



Review

Food and Garden Organic Waste Management in Australia: Co-Benefits for Regional Communities and Local Government

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Abstract: Landfilling organic waste generates greenhouse gases and contributes to climate change. While the management of organic waste has been identified by all tiers of Australian government as paramount to meeting net zero emissions targets, diversion of domestic organic waste from landfill is primarily the responsibility of local government. This review of academic and grey literature considers developments in food organics and garden organics collections in Australia and the implications for regional communities. It reviews source-separated collections and the treatment of organic waste administered by regional local governments and identifies there is a dearth of information in this area. Key knowledge gaps emerging from the study include: (1) There is a disconnect between the various state governments' policies, strategies, and regulation of organics diversion and action on mandating or supporting kerbside collections; (2) there is insufficient funding and subsidy to encourage councils to implement collection systems, and (3) the community has limited understanding of the cost and environmental burden of waste, and subsequently there is no willingness to pay for collection systems. This paper outlines how these issues contribute to individual regional councils deferring kerbside organic waste collection systems and offers recommendations that could enable the achievement of more ideal diversion targets that are relevant to, and affordable for, their local communities.

Keywords: FOGO; household food waste; municipal solid waste; social behaviour change; circular economy



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1. Introduction

The loss of embedded resources through food waste is a global concern, with around one third of food being wasted annually [1]. Annually, this amounts to 1.3 billion tonnes of food waste, costing the global economy around USD 940 billion, and accounting for up to 10% of global greenhouse gas (GHG) emissions [2]. As waste volumes have increased alongside growth in wealth and population, organic waste management has become a priority for political and environmental agendas globally [3]. Australia is no exception. In 2016–2017, 26 million Australians generated around 7.3 Mt of food waste. Of this, 34% originated from households and was collected through the municipal solid waste (MSW) collection system, with over 90% going to landfill [4]. Household food waste is commonly derived from food which has been lost, degraded, or contaminated due to over-purchasing, bad storage, over-preparation, and poor proportioning and cooking [5].

Landfilling the organic fraction of MSW (OFMSW), which includes food and garden organics, consumes valuable landfill space and contributes to climate change through the release of GHG. Once microorganisms within the landfill have consumed the available oxygen, the landfill environment becomes anaerobic, and the organic degradation pathway changes from one of primarily carbon dioxide release to one of primarily methane release. As a greenhouse gas, methane is 28–35 times more potent than carbon dioxide over

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a 100-year timeframe, and around 80 times more potent over a 20-year timeframe [6]. These gases when released from landfill are known as landfill gas and continue to be emitted from landfill for 50+ years following the closure of the landfill. In Australia, OFMSW accounts for around 3% of national GHG emissions and costs Australian local governments an estimated AUD 1.75 billion annually [7,8]. Addressing climate change is emerging as a key driver of improved waste management, and closing the loop, moving from the concept of 'end-of-pipe' waste management towards a more holistic resource management system, is regarded as the way of the future [9].

Targeting OFMSW enables economic and environmental benefits through increased resource recovery in line with the waste hierarchy: a framework to guide the order of preference for managing waste (Figure 1) [8]. In line with this hierarchy, many local governments have implemented waste management processes, such as source reduction, reuse, recycling, and recovery, to reduce final disposal to landfill. Technologies for management of OFMSW can include anaerobic digestion and composting. These technologies enable local governments to recover energy and/or nutrients to offset both fossil fuel and industrial fertiliser consumption, while returning organic matter to the soil. While the adoption of these technologies is quite advanced in some international contexts, adoption in Australia is only in its infancy [3,10]. This is due to three interrelated issues: (1) waste and resource recovery drivers in Australia are very different to those internationally; (2) the population of Australia is highly concentrated in major cities with relatively small regional population centres sparsely distributed over a vast continent; and (3) local governments vary in their ability to offer sustainable and effective organic waste collection and treatment systems [11].

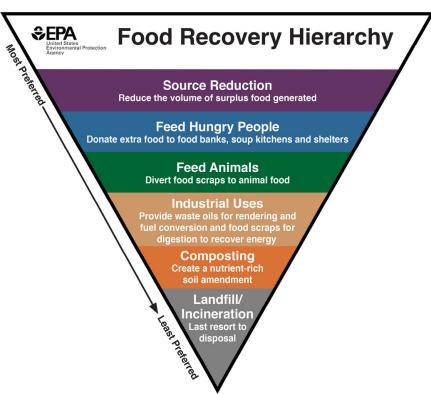


Figure 1. Waste hierarchy [8].

Processes to reduce waste to landfill in Australia are driven by the Commonwealth, state, and territory governments, as further outlined in Section 2. The Australian National Waste Policy [11] addresses the United Nations Sustainable Development Goal 12 [12] by establishing a strong national framework for sustainable consumption and production and, ultimately, improved management of waste. The implementation of these policies largely falls to local governments that are responsible for providing collection and processing of OFMSW. Waste services provided by local governments include managing and operating

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landfill sites, contracting or conducting waste and recycling collection services and treatment options, and delivering education and awareness programs [13]. The diversion of OFMSW from landfill presents additional challenges for councils, particularly in regional settings, where there are inconsistencies in processes for OFMSW collection and treatment. This is largely shaped by the capacity of local governments to collect OFMSW and the accessibility of suitable infrastructure for processing. Outside the capital cities, the relatively low population densities of rural and remote areas present problems for local government waste collection and processing. Australia's eight states and territories are divided into 537 local government areas (LGAs) governed by local councils, spread across metropolitan, rural, and remote areas. While 72% of the Australian population live in major cities on the coastal fringe of the continent, 26% live in regional areas with the small remainder living in remote and very remote areas [14]. While waste-stream composition and the environmental impact of waste disposal to landfill are similar in urban and regional councils, regional councils suffer challenges in accessing composting markets for recovery of organics. Logistics expenses are high and, in areas with low population density, any environmental benefits gained from recovering organics may be overshadowed by the cost of collection and transport systems [15]. Given these challenges for the sizeable regional population of some 6.7 million people, the management of food organics and garden organics (FOGO) in regional Australia is the focal area of this review. The waste strategies of local government areas in each Australian state/territory are analysed to consider how developments in FOGO collections in regional areas meet the requirements of state and local government waste strategies.

2. Methodology

A review was carried out of literature relating to local government and organic waste collections, policy, and treatment. For the academic literature, a search of university library databases and Google Scholar used the keywords: local government waste collection; food organic collection; garden waste collection; local government waste policy; organic waste treatment; composting; aerated pile static floor organic treatment. This area is still developing and there is not an abundance of academic literature on these keywords.

Grey literature searches included websites of international and Australian Government agencies, seeking policy and strategy detail for the higher tiers of government. Australian state government websites were also reviewed for policies and strategies relating to management of organic and household waste. A search of local governments in Australia provided a list of councils of size consistent with the study review, and publicly available information from these councils was reviewed for waste strategy content.

More than 500 documents were reviewed, of which 123 documents were incorporated into the literature review. Given the rapidly changing nature of the collection and treatment of organic waste from households, generally only documents dated post 2015 were considered.

3. Waste and the Role of Governments

The Commonwealth of Australia is a federation of six states and two self-governing territories [16]. The constitution gives certain powers to the Commonwealth (also known as the National or Australian Government), some to the states and territories, and some are shared between the Commonwealth and the states and territories. The states and territories have a significant degree of autonomy, each having their own constitution, parliament, government, and laws [17]. While the Commonwealth is responsible for national legislation, strategies, and policy frameworks for waste, including measures that give effect to obligations under international agreements, waste management and regulation are primarily the responsibilities of state and territory governments and their respective legislation, policies, and programs. Local councils have responsibility for implementation of waste management within their LGAs and within the regulatory framework of each state or territory [13].

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Collecting, treating, and disposing of Australian domestic waste costs local governments an estimated AUD 3.5 billion annually and this cost is passed onto ratepayers and residents. Regional councils manage around 26 percent of Australian waste, collecting around 9.7 Mt from kerbside bin services. While there are costs associated with improved management of organic waste, these are offset by positive outcomes for the environment both in terms of reduced climate change impacts and increased recovery of resources.

In Australia, a FOGO service is the collection of food organics (FO) and garden organics (GO) collected in a kerbside wheeled bin, generally with a lime green lid as per Australian Standard 4123.7-2006 [18], and as part of the suite of kerbside waste collection bins (e.g., Figure 2). The organic waste is transported to a compost facility and converted to a soil conditioner.

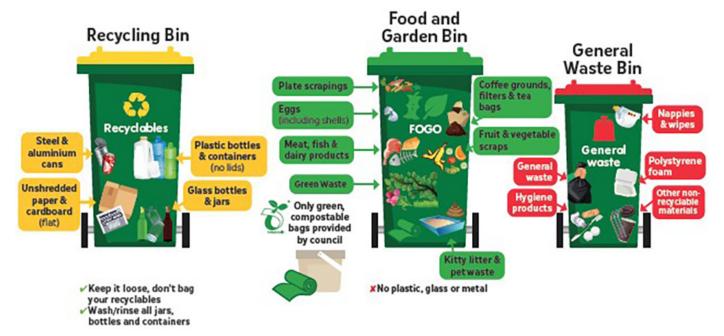


Figure 2. A typical three-bin waste system implemented by an Australian local government [19]. Reprinted/adapted with permission from Ref. [19]. 2022; Luke Stewart from Resource Recovery Group.

Councils offer FOGO services in a range of ways (Table 1). Adoption of FOGO collection is increasing across Australia, but this trend has stagnated in regional and rural communities. The first FOGO service in a metropolitan council area was introduced by Penrith, New South Wales (NSW) in 2010 [20], and 234 (44%) councils in Australia now offer FO and/or GO services (Figure 3) [21]. In NSW and Victoria, FOGO services are becoming more commonplace with waste strategies in these states focused on the reduction of organic waste to landfill [22,23]. However, across Australia there is no uniform adoption of organics collection, particularly as these collections present financial and logistical challenges for urban and regional councils. To date, there has been no consistent mandate from the Commonwealth or state governments to implement such systems. Knowledge gaps exist regarding differences in available collection systems, acceptance criteria, and local governments' rationales for implementing systems. Research into these programs may see more councils implement collection systems for organics, more types of collection services offered, and more types of organic waste that can be collected in the systems.

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Table 1. Various elements of a FO/GO/FOGO service provided by local government in Australia.

Elements of FOGO Service	Option	Comment		
Food organics	Not generally offered as stand-alone service to households but can be offered to commercial premises.	Some councils offer FO as an opt-in (residents pay an additional fee for the service) or mandatory (the service is incorporated into the waste management collection system).		
Garden organics	Generally offered as a fortnightly collection in a 240-L bin.	Can generally be collected fortnightly as garder waste does not cause odour or vermin issues.		
Food organics and garden organics	Can be offered weekly or fortnightly, depending on local government, and generally offered in a 240-L bin.	If food is incorporated, particularly meat/seafood/dairy, the service is generally offered weekly although some councils in cooler climates may offer the service fortnightly to reduce costs.		
General waste service Weekly or fortnightly. Can be 120-L or 240-L.		Depends on the nature of FO/GO/FOGO service, inclusion (or not) of meat, seafood, dairy, and local climate.		
Provided by councils to assist residents to handle food within the home before carrying it to the external bin for collection.		Not offered by all councils and depends on cost and nature of FO service.		
Compostable caddy liners	Can be provided by council at council expense or purchased by residents to assist in managing food in the kitchen caddy. Organic processors do not always accept FO/FOGO streams that contain caddy liners so this will determine whether councils offer them as part of the service.	An added expense for councils and residents but helps remove the 'yuck' factor of FO.		

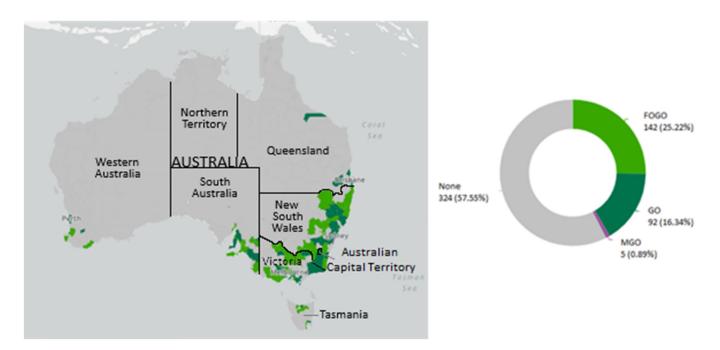


Figure 3. Distribution of food and/or garden waste collections across Australian local governments, modified from [21]. (FOGO = Food organics and garden organics, GO = Garden organics, MGO = Mixed garden organics). Map layers contributed by Esri, Garmin, FAO, NOAA, USGS | Esri, Garmin, FAO, NOAA, USGS.

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Recognising that financial and logistical challenges are occurring across urban and regional councils in Australia provides an opportunity to further explore and research this area.

4. Setting the Policy Scene for FOGO Collections

In Australia, the current National Waste Policy: Less Waste, More Resources 2018 [11] and accompanying National Waste Action Plan 2019 [24] provide national targets for waste reduction, including halving the amount of organic waste sent to landfill by 2030. The National Food Waste Strategy provides a platform to halve food waste by 2030 and aligns Australia with global action on reducing food waste [25]. In late 2020, the House of Representatives Standing Committee on Industry, Innovation, Science and Resources of the Australian Parliament was asked to inquire into and report on innovative solutions in Australia's waste management and recycling industries [7]. FOGO waste received considerable attention as a potentially valuable resource that can be recovered and reused. The inquiry identified food waste as a challenge for many Australian councils because it: (1) represents up to half of household waste; (2) consumes diminishing space in landfills and generates methane; and (3) represents collection and treatment challenges for councils; while (4) there is no consistent application of collection and treatment in regional or urban settings across the country. There are calls for a national approach for the diversion of organic waste from landfill and a national strategy is supported by some stakeholders [7].

Each state and territory in Australia has a waste strategy that aligns waste and resource recovery targets with the National Waste Policy 2018 (Table 2). These strategies ultimately align with the United Nations Sustainable Development Goal 12 for responsible consumption and production [12].

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Table 2. Summary of Waste Strategies in Australian states and territories and Linkage to the UN Sustainable Development Goals and the National Waste Policy 2018.

Achieving Goal 12 req			Responsible Consumer consumption and produced in the consumpti	evelopment Goal 12 Aption and Production Auction that is integrated a Corms on the management		al plans and sustainable bu s and waste [1].	usiness practices and
	Tai	get			Ta	rget	
By 2030, substantial	ly reduce waste generati and i	on through prevention, r euse.	reduction, recycling,			ail and consumer levels an hains, including post-harve	
Nati		Waste, More Resources : Action Plan 2019 [11,26]	2018		National Food W	Jaste Strategy [25]	
	Tai	get			Ta	rget	
Identify and address opportunities across the MSW stream for improved collection, recycling, and energy recovery, to deliver ongoing improvements in diversion from landfill, improved quality of recycled content and use of the waste hierarchy [11]. Reduce organic waste, including garden and food waste, by avoiding its generation and supporting diversion away from landfill into soils and other uses, supported by appropriate infrastructure [11].				— Halve food waste by 2030 [25].			
			Australian State	Waste Strategies			
Queensland	New South Wales	Victoria	South Australia	Western Australia	Northern Territory	Australian Capital Territory	Tasmania
Queensland Waste Management and Resource Recovery Strategy [26] Queensland Organics Strategy [27]	NSW Waste and Sustainable Materials Strategy 2041—Stage 1 2021–2027 [28]	Recycling Victoria: A New Economy [23]	Supporting the Circular Economy: South Australia's Waste Strategy 2020–2025 [29]	Waste Avoidance and Resource Recovery Strategy 2030 [30]	Northern Territory Circular Economy Strategy 2022–2027 [31]	ACT Waste Management Strategy: Towards a Sustainable Canberra 2011–2025 [32]	Waste Action Plan 2019 [33] Tasmanian Organics Strategic Framework [34]
<u> </u>			Australian Sta	te Waste Targets		<u> </u>	

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Table 2. Cont.

and 60% recycling urban areas for • 100% of Plan with generated in Perth rate of household processing and households have appropriate and appropriate appropriate and appropriate appropriate and appropriate		rate of household organic waste by 2030 Overall reduction of waste to landfill of 55% by 2025, 70% by 2030, 90% by 2040,	processing and small-scale onsite solutions in high-population areas and industry centres by 2030 Require separate collection of FOGO from all NSW	households have access to a separate food and organics recovery service or local composting	appropriate and progressive waste diversion targets in	and Peel regions is landfilled by 2030 • All waste is managed and/or diverted to better practice facilities	3—establish the circular economy industry to be a contributor to the Territory's	environmentCarbon neutral	• Reduce the volume of organi waste sent to landfill by 25% b 2025 and 50% by 2030
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	Policy Leve	rs Used by Australian S	tate/Local Governments	to Reduce Waste to Land	dfill and Increase Resou	irce Recovery	
Waste levy Waste strategy Regulation Subsidies and incentives	Waste levy Waste strategy Subsidies for councils to implement FOGO [35] Regulation Subsidies and incentives	Waste levy Waste strategy Household waste and recycling services are regulated [36] Subsidies and incentives	Waste levy Waste strategy Subsidies for councils to implement FOGO [37] Subsidies and incentives	Waste levy Waste strategy Subsidies for councils to implement FOGO [38] Subsidies and incentives		Waste strategy Subsidies and incentives	Waste levy Draft waste strategy Subsidies and incentives
	Exai	mples of Local Governm	nent Waste Strategy Inter	raction with and Reflect	ion on State Waste Strat	egies	
Lockyer Valley Regional Council Strategy recognises the National Waste Policy targets and refers to the state strategy [39].	Cessnock City Council References previous NSW state strategy. Notes targets and refers to new state strategy that was being developed at the time the Council strategy was prepared [40].	Baw Baw Shire Council Outlines linkages to Australian and state strategies with comprehensive acknowledgement and understanding of these documents [41].	Barossa Council Connection to the SA circular economy and food waste strategies. Mentions the National Food Waste Strategy. Recognition of policy position for SA for the solid waste levy. No mention of National Waste Action Policy [42].	City of Bunbury Aligned with the state waste strategy for targets and diversion rates [43].	Alice Springs Town Council No dedicated waste strategy so no reference to state or national strategies [44].	The ACT Government has responsibility for waste collection which is normally provided by local governments in other states and territories. The National Waste Policy is mentioned regarding working with other states and territories on product stewardship schemes, developing end markets for recovered resources and reducing greenhouse gas emissions from landfills [32].	Central Coast Council Mentions circular economy principles. Aligns with the state Draft Waste Action Plan and notes focus areas of state and national policy and regulatory settings. Mentions policy platforms such as waste levy and container refund scheme. Notes potential participation in national product stewardship schemes as an action [45].

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5. Policy Levers Used to Divert Organic Waste from Landfill

The European Union (EU) Waste Policy provided a framework to improve waste management, reduce the amount of waste generated, stimulate innovation in separate waste collection and recycling, limit the use of landfilling, and create incentives to change consumer behaviour [46]. However, in comparison, Australia has no similar directive or tool to change waste management behaviours away from landfilling. Landfilling therefore remains the most common form of organic waste management as it is a cost effective and easy solution in regional centres where land is more readily available at lower cost in comparison with metropolitan areas. While some state governments have implemented policy measures and introduced policy levers to encourage the use of alternate organic waste management systems and divert this waste away from landfill, these have not yet been successfully or consistently implemented in Australia [47], as discussed below.

5.1. Landfill Bans

A landfill ban is defined as a range of measures to prevent or restrict the disposal of waste to landfill. This can include outright exclusions or requirements for pre-sorting or pre-treatment. The bans may apply to all waste, to particular streams (e.g., MSW or OFMSW), or to individual products or materials [48]. Landfill bans have been used successfully in European countries since the 1990s. In the Netherlands, there are more than sixty waste categories banned from landfill and these waste types have recycling or incineration options to divert the streams from landfill [49]. Landfill disposal bans are typically introduced several years after the introduction of a levy on waste disposed to landfill [50].

Implementing and enforcing a landfill ban is a challenge as any ban must allow for alternative treatment options prior to its introduction. When identifying appropriate materials for inclusion in landfill bans, a government will consider the economic trade-off between the cost per tonne and the diversion rate from landfill, the market for reuse materials and recovery rates, and the number of processers available for the product. There are different landfill bans in place in different states and territories in Australia and these are supported by a range of national and state regulations and programs. Bans from landfill in Australia currently apply to products based on the properties of waste, particularly hazardous waste, and landfill bans on organic waste collected at the kerbside from households have not been implemented [51]. There is evidence that landfill bans in Victoria have led to stronger resource recovery for some waste types, but it can take many years for local governments to adjust long-term contracts and for this tool to achieve success [52].

In 2014, the Queensland Government identified organic waste in the south-east region of the state as a possible material to be subject to a landfill ban [50]. The report for a possible landfill ban, prepared for the government at that time, quantified the following impacts: reduction in the economic cost of disposal of waste to landfill; reduction in the cost of greenhouse gas emissions from landfill; increase in the economic value of the recovered material; increase in the costs of recovery and processing; increase in the cost of illegal dumping and associated compliance costs; cost of administration and reporting; and cost of policy development and implementation. At that time, the net impact of a landfill ban for OFMSW did not result in a positive outcome and the ban has never been progressed [50].

5.2. Levy on Waste Disposed to Landfill

Landfill levies are used to internalize the external costs of landfilling and make costs of resource recovery operations competitive with landfill; that is, levies make recycling more cost effective than landfilling [53]. There is resistance to landfill levies in local government as funds are often not fully hypothecated to the waste and resource recovery industries by state governments and therefore do not provide industry with the confidence to invest in new waste management and recycling infrastructure [54]. In regional areas, landfill levies are often lower to reduce the impact on residents and businesses in those areas but are still high enough to prevent waste being transported into these areas for disposal. At the same

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time, landfill gate fees are often lower in regional areas as a reflection of less expensive land prices, administration, and compliance costs for landfill operators (Table 3). Politically, there is little appetite in regional areas to increase waste-disposal costs, and policy levers to do so are resisted [54]. A significant element of this is that, in general, regional areas of Australia are characterised by greater socio-economic disadvantage than urban centres. Without charging gate fees consistent with metropolitan areas, regional councils are unable to establish the requisite resource-recovery operations, and nor do they have the necessary economies of scale to maintain such facilities. Policy positions such as landfill levies can assist in making gate fees competitive, but, in regional areas, they are often insufficient to make resource recovery options competitive with lower cost landfill prices.

Table 3. Waste 1	levies appli	ed in Australiar	n states and	l territories.
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State	Waste Levy			
New South Wales	87.30 AUD/t (regional) 151.60 AUD/t (metropolitan) [55]			
Victoria 125.90 AUD/t (prescribed municipal (metro) prem 62.95 AUD/t (non-prescribed municipal (rural) premi				
Queensland	95 AUD/t (in metro levy zones including inner regional councils) 88 AUD/t in regional areas in the levy zone [57]			
South Australia	149 AUD/t (metropolitan Adelaide) 74.50 AUD/t (non-metropolitan) [58]			
Western Australia 70 AUD/t (Perth metropolitan region only)				
Tasmania	20 AUD/t [60]			

5.3. Subsidies and Incentives

Pay-as-you-throw systems of waste management are used in some international jurisdictions. In these systems, residents are charged for the collection of MSW based on the amount they throw away (as opposed to a flat tax or rate through property charges) and this creates a direct economic incentive to recycle more and generate less waste [61]. Such systems are deemed more equitable as the cost of waste management is not 'hidden' in rates or taxes but is completely transparent to the resident generating the waste. In 2006, the Australian Productivity Commission recognised that basic forms of pay-as-you-throw pricing for kerbside waste and recycling collection services should be more widely adopted with information on the costs of waste management better communicated to households [62]. There is limited literature available on whether these types of pay-as-you-throw services are having an impact on waste reduction for the general community and not just for those who are committed to improving their environmental footprint.

Subsidies are financial transfers towards individuals to encourage waste reduction and the choice of more sustainable waste treatment and to promote selective sorting [63,64]. In Australia, some local governments provide an opt-in residential garden organics and/or food organics service whereby residents can pay for a bin and collection service. This relies on individual households seeking to improve their own waste-management outcomes. For example, in three major southeast Queensland cities (Brisbane, Ipswich, and Toowoomba), residents can opt in to a garden waste service, paying an annual fee of AUD 80 in Brisbane and Ipswich and AUD 45 in Toowoomba for a fortnightly kerbside collection of garden organics [65–67]. There has been little research on the success or otherwise of these schemes and there is a particular knowledge gap in understanding whether residents perceive opt-in systems as an incentive despite the cost.

Some state governments provide subsidies to local governments to enable implementation of organics collection services. An example of this is the NSW Go FOGO Grants scheme where the NSW state government supports NSW councils financially to deliver

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new weekly FO or FOGO services to their communities [35]. Councils can seek funding for a set amount per household to assist with implementation of new or improved organics collection services. The budget for this program is 50 AUD per single unit household and 25 AUD per multi-unit dwelling. Without such assistance, it is unlikely that local governments would introduce the services and therefore meet the requirements of the NSW waste strategy.

5.4. Regulation

There has been a long history of dumping waste into seas, on land, and in developing countries, and managing waste as a truly global issue requires cooperation from all countries [68]. Regulation is a key tool for implementing strategies for solid waste management and plans to improve environmental outcomes [69]. Some areas of waste management, including compliance of waste-treatment activities such as landfills, are heavily regulated. Internationally, tools such as the Waste Directive [70] in the United Kingdom are used to force behavioural change both among householders and local governments. In Australia, activities such as landfilling are heavily regulated to ensure environmental and public health protection. However, in contrast with European trends, there is a lack of regulation to force state or local governments to reduce waste to landfill and increase resource recovery. Regulating end-of-pipe activities such as landfills does not manage waste in its design or deconstruction phases. In contrast, European countries commonly adopt systems such as extended producer responsibility (EPR) and product stewardship (PS) to improve waste outcomes [71].

Extended producer responsibility assigns financial or physical responsibility to producers for the management of their end-of-life products, and they are required to minimise the cost of their products' end-of-life management [72]. Product Stewardship is similar to EPR in that is also requires producers to take responsibility for minimising the environmental impact of the product through its entire life cycle, but leans more to design for recovery rather than costing end-of-life into the product [73]. EPR and PS are not as readily designed for organic waste as they are for consumer items such as white goods. However, advances in items such as packaging can increase food shelf life to reduce the production of food waste, and compostable packaging may reduce other waste streams. EPR and PS schemes have been voluntary in Australia to date and while such schemes are accredited by the Australian Government, they rely on producers for implementation and operation. To date, organic waste has not been listed as a possible item for consideration for EPR or PS [74].

Most states' waste strategies are made under relevant waste regulation/legislation. For example, the Queensland Waste Management and Resource Recovery Strategy is made under the Waste Reduction and Recycling Act, 2011, Section 14. This legislation outlines what may be included in the state's waste strategy, when public notice should be given on a draft strategy, how submissions on a draft strategy should be considered, and how a strategy should be reviewed [75]. Section 123 of the same Act requires a local government to have, and implement, a waste reduction and recycling plan and to review that plan every three years. There is currently no penalty, financial or otherwise, for not having a waste reduction and recycling plan in Queensland.

The NSW Waste Avoidance and Resource Recovery Act 2001 requires the NSW Government to develop and approve a waste strategy for the state and commits the government to refreshing and updating the strategy every five years [28]. The Act also allows the NSW Government to request a local council to provide a report on waste strategy compliance, but there are no financial penalties for non-compliance. The NSW waste strategy facilitates a collaborative approach to improve waste management in the state and encourages and supports councils to work together regionally to improve waste outcomes [76].

The approach to improving outcomes across the Australian tiers of government tends to focus more on collaboration for improved waste outcomes rather than use of direct legislation to change waste services. Household waste services are provided almost exclusively by councils in every state and funded through rates collected by councils [77]. This

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generally sees state governments assisting councils with funding to improve waste services (as discussed in the section on subsidies and incentives, above) to reduce the burden on ratepayers and residents, while still seeking improved waste management outcomes, reduced waste to landfill, and increased resource recovery. This can be achieved through improved regulation, but consultation with local and state governments needs to occur to ensure policy decisions can be implemented at the local level.

5.5. Behaviour Change

State governments use behaviour-change programs to provide consistent messaging to residents by providing messaging and tools for councils to share with communities [78–80]. These programs are related to incentives and assist local governments to improve waste outcomes and meet state government targets. Most local governments in Australia provide a behaviour-change program to assist residents to understand and better manage household waste [77]. The causes of organic, particularly food, waste in households are complicated and include multidimensional effects such as social, economic, and individual influences [81]. Understanding residents' approaches to management of household food and garden waste is key to developing collection systems that meet the needs of communities, and effectively delivering programs that assist residents to reduce waste to landfill and increase resource recovery.

Collection systems provided by councils at the kerbside can assist residents to engage in behaviours that are considered pro-environmental. However, the current lack of standardisation in these programs across Australia can produce confusion [82]. While recycling education programs are well established in Australia, FOGO education programs are in their infancy across all state governments. The three-bin FOGO kerbside system has been shown to be the most efficient for the source separation of waste, but improving messaging to communities and providing such services are not embraced equally by all local governments [83]. There is scope for further research on how behaviour change programs can be used to assist local governments to meet targets set in state waste strategies.

6. Collection and Management of Waste in Australian Regional Settings

Source-separated organics collection systems are implemented to: (a) increase material recovery; (b) produce compost or soil conditioner suitable for use in agriculture, horticulture, or urban garden environments; (c) alleviate pressure on landfill capacity; (d) reduce greenhouse gas emissions to meet national and international targets; (e) increase the level of energy generated from waste material through anaerobic digestion; (f) reduce the adverse impact of landfill on the environment and human health by reducing generation of methane in landfills, and; (g) provide incentives for reducing the generation of waste material and reducing the community's dependency on landfill as a waste-treatment option [84]. Collecting source-separated organics from households can provide clean waste streams that allow options to create end-use products through processes such as composting or anaerobic digestion. However, local governments are very conscious that the cost of collection of these streams can add a financial burden to householders, and waste collection and prevention compete for attention on crowded local government agendas with limited personnel and financial resources [84,85].

Provision of waste-collection services can vary significantly between urban and regional environments due to economies of scale for waste-collection contracts and fleets. As noted above, the collection of source-separated MSW can be incentivised through different policy levers, but such collections tend to increase the fuel and time required to operate a fleet of collection trucks. Waste managers therefore need to determine whether incentives outweigh the cost [86]. When collection distances increase, the collection and transportation of organic waste can result in high environmental impacts [87]. This is particularly relevant in Australian regional settings. Source separation systems such as FOGO services further require continuous education and behaviour-change programs to ensure the correct material is placed in the appropriate bins and that contamination is minimised. The differences

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in costs for the various services, including the costs of processing collected organic material and behaviour change programs, and how councils and states fund these services has also been under-researched in the local government arena.

Where organic waste is transported from regional areas to urban areas for processing, emissions from road transport can be significant and contribute to overall greenhouse gas emissions from the waste sector. Madden, et al. [87] studied greenhouse gas emissions from household organic waste collection and transportation and found that FOGO waste has the lowest transport requirements of the three waste streams (FOGO, general waste, and recycling), but this was to be expected given that the FOGO collection stream is still in its infancy in local government, large distances are travelled to recovery, small tonnages are collected, and many councils are yet to introduce the system. The study also found that the average kerbside-collection fuel intensity was highest for FOGO collection when regional local governments provide the service and there are greater distances between bins when servicing.

Edwards, et al. [88] completed a life-cycle assessment on the environmental impact of seven contemporary food-waste-management systems. One of these systems was centralised composting whereby residents placed waste FO and GO into a large organics bin which was collected weekly and processed at a centralised windrow composting facility. The general waste bin is collected fortnightly in this system, as all organic waste should be in the organics bin. Other systems considered in the comparison included anaerobic co-digestion, in-sink maceration and co-digestion, home composting, mechanical biological treatment, and business as usual (landfill). In terms of rankings of the various systems, the landfill (business as usual) option ranked seventh. It involves landfilling all food waste which then degrades and contributes significantly to many air and groundwater emissions. Centralised composting ranked between fourth and sixth for the case studies carried out in the comparison, primarily because no energy generation is available when composting and relevant offsets and credits are therefore not available. This study notes that centralised composting is representative of waste management systems that are being implemented by rural and regional local governments in Australia. These governments choose these systems to reduce the quantity of waste being sent to landfill and reduce the global warming potential of their waste systems. However, if seeking the lowest global warming potential solution, the anaerobic digestion options would be more suitable. The capital cost of such solutions is probably out of reach of rural and regional local governments, so it is likely that the centralised composting option will remain an option of choice for such councils for some years yet.

Knowledge gaps exist regarding different collection systems, their acceptance criteria, how they are funded, and why local governments implement the different systems. Research into these programs and their effectiveness in diverting organic waste from landfill may see more councils implement collection systems for organics.

7. Regional Local Government Waste Strategies

State government legislation requires local governments to develop waste strategies that reflect the targets set in state government legislation or policies. These targets are not always mandated but in some instances state governments are beginning to mandate timeframes for implementation of services. For example, NSW and Victorian councils are required to introduce an organics collection for residents by 2030. This paper reviews several regional local government waste strategies from states and territories to assess their alignment with the relevant state legislation. To do this, one regional local government was selected for each state/territory, based on criteria that would, for a regional local government, generally make a FOGO collection more challenging than in an urban area. These criteria are a population of around 50–60,000 and a travel distance of around 1–2 h to a major urban area where a composting operation/organic treatment system is likely to be located.

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7.1. Cessnock City Council (New South Wales)

Cessnock City Council is located 120 km north of Sydney and 40 km west of Newcastle and the area has a population of almost 60,000 residents. The region has an extensive farming base, being one of the oldest wine-producing regions in Australia [89]. The Council's waste services include a 240-L general waste bin serviced weekly, and 240-L recycling and garden organics bins, both serviced fortnightly [90]. Food is not accepted in the garden organics bin, so Cessnock City Council does not yet meet the requirements of the NSW Environmental Protection Agency's state waste strategy which requires FOGO collections by 2030.

The Council's Waste and Resource Recovery Strategy 2020–2025 considers greater diversion of waste from landfill through improved resource recovery and aims to change residents' disposal behaviour by encouraging waste avoidance and a circular economy [40]. The strategy references the National Waste Policy [11] and the previous NSW waste strategy, the Waste Avoidance and Resource Recovery (WARR) Strategy 2014–2021 [91] which has since been replaced. The Council's waste strategy identifies the cost of waste, something rarely discussed in public documents by local governments. It recognises that providing waste management services is a significant cost to the Council and the community, and notes that every tonne of waste landfilled attracts the NSW government's waste levy. It also discusses the cost of operating the Council's waste facilities and services, notes that the existing landfill is nearing its operational capacity, and recognises costs associated with construction of a new landfill cell and remediation of old landfills. The Council has not identified its own waste targets, but notes that it will meet current and future NSW and regional waste and resource recovery targets for municipal solid waste [40].

7.2. Baw Baw Shire Council (Victoria)

Baw Baw Shire Council is located approximately 100 km east of Melbourne in the West Gippsland region. The region's population is currently 53,400 and is rapidly growing. Agriculture, manufacturing, and construction are the main industries in the Shire. The current compulsory three-bin waste system in the Shire includes a 120-L general waste bin collected weekly, a 240-L recycling bin collected fortnightly, and a 240-L garden waste bin collected fortnightly. In accordance with the Recycling Victoria strategy, the Council must provide a FOGO kerbside service by 2030; this service will be introduced in 2023–2024 and the Council will be compliant with state government requirements [41,92]. The strategy outlines linkages to national and state strategies with comprehensive acknowledgement and understanding of the connections to these documents.

7.3. Barossa Council (South Australia)

The Barossa Council, representing an area with a population of 25,569 is located 60 km northeast of metropolitan Adelaide in South Australia [93]. Under South Australian Government, Regional Waste Management Plans are required to be in place by 2023. Barossa Council is a member of the Legatus Group, a regional subsidiary established under the Local Government Act 1999 to represent fifteen councils that helps to facilitate and coordinate activities to contribute to economic and community development in the region. The Legatus group prepared a Waste and Resource Recovery Strategy 2021–2026 to outline goals and actions to assist councils to improve how they manage waste and create a consistent region-wide approach. The Barossa target is to reduce organics to landfill by 55% by 2026 [42]. In line with the state and regional strategies, in July, 2021 the Council introduced a mandatory 240-L green organics bin for food and garden waste in townships, collected fortnightly [94]. The regional strategy notes the connection to circular economy principles and the national food waste strategy. It also recognises the policy position of the state regarding the solid waste levy, a policy lever used to divert waste from landfill to resource recovery. There is no mention of the National Waste Policy.

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7.4. Central Coast Council (Tasmania)

The area represented by Tasmania's Central Coast Council is an 80 min drive from Launceston, with a population of around 23,000 [95]. The Council introduced a fortnightly FOGO kerbside collection for all domestic residents in 2019 [96]. The Council's Waste Management Strategy 2021–2026 notes that the FOGO service, since its introduction, has diverted 29% of the waste stream away from landfill. With recycling diversion at 18%, there remains potential for improvement if the Council is to meet their target of 75% diversion from landfill by 2025. The strategy mentions (1) circular economy principles, in alignment with the state Draft Waste Action Plan, and notes focus areas of state and national policy and regulatory settings; (2) policy levers such as a waste levy and container refund scheme; and (3) potential participation in national product-stewardship schemes [46].

7.5. City of Bunbury (Western Australia)

The City of Bunbury, with a population around 32,000, is located around two hours' drive from Perth in Western Australia [97]. The Council is aligned with the state's Waste Avoidance and Resource Recovery Strategy 2030 [38]. Bunbury was the first Western Australia council to introduce a three-bin system for waste. Weekly kerbside FOGO waste collection was introduced in 2013 and this service now aligns with the Western Australia waste strategy. This service has been successful in achieving a kerbside recovery rate of about 65% [98]. The FOGO material is sent to a local composting facility operated by Bunbury-Harvey Regional Council, a statutory local government established by Bunbury and Harvey Councils to manage waste recovery and disposal. This facility manages around 15,000 tonnes of organics and produces a range of compost products [98,99]. Whilst on the surface it would appear the kerbside process is successful and is reaching its diversion targets, recent media attention has focused on issues with the treatment process. The media reported that up to 25,000 tonnes of FOGO material was sitting unused in compost piles while households were still being urged to continue separating their waste at the kerbside. The organic waste facility was unable to process incoming material at the rate at which it was being generated and it is reported that 10,000 tonnes was taken to Council's landfill where it was used for rehabilitation, representing a known barrier to the establishment of organics processing facilities [100].

7.6. Alice Springs Town Council (Northern Territory)

With a population of 28,601 and located in the south of the Northern Territory, Alice Springs is one of the most remote regional centres in Australia [101]. The Council does not appear to have a dedicated waste strategy, but food waste is briefly mentioned in the Alice Springs Liveability and Sustainability 2030: Alice Springs Town Council's Strategic Plan [44]. In 2020 Council trialled a FOGO service with 86 participants where each property received a 240-L kerbside organics bin, an 8-L kitchen caddy, and compostable liners. Bins were collected weekly with some being collected fortnightly to determine the impacts of odour and vermin in the hotter summer months. Participants were selected through expressions of interest. The Council processed the collected organics themselves but encountered challenges reaching the Australian Standard 4454–2012 due to limitations in resources and staff capacity [102].

7.7. Lockyer Valley Regional Council (Queensland)

Lockyer Valley Regional Council is located one hour's drive west of Brisbane and represents a population of around 43,000 [103]. The Queensland Government funded the Council to undertake a twelve-month, 1000-household trial of a FOGO service. As part of the trial, the Council provided an additional bin to households for FOGO material and tested collection frequencies, infrastructure types, and community engagement methods [104]. The Council's Waste Reduction and Recycling Plan 2019–2022 recognises the National Waste Policy 2018 and was developed in parallel to the Queensland Government waste strategy. At the time the plan was developed, FOGO comprised 44% of the

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residual waste bin, which provided an opportunity for organics recovery. Targets set in the plan included identifying opportunities for improved resource recovery, with a particular focus on improving organics processing, reviewing local and regional markets for organics, and reviewing and trialling options for recovery of organics [39]. During the trial, the Council collected almost 400 tonnes of FOGO material and this was converted to compost in an aerated floor, static pile processing facility operated by the Council [105].

Whilst the above regional councils are only a snapshot of the organic waste collection activities carried out in Australia, it can be seen that regional councils are beginning to provide FOGO or other collection services for organic waste that reflect state strategy requirements. The challenge for regional local governments is to provide services that both meet the needs of state strategies and are also affordable for their communities with treatment options available for management of the collected organic waste.

8. Barriers, Constraints, and Challenges for Organics Collection

Management of organic waste starts in the household, and options for source separation of different waste streams are limited in Australia, particularly in regional areas. Households have various understandings of waste streams, and value the various streams differently. For example, gardeners may value food waste as they put in place the necessary processes to utilise the waste as a soil conditioner (compost), but those who are not gardeners may not see the value in systems such as composting. Australia is a high-income country and with the various food preservation systems available to consumers (i.e., refrigeration, readily available fresh foods, etc.), there is limited scarcity of food and therefore more food waste is generated. Behaviours of households in managing food waste, particularly when using source-separation collection systems, is pivotal to the success of such systems [106,107].

Treatment of organics has been limited by a number of factors including the low financial cost of landfilling in some countries [108], high establishment expenditure (i.e., capital and operating) and ongoing costs for different technologies, public acceptance (or social licence), and willingness to pay [109]. The challenge for governments now is to use the policy levers to make alternatives to landfilling more relevant and affordable to local government. Importantly, these policy levers should not only achieve outcomes in urban areas but also support regional local governments, which must manage waste effectively with fewer resources and funds.

Affordability is a challenge for regional local governments due to regularly competing priorities for small budgets. This challenge can be exacerbated when local governments divert funds collected for management and treatment of waste in order to balance budgets, as has occurred in Spain [110]. This also appears to be a common occurrence in Australia, and an area where effective policy levers established at the state and national level can generate positive change for improved waste outcomes. Many councils adopt full cost pricing to understand the cost of providing a waste service but then use the revenue raised to subsidise other council services [111]. State governments are similarly guilty, with the NSW Government pocketing two thirds of the waste levy rather than investing the dollars in the waste and resource recovery sector where the funds are generated [112]. The Queensland Government commits 70% of waste-levy revenue to reinvestment into waste management and resource recovery projects, infrastructure, and initiatives [113]. The Victorian Government uses waste-levy funds to support agencies to manage waste and resource recovery activities and the remainder is disbursed to initiatives under the Sustainability Fund, including sustainability initiatives not just related to waste and resource recovery [114]. Diverting funds collected from waste levies for activities not related to waste and resource recovery initiatives does not provide the best outcomes for the waste sector, and this is particularly the case for regional local governments where the ability of smaller councils with fewer rateable properties to collect funds to support improved waste management is limited.

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The challenges and constraints for organics collection in local government have been scrutinised and include some elements that are relevant to regional local government [115]:

- Collection and treatment of FOGO waste is more expensive than landfill where landfilling is low cost or where there is no landfill levy.
- Contamination may increase if food waste is added to existing green waste bins.
- Long distances can make kerbside waste collection very expensive in regional areas.
- Composting processors are generally located close to urban centres as they require significant tonnage to make business worthwhile. Regional centres are often located quite some distance from composters, which adds transport costs to local government pricing.
- The commercial composting market may not be of sufficient size to absorb additional waste streams and volume.
- The horticultural, agricultural, or landscaping industries may not be able to absorb the final compost product.

The reluctance of residents to pay for services over and above those already offered by local councils can be a barrier to introduction of new systems and can affect the political economic framework of new waste-collection services [116]. Benyam, Rolfe and Kinnear [116] researched the willingness-to-pay component of regional Queensland residents' beliefs and developed a new method for evaluating new policy options to improve waste management at a local level. The research showed that reduction of greenhouse gas emissions was not a key driver in willingness to pay for separate organics collection services. The willingness-to-pay estimates can be factored into a cost/benefit analysis and the estimates of likely support or opposition can be inputted into a political economy framework. Reluctance to pay is a barrier and knowledge gap that warrants further research to understand user behaviour and the likelihood of adopting any new service.

Education and behaviour change programs are essential when introducing or conducting any source-separated waste system. For FOGO, the challenges to reduce contamination to as low as possible are ongoing for local governments, and waste education programs for householders must always continue while the system is operational. The greatest challenges reported by producers of FOGO-derived composts relate to meeting the appropriate certification limits, particularly parameters related to physical contamination and, specifically, plastic content. Compliance with certification standards ensures market confidence in the resulting compost and subsequently greater availability of markets for FOGO use [117].

9. Recommendations and Future Work

This review found minimal literature on FOGO collection and treatment systems in Australia, which indicates these are still emerging in comparison with other countries. Whilst the NSW and Victorian state governments are national leaders in requiring FOGO collections for households by 2030, other states are silent on mandated FOGO collections in their waste strategies [23,28]. Leadership and direction from these state governments will set the path for local governments to follow. Mandated FOGO services will also be supported by appropriate funding programs in those states with mandated collections, which will alleviate financial pressures faced by local governments when implementing such collections [23,28]. Support though funding using subsidies or incentives for the establishment of FOGO programs is paramount to local governments introducing such services.

Programs such as mandated FOGO collections and landfill bans are all supported by regulation when the Australian or state governments require the necessary programs or change to be implemented. In Queensland, for example, fundamental legislative principles are considered when making and introducing legislation, and this includes consultation with affected parties including local governments. These parties are given an opportunity to comment on proposed regulation prior to introduction of any legislation for Parliamentary approval and Royal Assent [118]. This process has the effect of broadcasting proposed legislative and program change to local governments and allows time for programs to be

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prepared. Consideration for funding and incentives at the time of legislation development is key to ensuring the success of any new program.

The literature review identified the following knowledge gaps that, if addressed, could see improved outcomes in management of organic waste, reduction of the impact of this waste on GHG, and increased resource recovery:

- Programs for FOGO collection are emerging in Australia. Research is needed to
 identify the genuine barriers to the introduction of kerbside services for FOGO and
 how these barriers can be overcome to make such collections economically viable.
- The reluctance of ratepayers to pay for a separate organics waste service from a regional council is a barrier warranting further research to understand user behaviour and the likelihood of adoption of any new service.
- The cost and imposition of an organics collection service on ratepayers have not been thoroughly reviewed, particularly in a regional Australia setting, and leave scope for research.
- Some councils offer opt-in or opt-out organics collections systems. It is necessary to
 develop an understanding of how each system works and determine the success of the
 different systems and how they may be applied to different regional local governments.
- Lack of regulation to force state or local government to reduce waste to landfill is
 inconsistent with international trends. Researchers should consider how regulation
 could be used to improve organic waste collection and processing systems in regional
 settings and how such policy may be set at the state government level to assist local
 governments to implement the services most relevant for their communities.
- The varying layers of legislation affecting waste management and waste collection influence the activities undertaken by local government in organic waste collection. Consideration of how these legislative layers combine with regulation to 'force' councils to collect organic waste could provide improved services and further reduction of organic waste from landfill.

10. Conclusions

Management of organic waste by regional local governments is challenging in comparison to urban or metropolitan areas. This review identifies knowledge gaps around the collection and treatment of food and garden waste by regional local governments in Australia. Further research is required to understand how household attitudes and knowledge inform how residents separate waste at the source, and how this influences their willingness to pay for a separate FOGO collection system. The policy levers that drive change in waste management in Australia come from national and state tiers of government and are still in their infancy in comparison with European waste management, which is more sophisticated and involves diversion from landfill as standard practice. Regional local governments in Australia are a long way from achieving these outcomes and need encouragement and support through the right policy levers to improve resource recovery. Determining those that work best will drive the best environmental and economic outcomes for ratepayers.

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