REPORT

Tonkin+Taylor

Waste Management Feasibility Study

Prepared for

Cook Islands Infrastructure

Prepared by

Tonkin & Taylor Ltd

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Exceptional thinking together

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1 Introduction

Tonkin and Taylor International Limited (T+TI) have been commissioned by the Ministry for Cook Islands Infrastructure (ICI) to complete a study to determine a long term strategy for the management of waste on Rarotonga. The study Terms of Reference can be summarised as:

> *"Undertaking a Feasibility Study of alternative treatment technologies for the long term disposal of solid and hazardous waste for Rarotonga at a centralised facility.*
>
> *The facility is to receive and process all major waste streams generated in Rarotonga, and possibly the Outer Islands including, but not limited to, domestic waste, commercial and industrial waste, tourism waste, medical / healthcare waste, quarantine waste and waste arising from the clean up after cyclones."*[1]

The Feasibility Study has been completed by T+TI with specialist inputs from Eunomia Research and Consulting (Waste Technology) and Covec (Cost Benefit Analysis). The project also involved extensive stakeholder engagement and the project would not have been possible without their input.

This report is the output of the Feasibility Study and is structured as follows:

- Section 2 sets out the policy context for solid waste management in the Cook Islands;
- Section 3 summarises available information on waste generation and composition;
- Section 4 summarises available information on waste infrastructure including collections
- Section 5 summarises the identification of potentially feasible options;
- Section 6 Summarises the options evaluation process including high level cost benefit analysis of landfill vs waste to energy;
- Section 7 summarises cost recovery mechanisms; and
- Section 8 provides conclusions and recommendations.

[1] Section 6.1 (About these terms of reference) from the Request for Proposals for a Feasibility Study Of Alternative Treatment Technologies For The Disposal Of Solid And Hazardous Waste For Rarotonga, Cook Islands (Contract No: 16/02, Id Number: 151633, March 2016

2 Policy Context

There are a range of key policy documents of relevance to solid waste management in the Cook Islands. These are summarised below with additional detail provided in Appendix A where necessary. The policy summarised here sets the direction and desired outcome from the implementation of the options considered in this report.

2.1 National Waste Policy (2016)

The Cook Islands National Solid Waste Management Strategy 2013-2016 was developed by the National Solid Waste Management Committee and contains a mix of policy elements and more specific strategies. The policy elements have formed the foundation for the National Solid Waste Management Policy 2016-26.

The policy vision is:

'An informed and proactive community taking responsibility for sustainable solid waste management, aspiring towards Zero Waste Cook Islands.'

The objectives of the policy are:

- Objective 1. Minimise the generation of solid waste.
- Objective 2. Develop a clear and robust institutional and legislative framework.
- Objective 3. Develop appropriate waste management infrastructure including separation and storage facilities.
- Objective 4. Develop sustainable financing to manage solid waste.
- Objective 5. Promote individual and community responsibility for solid waste management.
- Objective 6. Develop a strong monitoring and evaluation system.

2.2 National Sustainable Development Plan 2016-2020

The National Sustainable Development Plan 2016-2020 (NSDP) is also an important policy document to consider when looking at options for solid waste treatment and disposal. The National Vision, as set out in the NSDP is:

> *“To enjoy the highest quality of life consistent with the aspirations of our people, and in harmony with our culture and environment”*

The NSDP sets sixteen national development goals. Goal 3 is of most direct relevance to this waste policy. It is to:

> *"3. Promote sustainable practices and effectively manage solid and hazardous waste"*

The NSDP has identified two indicators to measure progress towards this goal. Indicator 3.1 tracks total waste recycled. Indicator 3.2 tracks the percentage of hazardous waste that is accounted for and managed.

Other NSDP goals of relevance are:

> *"4. Sustainable management of water and sanitation"*
>
> *"11. Promote sustainable land use, management of terrestrial ecosystems, and protect biodiversity”*
>
> *“12. Sustainable management of the oceans, lagoons and marine resources"*

These goals are of relevance because of the adverse effects that poor solid waste management can have on the natural environment.

2.3 Other relevant policy

There is a wide range of other legislation and policy documents of relevance to this study. These include:

- The Cook Islands Public Health Act 2004
- The Cook Islands Environment Act 2003
- Pacific Regional Solid Waste Management Strategy 2010-2015
- Cleaner Pacific 2025 - Pacific Regional Waste and Pollution Management Strategy 2016 - 2025
- Cleaner Pacific 2025 - Pacific Regional waste and Pollution Management Strategy Implementation Plan 2016 - 2019

3 Waste generation and collection

Data on the generation of solid waste in the Cook Island is of variable quality. This reflects a mix of formal (government and private sector provided) services and informal (self-management) management of solid waste. Volume data has been used to develop estimates of tonnage, the more common way of presenting information on waste quantities. This also means that data presented is indicative of likely ranges rather than definitive numbers, with these ranges used for considering the feasibility of potential options.

3.1 Waste Quantity

Waste generated by households is either managed on site (animal feed, compost or burnt) or collected for disposal or recycling. Data on quantities collected can be estimated from the total quantity of material entering waste facilities (rubbish and recycling). An alternative approach is to develop an estimate of average waste per household and use this to estimate total waste tonnage. This approach has been used for Atiu as an indicator for all outer islands.

For this study data sources include:

- Average rubbish and recycling weights from a roadside waste survey completed in August 2016.
- Average bale weight and counts for rubbish bales at Rarotonga Waste Facility
- Records of loads entering Rarotonga and Aitutaki Waste Facilities
- Data from other organisations handling waste and recycling on Rarotonga.

Table 1 Estimated Waste Generation[2] on Rarotonga (T/year)

	Landfill	Recycle	Total	% Diversion
Rarotonga				
Households and small business	547	241	649	31%
Large businesses	726	807	1533	53%
Self-managed waste	571			0%
TOTAL	1,844	1,048	2,321	45%
Aitutaki				
Households and small business	92	49	141	35%
Large businesses	60	103	163	63%
TOTAL	152	152	304	50%
Outer Islands	10kg x 150 hhd x 26			
Households and small business	30	0	30	0%

Household Waste

Food waste is generally fed to household animals (pigs and chickens) rather than disposed of with other household waste. Garden waste is generally burnt or stockpiled on site.

On Rarotonga the remaining household waste is collected weekly with residents using their own containers or rubbish bags. Waste is manually loaded into a single compactor truck that services both residential and commercial customers. Residents separate glass, cans (aluminium and steel) and plastic bottles (PET and HDPE) for recycling. Recyclables are manually loaded into a dedicated collection vehicle and trailer.

[2] Waste generation in this context refers to material collected i.e. does not include self-managed materials.

On Aitutaki household waste is collected every two weeks with residents using their own containers or rubbish bags. Waste is manually loaded into an open tray truck that services both residential and commercial customers. Residents separate glass, cans (aluminium and steel) and plastic bottles (PET and HDPE) for recycling. Recyclables are manually loaded into a dedicated trailer.

On Atiu household waste is collected every fortnight from households by the Island Council. Each household was provided with a 120L Mobile Garbage Bins aka Wheelie Bins (MGB) in 20012/13. Waste is manually loaded on to the Island council truck. There is no collection of recyclables.

Commercial Waste

On Rarotonga and Aitutaki waste from small businesses is generally collected in tandem with household waste. Larger businesses purchase a collection service or transport their waste directly to the Rarotonga or Aitutaki Waste Facilities.

Many businesses have their own waste management/disposal arrangements for all or part of the waste they generate. For example:

- Many businesses provide food waste to animals and burn garden rubbish on site.
- Edgewater Resort have a burn pit opposite the old MOIP Office for disposal of materials not captured for recycling by their staff or guests. It is likely other Resorts have similar arrangements.
- The Port of Avatiu have a bunker for burning general waste.
- Pacific Resort on Aitutaki burn combustible waste and crush glass for use as aggregate and filter media across their operation.
- CITC collect, consolidate and export various recyclable materials from their operations and other businesses.
- Atiu Villas periodically burn their 'combustible' waste in a burn pit. Their organic waste is composted or buried in shallow pits.

There is no detail available on the quantity of material managed on-site by various businesses on Rarotonga or other islands. Available data has been used to develop an estimate of the total amount of waste generated by major businesses on Rarotonga based on businesses that bring all of their waste to the Rarotonga Waste Facility. This suggests that there could be over 500 tonnes of waste per year managed outside the Rarotonga Waste Facility - by burning or burial.

Other Wastes

Quarantine waste from the Airport, Port and clinical waste from Rarotonga Hospital is incinerated at the Airport (Airport, Port) and Hospital. The hospital burns several times a week while the airport indicates they burn around 2-400 kg per day[3,4] or 50-100 T per year.

Hazardous Waste

There are programmes in place to capture, store and export hazardous wastes including e-waste (computers, monitors, other electrical appliances), used batteries (lead acid and dry cell batteries) and used oil. Where materials are captured they are stored until there are sufficient quantities for export.

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[3] From around 19 internal flights each week: 16 from Auckland (A320 and B777), 1 from Sydney (B767), 1 from Los Angeles (B777), 1 from Tahiti (ATR 42).
[4] Estimates are based on 0.4 kg/passenger (60T/yr) and self-reported estimate (400kg/day).

Legacy materials

There is a range of other materials generated on Rarotonga and other islands on an ongoing basis including:

- Tyres
- Old machinery (Outer Islands and Rarotonga)
- Asbestos (from demolitions and storm damage)
- Whiteware
- Generators
- Intermediate Bulk Containers (IBC) used to import emulsion, diesel and similar products.

These materials are generated on an ongoing basis but in many areas have also accumulated over time. Examples include stockpiles of IBC's at Infrastructure depots, old machinery on the outer islands, and used tyres.

3.2 Waste System Overview

The Rarotonga waste flows are represented in the mass flow diagrams presented in Figure 1 and Figure 2. The difference between the two figures is the quantity of waste entering the system based on projections developed considering historic waste generation, population and commercial activity. The projections are summarised, by waste stream, in Figure 3. The model underlying the diagrams allocates waste to either landfill (reject of residual) or recycling markets with the same % recovery assume for 2015 and 2025.

Figure 1 Rarotonga Waste Management System (2015 estimated) flows

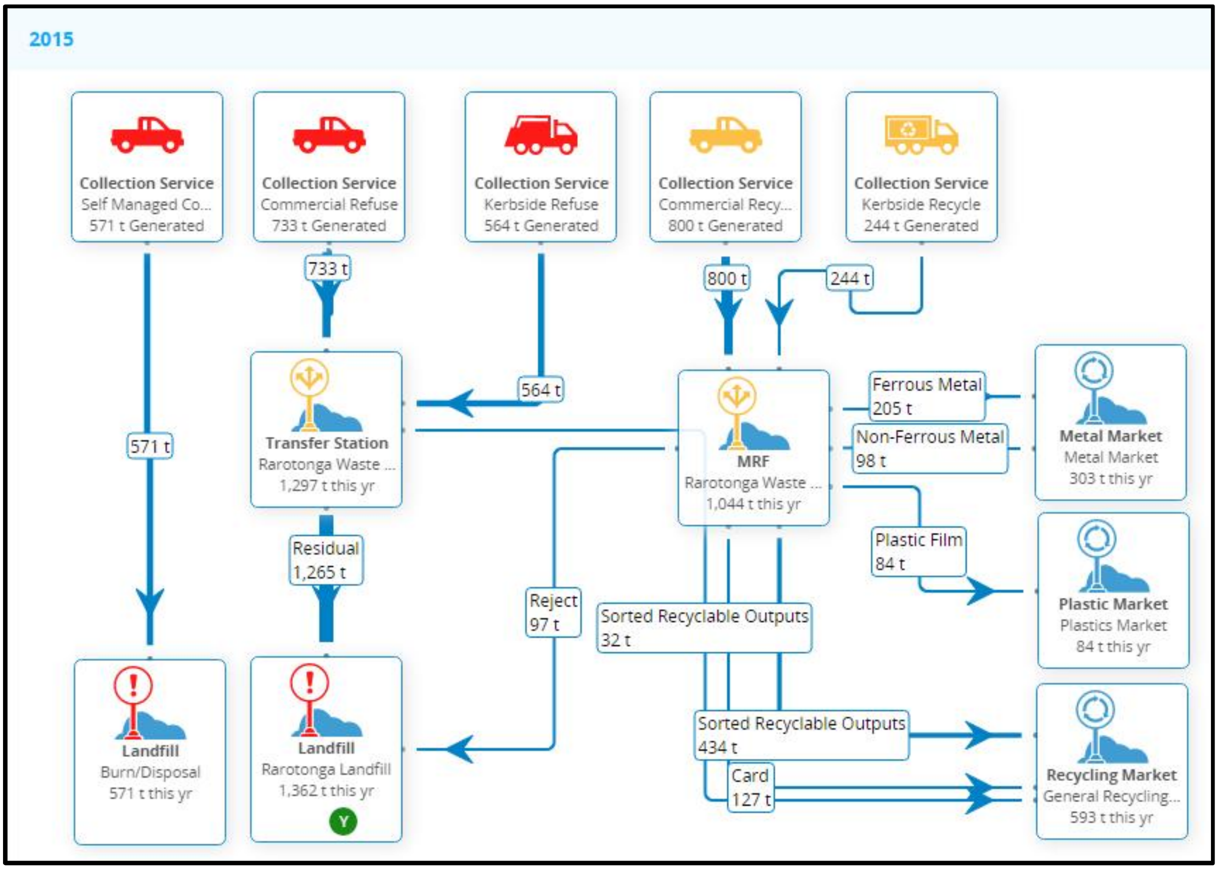


Figure 2 Rarotonga Waste Management System (2025 estimated) flows

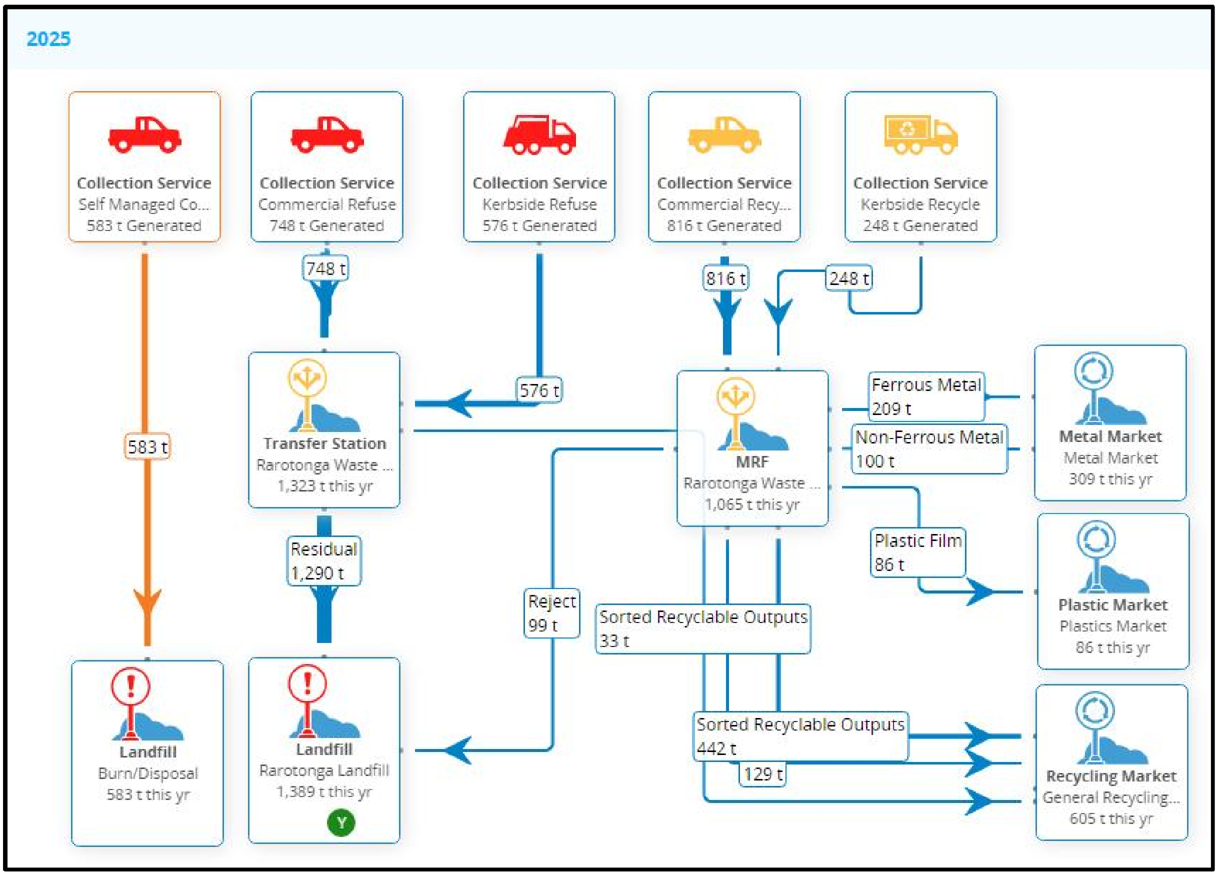
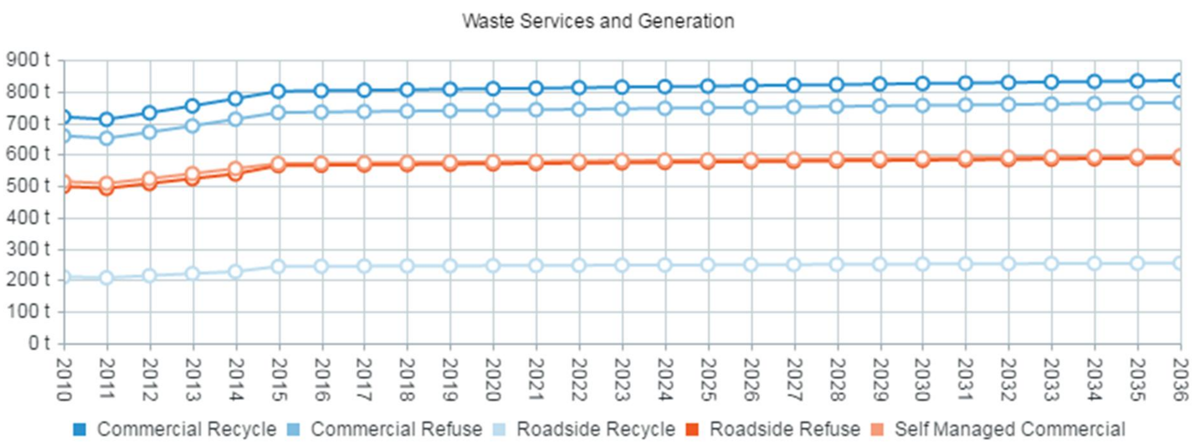


Figure 3 Projections of waste generation by waste stream



3.3 Waste Composition

A waste composition survey was carried out on Rarotonga in August 2016. The survey collected waste and recycling set out for collection from over 300 houses and provides an estimate of:

- Average weights of rubbish and recycling from households (including small commercial)
- Rubbish composition using 19 categories grouped in 12 primary categories.
- Recycling materials composition including contamination.

For the purposes of this study the data from Rarotonga is assumed to reflect household/small commercial waste on Aitutaki. This is because the two islands have similar roadside collection systems and regular transport and shipping links. For islands without recycling services such as Atiu combining the rubbish and recycling data from Rarotonga provides an indication of likely rubbish composition. The data presented in Table 2, Figure 4 and Figure 5 provide a picture of the overall waste composition with a focus on household waste and light commercial materials.

Points to note are:

- While organic waste (food scraps and garden rubbish) is a low proportion of waste compared with typical household and light commercial urban waste internationally it is a still over 10% of the waste stream.
- Plastic is a significant portion of the waste stream including a large amount of non-recyclable material (plastic bags, broken plastic items).
- Metals make up almost 10% of the waste (on Rarotonga) and are almost exclusively recyclable.
- Glass is a significant portion of the waste stream, again largely recyclable.
- Nappies (disposable) make up a large portion of the waste stream.

Table 2 Estimated Waste Composition

Category	Sub-Category	Rarotonga (survey) /Aitutaki (est)				Atiu (est)	
		Rubbish		Recycling		Rubbish	
Paper/Card		16.0%		4.5%		13.3%	
	Paper		4.8%		0.9%		3.9%
	Cardboard		7.0%		1.5%		5.8%
	Non-recyclable		4.2%		2.1%		3.7%
Plastic		27.0%		11.9%		23.5%	
	Plastic Recyclable		7.4%		5.5%		7.0%
	Plastic Non recyclable		19.6%		6.4%		16.5%
Organic		13.8%		7.6%		12.4%	
	Food		10.0%		7.1%		9.3%
	Garden		3.8%		0.5%		3.1%
Ferrous Metal		7.9%		2.4%		6.6%	
	Ferrous metals Recyclable		7.6%		2.4%		6.4%
	Ferrous non recyclable		0.2%		0.0%		0.2%
Non ferrous metal		1.5%		1.5%		1.5%	
	Non-ferrous metals Recyclable		1.3%		1.5%		1.3%
	Non-ferrous metals non recyclable		0.2%		0.0%		0.2%
Glass		15.0%		60.6%		25.5%	
	Glass Recyclable		14.3%		60.5%		25.0%
	Glass Non recyclable		0.7%		0.1%		0.5%
Textiles	Textiles	2.2%	2.2%	0.0%	0.0%	1.7%	1.7%
Nappies/Sanitary	Nappies/Sanitary	13.5%	13.5%	11.0%	11.0%	12.9%	12.9%
Rubble	Rubble	0.8%	0.8%	0.0%	0.0%	0.6%	0.6%
Timber	Timber	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubber	Rubber	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Potentially hazardous	Potentially hazardous	2.3%	2.3%	0.5%	0.5%	1.9%	1.9%
Total		100%	100%	100%	100%	100%	100%

Figure 4 Rarotonga Collected Waste Composition

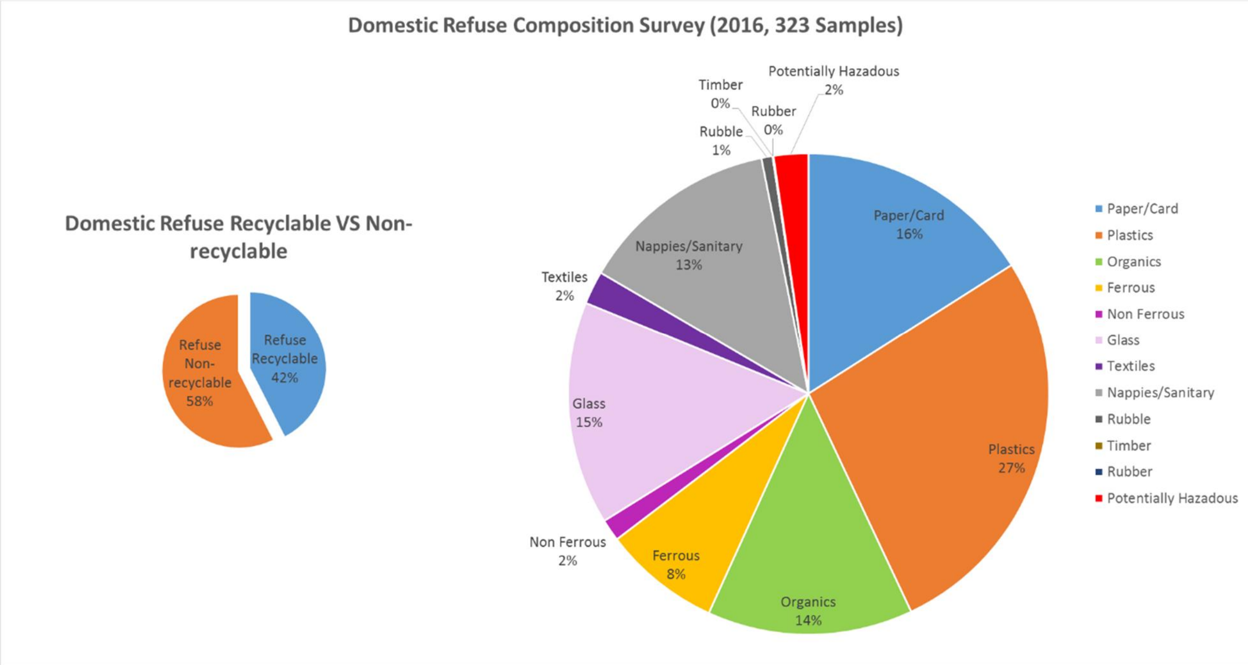
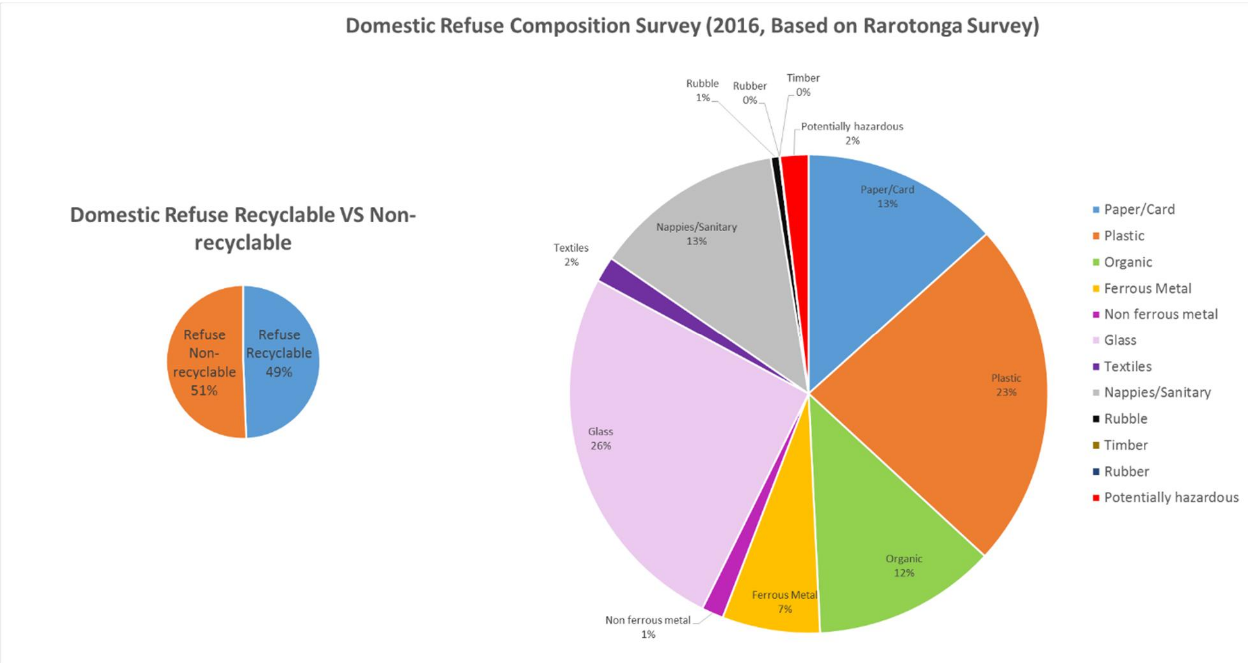


Figure 5 Atiu (outer islands) Estimated Waste Composition



3.4 Waste generation and composition - issues and constraints

While there is some information available about the quantity and composition of waste generated in the Cook Islands the data is incomplete. The available data needs to be interpreted considering that:

- Quantities have been derived using volume based estimates.
- A proportion of waste (household and commercial) is managed by burning or burial on site[5].
- There is no data on coverage, set out rate or participation rates for roadside collection.

There is potential to improve the estimates of waste quantity through improved reporting and periodic surveys of quantities of waste entering the Rarotonga and Aitutaki Waste Facilities. There may be potential to develop estimates of waste managed on site by households through the Tutaka inspections completed by the Health officials and targeted surveys of businesses.

[5] Comparing waste entering the Rarotonga Waste Facility from businesses with their own burning/disposal arrangements with businesses with no informal arrangements provides an estimate of total waste generated. Allowing for commercial collection of waste and recyclable materials provides an estimate of 500 T/yr of waste burnt or buried by businesses on Rarotonga. This is nearly 20% of the total waste stream on Rarotonga (see Table 1).

4 Waste Infrastructure and Services

4.1 Waste Collection

Once a material becomes waste it can either be managed on the site where it is generated or collected for management elsewhere. From a public authority perspective appropriate management on site may be preferable with the waste generator taking full responsibility. Public authorities provide collection services for waste to address waste streams households or businesses cannot manage themselves or manage using inappropriate methods.

4.1.1 Self-managed waste

On Rarotonga and elsewhere in the Cook Islands some wastes are effectively managed without government involvement. Examples include:

- Food waste - generally fed to animals
- Garden waste - variously composted or burnt on site
- Some recyclable materials from businesses - handled by the business themselves (CITC) or collected by commercial operators (T&M Heather, General Transport).

There are examples of waste materials handled by households or businesses themselves in ways that are not appropriate. Examples include:

- Open burning of waste (burning of plastic is banned by the Public Health Act) - burning of plastics in burn pits or simple rubbish piles.
- Dumping of rubbish at informal dump sites - common on the Outer Islands

4.1.2 Waste and Recycling Collection

Waste collection aims to collect and manage household and business refuse to minimise health and environmental impacts. This involves households or businesses storing waste in a suitable receptacle (bag or bin) and timely collection of waste. Collections are normally weekly but fortnightly collections do exist, often where organic waste collection means the putrescible component in the waste bin is low.

On Rarotonga and Aitutaki households and businesses use their own receptacles[6] with collectors emptying bins and picking up rubbish bags. On Atiu householders and businesses have 120L wheelie bins with Council emptying these bins once per fortnight.

Collection of recyclable materials is most effective when it is easy for householders to separate and present recyclable materials for collection. Most systems in place involve a standard receptacle (one or more crates or wheelie bin) with weekly or fortnightly collection. Larger receptacles generally encourage a higher capture of material. Encouraging householders and businesses to pre-sort material provides a higher quality (and value) product.

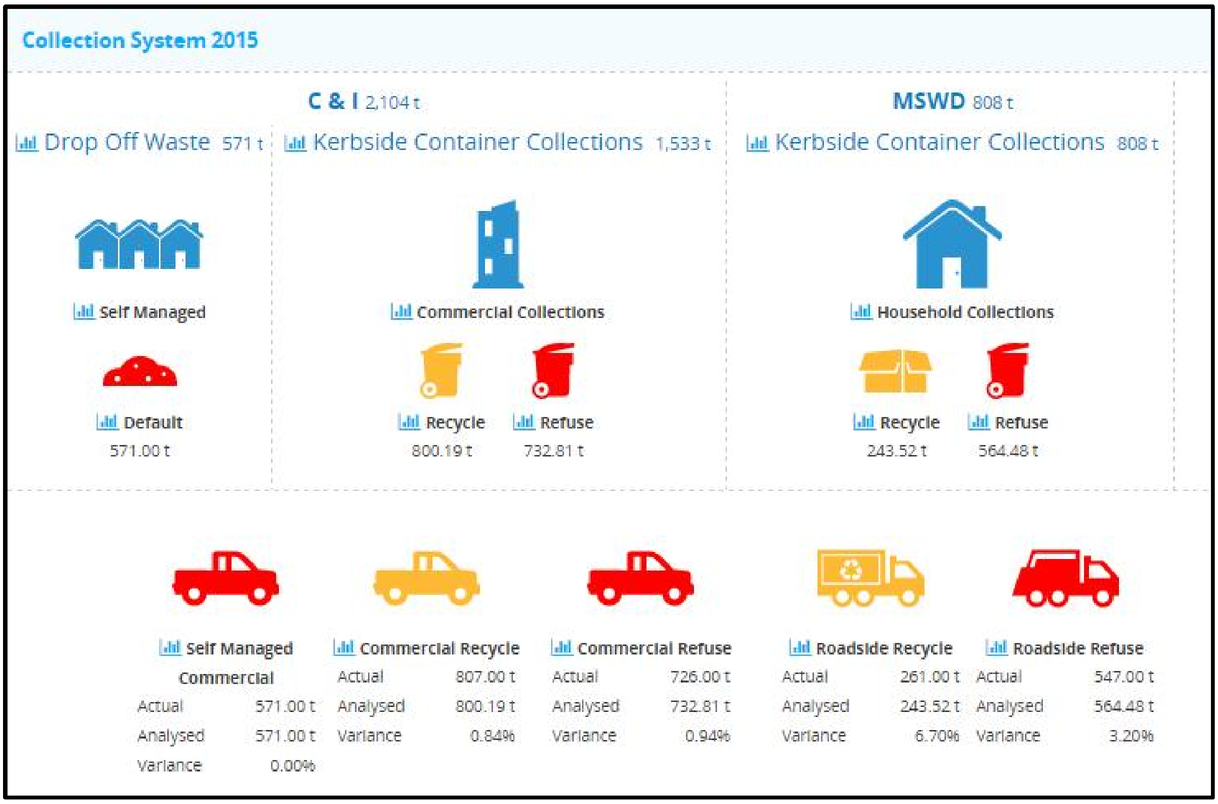
On Rarotonga, households and businesses use their own receptacles with collectors emptying bins and picking up bagged recycling. Recycling is collected separately from refuse and sorted further at the Rarotonga Waste Facility. On Aitutaki recycling is collected in the same vehicle as waste (in wool sacks) and sorted at the Aitutaki Waste Facility. No recycling service is available on Atiu.

6

On Rarotonga households were provided with refuse wheelie bins several years ago and many households still use these although in many cases the bins are beyond their useful life i.e. are broken or heavily degraded.

The waste and recycle collection system including estimated quantities for 2015 is presented schematically in Figure 6.

Figure 6 Schematic of Rarotonga Waste and Recycling System



4.1.3 Collection Service Performance

The performance of the collection system can be compared with benchmarks drawing on waste composition information, quantity data and estimates of the participation of households and businesses. The key metrics include:

- Recycling or diversion rate - the percentage of material captured for recycling - a high performing system will achieve 50-60% recycling rate but this typically includes collection of organic waste materials, not a significant portion of the waste stream on Rarotonga.
- Recognition rate - the percentage of recoverable material captured. A high performing system will capture 60% or more of available materials.

Table 3: Rarotonga Waste Management System Performance

	General		Recovery		Performance	
	Composition	Tonnes/Yr	Composition	Tonnes/Yr	Recycling Rate (%)	Recognition Rate (%)
Total	100%	1,844	100%	1048	36%	57%
Paper/Card	16.0%	295	5%	52	15%	15%
Plastic	27.0%	498	12%	126	20%	40%
Ferrous	7.9%	145	2%	21	13%	10%
Non Ferrous	1.5%	27	2%	21	43%	39%
Glass	15.0%	277	61%	639	70%	64%
Other (contamination)	32.7%	602	18%	189	18% contamination	

The data presented in Table 3 suggests there are opportunities to capture additional recyclable material through the roadside collection including cardboard, plastics and glass. Specifically:

- While cardboard is collected from some commercial premises a large proportion appears to be burnt and there is a significant quantity in the rubbish collected from households. With existing baling and reuse or export it should be possible to increase the capture of cardboard at both roadside and from businesses.
- Recovery of Plastic Bottles (PET and HDPE) is reasonable, but again it should be possible to increase the capture of materials at both roadside and from businesses.
- Aluminium recovery is at a reasonable level but there is potential to increase this.
- Glass recovery is at a reasonable level.

Waste from certain sources can also present challenges or opportunities and is worthy of consideration. Examples include:

- Business waste - waste from larger businesses is in some cases burnt rather than managed through government or island council provided services. This reduces the burden on public waste management services but involves risks to health and the environment as a result of air emissions (combustion products) and ash.
- Hazardous wastes - there are systems in place for the capture and export (for treatment or disposal) of hazardous waste from Rarotonga and the outer islands. Storage in some locations lack cover/containment and in some cases the availability of appropriate export options is not well understood.
- Bulky/difficult wastes - bulky or difficult wastes include tyres, white ware and end of life vehicles and machinery. In some cases programmes have been or are in place to capture materials for appropriate disposal or recycling but uptake has been mixed.

4.2 Waste Processing and Disposal

4.2.1 Waste disposal

Rarotonga

Rarotonga Landfill - solid waste from government collections, private sector collections and brought directly to the facility is disposed of at the Rarotonga Landfill at the Rarotonga Waste Facility. Waste material is placed in a concrete pad and baled daily (Monday to Friday) into 1 x 1.5 m bales for placement in the landfill. The landfill is lined (clay, GCL, HDPE) and has been filled to ground level. Waste bales are currently (2016) stockpiled on the landfill surface pending further liner construction or an alternative being in place. The original design anticipated a 15 year design life from completion of construction in 2004 i.e. completed around 2019.

Airport Waste Incinerator - quarantine waste from the airport (from international flights) and port (international shipping) is incinerated at Rarotonga Airport. The incinerator is overdue for replacement but has been waiting on the outcome of consideration of long term options for general waste and medical waste.

Hospital Waste Incinerator - medical waste from the Rarotonga Hospital is incinerated at the hospital. The incinerator is overdue for replacement but has been waiting on the outcome of consideration of long term options for general waste and quarantine waste.

T&M Heather - T&M Heather have a stockpile/disposal site for green and general fill immediately adjacent to the Rarotonga Waste Facility.

Edgewater Burn Pit - Edgewater Resort have a burn pit for general waste from their operation at Arorangi.

Aitutaki

Aitutaki Landfill - solid waste from government collections and brought directly to the facility is disposed of at the Aitutaki Landfill at the Aitutaki Waste Facility. Waste material is currently unloaded adjacent to the landfill and then transferred to the filling area using a loader. The landfill is lined (clay, GCL, HDPE) but exposure to the elements including significant tropical storms has resulted in significant deterioration of the exposed liner. The site has significant remaining capacity based on filling rates to date.

Outer Islands

Atiu - solid waste collected by the Island Council is currently disposed of at an informal dump site to the south of the island. The dump is immediately adjacent to the road with materials placed and periodically covered with soil.

4.2.2 Waste consolidation and diversion

Rarotonga

Rarotonga Waste Facility - materials collected or dropped off for recycling at the waste facility are sorted (if required) and baled. Some recyclable materials are captured from general waste as it is loaded (via conveyor) into the baler. Aluminium is periodically exported to New Zealand with revenue covering shipping costs and providing a return. Plastics (HDPE and PET) are baled and stockpiled because returns from sale do not cover the cost of shipping to New Zealand. Glass is crushed, usually by placing on the landfill and running over with an excavator, and reused at the Facility as an aggregate replacement. Hazardous materials (e-waste, chemicals, oil) are stockpiled before export.

The plastic that has been baled and stockpiled will be difficult to sell. This is because exposure to the elements has cause deterioration over time.

Cook Islands General Transport - General Transport accept a range of recoverable materials and consolidates loads prior to export to New Zealand. Materials handled include general scrap (vehicles, machinery), lead acid batteries, e-waste and whiteware. Some wastes attract funding support from the Cook Island Government or regional organisations (SPREP) while others are handled on a purely commercial basis.

Titikaveka Growers Association - the Titikaveka Growers Association compost organic materials for re-use on their market gardens.

Cook Islands Trading Corporation (CITC) - CITC collect cardboard and plastic film from their operations and some other businesses. The materials are reused on Rarotonga (some cardboard as cover eventually converting into compost on taro patches) or exported for recycling on a commercial basis.

CITC also collect and contain fluorescent light bulb tubes and sent away for safe disposals.

Aitutaki

Aitutaki Waste Facility - materials collected or dropped off for recycling at the waste facility are sorted (if required) and baled. Aluminium is periodically exported to New Zealand via Rarotonga with revenue covering shipping costs and providing a small return. Plastics (HDPE and PET) are baled and stockpiled with returns not covering the cost of shipping to New Zealand via Rarotonga. Glass is crushed using a single bottle crusher and reused on site. Hazardous materials (e-waste, chemicals, oil) are stockpiled.

4.3 Waste Infrastructure and Services - Issues and Constraints

In collating and considering information about the delivery of waste infrastructure and services in the Cook Islands, a number of issues were identified. These issues represent challenges in delivering effective services and achieving the aims of the National Waste Policy. In many cases the issues also present opportunities for the Ministry for Infrastructure Cook Islands, Island Councils, the community and/or the private sector to improve waste minimisation and management. The issues identified include:

- Illegal dumping of household and business waste including at old dump sites.
- Landfill operations - the landfills in Rarotonga and Aitutaki are not operated in a way that minimises exposure of placed waste to the elements.[7]
- Landfill construction - the landfills in Rarotonga and Aitutaki are in need of further development (Rarotonga[8]) and remediation (Aitutaki[9]).
- Outer Island dump sites for refuse disposal - on Atiu (assumed to be consistent with other Outer Islands) general waste is disposed of at uncontrolled dump sites.

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[7] Landfill operation typically includes use of daily cover (a small amount of soil or other temporary cover) and intermediate cover (for completed landfill cells). This cover minimises access to the waste for vermin (flies, rats, birds) and allows the landfill operator to more effectively manage rainfall entering the rubbish and the resulting leachate generation. For Rarotonga Landfill the Landfill Operations Plan sets out operations in defined cells with daily and intermediate cover. For Aitutaki Landfill the Operations Plan sets out similar requirements including minimising the area being actively filled at any point in time.

[8] The design for Rarotonga Landfill anticipated construction of a second cell including additional liner once filling reached ground level. This second phase of construction has not occurred and waste is currently stockpiled on top of the landfill

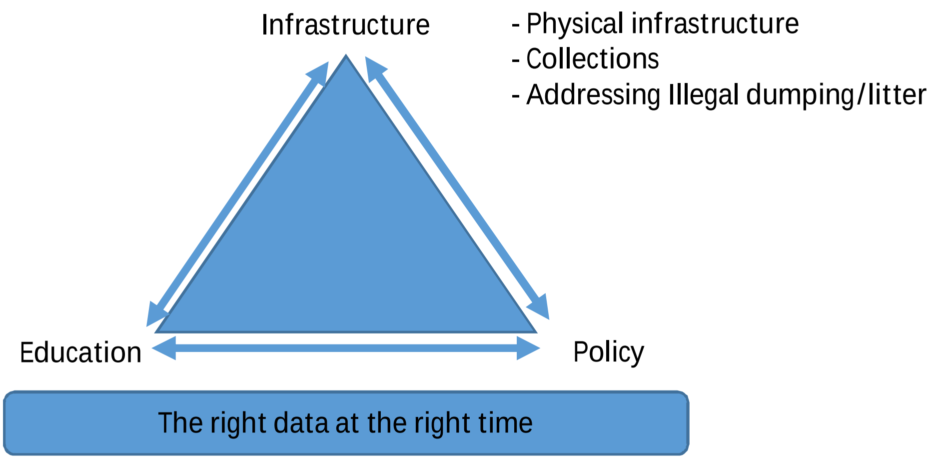
[9] Aitutaki Landfill's liner system was extensively damaged during storms several years ago. Remediation requires design but is likely to involve repairing and/or replacing the liner in the active filling area with provision to complete further remediation as filling progress through the site.

- Performance of the collection system, there is potential to increase the capture of
  - Cardboard
  - Plastic bottles
  - Aluminium cans
  - Steel cans
- Access to recycling services - outside of Rarotonga and Aitutaki access to recycling is extremely limited.
- Access to markets for recyclables - where materials are recovered access to viable markets is difficult due to transport costs and variable material values (when shipping costs are considered), reflecting uncertain markets for many materials and currently low prices for most recycling commodities.
  - Aluminium provides a small return.
  - Steel is currently marginal.
  - Plastic (PET, HDPE) is not viable to export for recycling - the cost of collecting, baling and exporting materials exceeds the revenue from sale of the materials in NZ.
  - Glass is not viable to export for recycling - the cost of collecting, consolidating and exporting glass exceeds the revenue from sale in NZ.
- There is a lack of enforcement of provisions banning illegal dumping of rubbish and burning of certain waste streams.

5 Option Identification

There are a wide range of approaches to providing waste minimisation and management services and programmes that could be adopted in the Cook Islands. A useful way to consider options is the model set out in Figure 7. Simply put, effective waste minimisation and management relies on a combination of infrastructure (including collection), education/information and regulation or policy. These are supported by having the right data to inform strategic and operational decision making.

Figure 7: Effective Waste Minimisation and Management



For this project options have been identified by considering key challenges for the Cook Islands (Refer Sections 3.4 and 4.3), referencing approaches adopted elsewhere and looking for new solutions where appropriate. Options have also been considered with reference to the current recovery rates of key materials[10] (see Section 4.1). This report focuses on infrastructure options but offers comment on Education, Policy and Data components where relevant.

Based on the model set out in Figure 7 options that could be considered can be grouped as follows.

Infrastructure

- Providing collection services - collection of waste, recyclable materials (at roadside or waste facility), organic waste and/or bulky items, litter bins;
- Providing physical infrastructure - drop off facilities, waste processing and/or disposal facilities;
- Managing the negative impacts of waste - litter/illegal dumping.

Education (outside the scope of this report)

- Changing behaviour - education programmes targeting schools, businesses and/or households
- Working with importers to consider the materials entering the Cook Islands (packaging)

Policy (outside the scope of this report)

- Implementation of existing policy e.g. regarding open burning of waste
- Targeted data collection, for example waste surveys
- Making information on waste issues and opportunities available.
- Seeking funding for infrastructure projects that deliver on the goals and objectives for waste minimisation and management

[10] Key materials include paper/card, plastics, glass, nappies, metals and glass

These options focus on the priority waste streams identified through the review of the current situation in Sections 3.4 and 4.3 and summarised in Table 4.

Table 4: Priority wastes and waste sources

Recyclable materials	Other materials requiring active management include:	Waste sources
· Paper/Cardboard	· Hazardous waste	· Households
· Plastics	· Difficult or special waste	· Tourism businesses
· Organic Waste	· General waste	
· Glass bottles	· Disposable nappies	
· Cans - steel and aluminium		

5.1 Collection options

Once a material becomes waste it can either be managed on the site where it is generated or collected for management elsewhere. From a public authority perspective management on site may be preferable with the waste generator taking full responsibility. Public authorities provide collection services for waste to address waste streams households or businesses cannot manage themselves or manage using inappropriate methods.

Self-Managed Waste

On Rarotonga and elsewhere in the Cook Islands some wastes are effectively managed without government involvement. Examples are noted in Section 4.1.1.There are also examples of waste materials handled by households or businesses themselves in ways that are not appropriate. Examples are noted in Section 4.1.1.

Waste and Recycling Collection

Waste collection aims to collect and manage household and business refuse to minimise health and environmental impacts. This involves households or businesses storing waste in a suitable receptacle (bag or bin) and timely collection of waste. Collections are normally weekly but fortnightly collections do exist, often where organic waste collection means the putrescible component in the waste bin is low.

Globally services are funded variously through:

- General funds
- A targeted charge for refuse services through property taxes
- User charges e.g. through the purchase of official rubbish bags or direct charging for collection services.

Collection of recyclable materials needs to make it easy for householders to separate and present recyclable materials for collection. Most systems in place involve a standard receptacle (one or more crate or wheelie bin) with weekly or fortnightly collection. Larger receptacles generally encourage a higher capture of material Encouraging householders and businesses to sort material provides a higher quality (and value) product.

Where there is a direct charge for rubbish collection there is a risk that households or businesses will avoid the charge through illegal disposal of rubbish. This is occurring to some degree with the reported illegal dumping or burning of commercial rubbish, possibly to avoid landfill disposal charges. Any direct charge, for example through the sale of rubbish bags, will need to be set at a level that is affordable for households and supported by education, and if required, enforcement.

Current arrangements:

- Refuse collection for households and small businesses is provided by the government (Rarotonga) or the Island Council, funded by the government.
- Recycling collection for households and small businesses on Rarotonga and Aitutaki is provided by the government or Council funded by the government.
- Larger businesses employ T&M Heather or Cook Islands General Transport to collect their waste and recycling or handle their own waste
- Businesses and households can drop waste and recycling at the Rarotonga or Aitutaki Waste Management Facilities.

Issues

- Illegal dumping of household waste
- No limit on quantity of waste put out by each household[11]
- High level of contamination in recycling collections on Rarotonga
- Low capture rates for recyclable materials from households
- Inappropriate disposal of hazardous wastes
- No recycling service on Atiu and outer islands

Rubbish collection options

The current refuse collection system is fully funded by the government. There is no detailed information on participation in the collection service or quantity of materials collected. There are some issues with contamination in the recycling collection and recyclable material placed with refuse for collections. There are also examples of illegal dumping of household refuse.

There are several reasons for considering changes to the way that rubbish is collected. Limiting the size of the collection container (bag or bin) can encourage households to recycle where recycling services are available. Limiting the size and/or providing for mechanised collection also minimises health and safety risks for collection personnel. Referencing approaches adopted elsewhere:

- In Australia roadside waste is almost exclusively collected in wheeled bins with automated loading.
- In New Zealand there is an active debate contrasting wheeled bins (safety benefits, efficiency) with bags (smaller, impose direct charges on households).
- In the UK there is a mix of wheeled bin and bag based collections with drivers including user pays (easier through bags) and the efficiencies (through automated collection).

Considering approaches adopted elsewhere waste collections could be:

- A government run and funded collection service with each household providing their own receptacle. This is the current approach and cost is assumed to be the same or similar.
- A government run, tax funded service with either official bags or small wheelie bins provided to each council. This approach is common with examples in New Zealand, UK and Australia. New costs would include the bins or bags (similar total cost over the 5-10 year life of a wheelie bin). Advantages include limited refuse capacity encouraging diversion of waste at home or into recycling and limiting weight of materials manually handled by the collection crew.

Objective:
Limit rubbish capacity to encourage reuse/ recycling and improve collection crew safety

[11] Limits on the quantity of materials households can place for collection can encourage waste reduction (buying less), re-use (reusing containers, animal food) and/or recycling.

- A government run, user pays refuse collection service. In most cases this is through collection of approved rubbish bags that are bought as required by households or businesses. In some cases households pay for a wheelie bin collection service. This is a common approach in New Zealand with rubbish bags typically in the range $2.50-3.00 per bag with prices range up to over $4.00 per bag in some areas. Assuming a single bag per week at this price for each household revenue in Rarotonga would be in the order of $3-400,000 per annum. In New Zealand households typical present bags 30-40 weeks per year, in Rarotonga this would translate to $100-$120 per household or $200 - $350,000 per annum total revenue.

Objective:
Limit rubbish capacity and impost cost to encourage reuse/ recycling

Recycle collection options

The current recycling collection system is funded by the government. There is some information on participation in the collection service and quantity of materials collected. Considering approaches adopted elsewhere council could consider:

- A government run and funded recycle bag service with each household providing their own container or putting materials out in bags. This is the current approach and cost is assumed to be the same or similar.
- A government run and funded recycle crate based service i.e. government providing one or more recycle crate(s). This is the most common approach currently employed in New Zealand and Australia. Advantages include providing a standard container for recyclables to encourage diversion of recyclables into the recycling collection. The crate limits the size (and weight) of materials with safety benefits for the collection crew.

Objective:
Increase recycling rate by providing a standard container

- A government run and funded recycle wheelie bin based service i.e. government providing recycle crate(s). This is a common approach in New Zealand and the default system in Australia. Wheelie bins are typically employed alongside automated collection. Advantages include providing a large storage container for recyclables and efficient collections.

Objective:
Increase recycling by providing a standard container

5.2 Technology options

In considering options that may be applicable in the Cook Islands it is important to recognise the challenges noted in the National Solid Waste Management Policy. Specifically the small quantity of waste, small population and lack of funding are important issues to be considered. Also important are the lack of specialist technical expertise, difficulty in maintaining a skilled operations team and distance from technical support and markets.

The characteristics of the waste stream is another important factor when considering potentially viable options. Key characteristics include likely calorific value, moisture content, recoverable material and whether it is preferable (financial, triple bottom line) to recycle or recover energy. In locations where advanced waste treatment is applied there are typically comprehensive recycling and recovery systems in place, e.g. roadside and self-haul recycling, organic waste collection and processing.

Electricity generation on Rarotonga is a mix of diesel generators and solar. There is a target to increase renewable energy generation and new diesel generators have recently been procured with a resulting improvement in efficiency. There is potential for combustible waste to provide a source of energy using conventional or innovative waste to energy technology.

In many cases options considered in other locations are likely to be too large, too complex and/or too costly for Rarotonga. In identifying options for this study we have:

- Looked at options for key waste streams - plastics, glass, special waste (medical, biosecurity, confidential) and residual waste
- Reviewed options designed for small, remote communities or small quantities of waste
- Considered options that simplify and scale down conventional approaches for larger communities

Current arrangements

- Rarotonga Waste Facility - sorting and baling of recyclables.
- Cook Islands General Transport - sorting and export of metals (including whiteware) and e-waste.
- CITC cardboard collections
- Commercial composting by Titikaveka Growers Association.
- Rarotonga Landfill for general waste disposal.

Issues:

- Landfill capacity - projected to be full around 2020.
- Illegal burning of commercial and household waste.
- Access to markets for recyclable materials.

5.2.1 Processing Options

There is a range of solid waste treatment technologies employed globally. These are discussed below with commentary on their suitability to Rarotonga.

Mechanical Biological Treatment (MBT)

Generic - mechanical (remove recyclable/recoverable materials) followed by biological (aerobic or anaerobic) treatment of biodegradable component. Configuration depends on objectives. The biological processing component may target production of a fuel (biodrying) or stabilisation (mass reduction, creating a soil amendment product). The mechanical processing may target specific materials or removal of anything that is not biodegradable.

In Rarotonga and many of the Outer Island rich soils means the market for soil amendment may be limited. There are examples in Rarotonga[12] of composting of food and garden waste with compost used to improve soil structure and provide nutrients.

Mechanical biological treatment processes typically employ automated sorting technology combined with enclosed composting and/or anaerobic digestion. Each of the components involve relatively complex mechanical engineering combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators.

Mechanical Heat Treatment (MHT)

Mechanical Heat Treatment involves mechanical processing (remove recyclable/recoverable materials) followed by heat treatment of remaining materials. Configuration depends on objectives. The heat component may target pasteurisation (removing infection risk), production of a fuel, mass reduction or creating a soil amendment product. The mechanical processing may target specific materials or removal of anything that is not amenable to heat treatment.

As noted above the market for soil amendment may be limited so MHT would most likely target volume reduction, pasteurisation or pre-treatment for waste as fuel. Heat treatment is used to

[12] Titikaveka Growers Association

render medical and quarantine waste suitable for landfill disposal, often with grinding of pasteurised material following heat treatment.

Mechanical heat treatment processes typically employ automated sorting technology combined with heat and/or heat with pressure processes. Each of the components involve relatively complex mechanical engineering combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators.

Composting

Commercial scale composting of food and garden waste is common in many parts of the world, the resulting product can be sold for use in home gardens or used by commercial growers. The Titikaveka Growers Association have a composting operation providing compost for their market gardens. Some households on Rarotonga compost garden waste for use on site.

In many cases the biological component of Mechanical Biological Treatment process involve composting food, garden waste, other organic material, paper, cardboard and other biodegradable materials in the waste stream such as disposable nappies[13]. There is potential to compost specific components of the currently landfilled waste stream to either pre-treat prior to landfill or produce a useable, compost like product.

Composting can involve:

- Complex, enclosed composting systems involving mechanical mixing of the composting material and sophisticated process control.
- Forced aeration of open composting piles e.g. via perforated pipes.
- Open composting in windrows or pile. The composting material can be left to compost over an extended period (static pile, 12-18 months) or regularly turned to improve aeration and reduce processing time (turned windrow).

Enclosed systems, and to a lesser extent forced aeration systems, are complex biological processes involving relatively complex mechanical engineering (enclosed systems) combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators.

Anaerobic Digestion (AD)

Commercial scale anaerobic digestion of putrescible waste material is increasingly common in the UK and Europe with the technology also applied elsewhere. Anaerobic digestion is well established for the treatment of wastewater treatment sludge providing stablisation, volume reduction and energy recovery. Anecdotally in Rarotonga putrescible material (food waste) is largely captured for animal feed. There could be potential for combining food waste with septage but on Rarotonga septage is already treated through ponds at the Waste Facility.

Anaerobic digestion is a complex biological process with the operator balancing residence time the digestion vessel, water content, temperature and agitation. Typical systems for solid waste or solid waste components involve relatively complex mechanical and process engineering combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators.

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[13] Enclosed composting of nappies in New Zealand has met with mixed success - key challenges include securing sufficient bulking material (garden waste, sawdust) and screening out physical contaminants (plastic) from the compost product.

Biodrying

Normally the objective of aerobic decomposition processes such as composting is to stabilise and produce a compost or composting like product. The composting process produces a significant amount of heat and this heat can be used to drying waste. Effectively the heat produced through aerobic decomposition of organic matter in the waste stream dries the overall waste mass. This process is known as biodrying. Biodrying is typically used as pre-treatment for waste to energy. This technology is applicable where there is a significant proportion of biodegradable material in the waste stream and a downstream process that requires or would benefit from a dry feedstock[14].

5.2.2 Disposal Options

There are several options potentially applicable for solid waste disposal or destruction on Rarotonga, these are discussed below. More detail is provided in Appendix B.

Conventional waste to energy

Conventional waste to energy is flexible but likely to be very expensive at the small scale required. The quantity of waste generated on Rarotonga is intermediate in scale - larger than shipboard systems (well established) but much smaller than even small scale municipal systems. Feasibility depends on a range of factors including:

- Inert content of the waste stream - non-combustible materials will cause issues with ash handling and disposal.
- Capability to operate and maintain the technology
- Access to use or disposal options for incineration residuals (bottom ash, air pollution control residues)
- Scale - conventional systems range from very small (50,000 Tonne per year) to more typical 150,000 - 500,000 tonne per year facilities.

Incineration systems typically employ automated sorting technology pre-incineration and may have automated ash handling systems. Each of the components involve relatively complex mechanical engineering combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators. Combustion by-products (air pollution control residues and bottom ash) require handling and suitable disposal or use options.

Advanced Thermal Treatment

Advanced thermal treatment technologies involve the oxidation of general waste in the absence of oxygen (in the case of pyrolysis) or in low oxygen containing environments (for gasification). Outputs include a syngas which can then be used to generate energy. Energy generation efficiencies are usually slightly lower for advanced thermal process than for conventional incineration. This is because some energy is lost at the syngas conversion stage. The multiple stages in the conversion from waste to energy also significantly increases the operational challenges for advanced thermal process. As with incineration, some solid output is produced, typically including some hazardous material.

Feasibility depends on a range of factors including:

- Content of the waste stream - inert materials will cause issues with processing equipment.
- Consistency of inputs - advanced processes typically process homogenous materials i.e. pre-processing via MBT, MHT or another pre-treatment process.

[14] For example incineration or advanced thermal treatment. Other pre-processing is likely to be required - to remove recoverable materials and bulky items, to produce a consistent 'fuel' for the downstream process.

- Capability to operate and maintain the technology
- Access to use or disposal options for process residuals (char, air pollution control residues)
- Commercial track record - there are very few facilities with a long track record and none with track record at a very small scale required for Rarotonga.
- Scale - existing or announced systems range from very small (50,000 Tonne per year) to more typical 150,000 - 500,000 tonne per year facilities.

Advanced thermal systems typically employ automated sorting technology pre-thermal system and may have automated product handling systems. Each of the components involve complex mechanical and process engineering combined with sophisticated process control systems. These in turn require access to specialised maintenance and repair skills as well as trained operators. Thermal treatment products (char, oil and air pollution control residues) require handling and suitable disposal or use options.

Sanitary landfill

A new landfill site could be constructed by 2020 to replace the existing site once it has been filled. A new site needs to be identified, secured and constructed in a relatively tight timeframe of 3 years. There was a 10 year lead time for the existing facility including site identification. There may be potential to extend the current site, either up or down the valley, but this is dependent on landowner and regulatory approvals. This will reduce lead time but it is estimated that community engagement, permitting, design and construction will still require at least 3 years.

Regardless of the treatment and conversion option selected a disposal facility will be required to accept residual materials (ash, char, and unsuitable materials).

Bale and export.

Another option is to consider exporting waste given the small quantity of material and challenges in securing a suitable disposal site. Waste could be baled but would require treatment from a biosecurity perspective prior to entering the destination country. It may be possible to pasteurise the waste prior to export using technology commonly used for medical and quarantine waste.

The cost of landfill in Rarotonga is around $100 per tonne for operations with an additional $100 per tonne funding for facility based on the capital cost of the existing facility. $200 per tonne for landfill disposal is not unusual in NZ context although commercial rates can be negotiated that are significantly lower for large volumes. Material would require treatment in Rarotonga and/or New Zealand to address biosecurity risks. The cost of treatment and transport are likely to make this option prohibitively expensive.

Quarantine/Clinical Waste

A new solution is required for clinical and quarantine waste on Rarotonga. Typical solutions globally include incineration[15] or sterilisation followed by grinding and landfill disposal[16]. The current systems for managing these waste streams are at the end of their serviceable life i.e. a new solution will be required regardless of the outcome of this study. Incineration or advanced thermal treatment could address these waste streams. If these technologies are not employed for general waste a single, small scale facility treating combined clinical and quarantine waste is an option for Rarotonga.

[15] SPREP have funded a number of small scale medical waste incinerators across the Pacific including for Aitutaki

[16] In New Zealand all medical and quarantine waste is treated by this method

5.2.3 Treatment and Disposal Options Considered

As noted previously in this report, there are some activities that must occur - to address immediate issues or avoid likely future problems. These include:

- Complete Rarotonga Landfill design and construction[17] - 2016/17.
- Improve Rarotonga Landfill operation - 2016 and ongoing.
- Improve Aitutaki Landfill Operation - 2016 and ongoing.
- Replace Medical and Quarantine incinerators (single facility) - as soon as possible[18].
- Capture and stockpiling of hazardous waste prior to export for appropriate treatment and disposal.
- Proactive enforcement of current regulations regarding the open burning and uncontrolled dumping of rubbish, particularly on Rarotonga.

Drawing on the discussion above, several options for the treatment and disposal of waste from Rarotonga have been considered. These are:

- New Landfill: A new landfill could be developed to accept waste once the existing Rarotonga Landfill is full. The existing landfill has a conventional design employing a fully engineered liner, leachate capture and treatment. A similar design, taking into account specific geology and topography could be developed either at the current landfill site (an extension) or another suitable site on Rarotonga. Key considerations include:
    - Securing access to land - a long term lease would need to be secured for the landfill site.
    - Land area required, currently estimated at around 4 – 5 acres
    - Funding - the existing site cost $4-5M to build and requires $100-150,000 per year to operate in a manner consistent with Landfill Operations Plan.
- Treat - MHT: Solid waste that is currently landfilled could be subjected to mechanical heat treatment (MHT), drawing on existing technology employed for larger scale plants in Australia, the US and Europe. Key considerations include:
    - MHT plants are typically large scale, application for such a small quantity of general waste is relatively unknown.
    - The heat component of the process requires significant energy.
    - The mechanical component of the process targets recoverable materials which then require a viable market.
    - A MHT plant will require a suitable location, with access to power, energy (heat source) and space for managing incoming waste, recovered materials and treated waste.
    - The treated waste is potentially suitable as a fuel (subject to a suitable facility requiring fuel), a low grade soil amendment or can be landfilled. The treatment process can sterilise the waste and reduces the volume of waste by 50-60%.
- Treat - MBT: Solid waste that is currently landfilled could be subjected to mechanical biological treatment (MBT), drawing on existing technology employed for larger scale plants in Australia, the US and Europe. Key considerations include:

[17] As noted previously the design for Rarotonga Landfill anticipated construction of a second cell including additional liner once filling reached ground level. This second phase of construction has not occurred and waste is currently stockpiled on top of the landfill with minimal containment.

[18] The cost for a new clinical and quarantine waste incinerator will vary depending on specifications, location for installation and supporting equipment and services. Based on a recent tender process for healthcare waste incinerators across the Pacific by SPREP the cost may fall in the range NZD$75-150,000 with installation, operator training and ongoing maintenance additional to this figure.

  - MBT plants are typically large scale, application for such a small quantity of general waste is relatively unknown.
  - The mechanical component of the process targets recoverable materials which then require a viable market.
  - The biological component of process involves processing of degradable material in an aerobic or anaerobic environment. The aerobic process is analogous to composting and produces a compost like output. The anaerobic process produces biogas and solid residue that can be further composted.
  - A MBT plant will require a suitable location, with access to power, suitable separation from land uses sensitive to odour and space for managing incoming waste, recovered materials and treated waste.
  - The treated waste is potentially suitable as a fuel (subject to a suitable facility requiring fuel), a low grade soil amendment or can landfilled. The treatment process reduces the volume of waste by 40-50%.
- Treat - Incineration: Solid waste that is currently landfilled could be processed through a conventional incineration plant. Waste incineration is a well-established with plants operating in Asia, USA and Europe with typical scale range from 60,000 Tonne per year (very small) to well over 500,000 tonnes per year. There are a range of variations with a focus on arrangements feeding waste and managing ash. Key residuals include bottom ash and air pollution control residues. Key considerations include:
  - Incineration plants are typically large scale, application for such a small quantity of general waste is unknown.
  - Incineration typically follows removal of bulky materials and metals.
  - An incinerator will require a suitable location, with access to power, suitable separation from land uses sensitive to air emissions and space for managing incoming waste, recovered materials and ash.
  - The bottom ash may be suitable as a low grade aggregate or could be landfilled. The incineration process reduces the volume of waste by 60-80%.
  - The air pollution control residues are hazardous waste and require stabilisation prior to disposal in a suitable facility.
- Treat - Advanced thermal treatment: Solid waste that is currently landfilled could be processed through an advanced thermal treatment plant with gasification the most advanced technology form a commercial perspective. Gasification is emerging at a commercial scale with plants operating in Europe and Asia. The technology is best suited to consistent feedstock - specific waste streams or pre-processed refuse. Commercial plants are similar in scale to other processing technologies but are often modular with relatively small modules combined making use of common pre-processing and energy utilisation infrastructure. There are a range of variations with a focus on waste consistency, batch vs. continuous processing and use of gasification products (char, syn gas). Key residuals include char and air pollution control residues. Key considerations include:
  - Advanced thermal plants are typically large scale, combining pre and post processing infrastructure to reduce cost. There are small scale examples operating on a pilot basis.
  - Advanced thermal treatments require a consistent feedstock. This is typically achieved through pre-processing ranging from grinding/shredding of waste through to complex refuse derived fuel production and additional to removal of bulky materials and metals.
  - An advanced thermal plant will require a suitable location, with access to power, suitable separation from land uses sensitive to air emissions and space for managing incoming waste, recovered materials and char.

  - The char may be suitable as a carbon black type product, a low grade aggregate or should be landfilled. The process reduces the volume of waste by 60-80%.
  - The air pollution control residues are hazardous waste and require stabilisation prior to disposal in a suitable facility.
- Treat - Target specific materials: As noted above many of the advanced waste treatment approaches involve removal of recoverable materials before thermal (heating, burning or gasification) or biological treatment of the residual material. There is potential to focus on specific materials within the residual waste stream drawing on components of MBT, MHT and pre-processing of materials prior to incineration or advanced thermal treatment. Examples include removal of recyclable materials prior to landfill[19] or putting in place processing for source separated waste streams e.g. food waste, garden waste, disposable nappies. Key considerations include:
  - Markets for captured materials. Recyclable materials captured from general waste are likely to be of lower quality (contaminated). Logical targets would be aluminium cans (over 1% of rubbish) and glass bottles (over 14% of rubbish).
  - Capacity to collect and process materials. The current arrangement at Rarotonga Waste Facility is an addition to a conveyor designed for feeding material into the baler, not for sorting. This means there is limited capacity to process/capture additional material with the current arrangements.
  - Additional materials will need stockpiling, processing and storage prior to dispatch on site.

[19] Currently materials are 'picked' off the conveyor feeding the waste baler at the Rarotonga Landfill. Larger scale systems designed for material capture typically have automated sorting, specifically designed sorting stations and conveyors designed for ease of sorting and capture.

5.3 Outer Islands Options

As previously noted, waste on the outer islands is either used on site (food waste for animals, garden waste for compost//mulch) or dumped. The current disposal arrangements are not ideal and there is potential for significant environmental impacts without improvements being put in place.

For waste on the outer islands, options to improve the management of waste include:

Education - inform the community and businesses about waste management and recycling including:

- Better management of hazardous wastes (stockpiling for export to Rarotonga)
- Management of food (animal feed) and garden waste (compost/mulch) at home
- Avoid burning of general rubbish and particularly hazardous wastes and plastics.
- Separation of recyclable materials, initially focussing on glass and aluminium cans

Recycling - capturing materials for recycling/reuse on the island or for export to Rarotonga.

- Using food waste and garden waste on site rather than disposing it with general rubbish
- Providing for drop-off of glass and aluminium cans so they can be stockpiled and then periodically returned to Rarotonga (cans) or crushed for use on each island (glass)
- Exploring options to fund the return of plastics and steel to Rarotonga

Improving management of rubbish.

- Removing hazardous waste before material is dumped
- Capturing materials for recycling - glass and aluminium cans and exploring options
- Improving on-island dumping of rubbish - developing controlled dump sites taking into account underlying soils, risk to drinking water and coastal waters, vermin and containment of leachates.
- Consolidation of general waste with periodic export to Rarotonga for treatment and disposal.

There is potential to address the range of issues and options noted above for the Outer Islands through the providing support for Island Councils. This could include:

- Developing clear and simple guidance on waste management and recycling.
- Providing practical, on the ground support for establishing recycling collection points, managing hazardous waste and establishing disposal sites.
- Assisting with arrangements for returning materials (recyclables, hazardous waste) to Rarotonga.

The Local Government Association of the Northern Territory (Australia) developed a suite of guidance materials for small communities in the outback[20]. A similar suite of material targeting practical, fit for purpose and effective strategies for the Outer Islands could be developed. Well designed, this material is likely to be relevant for other parts of the Pacific and other remote and/or small communities.

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[20] WASTE MANAGEMENT IN SMALL COMMUNITIES - web-resource with several guidance documents. Accessed August 2016 at http://www.lgant.asn.au/policy-programs/sustainability-environment/waste-management-in-remote-regional-indigenous-communities

6 Option Evaluation

6.1 Multi-Criteria Evaluation Approach

The options noted in Sections 5.1 to 5.3 need to be considered in light of the Cook Islands strategic direction for solid waste management. This means assessing their ability to contribute to the vision, goals and objectives of the National Waste Policy while providing good value for money. The criteria used for assessing options are set out in Table 5 below.

Table 5: Multi-Criteria Evaluation Framework

Criteria	Policy Objective	Comment
Cost to Government	Objective 4 - Develop sustainable financing to manage solid waste.	Options that minimise government funding requirements are preferred. Cost can be modelled for different scenarios under consideration.
Landfill disposal/ Diversion %	Objective 3 - Develop appropriate waste management infrastructure including separation and storage facilities.	Options that make it easy to avoid waste or divert unwanted material from landfill are preferred, measured as anticipated % diversion.
Local economic development opportunities	To maximise local employment and business opportunities	Options that provide opportunities for local businesses and community groups are preferred
Technology risk	Addressing implementation risk(s)	Options that employ well established technology are preferred - the simpler the better.
Market risk	Addressing implementation risk(s)	Options that have a viable market for the outputs are preferred e.g. for compost or recyclable materials
Community views	Addressing implementation risk(s)	Options that are, or are likely to be supported by the community are preferred.

For the treatment and processing options the leading options have then be subjected to a high level cost benefit analysis. The assumptions used in the Cost Benefit analysis have been employed for deriving indicative annual costs (amortised capital and operating). The Cost Benefit Analysis (Section 6.3) is presented after the Multi-Criteria Assessment (Section 6.2).

6.2 Multi-Criteria Evaluation Summary

There are several options for collection services and the supporting processing and disposal infrastructure. These options have been considered using the Evaluation Framework noted in Section 6.1. The evaluation considered performance and cost at 2020 - when a new option is required for Rarotonga.

6.2.1 Collection Options Evaluation

The collection options evaluated are summarised below.

Table 6: Collection Options Considered

Option	Description
Collection - Status Quo	Government funded roadside collection of household and small commercial rubbish and recycling. Households and businesses use own container. Estimated cost $450,000 / year for collection[21]
Collection - New Rubbish Bins	Government funded roadside collection of household and small commercial rubbish and recycling. Households and businesses provided with new, small (80L) wheeled bin. Estimated cost $450,000 / year for collection $50,000 / year for bins (amortised over 5 years)
Collection - New Recycle Bins	Government funded roadside collection of household and small commercial rubbish and recycling. Households and businesses provided with new recycling crate. Estimated cost $450,000 / year for collection $30,000 / year for crates (amortised over 5 years)
Collection - New Rubbish & Recycle Bins	Government funded roadside collection of household and small commercial rubbish and recycling. Households and businesses provided with new, small (80L) wheeled bin and recycling crate. Estimated cost $450,000 / year for collection $80,000 / year for bins (amortised over 5 years)
Collection - Education	Government funded roadside collection of household and small commercial rubbish and recycling. Households and businesses use own container. $20,000 per year allocated to education targeting contamination, materials recognition and participation in the recycling scheme. Estimated cost $450,000 / year for collection $20,000 / year for education.

Table 7 summarises the multi-criteria evaluation of collection options. Costs have been estimated based on current collection costs and incorporating likely capital costs for new collection containers.

[21] This is similar to the current Collection Contract.

Table 7:- Collection Options Evaluation

Criteria	Coll - Status Quo	Coll - New Rubbish Bins	Coll - New Recycle Bins	Coll - New Rubbish & Recycle Bins	Coll - Education
Annual cost to Government	$450,000	$500,000	$480,000	$530,000	$470,000
Landfill disposal/ Diversion %	No change landfill diversion	No change landfill diversion	Greater than 40% diversion	Greater than 40% diversion	Greater than 40% diversion
Local economic development opportunities	No change in economic activity in Cook Islands	No change in economic activity in Cook Islands	Small increase in economic activity (recycle processing)	Small increase in economic activity (recycle processing)	Small increase in economic activity (recycle processing)
Technology risk	Commercially implemented in the Pacific	Commercially implemented in the Pacific	Commercially implemented in the Pacific	Commercially implemented in the Pacific	Commercially implemented in the Pacific
Market risk	Single viable market	Single viable market	Single viable market	Single viable market	Single viable market
Community views	Community unlikely to have as strong view	Community likely to be supportive of change	Community likely to be supportive of change	Community likely to be supportive of change	Part of community supportive - schools and motivated households
Summary score	31/45	31/45	34/45	32/45	35/45
Conclusion	Do not progress	Do not progress	Seek funding	Do not progress	Recommended

The assessment summarised in Table 7 suggests that several options are not worthy of further consideration at this point in time. These include continuing with the current service with no changes and introducing new rubbish bins. There may however be an opportunity to investigate changing the approach to collection of rubbish when the current collection contract is renewed in 2019[22].

Introducing containers for roadside recycling warrants further investigation with a view to identifying a suitable source of funding for the containers. Containers could be crates (commonly employed in New Zealand and Europe) or wheeled bins (commonly employed globally, tend to be used with mechanised collection). Crates could be employed within the current collection system while effective introduction of wheeled bins may require new equipment and by implication changes to the current collection contract.

[22] Any review of collection service should focus on collection staff safety, impact on recyclables recovery, overall cost effectiveness and setting performance criteria for the contractor to reward the contractor achieving a high level of customer satisfaction and waste diversion.

Targeted education to improve the use of the current service and once new containers for recycling are introduced is also recommended. The data collected for this feasibility study suggests that key messages could address:

- Contamination - there is a relatively high level of contamination in the recyclable material collected. Messages may be focussed on targeted materials or on the impact of contamination (nappies, food waste) on the recyclable materials, people processing materials and the value of the product.
- Capture of recyclable materials - the composition data suggests there is a significant amount of recyclable material in rubbish (rather than recycling) put out for collection. Messages may focus on clearly explaining what can be recycled via the roadside collection and encouraging households to separate all that they can.
- Participation in the recycling collection - messages may focus on creating a community ‘expectation’ that all households participate in the recycle collection.

6.2.2 Treatment and Processing Infrastructure

The treatment and processing options evaluated are summarised below. In all cases the disposal or treatment option is for materials remaining after roadside recyclables collection and drop-off of separated recyclable material at the Rarotonga Waste Facility. The Waste Facility would continue to operate for all options capturing recyclable materials and where relevant baling rubbish for landfill. Each of the options could accommodate rubbish from the outer islands if required.

Table 8: Treatment and Processing Options Considered

Option	Description
Treat - New Landfill	A new, government funded and operated, landfill on Rarotonga accepting household (collections) and commercial waste. Estimated cost $5-6M Capital Cost $100,000 / year operating cost
Treat - MHT	A new, government funded and operated, Mechanical Heat Treatment process on Rarotonga accepting household (collections) and commercial waste. Estimated cost $6M Capital Cost $225,000 / year operating cost
Treat - MBT	A new, government funded and operated, Mechanical Biological Treatment process on Rarotonga accepting household (collections) and commercial waste. Estimated cost $5-6M Capital Cost $225,000 / year operating cost
Treat - Incineration	A new, government funded and operated, incineration plant on Rarotonga accepting household (collections) and commercial waste. Estimated cost $8-10M Capital Cost $200-250,000 / year operating cost
Treat - Gasification	A new, government funded and operated, Mechanical Biological Treatment process on Rarotonga accepting household (collections) and commercial waste. Estimated cost $8-12M Capital Cost $200-250,000 / year operating cost
Treat - Target specific materials	Targeted activity to capture and recycle, reuse or treat specific materials potentially including food waste, garden waste and disposable nappies. Estimated cost alongside new landfill Alongside new landfill, additional $20,000 operational expenditure

Table 9, presented below, summarises the multi-criteria evaluation of treatment and processing options. Costs have been estimated based on existing commercial examples or based on work completed in similar locations. As noted previously the small scale of the Rarotonga for advanced technologies means there is considerable uncertainty in the capital and operational costs estimates. The annual cost includes an estimate of annual operating costs and the amortised capital costs[23].

Table 9:- Treatment and Disposal Options Evaluation

Criteria	Treat - New Landfill	Treat - MHT	Treat - MBT	Treat - Incineration	Treat - Gasification	Treat - Target specific materials
Annual cost to Government	$310,000	$500,000	$450,000	$670,000	$670,000	$330,000
Landfill disposal/ Diversion %	No change landfill diversion	Greater than 40% diversion	Greater than 40% diversion	Greater than 50% diversion	Greater than 50% diversion	Greater than 40% diversion
Local economic development opportunities	No change in economic activity in Cook Islands	Small increase in economic activity (recycle processing, processing plant operations and maintenance)	Small increase in economic activity (recycle processing, processing plant operations and maintenance)	Small increase in economic activity (recycle processing, processing plant operations and maintenance)	Small increase in economic activity (recycle processing, processing plant operations and maintenance)	Small increase in economic activity (recycle processing, processing plant operations and maintenance)
Technology risk	Commercially implemented in the Pacific	Commercially implemented but not in the Pacific	New technology	New technology	New technology	Commercially implemented in the Pacific
Market risk	Landfill as the final destination for materials is a secure 'market'	No viable markets for heat treated residual, limited markets for recovered materials	No viable markets for compost like output. limited markets for recovered materials	Single viable market for energy, limited markets for recovered materials	Single viable market for energy, limited markets for recovered materials	Limited markets for recovered materials
Community views	Community unlikely to have as strong view	Community unlikely to have as strong view	Community unlikely to have as strong view	Community unlikely to have as strong view	Community unlikely to have as strong view	Part of community supportive - motivated households and businesses
Summary score	28/45	23/45	21/45	24/45	24/45	31/45
Conclusion	Recommended	Do not progress	Do not progress	Do not progress	Do not progress	Investigate further

[23] 25 years at 0.5% real interest rate.

While there are a range of waste processing and treatment approaches implemented globally continuing the current arrangements with a new landfill is the recommended option. This means that a new landfill site, or an extension of the current site, will be required from around 2020. The recommended option reflects a number of factors including:

- The comparatively high capital and operating costs for alternative technologies.
- Technical risks: the lack of commercially proven applications of advanced waste treatment technology at a scale comparable to Rarotonga.
- Market risks: the lack of markets for ‘products’ of the processes, in particular for heat treated residual waste (MHT), compost like output (MBT), bottom ash (Incineration) and char (gasification).
- The likelihood that a new landfill will be required for residuals from the various advanced waste treatment options considered.

There is also potential to build on the current capture of recyclable materials from the waste immediately prior to baling for landfill by targeting specific materials. This is a basic version of the mechanical sorting component of MHT and MBT or the pre-processing component of both conventional and advanced waste to energy plant.

6.3 High level cost benefit analysis

Approach

The leading options from the multi-criteria evaluation are the development of a new landfill, potentially supported by targeting specific materials for recovery. The next strongest option involved energy recovery - conventional incineration and advanced thermal treatment returned a similar weighted score. The economic analysis considers landfill vs. waste to energy to explore key drivers of cost. The cost assumptions are the same, where relevant, as those used to develop an estimate of annual cost covering capital and operating costs.

The economic analysis of waste disposal options uses a cost benefit analysis (CBA) framework. It compares the full costs and benefits over the lifetime of the project options in terms of the effects on the Cook Islands as a whole.

The benefits of the options being considered are all defined as the disposal and/or effective management of all waste produced in the Cook Islands. Thus the waste management benefit is the same in all instances. Our interest is in achieving these benefits at least cost.

Costs are defined as opportunity costs. The cost of using a resource for a particular activity is that the resource is not available for the next highest value use. This includes opportunity costs of capital (it could have been invested to create a return in some other venture), resources (they could have been used as inputs to some other industry) and labour (workers could be employed elsewhere).

Discount Rate in Net Present Value and Cost Benefit Calculations

Discount rates are used in CBA to adjust the impact on total value of costs and benefits, depending on the time period in which they accrue. This adjustment is not to deal with inflation, which is handled separately. Rather, it is to adjust values to take account of how any allocation of resources to a project, displaces the timing of consumption and/or investment relating to other activities.

ADB projects are generally analysed using a discount rate of 10-12%.[24] However, a recent ADB review[25] questions this practice and notes that rates might differ depending on whether inter-generational issues are at stake, and whether the primary impact is on consumption or investment.

Because the project being discussed is a significant capital project requiring Government funding, our assumption is that it is displacing capital expenditure, i.e. investment. For simplicity we have used a rate of 10% in our analysis.

Options for consideration

The Options

The existing landfill is close to capacity. A new disposal option is required to be in place by 2020. The options considered in this analysis are:

- a new landfill; and
- an advanced waste treatment plant (advanced thermal). It would require the disposal of residual ash /char and unsuitable materials.

In addition, there is the potential for increased recycling of waste. This would be in addition to one of the options above, although it could mean reduced quantities of waste require management.

Costs and other data

The costs for the individual options are summarised in Table 10. The advanced waste treatment plant requires both a plant and a new landfill for the disposal of the residuals. The total costs would include both components. For this assessment it is assumed that the capital costs of the new landfill would be similar but that the quantity of waste (and thus the operational costs) would be 10% of the landfill only option[26].

Table 10 Volume and cost data

Component	Common assumptions	New landfill	Advanced waste treatment	
Annual volumes (t pa)			Plant	Residuals disposal
Waste production	1,500			
Recycled	500			
Collection costs ($ pa)	$300,000 ($200/t)			
Capital costs ($)				
Design/permitting (2017/18)		$250,000 (2017/18)	$500,000 (2017/18	$250,000 (2017/18)
Construction, commissioning (2018/19 – 2019/20)		$5 million	$10 million	$5 million
Operating costs ($ pa)		$100,000 pa	$250,000	$10,000 pa

[24] Asian Development Bank (2013) Cost-Benefit Analysis for Development: A practical guide.
[25] ADB (*op cit*)
[26] Operational costs may be higher, reflecting high fixed costs regardless of scale although operational costs on Rarotonga have been relatively low with simple and cost effective approaches to waste handling and placement. Capital cost may be lower if it is decided that a smaller void space can be developed. On balance the total annual cost incorporating finance costs (for capital) and operational costs are indicative of likely overall annual costs for the disposal component.

The other information relevant to the consideration of costs and benefits and their timing, is that of the costs of finance. It is assumed that the capital costs for the project will be financed from an Asian Development Bank loan. The costs of borrowing depend on the period of the loan, which is assumed to be 25 years. The assumptions are shown in Table 11.

Table 11 Interest rate assumptions (25-year ADB loan)

Factor	Rate
Fixed swap rate (average 20 & 30 years USD)	1.88%
Contractual spread	0.50%
Maturity premium (17+ years)	0.20%
Total	2.58%

Source: Asian Development Bank Treasury Department (2016) Indicative Lending Rates for Loans under the LIBOR-Based Loan Facility Foreign Exchange Rates & Cap/Collar Premiums for Floating Rate Loans; ADB (2014) Financial Management Technical Guidance Note. Preparing and Presenting Cost Estimates for Projects and Programs Financed by the Asian Development Bank.

These are nominal interest rates, whereas the costs data included in Table 10 are in constant dollar (real) terms. We use an inflation rate of 2.1% based on estimated annual inflation rates over the previous five years.[27] To adjust the nominal interest rate to a real rate we use the following formula:

$$r_{real} = \frac{(1 + r_{nominal})}{(1 + i)} - 1$$

Where: r_{real} = interest rate in real terms

$r_{nominal}$ = interest rate in nominal terms

i = inflation rate

A nominal rate of 2.58% is equivalent to a real interest rate of 0.47% with an inflation rate of 2.1%.

In Table 12 we show the profile of costs between the two waste management options, including capital expenditure (capex), the finance costs which spread the capex costs over 25 years and the operating costs from the first year of opening of the landfill or waste treatment plant.

Table 12 Profile of costs

Year of oper-ation	Year	New landfill				Advanced waste treatment			
		Capex	Finance cost	Opex	Total	Capex	Finance cost	Opex	Total
	2017/18	$0.25m			$250,000	$0.75m			$750,000
	2018/19	$2.5m	$105,723		$105,723	$7.5m	$317,170		$317,170
	2019/20	$2.5m	$211,446		$211,446	$7.5m	$634,339		$634,339
1	2020/21		$211,446	$100,000	$311,446		$634,339	$260,000	$894,339
2	2021/22		$211,446	$100,000	$311,446		$634,339	$260,000	$894,339
..	..								
23	2041/42		$211,446	$100,000	$311,446		$634,339	$260,000	$894,339
24	2042/43		$211,446	$100,000	$311,446		$317,170	$260,000	$577,170
25	2043/44		$105,723	$100,000	$205,723		$0	$260,000	$260,000

[27] ADB Key Indicators for Asia and the Pacific 2015

Results

The overall results are shown in Table 13, in terms of an overall NPV to 2016 and an estimate of costs per tonne (in 2016 $ values).

Table 13 Cost benefit analysis results

Component	New landfill	Advanced waste treatment	New landfill	Advanced waste treatment
	PV ($m) to 2016		$/t	
Collection	$2.00	$2.00	$200	$200
Treatment		$5.44		$543
Disposal	$2.55	$1.95	$255	$195
Total	$4.55	$9.39	$455	$938

A new landfill is clearly the lower cost option; advanced waste treatment costs are over double the cost.

7 Cost Recovery Mechanisms

Waste management in the Cook Islands has high costs, including the costs of collection and for management which includes final disposal or recycling.

- There are a number of different options available for financing the costs of waste management. Typically these are one of the following options:
  Financed by central or local government with revenues raised via taxes or property rates;
- Financed by households and businesses via charges for services, e.g. weekly charges per household, or costs per bag collected.

As noted in Section 4.1 waste collection is funded by government with H&M Heather contracted to deliver rubbish and recycling collections. Waste disposal is partly funded through user charges with government providing additional funding where required. The capital costs associated processing (baler, Rarotonga Waste Facility equipment) and the Rarotonga Landfill are not separated out from broader government expenditure and debt.

Options to consider are those that shift the burden of costs from the government (and tax payers) to those that produce waste. The main options for doing so are:

- Waste collection fees that cover the full costs of collection and disposal; and
- Product charges which levy a charge on producers or importers of products, at the time that the product is first sold, to cover the costs of eventual disposal.

These options are discussed below.

7.1 Waste disposal charges

Currently waste disposal charges recover some but not all of the costs of disposal. A total of $180,000 is recovered from charges. This is equivalent to $120/tonne for the disposal of 1,500 tonnes of waste. This revenue covers the operational costs at the Rarotonga Waste Facility but does not offset the costs of collection or assumed cost of capital for the Rarotonga Landfill.

To recover the full costs of collection and disposal would require waste charges be increased to around $550/tonne.

The risk with this approach is that it would introduce incentives for unauthorised waste disposal (fly tipping). If this is thought to be significant, then finding other ways to pay for disposal will be preferable (see below).

7.2 Product Charges

Product charges, sometimes called advance disposal fees (ADFs), place a charge on producers or those first introducing products to the economy, on the basis of their expected impacts once they enter the waste stream. They aim to "internalise" the costs of disposal in the product itself, i.e. ensure that the purchaser of the product pays for its disposal at the time of purchase. In addition to providing revenue to pay for waste disposal, product charges can also have incentive effects. The type of incentive depends on the way in which they are levied.

- Those levied on the basis of weight or volume provide incentives for the purchase of lower weight or smaller items.
- If charges vary with recyclability of the product, incentives are provided for purchase of more recyclable products, although not necessarily for recycling itself.

Product charges are used in a large number of countries, but often for specific products, e.g. electronics, tyres, packaging, hazardous wastes and vehicles.[28] The charge bases include unit numbers, e.g. charge per product sold, by volume or by weight. A charge as a percentage of value, equivalent to a goods and services charge, would be an alternative approach. The best approach to use would depend on the objectives being pursued.

7.3 Raising Revenue

If the objective is solely to raise revenue, then the best approach is likely to be that which would raise revenue at least cost. If it is not expected to have an incentive effect, then the basis for deciding on a good mechanism is equivalent to that which governs good taxation policy, i.e. raising required revenue in a way which minimises distortions in the economy. Distortions occur where the tax results in a shift in resource use within the economy from what it would be in the absence of taxation. This includes changes in investment, hours of work and consumption.

Tax devices in the Cook Islands include company tax, income tax and value added tax (VAT). Because of the relationship of waste to consumption, an increase to VAT would appear to be a logical avenue; it would be most easily explainable and would be likely to best meet fairness criteria both because it targets tourists as well as locals and because of the relationship to products. However, increasing VAT may not necessarily be the least distortionary taxation option. This would require detailed analysis beyond the scope of this report. However, the point is that, if revenue is the sole purpose for the instrument, then general taxation provides a means to achieve this.

VAT is levied at 15% of the sales price in the Cook Islands. Approximately $85 million was raised from VAT in 2015.[29] The estimated annual costs of the different options, $311,000 and $673,000 for a new landfill or advanced waste treatment respectively, would be equivalent to a 0.4% or 0.8% increase in the VAT rate, i.e. to 15.4% or 15.8%. VAT was increased from 12.5% to 15% on 1 April 2014 and is the same rate as applies in New Zealand. A small rate increase may not be worthwhile as there will be transaction (administrative) costs for the government in introducing such a change which may cut into some of the revenue saved.

However, in comparison with setting up a new product charge mechanism to levy a charge per weight or number of products, extending the VAT level may have lower costs.

7.4 Incentives for waste minimisation

A product charge levied on a weight or volume basis, would provide incentives for reduced waste through purchase of products with lower weight or volume. A product charge that varied in level with the recyclability of the product would provide incentives for a shift in purchasing towards those that were more recyclable.

Product charges with an incentive effect will raise revenue also and can be set at a level which (in theory) would recover all annual costs. However, because of the incentive effect, the amount of waste would be expected to fall such that the revenue collected is less than expected from multiplying current waste quantities by the average charge level. The extent to which there is a revenue shortfall depends on the level of charge, and the price elasticity of demand. The elasticity

[28] OECD Database on instruments used for environmental policy (http://www2.oecd.org/ecoinst); St Brown M, Yoder J and Chouinard H (2011) Revenue sources to fund recycling, reuse, and waste reduction programs. Prepared for Washington State Department of Ecology

[29] Cook Islands Ministry of Finance and Economic Management (2016) Cook Islands Statistical Bulletin Taxation Statistics. March Quarter 2016

will depend, in turn, on the existence of substitute products. The relevant elasticities are for the range of individual products rather than for waste disposal itself.[30]

The reduction in expected revenue does not matter if the amount charged per product is equal to the disposal costs per product. However, because there are significant fixed costs of disposal (the capital costs of the landfill or treatment facility), the reduction in revenue is likely to be greater than the reduction in costs; average costs of disposal are greater than marginal (or variable) costs.

An alternative approach is to make the level of charge equal to the marginal costs of disposal, i.e. the change in total costs of disposal resulting from one less tonne or cubic metre of waste. Such a charge would not recover all the costs of disposal but it would be optimal from an economic perspective. People would make a decision to purchase a product which produced more waste when the additional amount that they paid was equal to the costs which their purchase imposed on the community because of the costs of final disposal. In theory, this results in the optimal amount of waste produced. The remaining costs of disposal can then be recovered using the least cost means, i.e. taxation as discussed above.

30 Price elasticities of demand for disposal are low. See: Covec (2012) Economic Factors of Waste Minimisation in New Zealand. Report to NZ Ministry for the Environment.

8 Conclusions and Recommendations

The analysis set out in Section 6 indicates a clear course of action for treatment and disposal of Waste on Rarotonga. The option identification and evaluation also considered collection of waste and options for improving solid waste management on the outer islands.

Key recommended actions arising from the analysis presented in this report are:

1 Implement an education programme to improve the performance of the rubbish and recycling collection system and address key high risk waste streams and activities across the Cook Islands. Key messages should include:
   - Appropriate management of hazardous wastes (stockpiling for export to Rarotonga)
   - Avoid burning of general rubbish and particularly hazardous wastes and plastics.
   - Management of food (animal feed) and garden waste (compost/mulch) at home
   - Separation of recyclable materials, initially focussing on glass and aluminium cans

2 Consider supplying recycling containers to households on Rarotonga and Aitutaki - to provide a convenient storage container and improve capture of recyclable materials from households and small businesses.

3 Complete Rarotonga Landfill design and construction and Aitutaki Landfill remediation.

4 Implement operational improvements at Rarotonga Landfill and Aitutaki Landfill.

5 Replace clinical and quarantine waste incinerators with a single facility.

6 Commence site identification community engagement, concept design, detailed design, procurement and construction for new Rarotonga Landfill.

7 Implement improvements in solid waste management on outer islands
   - Education - inform the community and businesses about waste management
   - Develop simple, pragmatic and fit for purpose guidance to assist Island Councils improve solid waste management on each island. Materials should cover:
     Implementing recycling initiatives - providing for drop-off of glass (to crush) and aluminium (return to Rarotonga), exploring options to fund the return of plastics and steel
     Improving management of rubbish - capturing hazardous waste, controlling on-island dumping of rubbish, considering consolidation and return to Rarotonga.

Table 14 summarises the actions noted above with indicative timing, indicative costs, responsible agency and supporting parties.

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Table 14 - Recommendation Summary

Recommendation	Indicative Timing	Indicative Cost	Responsible	Support
1. Implement an education programme	Commence Q1 2017.	$20,000 per year, potentially with initial investment in developing material followed by lower level of ongoing funding.	Infrastructure Cook Islands	Te Ipukarea.
2. Consider supplying recycling containers	Confirm costs Q1 2017 Confirm funding Q3 2017 Roll out containers Q1 2018	$30,000 per annum to fund recycle crates	Infrastructure Cook Islands	T&M Heather, CI General Transport
3. Complete Rarotonga Landfill design and construction	Design completed Q4 2016 Construction Q1-2 2017	Design $30-50,000 Construction	Infrastructure Cook Islands	Consultants
4. Implement operational improvements at Rarotonga and Aitutaki Landfills	Operations Plan and training Completed Q1 2017 6 monthly 'audit' against plan	Additional $50,000 per year operational funding for Rarotonga Waste Facility.	Infrastructure Cook Islands	Consultants
5. Replace clinical and quarantine waste incinerators	Confirm specification for new incinerator Q4 2016 Permitting and Procurement of new incinerator Q1-2 2017	TBC	Airport/ Hospital	Infrastructure Cook Islands
6. Commence new Rarotonga Landfill process	Site identification and community engagement Q1-2 2017 Design and permitting Q3 2017 - Q2 2018 Procurement and Construction Q3 2018 - Q4 2019	Permitting approx. $250,000 Construction approx. $5 - 7,000,000	Infrastructure Cook Islands	Consultants
7. Implement improvements in solid waste management on outer islands	Education - link to Recommendation 1 Develop guidance for effective solid waste management on remote island communities.	Annual Budget Appropriation for solid waste management and an estimated $200,000 capital per island one off	Te Pa Enua Island Governments	Infrastructure Cook Islands

9 Acknowledgements

Many stakeholders have contributed to the development of this report including providing valuable insights into solid waste management across the Cook Islands, sharing information and ideas about options for the future and risks to be considered. Tonkin and Taylor extends thanks to all who have offer their input to the study.

10 Applicability

This report has been prepared for the exclusive use of our client Cook Islands Infrastructure, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

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Appendix A: Policy Context

National Waste Policy (2016)

The Cook Islands National Solid Waste Management Strategy 2013-2016 was developed by the National Solid Waste Management Committee and contains a mix of policy elements and more specific strategies. The policy elements have formed the foundation for the National Solid Waste Management Policy 2016-26.

The Policy notes that the Cook Islands faces a number of unique challenges as it deals with externalities of economic development and its integration into the global economy. Solid waste management is a significant challenge because of its impact on human health and ecosystems. The contextual challenges include:

- Lack of legislation heightens ambiguous role responsibilities
- Limited institutional capacity due to small population
- High transport costs related to small dispersed land masses
- Lack of investment in infrastructure to manage solid waste
- Asymmetrical trade balance, with the vast majority of consumables imported
- Human and environmental health threatened by poor management of hazardous waste.

Several of these challenges are relevant to considering options for treatment and disposal of waste in Rarotonga. These are:

Limited institutional capacity due to small population

The limited number of knowledgeable staff working in solid waste management presents a significant challenge for the government to advance proper solid waste management. This issue is compounded by the country's depopulation trends. There is no appropriately resourced focal point within government that takes responsibility for waste management. For options that involve complex technology a key consideration will be ongoing access to skilled operators and technical support.

High transport costs related to small dispersed land masses

There are significant distances between the capital island, Rarotonga, and Te Pa Enua. This factor, combined with the Cook Islands isolation from metropolitan countries that have recycling facilities, increases the cost of recycling. This has inhibited solid waste recycling and the safe disposal of hazardous waste. Distance also has an impact on access to technical support for complex technology (see above) and may mean local treatment or processing is more cost effective than exporting materials for treatment elsewhere despite small quantity of material requiring management.

Asymmetrical trade balance

Imports to the Cook Islands far exceed exports. The provisional balance of trade figures for 2015 are NZ$157.2M for the value of imports, and NZ$20.2M for the value of exports. This is a negative trade balance of NZ$137.0M. The 2015 provisional figures categorise 25% of imports (by total value) as food and live animals, with a further 6% categorised as beverages and tobacco. Packaging from food, beverages and tobacco contributes significantly to the generation of waste. This waste stream increases to meet the additional consumption needs of visitors. In addition to this import export imbalance, many shipping containers return to New Zealand empty.

Human and environmental health threatened by hazardous substances

Any solutions considered must protect human and environmental health as a priority. This means considering high impact components of the waste stream such as hazardous wastes. Residuals from treatment or disposal must also be appropriately managed to avoid negative impacts.

The following principles during the development of the National Waste Policy and are relevant for this study:

1. Polluter pays principle

   Those responsible for causing pollution or generating solid waste should pay for the cost of dealing with the pollution, or for managing solid waste collection and disposal in order to maintain ecological health and diversity. Individual responsibility for solid waste management should be encouraged. It is essential to develop funding mechanisms based on the polluter pays principle, which will sustain solid waste management in the future.

2. Precautionary principle

   When an activity may lead to unacceptable but scientifically uncertain harm to human health or the environment, actions will be taken to avoid or diminish that harm without having to await the completion of further scientific research.

3. Consultation principle

   All levels of government, communities and organisations should be consulted throughout the development and implementation of solid waste management strategies and action plans. Such strategies or plans should be openly accessible to those in the community who are interested.

4. Waste hierarchy principle

   The 'Waste Hierarchy' is a strategic tool which prioritises actions for solid waste management. The general hierarchical model that will be used under this policy consists of 4 'Rs – Refuse, Reduce, Reuse and Recycle. This model prioritises waste avoidance and reduction methods, before reuse, recycling, and final disposal. In the Cook Islands, the first R, (Refuse) places the onus on importers and consumers to reject the purchase of products that produce waste that is difficult and expensive to dispose of in an environmentally sound manner.

5. Proximity principle

   Solid waste should be managed as close to the source as possible. This recognises the need for producers of waste to take responsibility for the management of that waste. It also recognises that there are costs - both environmental and financial - associated with transporting waste over longer distances.

Objectives and policies

Waste minimisation	
Objective 1.	Minimise the generation of solid waste.
Policy 1.1	Follow the waste hierarchy model of the four 'R's - Refuse, Reduce, Reuse and Recycle - prioritising waste avoidance and reduction, before reuse, recycling and final disposal.
Policy 1.2	Promote responsible supplier and consumer behaviour using advocacy, education, incentives and regulation.
Policy 1.3	Encourage and require reduction of waste.
Policy 1.4	Implement waste prevention and reduction approaches in all activities undertaken by government agencies.

Policy 1.5	Encourage businesses and industry to adopt waste minimisation practices, including cleaner production technologies.
Explanation of Objective 1 and Policies: The outcome sought by Objective 1 is minimum generation of solid waste. This outcome is essential to achieving the policy vision of sustainable solid waste management, aspiring towards Zero Waste Cook Islands. The associated policies give effect to Objective 1 by following the waste hierarchy model of refuse, reduce, reuse and recycle which is consistent with a zero waste approach. The policies recognise that minimisation of waste is the shared responsibility of a range of stakeholders including suppliers, consumers, government, businesses and industry. The policies also recognise that advocacy, education, incentives and regulation, are all important tools that need to work together to minimise the generation of solid waste.	
Institutional and legislative framework	
Objective 2. Develop a clear and robust institutional and legislative framework.	
Policy 2.1	Establish a regulatory framework that: a. Addresses solid waste prevention, recycling and management of different waste streams b. Articulates the roles and responsibilities of agencies responsible for the coordination of solid waste management c. Supports the waste hierarchy model of the four 'R's - Refuse, Reduce, Reuse and Recycle.
Policy 2.2	Implement an institutional framework to ensure co-ordinated, effective and efficient management of solid waste including supporting facilities and services.
Policy 2.3	Build capacity to ensure qualified and competent staff.
Explanation of Objective 2 and Policies: The outcome sought by Objective 2 is an institutional and legislative framework which can support the policy vision of sustainable solid waste management. This addresses two of the challenges identified in section 5.2 of this policy - the lack of legislation which heightens ambiguous role responsibilities, and the limited institutional capacity due to the small population. Policy 2.1 gives effect to the objective by recognising that a clear and robust legislative framework needs to address all aspects of the solid waste stream; clarify the roles and responsibilities of the agencies involved; and support the waste hierarchy model. Policies 2.2 and 2.3 give effect to the objective by providing for the institutional framework with capacity building to ensure qualified and competent staff.	
Appropriate infrastructure	
Objective 3. Develop appropriate waste management infrastructure including separation and storage facilities.	
Policy 3.1	Provide appropriate and effective waste management facilities across the country including community recycling centres and solid waste storage sites.
Policy 3.2	Store hazardous waste (including e-waste) safely as an interim arrangement, prior to its transfer to environmentally sound disposal facilities overseas.
Policy 3.3	Ensure waste management facilities are fit for purpose and are financially and operationally sustainable.
Explanation of Objective 3 and Policies: The outcome sought by Objective 3 is the infrastructure needed to achieve the policy vision of sustainable waste management. This addresses two of the challenges identified in section 5.2 of this policy - the lack of investment in infrastructure to manage solid waste, and human and environmental health threatened by hazardous substances. The associated policies give effect to the objective by providing for appropriately located facilities which are of the necessary standard for their intended use and which are financially and operationally sustainable. Policy 3.2 recognises the particular needs of hazardous waste which poses the most serious risks to human and environmental health.	
Sustainable financing	
Objective 4. Develop sustainable financing to manage solid waste.	
Policy 4.1	Introduce appropriate cost recovery measures such as: Advanced Disposal Fees, user pays for collection of household waste, use of fees from fines.
Policy 4.2	Give particular regard to cost recovery measures which encourage behaviour modification and more responsible waste management.
Policy 4.3	Undertake an economic assessment of the costs of solid waste management in the Cook Islands to inform cost recovery mechanisms.

Explanation of Objective 4 and Policies The outcome sought by Objective 4 is the sustainable financing needed to achieve the policy vision of sustainable waste management. This addresses two of the challenges identified in section 5.2 of this policy - the high transport costs related to small dispersed land masses, and the lack of investment in infrastructure to manage solid waste. The associated policies give effect to the objective by providing for cost recovery measures and an economic assessment of the costs of solid waste management. Policy 4.2 recognises that cost recovery measures can also promote responsible behaviour such as by encouraging recycling or requiring the consumer to contribute directly towards the costs of disposal.
Education and awareness
Objective 5. Promote individual and community responsibility for solid waste management.
Policy 5.1 Undertake education and awareness, targeting the following groups: Business and large scale waste producers General adult population Youth and children. Policy 5.2 Develop and implement a communication strategy for solid waste management.
Explanation of Objective 5 and Policies The outcome sought by Objective 5 is the individual and community responsibility needed to achieve the aspect of the vision expressed as 'an informed and proactive community taking responsibility…' This objective recognises that all stakeholders need to play an active role in moving to a zero waste approach. The policies give effect to the objective by providing for education and awareness, and a communication strategy.
Monitoring and evaluation
Objective 6. Develop a strong monitoring and evaluation system.
Policy 6.1 Collect accurate and up-to-date national statistics on solid waste. Policy 6.2 Ensure solid waste disposal facilities are monitored and managed in accordance with approved standards to minimise environmental damage.
Explanation of Objective 6 and Policies The outcome sought by Objective 6 is the monitoring and evaluation required to measure progress towards achievement of the vision. The policies give effect to the objective by providing for accurate and up-to-date statistics, and the monitoring of environmental standards at waste disposal facilities.

National Sustainable Development Plan 2016-2020

The National Sustainable Development Plan 2016-2020 (NSDP) is also an important policy document to consider when looking at options for solid waste treatment and disposal. The National Vision, as set out in the NSDP is:

> *"To enjoy the highest quality of life consistent with the aspirations of our people, and in harmony with our culture and environment"*

The NSDP sets sixteen national development goals. Goal 3 is of most direct relevance to this waste policy. It is to:

> *"3. Promote sustainable practices and effectively manage solid and hazardous waste"*

The NSDP has identified two indicators to measure progress towards this goal. Indicator 3.1 tracks total waste recycled. Indicator 3.2 tracks the percentage of hazardous waste that is accounted for and managed.

Other NSDP goals of relevance are:

> *"4. Sustainable management of water and sanitation"*
>
> *"11. Promote sustainable land use, management of terrestrial ecosystems, and protect biodiversity"*
>
> *"12. Sustainable management of the oceans, lagoons and marine resources"*

These goals are of relevance because of the adverse effects that poor solid waste management can have on the natural environment.

Appendix B: Waste Technology options

CONVENTIONAL INCINERATION	
Technology description	The technology involves the thermal combustion of waste in the presence of oxygen, liberating energy, usually in the form of steam. It is used to treat municipal solid waste (MSW) as well as other streams such as hazardous materials (e.g. clinical waste); the latter typically requires the use of more sophisticated emissions abatement equipment. Where MSW is the feedstock there is usually some generation of energy – most typically electricity, sometimes heat – from using the resulting steam in a steam turbine. Electrical generation efficiencies for the incineration of MSW (in the absence of any heat utilisation) range from 13%-29%, not taking into account the energy used within the plant itself. In addition to energy, ash is produced (around 25% of the tonnage treated at the plant). Depending on the abatement equipment being used, a portion of this solid output is usually hazardous, requiring additional precautions to be undertaken to reduce environmental impacts where it is landfilled.
Scale	The technology itself does not preclude the development of very small facilities (less than 10,000 tonnes per annum), whilst very large facilities treating in excess of 1 million tonnes per annum have also been developed. The energy generation potential decreases as the size of the facility decreases, whilst costs per tonne increase.
Risk	The technology has been widely used all over the world for many years, so operational risks are relatively low.
Indicative costs	Costs are dependent on facility size, pollution abatement requirements, and the approach to procurement. Indicative per tonne costs for a CHP facility in Shetland Islands (UK) treating 20,000 tonnes of waste annually were NZ$51 capex and NZ$131 opex. Smaller facilities would be more expensive but the generation of electricity only (as opposed to CHP) would be expected to reduce costs.

Exterior of a MSW Incinerator in Qatar

ADVANCED THERMAL TECHNOLOGIES – PYROLYSIS & GASIFICATION	
Technology description	These technologies involve the oxidation of carbon-based materials in the absence of oxygen (in the case of pyrolysis) or in low oxygen containing environments (for gasification). Outputs include a syngas which can then be used in a steam turbine – by far the most common application - or gas engine to generate energy. Where a steam turbine is used, generation efficiencies are usually slightly lower (for the same size of facility) than for conventional incineration as some energy is lost at the syngas conversion stage. Energy generation efficiencies are higher where a gas engine is used, but this significantly increases the operational challenges. As with incineration, some solid output is produced, typically including some hazardous material.
Scale	These technologies are commonly marketed as modular and there are a number of pilot facilities in operation, so the development of very small facilities is not precluded. However, as with incineration, costs increase and energy generation performance decreases for small scale plant.
Risk	Much higher risk than conventional incineration; many plant treating MSW have experienced operational difficulties due to the heterogeneous nature of the material. Risks are especially high for technologies using gas engines – there are very few reference facilities operating globally at any scale for this type of technology.
Indicative costs	Costs are dependent on facility size, pollution abatement requirements, and the approach to procurement. Costs for pyrolysis and gasification are unlikely to be cheaper than that of incineration.

Interior Photo of the Chinook Gasification System

MECHANICAL BIOLOGICAL TREATMENT	
Technology description	A generic term for facilities comprising a multi stage treatment process, combining a mechanical phase with at least one biological treatment step. The mechanical phase involves the removal of recyclable material (metals, plastics and sometimes others) using mechanised sorting processes. The biological phase can involve aerobic or anaerobic degradation; depending on the process objectives, the former can be used to produce a dried refuse derived fuel (RDF) or stabilised output reducing the impact of material subsequently sent to landfill. The use of anaerobic digestion results in energy generation (via a gas engine), whilst the RDF may be sent to an incinerator or an advanced thermal treatment process.
Scale	Facilities typically treat around 50-150,000 tonnes of waste per year. Very small facilities (operating commercially) are rare, as the unit cost of the equipment increases as scale decreases, although there is no technical reason to preclude the construction of very small plant.
Risk	Dependent on the combination of technologies being used. Mechanical sorting processes and aerobic degradation are relatively low risk processes, but the anaerobic degradation step has caused operational difficulties particularly where MSW is the feedstock.
Indicative costs	Dependent on the combination of technologies being employed; costs are also dependent on facility size, pollution abatement requirements, and the approach to procurement. Lower technology approaches (e.g. stabilisation) could result in costs similar to that of incineration; higher technology processes (e.g. AD-based systems) will result in higher costs.

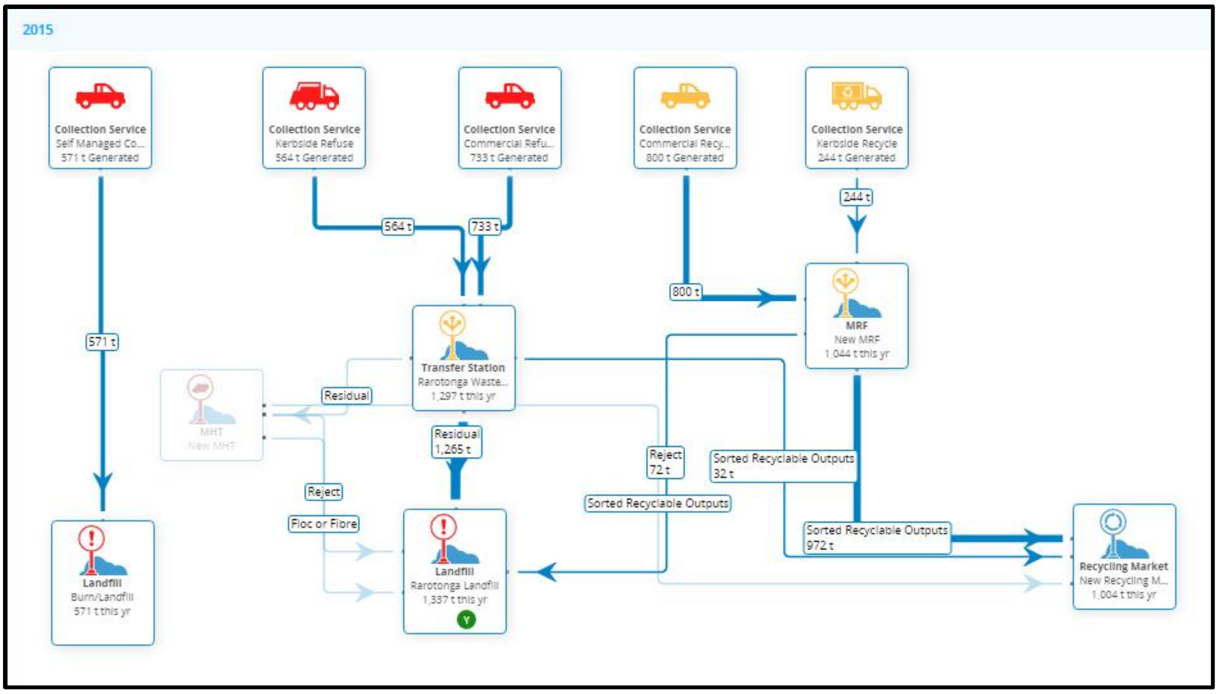
Interior showing Mechanical Sorting and Exterior showing Composted MSW

MECHANICAL HEAT TREATMENT	
Technology description	A variant of the mechanical biological treatment process. In this case, the waste is heated at high temperatures both to sterilise the material and to make it easier to subsequently remove a cleaner stream of recyclable materials using mechanical separation processes. A variation on the mechanical heat treatment process involves the use of elevated pressures as well as high temperatures in a process known as autoclaving. Depending on the approach used, the heat treatment step may also be followed by a biological treatment step. Some kind of RDF is also usually produced which may be used in an incinerator or an advanced thermal facility.
Scale	Pilot facilities have been developed at very small scale for some technology variants. However, the more typical operational capacity is 50-150,000 tonnes per annum.
Risk	Risks are high. There have been very few facilities operating globally using this type of technology in the past decade, and a number of those have experienced significant technical difficulties.
Indicative costs	Dependent on the combination of technologies being employed; costs are also dependent on facility size, pollution abatement requirements, and the approach to procurement. Costs for systems involving a mechanical heat treatment step are unlikely to be cheaper than that of incineration.

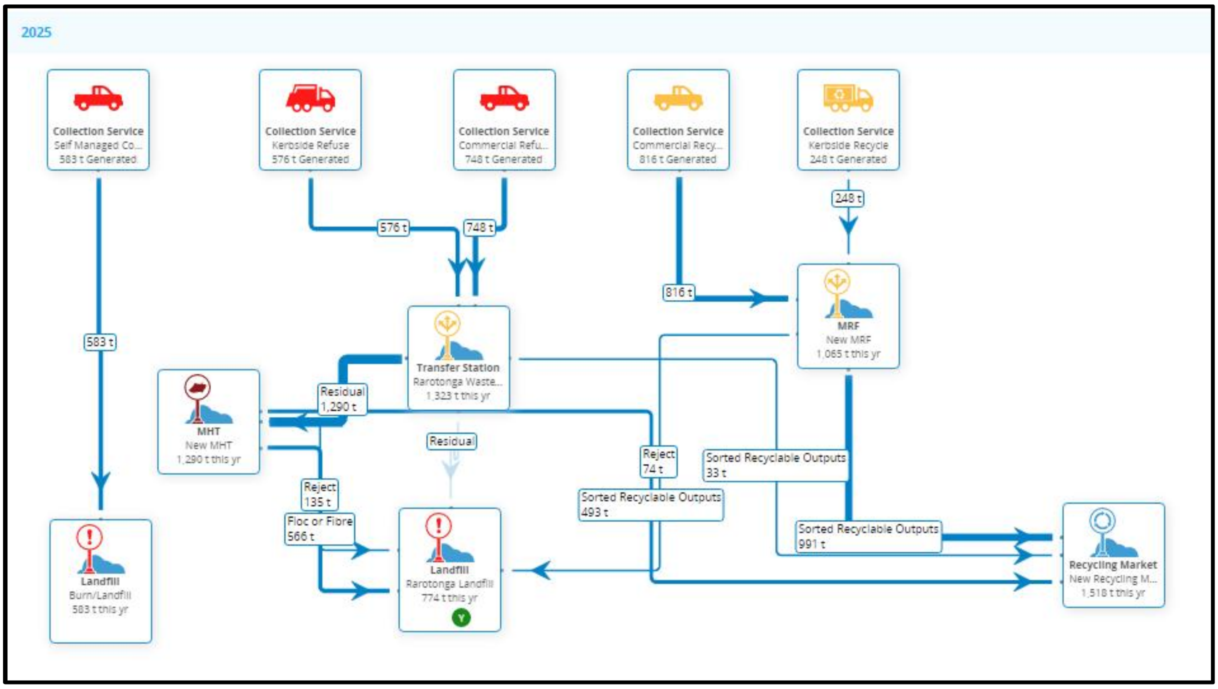
Interior of Orchid Environment Mechanical Heat Treatment Process

Appendix C: Options - Mass Flow Disgrama

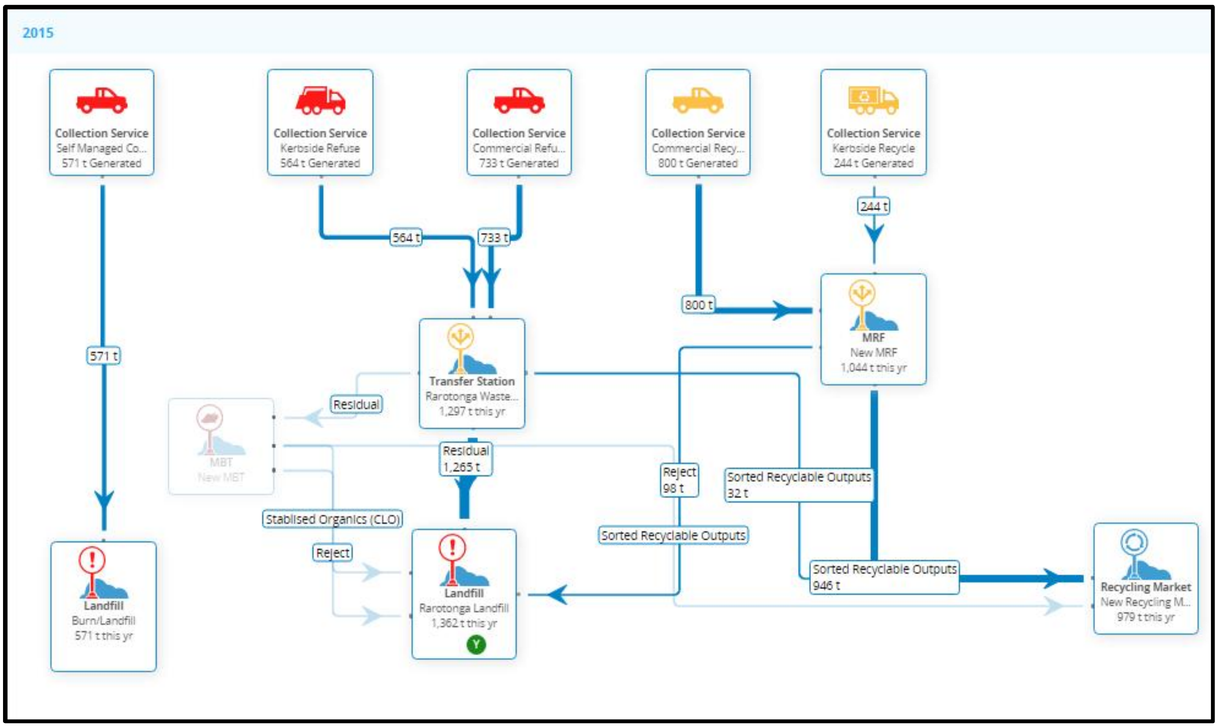
Treat - MHT 2015



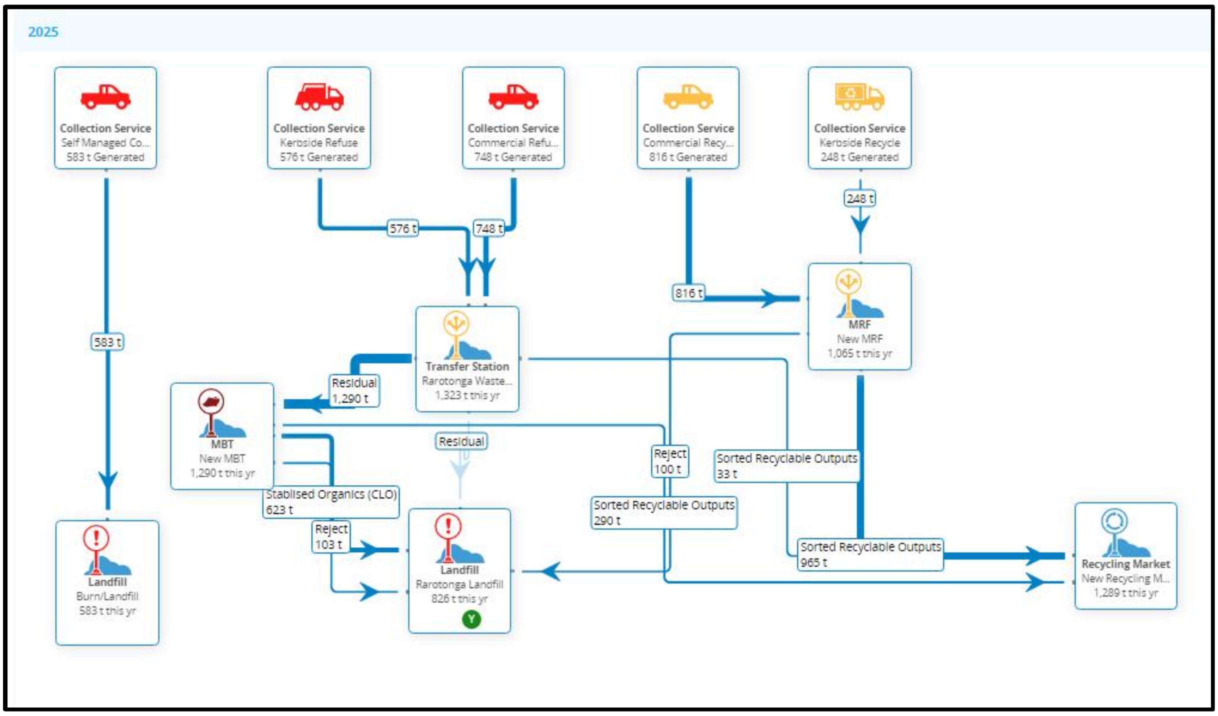
Treat - MHT 2025



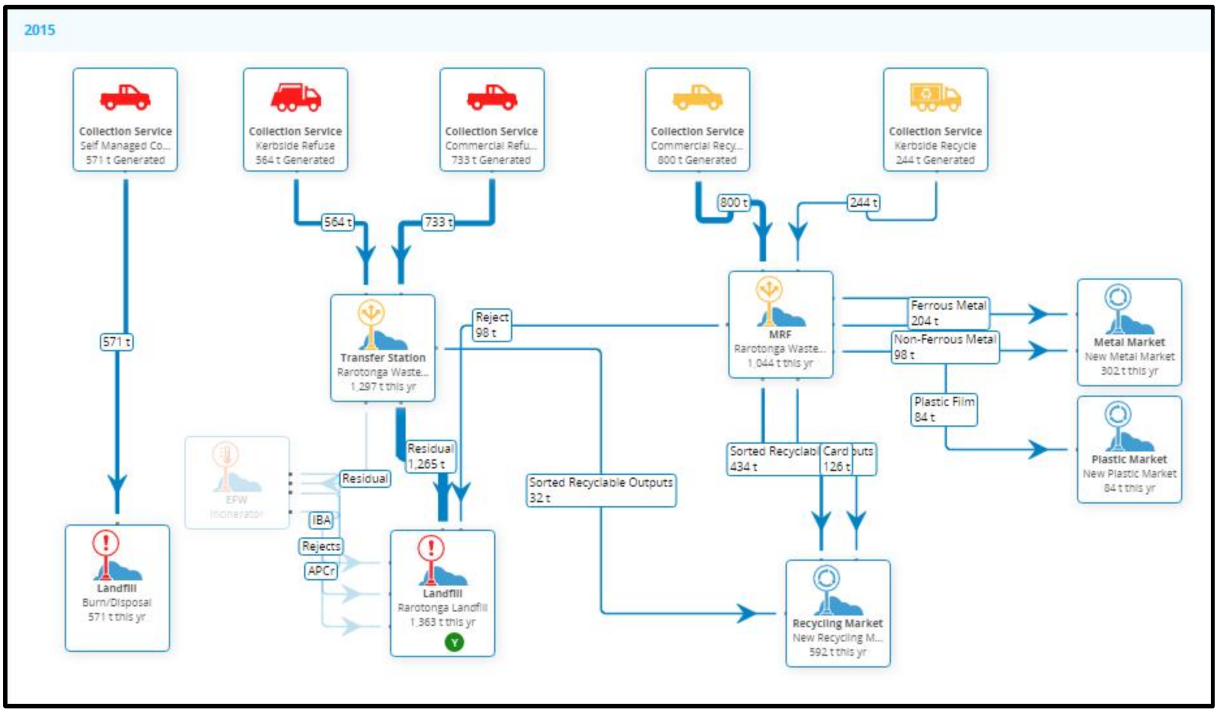
Treat - MBT 2015



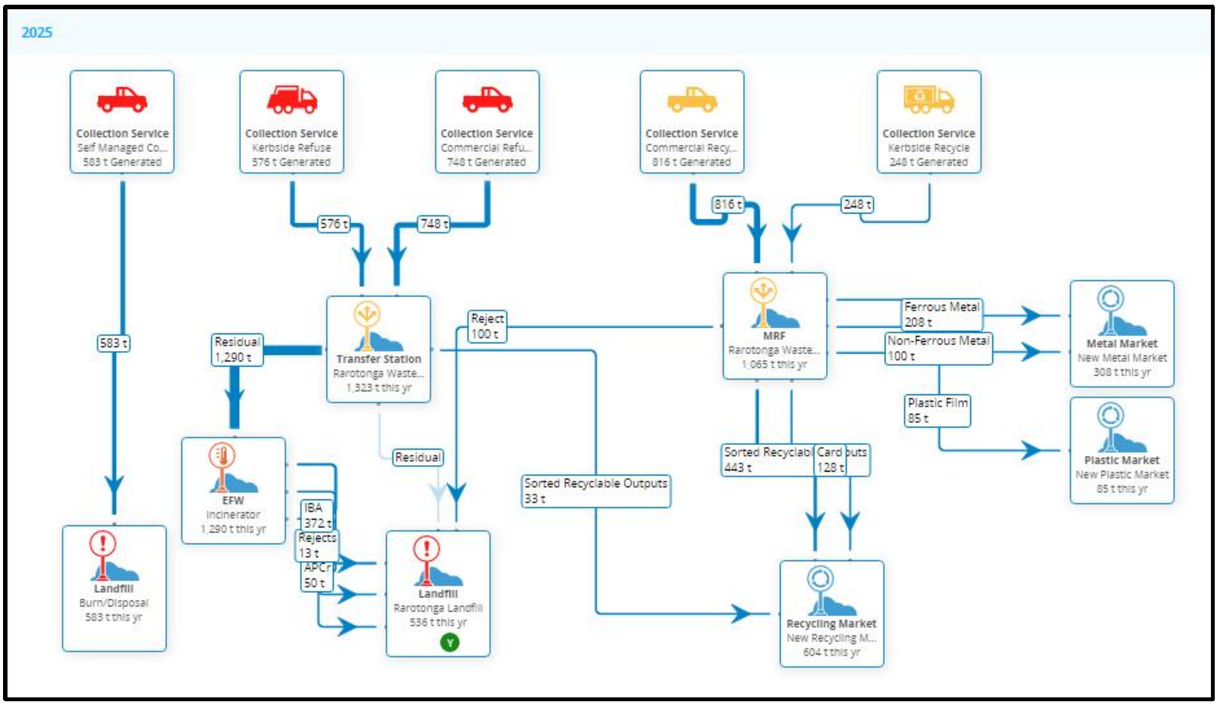
Treat - MBT 2025



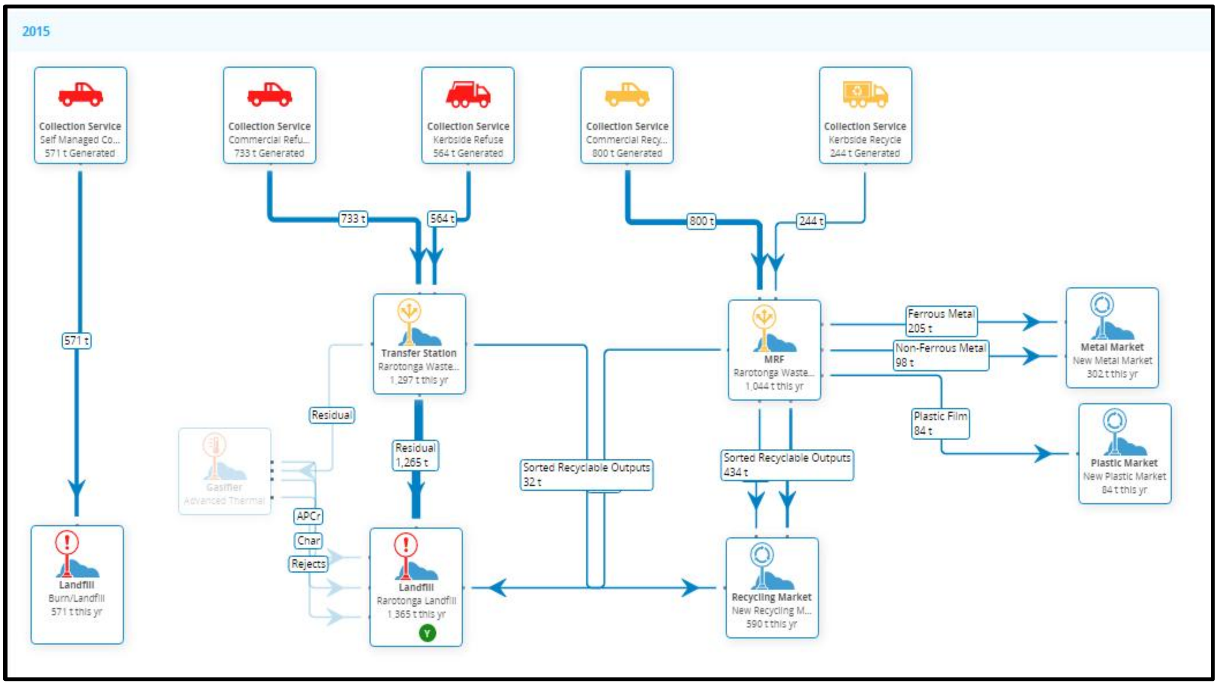
Treat - Incineration 2015



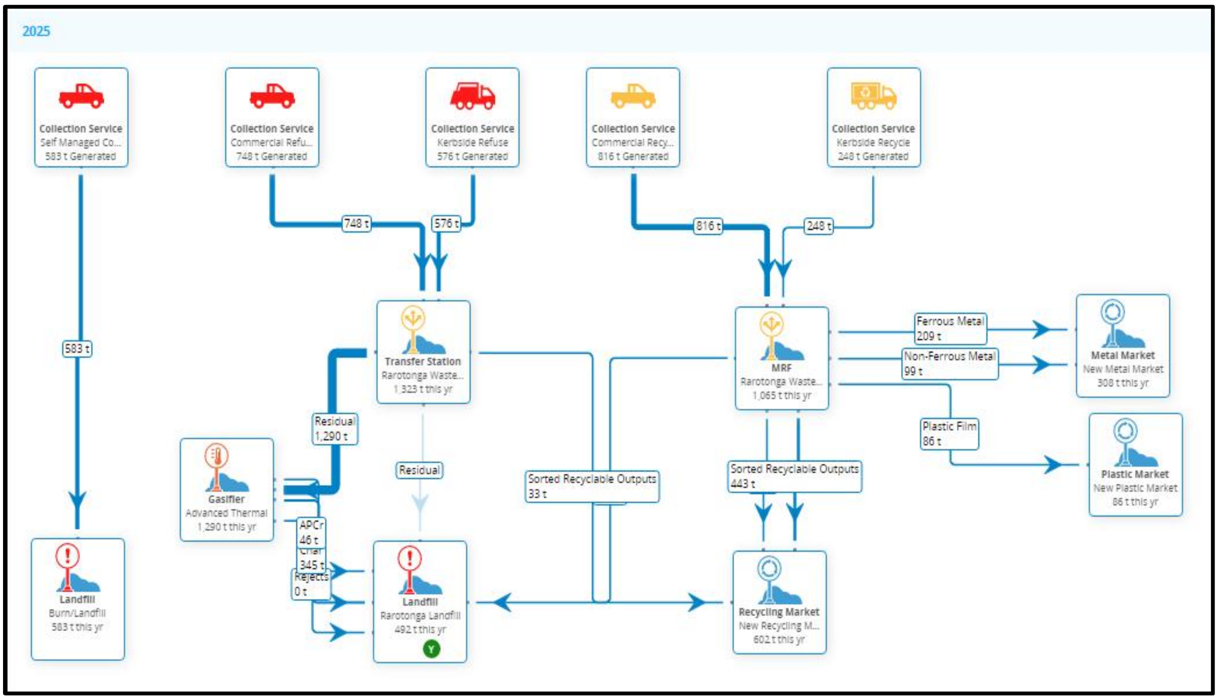
Treat - Incineration 2025



Treat - Advanced Thermal Treatment 2015



Treat - Advanced Thermal Treatment 2025



Appendix D: Cost Benefit Analysis Model

Assumptions	All	New landfill	Advanced waste treatment
Discount rate	10%		
Inflation rate	2%		
Finance cost - nominal (%)		2.6%	2.6%
Finance cost - real (%)		0.5%	0.5%
Loan period (years)		25	25
Collection costs ($/t)	$300		
Operating costs ($/t)		$67	$167
Project length		25	25
Residual waste (%)			10%

= inputs

Results	New landfill	Advanced wa	New landfill	Advanced waste treatment
	PV ($m) to 2016		$/t	
Collection	$3.00	$3.00	$300	$300
Treatment		$5.44		$543
Disposal	$2.55	$1.95	$255	$195
Total	$5.56	$10.39	$555	$1,038

Interest rate assumptions	
Years	25
Fixed swap ra	1.88%
Contractual s	0.50%
Maturity pre	0.20%
Total	2.58%

		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
		2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	2033/34
Waste	tonnes		0	0	0	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Recycled	tonnes		0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Burnt by others	tonnes		0	0	0	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Collection																			
Collection costs						$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000
Discounted						$307,356	$279,415	$254,013	$230,921	$209,928	$190,844	$173,494	$157,722	$143,384	$130,349	$118,499	$107,726	$97,933	$89,030
New landfill						1	2	3	4	5	6	7	8	9	10	11	12	13	14
Capex	Design/permitting		$250,000																
	Construction			$2,500,000	$2,500,000														
	Finance costs			$105,723	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446
Opex	Landfill operations					$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total cost			$250,000	$105,723	$211,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446
Discounted			$227,273	$87,375	$158,863	$212,722	$193,384	$175,803	$159,821	$145,292	$132,084	$120,076	$109,160	$99,236	$90,215	$82,014	$74,558	$67,780	$61,618
Advanced waste treatment				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Capex	Design/permitting		$500,000																
	Construction			$5,000,000	$5,000,000														
	Finance costs			$211,446	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893
Opex	Landfill operations					$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000
Total cost			$500,000	$211,446	$422,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893
Discounted			$454,545	$174,749	$317,726	$459,595	$417,813	$379,830	$345,300	$313,909	$285,372	$259,429	$235,845	$214,404	$194,913	$177,194	$161,085	$146,441	$133,128
Landfill for residuals						1	2	3	4	5	6	7	8	9	10	11	12	13	14
Capex	Design/permitting		$250,000																
	Construction			$2,500,000	$2,500,000														
	Finance costs			$105,723	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446
Opex	Landfill operations					$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Total cost			$250,000	$105,723	$211,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446
Discounted			$227,273	$87,375	$158,863	$151,251	$137,501	$125,001	$113,637	$103,306	$93,915	$85,377	$77,616	$70,560	$64,145	$58,314	$53,012	$48,193	$43,812

Assumptions	All
Discount rate	10%
Inflation rate	2%
Finance cost - nominal (%)	
Finance cost - real (%)	
Loan period (years)	
Collection costs ($/t)	$300
Operating costs ($/t)	
Project length	
Residual waste (%)	

		2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
		2034/35	**2035/36**	**2036/37**	**2037/38**	**2038/39**	**2039/40**	**2040/41**	**2041/42**	**2042/43**	**2043/44**	**2044/45**	**2045/46**	**2046/47**	**2047/48**	**2048/49**	**2049/50**
Waste	tonnes	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Recycled	tonnes	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Burnt by others	tonnes	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Collection																	
Collection costs		$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000	$450,000
Discounted		$80,936	$73,579	$66,890	$60,809	$55,281	$50,255	$45,687	$41,533	$37,757	$34,325	$31,205	$28,368	$25,789	$23,444	$21,313	$19,376
New landfill		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Capex	Design/permitting																
	Construction																
	Finance costs	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$105,723	$0	$0	$0	$0	$0	$0
Opex	Landfill operations	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Total cost		$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$311,446	$205,723	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
Discounted		$56,016	$50,924	$46,295	$42,086	$38,260	$34,782	$31,620	$28,745	$26,132	$15,692	$6,934	$6,304	$5,731	$5,210	$4,736	$4,306
Advanced waste treatment		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Capex	Design/permitting																
	Construction																
	Finance costs	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$422,893	$211,446	$0	$0	$0	$0	$0	$0
Opex	Landfill operations	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000
Total cost		$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$672,893	$461,446	$250,000	$250,000	$250,000	$250,000	$250,000	$250,000
Discounted		$121,026	$110,023	$100,021	$90,928	$82,662	$75,147	$68,316	$62,105	$56,459	$35,198	$17,336	$15,760	$14,327	$13,025	$11,841	$10,764
Landfill for residuals		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Capex	Design/permitting																
	Construction																
	Finance costs	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$211,446	$105,723	$0	$0	$0	$0	$0	$0
Opex	Landfill operations	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Total cost		$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$221,446	$115,723	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
Discounted		$39,829	$36,208	$32,917	$29,924	$27,204	$24,731	$22,482	$20,439	$18,581	$8,827	$693	$630	$573	$521	$474	$431