The Circular Economy in Regional South Australia: The potential for making and using organic compost

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Executive Summary

This project builds on a previous study of biosolids and septage waste within Legatus Group councils which found that there was insufficient volume of this material to establish a composting plant. This study identifies additional sources and volumes of compostable organic waste from primary producers in the Mid North and potential users of locally produced compost within Legatus council region. It also discusses challenges and opportunities of combining compost feedstocks, potential contamination and stakeholder engagement.

The main business obstacles within the scope of this study are feedstock contamination and industry standards, and availability of feedstock (Australian Organics Recycling Association 2021). Findings from this research suggest that sourcing a reliable supply of low-contaminant feedstock suitable for composting within the Legatus council region is likely to be a large obstacle that needs further investigation. Local government procurement of end products may also play a major role in the sustainability of a composting facility, particularly if the bulk of feedstock ends up being council collected organics. Utilising locally generated recycled organics within council projects such as landscaping would be a first step in implementing a circular economy within Legatus Group.

Research outcomes and business recommendations are summarised below:

1. Sources of high-carbon organic feedstock need to be targeted within the Mid North to balance the high nitrogen content in biosolids and sewage sludge. The agriculture industry potentially has large volumes of source-separated organic waste. Contaminants present in this feedstock would likely be identified through existing testing and knowledge of their produce.

While data from the South East agriculture industry show large volumes of organic material being generated, there is insufficient data about what types and volumes might be available within the Legatus region. Data of waste streams from Mid North and South East SA are estimates and note that much of it may already be allocated and unavailable or unsuitable for composting

Interviews with Legatus stakeholders indicate that primary producers are not reporting much waste and that they already have practices in place to manage what by-products are being generated. Farmers are using a combination of synthetic fertilisers, biosolids and manure to improve soil productivity. However, none of the three participants interviewed are using products that have been combined with other organic inputs.

Primary producers would like to use more compost and manure for longer-term benefits, ideally products that are produced locally. However, year-to year finances can be an impediment to investing in these.

- Further research is needed to identify potential sources of high-carbon compostable feedstock from the agriculture sector.
- Recommend developing and distributing a stakeholder survey via a communication campaign that focuses on the advantages of blending feedstocks into a more refined, treated composted product.

2. If stables volumes of feedstocks cannot be sourced from the agriculture industry, Legatus council-managed organic waste and biosolids may be the primary inputs for a regional composting plant. Both of these inputs are known to be high in contaminants. End products would need further research and testing before use. Legatus councils may also need to establish or expand kerbside organics waste collection to ensure sufficient supply of material to achieve starting C:N of 25-30:1.

- Recommend most likely application of these composted end products to be non-food chain applications such as landscaping (dependent on testing).
- Recommend implementing waste education plan for kerbside bin users to minimise contamination of materials.

3. While biosolids and sludge can be applied directly to agricultural land (as liquid slurry or dry pellets), it is the least ideal disposal option aside from landfill. Any soil

conditioning benefits must be weighed against the risk of physical, chemical and biological contaminants that can make their way into the human food chain.

Composting can help to mitigate these risks through heat pasteurisation and contaminant dilution. However, care must be taken when selecting organic inputs for combination as these can, and often do, contain contaminants as well. As contamination is large risk, input sources that maintain records of feedstocks need to be prioritised.

While the Australian standards for compost are voluntary, any composted material produced by a regional composting facility should be tested for compliance with the AS 4454:2012. Testing is needed to ensure quality and safety for end users, particularly if agriculture and horticulture are the main likely consumer markets.

Established commercial composting facilities were not contacted for this study, however they may be able to offer industry insight into sourcing appropriate feedstock, managing contaminants, technologies and additional markets for finished products. They should also be considered as potential outsourced operators and mutually beneficial partners with the Legatus Group.

- Recommend that compliance with AS 4454:2012 be considered best practice.
- Recommended future engagement with currently established commercial composters in South Australia.

Project Background

The background of this project is adapted from the contract between Legatus Group, APR Intern, and Central Queensland University.

The Legatus Group is a peak regional local government organisation. It has 15 member councils from the Adelaide Plains, Barossa Valley, Mid North, Yorke Peninsula and Flinders Ranges of South Australia. The Legatus Group is currently managing the drafting of a Regional Waste Management Strategy on behalf of the South Australian Regions of Councils (SAROC) and overseeing work on Community Wastewater Management.

The Legatus Group councils are located in agricultural areas, dotted with small rural towns. Both are sources of significant quantities of organic waste and there is potential to develop facilities to compost that waste into fertilisers that can also be used in the region. Realising that potential will provide a leading illustration of the circular economy in a regional setting.

This study addresses the problem faced by many Councils of managing biomass from wastewater treatment plant. It will also be of particular benefit to the agricultural sector. Organic waste is an inevitable consequence of growing and processing food and the region has many intensive horticulture and livestock farming sites, viticulture and abattoirs which have a particular need to deal with organic waste efficiently. The work also aims to benefit the food and wine industry, of which the region has many examples, by providing high quality, locally produced compost.

Research conducted in this study:

- Builds on previous work at Legatus, which has considered sewerage sludge as a source of compostable materials, to now include major agricultural sources of material (e.g., vegetative waste, manures, abattoir waste)
- Analyses the benefits and limits of combining available regional materials for compost
- Identifies the stakeholders among sources of inputs and uses of output

- Discusses the challenges and responses required to realise the potential for producing and processing locally produced compost for later use

Outcomes from research conducted include an assessment of the potential to apply the concept of the circular economy to organic compostable material in regional SA. This document highlights the challenges that might need to be overcome to reach that potential and makes recommendations to address them. The recommendations will be incorporated into advice to the South Australian Region Organisation of Councils (SAROC) and the South Australian Government regarding a strategy for regional Councils to participate in the regional economy, the so-called Regional Waste Management Strategy.

This report therefore:

- Identifies sources and users of potentially compostable material from wastewater plant in conjunction with agricultural waste in the Legatus region
- Estimates the quantities, applicability to composting and optimal combinations of these sources
- Discusses the stability and certainty of supply of inputs and demand for outputs from any regional composting plant
- Assesses the potential to make a more detailed business case for future investment

Research Method

Research conducted consists of a scoping literature review and semi-structured interviews. The literature search was undertaken by the PhD intern with guidance from both academic and industry mentors. Approximately halfway through the project, a collaboration was formed with a second PhD intern from Victoria University and his academic supervisor. They were working on the same regional composting project, but with a focus on supply chain logistics. The wider team developed a stakeholder questionnaire relevant to the overall project and human ethics was approved to conduct interviews with primary producers (Victoria University, HRE21-008 16/02/2021).

Desktop background research of currently available information was undertaken to investigate the potential to compost and use biosolids in regional South Australia. Sources focused on Australia where possible and included:

- Peer-reviewed academic literature (searched using Google Scholar, SCOPUS, and Science Direct)
- Industry publications, websites and webinars
- Online news articles
- Unpublished data from local consultants Rawtec and Cornell University

Primary producers within the Legatus region were interviewed by both interns to better understand the potential supply of compost input feedstocks, demand for end products, and how to ensure quality control along the supply chain. Potential stakeholders were identified and classified into sources, users, and processors of compostable organic material. However, overlaps between these groups were noted. Interview participants were approached through Legatus contacts and their recommended contacts using a snowball sampling method. Three participants took part in the study and were asked:

- What types of organic waste they are generating, how much, and when?
- What they are currently doing with their waste?
- What the costs/benefits/challenges are with current organic waste practices?
- Whether they use compost and their interest in locally produced soil amendments

Information from some stakeholders unable to be contacted was sourced from their websites.

Introduction

It is necessary to understand the composting process in order to identify appropriate sources and users of recycled organic products. An overview of compost methods and technologies being used in local and interstate facilities is provided to help assess potential benefits and challenges of establishing a new regional composting facility.

Biodegradable organic materials from municipal waste and agriculture industries can be recovered and recycled through composting. Compost is decomposed organic matter that has been broken down through a controlled microbial process. Microorganisms including bacteria, fungi and protozoa break down organic waste into a usable form for plant production and soil health (Epstein 1997). Recycled organics are classified as mulches, soil conditioners, and composts based on the quality of input materials and the outcome of the composting process (Environment Protection Authority 2019). Application of products range from rehabilitating degraded land to horticulture, while only composts that are sanitised, mature, and stable can be used without restrictions (Environment Protection Authority 2019).

Compost recycles nutrients and organic matter that benefit soil and plants when used as a conditioning amendment (Epstein 1997). Land application of stable compost improves the structure of soil by increasing soil carbon and moisture retention. This helps insulate and cool root zones from large temperature fluctuations. It also conserves water by reducing evaporation and the need for irrigation on crops.

Compost is relatively low in plant nutrients compared to fertiliser. However, depending on feedstock used, it can contain essential nitrogen, phosphorus, potassium and trace elements (Epstein 1997). The main advantage of compost application is to encourage and sustain beneficial soil microbes and organisms that are lost through crop production, drought, erosion, etc. Compost-amended soil microbes increase available plant nutrients and resilience to pests and diseases through competition (Epstein 1997). This in turn helps to reduce the need for chemical fertilisers and pesticides/herbicides.

Compost Process

Producing good quality compost relies on several factors: particle size of raw material, aeration, moisture, temperature, pH, carbon to nitrogen ratio (C:N) and contaminants, including pathogens (Epstein 1997, Agnew and Leonard 2003). The majority of industrial composting facilities in Australia use open air windrows to process recycled organics (Australian Organics Recycling Association 2021).

Windrows are piles organic materials placed in long rows that are turned and watered by special machines. Input materials are shredded to jump start the decomposition process and increase the surface area for microbes to thrive.

Equipment, such as the mechanical windrow turner shown in Figure 1, mix materials throughout the active composting phase and can be fitted to add water and blow air at the same time. Aerating the windrow provides sufficient oxygen concentrations (10-14%) to prevent the mixture becoming anaerobic. Physical turning of the compost mixture breaks up clumps of material, helps to regulate temperature, and ensures that all surfaces are exposed to heat for pathogen disinfection (Bolin and Pereira 2009).

Figure 1 Mechanical windrow turner

The optimal moisture content of compost is 50-60% (Epstein 1997). Water is lost through evaporation in open air windrows so often needs to be supplemented.

Microbes become water stressed when there is too little moisture, and the decomposition process slows or stops. Too much moisture can result in the mixture becoming anaerobic and emitting foul odours. When mature, maintaining ideal water content prevents the compost from becoming clumpy or dusty.

The aerobic composting process has three main temperature phases as seen in Figure 2. When organic materials, also known as feedstock or biomass, are combined, bacteria and fungi grow rapidly and begin to break down soluble sugar and starches. This first mesophilic, or ambient (10-40ºC), phase lasts only a few days. As microbes multiply, they create heat in the compost mixture and thermotolerant microorganisms become active. Intense decomposition occurs during this thermophilic phase (>40ºC) and most pathogens including weed seeds are disinfected when temperatures exceed 55ºC. Proteins, fats, and plant cellulose are broken down by microbes for days to weeks until they have used up their available food supply.

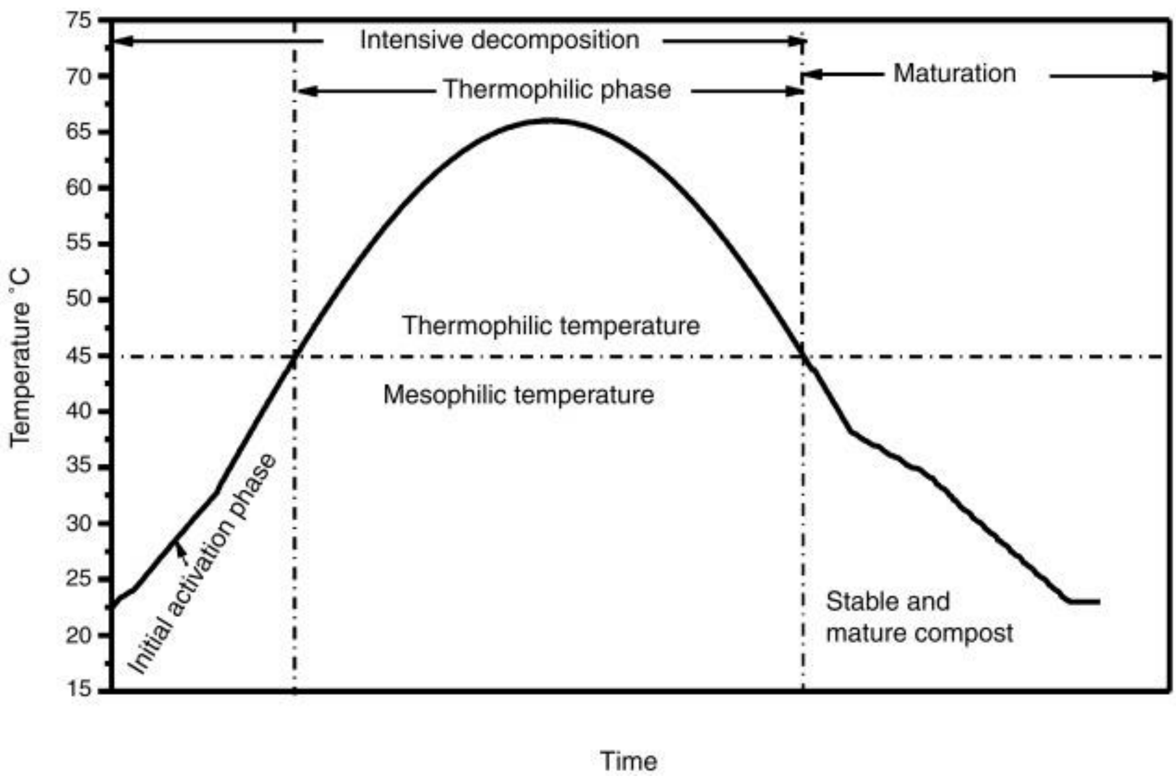

Figure 2 Phases of the aerobic composting process (Epstein 1997, p21)

With active composting complete, the compost mixture cools down and enters the final curing phase. Mesophilic bacteria, fungi, actinomycetes and invertebrates work on slowly breaking down the tough carbon-based materials that remain (Epstein 1997). Depending on what feedstock was used and the compost conditions, this phase can last weeks to months. The ideal end result is a mature, stable, pasteurised compost.

The decomposition process can be measured by changes in pH levels (Agnew and Leonard 2003). pH is the concentration of hydrogen ions, with low levels being acidic (lower than 7) and high levels being alkaline (higher than 7) on a pH scale of 0-14. As water (H_2O) evaporates and ammonia (NH_3) is released in the initial phase, hydrogen ions are lost, and the pH of the mixture becomes more acidic. Decomposing microbes become stressed when pH is too high or low, so they regulate their activity to encourage relatively neutral (6.5-7.5) pH conditions present in later phases (Epstein 1997).

The compost process is fuelled by microorganisms consuming organic matter as food. These microbes need 25-30 carbohydrates (C) for every protein (N) they consume (Epstein 1997). Therefore, ratios of organic materials need to be combined in the right proportion for microbes to effectively decompose them. The ideal starting ratio is 25-30 parts carbon to 1 part nitrogen, or a C:N of 25-30:1. Nitrogen and carbon are used up during the composting process as ammonia (NH_3) and carbon dioxide (CO_2) gas emissions. When the process is finished, a mature compost should have a C:N of 10-15:1, similar to that found in soil organic matter (Bolin and Pereira 2009). Compost with C:N higher than 10-15 can indicate that microbes are still active. If this compost is then applied to soil, the microbes will compete with plant roots for available nitrogen nutrients.

Compost Technologies

Aerobic composting is the most common method for managing organic waste, however anerobic digestion and vermicomposting technologies are also used (Bolin and Pereira 2009). Organics composted outdoors in commercial quantities break down naturally and considered to be cost and energy efficient. Using aerated containers or rotating drums can reduce processing time, but they also considerably increase infrastructure costs.

Anaerobic digestion breaks down organic material in enclosed vessels without oxygen using fermentation (Bolin and Pereira 2009). This process produces methane (CH_4), which can be collected and used as a biogas. Methane cannot be collected from windrows as they are open to the air. The remaining liquid and solids can then be further aerobically composted or dehydrated and pelletised for land application. Anaerobic digestion is considered a cost-effective method for areas with low volumes of organic feedstocks (Office of Green Industries SA 2015).

Vermicomposting utilises digestive microbes and enzymes of earthworm species such as *Eisenia foetida* to break down organic waste into vermicast (Fornes, Mendoza-Hernandez et al. 2012). Compost worms are unable to produce a heat-pasteurised product as they cannot survive long in conditions above 35ºC. Vermicast has value as a nutrient-rich soil conditioner but should be used with caution as it can contain pathogens. Alternatively, organic materials can be pre-treated using worms before aerobic composting to reduce processing time.

Compost Facilities

The following are examples of industrial compost facilities, mostly in regional areas. They illustrate how different compost technologies and partnerships between local councils and industry are being applied. Many of these facilities accept biosolids and septage waste as feedstock.

South Australia

South Australia currently has several commercial compost producers, mainly located in metropolitan Adelaide and the south-eastern regions. The facilities listed are known to be operating, however there may be others. Only one compost producer, North Waste, is located within the Legatus council area. Larger commercial facilities closest to the Mid North and Yorke regions are Jeffries, in Wingfield, and Peats Soil, in Dublin.

- Jeffries: Wingfield
- Peats Soil and Garden Supplies: Willunga, Brinkley, Dublin, Whyalla
- North Waste: Korunye
- SA Composters: Lonsdale
- Mulbarton Transport: Padthaway
- Van Shaik's BioGro: Mount Gambier
- Nuleaf Organics: Mannum
- Australian Vermiculture: Mt Compass

Jeffries uses open windrows to process 150,000 t/yr of mixed green waste, much of it consisting of food organics and garden organics (FOGO) from metropolitan Adelaide kerbside bins. Peats Soil operates across 4 sites, receiving and processing food waste, green organics, manure and sewage sludge. They also use turned windrows except at their Whyalla facility. This site uses anaerobic digestion to produce biogas sold to the grid and composted products sold to local agriculture consumers. Australian Vermiculture produce liquid and pellet fertilisers from worm castings, but it is unclear what types of organic materials they accept.

Regional New South Wales, Western Australia and Victoria

The Dubbo Regional Organics Processing Plant in NSW was co-financed though contributions from the NSW EPA, Dubbo Regional Council and commercial compost processor JR Richard & Sons (Waste Management Review 2018). The facility processes organic waste collected from 3 neighbouring councils.

In Port Stephens, NSW, organic materials are recycled as part of a single waste transfer station. The facility accepts comingled household rubbish and green organics from approximately 73,000 residents (Virtue 2017). Waste is screened upon arrival, with organic material removed and composted using a long rotating vessel. Composted products are used to rehabilitate mine sites in the Hunter valley. The facility was developed by Port Stephens Council and sub-contracted to operator Suez.

Suez is an international waste management business and industrial compost processor. Their plant in Bannister Park, WA is located 100km from Perth. They produce 23,000 t/yr of compost from household, commercial and agricultural waste using covered, aerated piles (Suez 2021b). The technology is similar to windrows, but they are covered to retain moisture and aerated with pipes underneath the piles rather than mechanical turning. The Suez facility in regional Epping, VIC processes 65,000 t/yr of organic feedstock collected from 5 councils (Suez 2021a). The open windrows system takes 8-12 weeks to complete and much of the end products meet AS 4454:2012, the Australian Standard for Composts, Mulches and Soil Conditioners (Suez 2021a).

Gippsland Water in Sale, Victoria processes up to 25,000 t/yr of biosolids (Gippsland Water 2021). The EPA-licensed waste treatment and composting facility accepts a wide variety of organic waste from agriculture, food processing, and municipal streams. Feedstocks are blended and composted using turned windrows. End products undergo in-house analysis and independent lab testing to demonstrate compliance with the AS 4454:2012standard. The compost is packaged and sold to the broadacre agriculture industry through an independent vendor.

Compostable Feedstock

South Australia currently has the highest organics material recycling rate at 78.9%, recovering 259,966 tonnes of waste in 2018-2019 (Australian Economic Advocacy Solutions 2020). Organic feedstocks appropriate for composting include a variety of materials from metropolitan and agricultural waste streams such as (Environment Protection Authority 2019):

- Untreated timber, sawdust, pallets, branches, straw, paper, cardboard
- Food waste, crop residues, grape marc, olive pomace, brewery waste
- Animal faeces, farmyard bedding and manure
- Sludge from food and agricultural and meat production and processing
- Biosolids and sludge from sewage treatment works

Types and Volumes

Existing reports approximate the quantities of council-managed biosolids and organic waste being produced within the Legatus Group region. It is estimated 3751 t/yr of sewage sludge is generated (Sapdhare 2019) and over 15,000 t/yr of organic materials are produced and collected (Rawtec 2020) amongst Legatus Group councils each year. Table 1 outlines the estimated volume of mixed organic waste, timber by council and means of collection – kerbside and drop-off. Cardboard volumes have been included as any soiled material unsuitable for recycling could be a potential compost feedstock. Timber waste is assumed to be untreated and appropriate for composting or mulching. It is unclear how much of these organic materials may already be allocated for other uses, unavailable, or unsuitable for composting.

Table 1 Estimated volumes of organic feedstock within Legatus councils (adapted from Rawtec 2020)

Legatus Council	Population	Organics kerbside recycling (tonnes)	Organics drop-off (tonnes)	Timber (tonnes)	Total Organics recycling (tonnes)	Cardboard (tonnes)
Adelaide Plains	8,801	232	29	276	**537**	196
Barossa	23,560	1,475	1,798	740	**4,013**	523
Barunga West	2,542	109	194	80	**383**	56
Clare & Gilbert Valleys	9,021		689	283	**972**	200
Copper Coast	14,138	181	2,147	444	**2,772**	314
Flinders Ranges	1,640		175	52	**227**	36
Goyder	4,134		500	100	**600**	1
Light	14,733	1,228	1,125	463	**2,815**	327
Mount Remarkable	2,861		218	90	**308**	64
Northern Areas	4,529		346	142	**488**	101
Orroroo Carrieton	899		50	28	**78**	20
Peterborough	1,678		50	53	**103**	32
Wakefield	6,804	256	519	214	**989**	151
Yorke Peninsula	11,060	1,000	150	347	**1,497**	246
Total	**106,400**	**4,481**	**7,990**	**3,312**	**15,782**	**2,267**

Some councils accept garden waste and others both garden and food waste in kerbside green bin services. Councils without kerbside bins and are anticipated to have large amounts of green organics in their general waste (landfill) bins. Much of this uncollected waste, both from residents and businesses, could potentially be composted if local facilities were available (Rawtec 2020).

By comparison, councils in the South Eastern region collect 20,900 t/yr of biomass waste, about 2/3 more than Legatus councils in the Mid North. 16,900t/yr of this waste is considered accessible for recycling (Rawtec 2014). Figure 3 shows that biosolids and septage make up a relatively small proportion of the overall residential and commercial waste being generated. An additional 50-60% of organic material may be ending up in landfill disposal but could be diverted to resource recovery. Nearly all (95-100%) of council managed material is currently being recovered and disposed of through direct land application and composting but it could be used to manufacture higher value products (Rawtec 2014).

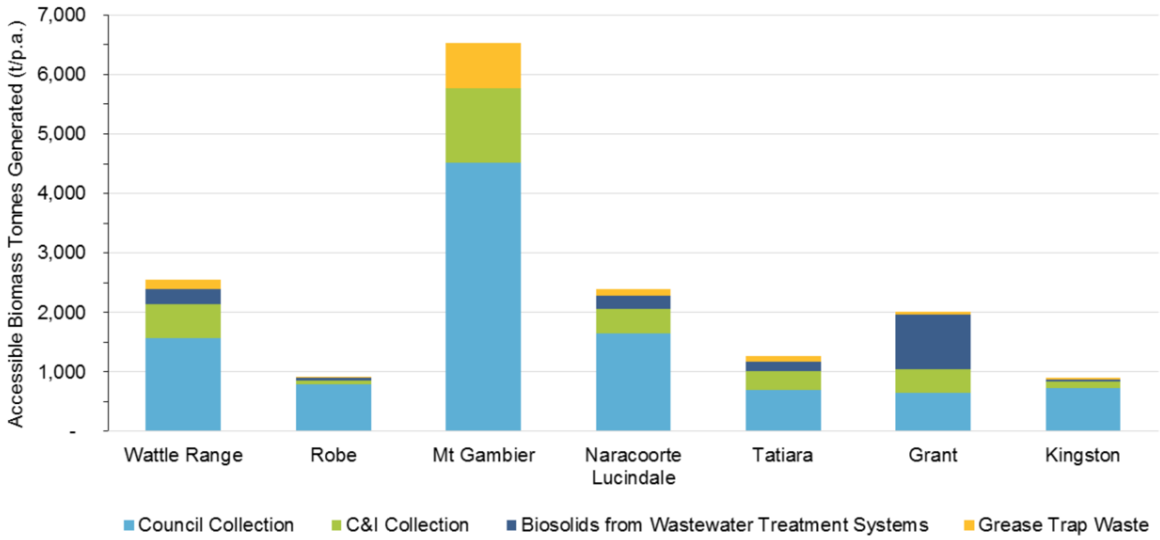

Figure 3 Accessible Waste Biomass residential and commercial organic waste tonnes generated by Council region and type (Rawtec 2014, p8)

There is no known data on the types and quantities of potentially compostable organic materials that are not managed by councils in the Mid North. However, the Legatus and South Eastern SA regions have similar primary industries such as broadacre crops, viticulture, horticulture and animal production. Sources and volumes of organic waste can be inferred from data on council, crop residue, agricultural processing, and animal waste in the South East. It is worth noting that most of the commercial composting facilities in SA are located in this region and that farmers are the main end users of commercial compost.

Figure 4 breaks down the 11 million t/yr of agriculture biomass by crop and each council. Broadacre cereal crops are the largest source (67%) of crop residue available in the South East at 3.5 million t/yr (Rawtec 2014). Up to half of the total crop waste is assumed to be committed to uses including animal feed, composting, and on-farm disposal (Rawtec 2014). Organic residue that is not being collected is most likely being left where it's produced, such as fields. This has the potential to be recovered and utilised.

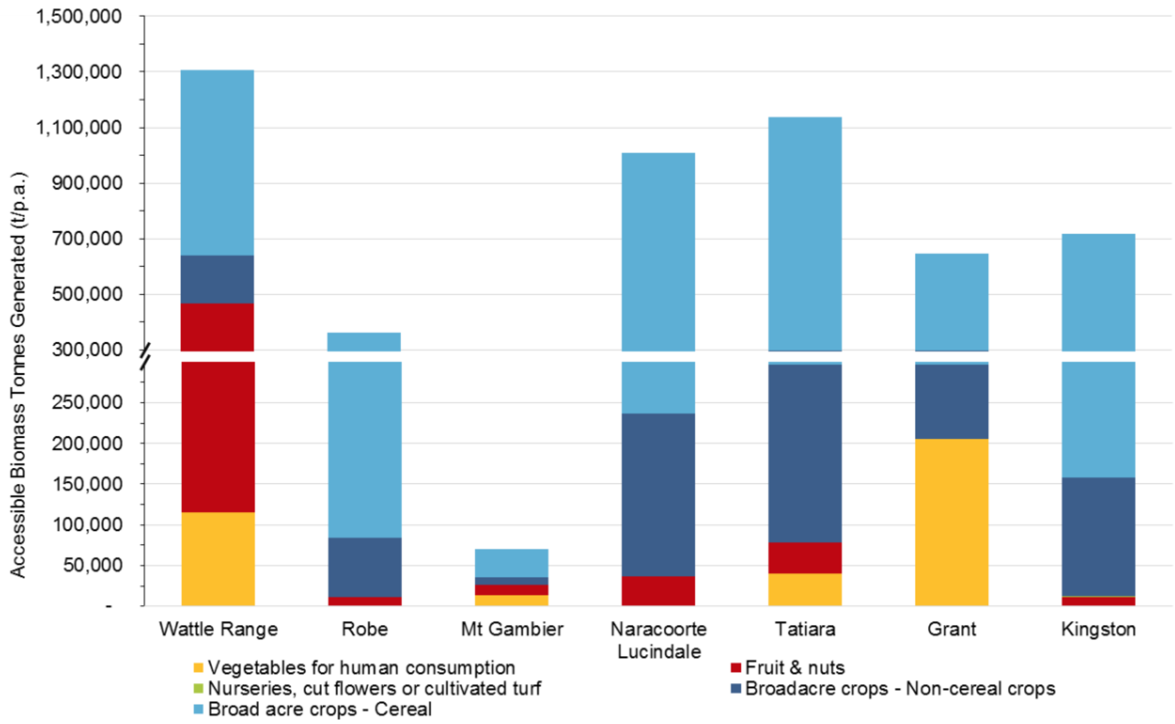

Figure 4 Accessible Waste Biomass crop residue tonnes generated by crop type and Council region (Rawtec 2014, p6)

Figure 5 summarises the estimated 72,000 t/yr of manufacturing and processing waste by industry and region. The wine and meat industries make up over 70% of this waste stream. Similar to council-managed waste, most of this material (95-100%) is thought to be allocated to resource recovery and disposal (Zero Waste SA 2014).

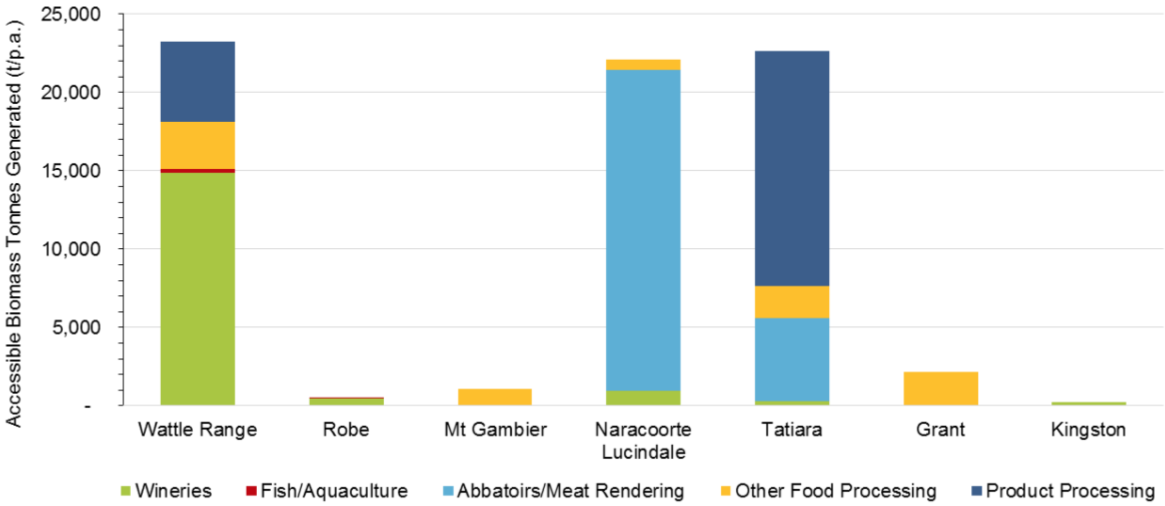

Figure 5 Accessible Waste Biomass from manufacturing and processing residue by industry type and Council region (Rawtec 2014, p7)

Approximately 15.5 million t/yr of waste biomass is generated from animal production in the South East. However, only 1% (209,000 t/yr) is considered accessible as most waste results from field animals which is difficult to recover (Rawtec 2014). Figure 6 shows estimated volumes by animal from industries including cattle stockyards and feedlots, dairy milking sheds, piggeries and poultry farms. Of the animal waste that is recovered, the bulk (95-100%) is thought to be committed to other uses such as land application and composting.

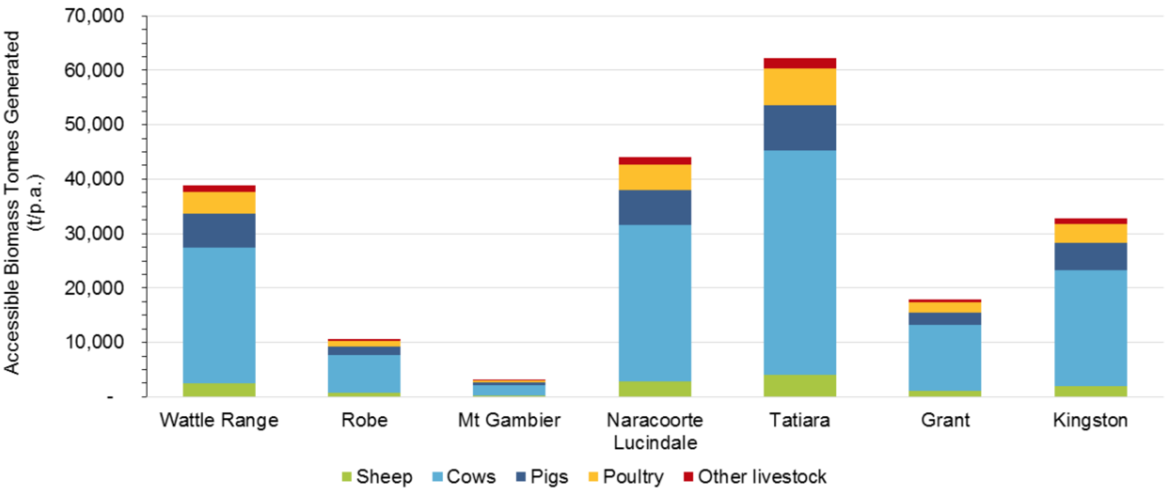

Figure 6 Accessible Waste Biomass animal wastes generated by Council region and animal type (Rawtec 2014, p7)

Combinations

Estimated carbon to nitrogen (C:N) ratios of compost feedstock can be sourced from existing data sets such as that from Cornell University (2014). Data typically includes the total percentage of nitrogen, carbon, C:N and moisture present in each material. Table 2 describes the average C:N of feedstock typically found in compost and assumed to be available within the Legatus council region. Materials rich in N include sludge, most animal manures, food waste and grass clippings. Digested sewage sludge is comparable to septage waste and biosolids that have gone through some initial microbial treatment. High C feedstocks include wheat straw and wood-based materials. Feedstocks that contain a more balanced C:N include olive husks, shrub trimmings and mixed council-based organic waste. Using a C:N calculator, data from various feedstock can be combined and adjusted to achieve an ideal estimated starting C:N of a compost mixture.

Table 2 Estimated carbon to nitrogen ratios (C:N) of compost feedstocks

High N Feedstock	C:N	High C Feedstock	C:N	Other Feedstock	C:N
Digested sewage sludge	16:1	Sawdust	442:1	Horse manure	30:1
Food waste	15:1	Lumbermill waste	170:1	Olive husks	32:1
Pig manure	14:1	Cardboard	563:1	Shrub trimmings	53:1
Cattle manure	19:1	Phone books	772:1	Dry leaves	54:1
Sheep manure	16:1	Hardwood chips	560:1	Oat straw	60:1
Poultry broiler litter	14:1	Softwood chips	641:1	Mixed council organic waste (food, paper, etc.)	57:1
Grape marc	24:1	Hardwood bark	223:1		
Hay	24:1	Softwood bark	496:1		
Grass clippings	19:1	Paper pulp	90:1		
Tree trimmings	16:1	Wheat straw	127:1		
Coffee grounds	20:1	Newsprint	625:1		

When considering the C:N ratio of council collected organic waste, it is important to note the difference between garden waste and food organics/green organics (FOGO) waste. Garden waste has a C:N of 57:1 as it contains mixed household green organics such as lawn and shrub clippings and dry leaves. FOGO waste will have a lower C:N than garden waste alone as it includes nitrogen-rich food scraps.

The C:N ratios of these types of council bins will also vary with the seasons, depending on how much nitrogen-rich grass clippings and carbon-rich dry leaves are present at the time.

Estimated quantities and combinations of compost feedstock can be calculated using the C:N ratios from Table 2 and a compost calculation spreadsheet (Cornell University 2014). Table 3 gives examples of possible combinations of feedstock thought to be available within the Legatus council area. The focus of these examples is on balancing the high nitrogen content in sewage sludge with high carbon inputs. For ease of comparison, the digested sewage sludge has been set to 10 tonnes. Example compost combinations achieve an ideal starting C:N of 25-30:1. Future combinations using high N feedstock from Table 2 would need additional high C input to maintain the ideal C:N ratio.

Table 3 Examples of compost feedstock quantities and combinations to achieve starting C:N 25-30:1

High N Feedstock	High N Feedstock	High C Feedstock	Other Feedstock	Other Feedstock	C:N
10 t Digested sludge		1 t Sawdust			30:1
10 t Digested sludge		2 t Lumbermill waste			25:1
10 t Digested sludge		1 t Cardboard			28:1
10 t Digested sludge		1 t Wheat Straw			26:1
10 t Digested sludge	10 t Grape marc		25 t Oat straw		26:1
10 t Digested sludge	2 t Food waste	1 t Tree trimmings	3 t Shrub trimmings		26:1
10 t Digested sludge	10 t Poultry broiler litter	0.5 t Phone books	2 t Mixed municipal organic waste	1 t Dry leaves	28:1
10 t Digested sludge	6 t Food waste	1.5 t Sawdust	5 t Mixed municipal organic waste		29:1

Case Study: Septage and green waste composting in Adelaide Hills

In 2006 the Adelaide Hills and Mt Barker councils conducted a trial co-composting their septage waste and kerbside garden organics (Kellog Brown & Root 2006). After testing, the C:N ratios of dewatered septage was found to be 24:1 and green waste was 47:1. Feedstocks were combined using one-part septage waste to three parts green waste. This study only looked at council green waste as a carbon source, but it’s important to consider outside sources as well.

Feedstock Sources

Primary industries in the Mid North and Yorke with potentially compostable waste are shown in the following maps generated from AgInsight (Government of South Australia 2021). The map outline is limited to the Mid North and Yorke Peninsula borders, but councils outside of this border such as Barossa sit within the Legatus footprint. Images are categorised by potential sources high C, high N, and other content (specifically viticulture). However, feedstocks with high carbon inputs should be prioritised to balance the nitrogen in biosolids.

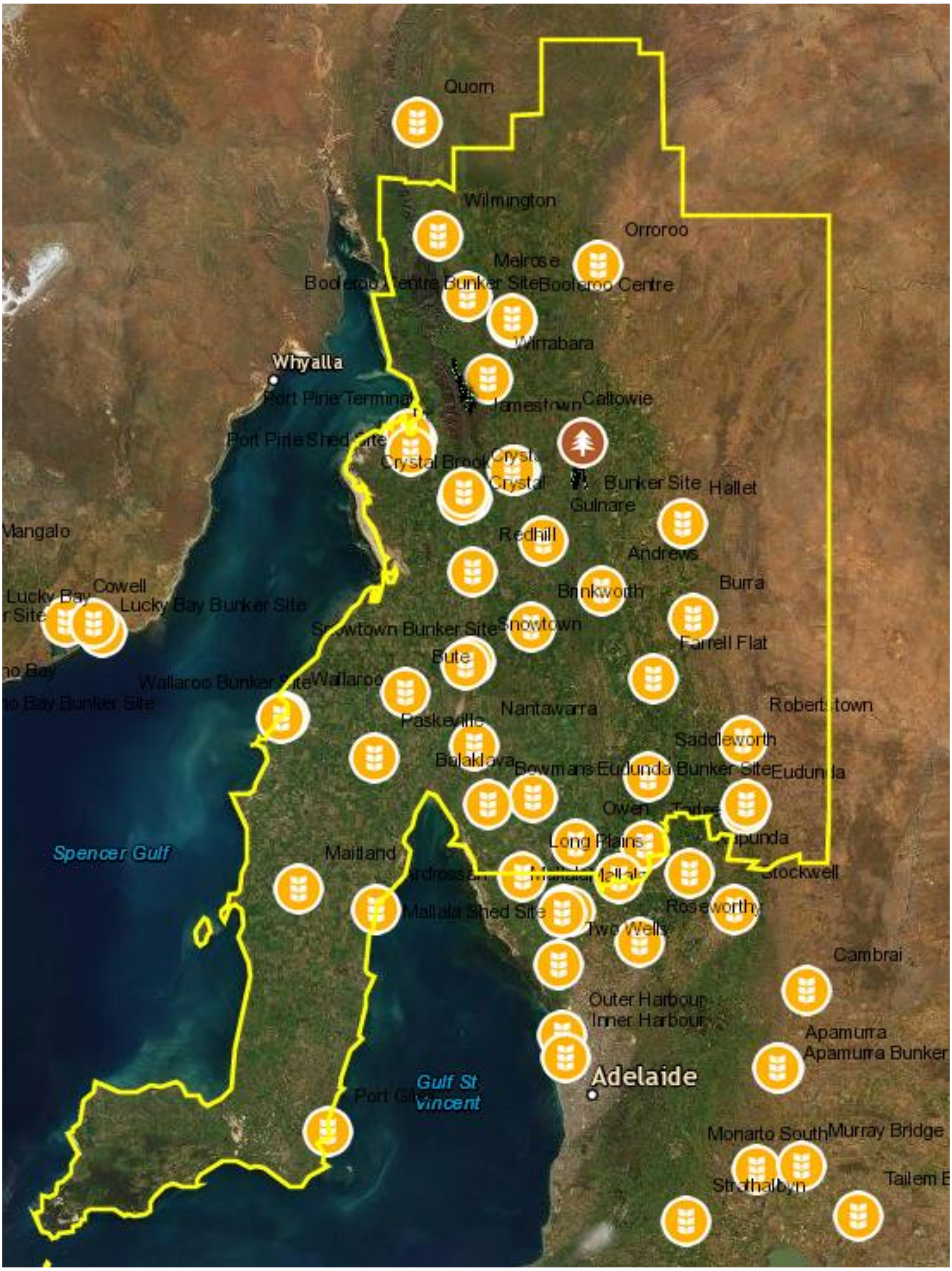

Figure 7 Potential sources of high carbon compost feedstock from Legatus region

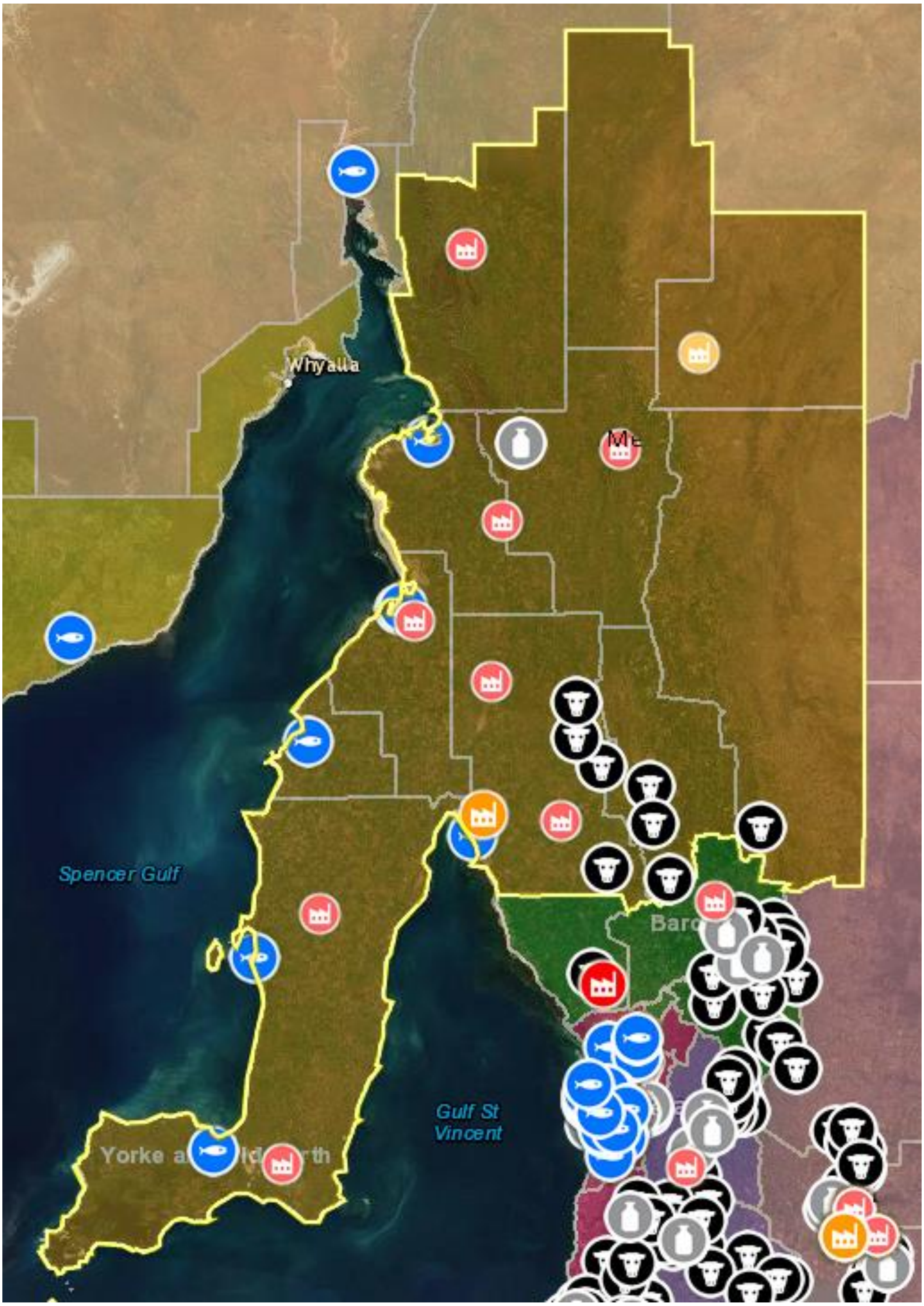

Figure 8 Potential sources of high nitrogen compost feedstock from Legatus region

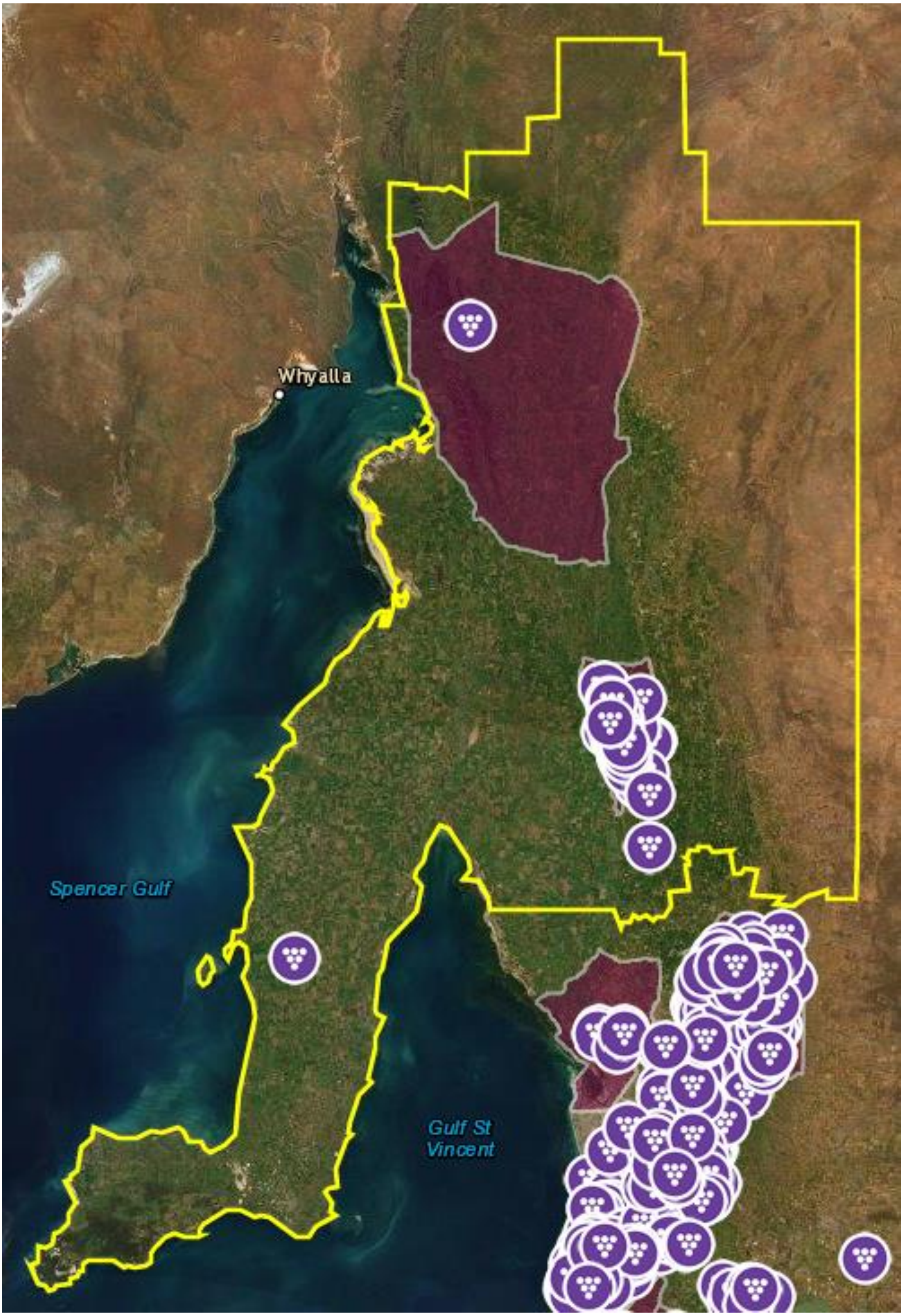

Figure 9 Potential sources of other (viticulture) compost feedstock from Legatus region

Potential stakeholders from the Mid North agriculture industry include:

- Primary Industries South Australia (PIRSA)
- Meat and Livestock South Australia
- Forestry SA
- Grain Producers SA
- Australian Milling Group
- Wilson Pastoral
- Balco Australia
- Viterra
- Golden North
- Barossa Valley and Clare Valley Wine and Grape growers

Compost and Feedstock Contamination

While the quality of some recyclable organic materials can be improved through the composting process, contaminants and pathogens may be present in any feedstock. Common contaminants from plant waste include weed seeds, pesticides and herbicides (Environment Protection Authority 2019). Bacteria, viruses, parasites, heavy metals, and chemical residues are found in animal manure and biosolids (Eamens, Waldron et al. 2006 , Smith 2009). Dehydration of sewage waste can help with transport to a composting facility, but the material still poses a microbial risk (Collivignarelli, Canato et al. 2019). Municipal mixed green organics often contain plastic and microplastic contamination that is difficult to remove before and after composting (Environment Protection Authority 2019).

Heat pasteurisation through the thermophilic phase helps destroy most pathogens and weed seeds in feedstocks. Mature compost that meets quality standards and has been heated to at least 55ºC for three consecutive day can be used without restriction (Environment Protection Authority 2019). However, any compost that includes sewage sludge or biosolids must have these contents clearly labelled (Environment Protection Authority 2020). Contaminants can also be diluted by blending with a wide variety of feedstocks as long as the additional materials are suitable for composting (Smith 2009, Environment Protection Authority 2010).

Mechanical screening of physical objects from both input material and end composted products can further reduce contaminants. Products that are sanitised, mature, and stable can be used without restrictions as commercial composts and in gardens. Composted organics can also be used in council landscaping, land care, and on mine sites.

Standards and Guidelines

There are several guidelines that need to be considered when establishing a new composting plant to process biosolids and septage waste. There are also some restrictions on the end use of composts that contain biosolids, as well as further testing that may be needed. The main documents to be aware of are:

- EPA Standard for Waste Derived Soil Enhancer (2010)
- EPA Guidelines for the safe handling and reuse of biosolids in South Australia (2020)
- EPA SA Compost Guideline (2019)
- Australian Standard for Compost, Soils and Mulches (AS 4454:2012)

Biosolids and sewage sludge are not considered suitable for use as a waste-derived soil enhancer without prior treatment, but composting is regarded as an acceptable treatment (Environment Protection Authority 2010). The South Australian Environment Protection Authority guideline for the safe handling and use of biosolids (2010) states that this material can be stabilised through windrow or vessel composting and recommends appropriate time and temperature parameters for treatment. Waste processors such as industrial composting facilities should also keep records of contaminants identified in any biosolid material received (Environment Protection Authority 2020).

The EPA SA Compost Guideline (2019) covers topics such as licensing and location of commercial compost facilities, appropriate feedstocks, contaminant testing, product labelling and environmental factors. The Australian Standard for Compost, Soils and Mulches (4454:2012) (2012) sets minimum standards for quality assurance to end users. Compliance with the standard is voluntary for compost producers (Standards Australia 2012). Composts that claim the AS 4454:2012 label are subject to independent laboratory tests to confirm they have been appropriately processed/pasteurised and meet the physical, chemical and biological properties for intended use.

Tests conducted include (Standards Australia 2012):

- Moisture, pH, C:N, total organic matter, wettability, electrical conductivity
- Maturity, stability
- Quantity of plant macronutrients and micronutrients
- Presence/quantity of chemicals including some pesticides and herbicides
- Presence/quantity/size of glass, metal and plastic contaminants
- Presence/quantity of bacterial pathogens (i.e., faecal coliforms, *E. coli*, and *Salmonella*)
- Presence/growth of plant propagules (i.e., weed seeds)
- Plant toxicity (bioassay)

There are no National Association of Testing Authorities (NATA) accredited facilities in South Australia that conduct compost analysis to the AS 4454:2012 standard. Two soil laboratories in NSW are accredited: Suez Recycling & Recovery SAWT Laboratory and Sydney Environmental and Soil Laboratory (SESL) (National Association of Testing Authorities 2021). Microbiology Laboratories Australia in metropolitan Adelaide is not NATA accredited, but does offer standard-compliant testing packages for compost. Other facilities locally and interstate may also offer appropriate compost analysis.

Case Study 1: Septage and green waste composting in Adelaide Hills

The Adelaide Hills and Mt Barker biosolids and green waste co-compost trial discussed earlier found several contaminants of concern in feedstocks and the final composts (Kellog Brown & Root 2006). Physical objects included syringe needles and various plastics. High concentrations of zinc and copper were found, likely from pharmaceuticals and sunscreens (Kellog Brown & Root 2006). Faecal coliforms and

E. coli were present in both septage and green waste. The researchers recommended dilution to mitigate contaminants by adding additional green organics as well as mixing compost with equal parts of low-zinc soil for land application (Kellog Brown & Root 2006).

Case Study 2: Herbicide contamination in Victorian commercial compost

Compost processed by Suez's Melbourne facility was found to be contaminated with powerful agricultural herbicides in October 2020 (Knight and Willingham 2021). The source of contamination was council green waste. Victorian home gardeners who purchased the packaged compost were left with damaged soil and ruined vegetable patches. The manufacturer also suffered financial losses through investigative testing and soil remediation.

Ironically, the affected batch of compost was tested by Suez prior to sale and it met Australian Standards (Knight and Willingham 2021). In this case, the herbicides were present in trace amounts that were not detected despite the damage they can cause at such low concentrations. It is likely that existing compost standards need to be updated and enforced to reflect current knowledge of environmental contaminants and test methods (Knight and Willingham 2021).

Feedstock Supply, Demand and Quality Control

Primary producers within the Legatus region were interviewed to better understand the potential supply of compost input feedstocks, demand for end products, and how to ensure quality control along the supply chain.

Stakeholder Interviews

Stakeholders were identified and classified into sources, users, processors of compostable organic material with crossovers between these groups noted.

Three participants were recruited and asked semi-structured questions about how their business's organic waste management practices. Recognising this as a small sample, interviewees were invited to comment on trends and practices within the Mid North's broader agricultural industry. Each of the participants taking part are employed within a target industry for locally produced compost: broadacre farming, timber processing, and animal production.

Questions

Questions specific to potential **sources** of feedstock asked:

- What organic waste materials are produced and how much is generated from your facility?
- Does it vary in quantity or quality?
- What do you do with it currently?
- How much does that cost (and does it generate any revenue or benefit to you)?
- What difficulties have you encountered with current arrangements?
- How much does that cost (and does it generate any revenue or benefit to you)?
- What difficulties have you encountered with current arrangements?
- Are you certified organic? Do you use compost or plant-based soil amendments?

Questions specific to potential **users** of feedstock asked:

- What is your current use of fertiliser and other chemical inputs?
- How much fertilizer do you use (i.e., t/yr)?
- What time of the year do you use it?
- Where do you source from, and how much does that cost you?
- Have you used compost or plant-based soil amendments before? If so, why? If not, why not?
- Where do you get it from?
- How much does that cost you?
- Have you ever used septage waste or biosolids? If so, why? If not, why not?

- What difficulties have you encountered with any of these current arrangements?

Responses

Responses from the interviews are summarised below.

Participant A: Broadacre grain and sheep producer (source/user)

- No waste is reported; any organic waste generated stating is used in some way already
- Uses chicken manure, biosolids and synthetic fertilisers to improve productivity of soil
- Chicken manure – has used both pure and blend of manure with straw bedding
    - Can be cost prohibitive and difficult to source and apply to land
    - Mainly purchased from farms in the Adelaide Plains (within 90 minutes of site) through 3rd party
    - High cost due to delivery and need for special equipment/labour to spread
    - Larger volume required to get same nutrient requirement as chemical fertilisers
    - Best results to crops in second year of application; some benefit in first and third years
- Biosolids applied direct to land for about 2 years
    - Sourced from Bolivar wastewater plant
    - Demand for biosolids often exceeds demand
    - Supplied as uniform pellets that are easy to spread without additional equipment
    - However, there is risk of receiving old stock that is very dusty
    - Aware of and concerned about environmental issues of using biosolids
        - Contaminants can leach into local waterways
        - High levels of heavy metals in soil decreases productivity and negates benefit of use

- Considers synthetics a better return on investment year-on-year
    - Purchased through local agribusiness from supply sourced overseas
    - Finds that synthetics yield more productivity year on year, but difficult to balance with long-term benefits of compost/manure/biosolids use
    - Current price of synthetic fertilisers is “sky high” due to Covid-19-related insecurities and shipping container costs
- It is common practice amongst farmers when finances are tight is to consider using half usual quantity of synthetic fertiliser and supplement with biosolids and/or manure
- A local, regular supply of recycled organic products would reassure farmers of supplies and might make them less inclined to source synthetic fertilisers from overseas
- Regional compost facility could be beneficial as long as it produces environmentally friendly products, and the processing plant does not impact the health of the community

Participant B: Sawmill (timber processor)

- They are producing about 25 cubic metres of mill waste per week
    - Mill waste is mostly from floor sweepings and consists of wood chips, wood shavings, sawdust, and tree bark
    - Mill waste is an unhomogenised, rough product that would need further processing by composting plant
- All mill waste is currently being sold with local customers prioritised first
    - Currently not looking to supply to new customers (unlikely to be able to supply regional composting plant)
    - There is a huge demand for sawdust, sold through fixed pricing
    - Some mill waste is sold to Peats Soil
    - Peats Soil could take 3 times as much as the mill can offer
- Bushfires are a threat to mill operations
    - Much of the local forest plantation stock was destroyed in bushfires, but replanting hasn’t begun yet
    - They are processing timber stock from Adelaide and southern areas

- To their knowledge, forest plantations are not using organic soil amendments such as compost, manure or biosolids

Participant C: Cattle feedlot (source/user)

- They used to produce organic wine in addition to beef cattle, but recently gave up winery due to drought
- Produce around 60,000-95,000 t/yr of cow manure
- Manure is mostly milled and spread on crop land
    - They have an EPA license to store manure in windrow piles while ageing
    - Manure is not composted or blended with other organic feedstocks
- Cow manure is sold to 3rd parties, both raw and aged
    - Manure sales are typically informal, but becoming more formal
    - No profit made, sold "at cost" after equipment and labour
    - Sells for $20-30/tonne, $40/tonne screened
    - Some buyers mix the manure with ingredients such as almond hulls and sell on for a premium, mostly to wineries
- Animal feed, manure and soil are all tested, but not for pathogens
- Their animal feed is not certified organic, but is free from pesticides
    - Only approved herbicides are used
    - Other inputs include a mix of vitamin supplements
    - Some grain which has been rejected by processors is purchased for animal feed
        - Depends on contaminants/reason for rejection; feedlot test it first
- Cows given vaccines and some antibiotics as needed
- They use chemical fertilisers, such as Enrich 3210
- Agronomists on site have been trialling application of cow manure for 2 decades
    - They plant canola to remediate compacted, heavy clay soil
- They have researched setting up on-site capacity to produce bio energy and biochar from manure (and potentially septage/biosolids)
    - Energy could be sold to grid and biochar to local farmers
    - Would provide extra income but start-up cost is prohibitive

- They would consider purchasing local compost if available, but it would need to be a premium product that met Australian standards to justify the cost
- Facility's biggest challenges with manure waste are the smell, combustible nature, and cost of freight to transport
    - Past incident with staff mishandling manure resulted in foul odour complaint

Additional Findings

- Mid North grain processors Balco and Viterra couldn't be contacted directly for this study, but information from their websites indicate that grain processed at their facilities undergo extensive testing to identify potential contaminants (Balco Australia 2021, Viterra 2021). Any rejected products or waste from their sites would likely be high carbon feedstocks and suitable for composting.

- Established businesses within Legatus council region are already processing some agricultural waste. One example, located in Nuriootpa and Berri, specialises in recycling residual waste from the wine industry. Their website states that they process over 4000 trucks of solid waste each year into value-added products (Tarac Technologies 2015). Grape marc is recycled into animal feed and soil conditioners.

- Legatus area business AgCommunicators was contacted during this study. They suggested that distributing a stakeholder survey along with a media and communications campaign would help get more people interested in a regional composting project. Groups such as Landscape Boards SA, AgBureaus, and Regional Development Boards would likely have great interest in the outputs of a regional composting plant (Cay 2021).

Additional stakeholders identified:

Australian Organics Recycling Association (compost industry peak body)
SA No-till Farmers Association
Landscape Boards SA

AgBureaus

Regional Development Boards

Conclusion and Recommendations

1. Sources of high-carbon organic feedstock need to be targeted within the Mid North to balance the high nitrogen content in biosolids and sewage sludge. The agriculture industry potentially has large volumes of source-separated organic waste. Contaminants present in this feedstock would likely be identified through existing testing and knowledge of their produce.

While data from the South East agriculture industry show large volumes of organic material being generated, there is insufficient data about what types and volumes might be available within the Legatus region. Data of waste streams from Mid North and South East SA are estimates and note that much of it may already be allocated and unavailable or unsuitable for composting

Interviews with Legatus stakeholders indicate that primary producers are not reporting much waste and that they already have practices in place to manage what by-products are being generated. Farmers are using a combination of synthetic fertilisers, biosolids and manure to improve soil productivity. However, none of the three participants interviewed are using products that have been combined with other organic inputs.

Primary producers would like to use more compost and manure for longer-term benefits, ideally products that are produced locally. However, year-to year finances can be an impediment to investing in these.

- Further research is needed to identify potential sources of high-carbon compostable feedstock from the agriculture sector.
- Recommend developing and distributing a stakeholder survey via a communication campaign that focuses on the advantages of blending feedstocks into a more refined, treated composted product.

2. If stables volumes of feedstocks cannot be sourced from the agriculture industry, Legatus council-managed organic waste and biosolids may be the primary inputs for a regional composting plant. Both of these inputs are known to be high in contaminants. End products would need further research and testing before use. Legatus councils may also need to establish or expand kerbside organics waste collection to ensure sufficient supply of material to achieve starting C:N of 25-30:1.

- Recommend most likely application of these composted end products to be non-food chain applications such as landscaping (dependent on testing).
- Recommend implementing waste education plan for kerbside bin users to minimise contamination of materials.

3. While biosolids and sludge can be applied directly to agricultural land (as liquid slurry or dry pellets), it is the least ideal disposal option aside from landfill. Any soil conditioning benefits must be weighed against the risk of physical, chemical and biological contaminants that can make their way into the human food chain.

Composting can help to mitigate these risks through heat pasteurisation and contaminant dilution. However, care must be taken when selecting organic inputs for combination as these can, and often do, contain contaminants as well. As contamination is large risk, input sources that maintain records of feedstocks need to be prioritised.

While the Australian standards for compost are voluntary, any composted material produced by a regional composting facility should be tested for compliance with the AS 4454:2012. Testing is needed to ensure quality and safety for end users, particularly if agriculture and horticulture are the main likely consumer markets.

Established commercial composting facilities were not contacted for this study, however they may be able to offer industry insight into sourcing appropriate feedstock, managing contaminants, technologies and additional markets for finished products. They should also be considered as potential outsourced operators and mutually beneficial partners with the Legatus Group.

- Recommend that compliance with AS 4454:2012 be considered best practice.
- Recommended future engagement with currently established commercial composters in South Australia.

Some of the operational and growth obstacles of the national compost industry are shown in Figure 10.

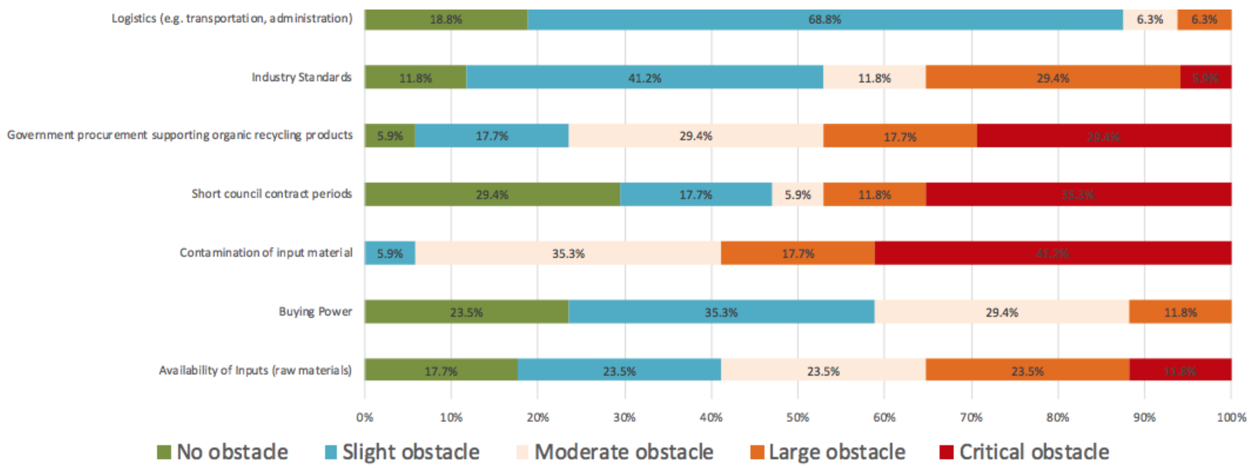

Figure 10 Obstacles to Australian Organics Recycling Industry Capacity (adapted from (Australian Organics Recycling Association 2021)

The main obstacles within the scope of this study are feedstock contamination and industry standards, and availability of feedstock (Australian Organics Recycling Association 2021). Findings from this research support the data here as sourcing a reliable supply of low-contaminant feedstock suitable for composting within the Legatus council region is likely to be a large obstacle that needs further investigation. Logistics and transportation may be a larger obstacle than indicated in Figure 10 since the proposed composting plant will be located in a regional area. Local government procurement of end products may also play a major role in the sustainability of a composting facility, particularly if the bulk of feedstock ends up being council collected organics. Utilising locally generated recycled organics within council projects such as landscaping would be a first step in implementing a circular economy within Legatus Group.

References

Agnew, J. and J. Leonard (2003). "The Physical Properties of Compost." Compost Science & Utilization **11**(3): 238-264.

Australian Economic Advocacy Solutions (2020). The Economic Contribution of the Australian Organics Recycling Industry.

Australian Organics Recycling Association (2021). Capacity of the South Australian Organics Recycling Industry, webinar.

Balco Australia. (2021). "Quality."   Retrieved 1 April, 2021, from https://www.balco.com.au/index.php/quality.

Bolin, J. L. and J. C. Pereira (2009). Composting : Processing, Materials and Approaches. Hauppauge, NY, Nova Science Publishers, Inc.

Cay, B. (2021). Assistance with organics recycling project, Email 15 March.

Collivignarelli, M. C., M. Canato, A. Abbà and M. Carnevale Miino (2019). "Biosolids: What are the different types of reuse?" Journal of Cleaner Production **238**: 117844.

Cornell University (2014). Moisture and Carbon/Nitrogen Ratio Calculation Spreadsheet.

Eamens, G. J., A. M. Waldron and P. J. Nicholls (2006). "Survival of pathogenic and indicator bacteria in biosolids applied to agricultural land." Soil Research **44**(7): 647-659.

Environment Protection Authority (2010). Standard for the production and use of Waste Derived Soil Enhancer. Adelaide SA.

Environment Protection Authority (2019). Compost guideline. Adelaide SA.

Environment Protection Authority (2020). Guidelines for the safe handling and reuse of biosolids in South Australia. Adelaide SA.

Epstein, E. (1997). The Science of Composting. Lancaster, Pa., Technomic Publishing.

Fornes, F., D. Mendoza-Hernandez, R. Garcia-De-la-Fuente, M. Abad and R. Belda (2012). "Composting versus vermicomposting: A comparative study of organic matter evolution through straight and combined processes." Bioresource Technology **118**: 296.

Gippsland Water. (2021). "Soil and Organic Recycling Facility "   Retrieved 1 April, 2021, from https://www.gippswater.com.au/residential/what-we-do/waste-recycling.

Government of South Australia (2021). AgInsight South Australia.

Kellog Brown & Root (2006). Mount Lofty Ranges Biosolids and Green Waste Regional Working Party - Septage and greenwaste co-composting trial, Adelaide Hills Council.

Knight, B. and R. Willingham. (2021). "Recycler Suez says herbicides in contaminated compost came from Melbourne council waste."   Retrieved 1 April 2021, from https://www.abc.net.au/news/2021-02-21/suez-herbicides-contaminated-compost-melbourne-council/13175200.

National Association of Testing Authorities. (2021). "Find accredited facilities." Retrieved 1 April, 2021, from https://nata.com.au/accredited-facility.

Office of Green Industries SA (2015). South Australia's Waste Strategy 2015-2020. Adelaide SA.

Rawtec (2014). Waste Biomass Opportunities Map for the South East SA, Zero Waste SA.

Rawtec (2020). Waste Volumes in Legatus Group.

Sapdhare, H. (2019). Legatus Group Regional Community Wastewater Management Scheme (CWMS) Survey and Sludge Processing Plant Viability Investigation Report.

Smith, S. R. (2009). "A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge." Environment International **35**(1): 142-156.

Standards Australia (2012). Composts, Soil Conditioners and Mulches (incorporating Amendment Np. 1) (AS 4454-2012). Sydney, NSW, Standards Australia.

Suez. (2021a). "Epping Organic Resouce Recovery Facility "   Retrieved 1 April, 2021, from https://www.suez.com.au/en-au/who-we-are/suez-in-australia-and-new-zealand/our-locations/waste-management-epping.

Suez. (2021b). "SUEZ North Bannister Resource Recovery Park."   Retrieved 1 April, 2021, from https://www.suez.com.au/en-au/who-we-are/suez-in-australia-and-new-zealand/our-locations/waste-management-north-bannister.

Tarac Technologies. (2015). "Winery residual management."   Retrieved 1 April 2021, from https://www.tarac.com.au/services/winery-residual/.

Virtue, R. (2017). War on Waste: Inside Australia's first co-composting waste facility at Port Stephens. ABC Newcastle.

Viterra. (2021). "Quality management."   Retrieved 1 April, 2021, from https://viterra.com.au/index.php/quality-management-2/.

Waste Management Review (2018). Dubbo Regional Council Opens New Organics Processing Plant. Waste Management Review,.