which Australia is a signatory, restricts export of hazardous waste from developed to developing countries. An amendment proposed in 2018 would list mixed and contaminated plastic scrap as restricted material.

In parallel to recycling challenges for mixed plastic and paper, there is growing public awareness of ocean plastic pollution. Policy responses include plastic bag bans in many countries, including Australia, and restrictions on single-use plastics. The EU and Canada have announced an intention to ban various single use plastics from 2021. These single-use items are typically non-recyclable. However, ocean plastics pollution is strongly linked to global reliance on plastic waste export for sorting and reprocessing overseas, because importing nations typically have weaker waste management and environmental protection regulations, and significant ocean leakage of low-grade recyclable materials and sorting residuals is understood to occur. Over 25% of global ocean plastics pollution in 2010 was estimated to originate from China.[2]

Circular economy

Current consumption and production is dominated by linear resource flows, in a wasteful 'take-make-dispose' economy. This form of consumption is unsustainable, as population growth and environmental degradation place pressure on both resource extraction and waste disposal. The United Nations Sustainable

[2] . Jambeck et. al., 2015, *Plastic waste inputs from land into the ocean*, available at: https://science.sciencemag.org/content/347/6223/768

Development Goal (UN SDG) 12, Sustainable Production and Consumption, specifically calls for action on these issues.

There is growing global momentum behind the concept of a circular economy. This is particularly evident in the European Union, where the Circular Economy Packaging was successfully ratified in 2018. The circular economy aims to decouple economic growth from resource consumption and environmental impact. It is restorative and regenerative by design and aims to keep materials and products in repetitive technical and biological loops, maintaining them at their highest utility and value. Figure 2 highlights the difference between linear and circular economies. Examples of circular economy approaches include:

- Replacing physical items with virtual ones.
- Sharing significant assets, so that they are used more efficiently, for example Airbnb accommodation, coworking spaces, car-sharing applications and Mobility as a Service offerings.
- Replacing products with services, such as leasing models for washing machines, furniture or office fit-outs which are eventually taken back, refurbished and leased again, encouraging design for durability and repair.
- Recycling and remanufacturing products, materials and organic waste, focusing on high quality and high value outputs. Source separation is a key enabler of higher value recovery outlets.
- Industrial symbiosis, where waste from one company becomes a raw material for another, for example waste bread used for brewing beer, waste carbon dioxide (CO_2) used to supply greenhouses, or waste heat reducing energy demand at a neighbouring industrial process.
- Optimisation of current processes to reduce waste in the supply chain and create efficiency despite more complex material flows and logistics.
- Shifting to regenerative approaches which use renewable energy, regenerate natural ecosystems and return recovered nutrients to the biosphere.

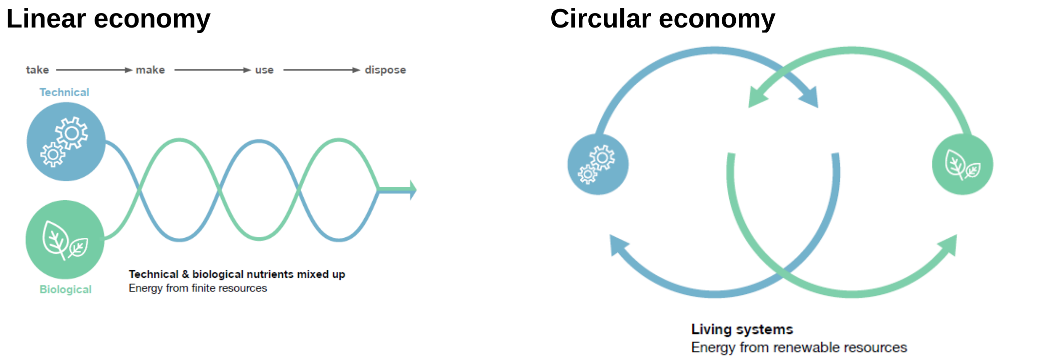

Figure 2: Linear and circular economy concept diagrams

2.2 Australian waste context

In Australia, waste and resource recovery are primarily managed at a state level, resulting in differing policy and regulatory approaches, and different resource recovery outcomes, between the states and territories. Inconsistency across jurisdictions has at times resulted in gaps and unintended consequences including the transport of waste across state border to avoid disposal levy liability. Waste and resource recovery data is consistently poor and is hampered by differing classification systems, regulatory systems and reporting requirements in each jurisdiction. Table 4 summarises trends of convergence or divergence in state approaches to key waste policies, programs and regulation.

There has historically been limited federal policy or intervention in waste and resource recovery issues. The *National Waste Policy: Less Waste, More Recycling* establishes a framework for national waste and resource recovery policy direction to 2030.[3] Its five overarching principles seek to create a circular economy that improves current national waste management practices. However, the previous iteration of the *National Waste Policy* failed to galvanise significant change and the updated version has been similarly criticised for lack of decisive action. The *National Food Waste Strategy* currently appears similarly under-resourced.

The growing awareness of waste issues has led to increasing engagement at the federal level, including several Council of Australian Governments (COAG) announcements relating to improving the recovery of packaging waste and responding to export restrictions. In 2019, a new ministerial portfolio, Assistant Minister for Waste Reduction and Environmental Management, was created and signals ongoing federal interest in waste and resource recovery issues

Table 4: Summary of waste policy, regulatory and program trends across Australian states and territories

Measure, principle theme or instrument	Summary of approaches
Landfill disposal levies	Convergence on use of landfill disposal levies across all jurisdictions.
Landfill disposal bans	Convergence on the application of bans. There is some divergence or inconsistency on the types of waste that are subject to bans.
Waste collection	General convergence towards provision of three bin systems, incorporating a third bin for garden or garden and food waste organics. Divergence on what can be recycled in different jurisdictions. Comingled recycling collection remains dominant, but some separate collection of either glass or paper are have emerged in QLD, NSW and Victoria.

[3] Australian Government Department of the Environment and Energy, 2018, *National Waste Policy: Less Waste, More Resources*, available at: http://www.environment.gov.au/protection/waste-resource-recovery/national-waste-policy

Measure, principle theme or instrument	**Summary of approaches**
End of waste (EoW) framework	Divergence in the implementation and operation of EoW frameworks.
Circular economy	The principle of the circular economy is a significant policy gap, with divergence regarding forward looking policy development. Some jurisdictions are developing policy, and some are not. Given the strong emphasis in the updated National Waste Policy in increasing federal interest in waste and resource recovery, a national approach appears more likely to be developed.
Product stewardship	Policy gap with a general absence of state-level product stewardship; lack of federal schemes under the Product Stewardship Act (2011)[4] other than the National Computer and Television Recycling Scheme.
Container deposit scheme (CDS)	Convergence on use of CDS and consistency of accepted containers between all schemes. Most recently, Tasmania announced plans to have a container deposit scheme in place by 2022. Victoria is the only state without a container deposit scheme planned or in place.
Procurement and market development	Policy gap, with only two jurisdictions implementing state policy and schemes.
Energy from waste (EfW)	Convergence on use or development of EfW policy, however significant gap with majority of states without EfW policy in place. The first modern EfW facility is under construction in WA and proposals have been announced in various states, including Victoria.
Waste infrastructure planning	Convergence on development and use of waste infrastructure plans. However, these are not yet completed in various jurisdictions. Victoria is most advanced in this area.
Proximity principle	Convergence away from use of the proximity principle, as is it difficult to enforce.
Education	Convergence on use of education programmes, divergence on approach.
Waste classification, reporting and data	Convergence on use of waste classification and data, divergence on consistency of approach.
Financial assurance	Convergence on use of financial assurance to manage environmental and legacy risks of waste infrastructure.

[4] Australian Government, Product Stewardship Act (2011), available at: https://www.legislation.gov.au/Details/C2011A00076

Measure, principle theme or instrument	**Summary of approaches**
Targets, monitoring and evaluation	Convergence on use of targets, however the Northern Territory and Tasmania are outliers. Victoria uses predominantly qualitative goals. Differing degrees of successful implementation of policy.
Waste transport	Convergence on licensing and tracking, however a gap in terms of the waste types included. Most states only focus on National Environment Protection Measures (NEPMs) controlled wastes, and non-controlled wastes are not subject to licensing or tracking. No jurisdictions have implemented a permanent transport subsidy for waste generated in rural, remote or regional areas. A temporary transport assistance fund was established in South Australia[5] to help regional councils to continue providing recycling services in the wake of China's import restrictions. NSW also implemented a temporary recycling relief fund[6] to also cover increased costs including transport costs. Queensland is potentially looking at utilisation of transport subsidies as part of their levy implementation.

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[5] South Australian Government, 2018, *Regional Transport Relief Fund Guidelines 2018-19 China's National Sword Policy Response Package Initiative,* available at: https://www.greenindustries.sa.gov.au/_literature_186962/Regional_Transport_Relief_Fund_Guidelines_and_Application_Form_(2018-19)

[6] NSW Environment Protection Authority, 2019, *Recycling Relief Fund*, available at: https://www.epa.nsw.gov.au/working-together/grants/councils/recycling-relief-fund

2.3 Victorian waste context

Global trends towards increasing source separation, use of levies or bans to divert recoverable materials from landfill, growing awareness of plastic waste and pollution and exploration of circular economy concepts are all currently evident in resource recovery practices and directions in Victoria.

Recent shocks and challenges in the waste and resource recovery sector have highlighted systematic failures which have undermined public trust in recycling.

- SKM Recycling was a major player in recycling and material recovery in Victoria, with contracts serving 33 Victorian local government councils in 2019.
- The company's facilities have a history of environmental non-compliance, including multiple stockpile fires and a high-profile incident in 2017 when a recycling stockpile fire at the SKM Recycling Coolaroo facility burned for 11 days and led to the evacuation of residents from smoke-affected areas. In August 2019, SKM Recycling reached a $1.2 million settlement with residents who were affected by the fire.[7,8]
- SKM Recycling was declared insolvent in August 2019.
- There have been various instances of kerbside collected recyclables being disposed to landfill due to contract re-negotiations in the wake of China's import restrictions, temporary closure of recycling sites due to stockpiling issues and the SKM insolvency.
- In 2019, the City of Ballarat announced a new kerbside recycling contract, but no longer accepts glass for comingled collection, switching instead to glass drop-off points.[9]

These events have driven significant Victorian Government actions and funding for kerbside recycling over the past 18 months, notably:

- The Recycling Industry Strategic Plan and accompanying $37 million in funding, released in July 2018.
- The $14.3 million Recycling Industry Development Fund announced in June 2019.
- Additional funding for new market entrants, council contract negotiation support and community education, announced in June 2019.[10]

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[7] ABC News 12 July 2017:https://www.abc.net.au/news/2017-07-14/coolaroo-residents-angry-at-handling-of-recycle-plant-fire/8709696
[8] ABC News 1 August 2019:https://www.abc.net.au/news/2019-08-01/skm-recycling-ordered-to-pay-million-dollar-settlement/11373754
[9] City of Ballarat, 2019, *Recycling in Ballarat is Changing…,* available at: https://www.ballarat.vic.gov.au/recycling-is-changing
[10] Premier of Victoria, June 2019, *Minister for Energy, Environment and Climate Change press release: Strengthening Victoria's Recycling Industry*, available at: https://www.premier.vic.gov.au/strengthening-victorias-recycling-industry/

The current focus on kerbside recycling comes in addition to various policies which are in place, or being developed, to improve waste management practices and resource recovery across a range of material streams. The following are particularly important in influencing the direction of resource recovery and recycling infrastructure in Victoria:

- *State-wide Waste and Resource Recovery Infrastructure Plan* (SWRRIP). (Sustainability Victoria)
- E-waste landfills ban in Victoria.
- *Victorian Climate Change Framework* (DELWP).
- *A circular economy for Victoria* issues paper 2019 (DELWP).
- *Turning Waste into Energy* discussion paper 2017 (DELWP).

2.3.1 Circular economy discussion paper

In 2018–19 the Victorian Government approved a $9.02 million funding allocation for DELWP to develop a whole-of-government waste policy that incorporates circular economy principles. An issues paper was released for public consultation and the final policy is due at the end of 2019.[11] The paper contains an overview of the key waste management and resource recovery issues in Victoria. These issues include materials being discarded during production processes (estimated as $5.4 billion spent by Victorian businesses in 2012), and improper disposal of food waste from Victorian households which is adding $2,000 a year to the food costs of an average Victorian household.

Furthermore, the paper identifies job creation and economic growth, improved material productivity, increased value from recovered materials, reduced environmental harm and creating a resilient recovery system for Victoria as benefits. While recycling and recovery is prioritised, the issues paper also highlights other waste management methods, such as EfW, as a means of utilising available technologies to improve the Victoria's waste situation and reduce the reliance on landfill.

An additional ten-year action plan will be established and focus on how the circular economy policy can be achieved across businesses and communities through improved material use and management.

[11] The State of Victoria Department of Environment, Land, Water and Planning, 2019, *A circular economy for Victoria issues paper*, available at https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/5115/6324/2021/A_circular_economy_for_Victoria_Issues_Paper_July2019.pdf

2.3.2 Victorian legislation

The Environment Protection Act 1970 is the overarching legislation that establishes the Victorian Waste and Resource Recovery Infrastructure Planning Framework (the framework). The purpose of the framework is to commit to long term planning for waste and resource recovery infrastructure objectives that are integrated with other land use and transport planning requirements.

This legislation was updated, and the Environment Protection Amendment Act 2018 provides the foundation to transform Victoria's environment protect laws and the Environment Protection Authority Victoria.[12] Key changes include but are not limited to general environmental duty (GED), a three-tiered permissions framework, tailored waste management controls, and Better Environmental Plans to enable the EPA to recognise innovative approaches to environmental protection.[13] To support this update, the Victorian Government is currently in public consultation on subordinate legislation including regulations, reference standards, regulatory impact statements, and impact assessments.[14]

This Act also requires Sustainability Victoria (SV), to develop the *State-wide Waste and Resource Recovery Infrastructure Plan* (SWRRIP) and establish seven regional waste and resource recovery groups, who each need to develop implementation plans for waste and resource recovery at a regional level (Regional Implementation Plan).

The SWRRIP provides strategic direction in Victoria for managing resource recovery and waste infrastructure for 30 years. Implementation at a local and regional level is described in the Regional Implementation Plans, which provide opportunities for local governments and communities to take a more active role in waste management planning in their regions.

The SWRRIP operates within a legislative framework, including but not limited to the following Acts:

- Environmental Protection Act 1970
- Environmental Protection Amendment Act 2018
- Planning and Environment Act 1987
- Sustainability Victoria Act 2005
- Transport Integration Act 2010 (TIA)
- Local Government Act 1989
- Climate Change Act 2017

[12] The State of Victoria, 2018, Environment Protection Amendment Act 2018, available at: https://www.environment.vic.gov.au/sustainability/environment-protection-reform/ep-bill-2018
[13] The State of Victoria Department of Environment, Land, Water and Planning, 2018, *Environment Protection Amendment Act 2018 Fact Sheet*, available at: https://www.environment.vic.gov.au/__data/assets/pdf_file/0019/334450/Factsheet_Environment-Protection-Amendment-Act-2018.pdf
[14] The State of Victoria Engage Victoria, 2019, *Proposed regulations and environment reference standards*, available at: https://engage.vic.gov.au/new-environmental-laws/subordinate-legislation

2.3.3 Other relevant policies, positions and regulations

The SWRRIP also incorporates relevant Victorian and national government policies, positions and regulations, and considers the following factors when delivering the long-term goals for Victoria's waste and resource recovery system:

Electronic waste ban to landfill

Since July 2019, electronic waste (e-waste) has been banned from landfills in Victoria. The generation of e-waste in Australia is growing three times faster than residual municipal waste. This waste stream contains valuable and hazardous materials which make it unsuitable for general landfill and crucial that e-waste is managed and recycled properly. The ban and the newly upgraded centres and facilities for e-waste support collection of source-separated e-waste streams for safe management and higher-value recovery and recycling.

Government entities such as SV, DELWP, EPA, and other regional groups are working together to ensure the ban is successful and the recycling measures are widely adopted.

Victorian Climate Change Framework

The 2017 *Victorian Climate Change Framework* sets an emission reduction target for Victoria. Under the Act, the Waste sector is required to produce an emissions reduction pledge for the period 2021-2025, which will become a ministerial responsibility.[15] Diverting organics from landfill to avoid generating methane is the key focus for emissions reduction in the waste sector.

Waste management policies[16]

The Environment Protection Act (1970) gives EPA the ability to create waste management policies (WMPs) in Victoria that better co-ordinate and improve the management of waste and material streams. These policies set state-wide, enforceable objectives and directions. The current series of policies target waste management as it impacts landfills, packaging materials and other waste and recovery related operations. The 2018 amendment will introduce tailored controls for specific hazardous industrial wastes and specific municipal and industrial wastes that have resource recovery, recycling and reuse potential.

Energy from Waste position

EfW is recognised as a potential opportunity in the future management of waste in Victoria, with two proposals for energy recovery from mixed waste publicly announced and under consideration in Victoria.

Various energy from waste technologies are mature and well established overseas, but the technology is new to Victoria and lack of a clear policy position creates

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[15] DELWP, 2017, *Climate Change Act 2017: Emissions Reduction Pledges*, available from: https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0027/55287/CC-Act-2017_Fact-Sheet_Emissions-Reduction-Pledges_v2.pdf

[16] Environment Protection Authority Victoria, 2019, *Waste management policies*, available at: https://www.epa.vic.gov.au/about-us/legislation/waste-legislation/waste-management-policies

various risks for both project proponents and the Victorian community. Energy from waste policy should establish acceptable residual materials for energy recovery, clear approvals pathways and expectations on key issues including air emissions, energy efficiency, appropriate siting and community consultation. A clear policy position on these issues can provide investment certainty for proposals which align to Victoria's goals and expectations, while deterring potentially risky or inappropriate developments. EPA Victoria released an energy from waste guideline (publication 1559.1) in 2017, which provides an interim position on these issues. Further consultation was undertaken by DELWP in late 2017, using the *Turning waste into energy* discussion paper. The final outcomes of this consultation are expected to be incorporated within the Circular Economy Policy, to be published in late 2019.

Waste avoidance

The Victorian Government is planning for new infrastructure and technologies to manage the growing waste generation. Reducing the amount of waste generated is the most desirable means of reducing the impact on the environment and community amenity. Lower volumes of waste reduce the pressure on the waste management systems and infrastructure networks, as well as reducing the demand for new resources. Supporting initiatives that help Victorians avoid generating waste in the first place is an important step to improve waste management outcomes and accommodate future population growth in Victoria. SV's *Victorian Waste Education Strategy* provides a consistent and co-ordinated approach to resource and waste recovery education.[17] SV delivers projects to realise the strategy at local government, company- and community-levels.

Product Stewardship Schemes

SV has a supported several national product stewardship approaches and waste and resource recovery programs for various priority materials, including e-waste, paint and tyres. These programs have all been successful in providing a clear picture of the barriers and opportunities for each waste stream, assisting to identify evidence, and trial systems that efficiently cost and recover priority products, inform policy and regulatory options, and provide evidence for potential stewardship interventions. SV continues to provide collection services through the Detox Your Home program, and they have led the development and facilitation of pilots and product stewardship schemes including:

- ByteBack – a free service available to Victoria residents and small business owners to dispose of unwanted computers, and input into the NTCRS product stewardship scheme design.
- BatteryBack – a pilot retail collection programme for used household batteries in Victoria.
- PaintBack – a scheme to collect waste paint for reuse and responsible disposal, which now has national drop off locations.

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[17] Sustainability Victoria, *Victorian waste education strategy 2016,* 2019, available at: https://www.sustainability.vic.gov.au/About-us/What-we-do/Strategy-and-planning/Victorian-waste-education-strategy

- FlashBack – a scheme to collect compact fluorescent lights.

The ByteBack scheme was important in the design of the national television and computer recycling program. SV is currently also leading the development of a national product stewardship approach for solar PV systems.[18]

2.3.4 Responsibility for recycling and resource recovery in Victoria

Multiple agencies contribute to Victoria's waste management and resource recovery, and VAGO detailed the accountabilities of DELWP, EPA and SV in the *Recovering and Reprocessing Resources from Waste* report – a summary is provided in Table 5.

Table 5: Accountabilities and key issues raised in VAGO's *Recovering and Reprocessing Resources from Waste*

Agency	**Responsibility**	**Key issues raised**
Department of Environment, Land, Water and Planning	Providing strategic leadership and direction for resource recovery and waste management	Clear need for DELWP to create an overarching waste policy, as other agencies are currently operating without a clear direction to minimise and recover waste efficiently.
Victorian Environment Protection Authority	Regulating the waste industry	Failures in their management of these responsibilities that have occurred in recent years with stockpiling of resources at landfills resulting in safety hazards across various sites. This has resulted in significant fires occurring at landfill and waste storage facilities recently in Victoria.
Sustainability Victoria	Implementing strategies to guide waste and resource recovery in Victoria Collecting waste-related data	Generally, unclear State-wide guidance and implementation resulting from vague actions and lack of targets in the SWRRIP, Victorian Organics Resource Recovery Strategy, Victorian Market Development Strategy for Recovered Resource, and the Victorian Waste Education Strategy.

[18] Sustainability Victoria, 2018. *Sustainability Victoria announces research project to support end of life solar panels*, available at:https://www.sustainability.vic.gov.au/About-us/Latest-news/2018/09/03/01/01/Sustainability-Victoria-announces-research-project-to-support-end-of-life-solar-panels

The *Recycling Industry Strategic Plan* (RISP), was developed in response to changes in global recycling markets which impacted Victoria's kerbside recycling.[19] Within this plan, actions were developed and assigned to agencies, which has been detailed below in Table 6. Note these actions relate to municipal kerbside recycling, and do not include other major waste streams (commercial and industrial waste (C&I) and commercial and demolition waste (C&D)).

Table 6: Actions and accountabilities in the *Recycling Industry Strategic Plan*

Actions	**Responsible lead agencies**
Support local government and industry to transition to new contract arrangements for recycling services	Local Government Victoria (LGV), Sustainability Victoria
Improve contracting and procurement processes used by local government for recycling services	LGV, MWRRG
Educate the community about recycling	Sustainability Victoria
Improve collection of recycled materials	Sustainability Victoria
Invest in recycling infrastructure to ensure market readiness of recycled products	Sustainability Victoria
Support collaborative procurement of recycling services	MWRRG, LGV
Improve safety and amenity of resource recovery facilities	EPA
Drive demand for products containing recycled materials through government procurement	Department of Treasury and Finance and Sustainability Victoria
Support the development of end-markets for recycled materials	Sustainability Victoria, DELWP
Industry and government collaboration to accelerate the design of products and packaging for sustainability, develop standards for products and access foreign markets	Federal Government

[19] The State of Victoria Department of Environment, Land, Water and Planning, 2018. *Recycling Industry Strategic Plan,* available at: https://www.environment.vic.gov.au/__data/assets/pdf_file/0013/326110/Recycling-Industry-Strategic-Plan.pdf

3 Waste and resource recovery scenarios

Recycling and resource recovery technologies and infrastructure are dependent on market, policy, and societal contexts, so an integrated assessment of options is required to understand how Victoria's recycling and resource recovery can be improved. Scenarios exploring plausible recycling and resource recovery futures in Victoria provide a thorough analysis and understanding of these interdependencies, outcomes, and associated enablers and barriers to success.

The scenarios developed for analysis explore different focus points and opportunities for recycling and resource recovery infrastructure, policy and investment. They are based on Arup's knowledge of recycling and resource recovery and infrastructure and policy across various jurisdictions, and draw on recent announcements, market trends and events in Victoria and Australia.

The scenarios developed for analysis are:

1. Out of Sorts: Continued investment in current resource recovery pathways but lacking significant change to policy or waste collections.
2. Food organics and garden organics (FOGO) FOMO: Focus on organic waste separation, recovery and landfill diversion driven by ambitious greenhouse gas emissions reduction commitments.
3. Closing the Floodgates: Significant investment in domestic recycling and energy recovery infrastructure in response to federal intervention in import and export of waste and raw materials.
4. Circular Stewards: Consumers and industry embrace the circular economy, while government policy focuses on supporting this shift and increasing separate collection and recovery of organics.
5. Packaging Crackdown: Significant restrictions on packaging to meet 2025 packaging targets, including restrictions on single use items and difficult-to-recycle packaging.
6. High Energy: Large-scale thermal EfW facilities become established in Victoria and Australia at large, and are accompanied by pay-as-you-throw charging to reduce waste generation, but recycling is limited.

The scenarios were assessed using multi-criteria analysis (MCA). The MCA provides a structured analysis against multiple, potentially conflicting, criteria and offers holistic view of options' performance. It is commonly used by governments in Australia when it is not possible to quantify key costs or reach a robust economic valuation of key benefits. For details on the MCA process, refer to Section 4.

3.1 Scenario development

The scenario development grouped related changes to technologies and processes to create coherent waste and resource recovery narratives. These narratives encompass multiple waste streams and all stages of the waste and resource recovery supply chain.

An initial list of potential actions, including changes to policies, processes and infrastructure was compiled by drawing on examples from other jurisdictions, policy announcements and directions from the Victorian and Australian Governments, as well as expanding existing Victorian policies and proposals but have limited scope or scale. The list included:

- Changing consumption patterns
- Container deposit scheme (CDS)
- Pay-as-you-throw (PAYT) charging
- Changes to source separation and collection formats
- Landfill bans for additional materials e.g. organics
- Active support for thermal waste to energy
- Active support for anaerobic digestion
- Product stewardship (new product or expanded / mandatory schemes)
- Circular economy policy
- Changing consumption patterns
- Export restrictions on material for recycling
- Import restrictions on virgin materials
- Financial restrictions on the use of virgin materials
- Single use plastics bans
- Action to achieve 2025 packaging targets (100% reusable, recyclable or compostable packaging)

Many of these actions address a specific material or point in the waste supply chain. Scenario development groups relevant actions together, recognising that changes in waste and resource recovery processes need to occur in concert, rather than in isolation.

Once a long-list of actions was developed, they were then grouped based on shared similar objectives and policy or market drivers. This approach ensured that the scenarios maintain a coherent narrative on drivers of change.

The complete scenario then explored the impacts of these key drivers and actions across multiple waste streams and points in the supply chain to identify broad infrastructure requirements, expected resource recovery outcomes, and associated enablers and barriers to success. This approach helps decision-makers to understand the relationships between policy, markets and infrastructure development which are fundamental resolving Victoria’s current waste and recycling challenges.

None of the scenarios are intended to present abject failure or utopian success for the waste and resource recovery sector. Instead, they aim to clearly explore the likely impacts and limitations of various plausible policy and market approaches.

To clearly communicate the cause and effect relationships within the scenarios, each scenario focusses on one of the following:

- Dry recyclables.
- Organics.
- Changing business models (e.g. product stewardship).

The scenarios and subsequent analysis focus on the municipal solid waste (MSW) and C&I waste streams, because these streams currently have lower resource recovery rates and are facing significant challenges in Victoria. Previous policy development and investments focused on C&D waste and succeeded in establishing high resource recovery rates. Additionally, key C&D markets such as metals recycling and concrete crushing have not been as adversely affected by recent global commodity market changes and are unlikely to be significantly impacted by any of the changes described in the scenarios. Consequently, masonry materials are excluded from the scenario development and subsequent analysis to focus on the impact of scenario interventions on the MSW and C&I streams.

In practice, multiple scenarios could be combined, or alternative future scenarios could be created by pursuing different combinations of actions and policy objectives. The six scenarios analysed in this report do not present an exhaustive view of Victoria's possible waste and resource recovery future. However, they do cover the full range of policy and infrastructure changes identified in initial research and do so in a way which highlights the interdependent elements of Victoria's waste and resource recovery supply chains. The scenarios and their characteristics are shown in Table 7.

3.2 Scenario timing

The scenarios do not propose explicit timeframes for implementation of the infrastructure and behavioural changes described. The pace of change depends primarily on the enabling policy actions discussed in Section 5. The scenario narratives use indicative timeframes: short term (1-3 years), medium term (3-10 years) and long term (10+ years), which assume decisive policy actions in the short term.

Table 7: Summary of scenario characteristics

Intervention components	Scenario Development					
	Out of Sorts (BAU)	**FOGO FOMO**	**Closing the Floodgates**	**Circular Stewards**	**Packaging Crackdown**	**High Energy**
MCA score	**0.47**	**0.62**	**0.60**	**0.65**	**0.52**	**0.58**
Infrastructure investment	**Medium** Focus on dry recyclables sorting to export quality	**High** Focus on organics	**High** Focus on dry recyclables sorting and reprocessing	**High** Focus on circular business models and organics	**Low** Focus on dry recyclables generation and sorting	**Medium** Focus on EfW and PAYT collections
Energy from Waste	**Low**	**High**	**High**	**Low**	**Low**	**High**
Organics separation	**Low**	**High** Mandatory	**Low**	**High** Mandatory	**Moderate** Accepts compostable packaging	**Low** High capture rate in established systems
Dry recyclables recovery	**Medium** Export focus	**Low** Export focus Energy recovery	**High** Domestic reprocessing focus Energy recovery	**Medium** Export focus Avoidance/reuse	**Medium** Export focus Compostable alternatives	**Low** Export focus Energy recovery
CDS in Victoria	**No**	**No**	**No**	**Yes**	**Yes** Includes all glass packaging	**No**
New product stewardship schemes	**No**	**No**	**No**	**Yes** Mandatory	**Yes** Mandatory – packaging only	**Yes** Voluntary

3.3 Scenario 1: Out of Sorts

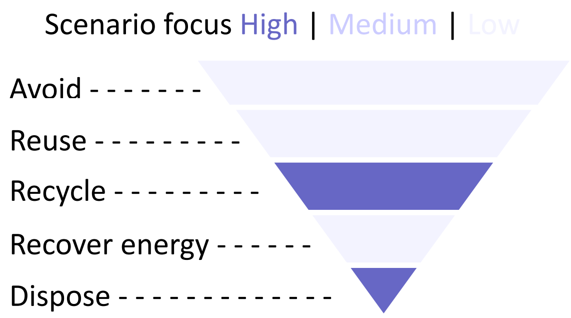
Indicator	Rating
MCA score	*0.47*
Infrastructure investment	*Medium*
Energy from waste	*Low*
Organics separation	*Low*
Recovery of dry recyclables	*Medium*
CDS in Victoria	*No*
New product stewardship schemes	*No*

Summary

This scenario explores the likely outcomes of business as usual (BAU) approach to resource recovery and recycling infrastructure. This assumes continued investment in the current areas of focus for resource recovery initiatives in Victoria. It has a strong focus on re-establishing outlets for dry recycling, without any major policy reform. It involves continued reliance on landfill disposal of residual waste and assumes no change to the landfill levy.

The key characteristics of this scenario are:

- Major investment into sorting technology at materials recycling facilities (MRF) and material upgrade / processing.
- Gate fee increases.
- No policy relating to source separation, waste generation, EfW of material or import/export.
- Infrastructure specifications and procurement of low-value, high volume recyclate.
- EfW not accepted.
- Increased tonnage to landfill.



Large-scale infrastructure and investments	**Small scale / emerging technologies**
▪ Resource recovery centres ▪ Recyclate sorting– optical and machine vision ▪ Robotic waste sorting ▪ Plastics washing, flaking and mechanical recycling ▪ Glass and plastics processing for use in infrastructure ▪ Open windrow composting	▪ E-waste recycling ▪ Textile recycling ▪ Organic valorisation – chemicals, insect protein ▪ Bulk plastic products

Scenario narrative

Efforts to restore the recycling sector focus on short-term investment in waste sorting and cleaning technologies to improve material quality. Infrastructure support is made available to MRFs to add additional sorting stages, including new lines of optical sorting to identify and separate plastics types, coloured glass and paper / fibre. Emerging technologies using machine vision and robotic sorting are also trialled and are effective for some segments of the comingled recycling stream. These technologies focus on pulling out plastics and composite packaging from a mixed recycling stream. Stable markets are established for well-sorted single-polymer streams and metals. However, to extract high-quality, high-value material streams, MRFs shift to a more selective positive-sorting regime and generate larger volumes of unsaleable mixed/residual material. One materials recovery facility also constructs further processing infrastructure for sorted plastic to increase access to markets. However, most materials recovery facilities are space-constrained and reluctant to invest in further processing infrastructure for a single material stream.

Infrastructure funding to expand washing, flaking and further processing capacity for plastics is taken up by some domestic remanufacturers over the short and medium term, allowing them to accept higher volumes of sorted recyclables from materials recovery facilities.

Operators increase gate fees to cover their operational costs in the new recycling landscape, and the tonnage of residual waste to landfill increases. MRFs tighten their acceptance criteria, and some materials such as liquid paperboard and polypropylene are no longer accepted. Mixed paper waste contaminated with glass fines from the comingled recycling stream is a significant challenge which cannot be addressed through sorting. Australian paper reprocessors remain reluctant to accept this material, despite funding availability for separate pulping equipment. Similarly, organics reprocessors will not absorb the low-grade fibre material due to glass contamination. The material is either exported to very low value markets, driving up MRF gate fees, or in various cases, landfilled.

Councils and businesses in Victoria are reluctant to change their waste separation and collection arrangements. Comingled recycling remains the dominant collection format for dry recyclables from households. Councils maintain their existing organics collections, but few are expanded to include food organics due to poor engagement and resistance to behaviour change from community. Separate collection of organics remains a niche market among environmentally conscious businesses.

Projects to demonstrate performance and develop specifications for low-grade recycling of glass fines and plastics in transport infrastructure prove successful and increasing volumes of low-grade waste can be absorbed into these infrastructure projects. However, these are low-value applications. They reduce the pressure on landfill airspace, but not on MRF gate fees.

Under this business as usual scenario there is low EfW capacity. One of the early proponents for a thermal EfW facility takes a minimum-effort approach to community consultation, engaging only as required by legislation and approvals processes. Various groups, both in the local and wider Victorian community are uncertain about the proposed facility. Community concerns about air pollution and cost build momentum, with protests receiving coverage on mainstream and social media. Without the social license to operate, the facility ultimately fails to gain all the necessary approvals. As a result, other energy for waste proposals in Victoria are shelved because proponents feel that community opposition poses an unacceptably high risk. Some thermal EfW capacity is already operational in Victoria at this stage, but EfW does not become a dominant waste management technology.

3.4 Scenario 2: FOGO FOMO

MCA score
0.62

Infrastructure investment
High

Energy from waste
High

Organics separation
High - Mandatory

Recovery of dry recyclables
Low

CDS in Victoria
No

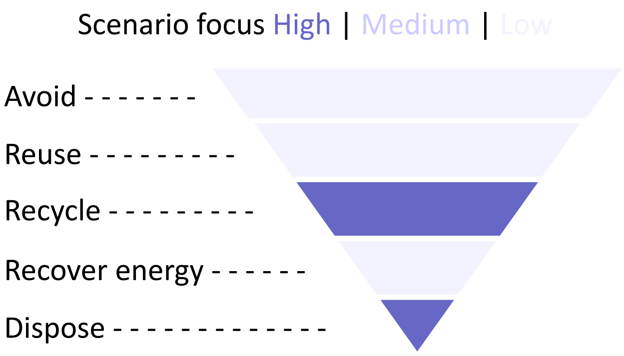
New product stewardship schemes
No

Summary

This scenario considers a focus on organic waste, with compulsory organics separation for both households and businesses. Climate change action drives landfill diversion and bioenergy investment. Energy from Waste is supported by government and community as part of the landfill diversion and emissions reduction portfolio. The recycling sector focuses on extracting clean streams of higher-value materials but reduces throughput under new market conditions. Some materials which were considered recyclable during the era of globalised recyclate trade become residual and suitable for energy recovery.

The key characteristics of this scenario are:

- Strong focus on organic waste.
- Climate Change Act (2017) drives landfill diversion and bioenergy agenda.
- All metro and larger regional councils separate food waste.
- Mandatory separation of food waste by food businesses.
- Landfill ban on organics.
- EfW becomes accepted, capacity plans for organics diversion.



Large-scale infrastructure and investments	**Small scale / emerging technologies**
▪ Digital technologies to optimise collection. ▪ Anaerobic digestion. ▪ In-vessel composting. ▪ Thermal energy from waste.	▪ Organic valorisation – chemicals, biofuels, insect protein. ▪ Rapid dehydration for business. ▪ Plastics to fuel. ▪ Biological degradation of waste plastics. ▪ Small-scale AD for businesses. ▪ Digital optimisation of collections.

Scenario narrative

Faced with ongoing price pressures and import restrictions on recyclable scrap from a growing number of importing nations, the state government turns to organic material to improve resource recovery. All metropolitan councils and some regional centres are required to introduce source separation of food and garden organics for all households. Funding is made available in the short term to support the transition, and all new services must be operational in the medium term. A ban on organic waste to landfill is scheduled within 5 years of the source separation transition.

The landfill ban is driven by the waste sector Emissions Reduction Pledge under the Climate Change Act 2017, which identifies methane emissions from organic waste in landfill as a key issue for the sector. Climate change action drives a focus on renewable energy generation from organic waste and bioenergy feed in tariffs are introduced which support anaerobic digestion. Several regional centres develop anaerobic digestion facilities using a 'regional biohub' which brings together several key operations in the local community, including the wastewater treatment plant and food manufacturing business, to secure organics feedstock and energy demand. Nutrient-rich digestate is returned to local agricultural activities.

The state government also introduces legislation making it mandatory for "food related businesses" to separate food waste and divert it from landfill. This includes businesses such as markets, supermarkets, cafes, restaurants, takeaway outlets, event venues and aged care facilities, as well as food processing businesses. Commercial waste streams achieve low contamination rates and are directed primarily to large-scale wet anaerobic digestion facilities, which have become commercially attractive in the context of incentives for renewable bioenergy and responsive, dispatchable power sources.

Opportunities to maximise the economic value of organic waste through high-value circular business models are explored and several technologies progress from research and development (R&D) programs to commercial scale-up over the medium term, extracting higher-value proteins, oils or chemicals from clean, source separated waste streams.

At the same time, EfW proposals in various stages, including Victoria, progress to commissioning stages. First-mover facilities carefully select well-proven technologies and uncontroversial industrial sites. Proponents take a proactive and comprehensive approach to community consultation and engagement, which reassures all but the staunchest objectors. The Victorian community and EPA Victoria both gain confidence and familiarity with EfW technology, and which comes to be generally accepted as a preferable fate to landfill.

The clear, state-wide commitment to source separation of organics helps inform project planning in the EfW sector. Feedstock modelling and EfW capacity does not include source-separated organic waste. EfW proposals are underpinned by red-bin residual waste from council and commercial sources. EfW for this residual stream complements the landfill ban on organics by recovering energy from organics which are incorrectly disposed to the residual stream, and non-recoverable partially-organic materials such as medical waste, hygiene products and nappies. In the long term, no residual waste from the metropolitan area is sent directly to landfill. Specifications, trials and resource recovery-focused procurement policies have successfully created a market for bottom ash from energy recovery, which is routinely included in road construction projects.

Meanwhile, the recycling sector focuses on extracting clean streams of materials which retain reliable commodity value, particularly metals, commercial source-separated cardboard, polyethylene terephthalate (PET) and high-density polyethylene (HDPE). Some assistance is made available to upgrade sorting lines. However, domestic reprocessing and manufacturing capacity remains unchanged, and continues its preference for high-quality recycled feedstocks and/or cheap virgin materials. Markets for mixed paper and mixed plastics do not recover and these become a liability for materials recovery facilities. Various MRFs stop accepting paper in the comingled recycling collection, and this is re-directed to the FOGO collection.

Source separated organics and recyclable materials are banned from EfW. Some MRF sorting residuals are permitted as EfW feedstocks. Limits were initially imposed based on typical facility performance prior to China's export restrictions. However, despite public education and investment in sorting technology, MRF recovery rates never return to the levels seen during era of mixed-recyclate export. As a result, stockpiling issues for MRF residuals emerge. Remembering the stockpile fires experienced in 2016-2019, authorities conclude that it is safer to allow controlled combustion in EfW facilities. MRF residual limits are relaxed and unsaleable materials are directed to energy recovery.

3.5 Scenario 3: Closing the Floodgates

MCA score
0.60

Infrastructure investment
High

Energy from waste
High

Organics separation
Low

Recovery of dry recyclables
High

CDS in Victoria
No

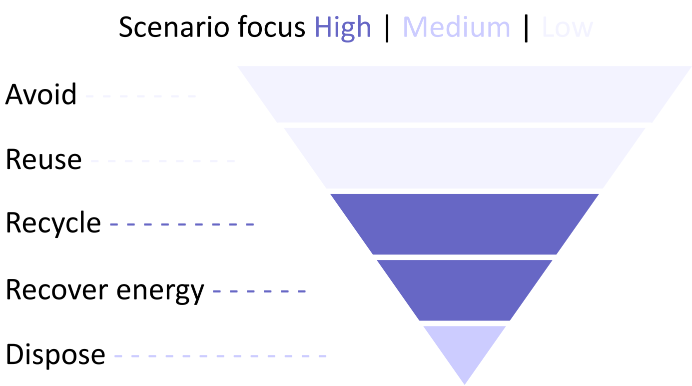
New product stewardship schemes
No

Summary

This policy-driven scenario is heavily focused on recycling and energy recovery. It explores the implications of federal intervention in export of recyclables, as foreshadowed by COAG in August 2019. Export restrictions are logically accompanied by import restrictions on virgin materials, investment support for major expansion of domestic reprocessing capacity and energy recovery to avoid accumulation of unsaleable materials in stockpiles or landfill.

The key characteristics of this scenario are:

- 'Export ban' – strict quality limits.
- Import duty on virgin material imports.
- Increased domestic material sorting, processing and manufacturing and infrastructure funding.
- Source separation of glass from paper.
- Quality focus at MRFs, more sorting residual.



Large-scale infrastructure and investments	**Small scale / emerging technologies**
▪ Energy from waste ▪ Separate collection of glass ▪ Glass beneficiation and reprocessing ▪ Plastic sorting and processing	▪ Digital collection optimisation ▪ Sorting dry recyclables – AI and machine learning ▪ Micro-factories ▪ Small-scale AD for businesses ▪ Rapid dehydration/composting for precincts ▪ Organics collection and valorisation – insect protein, chemical extraction ▪ Tyre pyrolysis

Scenario narrative

At the August 2019 COAG meeting, Australian leaders agreed that Australia should establish a timetable to ban the export of waste recyclables, domestic reprocessing capacity and market demand, focusing on upgrade of recovered materials into high-value commodities. An aggressive delivery timeline is developed with staged export bans coming into force in the medium term, paired with import restrictions on virgin material. Policymakers understand that export restrictions with no corresponding barrier to entry for cheap, imported virgin materials would lead to accumulation of unsaleable material in Australia, causing either stockpiling or disposal of recyclable materials on a massive scale.

The exact mechanism for import restrictions is not recommended here, but for the purposes of the scenario it is assumed that an import duty would be used and would apply to virgin raw materials and imported packaging. Finished products and their packaging are not affected and represent a large incoming material flow. Similarly, the export ban is assumed to be like the ‘import bans’ imposed by China and mirrored by other key importing nations. Some recycled materials can be exported but must meet quality specifications in order to be considered ‘products’ rather than ‘waste’.

By completing sorting and cleaning processes in Australia, under Australian environmental protection and occupational health and safety laws, the risk of irresponsible waste processing or dumping is reduced. However, the cost of processing increases, and international markets frequently choose cheaper virgin materials or recyclate over Australian material. The protected domestic market becomes the dominant outlet. Low-value, high-tonnage outlets for recyclable materials in infrastructure expand and play an important role in managing recyclate streams which remain unattractive to domestic reprocessors. The landfill levy increases to a level like New South Wales and South Australia, to encourage further support domestic recycling and discourage disposal of potentially recoverable materials.

Policymakers recognise that the success of the export ban policy relies on improving the quality of collected recyclable materials, which will increase costs compared to previous, unsustainable recycling practices. Councils are supported and strongly encouraged to increase source-separation of dry recyclables. Separate collection of glass is a priority, to reduce the contamination of other comingled recyclables with broken glass fragments, and separate collection for paper and card is also introduced. Councils experiment with various collection formats, including separate kerbside bins or crates for glass, like trials underway by Yarra City Council in Victoria, council-operated glass drop-off points which are separate from the kerbside collection system, similar to the Ipswich City Council model and new format introduced by the City of Ballarat in September 2019. Some councils opt for separate collection of paper and card, like several councils in NSW. Significant changes to collection formats are rolled out in the short term, and in the medium term the majority of Victorian councils adopt greater separation.

The removal of glass from the comingled recycling stream improves the quality of both glass and plastic streams, making them more attractive to domestic markets.

Infrastructure capacity to sort, clean and remanufacture recyclable materials expands over the short and medium term, with significant infrastructure funding support. This is distributed around Victoria, including several significant regional facilities which produce packaging for food products from agricultural centres. C&I waste streams continue to access well-established rebates for clean cardboard, and these supply chains begin to handle additional source-separated material types as Australian remanufacturing capacity increases.

At the same time, Energy from Waste proposals in various stages, including Victoria, progress to commissioning stages. First-mover facilities carefully select well-proven technologies and industrial sites, and invest significant effort in community consultation and engagement, which reassures both local communities and the wider Victorian community. In the context of the export ban, energy recovery is seen as an important pathway for Australia to take responsibility of its domestic waste, while reducing reliance on landfill.

Increases to the landfill levy makes energy recovery more commercially attractive. EfW facilities accept a range of waste streams, including MRF residuals, commercial and industrial waste and council residual waste streams, some of which still include a significant organic fraction. In the long term, no residual waste from the metropolitan area is sent directly to landfill. Specifications, trials and resource recovery-focused procurement policies have successfully created a market for bottom ash from energy recovery, which is routinely included in road construction projects.

Commercial and industrial customers also have increasing financial motivation and logistical support to improve waste separation. Overall, the cost of both waste and recycling services increases due to higher levels of onshore material processing, increased landfill levies and the entry of EfW into the market. There is a proliferation of logistics and data analytics service offerings in the waste management sector, both from major waste players seeking to add value to their existing customers, and from smaller new-entrants with a strong smart cities and sustainability focus.

Separate collection of organics continues in areas where it is already established, with modest uptake by some new local governments. Overall, processing of separately collected organics grows slowly. Facility operators prioritise commercial waste streams, as these generally provide less contaminated feedstocks and operators have a greater ability to influence waste quality through contracts and pricing. Waste disposal costs drive an increasing focus on source-separation of organics from food-related businesses.

3.6 Scenario 4: Circular Stewards

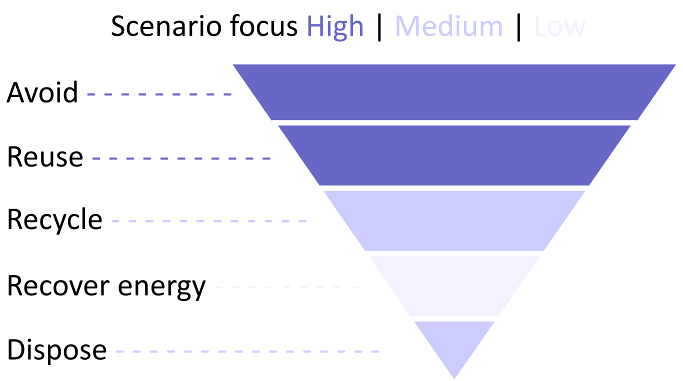
MCA score *0.65*	
Infrastructure investment *High*	
Energy from waste *Low*	
Organics separation *High - Mandatory*	
Recovery of dry recyclables *Medium*	
CDS in Victoria *Yes*	
New product stewardship schemes *Yes*	

Summary

Consumers and industry embrace the circular economy. Materials retain value for longer through new business models based on sharing, repair and high-value recycling. Mandatory product stewardship supports recovery of various challenging waste streams. The Internet of Things (IoT) sector expands to optimise the efficiency of these increasingly complex collection networks. Meanwhile, source separation of organics becomes mandatory for households and food businesses, supporting emissions reduction and higher quality organics recovery options.

The key characteristics of this scenario are:

- Circular Economy policy drives new business models – product leasing, sharing and refurbishment increase.
- Mandatory product stewardship schemes – containers, textiles, batteries, PV systems, e-waste, soft plastics.
- Specifications and targets and for recycled content in infrastructure and government procurement.
- Mandatory food waste separation by households and businesses.



Large-scale infrastructure and investments	Small scale / emerging technologies
▪ Drop-off points and collections for product stewardship schemes ▪ E-waste processing ▪ Battery recycling ▪ Reprocessing of glass and plastic for infrastructure applications ▪ Refuse-derived fuel (RDF) production	▪ Platforms supporting sharing/leasing ▪ Digital / Internet of Things collections optimisation ▪ AI / machine learning sorting ▪ Micro-factories ▪ Tyre pyrolysis ▪ Chemical recycling for textiles

Scenario narrative

Victoria's Circular Economy policy and action plan galvanises a shift in focus towards new business models which reduce waste generation and keep products and materials circulating at their maximum economic value for as long as possible. This is supported by changes in community expectations and consumption behaviours, with consumers opting to support responsible – and increasingly cost effective - circular businesses. Over the medium term, product leasing and sharing models become established for wide range of items, including commercial and household furniture, consumer electronics, toys, tools and mobility as a service. The change is most rapid and has greatest impact in urban centres, where population density makes these new business models convenient for a wide range of items.

Mandatory product stewardship schemes are introduced for a range of problematic wastes. Victoria maintains its strong preference and advocacy for national product stewardship schemes. However, the container deposit scheme provides a clear example of successful state-led mandatory product stewardship schemes. In the context of the Victorian landfill ban on e-waste and significant interest in emerging technologies for high-value recycling of electronic items, the Victoria government decides to take the initiative and introduces mandatory product stewardship schemes for several electronic products. These are subsequently expanded to other jurisdictions.

Product stewardship schemes support circular recovery pathways and provide funding to support separate collection and new processing pathways, including commercialisation of emerging smaller-scale technologies. New product stewardship schemes are established, and existing voluntary product stewardship schemes are made mandatory to increase coverage and reduce freeriding by some producers. This covers a range of products, including:

- Mobile phones (existing voluntary scheme – Mobile Muster);
- Batteries (existing voluntary drop-off point by some businesses);
- Photovoltaic systems;
- Tyres (existing voluntary scheme - Tyre Stewardship Australia);
- Textiles;
- Soft plastic packaging (existing voluntary scheme - REDcycle); and
- Container Deposit Scheme, accepting the same beverage container range as all other mainland states and territories.

Collection formats for the different product stewardship schemes vary, including:

- In-store drop-off points at relevant major retailers (expanding existing in-store network of REDcycle drop-off at Woolworths and Coles, battery drop-off at Aldi, textile drop-off at H&M, tyre management by vehicle servicing businesses);

- Small collection receptacles for businesses or community centres with-on-demand pickup by an affiliated transport and logistics service provider (like Mobile Muster);
- Reverse vending machines (CDS, mobile phones);
- Permanent sites capable of handling large drop-offs, aggregation and product sorting for onward processing (like large CDS depots in other states);
- Public drop-off points at council-operated transfer stations;
- Direct collection and refurbishment/recovery of end-of-life / end-of-lease products by product provider (solar panels, carpets, lighting);
- Scheduled 'pop-up' collections; and
- Reverse-logistics services for businesses, supported by all major parcel delivery businesses and various smaller players.

The format of some stewardship schemes offers reduced product stewardship contributions for companies who provide product leasing or direct collection services, encouraging refurbishment and reuse models which extend the useful life of items before recycling is required.

Over time, collection services become more convenient and Victorian households and businesses become accustomed to separating waste materials for higher-value collection and reprocessing. The burgeoning Smart Cities start-up sector becomes established and plays an important role in optimising the efficiency of these multiple segregated collections. Service offerings include level-sensing technology for collection points, data analytics and route optimisation, utilising spare capacity of existing small logistics and delivery providers.

Separate collection of organics is also strongly supported under the Circular Economy Policy. All metropolitan councils and some regional centres are required to introduce source separation of food and garden organics for all households. Funding for processing infrastructure and collection changes is made available in the short term, and all new services must be operational in the medium term. The state government also introduces legislation making it mandatory for "food related businesses" to separate food waste and divert it from landfill. This includes businesses such as markets, supermarkets, cafes, restaurants, takeaway outlets, event venues and aged care facilities, as well as food manufacturing businesses. In the medium term, food waste separation also becomes common in offices, schools and universities.

The Government actively supports a partnering service for the commercial and small business sector with complementary organic waste streams. This initiative, which has been very effective in Scotland, seeks to link or co-locate businesses where one operation's waste output is another's material input. This enables the maximum value to be realised and fulfils one of the key circular principles - keeping materials in circulation for as long as possible.

These initiatives support new reprocessing operations in Victoria and create both high and low skilled jobs. The economic value is high, as the mandatory producer contributions secured through stewardship schemes support higher-value recirculation of goods and materials. However, these schemes have limited impact on the remaining comingled recycling collections.

It remains challenging for MRF operators to bring recovered material to the international commodity market at an acceptable quality and price-point. In response, MRFs tighten their acceptance criteria, invest in additional sorting equipment and focus on extracting materials which retain a high market value. Diversion of some material into the CDS collection system, and reduction in packaging use reduces MRF throughput, which helps to improve sorting. However, MRF recovery rates never return to the levels seen during the era of globalised mixed-waste export. Some low-grade residuals are processed into fuel for co-combustion in industrial processes, while some are landfilled.

The Victorian Circular Economy policy establishes a position on the role of Energy from Waste in Victoria. This includes prescriptive conditions for mixed waste sorting and material recovery before residual waste can be directed to energy recovery. However, the prescribed recovery rates are too high under the prevailing, restricted export conditions. Materials cannot be extracted from mixed waste at marketable quality and an acceptable price-point, so the waste sorting conditions effectively deter development of energy recovery infrastructure for red-bin residual waste. Some EfW capacity is developed for source-separated waste streams, such as tyres, or co-combustion of waste wood in industrial furnaces.

The Victorian government begins to calculate a resource circulation metric for Victoria and introduces incentives to encourage use of recycled content in Victorian manufacturing operations. Government procurement policies and construction specifications for infrastructure projects are amended to significantly increase use of recycled content. Design for deconstruction becomes a focus of research. Pilot projects under the Circular Economy policy see material passports begin to be introduced for infrastructure projects, new public buildings and social housing projects.

3.7 Scenario 5: Packaging Crackdown

MCA score
0.52

Infrastructure investment
Low

Energy from waste
Low

Organics separation
Moderate

Recovery of dry recyclables
Medium

CDS in Victoria
Yes

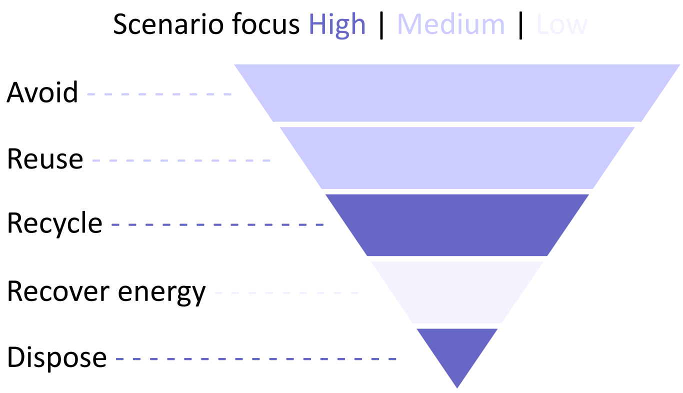
New product stewardship schemes
Yes

Summary

This scenario imagines a crackdown on packaging including a single use plastic ban and restrictions on difficult to recycle plastics. A CDS is introduced to help secure high-quality material streams which can meet both domestic recycling demand and export quality limits. This is a low EfW scenario that results in increased waste landfill.

The key characteristics of this scenario are:

- CDS adoption, and national expansion to include all glass packaging.
- Ban on single use plastic consumer products – straws, cutlery, cotton buds.
- Restriction on difficult-to-recycle plastic types and items.
- Increased waste to landfill, despite policy success for specific targeted materials/products.



Large-scale infrastructure and investments	Small scale / emerging technologies
▪ Optical sorting at MRFs. ▪ Plastics processing for export/domestic use. ▪ CDS collection infrastructure. ▪ In-vessel composting. ▪ Refuse-derived fuel production	▪ Bio-based product manufacturing.

Scenario narrative

In 2018, China's import restrictions on recyclable materials shocked the global recycling market, and other importing countries followed suit. Over time, it becomes clear that this is a new paradigm for global material flows. Policymakers recognise that Australia can no longer rely on other nations to convert contaminated, mixed recyclables into useful raw materials. There is a clear need to develop new supply chains which can successfully produce high-value recycled products in compliance with Australian labour conditions and environmental regulations. High-profile packaging issues become the focus for policy intervention.

Upgrading the same recyclable waste into clean, recovered materials in Australia will increase costs compared to previous, unsustainable recycling practices. This cost should be distributed as efficiently as possible across the waste generation and recovery supply chain.

CDS in various states demonstrate the success of separate collection systems in securing high-quality material streams which can meet both domestic recycling demand and export quality limits. The Victorian Government commits to implementing a CDS, completing CDS coverage of mainland Australia. Negotiations begin to merge state-based container deposit schemes into a single national Container Deposit Scheme. The harmonised scheme is expanded to accept all glass packaging, replacing separate kerbside collection as the primary collection pathway for glass over the medium term.

MRF operators benefit from the removal of glass from the comingled recycling stream, and from funding support for process upgrades, including additional investment in sorting technologies (e.g. optical-sorting lines to better identify and separate plastics). The removal of glass from comingled recycling improves the quality of mixed paper outputs, and markets for this material are re-established, including increased consumption by Australian paper mills. The expanded CDS reduces the tonnage and composition of material handled through MRF facilities which, in combination with facility upgrades, improves sorting efficiencies and the quality of the sorted material outputs. Dependent on the contractual arrangements with local councils and who 'owns' the waste that is collected, MRFs also benefit from any revenue sharing arrangements that apply to eligible CDS materials that are still collected through the kerbside comingled recycling stream. Despite community education efforts, strict contamination limits and limited domestic reprocessing capacity for plastics still leads to significantly increased residuals from the sorting process for comingled recycling. Some low-grade residuals are processed into fuel for co-combustion in industrial processes, while some are landfilled.

The Victorian Circular Economy policy establishes a position on the role of Energy from Waste in Victoria. This includes prescriptive conditions for mixed waste sorting and material recovery before residual waste can be directed to energy recovery. However, the prescribed recovery rates are too high under the prevailing, restricted export conditions. Materials cannot be extracted from mixed waste at marketable quality and an acceptable price-point. Accordingly, waste sorting conditions effectively deter development of energy recovery capacity for red-bin residual waste. Some EfW capacity is developed for dedicated source-separated waste streams, such as waste tyres, or co-combustion of waste wood in industrial furnaces.

The government builds on the success of the single-use plastic bag ban, introducing a ban on a range of other single-use plastic items. Drawing on the EU single use plastic ban, frequently-littered items including plastic plates and cutlery, straws, drink stirrers, cotton buds and balloon sticks are first to be banned. This move tackles a low tonnage, but high-profile waste stream, and sends an important signal that recycling and disposal technologies are no longer the sole focus of Victoria's War on Waste.

The Australian National Packaging targets become a focus for both state and national governments. The targets were introduced by Australian state and federal minsters in 2018 and the Australian Packaging Covenant Organisation was tasked with delivering them, towards a 2025 goal of:

- 100% reusable, recyclable or compostable packaging;
- 70% of plastic packaging being recycled or composted;
- 30% average recycled content in packaging; and
- Phasing out unnecessary and problematic single use plastic packaging.

Compliance with the Australian Packaging Covenant and implementation of packaging targets remains largely voluntary, but companies which place packaged goods onto the Australian market come under increasing scrutiny from policymakers at both state and federal levels. Uptake of the Australasian Recycling Label[20] and promotion of recycling pathways for packaging increase consumer awareness and engagement in packaging issues.

Restrictions are placed on materials which are challenging to recover through comingled collections, such as packaging with non-separable layers or parts made from different materials. The Australian Government supports conversion of the REDcycle scheme into a mandatory product stewardship scheme. This results in significantly increased processing of soft plastics into street furniture and landscaping products, along with a significant reduction in the use of soft plastics, including uptake of compostable alternatives for some products.

There is a strong focus on compostable packaging for in-home products as well as catering and event venues. Recognising that these products are only recoverable if appropriate infrastructure is available, federal funding is provided to promote separate collection and recovery of organics. This results in widespread expansion of garden waste collections to accept food waste, and expansion of composting infrastructure. Some councils simply advise that paper and card can be placed in existing garden waste bins.

[20] Planet Ark, *Australasian Recycling Label*,2015, available at: https://planetark.org/recyclinglabel/

3.8 Scenario 6: High Energy

MCA score
0.58

Infrastructure investment
Medium

Energy from waste
High

Organics separation
Low

Recovery of dry recyclables
Low

CDS in Victoria
No

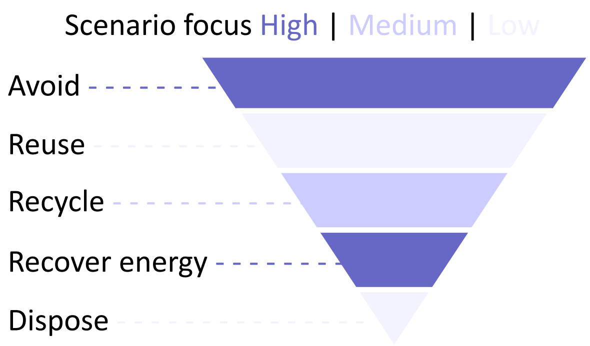
New product stewardship schemes
Yes

Summary

This scenario sees large-scale thermal EfW facilities become established in Australia. A polyvinyl chloride (PVC) packaging ban helps to mitigate community concerns over EfW and government subsidies help to establish the commerciality of EfW projects. A PAYT program helps to encourage the reduction of waste generation and provides funding for the EfW subsidies.

The key characteristics of this scenario are:

- Thermal EfW accepted, no metro MSW to landfill.
- PVC packaging banned. Slow voluntary reduction of difficult-to-recycle plastics.
- Cost of waste services increases.
- PAYT charging for waste services.
- Increased use of product stewardship / drop-off points.
- Mixed approach to MSW organics, no state policy, limited funding.
- Strong organics diversion by businesses – mixed technology preference.



Large-scale infrastructure and investments	Small scale / emerging technologies
▪ Thermal energy from waste ▪ On-site anaerobic digestion (limited) ▪ In-vessel composting (limited) ▪ Logistics – drop-off points / vacuum collection	▪ Organic valorisation – chemicals, biofuels, insect protein ▪ Rapid dehydration for business ▪ Small-scale AD for businesses ▪ Digital optimisation of collections ▪ E-waste recycling ▪ Chemical recycling of textiles

Scenario narrative

Large-scale thermal EfW technology becomes established and commonplace in Australia. EfW proposals in various states, including Victoria, progress to commissioning. First-mover facilities carefully select well-proven technologies and industrial sites, and invest significant effort in consultation and engagement, which reassures both local communities and the wider Victorian community. The Victorian community and EPA Victoria both gain confidence and familiarity with energy from waste technology, and which comes to be generally accepted as a preferable fate to landfill.

The landfill levy in metropolitan Victoria increases to level like New South Wales and South Australia. Reviews into the waste and resource recovery sector in response to the shocks to the recycling sector and instances of unacceptable stockpiling and clean-up costs include strengthening financial provisions for site closure and aftercare. These changes extend to landfill sites and increase the operational costs. Together, these changes increase the gate fee for landfilling putrescible waste and energy recovery becomes commercially competitive.

Energy from waste facilities accept a range of waste streams, including MRF residuals, commercial and industrial waste and council residual waste streams. In the long term, no residual waste from the metropolitan area is being sent directly to landfill. Specifications, trials and resource recovery-focused procurement policies have successfully created a market for bottom ash from energy recovery, which is routinely included in road construction projects.

Local governments and businesses both seek to control rising waste management costs by curbing waste generation, and PAYT charging models for waste collection are widely adopted. These are often framed as a way to ensure that the relatively high cost of disposing residual waste to EfW facilities is carried predominantly by the most wasteful generators. Increased compliance is introduced to limit cross-contamination of recycling streams.

Some metropolitan councils introduce source separation of food organics to reduce the residual waste stream and limit PAYT charges, and these FOGO collections achieve high capture rates. However, many councils are reluctant to embark on the necessary changes to collection regimes and community education. Though expensive, energy recovery is an easy option. State Government agencies continue to advocate source separation of organics and provide information for councils, but it does not become mandatory and financial support is rarely available, particularly as revenue from the landfill levy declines due to increasing adoption of non-leviable EfW for residual waste. In the absence of clear state policy, EfW proponents assume that organics in the residual waste stream will largely remain available EfW and plan their facility capacity accordingly.

Businesses with significant organic waste generation increasingly explore a range of organic waste separation and processing, including both collection for offsite processing, and uptake of onsite rapid dehydration or in-vessel composting (IVC) units. There is a proliferation of logistics and data analytics service offering in the waste management sector, both from major waste players and from smaller new-entrants with a strong smart cities and sustainability focus.

The PAYT system encourages greater use of other product stewardship and hazardous waste management systems which are unaffected by the changes in commodity markets for dry recyclables. For example, capture rates increase at council-run drop-off locations for e-waste and households hazardous waste, and shop-based drop-off points for product stewardship schemes include battery returns and REDcycle soft plastics recycling. Charity shops also grapple with an increase in "donation" of unsaleable household items. PAYT charging increases consumer awareness of single-use items or low quality "disposable" household product and drives a preference for more durable products and recyclable packaging. This drives a small reduction in residual waste generation over the medium term.

Governments struggle to reconcile recycling aspirations with market challenges in the recycling sector. Most councils remain unwilling to introduce new separate collections due to cost and contamination concerns. Despite ongoing education campaigns, both kerbside residual waste disposal and kerbside recycling increases in cost. Some MRF operators severely limit the range of materials that they will accept through kerbside recycling, and most restrict the range of plastic polymers accepted. Most also shift their operations to selectively extract cleaner streams of materials which have retained relatively high commodity value, including PET, HDPE and metals. These are sold on the international commodity market, or into existing domestic reprocessing facilities while the residual waste stream from recyclables sorting is directed to energy recovery.

Trends to end the use of PVC in packaging progress, culminating in a ban on PVC in packaging in the medium term. Lobbying from the increasingly-influential EfW players plays a role in elimination of PVC from the MSW and C&I waste streams. The Australian Packaging Covenant Organisation continue to work towards the Australian Packaging Targets, including the goal of 100% reusable, recyclable or compostable packaging by 2025. Packaging items with non-separable layers or parts made from different polymers are also eliminated. However, various technically-recyclable polymer types with very limited markets remain in use and are generally not recovered. Compostable packaging becomes more common, supported by actions under the Australian Government packaging agenda. However, collection and composting infrastructure is not always available to provide a recovery pathway, and in many cases the compostable packaging forms part of the residual or MRF-reject streams.

4 Multi-criteria analysis

MCA is a tool that is often used to inform decision-making around infrastructure development, policy and regulation. It is commonly used in Australia by governments to guide decision-making as it can evaluate options under consideration when it is not possible to quantify and value the main costs and benefits. An MCA can also evaluate options against multiple (potentially conflicting) criteria, to provide a holistic view option performance.

MCA traditionally follows a four-stage process of criteria development, weighting of criteria, scoring of each option and comparison of scores. The four key steps undertaken to complete the MCA are outlined in Figure 3.

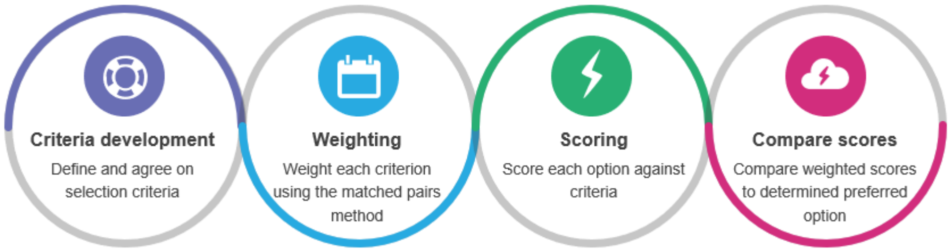


Figure 3: Multi-criteria analysis framework

In this work, MCA was used to understand the preferred technologies and infrastructure to improve Victoria's recycling and resource recovery. Arup used Infrastructure Victoria's *Victorian waste flows report 2019* prepared by Blue Environment[21] to inform some of the MCA evaluation, detailed further in the following sections as well as Appendix B.

4.1 Criteria development and weighting

The criteria and weightings for the MCA were agreed in consultation with Infrastructure Victoria. An MCA workshop was held in September 2019 with key representatives from Infrastructure Victoria and Arup technical specialists in waste, sustainability and cities. During the workshop, the criteria were refined, and weightings were developed through a pairwise comparison process.

The pairwise comparison method simplifies challenging decisions about weightings and trade-offs. Participants consider each possible pair of criteria and decide which one is more important. The pairwise comparisons are then combined and analysed to produce appropriate weightings for each criterion. The criteria and their weightings are shown in Table 8.

[21] Infrastructure Victoria, 2019, *Victorian waste flows report*, prepared by Blue Environment

Table 8: Weighting of MCA criteria

Criteria	Weighting
Resource recovery outcomes (Circularity Index)	35%
Cost of household waste services	20%
Waste management costs	20%
Capacity to produce economic uplift for the state	5%
Greenhouse gas (GHG) emissions reduction potential	20%
Total	**100%**

During the MCA workshop, related issues including logistical, economic and political risks associated with the scenarios were discussed. However, these are not inherent characteristics of the scenarios, rather, they are risk factors that can be addressed using policy, regulatory or economic instruments if necessary. Including risk factors in the MCA would introduce a bias for low-risk options, and as such the criteria did not consider such factors.

4.2 Scoring

The following section describes the scoring and justification for each of the scenarios. High-level quantitative approaches were used to assess the Circularity Index and greenhouse gas emissions reduction criteria, and these are given a quantitative percentage score. Costs and economic uplift were assessed qualitatively, using the scales detailed in the relevant section.

4.2.1 Resource recovery outcomes (Circularity Index)

Arup has developed a Circularity Index to assess resource recovery outcomes. The Circularity Index considers performance against the waste hierarchy across multiple material streams, in a single metric. It examines the tonnage of waste directed to each level of the waste hierarchy and assigns a score which reflects the contribution of these material flows to maintaining value and circulating materials. The Circularity Index breakdown of ratings of waste hierarchy categories is detailed in Appendix B1.1.

The Circularity Index for each scenario was calculated using data provide by Infrastructure Victoria.[21] The expected changes in material fate under each scenario were modelled using range of data sources, interjurisdictional experience and informed assumptions. Modelling assumptions and data sources are detailed in Appendix B.

Each of the scenarios were evaluated using the Circularity Index. Figure 4 shows the circularity score for each scenario and the contribution of each waste hierarchy category to these scores. This criterion had a 35% weighting in the MCA.

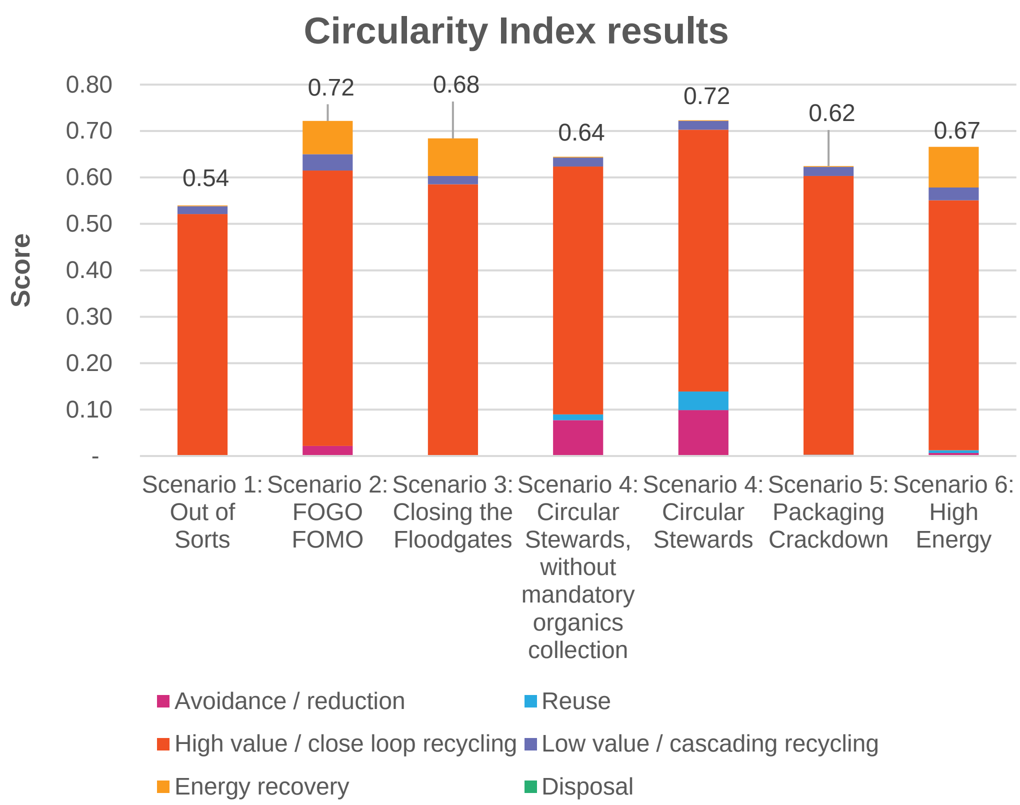


Figure 4: Circularity Index results and breakdown of waste hierarchy category.

The large recycling streams with stable markets do not change between scenarios, contributing 40% to the Circularity Index score. As a result, high-value recycling dominates the Circularity Index, and to some extent masks the differences between the scenarios.

These large, stable recycling streams include:

- Steel (880,000 tpa)
- Other non-ferrous and mixed metals (100% recovered, 440,000 tpa)
- Biosolids (432,000 tpa)
- Garden organics (at least 400,000 tpa)
- Other organics (100% recovery, assumed to include waste oil, food processing waste and similar, 430,000 tpa)
- Source-separated C&I paper and cardboard (at least 480,000 tpa)
- Source-separated office paper (165,000 tpa)

Despite its low desirability under the waste hierarchy (Circularity Index rating 0.25, see Appendix B1.1), energy recovery makes a notable contribution to the circularity score in scenarios with high energy from waste penetration because EfW can accept large tonnages of mixed residual waste including multiple material types and low-quality material.

All scenarios include some increase in separate collection of MSW organics. However, the capture rate of food organics remains imperfect, based on Australian experiences with FOGO collections, and as a result, food organics are still lost to the residual stream, even in scenarios with significant coverage of household FOGO collections. There is a higher reliance on these low-value outlets in scenarios where other dry recycling markets remain highly constrained. However, the overall contribution to the circularity score from this type of material recovery remains small due to its lower rating in the Circularity Index, and somewhat conservative estimates of maximum feasible uptake based on existing pilot-stage applications.

Low-value recycling of some glass and plastics is included in all scenarios, reflecting successful uptake of low-value recyclable materials such as glass fines and mixed plastics into construction applications. This success has followed a significant body of research and development, as well as pilot project work coordinated and funded by Sustainability Victoria.

Avoidance / reduction is a key feature of the *Circular Stewards* scenario, offsetting some losses in high-value plastics recycling due to ongoing market challenges for the plastics stream. The *Packaging Crackdown* and *High Energy* scenarios also include some material avoidance / reduction, driven by packaging and single use plastics restrictions or PAYT charging. However, the contribution of these changes to the overall circularity score is not significant.

The small avoidance score within *FOGO FOMO* and *Circular Stewards* scenarios reflects food waste avoidance. This is driven by state / local government-led education and behaviour-change initiatives, as part of the strong scenario focus on organic waste and supported by increasing awareness of food waste among households and businesses participating in mandatory separation of food waste.

4.2.2 Cost of household waste services

Victorian households pay for the collection, processing and disposal of waste and recyclable materials through council rates. Operational costs relate primarily to the efficiency of the collection routes and vehicles, and the gate fees agreed in contracts with recycling and waste disposal facilities. Any changes to existing systems incur a capital cost for changes to bins, collection processes and community education. If the cost to deliver these services increased, this impacts the cost of living for Victorians. However, Victorians also value their kerbside recycling services, and up until 2018, there was a longstanding sense of pride and trust in the kerbside recycling system, which makes it easy for every household to ‘do the right thing’ with their waste.

Over the past 18 months, kerbside recycling collections from some Victorian local governments have been suspended or redirected to landfill due to a range of issues, including temporary closure of SKM Recycling sites to resolve excessive stockpiling, insolvency of SKM Recycling or failure to renegotiate recycling contracts following Chinese import restrictions and the collapse of international commodity prices for mixed recyclables. In each case, the suspension of kerbside recycling services has been reported with shock and outrage.

The cost of household services has a 20% weighting in the multi-criteria analysis, recognising that waste services must be affordable, but some increase in cost is acceptable in order to achieve improved resource recovery and greenhouse gas emissions reduction outcomes. This criterion considers:

- Local government costs recovered through charges to households.
- Costs of collection, gate fees and operation of council facilities.
- Baseline as 2017 costs (i.e. prior to China import restrictions) as markets and contract prices have not yet stabilised.

The scoring description for the costs of household waste services criterion is described in Table 9.

Table 9. Criterion scoring description for cost of household waste services

Score	**Description**
1	Cost of household waste services increases substantially
2	Cost of household waste services increases somewhat
3	Cost of household waste services remains relatively consistent

The scenario scores for household waste services criterion is shown in Table 10 and the rationale for these scores is detailed in Appendix B1.14.

Table 10: Scenario scores for cost of household waste services

Scenario	**Score**
Out of Sorts	2
FOGO FOMO	1
Closing the Floodgates	1
Circular Stewards	2
Packaging Crackdown	2
High Energy	1

4.2.3 Waste management costs

Waste collection from Victoria businesses is managed through contracts with private service providers. Large businesses such as supermarkets, universities and manufacturers typically have direct visibility and control of their waste service arrangements, while smaller businesses typically receive waste services as part of building leasing and servicing arrangement and may have little understanding of waste costs.

Current charging models typically include a flat fee for service availability and a variable fee per bin lift or per kilogram, providing a weak signal to reduce waste generation for businesses with direct visibility over their waste costs. Source separation of cardboard is common, and many businesses receive a credit towards general waste services, recognising the value of the clean cardboard stream. Source separation of other materials varies depending on the business activities and contracting arrangements. Source separation and recovery of food waste is currently uncommon, except for large food processing businesses, and recovery of waste cooking oils under the EPA Victoria Industrial Waste Classification.[22]

The cost of waste services for the private sector is impacted by the gate fee to access disposal or resource recovery facilities and the cost for the waste service provider to operate its collection network. Changes to business practices such as introducing new source separation or waste handling/baling procedures requires staff education and engagement, which will be implemented if meaningful waste service cost savings are identified.

Waste management costs to the private sector has a 20% MCA, recognising that waste services must be affordable, but some increase in cost is acceptable in order to achieve improved resource recovery and greenhouse gas emissions reduction outcomes.

The waste management costs criterion considers:

- Relevant to C&I sector contracts.
- Gate fees.
- Collection / transport costs.

[22] EPA Victoria. 2017, *Unprocessed used cooking fats and oils classification,* available at: https://www.epa.vic.gov.au/business-and-industry/guidelines/waste-guidance/prescribed-industrial-waste-classifications/unprocessed-used-cooking-fats-and-oils-classification

The scoring description for the costs of household waste services criterion is described in Table 11.

Table 11: Criterion scoring description for waste management costs

Score	**Description**
1	Cost to most users increases substantially
2	Cost to most users increases somewhat
3	Cost to most users remains relatively consistent

The scenario scores for the household waste services criterion is shown in Table 12 and the rationale for these scores is detailed in Appendix B1.15.

Table 12: Scenario scores for waste management costs

Scenario	**Score**
Out of Sorts	2
FOGO FOMO	1
Closing the Floodgates	1
Circular Stewards	3
Packaging Crackdown	2
High Energy	1

4.2.4 Economic uplift

The economic uplift criterion considers both number and quality of jobs, and overall creation of economic value for Victoria. The scoring description for economic uplift is described in Table 13.

Table 13: Criterion scoring description for economic uplift

Score	Description
1	No uplift / low economic uplift opportunities for Victoria
2	Moderate economic opportunities for Victoria
3	High economic opportunities for Victoria

The scenario scores for the economic uplift criterion is shown in Table 14 and the rationale for these scores is detailed in Appendix B1.16.

Table 14: Scenario scores for economic uplift

Scenario	Score
Out of Sorts	1
FOGO FOMO	2
Closing the Floodgates	2
Circular Stewards	3
Packaging Crackdown	1
High Energy	1

4.2.5 Greenhouse gas emissions reduction potential

WRATE (Waste and Resources Assessment Tool for the Environment) software was used to model GHG emissions for each scenario and provide a lifecycle assessment of waste processing and fate, based on facility operational data contained within the WRATE program. The modelling approach GHG-specific assumptions are described in detail in Appendix B1.17.

Multiple policy and infrastructure initiatives are being developed concurrently, so relative scoring between scenarios was considered more relevant than scoring against a baseline. The GHG emissions score is presented as a percentage, relative to the range of waste and resource recovery sector emissions among the six scenarios. The scenario with the highest carbon dioxide equivalent emissions scores 0%. The scenario with the lowest emissions scores 100% and all other scenarios are scored within this range.

The WRATE modelling results are presented in Figure 5 and show a strong GHG emissions reduction for scenarios with compared to those without thermal EfW. Differences within these two scenario groupings are much more modest. There are three main reasons why energy recovery from residual waste contributes strongly to greenhouse gas emissions reduction:

1. When organics degrade in landfill, they emit methane, which has 22 times the GHG potential of CO_2. All scenarios included some improvement in organics separation and recovery. However, source separation systems do not completely capture organic waste, and some is still disposed to landfill in the residual waste stream. In scenarios which direct residual waste to energy recovery, all organics are diverted from landfill, either through composting or energy recovery.

2. The current Australian electricity mix is heavily reliant on fossil fuels. EfW offsets some of this electricity generation with partially renewable energy. This was found to have a significant impact on the magnitude of the GHG emissions reduction, but not on the performance of the scenarios relative to each other.

3. Metals can be recovered from mixed residual waste and incineration bottom as at a quality and price-point which is acceptable for recycling. This enables additional recycling or some metals which are currently disposed in the residual stream. This is a small total tonnage but has a significant impact on the GHG emission reduction evaluation because virgin metal production is emissions intensive compared to recycling.

It is also important to note that the modelling focuses on materials streams and does not fully evaluate the emissions saving due to reuse and avoidance of complete products, such as furniture, tools, appliances and vehicles, as is the case in *Circular Stewards*.

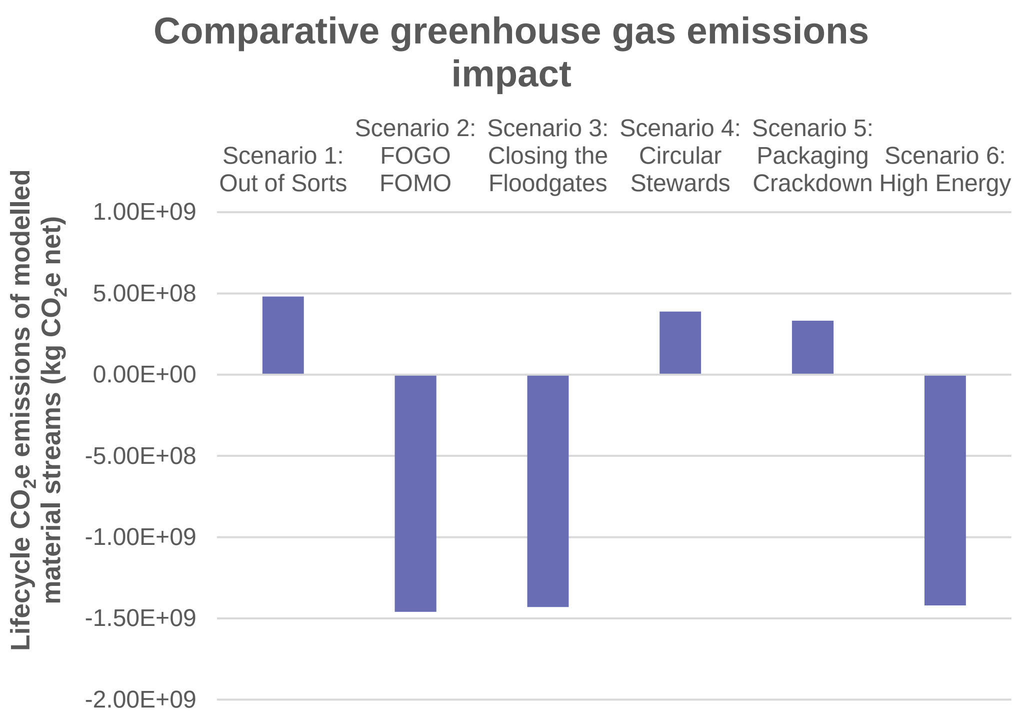


Figure 5: Summary of lifecycle emissions modelling results. Note, negative emissions indicate net emissions reduction due to energy generation and recycling offsets.

From this modelling, the GHG emissions reduction percentage of the scenarios was calculated and used in the MCA scoring, as is shown in Table 15.

Table 15: Scenario GHG emissions reduction score (% of GHG emission range)

Scenario	**GHG emissions reduction (% of GHG emissions range across the six scenarios)**
Out of Sorts	0%
FOGO FOMO	100%
Closing the Floodgates	98%
Circular Stewards	5%
Packaging Crackdown	8%
High Energy	98%

4.3 Summary of results

The results of the MCA are shown in Table 16, and the breakdown of scores for the criteria are shown in Figure 6. *Circular Stewards* the highest-ranked scenario (score of 0.65).

Table 16: Multi-criteria analysis results

Scenario	MCA score
Out of Sorts	0.47
FOGO FOMO	0.62
Closing the Floodgates	0.60
Circular Stewards	0.65
Packaging Crackdown	0.52
High Energy	0.58

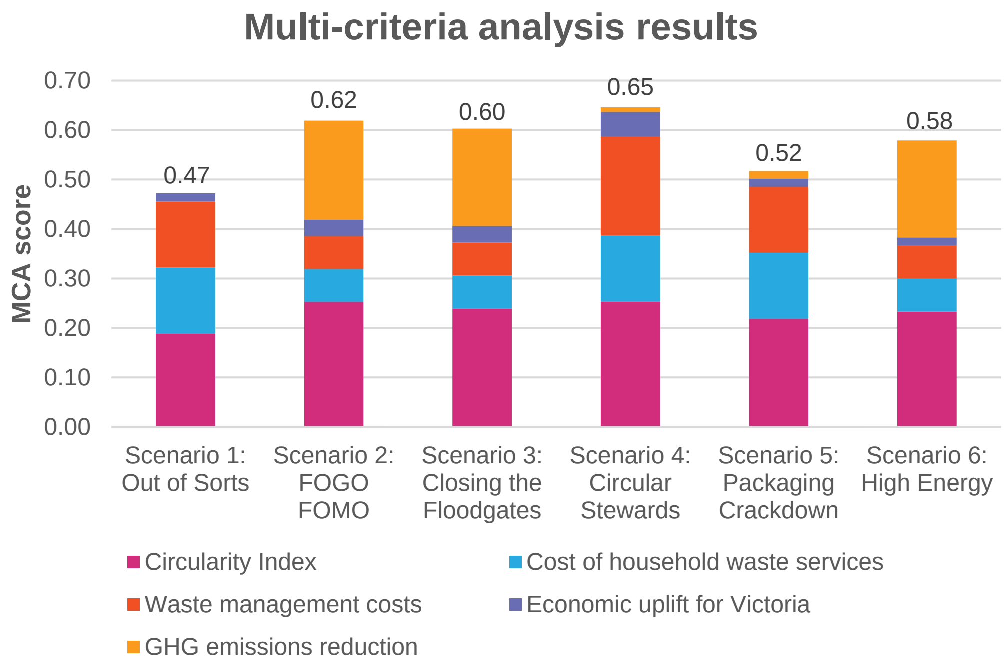


Figure 6: Breakdown of scenario performance for the MCA criteria, with the data label showing total MCA scores.

The was little differentiation between the three scenarios including energy recovery from residual waste (*FOGO FOMO*, *Closing the Floodgates* and *High Energy*). The low level of differentiation between the scenarios is reasonable, because each scenario focuses on improving a specific area of resource recovery –

either organics, dry recycling, or waste avoidance motivated by PAYT charging – while remaining residual waste is diverted to energy recovery. As a result, the overall circularity scores are relatively similar, with *High Energy* scoring slightly lower due to low emphasis on recycling. High organics diversion from landfill and generation of partially-renewable electricity to offset alternative generation from Victoria's fossil fuel-reliant grid result in high scores for greenhouse gas emissions reduction. However, the high costs of these infrastructure intensive scenarios to both household and private sector waste services reduces their overall scores.

Out of Sorts and *Packaging Crackdown* are clearly less desirable than any of the other scenarios because of their limited focus on certain sections of the dry recyclables supply chain results in a limited overall improvement in resource recovery. Meanwhile, these scenarios still have moderate cost increases due to ongoing challenges in recycling markets and higher operational costs for material recovery facilities. The failure of these scenarios to support significant landfill diversion of organics also negatively impacts GHG emissions reduction scores.

5 Policy interventions

The scenarios MCA focused on key outcomes for resource recovery, greenhouse gas emissions, costs and economic growth. In order to successfully steer Victoria towards the more desirable future scenarios, policymakers must also understand and address a range of contextual barriers including:

- Land use planning requirements.
- Community acceptance and social license to operate.
- Community education and behaviour change.
- Market development for immature or capacity-constrained markets.
- Cost or access equity for regional areas.
- Economic viability of infrastructure / business models in the absence of state intervention such as grant funding, favourable procurement or feed-in tariff commitments or market design through landfill levy increases.

These potential barriers pose varying levels of risk to the scenarios, depending on the types of infrastructure and magnitude of change involved. An appropriate suite of enabling policy, regulatory or economic instruments is needed to manage risks and drive change.

The Victorian Government can guide Victoria's waste and resource recovery future towards the preferred scenarios and outcomes through policy, regulation and program delivery, focusing on the issues which pose the highest risk to success.

Table 17 summarises the risk exposure for each scenario against a range of issues which frequently create barriers for the waste and resource recovery sector. These ratings are a high-level indication, based on the typical barriers and enablers related to the dominant infrastructure types in each scenario. Key policy issues are explored in subsequent sections. The Technology Guide provided in Appendix A provides more detailed discussion of barriers and enablers for specific technology types.

Table 17: Exposure mapping for policy interventions

Scenario	Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Behaviour change	Low Exposure	High Exposure	Medium Exposure	High Exposure	Medium Exposure	Low Exposure
End market maturity	Medium Exposure	Medium Exposure	High Exposure	High Exposure	Medium Exposure	Medium Exposure
Access to end markets	Medium Exposure	Medium Exposure	Medium Exposure	Medium Exposure	Low Exposure	Low Exposure
Regional equity	Medium Exposure	Low Exposure	Medium Exposure	Medium Exposure	Low Exposure	High Exposure
Land use planning, local acceptance	Low Exposure	Medium Exposure	Medium Exposure	Low Exposure	Low Exposure	High Exposure
Social licence to operate – state	Low Exposure	Medium Exposure	Medium Exposure	Low Exposure	Low Exposure	High Exposure
Financial viability without government intervention	Medium Exposure	High Exposure	High Exposure	High Exposure	Low Exposure	Medium Exposure

5.1 Waste levy and funding support for new technology and infrastructure

Disposing waste to landfill is the least desirable outcome under the waste hierarchy, principally due to the lost resource potential from burying valuable waste materials (loss of opportunity for direct material reuse, recycling into new materials and products or the calorific value of waste for energy generation), and the capacity for GHG generation and emissions, especially from the disposal of biodegradable organic wastes.

However, landfill in Australia is a relatively cheap waste management option and there are few waste reuse, recovery or recycling processes that are economically viable compared to landfill disposal. In general, waste materials in the waste supply chain flow to the lowest cost management options and if landfill is cheaper than resource recovery, waste will flow to landfill. To address this issue, governments use a range of regulatory and policy interventions and tools to drive higher-order waste management outcomes that are consistent with the waste hierarchy and circular economy principles.

One of these regulatory tools is the application of a levy on the disposal of waste at landfills. A landfill levy is an economic instrument that is designed to divert waste from landfill and provide a commercial driver towards more sustainable waste management practices. It achieves this by artificially increasing the cost of landfilling to a point where other more expensive but higher-order forms of waste management like reuse, recovery and recycling become more cost competitive with landfill disposal.

In addition to driving business and the community towards more sustainable waste management practices, landfill levies also have a number of broader environmental and social benefits, including market development for recycled products and materials, job creation in these new resource recovery and recycling sub-sectors and the preservation of valuable landfill to manage potentially dangerous wastes which have no higher-order use, such as asbestos.

Recycling, remanufacturing and treatment of waste materials is sometimes assumed to operate in the same way as a manufacturing business model, where raw materials are purchased, and the costs of processing and manufacturing a product are recouped from the sale of the product which has a market value. However, the business model for waste is the reverse of this. Fees are charged on receipt of the waste. This is the only revenue stream for disposal businesses and remains the major revenue stream for energy recovery businesses and many sorting and recycling businesses. This margin is reduced by operational costs for any actions after the waste is received (i.e. disposal, treatment, processing, remanufacturing etc.). The additional operational cost of processing recovered materials to a higher output quality is frequently not reflected in increase commodity value for the output product. This drives a recycling sector which typically aims to process materials to the minimum standard which end markets will accept. Limited sorting of dry recyclables and reliance on export of mixed materials is a clear example, as is the prevalence of pasteurised, immature compost in the recovered organics market.

The ongoing reliance on gate fees for receiving waste also creates an opportunity for levy avoidance and exploitation of the system by unscrupulous operators who charge attractive rates to receive waste and avoid waste processing costs through illegal dumping. It is imperative that these waste regulatory frameworks are sophisticated enough to manage these unintended consequences that can cause significant market distortion and to ensure that recycling and resource recovery outcomes are achieved.

Waste levies generate large revenue streams for government, which can be hypothecated to support innovation, education, infrastructure investment and market development in the broader waste management sector. A waste levy is integral to funding models that support uptake of new technology and infrastructure, particularly for modern, innovative, technology driven infrastructure, as these will often need to charge high gate fees to offset the capital and ongoing operational expenditure for the infrastructure. Unlike manufacturing industries, these costs generally cannot be offset by the market value of the outputs in the form of processed waste materials for manufacturing, waste-derived products or energy, and therefore require relatively high levy price points to ensure that they are able to attract waste materials as feedstock.

Levy funds can be used in a range of ways to support the uptake of new technologies, but the primary programs are infrastructure development grants and funding for market development for waste-derived materials and products.

It is necessary to provide further support with industry or waste stream specific initiatives that further drive the ongoing uptake and sustainable operation of these facilities. Some examples of this are:

MSW stream

- Funding for improved bin infrastructure and collection systems to provide better quality source-separated waste materials as feedstock for recycling and resource recovery. Separation of organics from other waste and separation of glass from paper and card are priority issues.
- Community education on bin collection systems, what materials can be recycled and the importance of properly separating waste and reducing contamination.
- Broader community education on what happens to separated waste streams to provide an evidence base for participation and to provide community confidence in recycling outcomes.
- Funding for trials of new collection systems and infrastructure that targets identified barriers to improved separation outcomes (e.g. multi-unit dwellings).

C&I waste stream

- Waste management audits for businesses to highlight waste minimisation and cost saving opportunities and to drive better separation and material collection outcomes.

- Support for business to business collaboration and colocation opportunities.

C&D waste stream

- Education on waste reduction and on-site separation opportunities for site generators and how to achieve better contamination management (e.g. asbestos).
- R&D grants for material innovation and market development.

5.2 Integrated land use planning and environmental regulation

Land use planning and environmental regulation has an important role in supporting the establishment of waste infrastructure and in protecting the community from adverse amenity impacts. Better precinct planning offers the potential for more integrated decision making and provides the opportunity for better whole of life outcomes.

Regulation

Waste management is regulated by the Environment Protection Act (1970), Environment Protection Amendment Act (2018) and Planning and Environment Act (1987)

The Environment Protection Act and its amendments sets out the regulatory framework for waste management and pollution control. Policies, best practice guidelines, and waste and resource recovery implementation plans have been established under the EP Act. The Act sets out the regulatory framework for the issue by the Environment Protection Authority of works approvals and licences for scheduled premises. A scheduled premise includes a premises at or from which waste is, or is likely to be discharged, emitted or deposited to the environment.

The Environment Protection Act has several environment policies that are relevant to waste management:

- State Environment Protection Policy (Air Quality Management)
- State Environment Protection Policy (Waters)
- Waste Management Policy (Siting, design and Management of Landfills)

Further, the Environment Protection Act establishes the Victorian Waste and Resource Recovery Infrastructure Planning Framework, including the following plans, policies and guidelines:

- State-Wide Waste and Resource Recovery Implementation Plan (SWRRIP)
- Regional Waste and Resource Recovery Implementation Plans, being the Metropolitan Waste and Resource Recovery Implementation Plan

- Best Practice Environmental Management – Siting, Design, Operation and Rehabilitation of Landfills

The P&E Act requires the preparation of local planning schemes which provide the decision-making framework for assessing whether to permit new waste and recycling facilities in consideration of protecting sensitive land uses (e.g. residential) from the potential adverse effects from waste facilities. Planning schemes provide this framework through the application of planning zones which specify land uses as either as of right land uses, requiring a planning permit or prohibited and by requiring a permit for specific buildings and works.

Planning schemes provide a planning policy framework for decision making on proposed land uses and developments that require a permit. Clause 19.03-5 of each planning scheme supports waste and resource recovery with the objective "To reduce waste and maximise resource recovery so as to reduce reliance on landfills and minimise environmental, community amenity and public health impacts". It has several strategies to implement this objective with this focused on recognising waste and resource recovery infrastructure needs and protecting these areas from new encroachment from incompatible land uses through applying buffers and by ensuring that facilities are sited, design, built and operated to minimise impacts on surrounding communities and the environment. When assessing a permit, there is a need to consider the plans, policies and guidelines in the Victorian Waste and Resource Recovery Infrastructure Planning Framework.

Exposures and opportunities

More sites across the metropolitan area are likely to be required for new recycling and resource recovery infrastructure and new models of materials handling, storage or separation. This presents challenges accessing land for such use. Preferred sites for this infrastructure have traditionally been low-rent to help make the low margin high volume business models profitable. These sites are often found in existing industrial zones rather than isolated from employment areas. Current sites for recycling and resource recovery are also shared with other waste storage facilities with many with illegally contaminated good and stockpiles of chemicals. Materials are regularly stored in temporary facilities like shipping containers and as such fall into a vague category of not stored but 'ready' for transport.

Communities have generally been concerned by perceived and / or real environmental and health concerns with EfW have generally resulted in strong community opposition. Odours from organic waste cartage and treatment is a challenge to any solution that relies upon organic waste treatment. Dislocation from local communities needs to be considered against the environmental impacts of transport and additional electricity infrastructure. Trucks are also generally not appreciated by the public due to being in general noisy, dirty and smelly. Communities have generally posed strong opposition to the establishment of certain technologies in their local area and the democratic nature of Victoria's planning system may compromise the ability to implement the optimum waste scenario given that the best solution may not be supported through the social licence allowed by local communities.

The SWRRIP provides a framework to supporting the protection of the community and environment and provides direction to integrate planning for land use, transport and waste and recovery. The SWWRIP has the following relevant strategic directions for planning and environment regulation:

- Strategic Direction 2: Reduce landfill reliance – Planning for new landfill airspace, including the scheduling of new landfill sites, will be based on:
  - Volumes of residual waste streams remaining after all materials that can be recovered viably have been extracted
  - A demonstrated need for additional airspace
- Strategic Direction 4: Utilise land – Suitably located and zoned land will be available for the expected mix of infrastructure required to manage waste and materials streams
- Strategic Direction 6: Integrated planning – Integrated state-wide planning and decision making will be capable of addressing local, regional and state needs to facilitate a cost-effective state-wide network of waste and resource recovery infrastructure.

Long-term strategic recognition of waste and recovery facility land needs in planning schemes has a critical role in the framework that is required to facilitate investment and development of new waste management infrastructure. Planning processes need to provide clarity and certainty in order to minimise investment exposure and deliver decisions in a timeframe that is commercially viable for proponents. Planning schemes should include consideration of designated land allocations for waste management precincts or co-location of waste management infrastructure in commercial and industrial areas that promote industrial ecology outcomes. Precinct based solutions incorporated into the planning scheme developed through community consideration provide opportunities to better facilitate the location of waste management infrastructure in a community acceptable manner.

Several land use exposures and opportunities are outlined in Table 18.

Table 18: Land use exposures and opportunities

Land use exposures	**Land use opportunities**
Industrial zoning planning controls not properly covering operations of facilities. Amenity issues created by urban encroachment (residential or commercial development in waste facility buffer zones). Loss of industrial/waste precincts driving increase transport distance and cost. Community opposition to transport and treatment in local areas.	Precinct based approaches to waste management and treatment. Colocation of energy recovery with industrial heat/power users. Colocation of MRF with materials reprocessing facility. Colocation of major C&I operator with materials reprocessing.

Land use exposures	Land use opportunities
	Proximity to major transport routes. Industrial development in waste precinct buffer zones.

Recommendations

To improve recycling and resource recovery in Victoria, the following land use planning and environmental regulation recommendations should be considered:

1. Undertake precinct structure planning and industrial structure planning to identify suitable land areas

   Undertake precinct based and structure planning strategies that are developed through community consultation to identify suitable areas for the facilitation of waste management infrastructure.

2. Integrate land-use planning and environment protection

   Better integration of land-use planning and environment protection regimes offers the opportunity to better meet community expectations and to reduce duplication and barriers to new facilities to achieve better whole of life outcomes. Identify opportunities to support early engagement with the Environment Protection Authority in strategic planning processes and in discussions on the establishment of new facilities.

3. Review land use planning terminology

   Review Clause 73.03 Land Use Terms, relevant zone table of uses and Clause 53.14 resource recovery in planning schemes to ensure the land use definition of different waste facilities adequately facilitates the use of land for sought facilities and protects from undesirable activities and adverse outcomes.

4. Prepare planning practice note

   To support decision makers to better under the distinction between land use terms and to assist in better location of facilities, prepare a planning practice note to provide information and guidance about waste management definitions, approval processes, protecting existing operations and Victorian government policy.

5.3 Environmental risks

Waste management facilities have the potential to cause a range of adverse impacts on the environment and the community if they are not designed, commissioned and operated according to appropriate standards. These impacts can include:

- Noise impacts from the on-site operation of heavy plant and machinery and from vehicle movements to and from the site (e.g. garbage trucks) and some maintenance equipment use.
- Traffic impacts from waste transport vehicles contributing to noise, increased traffic generation, local road congestion and potential increased occurrence of road damage due to heavy vehicle use.
- Dust and air emission impacts generated from the tipping, processing, stockpiling and / or combustion of waste materials, as well as movement of vehicles
- Odour impacts from all phases of processing including pre-treatment, decomposition, aeration and maturation, receival and storage of waste streams, storage of the end products, leachate storage and transport of waste materials and end products to and from the site.
- Surface and groundwater contamination impacts from on-site leachate generation and management, accidental spill or discharge of chemicals or hydrocarbons, such as fuels and oils in vehicles and/or equipment and storm water runoff contaminated by waste processing areas.
- Risk of fire from poor operational procedures in regard to the processing of waste materials such as excessive stockpiling, lack of adequate infrastructure or fire controls.
- Visual amenity impacts from wind-blown litter, dust and general waste processing activities.

The environmental impacts and corresponding mitigation measures associated with the operation of waste management facilities are generally assessed as part of an Environmental Impact Statement (EIS), managed via standard operating procedures and management plans and regulated via statutory planning and environmental protection licenses. These licences/permits contain conditions that aim to control the operation of the premises so that there is no adverse effect on the environment. These conditions address areas such as waste acceptance and treatment, air and water discharges, and noise and odour emission limits.
The Environment Protection Act 1970 specifies penalties for breach of licence conditions and for operating a site without a licence. It is the responsibility of the waste facility operator to monitor environmental aspects and ensure any exceedances are reported to the responsible regulatory agencies.

The assessment of potential environmental impacts through these frameworks often relies on the modelling of expected performance outcomes, given known geography, material inputs, treatment processes and technology operating parameters. This is particularly important in relation to understanding air and odour emissions profiles and leachate management requirements. This often means that controls are specific to waste and facility types.

Potential environmental impacts such as traffic, dust, noise and odour impacts are assessed at the planning and approvals stage of facility development and will need to consider the size, location and design of the facility, operational practices, and the material being processed. Environmental risks at waste management facilities can be mitigated through good design and siting decisions, and with appropriate operating procedures. Operators will need to ensure emergency management plans and pollution incident response management plans are prepared and implemented to deal with incidents and standard operating procedures and management plans should be reviewed on a regular basis.

Operators need to have the appropriate resources, training and technical capacity to understand and manage environmental aspects and impacts on site. This includes sampling, testing and reporting protocols to continually monitor on-site impacts and discharges over time, and more regular site inspections to ensure any operational and management requirements are being adhered to. This may extend to ensuring that only approved waste materials are being received at the site and are being stockpiled in locations with appropriate surface and groundwater controls as per the licence conditions.

The environmental risks associated with the illegal stockpiling of waste is a growing problem across many Australian jurisdictions. This risk is increased in jurisdictions that have implemented a landfill or waste disposal levy. Waste disposal levies are generally implemented to support jurisdiction waste strategy targets for reduction of waste disposal to landfill and promotion of resource recovery activities. Revenue collected from waste disposal levies, if hypothecated correctly, can assist to fund waste reduction schemes, resource recovery infrastructure and technology, education and investment.

Unfortunately, the implementation of waste disposal levies, if not tightly regulated and enforced, often have unintended consequences for the industry, usually driven by profiteering through levy avoidance practices. One of these unintended consequences is the uncontrolled and large-scale stockpiling of waste at both licensed and non-licensed facilities. The long-term storage of waste in an inappropriate or illegal manner has very serious fire, environmental and human safety risks. It is critical in these circumstances that the regulator has the resources, information, capacity and regulatory powers to appropriately deal with these scenarios before they create significant environmental impacts and / or legacy issues for the community and other stakeholders to deal with. Increased regulatory powers can contribute to a waste facilities social licence to operate in that the community feels comfortable that the regulator has the proper resources and jurisdiction to monitor and penalise non-performing waste facilities. It is noted that the Environment Protection Amendment Act 2018 has been passed and will come into effect 1 July 2020. The amended Act addresses access to information and increased regulatory powers and penalties.

The setup of a waste disposal levy framework focuses statutory record-keeping, reporting, management controls and payment triggers at the landfill or disposal end of the waste supply chain. This type of framework presents a business opportunity for waste materials to be driven further up the supply chain to transfer, sorting, reuse, processing or recycling facilities, where these levy controls don't apply.

5.4 Local community engagement and acceptance

The democratic nature of Victoria's planning system may compromise the ability to implement the optimum waste scenario given that the best solution may not be supported through the social licence allowed by local communities.

Communities have generally posed strong opposition to certain technologies in their local area. Perceived and / or real environmental and health concerns with EfW have generally resulted in strong community opposition. Odours, particularly odour arising from cartage and waste delivery, is a challenge for organic waste processing. Isolations of waste and resource recovery infrastructure from existing communities and future urban expansion zones needs to be considered against the environmental impacts of transport and additional electricity infrastructure. Trucks are also generally not appreciated by the public due to being in general noisy, dirty and smelly. Tighter controls on haulage vehicles may also improve public perception of waste processing.

The level of support or opposition to new waste and resource recovery infrastructure also varies significantly between communities, so this is a key consideration when introducing any changes.

5.5 Investment certainty

Planning processes also need to provide clarity and certainty in order to minimise investment exposure and deliver decisions in a timeframe that is commercially viable for proponents. This should include better integration of land-use planning and environment protection regimes to reduce duplication and barriers to more efficient outcomes.

Waste management facilities need to be viewed as an integral part of critical service infrastructure and planning for this needs to be on a long-term strategic basis. This should include consideration of designated land allocations for waste management precincts or co-location of waste management infrastructure in commercial and industrial areas that promote industrial ecology outcomes. Precinct based solutions pose challenges for where you can find large spaces in permissible communities.

5.6 Community consultation and social licence to operate

Genuine community consultation and engagement around the siting of waste management infrastructure is also critical to ensure that these facilities, which may have an operational life of 20 years or more, achieve the required social licence to operate both at a local and regional level.

- Consultation expectations vs. requirements for major infrastructure, especially EfW. Note the importance of selecting the right community – areas with established industrial activity and employment challenges are more likely to be supportive.
- Difficulty siting new landfills.
- Any reduction in resource recovery rates likely to be viewed negatively.

5.7 Energy from waste policy

According to WMRR[23], there are more than 2,000 EfW facilities operating safely across North America, Europe, Middle-East and Asia - with more than 200 of these constructed between 2011 and 2015. However, these facilities are new to Australia, and can be contentious, both with the local community and the wider population. Victoria has released an EfW guideline for proponents to follow, to deliver EfW projects which meet technical, environmental, regulatory and community expectations.[24]

This emerging industry needs a consistent approach and clear guidelines for proponents to follow, to deliver EfW projects which meet technical, environmental, regulatory and community expectations and are in the best interest of Victoria. This will help to prevent inconsistent decisions by different approvals authorities and deter higher-risk proposals.

Key concerns regarding EfW proposals are typically:

- Air emissions and potential public health impacts.
- Potential impact on recycling.
- Amenity impact of traffic and waste delivery.

All these issues can be adequately managed, as demonstrated by the many communities around the world where EfW facilities have come to be accepted, including facilities within dense urban centres.

[23] Waste Management and Resource Recovery Association Australia, 2019, *What is Energy from Waste?*, available at: https://www.wmrr.asn.au/Public/Conferences/Energy_from_Waste_Conference/Public/Conference_Websites/EfW2019/EFW2019%20Home.aspx?hkey=c6e170bd-a4fc-423b-84a0-8d86fe441156
[24] EPA Victoria, 2017. *Guideline: Energy from waste*. Available at: https://www.epa.vic.gov.au/~/media/Publications/1559%201.pdf

An EfW policy should provide clarity regarding which air emissions standards proponents will be expected to comply with. Air pollution controls can draw on extensive technical and regulatory experience developed in Europe over several decades and the European Union Best Available Techniques reference document (EU BREF) is generally viewed as international best practice in this area.

Potential impacts on recycling are a function of facility size, operating life and materials acceptance criteria. In order to achieve viable operating costs, commercial facilities are frequently designed for throughput in excess of 400,000 tpa and require long term foundation contracts, typically with local councils.

An EfW policy should provide clarity regarding acceptable residual materials that can be accepted for energy recovery. This could be based on the level of source separation applied at the point of disposal. Alternatively, EfW facilities could be required to undertake sorting for material recovery prior to combustion. This is the approach taken by the NSW Energy from Waste Policy. However, no EfW facilities have been developed to completion in NSW. Any sorting requirements must match available markets for recovered materials. Materials recovered from mixed residual waste are highly contaminated and if extraction to saleable quality is uneconomic, then prescriptive recovery requirements present a barrier to developing viable energy recovery facilities.

A clear EfW policy will result in energy from waste playing an appropriate role within a balanced, long-term infrastructure portfolio and supports Victoria's transition to a Circular Economy.

5.8 Policy, infrastructure and market support timing

The following provides a summary of the required interventions across the short (within 3 years) to medium term (3-10 years) for the each of the different scenarios.

5.8.1 Out of Sorts

Table 19 provides a summary of the interventions required under the *Out of Sorts* scenario.

Table 19: Interventions required for the Out of Sorts scenario

Timing	**Policy / regulation**	**Infrastructure and market support**
Short term	Public education on recycling materials restrictions and recycling outcomes	Funding for MRF upgrades and processing infrastructure Continued demonstration and testing of recycled content in construction
Medium term	None. The scenario explores a market-led response to recycling quality restrictions, with no policy intervention in waste production or collection	Procurement guidelines prioritising recycled content in infrastructure Review landfill airspace and lifetime, in light of increased disposal volumes
Ongoing	None. Recycling stabilises to focus on profitable recycling under higher quality expectations from end markets	Procurement of recycled content in infrastructure and commercial/consumer products

5.8.2 FOGO FOMO

Table 20 provides a summary of the interventions required under the *FOGO FOMO* scenario.

Table 20: Interventions required for the *FOGO FOMO* scenario

Timing	**Policy / regulation**	**Infrastructure and market support**
Short term	Timeline for mandatory organics separation Energy from Waste policy Build regulatory capacity for thermal EfW Waste sector emissions reduction pledge	Funding for council collection changes Funding support for additional largescale organic processing infrastructure Land use planning for additional organics processing infrastructure Improved quality specifications for recycled organics Market development for recycled organics Feed in tariff for bioenergy
Medium term	Public education on waste separation and recycling/resource recovery outcomes Review of recycling market performance and EfW acceptance criteria in stabilised recycling market Guidance for businesses on mandatory food waste separation Review of building guidelines to support separate collection of organics Technical guidance and policy on rapid dehydration unit outputs Implementation and compliance on organics landfill ban	Provide certainty on duration of short-term initiatives PIW guidelines for EfW ash recycling in place before first operational facilities Product testing and procurement specifications for EfW bottom ash recycling Research focus on potential emerging contaminants in recovered organics
Ongoing	Data collection and outcomes monitoring for existing policy	R&D or commercialisation funding for emerging, high-value organics recovery technologies

5.8.3 Closing the Floodgates

Table 21 provides a summary of the interventions required under the *Closing the Floodgates* scenario.

Table 21: Interventions required for the *Closing the Floodgates* scenario

Timing	**Policy / regulation**	**Infrastructure and market support**
Short term	Develop import and export restriction policy Announce mandatory changes to comingled recycling to separate glass from paper and card Energy from Waste policy Build regulatory capacity for thermal EfW Landfill levy increases	Funding for MRF upgrades Funding for recycling infrastructure development and expansion Land-use planning for new recycling infrastructure Transport or infrastructure support for regional areas Funding to councils for mandatory collection change Continued demonstration and testing of recycled content in construction
Medium term	Phase in import and export restrictions Public messaging on recycling and resource recovery outcomes Proactive compliance on landfill levy, stockpiling and dumping Technical guidance and policy on rapid dehydration unit outputs	Funding for infrastructure development/ expansion Procurement guidelines prioritising recycled content in infrastructure PIW guidelines for EfW ash recycling in place before first operational facilities Product testing and procurement specifications for EfW bottom ash recycling
Ongoing	Data collection and outcomes monitoring for existing policy Proactive compliance on landfill levy, stockpiling and dumping	Procurement of recycled content in infrastructure and commercial/ consumer products

5.8.4 Circular Stewards

Table 22 provides a summary of the interventions required under the *Circular Stewards* scenario.

Table 22: Interventions required for the *Circular Stewards* scenario

Timing	**Policy / regulation**	**Infrastructure and market support**
Short term	Circular economy policy Introduce container deposit scheme Introduce mandatory product stewardship schemes Timeline for mandatory organics separation	Support for demonstration precincts/initiatives B2B education and support to match businesses Funding for council collection changes Land use planning and funding support for additional organics processing infrastructure Improved quality specifications and market development for recycled organics
Medium term	Oversight of mandatory product stewardship schemes Guidance for businesses on mandatory food waste separation Review of building guidelines to support separate collection of organics Technical guidance and policy on rapid dehydration unit outputs	Procurement specifications for recycled content, material passports and circular business models in public projects Provide certainty on duration of short-term initiatives Research focus on potential emerging contaminants in recovered organics
Ongoing	Expand data collection and outcomes monitoring to capture reuse and B2B resource flows	R&D and commercialisation support for new business models and specialised recovery technologies

5.8.5 Packaging Crackdown

Table 23 provides a summary of the interventions required under the *Packaging Crackdown* scenario.

Table 23: Interventions required for the *Packaging Crackdown* scenario

	Policy / regulation	**Infrastructure and market support**
Short term	CDS introduction, national harmonisation and expansion to include all glass packaging Single use plastic bans National Packaging Targets implementation – led y APCO with state and federal support Announce restrictions on non-recyclable packaging. Develop monitoring/compliance capacity Energy from Waste policy (prescriptive acceptance criteria)	MRF upgrades Expansion of household organics collection and recovery (FOGO/ compostable packaging accepted in garden waste bin) Federal support for MRF, plastic recycling and composting infrastructure related to achieving National Packaging Targets Technical definitions/specification of recyclable/ compostable packaging Consumer and industry education
Medium term	Implement restriction on non-recyclable packaging Public education on recycling materials restrictions and recycling outcomes	Procurement guidelines prioritising recycled content in infrastructure, packaging and street furniture
Ongoing	Monitor new materials development and recyclability	R&D and commercialisation support for new biodegradable packaging/ food grade packaging recycling

5.8.6 High Energy

Table 24 provides a summary of the interventions required under the *High Energy* scenario.

Table 24: Interventions required for the High Energy scenario

	Policy / regulation	**Infrastructure and market support**
Short term	Energy from Waste policy Build regulatory capacity for thermal EfW Community engagement expectations/guidelines for thermal EfW Advice to councils on PAYT models and collection systems Landfill levy increases Product stewardship expansions	Land use planning for EfW, including support for colocation with industrial heat users
Medium term	PVC packaging ban Public education on recycling materials restrictions and recycling outcomes Proactive compliance on landfill levy, stockpiling and dumping Technical guidance and policy on rapid dehydration unit outputs	PIW guidelines for EfW ash recycling in place before first operational facilities Product testing and procurement specifications for EfW bottom ash recycling Transport or infrastructure support for regional areas
Ongoing	Proactive compliance on landfill levy, stockpiling and dumping	EfW bottom ash recycling in infrastructure R&D and commercialisation support specialised recovery technologies for source-separated wastes (e.g. textiles, e-waste)

6 Conclusion

Thorough analysis of potential technological and infrastructure changes to improve Victoria's recycling and resource recovery demonstrates the complexity of this challenge. The results of the MCA are presented in Figure 7 and shows similar performance across a range of potential scenarios.

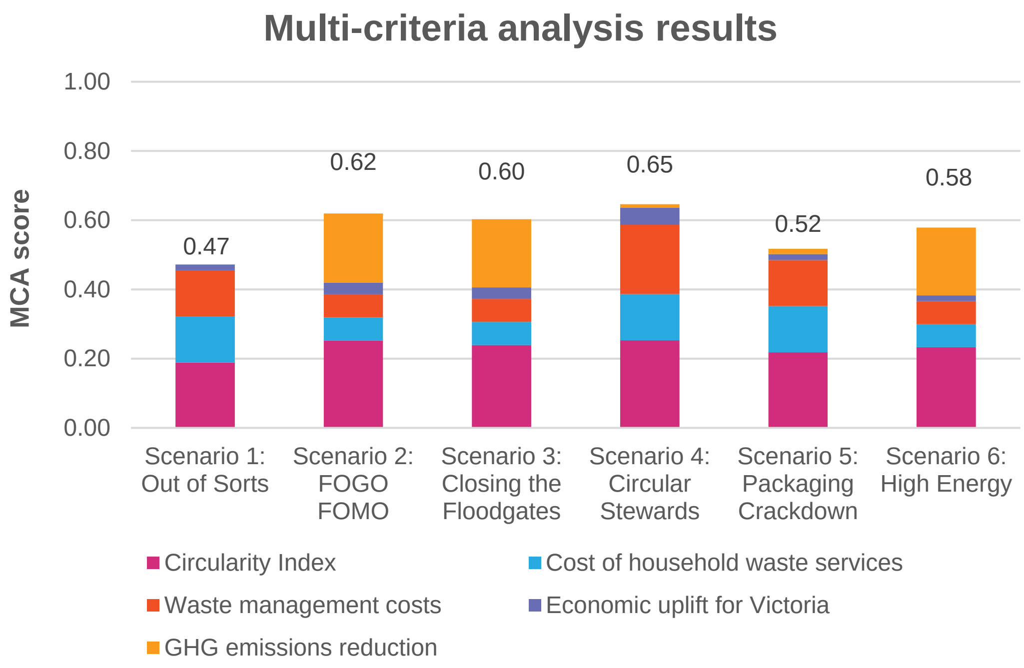


Figure 7: MCA results for the scenarios

The *Circular Stewards* scenario was ranked highest by our MCA process and warrants further development of supporting of policy and regulatory measures, as well as market and infrastructure support. This scenario is in line with the direction set by the Victorian Government *Circular Economy Policy issues paper* and should be supported by the resulting policy expected to be released later this year. Along with extending the breadth of mandatory product stewardship schemes and oversight, this scenario will be supported by the introduction of some form of container deposit scheme. It would also require consideration of land use planning for additional organics infrastructure. The government can also help this scenario by providing support for demonstration precincts / initiatives, business to business engagement and R&D and commercialisation support for new business models and specialised recovery technologies.

The MCA scoring also highlighted three next best choices with little differentiation. *FOGO FOMO*, *Closing the Floodgates* and *High Energy* all achieved relatively similar scores. The low level of differentiation between the scenarios due to each of the scenarios focuses on improving a specific area of resource recovery. High organics diversion from landfill and generation of partially-renewable electricity to offset alternative generation from Victoria's fossil fuel-reliant grid result in high scores for greenhouse gas emissions reduction. These scenarios if pursued are supported by a range of policy and regulatory measures for each scenario, and infrastructure and market support.

There are a range of issues that need to be considered and planned for, including:

- Land use planning requirements
- Community acceptance and social license to operate
- Community education and behaviour change
- Market development for immature or capacity-constrained markets
- Cost or access equity for regional areas
- Economic viability of infrastructure/ business models in the absence of state intervention

The relevant technologies for the scenarios are detailed in Table 25, and the support measures are described in Table 26 and Table 27.

Table 25: Technologies relevant to the scenarios

Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Resource recovery centres. Recyclate sorting– optical and machine vision. Robotic waste sorting. Plastics washing, flaking and mechanical recycling. Glass and plastics processing for use in infrastructure. Open windrow composting. E-waste recycling. Textile recycling. Organic valorisation – chemicals, insect protein. Bulk plastic products.	Digital technologies to optimise collection. Anaerobic digestion. In-vessel composting. Thermal energy from waste. Organic valorisation – chemicals, biofuels, insect protein. Rapid dehydration for business. Plastics to fuel. Biological degradation of waste plastics. Small-scale AD for businesses. Digital optimisation of collections.	Energy from waste. Separate collection of glass. Glass beneficiation and reprocessing. Plastic sorting and processing. Digital collection optimisation. Sorting dry recyclables – AI and machine learning. Micro-factories. Small-scale AD for businesses. Rapid dehydration/composting for precincts. Organics collection and valorisation – insect protein, chemical extraction. Tyre pyrolysis.	Drop-off points and collections for product stewardship schemes. E-waste processing. Battery recycling. Reprocessing of glass and plastic for infrastructure applications. Refuse-derived fuel production. Platforms supporting sharing/leasing. Digital / Internet of Things collections optimisation. AI / machine learning sorting. Micro-factories. Tyre pyrolysis. Chemical recycling for textiles.	Optical sorting at MRFs. Plastics processing for export/domestic use. CDS collection infrastructure. Refuse-derived fuel production In-vessel composting. Bio-based product manufacturing.	Thermal energy from waste. On-site anaerobic digestion (limited). In-vessel composting (limited). Logistics – drop-off points / vacuum collection. Organic valorisation – chemicals, biofuels, insect protein. Rapid dehydration for business. Small-scale AD for businesses. Digital optimisation of collections. E-waste recycling. Chemical recycling of textiles.

Table 26: Policy and regulatory support required for the scenarios

Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Public education on recycling materials restrictions and recycling outcomes.	Timeline for mandatory organics separation. Energy from Waste policy. Waste sector emissions reduction pledge. Land use planning for additional processing infrastructure. Improved quality specification for recycled organics. Public education on waste separation and recycling/resource recovery outcomes. Implementation and compliance on organics landfill ban. Build regulatory capacity for thermal EfW. Technical guidance and policy on rapid dehydration unit outputs.	Develop import and export restriction policy. Announce mandatory changes to comingled recycling. Land-use planning for new recycling infrastructure. Energy from Waste policy. Landfill levy increases. Phase in import and export restrictions. Public messaging on recycling and resource recovery outcomes Proactive compliance on landfill levy, stockpiling and dumping Build regulatory capacity for thermal EfW Technical guidance and policy on rapid dehydration unit outputs	Circular economy policy. Introduce Container deposit scheme. Mandatory product stewardship schemes. Oversight of mandatory product stewardship schemes. Land use planning for additional organics infrastructure.	CDS introduction, national harmonisation and expansion to include all glass packaging. Single use plastic bans. Announce restrictions on non-recyclable packaging. Develop monitoring/compliance capacity. Technical definitions/specification of recyclable/ compostable packaging. Implement restriction on non-recyclable packaging. Public education on recycling materials restrictions and recycling outcomes. Monitor new materials development and recyclability.	EfW and land use planning policy. Community engagement expectations/guidelines for thermal EfW. Advice to councils on PAYT models. Landfill levy increases to drive EfW. Product stewardship expansions. Build regulatory capacity for thermal EfW. PVC packaging ban. Public education on recycling materials restrictions and recycling outcomes. Proactive compliance on landfill levy, stockpiling and dumping. Technical guidance and policy on rapid dehydration unit outputs.

Table 27: Infrastructure and market support required for the scenarios

Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Funding for MRF upgrades and processing infrastructure. Continued demonstration and testing of recycled content in construction. Procurement guidelines prioritising recycled content in infrastructure. Review landfill airspace and lifetime.	Funding for council collection changes. Funding support for additional largescale organic processing infrastructure. Feed in tariff of bioenergy. PIW guidelines for EfW ash recycling. Market development for recycled organics R&D or commercialisation funding for emerging, high-value organics and plastics recovery technologies.	Funding for MRF upgrades. Funding for recycling infrastructure development and expansion. Funding to councils for mandatory collection change. Transport or infrastructure support for regional areas. Continued demonstration and testing of recycled content in construction. Funding for infrastructure development/ expansion. Procurement guidelines prioritising recycled content in infrastructure. PIW guidelines for EfW ash recycling.	Support for demonstration precincts/initiatives. B2B education and support in terms of consultancy to match and marry businesses. Procurement specification for recycled content, material passports and circular business models in public projects. Review landfill airspace and lifetime. R&D and commercialisation support for new business models and specialised recovery technologies.	MRF upgrades. Expansion of household organics collection and recovery (FOGO / packaging accepted in garden waste bin). Federal interest.	PIW guidelines for EfW ash recycling. Transport or infrastructure support for regional areas. R&D and commercialisation support for new business models and specialised recovery technologies.

Appendix A

Technology Guide

Appendix overview

This Appendix provides a guide to the relevant recycling and resource recovery technologies. It details:

- Victorian waste supply chains;
- Source separation and collection technologies;
- Sorting and processing technologies;
- Organic waste processing technologies;
- Energy from waste technologies
- Reprocessing and remanufacturing technologies; and
- Emerging waste technologies.

A1 Victorian waste supply chains

Many infrastructure development opportunities exist that could promote better resource recovery and waste management outcomes and create new revenue streams. Enablers for new infrastructure and technology include public education, land use planning, incentivising development, encouraging policy changes, attractive contractual arrangements and developing markets for both waste materials going to these facilities and outputs from these facilities.

The current waste and resource recovery supply chain for MSW, C&D and C&I streams in Victoria are shown in Figure 1, Figure 2 and Figure 3.

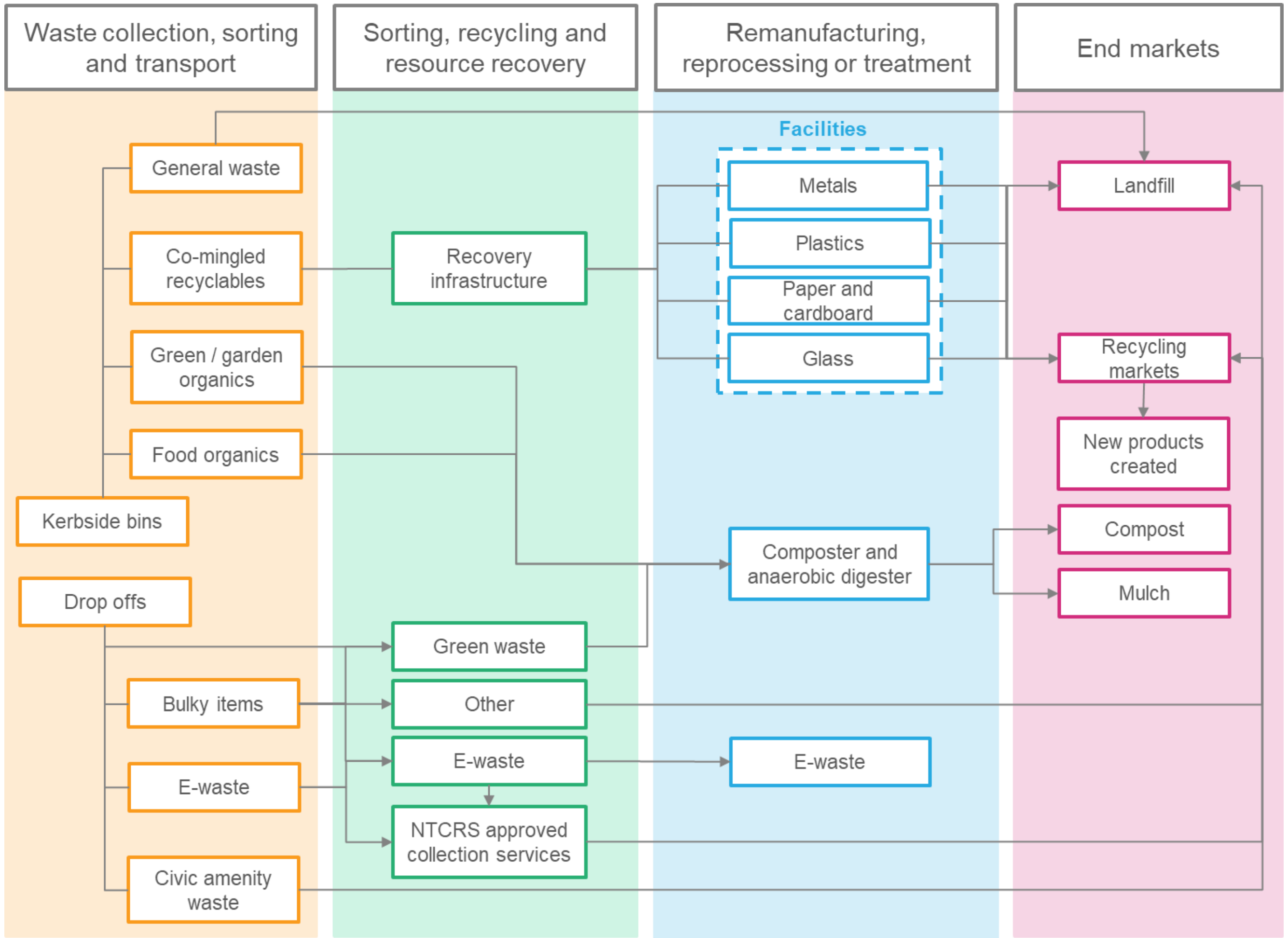


Figure 1: Supply chain for MSW waste stream in Victoria

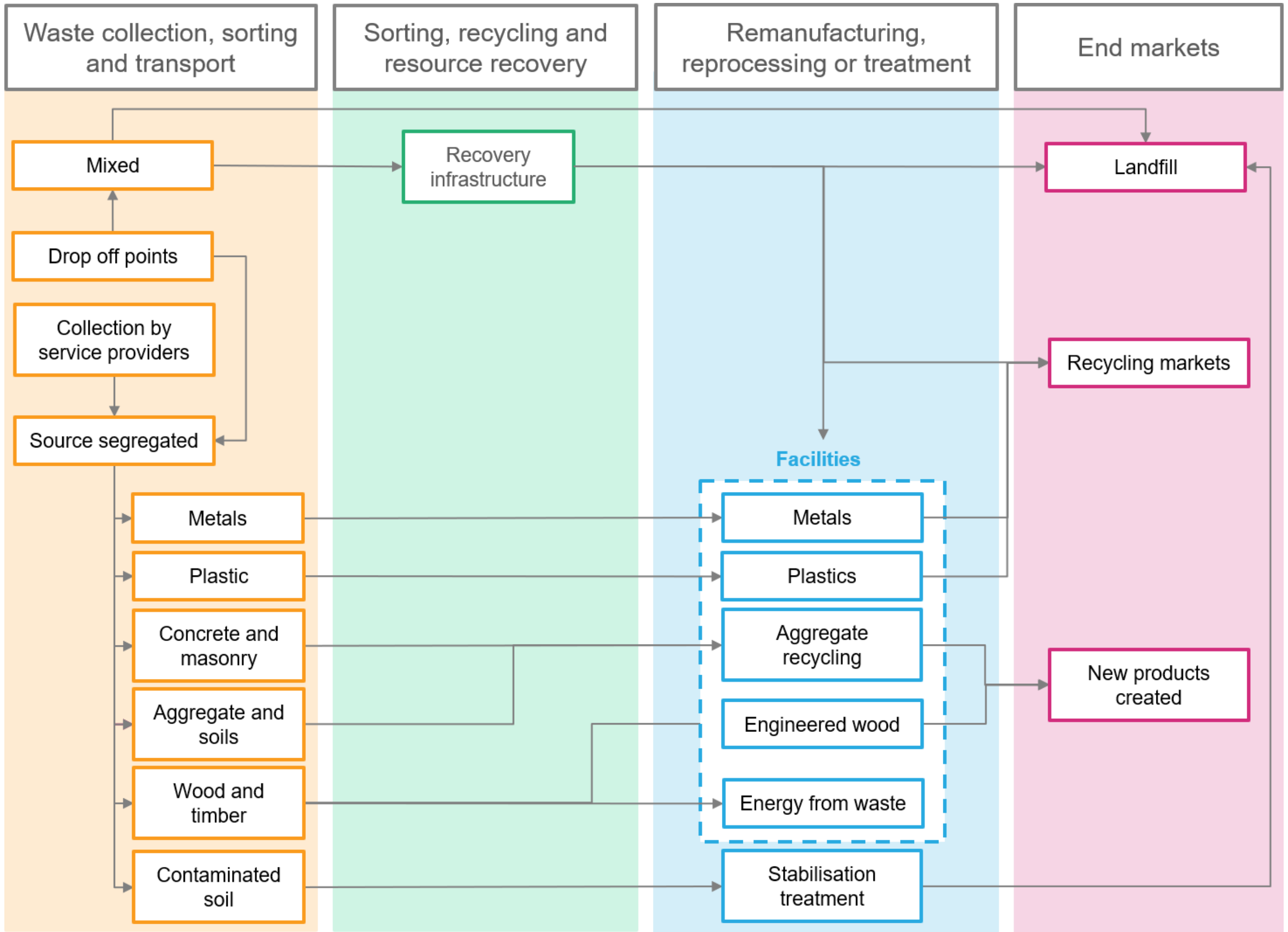


Figure 2: Supply chain for C&D waste streams in Victoria

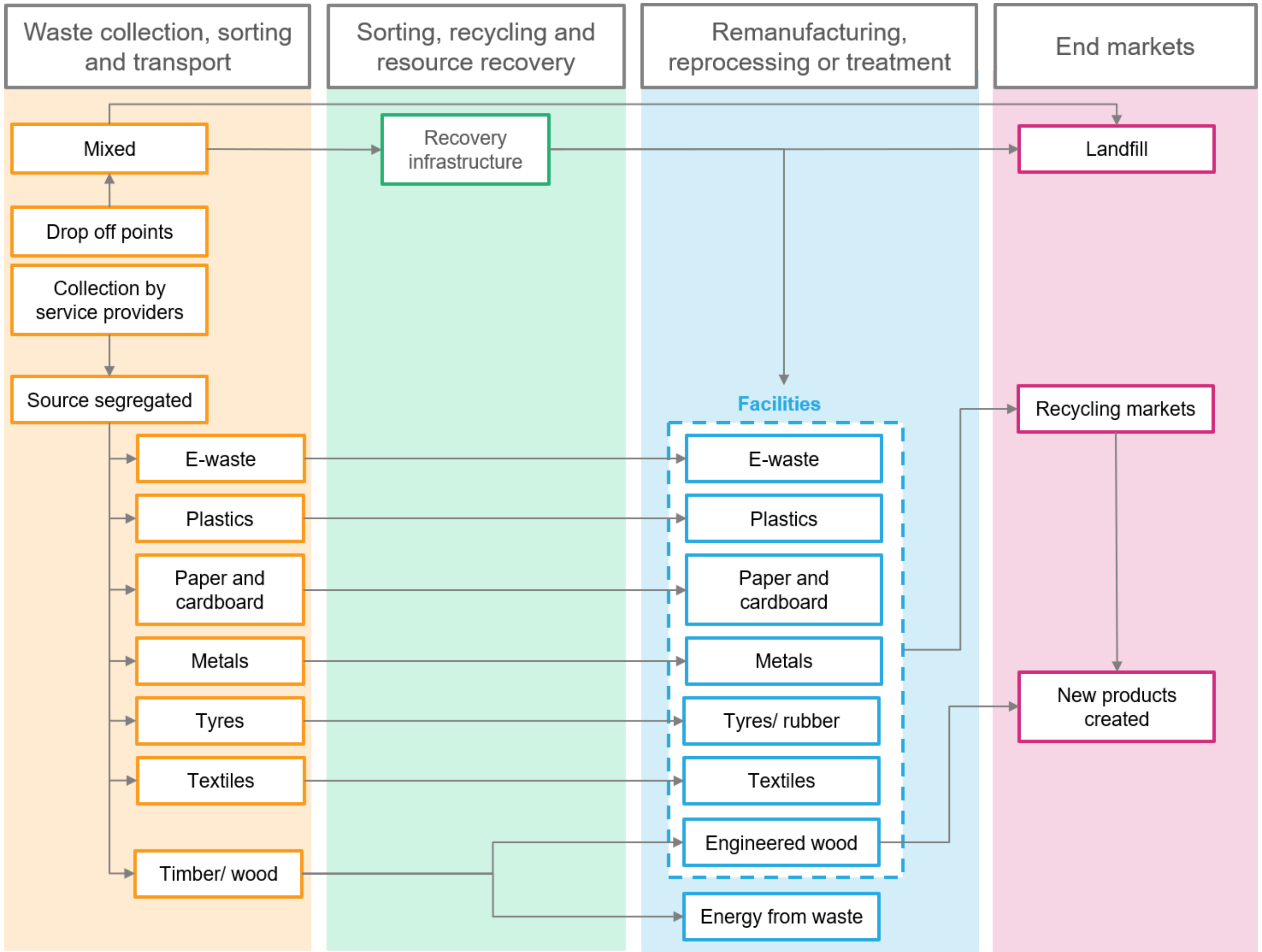


Figure 3: Supply chain for C&I waste streams in Victoria

A2 Technologies relevant to scenarios

Table 1. Technologies relevant to scenarios

Out of Sorts	FOGO FOMO	Closing the Floodgates	Circular Stewards	Packaging Crackdown	High Energy
Resource recovery centres Recyclate sorting–optical and machine vision Robotic waste sorting Plastics washing, flaking and mechanical recycling Glass and plastics processing for use in infrastructure Open windrow composting E-waste recycling Textile recycling Organic valorisation – chemicals, insect protein Bulk plastic products	Digital technologies to optimise collection Anaerobic digestion In-vessel composting Thermal energy from waste Organic valorisation – chemicals, biofuels, insect protein Rapid dehydration for business Plastics to fuel Biological degradation of waste plastics Small-scale AD for businesses Digital optimisation of collections	Energy from waste Separate collection of glass Glass beneficiation and reprocessing Plastic sorting and processing Digital collection optimisation Sorting dry recyclables – AI and machine learning Micro-factories Small-scale AD for businesses Rapid dehydration/composting for precincts Organics collection and valorisation – insect protein, chemical extraction Tyre pyrolysis	Drop-off points and collections for product stewardship schemes E-waste processing Battery recycling Reprocessing of glass and plastic for infrastructure applications Refuse-derived fuel (RDF) production Platforms supporting sharing/leasing Digital / Internet of Things collections optimisation AI / machine learning sorting Micro-factories Tyre pyrolysis Chemical recycling for textiles	Optical sorting at MRFs Plastics processing for export/domestic use CDS collection infrastructure Refuse-derived fuel (RDF) production In-vessel composting Bio-based product manufacturing	Thermal energy from waste On-site anaerobic digestion (limited) In-vessel composting (limited) Logistics – drop-off points / vacuum collection Organic valorisation – chemicals, biofuels, insect protein Rapid dehydration for business Small-scale AD for businesses Digital optimisation of collections E-waste recycling Chemical recycling of textiles

A3 Summary of technologies and associated enablers, barriers and context

Table 2 to Table 7 summarise technologies identified in the Sustainability Victoria *Resource and Recovery Technology Guide* and details barriers and enablers for increased use.[1] This summary excludes some technologies that were originally included in Sustainability Victoria's Resource Recovery Technology Guide, due to limited proven success and lack of relevance to the scenarios.

A3.1 Source separation and collection

Table 2 summarises source separation and collection technologies, barriers, enablers and Victorian context.

Table 2: Source separation and collection technologies, barriers, enablers and Victorian context

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Source segregation of waste streams: *Use of separate containers to receive and store segregated waste prior to collection.*	General waste Co-mingled recycling Organics: food Organics: garden Paper/card	Mature and established for 2/3 streams for MSW. C&I: more widely established to have multiple streams (3/4)	Inconsistency in collection regimes Contamination Space requirements for storage and collection points	Education programmes Effective signage and bin specification and colours	Kerbside collection covers 97% of Victorian Households, with commingled recycling at 96% coverage and garden waste at 70%.[2] [3] Higher resource recovery is generally achieved through a three-bin configuration with separate bins for residual waste, commingled recyclables and food and garden organics.[4]

[1] Sustainability Victoria, 2018, *Resource Recovery Technology Guide*, available at: https://www.sustainability.vic.gov.au/About-Us/Publications/RRE009-Resource-Recovery-Technology-Guide

[2] Sustainability Victoria, 2018, *Statewide waste and resource recovery infrastructure plan*, available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/SWRRIP-2018/SWRRIP-2018.pdf

[3] Sustainability Victoria, 2018, *Statewide waste and resource recovery infrastructure plan*, available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/SWRRIP-2018/SWRRIP-2018.pdf

[4] Sustainability Victoria, 2018, *Statewide waste and resource recovery infrastructure plan*, available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/SWRRIP-2018/SWRRIP-2018.pdf

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
	Glass	including paper/card and glass.			
Container deposit scheme: *Financial incentive to return eligible containers.*	Primary packaging and containers (bottles, cans and cartons made from glass, metals and paper/card).	Well established and mature across Australia. Victoria is the only jurisdiction in Australia not to currently to implement a scheme. Mature in some international jurisdictions.	Potential increase in product costs Start-up and operational costs, deposit facility roll-outs Political barriers Only targets specific waste items Behaviour change is required	Agreement and buy-in with manufacturers and councils High levels of litter and increasing public awareness	Victoria had a CDS scheme previously in the 1980s which was rescinded. Recent CDS scheme proposals have been defeated in the Parliament of Victoria. However, the government continues to look at models in other jurisdictions and monitor performance. South Australia's scheme is a well-known successful example which achieved a return of over 612 million containers in 2018-19 (an overall return rate of 76.4%) which equates to $61 million in refunds.[5] South Australia only has 2.8% of CDS-listed items in its litter streams, compared to 6.5% in Victoria.[6]
Pay-as-you-throw: *A usage-pricing model for collection of waste to encourage waste avoidance and segregation. Usage can be determined in various ways (volume, weight,*	Multiple: can be applied to any waste stream. Typically applied to MSW and C&I kerbside collections, with a differential pricing model to	Not mature in Australia. Successfully implemented and considered mature in some other countries including parts of the United States,	Potential for increased litter/illegal dumping Behaviour change is required Opposition to changes in collection charges	Increasing waste collection rates for householders Increasing public awareness of waste issues Recycling and landfill diversion targets	Has been proposed previously for Victoria by IV. Other jurisdictions in Australia have investigated PAYT but have yet to adopt. Applicability of PAYT including the potential for adverse effects to come about would need to be thoroughly considered prior to this form of scheme being implemented in Victoria. Residential disposal can be reduced by about 17% (example in in the United States).[7]

[5] SA EPA, 2019, *Container deposits*, available at: https://www.epa.sa.gov.au/environmental_info/container_deposit

[6] SA EPA, 2019, *Container deposits*, available at: https://www.epa.sa.gov.au/environmental_info/container_deposit

[7] Skumatz, L.A., and Freeman, D.J., 2006, *Pay as you throw (PAYT) in the US:*

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
number of containers, RFID, etc.)	incentivise less residual disposal.	EU and New Zealand.			
Automated waste collection systems (AWCS): *System of pneumatic pipes to convey waste from inlets to a centralised collection point, can typically handle up to three waste streams.*	General waste Co-mingled recycling Organics: food	Emerging adoption in Australia. Successful AWCS projects implemented in various jurisdictions including the US, EU, Middle East and Asia.	Significant capital cost Generally easier to integrate into new developments rather than existing developments Does not deal with all waste streams (e.g. bulky waste, hard waste, large quantities of segregated glass) Governance: challenge for early adopters to interface with council collection and disposal	Desire to reduce vehicle movements and environmental/amenity impacts Established source-segregation Promotion of reduction in manual handling requirements and reducing OH&S risk Promotion of innovative and forward-looking	Yet to be adopted in Victoria or at a national level. The first AWCS system in Australia is being installed in the Maroochydore CBD greenfield development in Queensland and will use an Envac system comprising 6.5km of underground piping to transport waste from on-street bins.[8] AWCS named as an innovative technology to be considered for larger developments by Sustainability Victoria.[9] Penrith Council (NSW) has been actively investigating applicability of AWCS, concluding it should be considered for all high-density developments of 1,000 dwellings or more.[10] AWCS is being more frequently considered by developers and councils for new projects in Australia.

2006 update and analyses, Superior, CO: US Environmental Protection Agency and Skumatz Economic Research Associates (SERA), available at: http://www.paytnow.org/PAYT_EPA_SERA_Report2006G.pdf

[8] Sunshine Coast Council, 2019, Automated waste collection system, available at: https://www.sunshinecoast.qld.gov.au/Council/Planning-and-Projects/Infrastructure-Projects/Automated-Waste-Collection-System

[9] Sustainability Victoria, 2019, *Waste and recycling in multi-unit developments*, available at: https://www.sustainability.vic.gov.au/Government/Waste-and-resource-recovery/Waste-management-in-multi-unit-developments

[10] Penrith City Council, *Automated waste collection systems waste management guidelines*, available at: https://www.penrithcity.nsw.gov.au/images/documents/building-development/planning-zoning/planning-controls/Waste_Management_Guidelines_Waste_Collection_Systems.pdf

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
			contracts and realise operational savings Business case typically becomes viable only for high-density developments	waste management practices Can integrate with PAYT charging systems	There are examples of local goverments mandating AWCS for new high-density development (Singapore) or incorporating it into large urban renewable precincts (South Korea, India). In Stockholm, the local government is slowly taking ownership of exisitng small AWCS systems which were previously privately operated and maintained.
Collection vehicles: *Vehicles that collect waste from receptacles (kerbside bins or larger bulk bins).*	General waste Co-mingled recycling Organics: food and garden Source segregated recyclables	Use of diesel-powered collection trucks is mature in Australia, typically one vehicle per waste stream.	Capital investment required Current EV range limiting for regional/rural areas. Availability of commercially produced heavy EVs offered by original equipment manufacturers High costs to retrofit electric engines into existing fleets Multi-compartment truck access is difficult in some areas	Public awareness of vehicle emissions and noise Operational savings Change must be driven by local councils seeking to improve efficiencies and reduce costs Development of new collection routes and timetables for multi-compartment trucks	While multiple collection rounds utilising single-compartment vehicles is commonplace in councils throughout Victoria, the single vehicle with multiple compartments approach has gained traction in some areas of the world. The town of Anglesey in Wales is one such example which uses a single-pass truck comprising five compartments. Although no statistics exist on the recycling benefits achieved so far, Anglesey is aiming for an increase of 10.5% (from 59.5% to 70%), primarily from this scheme, in addition to taxpayer benefits gained from a 33% reduction in collection vehicle trips and lower emissions from fewer trips.[11] Consideration of vehicles that use alternative sources of power including EVs, biofuels and even hydrogen is becoming more widespread. The recent rollout of electric vehicles in Victoria including in the City of Casey and the City of Hobsons Bay highlight an emerging opportunity in

[11] Isle of Anglesey County Council, 2019, *Household waste collection on Anglesey*, available at: https://www.anglesey.gov.uk/en/Residents/Bins-and-recycling/Household-waste-collection-on-Anglesey.aspx

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
				Market development for heavy EVs	this space. These vehicles have approximately 180-200km ranges, do not have air emissions and are considerably quieter than their diesel counterparts. Moreland Council trialling hydrogen-fuelled garbage trucks, planning to convert 12 of their 18 trucks by early 2020.[12]
Organics to sewer: *Grind/macerate food waste and dispose of it via the sewerage system.*	Organics: food	Adopted all over the world. Reasonably mature in some parts of Australia.	Potential to clause blockages in pipe networks as food is sometimes not broken down sufficiently and fats oils and greases (FOGs) can accumulate Potential increased operational costs for waste water industry	Increasing waste collection rates for householders Significant quantities of centralised food waste generation Agreement with sewage utility companies Ability of sewage network to accommodate within existing waste water treatment facilities	Typically implemented on a per household or business basis and as such not specified at a council, state or policy level. In the UK, the increased costs to the water system have been seen to outweigh the benefits to local authorities, rendering a widespread rollout of this initiative potentially uneconomical.[13]

[12] Moreland City Council, Renewable hydrogen waste truck trial, available at: https://www.moreland.vic.gov.au/about-us/projects/environmental-projects/renewable-hydrogen-waste-truck/

[13] Iacovidou, E., Ohandja, D.G. and Voulvoulis, N., 2012, *Food waste disposal units in UK households: The need for policy intervention*, Science of the Total Environment, 423, 1-7, available at: https://www.agro.uba.ar/users/semmarti/RSU/Individual%20disposal%20of%20organics%20in%20UK.pdf

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Contamination management: *Measures to reduce contamination of segregated waste streams and incentivise good practice such as bin tagging, collection vehicle cameras and use of clear bin bags / bins*	General waste Co-mingled recycling Organics: food and garden Source segregated recyclables	Some Australian councils have adopted contamination management measures. Widely used in international jurisdictions.	Concerns from residents/businesses about how data is used Operational cost Behaviour change may be required	Buy-in from residents, businesses and collection crews Increasing waste collection rates for householders Increasing public awareness of waste issues	Bin tagging has been used in Victoria. Bins are visually inspected at the kerbside prior to collection, providing direct feedback on the content of waste through use of some form of coloured/rating tag system. If contamination levels are seen to be low, many systems use 'happy' green tags to reiterate positive recycling behaviours, with Frankston Council incentivising good practice through weekly movie ticket draws. Poor practice will see an 'unhappy' red tag placed on the bin which identifies what can and cannot be placed in each bin type. In some cases, council may refuse to accept the content of a bin, which is thought to spark behavioural change.

A3.2 Sorting and processing

Table 3 summarises sorting and processing technologies, barriers, enablers and the associated Victorian context.

Table 3: Sorting and processing technologies, barriers, enablers and Victorian context

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
MRF (clean): *sort recyclable material streams into single-material streams which are then on-sold to dedicated materials reprocessors.*	Co-mingled recycling from MSW, C&I sources to extract: Glass Paper and cardboard Metals Plastics E-waste	Well established: 21 clean MRFs in Victoria, many more operating across Australia.	Fluctuations in market demand: can lead to stockpiling Contamination, such as glass fines OH&S risks with manual operation and picking Varying material acceptance and inconsistency Fire risks	Creation of infrastructure: i.e. networks or reuse centres Market development: development of alternative uses forlass recyclables Policy change: Victoria e-waste banned from landfills Education programmes Co-location with reprocessing facilities	The number of sorting and processing facilities in Victoria is steadily increasing, with an increase of approximately 22% between 2012 and 2018 based on Sustainability Victoria data. Stockpiling as a result of the collapse of export recyclables markets has led to some MRF operators going out of business, and many recycling contracts are currently facing uncertainty in Victoria. Optical sorting technology is now mature and used in the majority of medium-large MRFs. This is an area of ongoing refinement. Robotic sorting, using a combination of sensors and machine-learning (including between different MRF facilities) for image recognition is a developing area, which may further improve the accuracy of waste identification and sorting in the future. Like optical sorting, it presents a trade-
MRF (dirty): *Also known as mixed-waste MRFs, process material which cannot be cleaned sufficiently to access traditional materials recycling markets. Consequently, mixed-waste MRFs are linked to a lower-order recovery process which*	MSW / C&I / C&D residual waste to extract: Organics: food Organics: garden Paper and cardboard Plastics Aggregates, masonry and soils Textiles	Well established: several dirty MRFs in Victoria.	Market challenges Contamination Fire risks	Market: demand for end products Infrastructure Development: expand C&D reprocessing facilities Creation of infrastructure: i.e. networks or reuse centres Co-location / integration with MBT/MHT	

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
can accept the relatively contaminated material as feedstock	Can be used to produce RDF.			Thermal EfW (for RDF)	off between capital cost and output quality, and between throughput rate and output quality.
Mechanical biological treatment (MBT): *sorting mixed residual waste and stabilising the organic fraction through in-vessel composting.*	MSW / C&I residual waste to extract: Organics: food Organics: garden Paper and cardboard Metals: mixed residual waste Wood and timber Can be used to produce RDF and compost.	Well established: six commercial facilities in other jurisdictions in Australia, over 300 in Europe.	Safety: fire risks Contamination: chemical Policy: no existing sites in Victoria, regulation untested Concerns over risk of emerging contaminants	Creation of infrastructure: i.e. networks or reuse centres Investment: i.e. artificial intelligence, robotic sorting system Landfill diversion Thermal EfW (for RDF)	MBT facilities are operated in Australia by various major waste sector players in NSW and QLD, but there is are no MBT facilities in Victoria. Some facilities have faced operational challenges in producing recovered organic output that is at a sufficient quality standard. In NSW in 2018, NSW EPA banned the use of mixed-waste derived organics on agricultural land and suspended their use in forestry and site rehabilitation applications until further notice. This has resulted in organic outputs from MBT going to landfill. With increasing focus and concern regarding emerging contaminants, it is likely this trend will spread throughout Australia. MBT is unlikely to see significant interest in Victoria, and there is unlikely to be significant development of new MBT facilities in the EU.

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Mechanical heat treatment (MHT): *Two main types; pressurised thermal autoclaving and non-pressurised thermal heat treatment. Autoclaving involves using pressurised steam to heat and sterilise waste in a sealed vessel. Non-pressurised thermal heat treatment involves heating mixed waste in a sealed vessel to dry it.*	Mixed residual waste Clinical and related waste Hazardous waste Can extract recoverable materials including metals, plastics and RDF	Reasonably mature internationally for treating specific clinical and related wastes as well as hazardous wastes. Limited track record in Australia, mainly used on a small scale for clinical and related hazardous wastes. Application of MHT to mixed wastes such as MSW is relatively unproven.	Market challenges Safety: explosion risk Air quality and emissions Regulatory change restricting outlet for recovered organics	Policy: stricter safety requirements Requirement to safely treat and sterilised some clinical and related wastes	EPA Victoria recognise that autoclaving is a suitable treatment process for some types of clinical and related waste.[14] Shoalhaven City Council, in NSW, is currently considering use of MHT type technology to process red-bin MSW. No proposals for MHT of mixed waste at current time for Victoria.

[14] EPA Victoria, *Clinical and related waste – operational guidance*, available at: https://www.epa.vic.gov.au/~/media/Publications/IWRG612%201.pdf

A3.3 Organic waste processing

Table 4 summarises organic waste processing technologies, barriers, enablers and Victorian context.

Table 4: Organic waste processing technologies, barriers, enablers and Victorian context

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
Open windrow composting: *Simple composting method where organic waste is piled in rows. Suitable for large volumes of organic material*	Organics: food Organics: garden Generally, more suitable for garden waste and timber/agricultural residues Outputs: compost	Well established with many facilities in Victoria and hundreds of facilities across Australia.	Contamination of feedstock Air, vermin and odour concerns Land use planning: moderate land capacity required Lack of product specifications Market confidence in product quality Transport costs to access agricultural markets	EPA composting guidance Awareness and education Separate food and garden waste collection services Development of product specifications Market development	The *Guide to Biological Recovery of Organics*, published by Sustainability Victoria, provides more detailed information on best-practice biological processing in the Victorian context. [15] Victoria currently has an active organics recovery industry, producing mulches, soil conditioners, composts, salvage timber, proves derived fuels and energy from organic waste. Lack of product specifications and widely varying composition and quality between products and operators is an ongoing challenge which erodes market confidence, particularly in agricultural markets where alternative
Aerated static pile composting: *Alternative configuration of composting to increase the precision and control of the composting process*	Organics: food Organics: garden Outputs: compost	Established: several facilities across Australia.			

[15] Sustainability Victoria, 2018, *Guide to biological recovery of organics*, available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/Victorian-Organics-Resource-Recovery-Strategy/RRE007-Guide-to-Biological-Recovery-of-Organics.pdf?la=en

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
In-vessel composting: *Composting within a sealed chamber, using forced aeration and temperature sensing instrumentation.*	Organics: food Organics: garden	Well established: small number in Victoria, several in Australia and hundreds in Europe.	Extreme weather can affect outputs (less applicable for IVC) Fire risks Vermi-composting can be particularly sensitive to feedstock	As above	products such as synthetic fertilizers and manures are competitive and well understood.
Vermi-composting: *Vermicomposting involves breaking down organic material using worms.*	Organics: food Organics: garden Outputs: Liquid fertiliser Worm castings/ vermi-compost Worms: protein source for fish/animal feed	Limited: proven technology but limited commercial plants.			
Anaerobic digestion: *Biological degradation process where methane can be collected and used to generate power or as a fuel.*	Organics: food Organics: garden Outputs: Methane rich biogas Digestate	Well established: small number in Australia using wet AD, Dry AD has significant European presence.	Contamination of feedstock Air, vermin and odour concerns Land use planning Feedstock quality control Price and volatility of wholesale electricity market	Organics and EfW policy creation Awareness and education Separate food and garden waste collection services Co-location of demand for energy offtake	The *Guide to Biological Recovery of Organics*, published by Sustainability Victoria, also provides more detailed information on best-practice anaerobic

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
Fermentation: *Anaerobic process which converts sugars into alcohols or acids which can be sold to end markets.*	Organics: food Organics: garden Agricultural residues	Limited. Fermentation facilities are not yet operating commercially.	Commercial track record Transport economics	Demonstrated / pilot projects Education and awareness	processing in the Victorian context.[16] It also provides guidance on products and markets from organic waste processing.
Dehydration / Rapid food waste decomposition: *Self-contained rapid reduction the volume of organic waste to improve amenity and reduce storage space and disposal cost*	Organics: food	Established: commercial plants in operation but only small niche applications.	Awareness and education Energy consumption and capital leasing/purchase costs	Market development Education and awareness Space and labour constraints for management of organic wastes from C&I premises in urban locations	The NSW EPA has current Resource Recovery Exemption Orders for rapid food waste decomposition technologies from three providers: Closed Loop, EcoGuardians (SoilFood System) and GreenTech Industries. Approval for a new entrant, emnrich360, is currently under consideration by the NSW EPA. Case studies are available in various Australian states including Victoria, but the technology still has a low awareness and adoption rate among potentially suitable waste generators.

[16] Sustainability Victoria, 2018, *Guide to biological recovery of organics,* available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/Victorian-Organics-Resource-Recovery-Strategy/RRE007-Guide-to-Biological-Recovery-of-Organics.pdf?la=en

A3.4 Energy from waste

Table 5 summarises energy from waste (EfW) technologies, barriers, enablers and Victorian context.

Table 5: Energy from waste technologies, barriers, enablers and Victorian context

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Combustion, moving grate: *waste undergoes full combustion as it is mechanically driven over a grate with air blown through it. The combustion of waste generates hot gases which are used to raise steam in a boiler. The steam can then be used to generate power and/or heating or cooling. Ash falls at opposite end of furnace, and the flue gases have to undergo flue gas treatment prior to emission to the atmosphere. Combustion usually occurs at temperatures between 850 and 1,300 °C.*	Residual mixed waste from MSW and C&I sources RDF Biomass Outputs: Power Heat Recovered metals Bottom Ash Air Pollution Control Residue (APCr)	Well established and mature on a global basis particularly in the EU, US and Asia. The most common combustion technology for waste. No operational facilities in Australia (there are some small facilities focusing on biomass).	Community perception Opposition from environmental campaign groups Potential impacts on air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Requires a consistent supply of feedstock	Large volumes of waste High regulatory standards for EfW R&D technology investment Market development Market for created energy, or co-location with users of power or heat Landfill levy Proactive and genuine community engagement and demonstration of social license EfW policy	No facilities currently operating in VIC, but there are significant developments in progress and it is considered likely a facility will become operational in the short to medium term. Australian Paper in the Latrobe Valley, Victoria, is proposing to develop a 650 ktpa facility based on combustion moving grate technology. It will process both MSW and C&I waste, producing around 30MW of electricity or 130 tph of high-pressure steam. The project recently gained EPA Works Approval. In August 2019, a $300 million facility 400 ktpa in Ballarat has been put on hold by the local council, as they await the circular economy policy from the Victorian Government. In September 2019, Energx Pty Ltd lodged an application to develop an EfW facility in Hume, Victoria. First operational facility in Australia likely to the 400 ktpa Kwinana facility in WA, currently under construction.

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Combustion, fluidised bed: *Complete combustion using a fluidised bed (bubbling or circulating type) – a bed of inert material such as sand that is fluidised with hot blown air. Heat from combustion raises steam in a boiler which can be used to generate power. Combustion typically occurs at temperatures between 850 and 950 °C*	Single source feedstock or RDF derived from MSW/C&I mixed waste that is homogenised and uniformly sized. Can also be used to process industrial, sewage, clinical and hazardous wastes.	Well established and mature on a global basis, used extensively for RDF, sewage sludge and industrial waste. Less well proven for mixed waste streams that are not pre-treated.	Requires pre-treatment (i.e. processing) of mixed waste streams which can add complexity and cost Community perception Opposition from environmental campaign groups Potential impacts on air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Requires a consistent supply of feedstock	Large volumes of waste High regulatory standards for EfW R&D technology investment Market development Market for created energy, or co-location with users of power or heat Landfill levy Proactive and genuine community engagement and demonstration of social license EfW policy	No facilities currently operating in Victoria, with the focus on moving grate technology or gasification. No operational facilities or known proposals in Australia. Fluidised bed technology may attract interest in circumstances where flexibility of fuel type is required, or where there are constraints on land area as their vertical configuration can result in less land-take than other combustion technologies.

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Combustion, rotary kiln: *Waste is combusted within a cylindrical kiln which is rotated or oscillated – this mechanical action moves the waste through the kiln driving combustion. Heat from combustion raises steam in a boiler which can be used to generate power. Waste is typically combusted at temperatures of between 800 to 1,500 °C.*	Residual mixed waste from MSW and C&I sources Outputs: Power and/or heat Bottom Ash Recovered metals APCr	Rotary kiln systems are well proven at a smaller scale (>100 ktpa) internationally. It is rarely used for the treatment of MSW or other large volume waste streams.	Community perception Opposition from environmental campaign groups Potential impacts on air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Requires a consistent supply of feedstock	Small to medium volumes to waste Local treatment solution High regulatory standards for EfW R&D technology investment Market development Market for created energy, or co-location with users of power or heat Landfill levy Proactive and genuine community engagement and demonstration of social license EfW policy	No rotary kiln combustion facilities in Australia. May find suitable applications in more rural areas but current focus in Victoria is on combustion technologies that can handle larger volumes of waste and offer better economies of scale.

Technology / system	**Target waste / material**	**Maturity**	**Barriers**	**Enablers**	**Current Victorian context and direction of travel**
Gasification: *partial combustion in the presence of limited air/oxygen leading to production of syngas at temperature range of 750 to 1,100°C.* *Different types of grate including fixed grate, rotary kiln and fluidised bed.*	Single source feedstock or RDF derived from MSW/C&I mixed waste that is homogenised and uniformly sized. Outputs: Syngas Char APCr Bottom Ash	Commercial facilities in Europe, North America and Japan. Relatively un-proven on mixed wastes that have not been pre-treated. While gasification technologies exist in Australia, there are yet to be any waste gasification facilities with the exception of the failed Solid Waste and Energy Recycling Facility in NSW.	Community perception: particularly with previous NSW plant failure Air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Mixed wastes require pre-treatment	High regulatory standards for EfW R&D technology investment Market development Market for created energy Creation of fuels EfW policy	Gasification opportunities are starting to be explored across Australia. Recovered Energy Australia in 2018 put forward a proposal for a $100m gasification plant in Laverton North, located in Melbourne's West 25km from the Melbourne Airport, to process up to 200,000 tonnes of residual household waste which is currently sent to landfill. It is currently under assessment by the Victorian EPA and Wyndham City Council. New Energy and the Town of Port Hedland signed a 20-year contract in 2016 to develop the first EfW facility in Western Australia. This facility is proposed to be a gasification plant and has a capacity to treat about 40,000tonnes of residential and commercial waste per annum. The renewable energy produced from the facility will be supplied back to the Council via the Northwest interconnecting power grid. The driver for the project is that the mining industry is facing a down turn due to

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Pyrolysis: *waste thermally degrades in the absence of oxygen, to produce syngas, char and/or oil depending on the process configuration and feedstock. The syngas can be combusted to generate energy, and the char and oil can also potentially be used as fuels or feedstock for other products. Reaction temperatures are typically between 300-850°C.* *Multiple types of grate available including fixed grate, rotary kiln and fluidised bed.*	Single source feedstock or RDF derived from MSW/C&I mixed waste that is homogenised and uniformly sized. Outputs: Syngas Char APCr Bottom Ash	Limited maturity. Largely unproven on mixed wastes such as un-treated residual MSW.	Community perception: particularly with previous NSW plant failure Air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Mixed wastes require pre-treatment	High regulatory standards for EfW R&D technology investment Market development Market for created energy Creation of fuels EfW policy	the environmental concerns. New Energy believes the diversion of waste from landfill to recover energy and return from renewables to the Council and industry will set a model for sustainability.[17] One notable failure is the Solid Waste and Energy Recycling Facility (SWERF) in Wollongong, NSW. This plant was based around a steam reforming gasifier technology which processed mixed municipal waste. Pyrolysis technology in Australia has largely focused on tyre waste.

[17] NewEnergy, 2016, *New Energy and Town of Port Hedland sign 20 year Waste and Renewable*, available at: http://www.newenergycorp.com.au/news-and-media/news/full/new-energy-and-town-of-port-hedland-sign-20-year-waste-and-renewable-power-services-agreement

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Gasification/pyrolysis (specifically of tyres): *the thermochemical degradation of the organic components of tyres in the complete absence of any reactive gases such as air or oxygen (pyrolysis) or partial presence of reactive gases (gasification). Breakdown of the rubber within the tyres typically occurs within a temperature range of around 400 to 1200°C, either at atmospheric pressure or within a vacuum.*	Tyres Outputs: Char/carbon black Sygnas Steel Oil Sygnas	Limited: some demonstration plants operate in Australia, however no plants operating continuously at a commercial scale. Some developing examples internationally including US, Germany, Korea, Japan.	Community perception: particularly with previous NSW plant failure Air quality and emissions Land use planning: site needs to be quite large to achieve good economies of scale Market challenges: stockpiling of tyres Market challenges: limited markets Challenges regarding product quality and specifications Mining tyres often problematic If tyres are not shredded, pre-treatment is often required	High regulatory standards for EfW R&D: technology investment Market development Market for created energy Policy: enforce higher standards for stockpiling / tyre storage EfW policy Tyre stockpile concerns (fire and pathogen risk)	Few commercial scale facilities operating in Australia but developing interest in new proposals and pilot scale facilities including the following organisations/proponents: Pearl Global (pilot plant ramping up to commercial scale in Queensland) Greentec Southern/Northern Oil Green Distillation Technologies

A3.5 Reprocessing and remanufacturing

Table 6 reprocessing and manufacturing processes, barriers, enablers and Victorian context.

Table 6: Reprocessing and remanufacturing processes for specific material streams

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
Plastics reprocessing	Plastics	Well established: but only small-scale existing facilities in Victoria.	Safety: fire risks Market demand Commercial collection Contamination due to mixed nature of plastics Competition from new packaging types	Creation of infrastructure: i.e. networks or reuse centres Market development: larger end markets to reduce exports Trade agreements	New $20m plastics recycling plant opened in Somerton, Victoria in June 2019 to reduce reliance on export markets since recent restrictions. Replas, GT Recycling and Integrated Recycling continuing to manufacture outdoor furniture, bollards, bins, pipes, fencing, railway sleepers etc. on a small-medium scale. Recyclers have indicated they have the capacity to handle double the current volumes if end markets could be assured. However, there is little demand for recycled plastic products in Australia, resulting in export for further processing. SKM recycling plant fire in July 2017.
Concrete and brick recycling	Aggregates, masonry and soils	Well established: multiple plants in operation in Victoria.	Market demand Contamination from pyrrhotite and asbestos No refinement or energy recovery opportunities Air quality Odour	Land use planning: concrete & brick mobile site could share land with MRF Market: demand for end products Infrastructure Development: expand C&D reprocessing facilities Creation of infrastructure: i.e. networks or reuse centres	New $20m glass and asphalt recycling centre in Laverton North in May 2019, operated by Alex Fraser Group. C&D waste avoidance, reuse and remanufacturing is a maturing market. Increasing focus on resource-to-road applications together with other waste streams.

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
				Government incentivisation	
Paper and card processing	Paper and card	Well established: multiple plants in operation in Victoria.	Contamination from glass fines and organics Commodity price fluctuations Product quality	Cogeneration infrastructure to reduce on-site energy consumption	The market for recycled paper and cardboard is mature in Australia and the rest of the world. Average prices of mixed paper scrap fell from $124 per tonne to $0 per tonne between early 2017 and February 2018, impacting export opportunities[18]
Glass fines beneficiation	Glass	Established: small number of large commercial facilities in Australia.	Awareness and education Air quality: dust emissions Competition with low-cost glass imports Trend away from glass packaging to plastics Recycled product quality Conventional glass furnace safety issues	Creation of infrastructure: i.e. networks or reuse centres Market development: alternative uses for glass recyclables domestically	Domestic remanufacturing processes will remain essential as there is no export of glass cullet from Australia for recycling. The market is mature but continues to face significant barriers. More than 300,000 tonnes of glass fines are currently stockpiled in Metropolitan Melbourne.[19] The Owens Illinois glass plant in Spotswood remains as the only major glass reprocessor in Victoria.
Metals recycling	Ferrous metals Non-ferrous metals	Established: medium-scale for ferrous metals and small-scale for non-ferrous metals	Manual and mechanical processing durations Low output levels Recycled product quality	Market development to reduce export and increase local remanufacturing Promotion of product quality	The processing of ferrous metal scraps is a mature market which struggles due to the high cost of manual labour. Local refining or remanufacture of non-ferrous scrap metals is small

[18] Packaging Covenant, 2018, *Market Impact Assessment Report Chinese Import Restrictions for Packaging In Australia*, available at: https://www.packagingcovenant.org.au/documents/item/1224

[19] Sustainability Victoria, 2018, *Statewide waste and resource recovery infrastructure plan*, available at: https://www.sustainability.vic.gov.au/-/media/SV/Publications/About-us/What-we-do/Strategy-and-planning/SWRRIP-2018/SWRRIP-2018.pdf

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
					This industry has significantly declined in recent decades, resulting in Australia exporting most of its non-ferrous scrap.
E-recycling	E-waste	Small establishments: evolving sector and technologies. Approximately 14 reprocessors operating in Melbourne.	Market challenges Lack of awareness	Policy change: Victoria e-waste banned from landfills Support industry Creation of infrastructure: i.e. networks or reuse centres	In July 2019, the Victorian Government implemented a ban on e-waste from landfills and launched an educational video 'take your e-waste to a better place' to support the ban, investing $16.5 million to upgrade e-waste collection and storage facilities across the state. The Battery Stewardship Council was established nationally by the Queensland Government with industry, yet solar photovoltaics still require further consideration.
Mechanical recovery of rubber	Tyres and rubber	Well established: proven technology with several plants around Australia including in Victoria.	Safety: fire risks Market challenges: stockpiling of tyres Market challenges: limited markets	Market development R&D investment Policy: enforce higher standards for stockpiling / tyre storage	Illegal tyre dump in Numurkah, Victoria shut down in late 2018 after concerns of repeat fires. The tyres were taken by Melbourne-based Tyrecycle.
Timber shredding	Wood and timber	Well established: Several plants around Victoria and Australia.	End-market challenges High operational and maintenance costs Contamination Competition from cheap virgin timber products	Market development	Whilst timber waste reprocessing technologies are well-established, commercial viability greatly limits the scalability of facilities. Mulch provides some growth opportunities, but this mature market is susceptible to the cyclical nature of large civil construction projects.

Technology / system	Target waste / material	Maturity	Barriers	Enablers	Current Victorian context and direction of travel
			Consistent material stream		D&R Henderson, Australian New Energy and Bark King are strong performers in the timber recycling space in Victoria.

A3.6 Emerging waste management technologies

Table 7 summarises emerging waste management technologies, barriers, enablers and Victorian context.

Table 7: Emerging technologies, services and initiatives

Technology / service	Target waste / material	Overview	Examples
Smart bins	Multiple: can be applied to any waste stream Typically applied to MSW kerbside collections	Reimagining the pre-programmed kerbside waste collection practice through the live tracking of bin capacities to optimise collection frequencies and routes. Fewer waste collection trucks are utilised which reduces vehicle emissions, operational costs and road congestion. Smart bins are solar-powered and contain sensors to allow for the tracking of data and internal compactors which can increase bin capacity by 6-8 times.[20] One such smart bin can sort waste into recycling categories using sensors, image recognition and artificial intelligence. Melbourne trialled BigBelly solar bins in 2015 but chose to adopt Ecube smart bins on a wide scale in early 2018 after a trial in late 2017.[21,22] Scalability is possible due to management systems provided by technology providers.	BigBelly Solar, Ecube, Underground bins (Cascais, Portugal), Bin.E

[20] Solar Bins Australia, 2019, *BigBelly Solar Compactors*, available at: https://solarbins.com.au/features/big-belly-solar-bin/
[21] City of Melbourne, 2019, *New bin sensors to reduce waste overflow*, available at: https://www.melbourne.vic.gov.au/news-and-media/Pages/Newbinsensorstoreducewasteoverflow.aspx
[22] Ecube Labs, 2019, *Melbourne Combats Littering with Ecube's Smart Bins*, available at: https://www.ecubelabs.com/melbourne-combats-littering-with-ecubes-smart-bins/

Technology / service	Target waste / material	Overview	Examples
Intelligent sorting machines	Multiple: can be applied to any waste stream Typically applied to MSW and C&I waste at sorting and recycling facilities	Machines which utilise robotic or optical sorters to pick and sort up to 65 items per minute from a mixed waste stream into individual streams.[23] These machines use machine-learning to improve productivity and adaptation to new materials. Unlike humans, these machines can work 24 hours day without needing a break, greatly improving the efficiency of waste sorting and processing. These machines can be retrofitted into existing facilities, allowing for easy uptake on a wide scale.	Max-AI
Waterway cleaning machines	Plastics Paper and card	Machine-learning robots which can autonomously clear waterways of plastic pollution. These machines are solar-powered, propel themselves and can navigate complex obstacles, using an array of sensors, cameras and GPS, a conveyor and compactor to manage waste. This technology focused primarily on plastic waste but could be adapted to suit paper and card.	Yindi Blue
Intelligent waste management systems / IoT	Multiple: can be applied to any waste stream Applied to MSW, C&I and C&D waste	Although smart cities have been a talking point for the past ten years, smart waste management solutions, enabled by internet of things (IoT) sensors and 4G / 5G mobile technology are still emerging technologies. The most common technology in this realm is based on the use of in-truck sensors and cameras, as well as cloud-based analytic systems to track, analyse and report on waste. Customers (often businesses and governments) and haulers are linked to optimise schedules and to monitor the fullness, content and location of their bins and dumpsters, with incentives in place for service providers to save their customers money. Similar technologies have also been used in the hospitality industry to minimise food waste, reduce over-production and ultimately save money. Data security and privacy issues of real-time data remain as issues today, resulting in slow R&D. Subsequently, the business case for IoT ecosystems continues to struggle.	Enovo, Winnow, Rubicon, Compology, IBM

[23] Recycling Today, 2018, *The evolution of Max-AI*, available at: https://www.recyclingtoday.com/article/the-evolution-of-max-ai/

Technology / service	Target waste / material	Overview	Examples
On-demand waste pickup platforms	Multiple: can be applied to any waste stream Typically applied to C&D waste	Through a mobile app, construction and demolition sites can order waste collection and appropriate skip bins to be delivered and picked up, allowing contractors to order waste services on demand, saving valuable site space. Trials of the technology originated in Austria and are now moving into German, UK and French markets.[24] This may be disruptive to the Australian construction industry – an industry that is generally considered to lack innovation when compared to others.[25] Hence, whilst this technology is promising, adoption in the Victorian context may be difficult to achieve.	Wastebox.biz
Materials databases	Multiple: can be applied to all material types	The goal of the key player in this space is to be the cadastre of materials – eliminating 100% of waste by providing all the materials within buildings a documented identity as well as a value. In this way, we can better understand where materials are, in which buildings and when they will be taken out, leaving the option to reuse always open. In terms of finance, every building becomes a bank of materials, because the technology monitors the material value of the building throughout time. This technology is best-suited to European ecosystems, with the scalability of this technology in an Australian context potentially being difficult due to our expansive land.	Madaster
Circular economy platforms	Multiple: can be applied to all material types Can be applied to all industry sectors	Building upon traditional reuse centres, online platforms for the listing of surplus items are an emerging space. These stewardships are effectively circular economy enablers which bring together specialist knowledge, software tools and networks to help organisations and individuals reduce environmental impacts, improve social engagement and create economic benefit. Such platforms have been successful in the C&D space in finding reuse of materials and at the household level, primarily with furniture and clothing. These efforts focus at the 'reduction' and 'reuse' levels of the waste hierarchy. Great levels of behavioural change would be necessary to increase the use of such stewardship programs in Australia.[26]	Loop Hub, Worn Again, Blocktexx

[24] Recovery Worldwide, 2018, *New company called Wastebox Germany introduced innovative business model at the NordBau*, available at: https://www.recovery-worldwide.com/en/news/new-company-called-wastebox-germany-introduced-innovative-business-model-at-the-nordbau_3231067.html
[25] McKinsey & Company, 2017, *Digital Australia: Seizing opportunities from the Fourth Industrial Revolution*, available at: https://www.mckinsey.com/featured-insights/asia-pacific/digital-australia-seizing-opportunity-from-the-fourth-industrial-revolution

Technology / service	Target waste / material	Overview	Examples
E-waste ATMs	E-waste	These kiosks provide a safe, convenient and easy way for people to trade in their used electronic devices for a financial reward. Online platforms allow customers to obtain price estimates for their devices and experience their kiosks virtually before traveling to their closest kiosk. Whilst this process is simple, the sale of stolen devices remains an issue, with approximately one out of every 1,500 devices exchanged reported as stolen.[27] Headshot photos, signatures for authorisation and thumbprint scanners work to reduce the likelihood of stolen goods being exchanged. This service is like that of a CDS scheme which has the potential for wide-scale rollouts.	EcoATM
Specialised e-waste salvaging	E-waste	Although the idea of managing the commissioning, disposal and remarketing of IT equipment has been around since the early 2000s, recent increases in e-waste globally have prompted further developments in this space.[28] Rather than just focusing on reuse, new processes now focus on the use of specialised microorganisms to purify the metals from e-waste, to salvage high-value metals such as gold, silver and palladium. Lithium-ion battery recycling is becoming more prevalent, with powder containing critical battery materials being generated from spent batteries for export and refining. Partnerships with Mint Innovation and Lithium Australia are progressing this space.[29] [30]	Remarkit, Envirostream

[27] Today Show, 2013, *ecoATM Media Coverage Report*, available at: https://www.tacoma.uw.edu/sites/default/files/sections/CenterforLeadershipandSocialResponsibility/Media%20Coverage%20Report.pdf
[28] Remarkit, 2019, *About Us*, available at: https://shop.remarkit.co.nz/pages/about-us
[29] Business Wire, 2018, *Mint Innovation to Upscale before Global Leap*, available at: https://www.businesswire.com/news/home/20180529005447/en/Mint-Innovation-Upscale-Global-Leap
[30] Small Caps, 2019, *Lithium Australia surges into lithium-ion battery recycling with Envirostream partnership*, available at: https://smallcaps.com.au/lithium-australia-lithium-ion-battery-recycling-envirostream-partnership/

Technology / service	Target waste / material	Overview	Examples
Resource recovery to road construction	Aggregates, masonry and soils Glass Tyres and rubber	Resource recovery in road construction is being explored as a potential high-volume outlet for recovered material which can be directly influenced by government procurement. Successful pilot and full-scale projects include: recovered asphalt, glass sand and crushed concrete replacing virgin aggregate material in road base, asphalt or concrete, crumb rubber sprayed seals in substitution of virgin materials in road surfacing, and the incorporation of toner from spent printer cartridges, post-consumer plastics and glass fines into road-surfacing products. The key challenge to realising this opportunity at scale is demonstrating that construction incorporating recycled material performs adequately and does not adversely impact the lifetime of major infrastructure. Risk allocation and contractual arrangements can be barriers to adoption of recycled materials. Once materials are accepted for use, incorporation into construction specifications by local or state authorities can increase industry confidence and awareness of recycled products and support greater uptake.	Widespread applications
Non-toxic pulp remanufacturing	Paper and card	Involves the use of a unique enzymatic process to recycle the pulp of waste straw from rice and wheat harvests without the addition of harsh chemicals to create a sustainable paper. Moulds can also be used to form and dry the pulp using non-toxic binders into bricks and boards for architectural applications. The commercial viability of this technology has been proven by one Taiwan-based company, with upscaling dependent on what additional waste streams they can process and manufacture into new products.[31]	YFYJupiter
Fly ash carbonation	Fly ash Typically obtained from hazardous waste landfill	Fly ash carbonation is based on ‘accelerated carbon technology’ which uses carbon dioxide to carbonate and convert some components of fly ash from waste incineration (typically disposed of in hazardous waste landfill) into a lightweight construction aggregate. The process claims to capture carbon dioxide, divert waste from landfill and replace virgin aggregates in construction.[32] There is still some concern regarding dioxins and other contaminants within the aggregate product products and potential pathways for inhalation through dust created when handling, crushing, drilling and disposing of blocks and construction materials manufactured from this process.	Carbon8

[31] YFYJupiter, 2019, *NPULP*, available at: http://www.yfyjupiter.com/about-us/npulp/
[32] University of Greenwich, 2014, *Treating waste with carbon dioxide*, available at: https://impact.ref.ac.uk/casestudies/CaseStudy.aspx?Id=3914

Technology / service	Target waste / material	Overview	Examples
Milk-fibre fabrics	Organics: food	Involves the processing of non-food grade milk to create high-end and environmentally-friendly fibres. Liquid milk is dehydrated to extract milk proteins which are further dissolved into fibres using chemicals. These are then spun by machines into a substance that becomes yarn and subsequently, a fabric. In addition to textiles, old milk can be reprocessed into cosmetic products, toilet paper, wipes and spunlaces which require materials that dissolve when they meet water.	Qmilk
Coffee ground recycling	Organics: food	These initiatives help to divert coffee grounds from landfill through reprocessing them into new products. Bin infrastructure and a pick-up service is provided as part of a subscription-based service for cafes, coffee roasters and non-hospitality businesses. The waste is then transported to community gardens, home gardeners or local plastics recyclers who put the waste to positive use, such as compost, mulch or food for worms.	Reground
Insect-based waste management	Organics: food	This system utilises black solider fly larvae to break down food organic scraps, with the larvae then being sold off as livestock feed to farmers. Commercially-speaking, large self-contained capsules are provided to purchasers which are installed at sites that generate high levels of food waste such as farms, public transport hubs, hotels and hospitals. Within the capsules, a robot assists the process, helping to feed and weigh the larvae as they grow.	Goterra

Appendix B

MCA assumptions and scoring

B1.1 Criteria 1: Circularity Index definitions and calculation

The Circularity Index assigns a rating for each category of the waste hierarchy, which is multiplied by the fraction of total material tonnage destined for that fate. The resulting number is the Circularity Index, with an example shown in Table 1.

The score assigned to each category of the waste hierarchy reflects the contribution to maintaining value and circulating materials. Disposal has a score of zero because materials are lost from circulation and no value is recovered. If all material is recycled in closed loop / high value recycling, this would give a total circularity score of 100%. Avoidance and reuse outcomes have a rating greater than one because they are preferable to recycling under the waste hierarchy. The technical maximum circularity score is 200%, if all waste were avoided. However, in practice it is not possible to avoid all waste.

Table 1: Circularity index scoring example

Waste hierarch category	**Rating**	**Waste tonnage fraction**	**Product**
Avoidance / reduction	2	10%	0.2
Reuse	1.5	20%	0.15
Closed loop / high value recycling	1	20%	0.2
Cascading / low value recycling	0.75	20%	0.15
Recovery of energy	0.25	20%	0.05
Disposal	0	20%	0
		Circularity score	*75%*

The distinction between high-value recycling and low-value recycling is not typically shown in waste hierarchy diagrams. However, it is important from a circular economy perspective. High-value recycling (also referred to as closed loop recycling) can typically be performed multiple times and keeps materials in circulation in the same or similar products. In contrast, low-value recycling (also referred to as cascading recycling, or secondary / tertiary recycling) degrades material value, and can often only be performed once. Low-value recycling pathways extend the useful life of material, but value is lost over time.

Table 2 details examples of closed loop and cascading recycling.

Table 2: Examples of high and low value recycling

Closed loop / high value recycling	**Cascading / low value recycling**
Textiles into new fibre or textile	Textiles into rags, carpet underlay or insulation
Glass into new containers	Glass into bedding sand, concrete or asphalt
Plastic into new packaging	Plastic into mass-plastic street furniture
Plastics into textiles	Plastics into asphalt
Paper pulp into cardboard boxes	Paper pulp into kitty litter or toilet paper
Organics into compost, mulch or soil	Organics into contaminated compost-like product (limited allowable uses)
Organics into energy and soil conditions (AD)	
Organics into animal feed	
Organics into chemicals or proteins	
Metals into new metal products	

Aggregate and masonry materials were excluded from the Circularity Index because they are a large waste stream by weight with a high existing recovery rate which does not change between scenarios. The existing, stable market outlet for recovered masonry and aggregate is not impacted by recent shocks to the recycling industry, nor by the policy and infrastructure changes proposed in each scenario. Inclusion of this material would mask the impact of each scenario on relevant waste streams which are currently facing challenges.

Specific modelling assumptions and data sources for each of the modelled material streams are presented in the following sections.

B1.2 Energy from Waste

Relevant scenarios: *FOGO FOMO, Closing the Floodgates, High Energy*

For scenarios including high Energy from Waste development, 80% of combustible residual waste was assumed to be diverted to an Energy from Waste process.

This is based on population distribution data from the latest Victoria in Future population dataset published by DELWP and uses the following assumptions:

- Energy from Waste infrastructure investment must be underpinned by significant MSW feedstock contracts to provide investment certainty.
- Population coverage by facility waste contracts is used as a proxy for waste tonnage captured form both MSW and C&I streams.
- 75% of the Victorian population resides in the Metropolitan area.
- No regional population centre is large enough to support a dedicated commercial EfW facility. However, a facility could be sited outside the metropolitan area, but receive waste from both metropolitan and local regional councils. The Australian Paper proposal in the Latrobe Valley is an example of this situation.
- Ballarat, Geelong and part of Gippsland are assumed to have access to an EfW, shared with some metropolitan councils. This brings the EfW population coverage rate to 80%.

B1.3 Container deposit scheme

Relevant scenarios: *Circular Stewards, Packaging Crackdown*

Scenarios including a CDS draw on South Australian data and a summary report into Best Practice International Packaging Approaches, prepared for the Australian Environmental Protection and Heritage Council in 2011, when selecting recovery rates for eligible containers. The 2011 report also provided South Australian estimates of the proportion of CDS eligible material for each material type. The CDS was assumed to capture material currently disposed to the residual stream, as well as material currently captured for comingled recycling.

All material recovered through the CDS was assumed to have a viable market outlet due to improved quality, in agreement with an early performance assessment of the NSW Container for Change scheme, published in 2018[1] and reflecting market conditions following China's import restrictions.

Table 3. Container deposit scheme effectiveness[2,3]

	SA	**Germany –also has refill system**	**California 2010**	**British Colombia (CA)**	**Denmark**
Overall	80% - 76.5%			80%	
Glass	86% - 80%		85%	93%	83-93%
Aluminium	89% - 83%	99%-96%	94%	83%	83-84%
PET	78% - 68%	97% - 98.5%	68%	78%	88-93%
HDPE	64% - 56		92%		
Liquid paperboard	67% - 49%			60%	

[1] Boomerang Alliance, 2018, *Return and Earn – Has it Worked?,* available at: https://d3n8a8pro7vhmx.cloudfront.net/boomerangalliance/pages/3728/attachments/original/1543818942/Boomerang_Report_dec_2018-final2_small.pdf?1543818942

[2] National Environment Protection Council, 2011, *Best Practice International Packaging Approaches*, available at: http://www.nepc.gov.au/system/files/consultations/c299407e-3cdf-8fd4-d94d-6181f096abc8/files/att-b-appendix-b-best-practice-intl-packaging-approaches.pdf

[3] South Australia Environment Protection Authority, 2019, *Container Deposits*, available at: https://www.epa.sa.gov.au/environmental_info/container_deposit

B1.4 Recycling exports versus domestic processing

The distribution of recyclable material to high value recycling, low value recycling and lower-order outlets under each scenario was a key topic for the Circularity Index calculation. Key data sources used were:

- Victorian Recovered Resources Market Bulletins for Apr-May, June and July, published by Sustainability Victoria as part of the Victorian Market Intelligence Pilot Project.[4,5,6]
- Infrastructure Victoria's *Victorian waste flows report 2019* prepared by Blue Environment [7]
- 2018-19 National Australian recycling export figures and state-based distribution prepared for the Business Council of Sustainable Development Australia.
- Victoria Recycling Industry survey data 2017-18 (this underpins the BEG waste flow modelling).[8]
- Australian Plastics Recycling Survey report 2017-18.[9]

The tonnage estimates for exported and domestically recovered material sometimes varied between these sources by over 100%, due to the generally low quality of Australian waste data. Recent analysis of export market trends and value identifies a significantly lower total tonnage of recyclable material that the flows reported in the Victorian Recycling Industry Survey and presented in Blue Environment material flow modelling. It is unclear whether the balance of material is reprocessed domestically through stable market channels or received for recycling and stockpiled. Material categories and descriptions give limited indication of material quality, which the key factor for market outlets.

Estimates were reconciled where possible to achieve maximum confidence on the selected material distribution. However, total waste flows in the Infrastructure

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[4] Waste Management and Resource Recovery Association of Australia & Sustainability Victoria, 2019, *Recovered Resources Market Bulletin April-May 2019*, available at: https://www.sustainability.vic.gov.au/Business/Investment-facilitation/Recovered-resources-market-bulletin

[5] Waste Management and Resource Recovery Association of Australia & Sustainability Victoria, 2019, *Recovered Resources Market Bulletin June 2019*, available at: https://www.sustainability.vic.gov.au/Business/Investment-facilitation/Recovered-resources-market-bulletin

[6] Waste Management and Resource Recovery Association of Australia & Sustainability Victoria, 2019, *Recovered Resources Market Bulletin July 2019*, available at: https://www.sustainability.vic.gov.au/Business/Investment-facilitation/Recovered-resources-market-bulletin

[7] Blue Environment Group for Infrastructure Victoria, 2019, *Victoria's waste flow report 2019*.

[8] Sustainability Victoria, 2019, *Victorian Recycling Industry Annual Report 2017-18*, available at: https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Victorian-Recycling-Industry-Annual-Report

[9] Department of Energy and Environment, 2019, *2017-18 Australian Plastics Recycling Survey National Report*, available at: https://www.environment.gov.au/system/files/resources/3f275bb3-218f-4a3d-ae1d-424ff4cc52cd/files/australian-plastics-recycling-survey-report-2017-18.pdf

Victoria's Waste Data Flows Report 2019 were retained for consistency, with fate distributions applied from other sources where required.

B1.5 Glass

Supply of packaging glass in Australia will always exceed domestic reprocessing demand due to import of packaging products. 100% high value recycling is not feasible, so some lower value recycling (into infrastructure) or disposal is needed in every scenario.

- Infrastructure Victoria's Waste Flows Report 2019, developed by Blue Environment, reports a total of 263,686 tpa of recovered glass.
- Victorian Recovered Resources Market Bulletins 2019 report 150,000 tpa glass recovered through from kerbside collections.
- The balance of these tonnages (approx. 113,600 tpa) is assumed to be predominantly C&I glass, collected through either source separated streams (e.g. bars and hospitality businesses) or comingled recycling. This split appears reasonable.

The Blue Environment waste flow modelling report draws on the Victorian Recovered Resources Market Bulletins and reports that:

- Approximately 30% of collected glass is currently lost as fines during sorting.
- Victoria's only glass manufacturer, Owen-Illinois currently uses approximately 37% recycled cullet, or 66,600 tpa. This is approximately 25% of the current tonnage received for recycling.

Owen-Illinois could increase consumption to 50-60%, or higher, where adequate quality is available at an acceptable price-point. Table 4.

Table 4 presents the values adopted for each scenario.

Scenarios which maintain current collection formats, with some investment in sorting improvements are modelled at a modest increase in high-value glass recycling, to 30% of to the current stream. Scenarios which generate a high-quality source-separated glass steam through a CDS, or separate collection are modelled using 50%-60% diversion to high-value recycling, depending on the range of glass products captured by separate collection. This reflects very high uptake by Owen-Illinois as suggested in the Victorian Recovered Resources Market Bulletin.

Scenarios with no change to collection formats are assumed to maintain the current 30% sorting loss rate of glass fines, destined for disposal. This loss rate is reduced in scenarios with separate collection for glass through a CDS or alternative kerbside collections. The balance of recovered glass is directed to low-value recycling in infrastructure.

The adoption values for glass flows to high- and low-value recycling, as well as disposal, is shown in Table 4.

Table 4: Summary of recovered glass fates assumed in Circularity Index modelling

Scenario	**Packaging glass fate**	**High-value recycling**	**Low-value recycling**	**Disposal**
Out of Sorts	Like current, some sorting improvements	30%	40%	30%
FOGO FOMO	Like current, some sorting improvements	30%	40%	30%
Closing the Floodgates	Separate collection of glass	60%	30%	10%
Circular Stewards	CDS (beverage containers only)	50%	30%	20%
Packaging Crackdown	CDS including all glass packaging	60%	30%	10%
High Energy	Like current, some sorting improvements	30%	40%	30%

Greater diversion of glass from the current residual stream was also considered where there is a financial driver for behaviour change. Modelling assumptions and rationale are shown in Table 5.

Table 5: Circularity Index modelling assumptions for diversion of glass from current residual streams

Scenario	Glass diversion from residual stream	Assumptions	Rationale
Circular Stewards	CDS for beverage containers	60% eligibility and 80% capture rate of eligible MSW glass.	South Australian CDS capture rates and eligibility figures. C&I streams with high eligible containers (e.g. bars) expected to already by recycling. CDS on beverage containers unlikely to drive business behaviour change.
Packaging Crackdown	CDS for all glass packaging	90% eligibility and 80% capture rate of eligible MSW glass. 50% eligibility and 60% capture rate of eligible C&I glass.	South Australian CDS capture rates. C&I streams are expected to contain more ineligible glass (e.g. windscreens, tableware) and the CDS will not motivate separation for all businesses.
High Energy	PAYT charging and glass not desirable for EfW	90% recyclable and 80% capture rate of eligible MSW glass. 50% recyclable and 60% capture rate of eligible C&I glass.	Similar assumed diversion to Packaging Crackdown (S5). Diversion route most likely to comingled recycling. Other possibilities include glass drop-off point or sorting prior to EfW – not explored in detail. Sorting quality and market challenges remain – additional collected tonnage allocated to low-value recycling.

B1.6 Paper and Card (PAC)

The paper and card material data quality may be limited in the categories reported in the Infrastructure Victoria's 2019 waste flow modelling and there is some uncertainty in terms of tonnage and material descriptions which impacts assumptions about likely material fate. In particular, the waste flow modelling report indicates that the "Mixed paper and cardboard' category includes material from kerbside collections as well as separately collected C&I cardboard. This leaves a 794,000 tpa "Other paper and cardboard" category without any clear source or quality descriptors. The source data, from the Victorian Recycling Industry Survey, was compared against several other sources to arrive at assumed material source and fate assumptions for the scenario modelling. Due to the limitations of available datasets, the waste flow modelling also does not appear to account for current severe market challenges and stockpiling practices due to closure of export markets for low-quality recovered paper and card. A 95% actual recycling rate is assumed for all paper and card received for recycling. The paper and card assigned to landfill is based on known landfill tonnages and composition for MSW, C&I and C&D stream, and does not include stockpiling of currently unsaleable mixed paper and card.

B1.6.1 Reconciliation of data sources

Waste flow modelling data derived from the Victorian Recycling Industry Survey indicates that approximately 1.48 million tonnes of paper and card is received for recycling in Victoria each year.

Australian recyclate export estimates suggest that 44% of Australia's national paper and card exports, or approximately 500,000 tpa, leave from Victoria each year. This is supported by Victorian Recycling Industry Market Bulletin estimates, which place total paper and card exports from Victoria at 550,000 tpa.[10]

This suggests that around 1 million tonnes of paper and card is processed in Victoria each year. Domestic reprocessors typically select higher quality material, including separated office paper (173,752 tpa identified in Victoria recycling industry data) and newsprint / magazines (173,864 tpa identified in Victoria recycling industry data). VISY processes approximately 120,000 tpa of mixed kerbside paper and card through its vertically integrated MRF and paper mill operations.

Based on these figures, the balance of domestic reprocessing is approximately 500,000 tpa and is assumed to be predominantly source-separated C&I cardboard. This tonnage figure is very similar to the quantity reported by the Victorian Recycling Industry Survey as 'cardboard / packaging paper' and labelled as 'mixed paper and cardboard' in Infrastructure Victoria's 2019 waste flow modelling by Blue Environment.

[10] Waste Management and Resource Recovery Association of Australia & Sustainability Victoria, 2019, *Recovered Resources Market Bulletin July 2019*, available at: https://www.sustainability.vic.gov.au/Business/Investment-facilitation/Recovered-resources-market-bulletin

B1.6.2 Modelling assumptions

Based on this comparison of data sources and commentary on material quality and fates, the following assumptions were adopted for the scenario modelling Circularity Index modelling assumptions, presented in Table 6.

Table 6: Summary of recovered paper and card flows assumed in Circularity Index modelling

Material Category (as used in Infrastructure Victoria's 2019 waste flow modelling)	**Tonnage reported as received for recovery (tpa)**	**Assumed sources and fates**
Mixed paper and cardboard	513,054	100% source separated C&I cardboard, currently reprocessed in Victoria. This reprocessing continues in all scenarios, despite temporary challenges due to virgin pulp price fluctuations
Office paper	173,752	100% source separated streams currently reprocessed with stable value in Victoria.
Other paper and cardboard	794,211	Includes 320,000 tpa kerbside mixed paper and card, of which 120,00 tpa has a stable outlet through VISY operations and 200,000 tpa currently has no market outlet. (Victorian Market Bulletin – July 2019) 173,864 tpa of separated newsprint / magazines currently reprocessed in Victoria with stable value. This continues in all scenarios. Balance of material (approximately 300,000 tpa) is mixed paper and card from C&I comingled sources, with low value and no current market outlet. There is approximately 500,000 tpa of low-grade paper and card from MSW and C&I sources was previously exported and is the focus of alternative fate assumptions in each scenario.

In addition, the following assumptions are drawn from Victorian Kerbside Recycling Market Bulletins:[4,6]

- Moulded fibre products (egg cartons, fruit trays) and other low-grade fibre products (kitty litter, sprayable soil stabilisers) are relatively minor applications at approximately 30,000 tpa (4% of mixed paper).
- This capacity is doubled under the *Closing the Floodgates* scenario due to deliberate investment in processing infrastructure and market support for recovered products.

Table 7 presents the modelling assumptions and rationale used to assign the fate of paper and card which is currently disposed in the residual stream (approximately 515,313 tpa) or recovered for recycling but has no current market outlet (approximately 500,000 tpa).

Table 7: Assumptions and rationale for the fate of current unsaleable and residual paper and card streams in Circularity Index modelling

Scenario	**Paper and can card in current residual stream**	**Mixed paper and card (PAC) with no current market outlet**
Out of Sorts	No change in tonnage. Disposal to landfill.	50,000 tpa recovered to saleable quality by further sorting of comingled stream. 30,000 tpa directed to low value fibre outlets. Remainder becomes residual and is ultimately landfilled.
FOGO FOMO	Some households encouraged to direct paper and card to FOGO bins (low value recycling for paper) Assume 50% capture rate of current MSW residual. Remaining residual is directed to energy recovery at 80% coverage.	Some households encouraged to direct paper and card to FOGO bins (low-value recycling for paper) Assume 50% capture rate of the 200,000 tpa kerbside PAC currently without a market. 30,000 tpa directed to low value fibre outlets. Remainder becomes residual and is directed to energy recovery.
Closing the Floodgates	No change in tonnage. Directed to energy recovery at 80% coverage.	Removal of glass contamination and investment in sorting, pulping and reprocessing infrastructure improves quality of mixed material. 90% of current mixed stream finds a high-value recycling market outlet, either domestically or overseas. Production capacity for moulded fibre products increase, doubling current output to 60,000 tpa. Processing residual to energy recovery.

Scenario	**Paper and can card in current residual stream**	**Mixed paper and card (PAC) with no current market outlet**
Circular Stewards	No change in tonnage – paper packaging not influenced by product-focuses circular initiatives. Circular Economy Policy position on energy from waste acceptance criteria does not support development of EfW capacity. Disposal to landfill.	Changes in product flows, logistics optimisation and uptake of pooled, reusable B2B packaging reduces C&I cardboard by 50%. 30,000 tpa directed to low value fibre outlets. Generation of mixed paper and card stream remains stable. Limited investment in improved sorting or reprocessing. Material without a current market largely becomes residual and is directed to landfill.
Packaging Crackdown	No change in tonnage. Disposal to landfill.	Removal of glass from the comingled collection stream improves the quality of mixed paper and card. Packaging redesign/regulation for recyclability also supports sorting and recovery. 80% of mixed paper and card finds a stable market outlet. Low-value recycling capacity roughly doubles, taking 10% of the mixed paper and card steam. This includes increased use of compostable packaging for catering/food, and recovery of compostable packaging with food waste
High Energy	5% reduction in consumption of products which generate non-recyclable PAC waste due to restrictions on recycling acceptance criteria and pay-as-you-throw charging. Remaining residual to energy recovery at 80% coverage.	30,000 tpa directed to low value fibre outlets. No investment of further sorting. Mixed paper without a viable market becomes residual and is directed to energy recovery at 80% coverage.

B1.7 Plastics

Plastics waste flow data is provided based on tonnages received for reprocessing and composition data of for mixed plastics sources from the National Plastics Recycling Survey 2017-19. This source also indicates the export and domestic recovery rates for different plastic polymers. However, there is no clear indication of how much of this material is source-separated or sorted into a clean stream and how much was previously exported as mixed plastics, which have negligible market value following international import restrictions.

The Victoria Resource Recovery Market Bulletin provides information about typical plastic sorting of kerbside material, but not similar information is available for C&I stream. It also indicates that approximately 45,600 tonnes per year of plastics are received from recovery through kerbside recycling collections. This is approximately one third of the 137,167 tpa of plastics received for recycling according to Infrastructure Victoria's *Victorian waste flows report 2019* prepared by Blue Environment. This figure is derived from the Australian Plastics Recycling Survey 2017-18.

The Australian Plastics Recycling Survey 2017-18 is the primary information source about plastic polymer sources and fate. It notes several relevant characteristics of the Victorian market:[11]

- Victoria has the highest number of plastics recyclers of any state (25 reprocessors, compared to 14 in NSW and fewer in other states)
- Reincorporation of manufacturing scrap into plastics processing is included in the waste generation and recovery rates for Victoria. Consequently, Victoria also shows a higher plastic consumption (880,900t), recyclate consumption (137,200t) and plastic recycling rate (15.6%) than other jurisdictions.
- Recycling of manufacturing scrap within plastic production processes is not threatened by current market challenges.
- National breakdowns are provided for the fate of recovered plastic polymers. Existing local reprocessing to local use and local reprocessing to export are assumed to maintain a stable market (48,010 tpa and 4,110 tpa respectively in Victoria).
- Recovered plastic sent direct to overseas is at risk from international import restrictions (85,000 tpa in Victoria.)

The Blue Environment modelling provides a breakdown of plastics received for recovery by polymer and fate based on 2017-18 data, summarised in Table 8. Current market challenges and stockpiling issues are not reflected but are assumed to predominantly affect plastic that is directly exported for processing overseas. Plastic fate under each scenario were estimated by drawing on this reported data

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[11] Australian Plastics Recycling Survey 2017-18. Prepared by Envisage Works for the Department of Environment and Energy. Available from: https://www.environment.gov.au/system/files/resources/3f275bb3-218f-4a3d-ae1d-424ff4cc52cd/files/australian-plastics-recycling-survey-report-2017-18.pdf

and considering the dominant sources and recovery pathways for different polymer types, as summarised in Table 9.

Table 8: Fate of plastics recovered for recycling, by polymer type[12]

Polymer	**Tonnes per year in Victoria**	**Local reprocess to local use**	**Local reprocess to export**	**Direct to overseas**
PET	28,561	8%	0%	91%
HDPE	40,053	30%	2%	67%
PVC	3,249	74%	2%	24%
Low-density polyethylene (LDPE)	26,150	51%	7%	42%
Polypropylene (PP)	23,122	56%	0%	44%
Polystyrene (PS)	5,987	31%	7%	62%
Other	7,408	39%	10%	51%
Mixed plastics ex MRF	2,637	0%	0%	100%

[12] Infrastructure Victoria, 2019, *Victorian waste flows report*, prepared by Blue Environment

Table 9: Summary of recovered plastics flows assumed in Circularity Index modelling

	PET (1), HDPE (2)	**LDPE (4)**	**PP (5) PVC (3), PS (6), ABS (7), Others (7)**
Dominant polymer uses and recovery routes	Recovered primarily through MSW packaging stream. PET and HDPE retain market value if well-sorted. Typical MRF operation extracts approx. 80% into single polymer bales, with remainder in mixed plastic stream.	LDPE is soft plastic. Dominant recovery route is through C&I packaging (82%), which is predominantly source-separated pallet wrap. Not recyclable through kerbside collection. REDcycle post-consumer collection accepts a high proportion of LDPE, but tonnage data is not available.	Typically recovered as mixed plastics if collected in comingled stream. Other C&I/ manufacturing scrap may generate clean streams. Very small tonnages of source separated PE or PVC. Existing domestic recovery rates: PVC 75% PP 60% PS 40% Other 50%
Out of Sorts	More extraction of PET and HDPE, reaching 90% as saleable single polymer. 10% in mixed plastics lost to landfill disposal.	Maintain high-value recycling from source-separated C&I - 80% overall capture rate and some viable export. 10% low-value recycling through REDcycle and infrastructure. Remaining 10% becomes residual.	Material previously sent direct to overseas becomes residual to disposal. Dedicated extraction and recovery of PP at some MRFs increases to 70% recovery. Plastics to infrastructure accepts 10% of other plastic polymers.

	PET (1), HDPE (2)	**LDPE (4)**	**PP (5) PVC (3), PS (6), ABS (7), Others (7)**
FOGO FOMO	Extraction of PET and HDPE, reaching 85% as saleable single polymer. 15% in mixed plastics lost to energy recovery or disposal.		Material previously sent direct to overseas becomes residual to energy recovery at 80% coverage.
Closing the Floodgates	Improved sorting and increased reprocessing raised recovery rate to 95%. 5% sorting/processing losses to energy recovery.		Investment in domestic sorting and processing capacity increases PP recovery like PVC and HDPE (95%). Other material previously sent direct to overseas becomes residual to energy recovery at 80% coverage. Plastics to infrastructure accepts 10% of other plastic polymers.
Circular Stewards	Extract of PET and HDPE, reaching 85% as saleable single polymer. 15% in mixed plastics lost to disposal.	Maintain high-value recycling from source-separated C&I - 80% overall capture rate and some viable export. High uptake of REDcycle drop-off and some use in infrastructure, reaching 15% low value recycling.	Material previously sent direct to overseas becomes residual to disposal. Leasing/sharing/repair models of consumptions avoid 10% of plastic in residual and extend the useful life a further 10% through greater reuse of durable plastic items (e.g. toys, containers). PVC product stewardship become mandatory, increasing recovery rate to 80%, while 10% of PVC use is phased out.

	PET (1), HDPE (2)	**LDPE (4)**	**PP (5) PVC (3), PS (6), ABS (7), Others (7)**
Packaging Crackdown	Sorting investment and reduction is contamination/ difficult-to-recycle items in the packaging stream allows MRFs to increase extraction of PET and HDPE to 90%. 10% in mixed plastics lost to landfill disposal.	10% reduction is use due to pressure shift towards readily recyclable packaging. Maintain high-value recycling from source-separated C&I - 80% overall capture rate and some viable export. Remaining 10% low-value recycling through REDcycle and infrastructure.	Material previously sent direct to overseas becomes residual to disposal. PVC eliminated from packaging. Plastics to infrastructure accepts 10% of other plastic polymers. Single use plastic ban results in 1% reducing in plastic disposal to the residual stream and 1% increase in reuse. This is roughly double the tonnage of single use plastic avoided in major supermarkets in 2018/19, following plastic bag bans[13]
High Energy	Extraction of PET and HDPE, reaching 85% as saleable single polymer. 15% in mixed plastics lost to energy recovery.	Maintain high-value recycling from source-separated C&I - 80% overall capture rate and some viable export. 5% low-value recycling through REDcycle and infrastructure. Remaining 10% to energy recovery at 80% coverage.	Material previously sent direct to overseas becomes residual to energy recovery at 80% coverage. PVC eliminated from packaging. PAYT drives 5% greater reuse of durable plastic items (e.g. toys, containers)

[13] James Hall, 2019, *Weight of bags taken out of circulation at Woolworths weigh more than 780 elephants*, available at: https://www.news.com.au/finance/business/retail/weight-of-bags-taken-out-of-circulation-at-woolworths-weigh-more-than-780-elephants/news-story/b3aad3d57ca5153acfe4b58f29e9a8ab

B1.8 Organics

Capture rates for FOGO systems are based on analysis of audit data from various NSW councils, prepared for the NSW EPA. Capture rates were adopted based on the average performance for the best-performing FOGO configuration (in terms of bin size and collection frequency)

- 54% capture of food waste.
- 98% capture of garden waste.

The food waste capture rate corresponding to the best -performing council in the NSW audit was used for the *High Energy* scenario, reflecting stronger financial motivation to participate under the PAYT regime.

- 75% capture of household food waste.
- 30% capture rate of C&I food waste, reflecting uptake only where clean streams offer valorisation opportunities.

A higher food organic capture rate of 75% was adopted for the C&I stream under the *FOGO FOMO* and *Circular Stewards* scenarios, as food waste separation becomes mandatory from many businesses. These scenarios also include 10% food waste avoidance, because source separation by both households and businesses increases awareness of food waste, and the strong policy focus on organic waste includes significant education and behaviour change. This level of food waste avoidance is broadly consistent with the NSW experience, which reported an 8% drop in household food waste generation after two years of the Love Food, Hate Waste program[14].

All scenarios include some increase in source separation of organics, in line with published advice and direction by state government agencies. This varies between scenarios based on the level of prioritisation and funding available, as qualitatively described within the scenario narratives.

[14] Waste and Resource Recovery Strategy Progress Report 2017-18, page 17. NSW EPA. 2018: https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/recycling/19p1690-warr-strategy-progress-report-2017-18.pdf

Table 10 shows the assumed adoption rates for extension of FOGO services to additional households while Table 11 summarises the organics diversion assumptions for each scenario.

Table 10: Separated collection of organics coverage rate assumptions used in Circularity Index modelling

Qualitative description	Scenarios	Uptake rate
Some Not a priority Limited funding	Out of Sorts, Closing the Floodgates	20%
Many councils Widespread expansion	Packaging Crackdown	75%
All councils	FOGO FOMO, Circular Stewards	100%

Table 11: Separate collection of organics - coverage and capture rates assumed in Circularity Index modelling

<table>
<tr><th></th><th>MSW coverage</th><th>MSW capture</th><th>C&I total capture</th><th>Food waste avoidance</th><th>Rationale</th></tr>
<tr><td>Out of Sorts</td><td>20%</td><td rowspan="5">50% food
98% garden</td><td>No change</td><td>No change</td><td>Organics not a priority</td></tr>
<tr><td>FOGO FOMO</td><td>100%</td><td>75%</td><td>10%</td><td>High priority - policy and funding
Mandatory separation by businesses
Education and awareness</td></tr>
<tr><td>Closing the Floodgates</td><td>20%</td><td>No change</td><td>No change</td><td>Organics not a priority</td></tr>
<tr><td>Circular Stewards</td><td>100%</td><td>75%</td><td>10%</td><td>High priority - policy and funding
Mandatory separation by businesses
Education and awareness</td></tr>
<tr><td>Packaging Crackdown</td><td>75%</td><td>No change</td><td>No change</td><td>Secondary policy focus – MSW only
Composting infrastructure supports packaging changes</td></tr>
<tr><td>High Energy</td><td>20%</td><td>75% food
98% garden</td><td>30%</td><td>No change</td><td>PAYT charging</td></tr>
</table>

B1.9 Timber

Baseline data reports 589,000 tonnes of timber waste generated in Victoria, with a recovery rate of 32%, according to Infrastructure Victoria’s Waste Flows Report 2019, developed by Blue Environment. Current landfilling of timber is primarily through the C&I stream and includes a mixture of treated and untreated timber. The resource recovery infrastructure and collection changes described in the scenarios have little relevance to mixed timber, and the recovery rate has not been changed between scenarios. Timber is suitable for energy recovery and residual timber is allocated to energy recovery rather than disposal in scenarios with high energy from waste.

In *Circular Stewards* 1,000 tpa of timber is avoided and 5,000 tpa is reused through changes in furniture purchasing, leasing and refurbishment. This represents just over 1% of the timber waste stream.

B1.10 Metals

Markets have generally remained stable, and this situation is assumed to continue in all scenarios. Metal recovery rates do not change except in *High Energy*, in which the PAYT charging model drives more conscientious separation of recyclable metals from residual waste. An 80% diversion rate was adopted, like successful CDS recovery rates.

In *Circular Stewards*, a 15% improvement in reuse is allocated against steel, reflecting greater design for durability and repair to support leasing, sharing and refurbishment for products such as washing machines, tools and machinery. This means that the current 95% recycling rate reduces, as circular business models shift from recycling to reuse.

In scenarios including thermal energy from waste, metals can be recovered from mixed residual waste at a quality and price-point which are acceptable to recycling market. Large metal items are recovered prior to incineration, to reduce parasitic load and improve energy recovery efficiency, while a further metals extraction stage is also applied to bottom ash. Additional recycling has been applied to metals in the current residual stream, assuming 80% coverage rate of energy from waste and 65% capture rate of metals processed, based on an assumed 50:50 ferrous: non-ferrous compositional split.

B1.11 E-waste

E-waste is a relatively low volume stream but has some high value components and poses high environmental risks from inappropriate disposal. Expansion of e-waste processing capacity and development of high-value recycling infrastructure will be required in future years to support the recent landfill ban on e-waste in Victoria, but has not been explored in detail.

The waste flow modelling provides a baseline recovery rate of 65% but notes significant uncertainty in tonnage reporting and fate of recovered items, and states that this rate is considered an overestimate. Expansion of e-waste processing capacity and development of high-value recycling infrastructure will be required in future years to support the recent landfill ban on e-waste in Victoria but has not been explored in detail.

The reported 65% recovery rate has been adopted as a consistent baseline for comparison between scenarios. In most scenario, recycling remains predominantly low value, characterised by high levels of manual disassembly and partial processing prior to export. Recovery increases to 85% in *High Energy* due to PAYT drivers for separation, increased uptake of voluntary product stewardship recovery pathways and education campaigns to keep e-waste, which includes high levels of potentially toxic materials, out of energy recovery feedstock streams. In *Circular Stewards*, there is a much stronger emphasis on design for disassembly and upgrade, product reuse, and development of emerging technologies to extract high-value materials and components.

Energy recovery is not an appropriate fate for e-waste, although some fractions, such as low-value plastics, could be directed to energy recovery after items have been disassembled.

The reuse, high- and low-value recycling and disposal of e-waste in each scenario is shown in Table 12.

Table 12: Summary of e-waste fates assumed in Circularity Index modelling

Scenario	Details on e-waste fate	Reuse	High-value recycling	Low-value recycling	Disposal
Out of Sorts FOGO FOMO Closing the Floodgates Packaging Crackdown	Like current, draws on baseline data and assumes some expansion of infrastructure for domestic high-value recycling.	-	25%	40%	35%
Circular Stewards	Sharing and leasing models increase reuse compared to current. Product stewardship and collection optimisation improve capture rate. Emerging and small-scale technologies for high-value recycling strongly supported.	10%	60%	15%	15%
High Energy	Assumes some expansion of infrastructure for domestic high-value recycling, like other scenarios. PAYT and EfW acceptance criteria reinforce diversion. PAYT motivates uptake of voluntary product stewardship. Additional diverted materials directed to low-value disassemble and export.	-	25%	60%	15%

B1.12 Textiles

Textile processing infrastructure has not been analysed in detail within the scenarios because capture and recycling pathways are currently underdeveloped, with low throughout and very poor data capture. It is noted that some textile recycling of mattresses, B2B arrangements and remanufacturing by two Victoria carpet manufactures is known to occur, but data is rarely available, and tonnages are understood to be very small (approximately 200 tonnes or 0.1% recycling rate reported). The accompanying waste flow modelling data reports 100% disposal of known textiles.

Current reuse channels such as donation to charity shops is not captured in current waste data and is not included in the Circularity Index for any scenario. Where a value is allocated to textile reuse, this is assumed to be in increase above current behaviours.

Mechanical sorting of textiles is practiced in the UK and Europe and supports diversion to reuse in developing countries or low-value recycling as rags, automotive insulation carpet underlay and similar uses. Various chemical recycling processes for both synthetic and cellulose-based textiles have been developed over several decades, without commercial-scale success. Chemical recycling of textiles is currently viewed as a promising technology for cellulose-based and polyester fibres. It produces new fibres which can be woven into new, high-quality textiles, create a closed-loop system. Several global fashion brands are supporting textile recycling as a cornerstone of their corporate social responsibility actions. Many proprietary technologies have reached pilot-scale commercial facilities, but their future trajectory remains unclear.

Recycling rates under *Circular Stewards* and *High Energy* are assumed and reflect a likely increasing in funding and clean textile streams to support development of recycling capacity, rather than specific case studies in other jurisdictions.

Table 13: Summary of textile fates assumed in Circularity Index modelling

Scenario	Details on textile fates	Avoid / reuse (over current levels)	High-value recycling	Low-value recycling	Recover energy	Dispose
Out of Sorts Packaging Crackdown	No change from current.	-	-	-	-	100%
FOGO FOMO Closing the Floodgates	No change from current. Residual directed to EfW at 80% coverage.	-	-	-	80%	20%
Circular Stewards	Sharing, leasing and refurbishment increase reuse and avoidance compared to current. Mandatory product stewardship and collection optimisation improve capture rate. Emerging and small-scale technologies for high-value recycling supported.	15%	30%	30%	0%	25%

Scenario	Details on textile fates	Avoid / reuse (over current levels)	High-value recycling	Low-value recycling	Recover energy	Dispose
High Energy	PAYT motivates small increases in reuse and uptake of voluntary product stewardship. Textiles collected through voluntary drop-offs are recycled. Recycling capacity is developed with the support of voluntary product stewardship. Textiles remaining in residual stream are suitable for EfW, at 80% coverage.	5%	20%	30%	36%	9%

B1.13 Tyres

Tyres are included in the Circularity Index, however, the collection and processing routes for tyres are independent of the changes described in the scenarios. Within populated areas, tyres are collected separately from other materials, predominantly through C&I channels. Separate collection of tyres currently works reliably. Market outlets and stockpiling of tyres do pose significant challenges, but the tonnage involved is small compared to other streams modelled in the Circularity Index, and processing technologies and markets are independent from the infrastructure focus in each of the scenarios. Similarly, it is acknowledged that there are significant issues with the management of mining tyres, which are generated in remote areas and rarely recovered. However, this waste stream is poorly captured by existing data and is not impacted by the policy and market changes described in the scenarios, so is not included in the Circularity Index.

The same fate distribution was applied in all scenarios and was adopted from Infrastructure Victoria's 2019 waste flow modelling report, prepared by Blue Environment. The report provided a breakdown of current tyre fates to domestic reprocessing, export of stockpiling / disposal / loss.

Physical recycling of tyres typically involves chipping and production for products such as playground soft-fall, railway matting or asphalt binder. It cannot be recycled back into new tyres. All domestic recycling is categorised as low-value recycling from the perspective of the waste hierarchy. Viable business models and significant commercial value are available, but the number of material cycles for rubber in these products is limited.

The fate of exported tyres is unclear in the data but is understood to be primarily energy recovery in cement kilns or pyrolysis plants in Asia and India. All exported tyres are classed under energy recovery in the Circularity Index modelling.

Some scenarios are likely to support expansion of emerging domestic pyrolysis facilities for waste tyres or use of waste tyres are feedstock in large energy from waste plants which also accept mixed residual waste. However, this would still be classed as energy recovery within the circularity index. The shift from overseas to domestic energy recovery would not change the overall circularity score for the scenarios and is not explored in detail.

All scenarios use the following material fate distribution for tyres:

- 17% low-value recycling (corresponds to current domestic recycling)
- 65% energy recovery (corresponds to current exports)
- 18% disposal (corresponds to current loss / disposal / stockpiling)

B1.14 Criteria 2: Cost of household waste services

Table 14 provides a detailed justification for the scoring of the cost of household waste service criterion.

Table 14: Scoring for cost of household waste services criterion

Cost sources	Score	Landfill disposal – gate fees	Energy from waste – gate fees	Organics recovery – gate fees	Dry recycling (MRF) – gate fees
Baseline information	N/A	$95/t-120/t gate fee including levy reported for 2017-18.[15] Approx. $230/tonne or $100/hh/yr in 2017-18 including collection.[16]	$200/t-$300/t gate fee expected by industry.	58 of 79 councils offer some form of garden organic collection. 22 of 79 councils currently provide FOGO collection.[16] Cost of GO service approx. $40-$50/hh/yr including collection. Cost of FOGO service $60-$90/hh/yr including collection. Net saving due to landfill avoidance in metro areas. Net cost in regional areas.[17]	All councils offer recycling services- SKM insolvency disrupted some contracts. $60 gate fee reported in 2017-18.[15] Approx. $140/tonne or $30/hh/yr in 2017-18 including collection [16] Subsequent developments: Export market restrictions and price collapse for mixed product. Contract renegotiations and state government assistance to councils.

[15] Inside Waste, 2019, *Inside Waste Industry Report - Volumes and Values 2017-2018*, prepared by Arcadis
[16] Sustainability Victoria, 2019, *Victorian Local Government Annual Waste Services Report 2017-18*, available at: https://www.sustainability.vic.gov.au/Government/Victorian-Waste-data-portal/Victorian-Local-Government-Annual-Waste-Services-report
[17] Sustainability Victoria, 2019, *Guide to preferred standards for kerbside collection in Victoria*, available at: https://www.sustainability.vic.gov.au/Government/Waste-and-resource-recovery/Kerbside-waste-and-recycling/Guide-to-preferred-standards-for-kerbside-collection-in-Victoria

Cost sources	**Score**	**Landfill disposal – gate fees**	**Energy from waste – gate fees**	**Organics recovery – gate fees**	**Dry recycling (MRF) – gate fees**
				Open windrow composting currently dominant. $60-100 gate fee for in-vessel composting expected by industry.	SKM Recycling insolvency.
Out of Sorts	2	Increased tonnage	N/A	Modest, uncoordinated increase.	Restricted materials- reduced tonnage. Gate fees increases to cover increased operational costs – additional sorting, increased unsaleable residual.
FOGO FOMO	1	No direct disposal in metro areas. Landfill ban on organics drives residual diversion to EfW.	All residual waste.	Food and garden organics collection by all councils.	Restricted materials- reduced tonnage. Gate fees increases to cover increased operational costs – additional sorting, increased unsaleable residual.
Closing the Floodgates	1	Direct disposal reduces due to constrained landfill capacity. Landfill levy increases.	Accepts MSW residual waste and unsaleable recyclables.	Modest, uncoordinated increase. Not a priority.	Separate collection for glass – collection cost increase offsets material value improvement. Stable tonnage, but cost increases somewhat due to onshore reprocessing under Australian labour and environmental standards. Recycled content procurement and import protection

Cost sources	Score	Landfill disposal – gate fees	Energy from waste – gate fees	Organics recovery – gate fees	Dry recycling (MRF) – gate fees
					from virgin materials protects recycled product value and limits cost pressure on raw recyclables.
Circular Stewards	2	Increase in materials excluded from recycling collection. Reduced disposal of products due to changing consumption patterns and product sharing/leasing/repair.	N/A	Food and garden organics collection by all councils.	Restricted materials- reduced tonnage. Gate fees increases to cover increased operational costs – additional sorting, increased unsaleable residual. Diversion through mandatory product stewardship (textiles, soft plastics, e-waste etc) creates a cost to consumers at point of purchase but no cost to waste services.
Packaging Crackdown	2	Continued reliance. Avoided single use packaging has minimal impact on overall residual tonnage.	N/A	Widespread increase. Non-mandatory.	Gate fees increases to cover increased operational costs – additional sorting, increased unsaleable residual. Reduced tonnage – CDS accepts beverage containers and all glass.
High Energy	1	Limited direct disposal. EfW is dominant fate for residual waste.	All residual waste. PAYT reduces waste generation, but	Moderate increase. Uncoordinated.	Restricted materials- reduced tonnage.

Cost sources	Score	Landfill disposal – gate fees	Energy from waste – gate fees	Organics recovery – gate fees	Dry recycling (MRF) – gate fees
		Landfill costs increase due to levy and aftercare funding requirements.	tonnage reduction does not offset gate fees increase compared to 2017/18.		Gate fees increases to cover increased operational costs – additional sorting, increased unsaleable residual. Increased use of drop-off services and voluntary product stewardship.

B1.15 Criteria 3: Waste management cost

Table 15 provides a detailed justification for the scoring of the waste management cost criterion.

Table 15: Scoring for the waste management cost criterion

Scenario	Score	Business models	Organics recovery	Dry recycling	Landfill disposal	Thermal EfW
Baseline information		Current state – waste management included with building lease, limited direct understanding or control of waste cost for many businesses. Source separation of large stream (cardboard, glass) is common and can be a rebate on residual waste services.	Open windrow composting currently dominant. Gates fees upwards of $100/tonne for other technologies, depending on scale, feedstock and market development/ procurement.	Approx. $114/tonne in 2017-18 including collection.[17] Subsequent developments: • Export market restrictions and price collapse for mixed product • Stable markets remain available for high-quality source separated material (e.g. office paper) • Source separated cardboard price vulnerable to virgin material price fluctuations, but generally retains a market.[17]	Approx. $290/tonne in 2017-18 including collection.[17]	$150/t-$300/t gate fee depending on scale, feedstock and technology. Collection and transport costs typically $120/t.[17]

Scenario	Score	Business models	Organics recovery	Dry recycling	Landfill disposal	Thermal EfW
Out of Sorts	2		Not a priority.	Source-separated materials retain value. Restricted materials in comingled collections - reduced tonnage. Gate fees increases for comingled materials to cover increased operational costs – additional sorting, increased unsaleable residual.	Little change. Increased tonnage from some businesses.	N/A
FOGO FOMO	1		Mandatory food waste separation – process change. Economic benefit for some businesses. Possible net cost increase depending on collection frequency.	Source-separated materials retain value. Restricted materials in comingled collections - reduced tonnage. Gate fees increases for comingled materials to cover increased operational costs – additional sorting, increased unsaleable residual.	No direct disposal in metro areas. Landfill ban on organics drives residual diversion to EfW.	Landfill ban on organics drives residual waste to EfW.

Scenario	Score	Business models	Organics recovery	Dry recycling	Landfill disposal	Thermal EfW
Closing the Floodgates	1		Increased to avoid EfW costs. Uncoordinated. Possible net cost increase depending on collection frequency.	Onshore processing increases and accepts higher tonnage of C&I materials. Import/export restrictions control recycling gate fees but increase the price of some C&I packaging and products.	Limited direct disposal due to constrained landfill capacity. Landfill levy increase.	Accepts residual waste and unsaleable recyclables.
Circular Stewards	3	Circular business models adopted based on economic benefit. Reduced disposal of products due to changing consumption patterns and product sharing/leasing/repair.	Mandatory food waste separation – process change. Economic benefit for some businesses. Possible net cost increase depending on collection frequency.	Source-separated materials retain value. Restricted materials in comingled collections - reduced tonnage. Gate fees increases for comingled materials to cover increased operational costs – additional sorting, increased unsaleable residual. Shift from disposable to reusable B2B packaging delivers savings. Participation in mandatory product stewardship schemes, costs passed to consumers.	Reduced disposal of products due to changing consumption patterns and product sharing/leasing/repair. Reduced tonnage due to organics separation.	N/A

Scenario	**Score**	**Business models**	**Organics recovery**	**Dry recycling**	**Landfill disposal**	**Thermal EfW**
Packaging Crackdown	2		Not a priority	Source-separated materials retain value. Restricted materials in comingled collections - reduced tonnage. Gate fees increases for comingled materials to cover increased operational costs – additional sorting, increased unsaleable residual.	Continued reliance. Avoided single use packaging has minimal impact on overall residual tonnage.	n/a
High Energy	1		Increases to avoid EfW costs. Uncoordinated. Possible net cost increase depending on collection frequency. Modest waste avoidance savings due to increased awareness.	Source-separated materials retain value. Restricted materials in comingled collections - reduced tonnage. Gate fees increases for comingled materials to cover increased operational costs – additional sorting, increased unsaleable residual.	Limited direct disposal. EfW is dominant fate for residual waste. Landfill costs increase due to levy and aftercare funding requirements.	All residual waste. PAYT reduces waste generation, but tonnage reduction does not offset gate fees increase compared to 2017/18.

B1.16 Criteria 4: Economic uplift

Table 16 provides a detailed justification for the scoring of the economic uplift criterion.

Table 16: Scoring for economic uplift

Scenario	**Score**	**Business models/ resource efficiency**	**Organics recovery infrastructure**	**Dry recycling – sorting and reprocessing**	**Energy from waste**	**Small scale/emerging technologies**
Baseline information	N/A	SA estimates 25,700 jobs by 2030 from a Circular Economy transitions (predominantly in professional, scientific and technical services and construction)[18] Ellen Macarthur Foundation estimates global cost savings of $1 trillion by 2025, including up to $USD 630 billion in manufacturing in the EU.[19]	Capex investment and construction/operational jobs varies significantly with technology and scale. High potential for regional facilities.	Higher operational jobs than disposal or energy recovery. Sorting generates predominantly lower-skilled jobs while reprocessing and remanufacturing creates greater value and supports more skilled roles.	Major capex investment 400-800 construction jobs and 50-70 operational FTE per facility. Operational jobs higher than landfill but lower than recycling	Potential high-volume, low value options. Distributed operations and regional applications. Uncertain development and commercialisation – no scenario relies only on emerging technologies.

[18] Green Industries South Australia, 2017, *Benefits of a Circular Economy in South Australia*, available at: https://www.greenindustries.sa.gov.au/circular-economy
[19] Ellen MacArthur Foundation, 2014, *Towards the Circular Economy: Accelerating the scale-up across global supply chains*, available at: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Towards-the-circular-economy-volume-3.pdf

Scenario	**Score**	**Business models/ resource efficiency**	**Organics recovery infrastructure**	**Dry recycling – sorting and reprocessing**	**Energy from waste**	**Small scale/emerging technologies**
Out of Sorts	1	Recycling and disposal remain dominant.	Modest increase in processing, approximately 70,000 tpa new processing capacity. Not a priority.	Focus on sorting. No significant expansion of domestic reprocessing.	N/A	Limited support for development.
FOGO FOMO	2	Recycling and energy recovery remain dominant.	650,000 tpa additional capacity developed, including approx. 500,000tpa food waste processing capacity, which generally requires more complex infrastructure. Multiple facilities, including regional biohub models.	Focus on sorting and reduced saleable output. No significant expansion of domestic reprocessing.	3-4 facilities depending on size.	Focus on emerging solutions for niche organics streams, including business/ precinct-scale management or biorefining.
Closing the Floodgates	2	Recycling and energy recovery remain dominant, with higher domestic reprocessing and consumption of domestically recycled material.	Modest increase in processing. approximately 70,000 tpa new processing capacity. Not a priority.	Very significant investment in domestic reprocessing capacity expansion in multiple locations, including regional facilities.	3-5 facilities depending on size.	Some development, in competition with large-scale reprocessing operations. Focus on small scale organic biorefining.

Scenario	Score	Business models/ resource efficiency	Organics recovery infrastructure	Dry recycling – sorting and reprocessing	Energy from waste	Small scale/emerging technologies
Circular Stewards	3	Circular business models improve resource productivity and generate economic uplift.	650,000 tpa additional capacity developed, including approx. 500,000tpa food waste processing capacity, which generally requires more complex infrastructure. Multiple facilities, including regional biohub models.	CDS introduction and increasing source separation improves material quality and value of some streams. Increased domestic use of material, but limited expansion of large-scale reprocessing capacity. Comingled recycling tonnage reduces, and business model remains challenging.	N/A	Mandatory product stewardship and new business models support emerging technologies for various products and materials. Mandatory source separation of organics supports emerging biorefining technologies.
Packaging Crackdown	1	Recycling and disposal remain dominant.	Approximately 300,000 tpa additional capacity developed.	Focus on sorting and some increases in domestic reprocessing. CDS introduction, including all glass, and packaging changes to improve recyclability improve material quality and recycling value.	n/a	Limited support for development. Some interest in bio-based and compostable packaging.
High Energy	1	PAYT drives some waste avoidance through more circular business models, but recycling and energy recovery remain dominant.	Approximately 300,000 tpa additional capacity developed.	Focus on sorting and reduced saleable output. No significant expansion of domestic reprocessing.	3-5 facilities depending on size	Voluntary product stewardship supports emerging technologies for textiles, e-waste and organics.

B1.17 Criteria 5: GHG Emissions

High level greenhouse gas emissions estimates were modelled using WRATE software. This software compiles multiple environmental and operational performance parameters for a broad range of recycling and resource recovery infrastructure types. Reference facilities are predominantly UK and EU-based. Consequently, the results are not intended to provide an accurate assessment of Victoria's waste sector GHG emissions. However, WRATE is a useful tool which enables a comprehensive comparison of the scenarios against each other using a consistent assessment approach and taking a life-cycle analysis approach.

The material flows used in the Circularity Index scoring were translated into a material flow system within the WRATE software. The WRATE software then applied in-built performance datasets for each material recovery process and material fate to calculate an overall system GHG emissions result.

Emissions arising from transport of goods and materials were not included as the scenarios do not identify specific sites or infrastructure hubs. Transport is also a significant source of uncertainty in scenarios with high uptake of source separation for multiple material streams, under product stewardship arrangements or circular economy business models. Smart City sensing and analytics technologies offer potential efficiency gains in these increasingly complex logistics networks, but the uptake and impact logistic optimisation of new collection networks has not been modelled.

No 'baseline' emissions trajectory was developed, because the Victorian waste and resource recovery sector is currently undergoing significant change in response to multiple drivers, including:

- International recycling import restrictions;
- SKM Recycling historical performance issues and 2019 insolvency;
- Upcoming waste sector emissions reduction pledge under the Climate Change Act 2017 (pledge due 2020);
- Circular economy policy currently under development, including the Victorian Government position on energy from waste; and
- Market-led proposal for largescale energy from waste.

Multiple policy and infrastructure initiatives are being developed concurrently. In this context, relative scoring between scenarios was considered more relevant than scoring against a baseline. The greenhouse gas emissions score is presented as a percentage, relative to the range of waste and resource recovery sector emissions among the six scenarios. The scenario with the highest carbon dioxide equivalent emissions scores 0%. The scenario with the lowest emissions scores 100% and all other scenarios are scored proportionally between these two.

A few additional assumptions were adopted in this GHG modelling:

- Some scenarios have waste avoidance compared to current practices. This was included in WRATE but has limited accuracy. Waste avoidance fates allow materials to leave the WRATE calculation without incurring any environmental impact. The possible benefits of avoided consumption of virgin materials or products are not modelled.

- The WRATE software requires an electricity generation mix. Energy recovered from waste offsets demand on this existing network generation mix, which has a positive GHG impact compared to Victoria's current fossil-fuel reliant electricity mix. Table 17 shows the baseline fuel mix adopted in the WRATE model, as reported by the Australian Department of Environment and Energy for the 2017/18 financial year. [20]

Table 17: Victorian electricity generation mix FY 2017/18[20]

Fuel source	**GWh**	**% of total**
Coal	36067	76.21%
Gas	3899.4	8.24%
Oil	164.8	0.35%
Biomass	661.8	1.40%
Wind	4224.2	8.93%
Hydro	785.3	1.66%
Solar PV	1520.6	3.21%
Total	47323.1	100.0%

[20]Department of Environment and Energy, 2019, *Australian Energy Statistics, Table O: Australian electricity generation, by fuel type, physical units*, available at: https://www.energy.gov.au/sites/default/files/2019_aes_table_o_march_2019.pdf

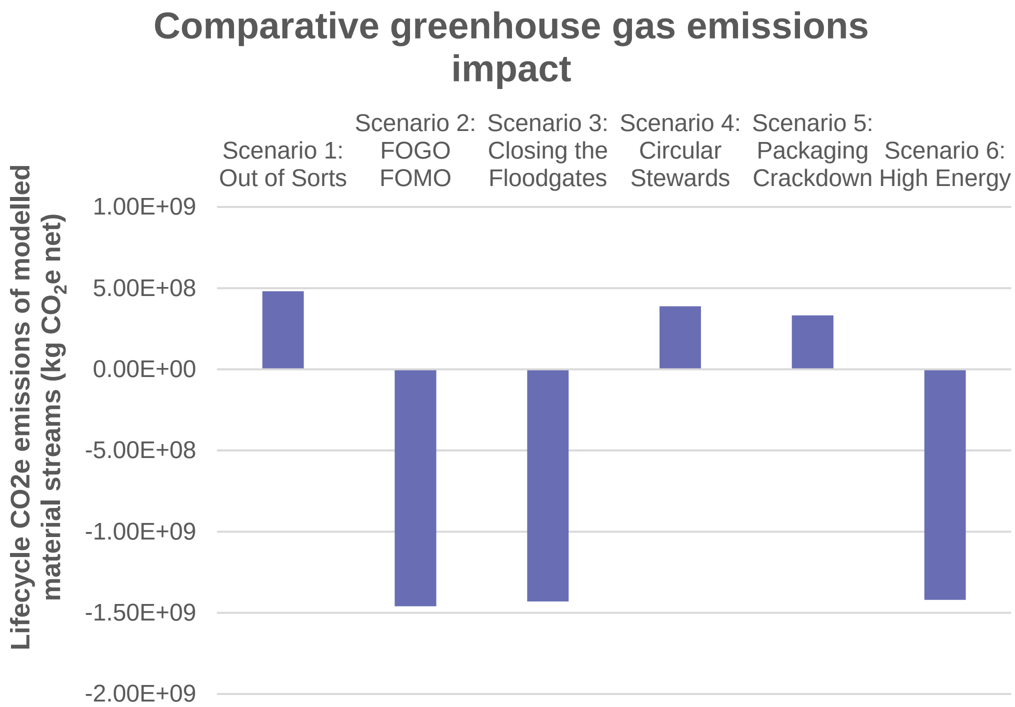

Figure 1: Summary of lifecycle emissions modelling result

Negative emissions indicate net emissions reduction due to energy generation and recycling offsets.

The results show a show a strong GHG emissions reduction for scenarios with compared to those without thermal EfW. Differences within these two scenario groupings are much more modest. There are three main reasons why energy recovery from residual waste contributes strongly to greenhouse gas emissions reduction:

1. When organics degrade in landfill, they emit methane, which has 22 times the GHG potential of CO_2. All scenarios included some improvement in organics separation and recovery. However, source separation systems do not completely capture organic waste, and some is still disposed to landfill in the residual waste stream. In scenarios which direct residual waste to energy recovery, all organics are diverted from landfill, either through composting or energy recovery.

2. The current Australian electricity mix is heavily reliant on fossil fuels. EfW offsets some of this electricity generation with partially renewable energy. This was found to have a significant impact on the magnitude of the GHG emissions reduction, but not on the performance of the scenarios relative to each other.

3. Metals can be recovered from mixed residual waste and incineration bottom as at a quality and price-point which is acceptable for recycling. This enables additional recycling or some metals which are currently disposed in the residual stream. This is a small total tonnage but has a

significant impact on the GHG emission reduction evaluation because virgin metal production is emissions intensive compared to recycling.

It is also important to note that the modelling focuses on materials streams and does not fully evaluate the emissions saving due to reuse and avoidance of complete products, such as furniture, tools, appliances and vehicles, in *Circular Stewards*.

Table 18 outlines the characteristics of each scenario which contribute most strongly to its greenhouse gas emissions score.

Table 18: Scoring for greenhouse gas emissions reduction potental

Scenario	Score	Relevant scenario characteristics
Out of Sorts	0%	Reduced volume of recyclate processed, offsetting virgin material processing. Minor improvement in organics diversion from landfill. Ne energy generation from waste.
FOGO FOMO	100%	Separate collection for organics – MSW and C&I. High coverage and typical capture rate. Incentives for bioenergy – fossil fuel offset. Very high landfill diversion of organics – landfill ban and residual diversion to energy recovery. Thermal energy from waste – partially renewable energy offsets fossil-fuel-reliant Victorian fuel mix. Metals recycling from residual stream at EfW facilities Reduced volume of recyclate processed, offsetting virgin material processing.
Closing the Floodgates	98%	Very high landfill diversion of organics - residual diversion to energy recovery. Thermal energy from waste – partially renewable energy offsets fossil-fuel-reliant Victorian fuel mix. Metals recycling from residual stream at EfW facilities Highest volume of recyclate processed, offsetting virgin material processing.

Scenario	Score	Relevant scenario characteristics
Circular Stewards	5%	Improved product reuse and waste avoidance through circular business models – impact of avoided production not fully captured. Separate collection for organics – MSW and C&I. High coverage and typical capture rate. Residual waste, including some organics, disposed to landfill. No energy recovery from waste. Moderate tonnage of recycling processed (CDS material, products under stewardship schemes.)
Packaging Crackdown	8%	Moderate tonnage of recycling processed (CDS material, paper and some plastics). Organics diversion form landfill due to moderate increases in source separation coverage and typical capture rate. Residual waste, including some organics, disposed to landfill. No energy recovery from waste.
High Energy	98%	Very high landfill diversion of organics - residual diversion to energy recovery. Thermal energy from waste – partially renewable energy offsets fossil-fuel-reliant Victorian fuel mix. Metals recycling from residual stream at EfW facilities Waste avoidance due to PAYT charging – impacts of avoided consumption not fully captured. Lower volume of recyclate processed, offsetting virgin material processing. Higher-order recycling supported by voluntary product stewardship (limited tonnage).