Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry

Horticulture Australia Project Number: VX99002 (May, 2002)

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This is the final report of the above project. It covers the conduct and results of the project in detail, and also includes media and technical summaries.

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Horticulture Australia

RURAL INDUSTRIES RESEARCH & DEVELOPMENT CORPORATION

Contents

Media Summary

A project was undertaken to investigate some of the perceived barriers to greater use of recycled organic materials in the Tasmanian vegetable industry. Three of these barriers are:

- availability of suitable products
- transport, handling and processing costs
- concerns regarding food safety.

Some 250,000 tonnes of solid organic residuals suitable for reuse in agriculture are produced in Tasmania each year, mostly by the food processing and forestry industries. Information from a survey of businesses that produce organic residuals will be placed on the Tasmanian Waste Exchange at http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/EGIL-53M7AH?open.

Economic modelling showed that the cost of compost production in small on-farm operations could be lower than large enterprises, providing on-site infrastructure and other fixed overheads were low. However, it is expected that quality control would be relatively low in such operations. When determining the economic viability of larger scale operations, production volume, tip fees and transport distances are important.

A review of alternative uses for organic residuals indicated that there is scope in Tasmania to produce "designer" composts and mulches with potential benefits to vegetable production. Producers of composts and similar products must meet high quality standards in order to minimise the risk of food safety issues.

Soil organic matter loss and organic waste management are significant issues in intensive vegetable production. Both impact on perceptions of "clean, green" produce and the long-term sustainability of agricultural production systems. Both issues can be addressed while improving the economic and environmental performance of the production and processing sectors of the vegetable industry. When viewed as a "waste", residual organic materials must be managed to minimise environmental damage. When viewed as a properly processed resource, they are sources of organic matter and plant nutrients.

Businesses need information on the availability and nature of organic wastes to evaluate opportunities for market development. It is recommended this information be provided to facilitate the flow of materials from waste generators to potential end users.

It is recommended that the economic model developed by the project be integrated with other models related to compost recipe design and site development. This would provide a suite of computer programs for determining the requirements and economics of proposed organic recycling initiatives.

There is a need to provide better information on issues surrounding the use of recycled organic materials and food safety. It is recommended that the recycled organics and agricultural industries promote the message that properly processed and managed organic residuals are safe to use in food production.

Technical Summary

Background
Loss of soil organic matter is a significant challenge facing the intensive vegetable industry. Organic wastes produced by urban and agri-industrial activities present major disposal and management problems to local government and environmental authorities. While the current perception of Tasmania as a supplier of "clean, green" produce is primarily based on food quality, the sustainability of agricultural production systems will become more important as a marketing tool in the future. This is not to ignore the environmental and production imperatives of improving the sustainability of farming systems.

The challenges of soil organic matter decline and organic waste disposal provide an opportunity to improve the economics and environmental credentials of the production and processing sectors of the vegetable industry. When viewed as a "waste", residual organic materials must be managed to minimise environmental damage. When viewed as a resource, they can be returned to land in a properly managed fashion as sources of organic matter and plant nutrients.

The use of recycled organic materials in agriculture and horticulture is not widespread, with some of the reasons being:

1. lack of knowledge of benefits to growers
2. availability of suitable products
3. transport, handling and processing costs, and
4. concerns regarding the impact of organic waste reuse in the context of QA schemes and food safety.

Project findings
This project focused on the last three of these points. A survey of organic waste materials produced in Tasmania was conducted to identify those potentially available for use in agriculture. Arrangements are in place to make the information publicly available through the Tasmanian Waste Exchange web-site at http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/EGIL-53M7AH?open. There is some 250,000 t of solid organic residuals produced each year that could be suitable for reuse in agriculture. A further 30,000 t/y of sludges and 20,000 ML/y of liquids are also produced. These materials are mostly produced by food processing and forestry operations. The figures do not include mixed putrescible waste, paper-based products, green waste (garden trimmings) or sewage sludge.

An economic model was developed to allow estimation and comparison of the various costs associated with reusing organic residuals in agriculture. The model allows costs to be estimated for a range of processes leading up to land application of residuals. The model showed that small on-farm compost operations tend to be cheaper if there are low costs associated with on-site infrastructure and other fixed overheads. Volume throughput and the level of tip fees are important variables in determining the economic viability of larger scale operations. Tip fees are particularly important for larger operations, as the revenue potential from compost sales will always be influenced by price sensitivity in agricultural markets. Amenity horticulture markets are more accepting of higher prices. Arrangements are being made to make the model available through the Tasmanian Department of Primary Industries, Water and Environment web site at: http://www.dpiwe.tas.gov.au.

A review of alternative uses for organic residuals indicated that there is potential in Tasmania to produce "designer" composts and mulches with particular attributes of benefit to vegetable production.

Society delivers mixed signals in relation to the use of recycled organic materials for food production. Fears of food contamination tend to work against the reuse of such materials in agricultural settings. However, expectations of responsible environmental management drive significant changes in waste management and agriculture. The fresh market sector raises more questions regarding food safety than the processing industry. It is important that producers of composts and similar products meet high quality standards in order to minimise risks to food safety.

Recommendations and future work

Information on the availability and nature of organic wastes is important to enable businesses to evaluate the opportunities for further development of agricultural reuse markets. It is recommended that arrangements be established in agricultural areas to provide this information to facilitate the flow of materials from waste generators to potential end users.

While the economic model developed as part of this project is versatile, it would benefit from the expertise of a computer programmer to make it more user-friendly. It also has the potential to be linked to other currently available software programs that focus on compost recipes and site infrastructure development. It is recommended that this development be undertaken to provide a suite of inter-linked programs for determining the requirements and economics of proposed organic recycling initiatives.

There is also a need to provide better information on issues surrounding the use of recycled organic materials and food safety. It is recommended that the recycled organics and agricultural industries promote the message that properly processed and managed organic residuals are safe to use in food production. Mature compost is not "waste" – it is a potentially valuable input to agricultural production systems.

Introduction

Land degradation is one of the most important challenges facing Australian agriculture. Loss of soil organic matter is a significant factor. This is apparent across the range of agricultural industries, from intensive vegetable production to extensive grazing. At the same time, organic wastes produced by urban and agri-industrial activities present major disposal and management problems to local government and environmental authorities.

Both issues (land degradation and organic waste disposal) impact on the long term sustainability of agriculture and the "clean and green" image that Australian produce holds in international markets. The image of Australia as a supplier of "clean, green" produce is currently based on the quality of exported produce – essentially a food safety perspective. The perceived sustainability of our agricultural production systems will become more important as export markets increasingly choose to source produce from areas which use environmentally sustainable production methods.

Industries which can capitalise on the use of "environmentally friendly" production techniques stand to increase market share. The pressures of these changes are particularly apparent in the Tasmanian vegetable industry. Tasmania has an enviable "clean and green" reputation in many export markets, and the increasing interest in environmentally sustainable food production is important to the Tasmanian vegetable industry.

The twin challenges of declining soil organic matter and organic waste disposal present an ideal opportunity to improve the economics and environmental credentials of the production and processing sectors of the vegetable industry through a joint solution. Many organic wastes are valuable sources of organic matter and plant nutrients. They also have the potential to pollute the environment if not managed correctly. Returning these materials to land benefits the waste producer and the landholder. However, there are some concerns about the food safety implications of reusing some organic residuals.

Management of residual organic materials is a significant challenge in many areas, with wastes from food processing, on-farm production, industrial processes and municipal sources contributing to the issue. Locally generated and processed organic materials could help replace other imported nutrient sources currently used by the vegetable industry. There is also the opportunity to improve soil water holding capacity through the addition of organic matter and potentially reduce water use and irrigation costs. Beyond the individual farm level, the well managed collection, processing and use of organic residuals can help minimise catchment level pollution associated with poorly managed disposal activities.

As part of the move to more sustainable vegetable production methods, there is increasing interest in the reuse of organic materials, particularly those that have been value-added, such as compost. Processed organic materials can help improve the economics and environmental sustainability of the production and post-farm gate sectors of horticulture.

A wide variety of research relating to the benefits of using organic materials in agriculture is reported in the literature. All aspects of agricultural and horticultural production are covered, from extensive grazing to intensive vegetable production (Maynard, 1994; O'Brien and Barker, 1995; Warman, 1995; Fauci *et. al.*, 1999; Marull *et. al.*, 1997; Gulliver, 2000). However, there is still not widespread use of recycled organic materials in agriculture and horticulture. Biala & Wynen (1998) outlined a number of possible barriers for the low uptake of organic materials use in agriculture, namely:

1. lack of knowledge of benefits to growers
2. availability of suitable products
3. transport, handling and processing costs, and
4. concerns regarding the impact of organic waste reuse in the context of QA schemes and food safety.

Unlike other Australian states, Tasmania does not have a significant urban population to encourage or support the production of large quantities of high quality compost for amenity horticulture. However, the per capita production of residual organic materials is relatively large, being heavily influenced by food and timber processing industries. Consequently, Tasmania has a relatively large supply of organic residual materials, but a small population to support the high value end of the market in home gardening and amenity horticulture. It is therefore necessary to deliver processed or unprocessed organic materials to the farm gate at competitive prices to maximise the beneficial reuse of organic residuals and encourage the establishment of organic recycling businesses.

Many variables influence the economic viability of organic residuals processing. It has long been suggested that viable operations require significant capacity to generate economies of scale. This requires large capital investment to establish an operation such as a composting facility, and can mean relatively large transport distances for both raw feedstock and finished products. All of these factors inhibit the establishment of processing operations. However, there is evidence to suggest that smaller operations, perhaps farm based, can process organic residuals with lower infrastructure and operating costs. This would make processed organic materials available for on-farm use at costs that are more attractive to end users (Verville, 1996; Goldstein, 1996; Hayes, 1997).

Another important factor is the ready availability of organic materials suitable for recycling or processing. A review of organic waste sources in Tasmania was published in 1993 (Leonard) which showed that over 600,000 t of solid organic wastes were produced by agri-processing and forestry operations each year.

This project was initiated to provide information to help address some of the barriers outlined by Biala & Wynen (1998), in particular barriers 2 - 4 mentioned above. The project was developed with the Tasmanian vegetable industry in mind, although a considerable amount of the information gathered will have relevance to other agricultural sectors and regions. The specific objectives of the project were to:

1. Determine the amount of organic residuals available for agricultural/horticultural end use in Tasmania, and the likely cost structures associated with end use options.
2. Identify alternative processing and reuse options for currently unutilised organic residuals based on the information collected in objective 1.

3. Compare the economics and logistics of three organic residual processing alternatives for production of material for on-farm use, namely:
   - relatively small scale on-farm processing using existing farm equipment, drawing materials from on the farm or short off-farm distances and reusing the material on the farm.
   - Municipal or district, medium-sized on or off-farm processing operations using higher level processing technology, drawing feedstock material from farms and other sources in a district or municipality, and returning processed material back to those farms.
   - centralised regional facilities using specialist equipment, drawing materials from a wider area and selling quality assured products for agricultural use.
4. Identify QA (Quality Assurance) and HACCP (Hazard Analysis and Critical Control Point) issues relevant to food production and environmental sustainability with regard to organic waste processing and reuse, and review these with respect to their impact on the further development of organic residuals use as a component of sustainable agriculture.

Methods

Objective 1 - Determine the amount of organic residuals available for agricultural/horticultural end use in Tasmania, and the likely cost structures associated with end use options.

Leonard (1993) undertook the first study of this nature. This project set out to update the information from that study and construct a database of information on organic residuals that are generated by agri-industry in Tasmania.

The major aim of the most recent study was to identify the quantity, type, and location of organic residuals that are suitable for recycling. This information is important to businesses wishing to process and value-add these materials. At the time of commencing the survey, there was no central information source within Local or State Government to ascertain the major producers of organic materials, how much was produced or the nature of the materials.

As the first step in the process, industries likely to produce organic residuals within Tasmania were identified. This was undertaken through the following processes:

- discussion with Department of Primary Industries, Water and Environment (DPIWE) staff in the Environmental Planning and Scientific Services Division (EPSS) to ascertain those licensed premises likely to produce significant quantities of organic residuals.
- contact with planning or environmental health staff at relevant Councils to identify the local industries likely to be producing substantial quantities of organic residuals.

- discussion with the Country Sawmillers Association (CSA) to determine the main timber processing companies in the State.
- discussion with the Department of State Development (DSD), in particular the recently formed Food Industry Council of Tasmania (FICT), and use of their database to identify major food processors and packers in the State.
- use of Yellow Pages listings to ascertain any other potential organic residuals producers within each of the industry classifications used in the survey.

A postal survey was conducted, focusing on businesses that generate more than 100 t/y of organic residuals. A survey form was sent to each identified business (see Appendix A). Protocols for recording information and data entry were established to ensure consistency with the earlier study (Leonard, 1993). A total of 153 businesses were surveyed, most of them being in either the food processing or forestry sectors.

Surveys were completed and returned by mail, or completed via a phone interview process. Information was then entered into an Excel spreadsheet in a format suited to direct importation into a GIS database.

Objective 2 - Identify alternative processing and reuse options for currently unutilised organic residuals based on the information collected in objective 1.

A review of previous Tasmanian work was conducted, and discussions were held with participants of the organic waste management industry, to identify alternative uses for some of the materials listed in the database developed in Objective 1. Discussions were also held with agricultural researchers and others in the agricultural industries to identify production and sustainability challenges, which may benefit from the use of value-added products arising from the processing of organic residuals. With this knowledge, it was possible to speculate on some of the end products that might be manufactured from the organic residuals that are currently available in Tasmania. The information arising from these discussions and ideas generating exercises appear in the Results and Discussions sections of this report.

Objective 3 - Compare the economics and logistics of three organic residual processing alternatives for production of material for on-farm use, namely:

- *relatively small scale on-farm processing using existing farm equipment, drawing materials from on the farm or short off-farm distances and reusing the material on the farm.*
- *municipal or district, medium-sized on or off-farm processing operations using higher level processing technology, drawing feedstock material from farms and other sources in a small region, and returning processed material back to those farms.*
- *centralised regional facilities using specialist equipment, drawing materials from a wider area and selling quality assured products for agricultural use.*

The economic viability of organic residuals processing, and particularly compost production, is dependent on many factors. Scale of operation is one of the most discussed issues, with the suggestion that viable operations require large capacity to be economical. This approach can mean large transport distances for both raw feedstock and finished products, with a consequent impact on farm gate prices of compost. However, there is also evidence to suggest that smaller operations, perhaps farm based, can process organic residuals with lower infrastructure and operating costs, and thereby make processed products readily available for on-farm use at costs which are more attractive to end users.

Processing of organic waste for on-farm use can be as simple as spreading some material on a paddock, or as complex as transporting, sorting, mixing, composting and spreading a finished product. In order to analyse and compare the economics and logistics of organic waste processing, transport and application at differing scales of operation, it is necessary to understand the associated processes, equipment and costs. As a first step to this process, a number of interviews were conducted with industry participants to determine all of the possible steps associated with the processing and application operation, the likely equipment selections and their associated operating and ownership costs.

The possible steps involved in processing and reuse of organic residuals is outlined in Figure 1. Not necessarily all steps are used in a given situation.

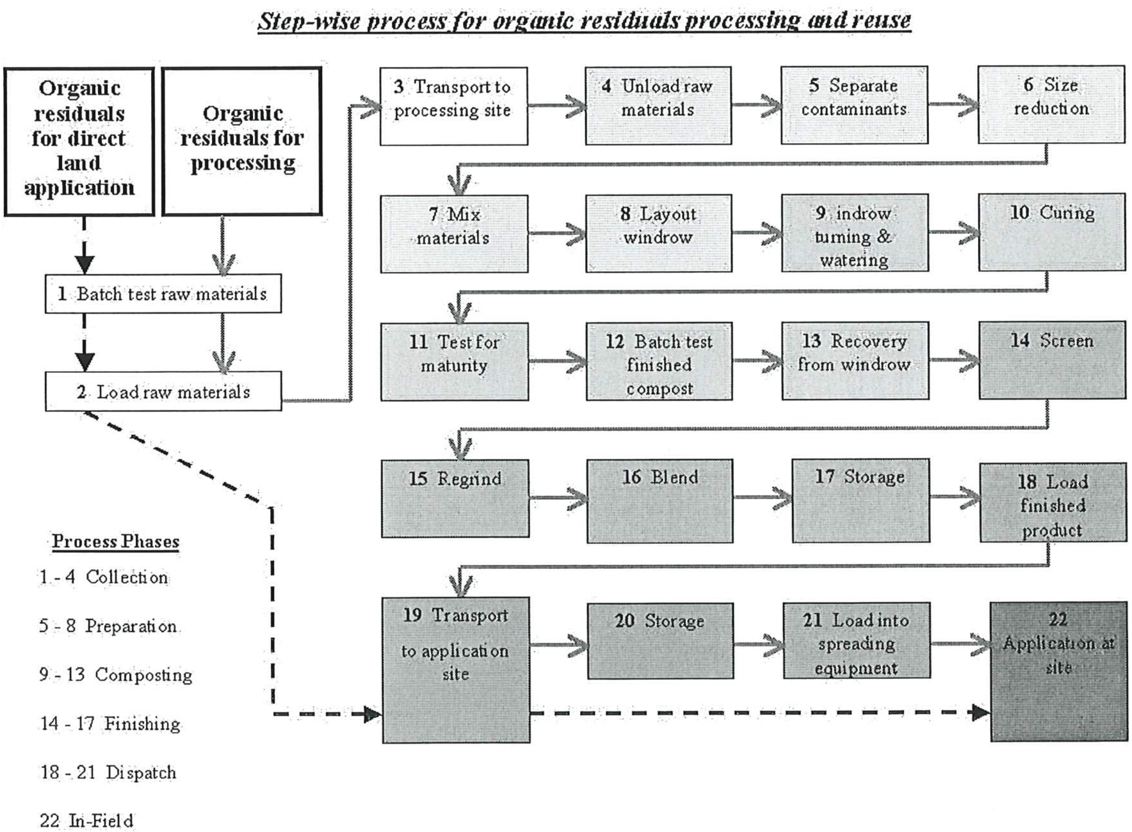

Figure 1. Step-wise processes involved in the processing and application of recycled organic materials in agriculture.

Given the wide variation in possible process steps and equipment selection, it was decided that the questions related to differing scales of operation would be best answered by use of a computer model. An Excel based model was developed for this purpose. This model allows a range of processing scenarios to be assessed on the basis of production costs and includes the ability to calculate the final cost of applying recycled organic material on the farm. Although the model has been structured with composting in mind, it is possible to assess the costs associated with the transport, processing and application of a range of materials merely by including or excluding various steps and equipment selection options.

Although this goes beyond the original intent of the objective, it became clear during the project that a flexible tool was required to assess the economics of various operational choices. The model would require more programming work to be a fully "user friendly" tool, but it is a valuable preliminary investigative tool for considering the economics of composting as a process to manage organic residuals for eventual use on farms.

Objective 4 - Identify QA (Quality Assurance) and HACCP (Hazard Analysis and Critical Control Point) issues relevant to food production and environmental sustainability with regard to organic waste processing and reuse, and review these with respect to their impact on the further development of organic residuals use as a component of sustainable agriculture.

The recycling of organic materials in agriculture sometimes attracts bad press from the perspective of food safety. On the other hand, use of recycled organics is often a positive in the context of environmental QA schemes. The reality is that most organic materials can be recycled in agricultural systems provided sensible measures are put in place to minimise contamination of foodstuffs. These measures can include the imposition of withholding periods, or the use of materials that have been modified through processing, such as compost.

Interviews were held with a number of representatives of the Tasmanian vegetable industry, including growers, processors and marketeers. The information from these interviews, and other sources, was used as material for a review of the QA and HACCP issues associated with the use of recycled organic materials in vegetable production.

Detailed results

Objective 1 - survey

Survey responses

The survey was conducted towards the end of 2000 and the first half of 2001. Table 1 shows the participation status of those contacted in the survey. A significant percentage of the respondents interviewed were not included in the database, as the volumes of materials they produced were insignificant. For example, the apple packing industry produces insignificant waste, as there is a market for all damaged and low grade produce as feedstock for the juicing industry. Some businesses could not be contacted, possibly because the may be seasonal operations, or may no longer be operational.

Table 1. Number and percentage of respondents and their status within the survey sample.

No. of respondents	%	Respondent Status
99	65	Positive respondents – entered into database.
22	14	Waste quantity less than 5 tonnes per annum – not included in database.
20	13	Did not wish to participate
12	8	Could not be contacted
153	**100**	

Waste quantities

The quantities shown in Tables 2 - 4 are the aggregate of the individual entries in the database. Although solid wastes are the major focus of work on the reuse of organic materials in agriculture, the survey presented an opportunity to collect information on a broader range of materials. Consequently, the survey sought separate information on solids, sludges and liquids from each enterprise. The figures are indicative only, as many survey respondents could only give approximate quantities. Units of measurement varied, and approximate conversions had to be made in some instances. This summary does not include the organic resources produced by those who did not wish to participate in the survey.

Table 2. Total organic material as solids (t/y) produced by industry sectors in each region and the whole state.

Type of Enterprise	Southern region	Northern region	North-west region	Total Tasmania
Abattoir	5,050	10,210	12,990	**28,250**
Vegetable & Fruit Processing	2,590	1,200	13,180	**16,970**
Vegetable & Fruit Packing[1]	10	0	10,590	**10,600**
Dairy Processing	540[2]	4	2	**546**
Fish Processing	780	1,000	837	**2,617**
Extraction[3]	4,000	21,800	4,500	**30,300**
Beverage (wine, beer etc.)	3,040	4,800	0	**7,840**
Forest Processing	18,425	74,356	38,245	**131,026**
Other		15,750	50	**15,800**
Total solids	**34,435**	**129,120**	**80,394**	**243,949**

[1] Fresh vegetable and fruit industry products
[2] Reflects waste from chocolate manufacturing as opposed to milk processing in north and north-west regions.
[3] Industries such as pyrethrum, medicinal poppies and essential oils.

Table 3. Total organic material as sludge (t/y) produced by industry sectors in each region and the whole state.

Type of Enterprise	Southern region	Northern region	North-west region	Total Tasmania
Abattoir	2,000	0	100	**2,100**
Vegetable & Fruit Processing	0	7,060	11,960	**19,020**
Vegetable & Fruit Packing	0	0	0	**0**
Dairy Processing	1,945	500	3,250	**5,695**
Fish Processing	0	0	0	**0**
Extraction	0	1,500	0	**1,500**
Beverage	360	700	0	**1,060**
Forest Processing	0	0	0	**0**
Other	0	100	0	**100**
Total sludges	**4,305**	**9,860**	**15,310**	**29,475**

Table 4. Total organic material as liquid (ML/y) produced by industry sectors in each region and the whole state.

Type of Enterprise	Southern region	Northern region	North-west region	Total Tasmania
Abattoir	2	197.6	0.2	199.8
Vegetable & Fruit Processing	0	0	0	0
Vegetable & Fruit Packing	0	0	0	0
Dairy Processing	162	0	367	529
Fish Processing	Unknown	Unknown	Unknown	Unknown
Extraction	0	4	0	4
Beverage	0	0	0	0
Forest Processing	19,500	0	0	19,500
Other	0	0	0	0
Total liquids	**19,664**	**201.6**	**367.2**	**20,232.8**

Current Practices

As part of the survey, questions were asked about the practices currently used by businesses to manage their organic residuals. The information presented in the following sections provides an overview of the commonly used recovery and disposal practices amongst the varying industry sectors.

Abattoirs
The most common practice is to transport offal waste to a blood and bone manufacturing plant in Devonport. However, some respondents reported that paunch waste needed to be kept separate. These respondents stockpiled this component of the waste stream and applied it to land, or disposed of it at landfill. Although landfilling offal is becoming less common as landfill sites develop more stringent waste acceptance criteria, this disposal option is still used by some smaller operations. There are some innovative recycling initiatives in place with abattoir waste, with some materials being composted or vermi-composted.

Vegetable and Fruit Processing
Reuse practices are very common in this industry. Residuals are used as stockfeed, mulch and/or compost in orchards, or alternatively, stockpiled and applied to land. Landfilling is still used as an option by some respondents. This is particularly the case for larger operations, most of which undertake some reuse, but resort to landfilling when there is a significant excess of materials.

Vegetable and Fruit Packing
This industry produces little waste, as low grade or reject material is often a saleable commodity for end uses such as juicing or as stock feed. Specific materials, such as onion waste, are more likely to be landfilled. Sometimes residuals are landfilled when the quantity is in excess of that needed for other uses.

Dairy Processing
The dairy processing sector produces a range of waste streams. There is currently no recycling of the food waste components. Liquid and slurry waste is often disposed of to sewage or liquid waste treatment plants. Some operators apply this resource to irrigated pasture. Solids are either utilised as stockfeed or landfilled.

Extractive
The spent marc products from extractive processes are usually utilised in some form for land application. The material has good plant nutritional properties and the extraction processes used often produce a material of ideal consistency for land application or input into composting processes.

Fish Processing
Fish waste is sought after for its nutrient value by commercial composters and organic farmers. The majority of waste from this sector is utilised in this manner. The industry has been proactive in seeking value-added end uses, and there are a number of examples of waste being used as a compost feedstock or for high value products. One example is a small export market of abalone shells for button making and jewellers. Some waste from this sector is also landfilled.

Beverage Industry
A significant proportion of the organic resources from the beverage industry sector is reused as stock feed or mulch. Wineries reuse waste as mulch or compost for vineyards, and the scale of most wine-making businesses allows for closed loop operations. The beer

brewing industry produces a yeast sludge, which is currently being landfilled or disposed of to sewer. Solid wastes from the brewing industry are utilised as stockfeed.

Timber Processing

The timber processing industry is a major producer of wastes which can be used as carbon sources in the composting process, particularly sawdust and shavings. A significant quantity of sawdust is reused in intensive animal farming operations, such as poultry sheds. Other uses include compost and mulch products, pony clubs and kiln firing for brickworks. Off-cuts are usually reused as firewood. Some waste products, particularly from dried timber, are utilised as boiler fuel. A common issue for producers is the fluctuating demand from end users, resulting in the need to landfill surplus quantities.

Willingness to seek alternative options

Respondents were also asked about their experience with alternative methods of residuals management, such as composting, what they saw as the potential for alternative uses of their residuals, and perceived barriers to changing practices. Table 5 outlines the receptiveness of respondents to changing practices within each of the industry sectors.

Table 5. Receptiveness to alternative disposal, recycling or treatment options (industry sectors on a statewide basis)

Type of enterprise	Satisfied with current practices	Interested in alternatives but low priority	Actively seeking recycling practices
Abattoir	53%	34%	13%
Vegetable & Fruit Processing	20%	60%	20%
Vegetable & Fruit Packing	50%	33%	17%
Dairy Processing	38%	38%	24%
Extractive	50%	50%	0%
Fish Processing	57%	36%	7%
Beverage	25%	75%	0%
Forest Processing	38%	38%	24%
Other	67%	33%	0%

It appears from Table 5 that there is considerable latent interest in alternatives to disposal of organic wastes, but this interest is generally of a lower priority than other issues affecting the respective businesses. This may be a reflection of relatively low disposal costs, suggesting that the priority of these issues might rise with increased disposal charges.

Barriers

The respondents described a number of barriers to alternative disposal/recycling options, mostly centering on costs and economy of scale issues. Table 6 shows the number of people naming each of the listed barriers in their response to the survey. The listed barriers were not given as prompts in the survey process, so the responses are indicative of the perceived barriers put forward by each individual.

Table 6. Barriers to alternative disposal or recycling practices

Type of enterprise (number of database entries from each industry sector shown in brackets)	**Perceived cost of alternative options**	**Lack of expertise**	**Lack of suitable site**	**Transport costs prohibitive**	**Quality control**	**Low volume / Lack of economy of scale**	**Inadequate Govt. regulation / policy**	**Environmental issues – eg, odour, leaching**	**Material handling problems**	**Lack of suitable markets**
Abattoir (20)	7	1	0	3	0	4	0	5	2	1
Vegetable & Fruit Processing (9)	5	0	0	1	0	0	1	2	1	1
Vegetable & Fruit Packing (6)	1	0	0	0	0	0	0	1	1	0
Dairy Processing (7)	2	0	0	1	0	1	0	1	0	2
Fish Processing (14)	2	0	0	0	0	2	1	1	0	1
Extractive (5)	0	0	0	0	0	0	0	1	0	0
Beverage (6)	4	1	0	1	1	1	0	0	0	1
Forest Processing (28)	7	0	2	4	1	2	1	1	0	2
Poultry Farm (1)	0	0	0	0	0	0	0	0	0	0
Other (3)	0	0	0	0	0	0	0	1	0	0

It is clear from the barriers that were self-selected by the respondents that the perceived cost of alternatives is a significant barrier to changing perceptions in relation to organic waste reuse.

The survey has provided a good overview of the sources, quantity, type and location of residual organic materials in Tasmania, particularly with respect those materials generated in the agri-industry, forestry and food processing sectors.

Objective 2 – alternative reuse options

The choice of compost or manufactured products

One of the most obvious potential uses for recyclable organic material is as mulch or compost. While this approach represents an ideal opportunity to "close the loop" in terms of soil sustainability and other agriculturally related matters, it is always useful to investigate options for the maximum value-adding potential of organic waste materials. There are a number of barriers to creating higher value products from residual organic materials. These include:

- the technologies for alternative uses are often still in the development stage – eg. composite fibre materials for construction
- the infrastructure is often quite complex and expensive – eg. plastics from some starch materials
- the market is often a specialist niche, with the inherent danger of either over supply or disappearance through competition from other sources – eg. pharmaceuticals, cosmetics
- there is often a need for pure (ie single component) waste streams, which is often difficult to achieve when the attitude of many waste generators is not "core business"

A number of higher value options have been pursued in the past for some organic residuals in Tasmania. These include ethanol from potato waste and onion oil from reject onions.

Potato waste

Tasmania processes some 450,000 t/y of potatoes, mainly for the production of French fries and other processed frozen products. The industry produces some 30,000 t/y of waste material. Some of this, particularly potato peel, off cuts from sub-standard tubers and whole reject tubers, would be suitable for the production of ethanol. A study was conducted in 1995 to determine the feasibility of fermenting a slurry waste to produce fuel ethanol, and develop value-added by-products (HRDC Project VG 332).

The focus of the study was fuel grade ethanol because, at the time, the Commonwealth Government was promoting its use to as a substitute for lead additives with the promise of a bounty to subsidise production costs. Whilst ethanol was produced, the proponents were unsuccessful in winning the bounty. This created difficulties in raising venture capital, and the study ceased. As a result, the value-added by-products were not developed. The possible by-products were:

- de-starched, and therefore protein concentrated, residues from the fermentation process with potential as a stock or pet food ingredient.
- an aqueous wash, containing plant nutrients and potato specific tertiary metabolites. This could have had potential as a liquid fertiliser and an IPM tool, making use of the metabolites to stimulate the growth of potato pathogens in the non-potato phase of a crop rotation.
- carbon dioxide, which could be bottled for industrial purposes.

Without the ethanol bounty to underwrite the enterprise, it was apparent that the venture would have struggled to achieve viability in its early years of operation. More recent investigations into the production of ethanol from agricultural crops have indicated that the economics are still marginal. In addition, upgraded processes in the potato industry have reduced the starch component of the waste stream, thereby reducing the potential ethanol yield. Therefore, it is unlikely that this process offers a viable alternative end use for the residuals produced by the potato industry.

Onion waste
The Tasmanian onion industry is export based, with one major, and a number of smaller, packing operations handling the bulk of the crop. Reject onions, dry skin and leaves make up the bulk of the approximate 5,000 t/y waste stream. A privately funded study by one of the packing companies was conducted during the late 1990's to determine the feasibility of using this waste as a source of distilled onion oil. This proved to be uneconomical, primarily due to low oil yields. High oil onion varieties are used in overseas production areas that focus on oil as a primary product. The onions grown in Tasmania are for fresh export markets. It is apparent that economical oil production would require selection of varieties for that purpose.

Abalone shells
Although produced in relatively small volumes, abalone shells, and similar shellfish residuals, represent one of those rare cases in which a highly value-added use, and a simple processing technology, occur together. Abalone shells are currently used for the manufacture of hand-made buttons for clothing, a process that adds greatly to the value of what is otherwise a useless by-product of the industry.

The compost and mulch option
Many of the waste streams identified in the survey are not kept separate at the point of generation, and therefore are not well suited to higher value-adding opportunities. It may be possible to separate some of these materials to maintain purity, but this is seen as an added cost to the operator, and not warranted for a function which is not "core business".

In light of the limited opportunities for higher value adding on the basis of single material waste streams, it has been assumed that the main use for the organic residuals generated by industry will be as feedstock for mulch and compost production. This assumption is based on the premise that:

- the technology to do this is well developed
- the infrastructure required is not complicated or excessively expensive
- there appears to be a broad market and consistent demand for the end product, although the acceptance and use of compost in broad scale agriculture is still in its infancy.

While the end products of these processes could largely be considered to be mulches and composts, there is opportunity to develop and produce materials with specific attributes, a process that represents higher value adding within the compost and mulch market.

One of the barriers to further development along these lines is that many waste generators assume that, once a waste that is currently incurring a disposal cost appears to have a use, it should be sold at a profit, rather than being supplied to the materials processor at no cost. The generator of such wastes often ignores the fact that they currently incur significant costs to meet disposal and other management requirements.

Alternative uses of high carbon organic materials derived from timber
Given the above background, a range of alternative products and end uses were scoped in consultation with agricultural and waste management industry participants. Not all of the following alternatives to basic compost production will be commercially viable in the short to medium term. Some will require significant research and development and/or infrastructure before commercialisation can be contemplated. Current use of these processes is either non-existent, or at a low level, in Tasmania.

Soil amendments
Considerable volumes of sawdust and other small particle organic residuals are generated by the timber industry, some of which are currently landfilled. Sawdust has a high C:N ratio and therefore must be used with discretion when added to soil or in potting mixes because of the inherent danger of significant "nitrogen draw-down".

However, there are situations in which high nitrogen can cause problems in the field. One specific example is on intensive dairy farms, where paddocks are often grazed until manure cover reaches 25% before stock are moved. This equates to 25 – 75 m^3/ha of manure (assuming a thickness of 10 - 30mm).

Such concentrations of manure pose pollution risks to streams, due to surface water run off, and shallow ground water supplies, due to infiltration. Specialist equipment has been built and demonstrated by the Tasmanian DPIWE to incorporate straw into contour channels as a soil erosion management tool in vegetable cropping areas (Ashley, 2001). This equipment could be adapted to apply sawdust in a similar fashion to trap manure run off and hence protect streams from high nutrient pollution.

A simpler alternative would be to simply top dress the pasture with sawdust, possibly using an adapted fertiliser spinner. The net result would be, in effect, composting *in situ.*

Carcass composting
The "dry composting" technique for managing livestock mortalities is gaining widespread use in the intensive livestock industries (McGahan; Langston *et. al.*; Glanville *et. al.*, 1997; Fulhage, 1994). The aim is to envelop the carcass in sufficient sawdust to absorb moisture and odours, and act as a thermal blanket. After a period of time, the result is an end product suited for use as an ingredient for standard composting or for direct application to land.

It has been estimated that there are several thousand animal mortalities per year in the Tasmanian dairy industry. These carcasses are usually buried, and often present a risk to ground water supplies. The use of sawdust for this purpose could provide significant environmental benefits.

In addition, the establishment of such a process could provide a more effective and useful way of managing mass slaughtering programs such as might occur in times of drought or during an exotic disease out break. It would also provide a more consistent and predictable outlet for the use of sawdust residuals from the forest industries.

Value - added or "designer" mulches

Large volumes of organic material derived from wood are used throughout Tasmania as mulch. This is the simplest possible reuse option for this particular product. Mulch is usually promoted as a relatively inert physical barrier, used to reduce soil water evaporation and impede weed growth. Finer grade material needs to be replaced annually and coarser grades every three to five years, which is sometimes seen as a disadvantage because of recurrent costs.

It is reasonable to expect that the residuals from different tree species will produce mulches with different characteristics. There is potential to exploit these differences and explore the possibilities of quantifying positive aspects of the natural degradation process. This may include reduced plant disease due to increased antibiotic activity. Such effects have been shown for eucalypt derived mulches in the control of onion white root rot (*Sclerotium cepivorum)* (Dennis, 1996). It may be possible to quantify the specific diseases that are suppressed by mulches derived from different tree species, thereby allowing these materials to be marketed for specific uses.

Value-added or "designer" composts

There is potential for value adding what might otherwise be "standard" compost products by considering the specific qualities of the organic matter used in the process. Optimum compost mixes are usually defined in terms of chemical characteristics such as the carbon to nitrogen ratio (C:N ratio). Physical characteristics, such as particle size and moisture content, are also important. The finished compost product is often described in terms of its nutrient and trace element content, which is usually a requirement of national or industry based labelling standards.

At the simplest level, it should be possible to differentiate the various wood derived organic matter streams on the inherent characteristics of the species, as proposed earlier for mulches.

- *Composts from leguminous trees*
  The bark from tree legumes, such as Blackwood (*Acacia melanoxylon*), will be inherently higher in nitrogen than barks from non-legumes. In addition, it will contain a diverse range of tertiary metabolites, some of which will be sufficiently stable to be carried through the composting process. Some of these metabolites are likely to have beneficial effects on organisms grown in the compost. Further, the organic matter derived from flower heads and seeds will contain anthocyanin-based compounds, which have a range of effects on plant growth, such as seed and sprout germination promotion and inhibition. It will be necessary to quantify the modes of action of these compounds before proceeding to "design" specific compost products, but there is the potential to produce a range of novel and useful products for horticulture. An interview with the manager of one saw mill indicated that sawdust derived from particular tree species might provide the desired substrate for the production of niche market mushrooms.

- *Compost from Crack Willow (Salix fragilis)*
  Crack willow is a serious environmental weed tree that has infested many stream banks in Tasmania. Numerous programs are underway to eradicate this weed and rehabilitate stream banks. This work will receive a significant boost in 2002 when a major NHT program will target eradication of this tree, considered to be the worst weed in Tasmania.

  Preliminary tests indicate that using mulched willow as a carbon source produces a hotter compost heap than would be expected from other carbon sources. This may be due to its known salicylic acid content, the precursor to Asprin. Salicylic acid has been shown to be produced by some plants in response to pathogen attack. The salicylic acid repels the pathogen by raising temperatures up to 80 °C at the attack site. This kills the pathogen at the sacrifice of a small number of cells within the plant. It is possible that mulch and (more likely) composts which are based on willow derived carbon may have some beneficial properties in relation to disease protection of plants.

- *Root striking extracts from Crack Willow (Salix fragilis)*
  The effectiveness of Crack Willow as an invasive weed is due to its aggressive root striking ability. Preliminary tests (M. Walker, pers. comm.) indicate that a simple aqueous extract taken from willow saplings at bud burst was more effective at inducing root strike in cuttings than a standard commercially available product. It is possible that there may be a niche market for such extracts in the nursery industry.

Objective 3 – economics and logistics analysis

Model inputs

The model that was developed allows rapid assessment of a range of processing scenarios. The model allows input of the following variables:

- The types of organic materials to be recycled, including some properties such as bulk density. (It is expected that the user of the model will develop a recipe mix on the basis of other knowledge about the chemical properties of the feedstocks.)
- Variable costs such as labour, fuel etc.
- Choice of owned or contracted equipment
- Inclusion or exclusion of any step in the process
- Selection of equipment from a compiled list, or inclusion of specific equipment and relevant data by the user
- Infrastructure development costs (particularly relevant to larger scale sites)

The model is accompanied by a Guide that explains how to use the model and interpret the results. A copy of the model will be made available on the DPIWE web site, http://www.dpiwe.tas.gov.au.

The model is structured to represent 5 distinct phases of the organic materials processing operation:

- Phase 1 Collection
- Phase 2 Preparation
- Phase 3 Composting
- Phase 4 Finishing
- Phase 5 Dispatch & Application

- Phase 1 allows the cost of preparing and transporting the material to the processing site to be calculated. Phase 1 costs are often met by the generator of the waste material through provision of transport of raw feedstocks to the processing site, although in some cases the organic processing site operator may need to pay for transport. Even if the waste generator meets this cost, the operator will need to consider it in the context of setting a tip fee, to ensure that supply of the material to a re-processing site is a viable option for the waste producer.
- Phases 2 – 4 allows calculation of the actual processing costs associated with converting organic residuals into a useful agricultural product. Most organic materials recycling and processing operations will face the costs associated with phases 2 – 4. Sometimes elements of Phase 1 will also impact on this cost (eg. purchase of feedstocks).
- Phase 5 allows calculation of the cost of transporting and applying the finished product to land, which are normally met by the purchaser of the end product, either directly, or through the purchase price. Although the site operator does not usually cover Phase 5 costs, it is important to know the costs associated with transport and application. A grower interested in using compost or a similar recycled organic material will have a view as to a reasonable price, taking into account application costs and likely benefits. The producer of the material needs to set an ex-site price to cover the costs of production, but also needs to know the additional costs in the context of what growers are prepared to pay.

Model outputs

The model provides production cost information at a number of levels:

- The "Operating Costs of Production (machinery & labour)" cover all costs related to labour and equipment operations and are made up of the following:
  - labour costs
  - machinery variable costs
  - machinery fixed overhead costs
  - contract machinery costs
- "Material Costs" covers expenses related to the purchase of feedstocks and the disposal costs of oversize materials resulting from the screening of finished product.
- "Overhead Costs" cover fixed overheads arising from site infrastructure development and other on-going fixed costs related to the business operation.
- The "Total Costs (ex-site)" are calculated from the sum of operating costs of production, material costs and overhead costs.
- The "Transport & Land Application Costs" are listed separately as a cost which may not

be met by the waste processor, but which will impact on the achievable sale price.

- Revenue from feedstock tip fees and sale of oversize screenings is subtracted from the "Total Costs (ex-site)" to give the "Break-Even Sale Price".
- The "Transport & Land Application Costs" are then added to the break-even price to arrive at the "Break-Even Sale Price + Transport & Land Application Costs". This represents the minimum price that material could be supplied "on the paddock". In reality, the cost would be higher, to allow for the profit of the waste processor. For on-farm operations, the "Break-Even Sale Price + Transport & Land Application Costs" would represent the cost of providing that material as a production input, and allow the grower to make a comparison to the cost of buying in such inputs from another source.

Structure of the cost information in this fashion allows different users to extract information related to different areas of interest. For example, a grower could use the output figure of "Break-Even Sale Price + Transport & Land Application Costs" as an input to a farm budget model to create various cost/benefit scenarios which might arise from the application of compost or similar material.

Alternative scenarios

The model was used to estimate the cost of producing compost for agricultural use for three different scenarios at three different scales of operation – small (<5,000 m^3/y of feedstocks), medium (5,000 – 15,000 m^3/y) and large (>15,000 m^3/y). The throughput capacity of an operation does not necessarily correlate with the distinction of the operation being farm based, regional or centralised. Although this will often be the case, it is possible that a regional operation, which draws feedstocks from a relatively small area, may have a high throughput. Likewise, in another situation, a facility might need to operate in a centralised fashion in order to capture enough feedstock volume to be viable.

The scenarios used in this exercise were constructed to represent realistic situations in both the agricultural and waste management industries. Choices were made regarding the volume of feedstocks, equipment selection, transport distances, overhead and infrastructure costs and the steps used in the process. Details of the various scenarios are shown in Appendix B.

The production cost of compost varied considerably between scenarios, based on the assumptions used. In all cases, it was assumed that the costs of transport of the feedstocks would not contribute to the cost of production. For small-scale on-farm operations, the cost of handling raw materials to the compost site is very low, as the site is usually nearby the source of materials – eg. beside a dairy. For larger scale operations receiving materials from off-site, it is normal for the waste generator to cover the cost of transport as part of their waste management costs.

Small scale on-farm

Small-scale on-farm scenarios tended to be the cheapest, with production costs ranging from about \$3.40 - \$5.50/m^3. Overhead costs for the same scenarios ranged from \$1.00 - \$2.80/m^3. The addition of the transport and field application costs lifted the total price of material applied to land to \$5 - \$14/m^3. It was assumed that these operations would draw feedstocks from within the farm enterprise (eg. manure, spoiled hay etc.). The minimum final cost applied to land is heavily influenced by the following assumptions:

- no significant investment in site infrastructure
- most machinery would already be in use on the farm
- end use of the compost would be on the farm, hence low transport distances and no testing or analysis costs
- in one example scenario, no allowance was made for labour costs, the labour being supplied by the farmer. In this case, the cost of compost applied to land increased from $4.94 to $11.30/m^3 if labour costs were considered at market rates, which demonstrates the short-coming of ignoring labour costs for on-farm operations.

Medium scale

Medium scale operations were assumed to be on-farm, but with access to larger volumes of feedstocks, some from off-site. Production costs ranged from about $10.70 - $16.00/m^3. Overhead costs for the same scenarios ranged from $1.00 - $1.60/m^3. The lower overhead costs (compared to the small scenario) were a function of increased throughput volume, while not having excessively high overheads as a result of being a farm based operation. The addition of the transport and field application costs lifted the total price of material applied to land to about $8 - $25/m^3. The large variation in this range of costs reflects revenue from tip fees in one scenario, which acts to lower the ex-site cost of the product. The results of the medium scale scenarios were heavily influenced by the following assumptions:

- volume of material processed, with the flow on effect on fixed machinery ownership costs
- revenue from tip fees
- transport costs

Large scale

Large-scale operations were assumed to be centralised enterprises in which the processing of organic wastes was the sole purpose of the business. All processed products were assumed to be sold off-site, requiring greater quality control through material analyses and process monitoring. Costs of production ranged from about $10 - $23/m^3. Overhead costs for the same scenarios ranged from about $8.00 - $18/m^3. The throughput volume heavily influenced both production and overhead costs. Overhead costs also reflect the greater investment required in site infrastructure for an operation that is dedicated to compost processing, rather than a site which is supplementary to a farming operation. The addition of the transport and field application costs lifted the total price of material applied to land to about $14.50 - $41.50/m^3. This large range in final costs reflects a combination of variable revenue from tip fees and variations in throughput volume, while site infrastructure investment remained relatively constant. The results of the large-scale scenarios are heavily influenced by the following assumptions:

- significant investment in site infrastructure, which is not normally required for smaller farm-based operations
- volume of material processed, with the flow on effect on fixed machinery ownership costs and site infrastructure costs

- revenue from tip fees
- transport costs, which tended to be higher due to longer transport distances

Sensitivity analysis

The model was also used to undertake a sensitivity analysis of the effect of transport distance on the final cost of compost applied to agricultural land. Transport distance is often cited as a factor limiting the more wide spread use of compost in agriculture. The scenario modelling and sensitivity analysis undertaken with the model indicate that this is not always the case, and the importance of transport in the overall production cost structure is dependent on a number of variables.

Transport costs for small farm-based operations tend to be low, as the transport costs are purely on-farm. Medium and large-scale operations are likely to be faced with greater transport distances, as they would normally serve a larger region than one farm. However, factors such as the fixed overhead costs for machinery and infrastructure were also important in determining the total costs associated with processing. Low production volumes and high fixed overheads have a large impact on the per m^3 costs. If fixed overheads are high on a per m^3 basis, an increase in transport costs, while significant in absolute terms, might not be so relatively important.

The sensitivity analysis involved an assumed likely transport distance, which was then changed by factors of 0.5, 2 and 4. In many cases, even small increases in transport distance can have a large effect on the transport and application costs. However, when transport is considered as a component of the entire processing and application system, it usually requires an increase in transport distance of about 100 km to cause a significant (15 – 30%) increase in the overall cost of processed compost applied to land.

Objective 4 – review of QA and HACCP issues

Interviews with participants in the Tasmanian vegetable industry highlighted two main streams of thought in relation to the use of recycled organic materials in the vegetable industry. These can be categorised broadly in the context of the fresh market and processing sectors.

The primary concerns of the fresh fruit and vegetable industry come from the retail and catering sectors, and relate to the health risks associated with food produced using recycled organic materials. While the risks associated with the proper use of recycled organic materials are very low, it is important that the recycled organics industry, and producers who use organic products, take a comprehensive approach to QA and HACCP systems in order to manage the issues.

The processed vegetable sector is not overly concerned about health risks in the final product, given the strict regulations already in place governing processing. For the most part, the primary concern of the processor is that the product meets the desired specifications.

Discussion of results

Objective 1 - organic waste survey

An inventory of organic resources can only provide a snapshot of available materials at a given time. The ability to update the information is important for maximum benefit to be derived over the longer term.

The survey examined only those wastes that are homogenous and readily available for use as a part of the recycled organic materials industry, and likely to supply useful products to agricultural markets. A number of important organic waste resources arising from urban areas were not included in this survey. These are mixed putrescible waste, paper based products arising from the commercial and industrial sector, green waste (garden trimmings) and sewage sludge produced at the Municipal level. The sources of these materials tend to more geographically spread and vary in output, both in relation to the size of the source and seasonality. Putrescible domestic waste and green waste tend to be more variable in composition than many industrially sources materials, and therefore can present challenges in the production of end products of consistent quality, such as compost. Although these materials were not considered as part of the survey, it is recognised that they may be used as feedstocks in the recycled organic materials industry.

A further limitation of this study is common to survey based research. Whilst the participation rate of 79% is a good response, it does not present the complete picture. A major reason for non-participation can be the perception of surveys as a time wasting exercise by some respondents. To counteract this perception, the survey was presented as an opportunity, and a means to assist the recycled organic materials industry and stimulate broader options for management of waste streams. This approach was useful, but not enough to convince some respondents to participate. However, most of those identified as the major organic waste producers in Tasmania participated. As such, the information presented provides sound indicative data on organic resources in Tasmania as of mid-2001.

This survey identified a broad range of materials with potential for either direct use, or use after processing, in the agricultural industries. Of particular interest were the views of respondents to questions of alternatives and barriers to the uptake of alternative recycling options. It is clear from Table 6 that the cost of alternatives is seen as a major barrier. The survey did not question deeply enough to determine if the perceptions about cost included consideration of the current costs of disposal (tip fees) or the opportunity costs of resources being lost from the business through the waste stream. This probably reflects that landfill charges are still too low to encourage alternative management options that focus on resource recovery. It may also reflect that many businesses don't view waste management as a core function, but rather one that is best solved by paying someone else to take the waste away.

The survey also sought details on the physical and chemical properties of the wastes, which is valuable information for potential users of the material. Information in these areas was notable by its absence, reflecting a major barrier to identifying materials that could be reused in agriculture. Physical properties are important from a transport and materials handling perspective. Chemical properties are essential to determine appropriate application rates of materials to land in order to ensure that reuse is undertaken in a beneficial manner, or for the formulation of recipe mixes for composting operations.

The information collected in the survey is currently assembled in an Excel spreadsheet. The data is in a form suitable for incorporation in a Geographical Information System database, which could map organic waste resources and transport routes to provide a user friendly system of information provision to industry. However, there is no clear advantage to presenting the data in this form at the present time. Instead, arrangements are in place for the information to be made publicly available through integration with an existing database known as TWEX, the Tasmanian Waste Exchange. The information will be available at http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/EGIL-53M7AH?open. The availability of this information has the potential to assist operators develop the recycled organics industry in Tasmania.

Generators, and potential end users, of residual organic materials in Tasmania now have, for the first time, a comprehensive database of information relating to the availability of organic materials suited for recycled. The current database has two major limitations:

- there is currently no provision for updating the information. This is an exercise that will need to be undertaken about every two years. Now that the format for the database is established, it should not be an onerous task.
- there is a noticeable lack of data on the physical and chemical properties of the organic waste materials generated by industry. This could be overcome via another project designed specifically to collect that information.

Despite these two limitations, the database should now make it easier for potential end users or processors of organic waste materials to determine the location and volumes of feedstocks. This should enable better decisions to be made on appropriate recycling activities in particular areas, and in turn lead to greater availability of processed organic materials for use in agriculture.

Objective 2 – alternative reuse options

There has been an abundance of research done the world over to find alternative uses for waste materials, particularly organic materials, given the fact that they can present some significant environmental management problems. Many different and highly valued products can be manufactured from organic waste materials, but many of the processes require significant investment in technology and access to niche markets. Alternative uses of recyclable organic materials in Tasmania, other than for mulch and compost, appear to be limited by a number of factors:

- a significant number of mixed waste streams make it difficult to pursue options that require a degree of purity
- the investment required for new technologies is significant
- the development of new products requires significant investment in research and

development

As mulch and compost production are already accepted uses for residual organic materials, it is probably more fruitful to add value to those uses in the ways suggested rather than looking for alternatives.

There have been a number of efforts in the past to make higher value added products out of organic waste materials in Tasmania. The nature of the generating industries, access to markets for specialist products, and the significance of agriculture in the State, indicates that production of materials for use in agriculture and amenity horticulture will most likely offer the best opportunities for beneficial re-use of residual organic materials. While this will still require significant investment across a range of sites, the technology and processes are well known. In addition, the regionally dispersed nature of waste generation sites means that it will often be easier and more economical to combine materials for local compost production than to transport them to centralised sites for higher value processing.

The establishment of a number of composting sites in regional locations around the State would make compost and similar products more readily available to agriculture. This could be particularly important in regions of intensive vegetable production, as these regions are likely to be in need of recyclable organic materials to apply to land. Fortunately, the same regions also have the greatest concentrations of sites producing organic waste materials.

Objective 3 – economics and logistics analysis

The scenarios that were modelled as part of the project provide insight into the issues that effect the final cost of compost applied to land. For large-scale operations, which are not associated with a farming enterprise, the volume of throughput is important in order to reduce the per m^3 cost of fixed overheads related to machinery and site infrastructure. Considerations related to infrastructure costs are likely to be less important for smaller operations that are farm-based, as there is not likely to be the same need for extensive site development.

Machinery selection is important, as the choices made have a direct influence on capital costs and, by virtue of differing production rates, they also impact on the labour hours and costs.

The impact of transport costs is very dependent on the overall production cost structure and the likely region of operation. It is apparent that each operation would need to be considered on a case-by-case basis in relation to the impact of transport costs. However, it would appear that transport distances greater than about 100 km are likely to add significantly to the final cost of land applied materials, regardless of the characteristics of the operation and the cost structure.

Tip fees are very important in the overall economic analysis of waste processing operations. Current industry evidence suggests that on-farm sales of compost are mostly in the \$20 - \$30/m^3 range. The amount of income required from sales decreases if part of the revenue can be derived from tip fees. The importance of this was shown in the results of one scenario in which the ex-site costs associated with production were about $18/m^3, but almost half of that cost could be met through tip fee revenues.

Another factor that impacts significantly on the cost of the finished product is the volume loss that occurs in processing, particularly in composting operations. The final output of an operation may be less than 50% of the original volume of feedstocks taken in, as a result of volume losses in mixing, the composting process and screening. Since all the costs of production have to eventually be written off against the volume produced, the impact of this volume loss is very significant, but easily overlooked by someone not familiar with composting processes. Of the medium and large scale scenarios run through the model, those with high break-even costs were those which received minimal or no revenues from tip fees, or with low volume throughput.

The scenarios modelled in the project indicate that it should be possible to produce compost in most circumstances at costs that are reflective of what growers are likely to pay ($20 - $30/m^3). However, in many cases, particularly medium and large-scale operations, it would be necessary to attract tip fees as an additional source of revenue to make the process economically viable. This point is of particular importance for those industries that generate organic wastes that are suitable for processing into beneficial agricultural products. Many waste generators seem to conclude that if someone else can make money out of their waste, then they should receive payment for it. Waste generators already face costs associated with waste management. Their primary focus in directing wastes to further processing should be to minimise those costs. It is going to be very difficult, if not impossible, for composters and other waste processors to survive economically if they are required to pay for feedstocks.

Objective 4 – review of QA and HACCP issues

Background - the dimensions of Quality Assurance

"Quality" is defined in many ways. The most traditional manner equates "quality" with "expense" i.e. if an item is expensive, then it must be of high quality. A more contemporary definition includes "fitness of purpose" i.e. if an item does a job well for the customer then it will be regarded as high quality, regardless of cost.

Whatever the definition, customer/market perception is a key issue. This is particularly so in the organic food industry. For Tasmania, the perception of quality is critical to the "clean and green" image so widely used in the promotion of food products in various markets.

Producers often assume that a "quality assured" product will attract a price premium, linking it with the traditional definition. This is rarely the case. It is more often the case that the producer simply has continued access to a market if the quality of the product is assured.

"Assurance" is fundamentally different from "control". In the latter, Quality Control is maintained as a separate function in the production system, the responsibility being delegated by the producers to a Quality Control system. It is an "end of line" approach to ensuring quality, wherein product quality is compared to a predefined standard at the completion of the processing system.

Under Quality Assurance (QA), quality is the responsibility of production, and it is assumed that the product will be of a consistent quality as a result of the production processes that are adhered to as part of the QA system. Production systems are audited periodically to ensure adherence with requirements. This approach relies heavily on training and self-management.

Since the early 1990's two different approaches to QA have developed to the stage where it is now not only possible for agricultural enterprises to be formally accredited, but in some instances "accreditation" is now a pre-requisite for access to certain markets. The two basic concepts are "standards" (eg. ISO) and "risk management" (eg. HACCP).

ISO

The International Standards Organization (ISO) was set up in the context of manufacturing, and the need to ensure that products traded internationally were produced to the same specifications. The basic concept is to develop an industry standard for a product. The standard specifies measurable parameters that are to be used in defining quality.

The Standards approach has been expanded from its original manufacturing origins. A recent addition is the ISO 14000 series that covers environmental standards.

At the agricultural production level, some exporters in Tasmania have put in place production systems for their suppliers to ensure that customers in Europe receive product that has been grown within an environmentally responsible framework. The most notable example of this occurred in the onion industry in which growers became accredited under the Tesco Nature's Choice environmental management system in order to gain access to a particular market segment in the UK.

HACCP

"HACCP" stands for "Hazard Analysis and Critical Control Points". The concept was originally developed to ensure that delivery systems for astronauts are "fail safe". The HACCP system has been used widely in the aviation industry to manage safety issues related to flying, and airline catering services were among the first to use it regarding food safety. It was a natural progression for it to be used in the general food processing industry.

The emphasis in on analysing what can go wrong (the Hazard Analysis) and then identifying how this can be controlled (the Critical Control Points). The main difference between ISO and HACCP is that establishing the standard is the primary emphasis of ISO and establishing the process to control the risk of a hazard emerging is the emphasis of HACCP.

The two are complementary and both require:

- training to ensure the reality of self-management
- a "paper trail" to make external audit possible

For both, the slogan is "Describe what you do, do it, prove it".

QA and HACCP issues relevant to use of organic residuals
There are a number of issues that need to be addressed in the context of QA and HACCP in relation to organic waste processing and the use of processed organic materials in the food production industry. These include:

- the quality of processed organic products that are used for food production
- health risks associated with
    - handling the processed organic products
    - consuming the resulting food product
- the contribution of the organic product to sustainable agriculture

The quality of the organic product
Contemporary agricultural production systems require consistent, reliable inputs. For products such as composts to be used in extensive agricultural production systems (at the scale of 10 ha or more) there is a requirement for a consistent quality of product and a predictable response from the crop. This means a level of consistency of the product, which is easy to achieve with factory manufactured "artificial" fertilisers, but much more difficult with compost and similar products.

This consistency relates not only to the standard labelling requirements for nutrients and other chemical components, but also to physical parameters such as particle size (particularly for mulches), organic matter and moisture content.

Recycled organic materials, particularly compost, have a number of potential benefits when used in crop production systems. These include improvements in soil structure, leading to lower water use, and disease reduction. It is important that these benefits are quantified for the end user. Otherwise, products derived from organic materials will have to compete with "artificial" fertilisers on the basis of their major nutrient content. This is always difficult for materials such as compost, as the nutrient content is always much lower than fertilisers. It will be important for the growing recycled organics industry to adopt quality standards, such as those defined in the Australian Standards for Composts, Mulches and Soil Conditioners (AS 4454), in order to assure end users of the value of the material as an input to crop production.

Health risks associated with handling the product
Many of the benefits of organic materials are due in part to the living nature of the product. Compost, for example, is a biologically active material containing a vast range of micro-organisms.

This has caused concern about the risk of operators inhaling bacteria, and warnings of this risk are now incorporated in the label on bagged products. In more recent times, there has been international concern about "Mad Cow Disease", which has precluded the use of some traditional organic fertilisers, such as blood and bone, on growing crops destined for some

Japanese markets.

There are some legitimate health concerns associated with the use of recycled organic materials, such as human pathogens in biosolids, and *Legionella spp.* in compost. Well established quality assurance and HACCP systems will be important for the industry to manage the risks associated with these issues.

Health risks associated with consuming the resulting food product
Interviews of industry participants in Tasmania showed that the health risk concerns associated with food produced using recycled organic materials are primarily evident in the retail and catering sectors of the fresh fruit and vegetable industry. Because of its traditional association with organic production, and the highly perishable nature of most products, the culinary herb segment of the industry was the first on which HACCP based production systems were imposed by the two major supermarket chains. While the risks associated with the proper use of recycled organic materials are very low, it is important that the recycled organics industry, and producers who use organic products, take a comprehensive approach to QA and HACCP systems in order to manage the issues.

Interviews with representatives of the processed vegetable sector indicated that the processors were not overly concerned about health risks in the final product, given the strict regulations already in place governing processing. For the most part, the primary concern of the processor is that the product meets the desired specifications. The production system that is used to produce the product is not a primary concern. Interestingly, this does not concur with the approach of major processing companies in Tasmania to resist the use of secondary treated municipal wastewater as a source of irrigation water for processing crops. This is due to company perceptions and fears of consumer backlash, despite the fact that the risk of biological contamination surviving the processing operation is extremely low. It seems there is some way to go yet in the educational process of accepting the use of recycled materials as inputs to crop production.

Issues regarding environmental sustainability
The HACCP approach has tended to highlight the negative aspects of the use of processed organic materials in fresh fruit and vegetable production. Conversely, the ISO 14000 system, and similar QA systems which focus on improved environmental management, favours their use. Improved environmental sustainability has long been a justification for the use of recycled organic materials.

It is assumed that production systems involving inputs derived from recycle organic materials are more sustainable than those with inorganic inputs, although the proof of argument for one approach or another is far from clear cut. This highlights the importance of market perception in this context, and has given rise to the requirement of some importers of Tasmanian product to have assurance that environmentally sustainable production systems are being used. Whether or not this is a fact or a perception is a separate issue.

It is likely that the growing importance of QA and HACCP will impact on the further development of organic waste reuse as a component of sustainable agriculture. Recent events indicate a trend for greater adoption of quality assurance systems and principles in the area of Government policy. For example, the recently enacted National Action Plan for Salinity and Water Quality is based on ISO principles. It involves deriving standards for the water resource condition in priority regions in each State, developing targets to be met on the way to achieve those standards, and establishing systems to meet the targets.

The fact that the National Action Plan on Salinity and Water Quality is based on ISO principles suggests that Government policy in the broader context of natural resource management will become increasingly centred on these principles. In addition, there is rapidly increasing interest, particularly at the Government level, in the application of environmental management systems to agricultural production in order to meet natural resource management objectives.

It is inevitable that agricultural production will be operating in an environment of increasing emphasis on environmental management in the future. It is likely that Government policy, as well as market perception, will drive moves to use the organic materials arising from agricultural production more productively, with an emphasis for the resultant processed materials (compost etc.) to be used back in agricultural production systems.

The pressures on the secondary industry sectors of agriculture, in particular food processors, will also play a part in this trend. Most industries will face increasingly tighter controls on waste management, and the recycling of residual organic materials to farmland offers opportunities for companies to display good corporate citizenship on the environmental front. It is not only about being seen to do the right thing. The concepts of 'Natural Capitalism', wherein maximum beneficial use is extracted from all resources at an economic advantage to the business, will also be a driver in this context. The most successful companies in the manufacturing sector are now managing and developing in line with the principles of 'Natural Capitalism'. As with ISO and HACCP, it seems likely that this trend will expand to include sustainable agriculture.

Technology transfer

At the time of proposing this project, it had been intended to conduct field days and workshops to expose growers and operators in the recycled organics industry to some of the issues associated with the processing and reuse of organic wastes, particularly in the context of compost production. The project suffered considerable setbacks due to a number of factors, including delays in funding. Over the duration of the project, two commercial composting operations have been established in Tasmania, and a third is in the planning phase. These developments will result in a major composting operation in each significant agricultural region of the State, being the south, north-east and north-west. In addition, existing and new businesses have entered the market in relation to the application of organic wastes to land, particularly those that are suitable for direct application without additional processing.

Compared to many mainland States, Tasmania has relatively short transport distances between sites that generate organic residuals and agricultural land. With this in mind, it is likely that the development of the organic waste recycling industry will follow a municipal or district structure, rather than small on-farm or large centralised operations. The reasoning behind this assumption is that transport distances from municipal or district facilities to the farm gate will be short enough to enable cost effective delivery to local farms. The relatively short transport distances also suggest that individual on-farm composting operations will not be duplicated to any great extent, with activity being concentrated at a municipal or district level. At the other end of the scale, centralised or regional sites serving large geographical areas would still face relatively higher transport costs associated with longer haulage distances. Transport distances in such cases could still be in the order of 100 – 200 km, and hence be a barrier to economical supply to farms.

In light of the foregoing discussion, it seems that the greater need for technology transfer lies in the area of increasing the awareness of the benefits to growers of using recycled organic materials, particularly compost. This was not the major focus of this project.

Participants in the recycled organics industry and growers were made aware of the project and its objectives through the following events and publications:

- Compost seminar – New Town Research Laboratory, Hobart, Sep 17th, 1999
- "ROM – is it just something to do with computers?", Agriculture Tasmania, Sep 1999.
- Progress report published in Potato Australia – Sep 1999, 2000, 2001
- Forthside Research Farm field day – Feb 9th, 2000
- Potato and Vegetable Agricultural Research Advisory Committee presentation day – Aug 10th, 2000
- AgFest display, 3rd – 5th, May, 2001
- Forthside Research Farm field day – Dec 13th, 2001

In addition, the project was discussed widely with various sectors of the agri-food industry as part of the survey process. Businesses interviewed were made aware of the aims of the project, and in many cases, were eager to see the results of the survey made available as a means of encouraging progress in the area of beneficial reuse of organic waste materials.

The results of the project, particularly the survey and the economic model, will be available on the Tasmanian DPIWE web site. Those involved in the recycled organics and agricultural industries will be made aware of these tools through appropriate media exposure when the details become available on the web site.

Recommendations

The recommendations arising from this project relate to aspects of potential future work and to the opportunities in the recycled organics industry in general.

Maintaining currency of information
There is currently no provision for updating the information in the database of organic waste material producers that was generated as part of this project. This is an exercise that

will need to be done about every two years, and is the part of this type of work that is most often neglected. Incorporation of the database in the Tasmanian Waste Exchange should help alleviate some of this problem, but it is recommended that attention be given to a system to ensure information is kept up to date. This applies to other similar databases in other regions, as a current database of waste material information is of great help in encouraging the beneficial reuse of organic residuals.

Waste material characteristics
There is almost a complete absence of data on the physical and chemical properties of the organic waste materials generated by industry. This information is essential for waste processors to determine the scope for inclusion of materials in processing operations, such as composting. In the Tasmanian context, this could be overcome with another project designed specifically to collect that information.

Economic model development
The model developed to answer questions related to the economics of organic residuals processing and reuse has its limitations in regard to user friendliness. While it is not difficult to use in itself, it became apparent during the assessment of different compost production scenarios, that some aspects of its use were dependent on good background knowledge of both the model and the composting process. Another project, which would require significant computer programming input, could update the model to a dedicated piece of software incorporating more user-friendly features. In addition, such a project could add even greater value by integrating the economic model with other currently available models that allow evaluation of recipe mixes and design of infrastructure for composting operations.

Agricultural production information
The major limitation for growers remains concise information regarding the production benefits of inputs such as compost. There is an increasing amount of scientific work being conducted in this area, and it is recommended that priority be given to work of this nature to provide solid information for growers so they can make effective production decisions. It is inevitable that there will be variation in the conclusions of such work, depending on a range of factors that are particular to any given study. This should not be a reason to avoid such research.

The economics of composting
It is unlikely that commercial composting businesses will survive on the basis of sales alone. There is a need for composting operations to be able to generate revenue from tip fees, and this is only likely to occur with any reliability when there is realistic costing for waste disposal options. Access to tip fees, and the resultant ability to supply compost to agriculture at lower prices, is important to allow expansion in the price sensitive agricultural market. Agri-industrial producers of organic wastes must realise that tip fee revenue is equally as important as sales revenue for the compost operation. Generators of organic wastes will logically look for the cheapest form of waste management, but the notion that they should receive payment for wastes purely because someone else can use them to establish a financially viable enterprise will ultimately mean the demise of composting as an alternative waste management strategy.

The place of compost in agricultural production
Society has a mixed value system in relation to the use of recycled organic materials for food production. On the one hand, issues of food safety tend to work against the use of such materials, with largely unfounded fears of food contamination. On the other hand, expectations of responsible environmental management are driving significant changes in the areas of waste management and agriculture. Both the recycled organics and agricultural industries need to champion the message that properly monitored and managed composting operations produce products that are quite safe to use in food production agriculture. Mature compost is not "waste" – it is a potentially valuable input to agricultural production systems.

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Appendix A

Appendix A contains a copy of the survey form which was used to collect information from businesses in Tasmania which produce residual organic materials.

Recyclable Organic Materials Database Survey

Part A – General Information

Name of operation:……………………………………………………………………

Location address: ……………………………… Postal address:…………………

………………………………   …………………..

………………………………   …………………..

Ph:………………………………   Fax:……………………………..

Email:…………………………..   Mobile:…………………………

Contact person:……………………………………..

Type of operation (refer to list in Table 1):…………………………………………

Size of operation (as measured by raw product input):………………………………..

Unit of measure for size (eg. t/y, m^3/y, ML/month etc):……………………………...

Table 1. Type of enterprise ID numbers for database records

Type of Enterprise	Identification number ranges for database
Abattoir	0001-0100
Vegetable & Fruit Processing	0101-0200
Vegetable & Fruit Packing	0201-0300
Dairy Processing	0301-0500
Fish Processing	0501-0600
Extraction	0601-0700
Beverage (including wine, beer etc.)	1001-2000
Dairy Farms	2001-3000
Pig Farms	3001-4000
Poultry Farms	4001-5000
Timber Processing	5001-6000

Information to be filled in after interview

Database ID number:……………..

Easting:…………………………   Northing:…………………………

Mapsheet:………………………

Details of the organic waste materials generated by your enterprise

Part B - Solid Waste Materials

1. How many different solid organic waste materials do you generate?.................
2. Are they mixed or kept separate?..
3. What is the major component of the solid organic waste materials that you generate?..
4. Total quantity of waste:...
5. Unit of measure of quantity (eg. t/y, m^3/y, ML/month etc):............................
6. Months of generation (eg. Feb – May, Jan – Dec etc.):.................................
7. What happens to the solid organic waste materials now? (eg. Landfill, on-site treatment, reused etc.)...
8. **Comments (the following prompts may be useful, or you may have other comments to add). In relation to the** solid organic waste materials **generated by your enterprise:**
   - What is your prior experience with alternatives to disposal?

     ....

     ....
   - What do you see as the potential for alternatives to disposal?

     ....

     ....
   - What do you see as the barriers to alternatives to disposal?

     ....

     ....

The following information is very useful in determining possible end uses of solid organic waste materials. If you have this information about the solid organic waste materials generated by your enterprise, it would be a valuable addition to the database.

Moisture content (% dry basis):......................Density:...................................(kg/m³)

Level of contamination (%):	*0*	*<1*	*1 – 5*	*5 – 10*	*>10*
(ie non-organic materials)	☐	☐	☐	☐	☐

Are the following available:

Nutrient analysis? ☐ *yes* ☐ *no* *Chemical analysis?* ☐ *yes* ☐ *no*

Energy value? ☐ *yes* ☐ *no* *If so, what is it?....................... (MJ/kg)*

C/N ratio? ☐ *yes* ☐ *no* *If so, what is it?...........................*

Part C - Slurry Waste Materials

1. How many different slurry organic waste materials do you generate?.................
2. Are they mixed or kept separate?..
3. What is the major component of the slurry organic waste materials that you generate?..
4. Total quantity of waste:...
5. Unit of measure of quantity (eg. t/y, m^3/y, ML/month etc):............................
6. Months of generation (eg. Feb – May, Jan – Dec etc.):................................
7. What happens to the slurry organic waste materials now? (eg. Landfill, on-site treatment, reused etc.)...
8. **Comments (the following prompts may be useful, or you may have other comments to add). In relation to the** slurry organic waste materials **generated by your enterprise:**
   - What is your prior experience with alternatives to disposal?

     ....

     ....
   - What do you see as the potential for alternatives to disposal?

     ....

     ....
   - What do you see as the barriers to alternatives to disposal?

     ....

     ....

The following information is very useful in determining possible end uses of slurry organic waste materials. If you have this information about the slurry organic waste materials generated by your enterprise, it would be a valuable addition to the database.

Solids content (%):....................................Density:..................................(kg/m³)

Level of contamination (%):	*0*	*<1*	*1 – 5*	*5 – 10*	*>10*
(ie non-organic materials)	☐	☐	☐	☐	☐

Are the following available:

Nutrient analysis? ☐ *yes* ☐ *no* *Chemical analysis?* ☐ *yes* ☐ *no*

Energy value? ☐ *yes* ☐ *no* *If so, what is it?..............................(MJ/kg)*

C/N ratio? ☐ *yes* ☐ *no* *If so, what is it?..............................*

Part D - Liquid Waste Materials

1. How many different liquid organic waste materials do you generate?.................
2. Are they mixed or kept separate?...
3. What is the major component of the liquid organic waste materials that you generate?..
4. Total quantity of waste:..
5. Unit of measure of quantity (eg. t/y, m^3/y, ML/month etc):............................
6. Months of generation (eg. Feb – May, Jan – Dec etc.):................................
7. What happens to the liquid organic waste materials now? (eg. Landfill, on-site treatment, reused etc.)...
8. **Comments (the following prompts may be useful, or you may have other comments to add). In relation to the** liquid organic waste materials **generated by your enterprise:**
   - What is your prior experience with alternatives to disposal?

     ....

     ....
   - What do you see as the potential for alternatives to disposal?

     ....

     ....
   - What do you see as the barriers to alternatives to disposal?

     ....

     ....

The following information is very useful in determining possible end uses of liquid organic waste materials. If you have this information about the liquid organic waste materials generated by your enterprise, it would be a valuable addition to the database.

Solids content (%):..................................

Level of contamination (%):	*0*	*<1*	*1 – 5*	*5 – 10*	*>10*
(ie non-organic materials)	☐	☐	☐	☐	☐

Are the following available:

Nutrient analysis? ☐ *yes* ☐ *no* *Chemical analysis?* ☐ *yes* ☐ *no*

BOD_5? ☐ *yes* ☐ *no* *If so, what is it?* ....*(mg/L)*

Appendix B

Appendix B contains details of the scenarios which were modelled using the recycled organic materials model.

Small operation	Scenario 1	Scenario 2	Scenario 3
Setting	Intensive livestock farm	Small farm	Small organic farm
Raw material intake p.a.	2,575 m^3	2,450 m^3	1,350 t
Feedstocks	Manure, straw	Manure, pyrethrum marc, spoiled hay	Grape marc, vegetable discards, lucerne hay
Tip fees	No	No	No
Loader	75 kW tractor with 0.75 m^3 bucket	75 kW tractor with 0.75 m^3 bucket	65 kW tractor with 0.5 m^3 bucket
Turner	Tractor and bucket	Tractor and bucket	500 – 1,000 m^3/h PTO turner
Grinder	none	none	none
Mixer	Mixed in the windrow with tractor	Mixed in the windrow with tractor	Mixed in the windrow with PTO turner
Screen	none	none	none
Transport	8 m^3 truck	15 m^3 tractor towed tipping trailer	12 m^3 tractor towed spreader
Spreader	16 m^3 tractor towed moving floor trailer	15 m^3 tractor towed tipping trailer	12 m^3 tractor towed spreader
Labour	Permanent labour	Labour not costed	Permanent and casual labour

Annual overhead and infrastructure costs were kept constant within each scenario capacity:

Small – $1,350 infrastructure costs

Medium operation	Scenario 1	Scenario 2	Scenario 3
Setting	Broad acre farm	Large vegetable farm	Poultry producer
Raw material intake p.a.	15,500 m^3	4,600 t	7,700 m^3
Feedstocks	Manure, sawdust, vegetable processing waste	Waste potatoes, onions, softwood sawdust	Chicken manure, hardwood sawdust, chicken carcasses
Tip fees	Yes	No	No
Loader	75 kW tractor with 0.75 m^3 bucket	15 t excavator with 0.8 m^3 bucket	75 kW tractor with 0.75 m^3 bucket
Turner	500 – 1000 m^3/h PTO turner	Excavator used	500 – 1000 m^3/h PTO turner
Grinder	none	none	none
Mixer	Mixed in the windrow with turner	Mixed in the windrow with excavator	Mixed in the windrow with turner
Screen	20 – 60 m^3/h contracted screen	none	20 – 60 m^3/h contracted screen
Transport	45 m^3 contract transport	25 m^3 owned trailer	15 m^3 contract transport
Spreader	15 m^3 contract spreader	15 m^3 owned spreader	15 m^3 contract spreader
Labour	Permanent labour	Permanent labour	Permanent and casual labour

Annual overhead and infrastructure costs were kept constant within each scenario capacity:

Medium – $11,150 infrastructure costs, $2,000 annual costs

Large operation	Scenario 1	Scenario 2	Scenario 3
Setting	Regional facility	Regional facility	Facility servicing local aquaculture industry
Raw material intake p.a.	43,000 m^3	25,000 t	18,000 m^3
Feedstocks	Liquids, garden organics	Clarifier sludge, paunch and tannery waste, liquids	Fish wastes, hardwood sawdust, animal bedding
Tip fees	Yes	Yes	Yes
Loader	Front end loader with 2 m^3 bucket	Front end loader with 2 m^3 bucket	75 kW tractor with 0.75 m^3 bucket
Turner	1,000 – 1,500 m^3/h front mounted turner	1,000 – 1,500 m^3/h front mounted turner	12 t excavator with 0.6 m^3 bucket
Grinder	30 m^3/h grinder	none	none
Mixer	16 m^3 mixer driven by 75 kW tractor	Mixed in the windrow with turner	Mixed in the windrow with excavator
Screen	20 – 60 m^3/h contract screen	20 – 60 m^3/h contract screen	20 – 60 m^3/h owned screen
Transport	45 m^3 contract transport	45 m^3 contract transport	15 m^3 owned trailer
Spreader	15 m^3 contract spreader	15 m^3 contract spreader	15 m^3 contract spreader
Labour	Permanent and contract labour	Permanent and contract labour	Permanent and contract labour

Annual overhead and infrastructure costs were kept constant within each scenario capacity:

Large – $159,850 infrastructure costs, $106,338 annual costs