GREEN WASTE MANAGEMENT IN FUNAFUTI

COST-BENEFIT ANALYSIS REPORT

SPREP
Secretariat of the Pacific Regional Environment Programme

The **Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR)** is a regional program which aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes (i.e. 'climate change and disaster risk mainstreaming').

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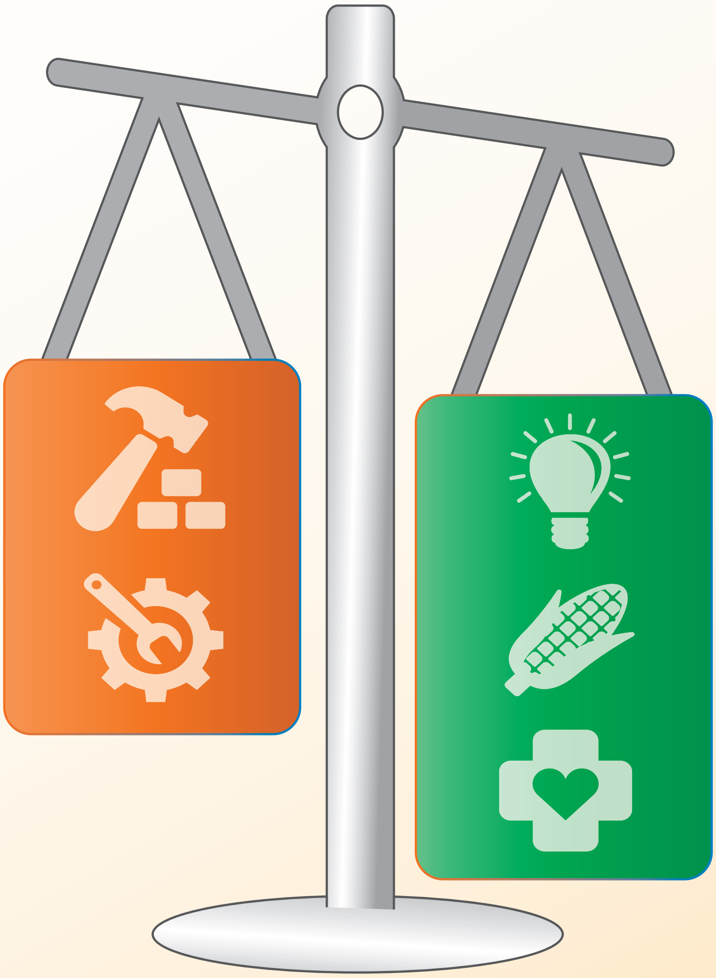

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FUNDING AND ASSISTANCE

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Executive summary

Green waste is a significant issue in Funafuti because of the limited space available for landfill and the large volume of the waste stream it represents (approximately 50%). When it is poorly landfilled, green waste also produces harmful leachates and potent greenhouse gases (methane) and increases the fire risk at landfills. When green waste is burnt, it produces harmful air pollutants and other persistent toxic compounds (dioxins/furans).

Green waste is also a valuable lost resource capable of improving serious soil health deficiencies, such as soil carbon, in Tuvalu and other Pacific island nations and is a potentially important component for effectively managing negative piggery waste impacts and in increasing total agricultural productivity.

The Government of Tuvalu is in the process of developing the National Integrated Waste Policy and Action Plan with a strategic action devoted to recovery of green wastes from the waste stream. The target for that Policy is a *reduction of green waste by at least 20 per cent on first year (2017) and progressively by 20% each following year (until 2026),* although it should be noted that this target is under review.

Under the auspices of the Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR), this cost-benefit analysis (CBA) assesses options to address green waste management problems in Tuvalu. This will serve to inform the prioritisation and refinement of solid waste management options to be included in the forthcoming National Integrated Waste Policy and Action Plan. The geographical focus of this study is Funafuti.

Through consultation, the green waste CBA team identified four options for assessment:

- Option 1 (minimal approach). Under this option, only minimal and low-cost investment actions are included, with a particular focus on awareness programs aimed at changing householders' behaviour to reduce green waste volumes.
- Option 2 (limited conversion and similar to current practice). This option is similar to Option 1, with a few notable additions. Specifically, green waste is subject to limited conversion (mulched only) and made available to end users. In addition, further enforcement of green waste regulations would be undertaken.
- Option 3 (significant conversion – using exploitable inputs). Under this option, a more comprehensive and expensive suite of actions is undertaken, including activities to increase demand for the use of mulch as a recycled product.
- Option 4 (significant conversion – augmented inputs). This option is similar to Option 3, except that we assume that there are not options to exploit inputs such as free clean pig dung. This lack triggers a need to augment these critical inputs (capital and operating expenditure).

A number of approaches to the estimation of specific costs and benefits were required. The findings from the CBA for each option are shown in Table ES1.

A comparison of the options shows that Options 1 and 2 are not economically viable because their costs are greater than their benefits. Furthermore, these options would not generate sufficient demand for recycled green waste by end users, resulting in continued stockpiling of mulch at the depot, or additional costs to SWAT to dispose of the mulch on public land or in the landfill site.

Options 3 and 4 are economically viable, and both should result in sufficient demand for recycled product. However, Option 3 achieves the same benefits at a lower cost and has a superior BCR (1.45 compared to 1.25 for Option 4). Therefore, Option 3 is considered superior.

It should be noted that for green waste strategies to be economically viable, they do need to generate recycled product (mulch) that is actually used by end users. In effect, any implementation of the green waste strategic action will also require complementary initiatives to expand horticultural production and the consumption of manure.

This action will also provide significant nutritional benefits to the community by reducing the need for importing less nutritious food, play an important role in improving soil health by increasing soil organic matter content and improving water holding capacity, and help address negative impacts from piggery wastes (odour and effluents from pig production).

TABLE ES1. HIGH LEVEL RESULTS (RESULTS ARE IN PRESENT VALUE TERMS AS AUD)

COST OR BENEFIT	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Costs				
Awareness programs (staff and operating costs)	$97,434	$97,434	$97,434	$97,434
Enforcement green waste laws (staff and operating costs)	$97,434	$97,434	$97,434	$97,434
Efficiency trials and M&E (staff costs)	$0	$9,473	$9,473	$9,473
Upgraded chipper (capital cost)	$0	$4,737	$4,737	$4,737
Compulsory home compost use (awareness and regulation)	$163,147	$163,147	$163,147	$163,147
Mobile wood chipping and disposal in situ (staff and fuel)	$40,925	$40,925	$40,925	$40,925
Better product available for compost (staff and fuel)	$0	$40,925	$40,925	$40,925
Additional commercial horticulture (all inputs)	$0	$0	$562,446	$739,074
Use of mulch in dry pig waste management (guidance)	$0	$0	$109,994	$109,994
Total costs	**$398,939**	**$454,075**	**$1,126,515**	**$1,303,142**
Benefits				
Landfill (reduced consumption of landfill space)	$66,003	$66,003	$66,003	$66,003
Imports avoided (reductions in imported garden media)	$11,834	$11,834	$11,834	$11,834
Service delivery efficiencies (reduction of SWAT costs)	$0	$48,229	$48,229	$48,229
Emissions (reductions in greenhouse gas emissions)	$41,049	$41,049	$41,049	$41,049
Home gardens (additional output)	$18,546	$38,638	$38,638	$38,638
Commercial gardens (additional output)	$0	$0	$1,262,614	$1,262,614
Sales and fees (sales of recycled green waste)	$0	$0	$162,361	$162,361
Total benefits	**$137,432**	**$205,753**	**$1,630,728**	**$1,630,728**
Net present value	–$261,507	–$248,322	$504,213	$327,586
Benefit cost ratio	0.32	0.45	1.45	1.25

Sensitivity analysis conducted for the CBA found the results were not materially impacted by most input parameters tested. However, the results are materially impacted by two interrelated assumptions:

- the effectiveness of awareness programs relating to the production of clean pig waste through deep litter approaches to create the mulch/manure mix for expanded gardening; and
- the use of mulch in production. Specifically, even for the most superior option (Option 3) to be economically viable, it is necessary to double the use of mulch on existing commercial gardening and expand the production area by at least 20%. To ensure the Waste Policy volumetric objectives are achieved, commercial gardening would need to expand by 80% to absorb the available mulch by approximately the 5th year of the Policy.

To achieve the final objectives of the Waste Policy being developed, proactive actions will need to be taken to create demand for mulch via increased garden production or related soil improvement programs.

Key recommendations from the CBA project are:

- the Waste Policy should include actions similar to Option 3 outlined in this report. Option 3 is both economically viable and should meet the objectives of the Waste Policy.;
- SWAT will need to work jointly with other stakeholder organisations to ensure the objectives of the Waste Policy are achieved;
- proactive actions will need to be taken to create demand for mulch via increased garden production and to ensure pig waste is of an appropriate quality to mix with mulch for gardening inputs; and
- an effective monitoring and evaluation policy for green waste management should be established that covers physical waste flows, the effectiveness and costs of service provision, and community behaviour and use of recycled product.

1. Introduction and context

Tuvalu is one of the most vulnerable countries in the South Pacific to environmental risks, both to external risk factors such as climate change and manageable risk factors such as solid waste disposal. Green waste management is one of the key challenges facing the nation, particularly in Funafuti due to high population densities and due to the recent filling of borrow pits that were effectively used as informal landfill sites and the loss of landfill space due to excavated borrow pit wastes being disposed of within the landfill.

1.1 Green waste management in Funafuti

Green waste is a very significant issue in Funafuti because of the limited land available for landfill. World Bank data[1] indicates the population density on Tuvalu is one of the highest in the Pacific (330 persons per km^2).[2] However, based on a land area of Funafuti (2.8 km^2), the estimated population density of Funafuti is 2,130 persons per km^2 (extremely high by world standards).

1.1.1 GREEN WASTE RISKS AND OPPORTUNITIES

While green waste is a relatively low direct risk to the environment and human health compared to some other waste streams (e.g. chemical or medical waste), green waste creates significant management challenges due to the volume of waste, potential health risks (e.g. attracts vermin and insects) and potential environmental risks (e.g. from organic and acidic leachates which can mobilise other contaminants such as heavy metals from the general landfill wastes [household batteries, E-waste, metals and assorted plastics]). These risks are outlined further below.

The leachates are able to escape from the landfill sites through the permeable strata where they can negatively impact coral reefs on the seaside, causing overgrowths of algae which can potentially weaken the reef, and hence make the island less resilient to wave action and more vulnerable to extreme events (i.e. natural disasters/climate change impacts).

If the leachate migrates to the lagoon side, it can also cause habitat change through increasing algal growth and carry with it harmful organic and inorganic pollutants which may negatively impact on marine life, bio-accumulate within the food chain, or cause chronic health impacts on frequent swimmers from the community.

Landfilling green waste also results in the production of methane that is a potent greenhouse gas with an efficacy 20 times greater than carbon dioxide. Disposal of green waste through burning produces harmful airborne contaminants which worsen respiratory illness, result in an increase in eye-related disease, and produce persistent pollutants (dioxins and furans) which are subject to control under international environmental law (the Stockholm Convention).

While there are risks associated with green waste, proper management and use of green waste create a number of opportunities.

Green waste is potentially an essential key to managing piggery wastes in Tuvalu, which equally threaten lagoon waters and the coral reef in the same way green waste leachates can but also present a further human health through direct exposure to the effluents, through contamination of public spaces, through providing flies with breeding sites, and by decreasing amenity through odour impacts. Mulched green waste can be used in a deep litter system within the pigpens that both absorbs the effluents, thereby greatly reducing the negative impacts listed, and brings together the two components (green waste and piggery waste) together to make effective compost for growing vegetables and otherwise improving soil quality.

1 http://data.worldbank.org/indicator/EN.POP.DNST

2 This compares to figures of 136, 294, and 149 persons per km^2 for Kiribati, the Marshall Islands, and Micronesia, respectively.

Coral atolls typically have very infertile soils, but Funafuti's' fertility is even lower than a typical atoll due to its younger geological age. Because of this, Funafuti (Tuvalu) along with a number of other atoll nations has been targeted by SPC for a soil health improvement project. Green waste converted into both mulch (mechanical shredding only) and compost (pig wastes added) is essential for such a project and will add soil organic matter and other key nutrients into the soil to permit viable vegetable and other plant growth.

Soil enhancement through use of green waste is also important in promoting further food security, which is at a low base in Funafuti, because it would permit expansion of vegetable and home garden production, allowing for a greater variety and quantity of fruit and vegetables than are currently present. There is also the added benefit of much better water retention in the soil because soils with higher levels of organic matter binds soil particles and are able to hold higher levels of soil moisture, which would also decrease the quantities of airborne dust during droughts.

Table 1 summarises the drivers and causes of the green waste problem identified by the group. These have been clustered into themes. It is important to note that many of the drivers and causes may be interrelated.

TABLE 1. DRIVERS AND CAUSES OF PROBLEM

THEME	KEY ELEMENTS / EXAMPLES
Drivers	**Key elements / examples**
Drivers that cannot be controlled in this policy	Income growth and changing consumption patterns (including less home gardening) Climate change and climate variability, particularly relating to drought and cyclones Population growth (natural growth and migration from the outer islands)
Causes	
Information and knowledge	Risks of green waste often poorly understood Green waste management arrangements at the home scale often poorly understood (including differences between long-term residents and immigrants) Solutions often not known (how effective are alternative options? what will they cost?)
Public goods	No exclusions on dumping (free access and use) Dumping waste by one person doesn't stop another doing the same thing
Incentives and disincentives	The lack of pricing of green waste management services does not discourage waste generation or direct disposal to landfill Lifestyle reasons for not using green waste at home (less home gardening by people with jobs for wages)
Government policies / distortions	Subsidies (e.g. free disposal) distort decisions and investments Few or no consequences of illegal dumping (e.g. on road side)

1.1.2 GENERATION OF GREEN WASTE FOR COLLECTION

Previous studies[3] estimated total solid waste in Funafuti is approximately 0.43 kg per person per day, of which 50% is green waste. These volumes are similar to Pacific estimates available (e.g. 0.43 in Port Vila, 0.88 in Suva, 0.37 in Nadi, and 0.43 kg per person per day in Lautoka) but lower than some other broader modelled estimates.[4]

3 Government of Tuvalu. 2012. Tuvalu Infrastructure Policy and Investment Plan. Pacific Infrastructure Advisory Center, Sydney.

4 See: Kawai K and Tasaki T (2015) Revisiting estimates of municipal solid waste generation per capita and their reliability. Journal of Material Cycles and Waste Management. January 2016, Volume 18:1–13. It should be noted these estimates are for *total municipal solid waste generation for collection (kg / person / day) (Solomon Islands = 4.3, Tonga = 3.7, Vanuatu = 3.3, Fiji = 2.1).*

Household collection

General waste is collected in plastic bins (at source and is not further segregated). This fee-for-service household collection service was run by the Funafuti Kaupule (AUD 40 per household) until approximately 2015 but is now provided free of charge. Consultation indicates that while this reduced the incidence of dumping waste outside formal landfill sites, it has left the Kaupule financially exposed to fluctuations in year-on-year funding.

Green waste is generally left beside the bins for collection and is collected under a free Tuvalu Government programme (run by the Solid Waste Agency of Tuvalu [SWAT[5]]). This waste is generally partially segregated, where smaller green waste (e.g. leaf litter) is left for collection in sacks, while larger green waste items (e.g. palm fronds) are left loose on the side of the road for pickup. A centralised collection and composting facility is operating consisting of three mobile chippers and shed infrastructure (for storage). However, some of the existing green waste collected is contaminated with residues from other waste streams (particularly plastics) and is therefore of limited use for soil conditioning.

In April 2016, a new awareness and compliance mechanism was initiated by SWAT. This mechanism involves a process of two warnings for a household, a penalty notice, followed by a court appearance if fines are not paid, or the problem persists. Analysis of data provided by the SWAT team (two weeks in April 2016) indicates approximately 0.5% of households are currently detected as having major contamination of green waste left for collection (i.e. other waste products are mixed with the green waste which makes it unsuitable for mulching).

Collections are undertaken twice a week. Two vehicles are used for the collection: a light truck (total five staff) that is used for the bulk of the regular green waste load and a smaller pickup (total three staff) that picks up larger green waste at irregular intervals.

Quality compost is used at both the Taiwan agricultural project site as well as being available for sale to households for soil conditioning.

Estimates of current volumes

Based on drivers' log data from the SWAT team[6] and the sizes of collection vehicles, MainStream has established some indicative estimates of the current generation of green waste to the street for collection. The estimated annual volume of green waste collected is approximately 2,265 m^3, of which approximately 10% is composed of very large pieces. This equates to approximately 2.5 m^3 of green waste per household. Data available indicate this is marginally lower than volumes from comparable Pacific countries. However, it should be noted that none of the data available are particularly reliable.[7]

TABLE 2. ESTIMATE OF GREEN WASTE TO THE STREET FOR COLLECTION

ESTIMATED COLLECTION PER MONTH (m^3)	ESTIMATED COLLECTION PER YEAR (m^3)	ESTIMATED HOUSEHOLD ANNUAL PRODUCTION (m^3)	ESTIMATED ANNUAL VOLUME ONCE MULCHED (m^3)
197	2,265	2.5	788

5 SWAT is a Department within the Ministry of Home Affairs. Their responsibilities include both regulatory and service delivery functions, including the development and implementation of all waste-management policies and regulations, provision and coordination of specific waste-management services including green waste, management of the landfill, awareness and behaviour programs, and the sale of mulch.

6 A sample of available log book data (two weeks in February 2016) was collected and entered into a spreadsheet an analysed. It should be noted that log book data is available from July 2015; however, entering all of this data is not possible within the project resource constraints.

7 Kawai and Tasaki (2015) Revisiting estimates of municipal solid waste generation per capita and their reliability.

1.1.3 CURRENT RECYCLING

Because there is at least partial segregation of green waste at the household scale, the bulk of green waste is already recycled in Tuvalu. This process is briefly outlined below.

Recycling at the hanger

The collation and creation of mulch is undertaken at the hanger adjacent to the airstrip by SWAT, building on an initiative from a previous NAPA aid project. From an inspection of the site on 11 May 2016, it is estimated that the current stockpile of mulch mix was in the range of 50–100 m^3, spread across two piles at different points of readiness for use. There was evidence of contamination within this mix (plastic bags, etc.). However, the level of contamination within more recent collections was significantly lower, evidence of the success of the current awareness and enforcement policies. This mix is available for purchase by households for use in home gardens and the Taiwan garden project[8] at AUD 2 per bag (rice bag). A similar volume of larger green waste (e.g. large branches) was also at the site that had not been converted in any way.

There may be opportunities to expand the volume of recycling at the hanger and end use of compost in home gardens if contamination levels can be reduced and demand by end users increased. Consultation revealed two immediately implementable actions:

- improvement of the awareness of household consumers that the benefits of using mulch on home gardens will be negated if pig dung contaminated with salt water is used; and
- simple changes to the sales process. Currently, consumers must make a payment for mulch at the Government Offices before proceeding to the hanger to pick up mulch. This additional time requirement increases the transaction cost of using mulch. Simple measures such as providing mulch for sale through retailers adjacent to the hanger or sales of pre-bagged mulch from the collection vehicles (effectively a delivery service) could be trialled to test the impact on demand.

Use in commercial horticulture

The Taiwan gardening project (the largest horticulture enterprise in the country) is a major end user of processed (mulched) green waste. This mulch is mixed with pig manure collected from local pig pens at the Taiwan garden to create compost for use in the horticultural operations. Project staff advised that the project could use more compost and expand production if two key constraints were overcome.

First, the size of the provided green waste matter is relatively large which significantly slows down the process of composting. This constraint could be overcome with the use of a modified chipper that produces smaller pieces, or use of mulch in production once the process of composting is already underway.

Second, the availability of clean pig manure is a constraint because the dominant practice of cleaning out pig pens uses salt water. Progressive build-up of salt concentrations in the compost mix effectively slows the composting process and inhibits plant growth.

Most pig pens are located on the ocean side of the island. Salt water is typically used on a daily basis to washout the pig pens because freshwater is often a scarce and valuable resource that can only be obtained from water tanks.

Consultation undertaken during the two visits to Funafuti during this project indicated:

- there was an interest in trialling new pig management systems such as deep litter (compost piggeries) because the effort required to use mulch in pig pens is likely to be lower than daily cleaning using salt water;

8 This project consumes approximately 1,500 bags per year.

- management at the Taiwan Garden Project indicated that they would use more manure if it was available using their current pick-up system from suitably managed pig pens; and
- the proposed move of the SWAT depot to the ocean side of Funafuti will mean that the pick-up point for mulch will be very close to the majority of the pig pens. This will make mulch more convenient and attractive to pig owners.

There may be opportunities to expand the use of compost at the Taiwan gardening project if the conversion of green waste produces smaller pieces and if a larger supply of uncontaminated pig manure were available. This process has major potential benefits for waste management and food security on Funafuti.

1.1.4 LANDFILL

The current landfill site in Funafuti operated by SWAT is rapidly approaching full capacity with an estimated three months of space remaining. No charges are imposed on dumping green waste at the site. The diversion of green waste to beneficial uses will therefore significantly reduce the use of the current site and subsequently increase the life of the current site. This benefit is critical because alternative sites are scarce and opposed by the community. To the extent that green waste is currently collected separately, mulched, and made available for beneficial use, only a small proportion of green waste is currently going directly to landfill. However, there is no available data to estimate the proportion. Furthermore, unless demand for mulch is established and the product is usable, stockpiles of green waste will continue to grow and create potential pressure to dispose of it to the Northern End landfill.

Key findings

- Annual generation of green waste left for collection in Funafuti is estimated at 2,265 m^3.
- To the extent that green waste is currently collected separately, mulched, and made available for beneficial use, only a small proportion of green waste is currently going directly to landfill. However, unless demand for mulch is established and the product is usable, stockpiles of green waste will continue to grow.

1.2 Identified objectives of green waste management

The objective statement for the Tuvalu green waste management policy (in development) is a *reduction of green waste by at least 20 per cent on first year (2017) and progressively by 20% each following year (until 2026).* However, it should be noted that this target is under review. During the process of this project, the CBA team identified three sub-objectives:

1. Reduce the amount of green waste generated by household going to roadside (for collection) and ensuring what does go to the roadside is properly segregated for recycling.
2. Improve the efficiency of collection and conversion services of green waste.
3. Increase the level of recycling of green waste into useful products.

The three sub-objectives are specifically designed to focus policy development and program delivery in an integrated way and at the appropriate entities along the green waste management system. Table 3 outlines the rationale and target entities for each sub-objective.

TABLE 3. SUB-OBJECTIVES, RATIONALE, AND TARGET ENTITIES

SUB-OBJECTIVE	RATIONALE	TARGET ENTITIES
1. Reduce the amount of green waste generated by household going to roadside (for collection) and ensuring what does go to the roadside is properly segregated for recycling.	Focuses on reducing the volume of green waste put out for collection at the source and ensuring that any green waste to be disposed by households is suitable for recycling. This makes the green waste problem both smaller and easier to manage.	This sub-objective is primarily targeted at the household level and would be supported by targeted relevant Government and Kaupule policies and programs including the recently established bylaws.
2. Improve the efficiency of collection and conversion services of green waste.	Focuses on ensuring the green waste service organisation (currently SWAT) performs their functions efficiently. This should ensure effective services are delivered to the community at an efficient cost. This should also include appropriate pricing of services.	Green waste management service providers.
3. Increase the level of recycling of green waste into useful products.	Focuses on actions to increase the level of green waste that is recycled into useful products (e.g. conversion to compost) and that the products are used in an efficient manner (e.g. soil conditioner to increase garden yields).	End users of recycled green waste products.

These objectives should be achieved through the appropriate suite of information, incentives and use of technology.

1.3 Broad objective of this study

Under the auspices of the Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR), this cost-benefit analysis (CBA) is to assess options to address green waste management problems in Tuvalu.[9] This CBA will serve to inform the prioritisation and refinement of solid waste management options to be included in the forthcoming National Integrate Waste Policy and Strategic Action Plan. The geographical focus of this study is Funafuti.

1.4 Options assessed

Based on research of previous programs and through the workshop on 13 May, draft options for assessment in the CBA were developed[10] through a number of processes:

- A presentation providing an overview of green waste management in the Pacific was provided, followed by group discussion.
- Group work was undertaken to identify and briefly scope specific actions that could address the objectives of green waste management.
- The group then developed four options for assessment in the CBA. Each option contains a cohesive subset of all of the actions identified.

This approach ensured that the options being developed address all three sub-objectives for green waste management. Each option was made up of a suite of cohesive individual actions.

1.4.1 INDIVIDUAL ACTIONS

Individual actions identified in the workshop are shown in Table 4. These have been clustered under their relevant green waste management sub-objective.

9 Project terms of reference.

10 These discussions also raised reasons for the limited success of some previous programs in Tuvalu due to breaches in regulations not being addressed, insufficient budgets to maintain service levels, insufficient (no) service charges, and insufficient targeting of awareness campaigns.

TABLE 4. INDIVIDUAL POTENTIAL ACTIONS

	ACTION	ACTION DESCRIPTION
Actions to achieve Sub-objective 1		
1	Basic awareness program	Develop and deliver a basic awareness program aimed at households to inform: The potential use of green waste at home (compost, pig food etc.) The correct way to segregate waste being left out for collection.
2	Targeted awareness program	Similar to Action 1, except that messages and delivery of awareness will be specific to sub-section of the community (e.g. based on gender, language, home owner/renter, local/recent immigrant, literacy levels etc.). This would also include a dedicated survey to underpin the design of the awareness program.
3	Household bins	Provision of dedicated green waste bins at a household scale (noting the need to increase the budget to cover additional costs).
4	Enforcement of solid waste laws	Potential amendments and greater enforcement of relevant regulations (e.g. Waste Operations and Services Act and Environment Protection Litter and Waste Control Regulation). This would include additional enforcement officers.
5	Demonstration fale	Expansion of current TEC energy efficiency demonstration fale to include a home garden and green waste component. This would require negotiating a joint demonstration fale with the TEC.
Actions to achieve Sub-objective 2		
6	Efficiency trials	A series of trials to determine the most cost effective frequency and approach for collection of green waste.
7	Monitoring and evaluation of service provider	Establish monitoring and evaluation of green waste service provider to establish efficient costs. Funding provided to match efficient costs to encourage efficiency in service delivery.
8	Monitoring and evaluation of service provider + fee for service	Similar to Action 8, but incorporating the introduction of a fee for service at the household level. Funding to service provider would be set at efficient costs less fee revenue estimates. Fee for service levels could be gradually increased over a period (the 'price path' approach, potentially with targeted rebates for the very poor.
9	Upgraded chipper	Purchase and operation of an upgraded chipper (or modification of existing ones) to produce finer much that creates better quality compost materials.
Actions to achieve Sub-objective 3		
10	Compulsory home compost use for small green waste materials[11]	Use of all small green waste materials (e.g. leaf litter) at home. This would be achieved through ceasing pickups of smaller green waste and changes to laws.[12]
11	Mobile wood chipping and disposal of large green waste in situ	Use of existing portable green waste chippers to move around the community chipping larger waste for use in situ (e.g. as a replacement for gravel in the home, to be dumped on public roadsides to suppress weeds). Potential to introduce a fee-for-service as the woodchips are an economic resource.
12	Better quality converted product available for compost	Composting and storage of segregated green waste at the hanger. Green waste available to the public for compost.
13	Woodchips available for compost toilets	Larger green waste converted to wood chips and stored at the hanger for collection and use in the composting toilets in Funafuti.
14	Manure production for commercial horticulture and/or sale (exploiting current excess clean dung supply and deep litter technologies	Program to convert, store and mix green waste compost with available clean pig dung (no salt water content) for use in the Taiwan garden project. Given the need for dung with zero salt content, houses currently using fresh water to clean pig pens and houses participating in biogas trial would be trialled (because they are being provided pen and rainwater tank infrastructure to ensure uncontaminated dung for digester). In addition, deep-litter technologies would be used for pig pens (i.e. lining pig pens with dry mulch, and shovelling out pre-mixed compost once a week instead of cleaning with salt water). Potentially required relocation of conversion site from hanger to Taiwan horticulture project site to reduce double handling.
15	Manure production for commercial horticulture and / or sale (augmenting clean dung inputs supplies)	Similar to Action 14, but investment required to augment availability of uncontaminated dung for compost/dung mix. This would include capital expenditure on concrete floors for pens and rainwater tanks to provide fresh water for cleaning pens and mixing compost.

Source: Stakeholder workshop 13 May 2016

11 Similar initiatives promoted by SPREP in other Pacific nations (e.g. Samoa) have only resulted in very limited success.

12 Note: This action may result in an unintended outcome where household co-mingle small green waste with other waste streams to avoid compliance with new regulations.

1.1.1 OPTIONS FOR ASSESSMENT IN THE CBA

Workshop participants selected from the full list of possible actions to establish four credible options to assess in the CBA. These four options were effectively a complimentary subset of the full set of actions available:

- **Option 1 (minimal approach)**. Under this option, only minimal and low-cost investment actions are included, with a particular focus on awareness programs aimed at changing householders' behaviour to reduce green waste volumes.
- **Option 2 (limited conversion and similar to current practice).** This option is similar to Option 1, with a few notable additions. Specifically, green waste is subject to limited conversion (mulched only) and made available to end users. In addition, further enforcement of green waste regulations would be undertaken.
- **Option 3 (significant conversion – using exploitable inputs).** Under this option, a more comprehensive and expensive suite of actions is undertaken. This includes activities to increase demand for the use of mulch as a recycled product.
- **Option 4 (significant conversion – augmented inputs).** This option is similar to Option 3, except that we assume that there are not options to exploit inputs such as free clean pig dung. This lack triggers a need to augment these critical inputs (capital expenditure).

TABLE 5. OPTIONS ASSESSED – SPECIFIC ACTIONS INCLUDED[13]

OPTION 1	OPTION 2	OPTION 3	OPTION 4
Actions to achieve Sub-objective 1			
Basic awareness program (1)	Basic awareness program (1)	Targeted awareness program (2)	Targeted awareness program (2)
Enforcement of solid waste laws (4)	Enforcement of solid waste laws (4)	Enforcement of solid waste laws (4)	Household bins (4)
			Enforcement of solid waste laws (4)
Actions to achieve Sub-objective 2			
Monitoring and evaluation of service provider (8)	Efficiency trials (7)	Efficiency trials (7)	Efficiency trials (7)
	Monitoring and evaluation of service provider (8)	Monitoring and evaluation of service provider (8)	Monitoring and evaluation of service provider (8)
			Upgraded chipper (10)
			Mechanical lifter (11)
Actions to achieve Sub-objective 3			
Compulsory home compost use for small green waste materials (10)	Compulsory home compost use for small green waste materials (10)	Compulsory home compost use for small green waste materials (10)	Compulsory home compost use for small green waste materials (10)
Mobile wood chipping and disposal of large green waste in situ (11)	Mobile wood chipping and disposal of large green waste in situ (11)	Mobile wood chipping and disposal of large green waste in situ (11)	Mobile wood chipping and disposal of large green waste in situ (11)
	Better quality converted product available for compost (12)	Better quality converted product available for compost (12)	Better quality converted product available for compost (12)
		Woodchips used in compost toilets (13)	Woodchips used in compost toilets (13)
		Compost production for commercial horticulture and/or sale (exploiting current excess clean dung supply).[13] (14)	Similar to action 14, but this option would require rainwater tanks for cleaning out pig pens. (15)

13 SWAT's (or a contracted service provider's) responsibilities would be the production of clean mulch, which would be mixed at the garden with dung collected separately by the Taiwan Garden Project.

2. Approach to CBA

This section briefly outlines the approach used for the analysis, key input data and other relevant parameters.

2.1 Analytical approach – CBA

Any decision to change green waste management in Funafuti will involve economic costs and benefits. These costs and benefits will be unevenly distributed over time and between project households, businesses, and third parties (project donors, the Tuvalu Government, and broader society).

CBA is one of the main tools used by economists to identify whether projects or policy changes are worthwhile to society overall. CBA assesses the overall outcomes of a proposal by adding up *all* the costs and benefits associated with the proposed change. It can also inform project design, modification, and evaluation through testing underlying assumptions and other relevant parameters used in the analysis.

CBA for an assessment of project such as those considered in this report is equivalent to a profit-and-loss analysis is for a firm. However, there are two critical differences: (1) CBA is a tool for helping to make public decisions, taking the standpoint of society in general rather than a single firm; and (2) CBA is often done for projects, policies and programs that have non-marketed types of outputs, such as improvements in health or the environment.

If the net result is positive (benefits minus costs is AUD >0), then the implication is that the proposed change is a worthwhile thing to do. This calculation is called the net present value (NPV). In addition, the ratio of benefits to costs can also be calculated. This calculation is called the benefit-cost ratio (BCR). Where that ratio is >1, the project is economically viable. Higher ratio values indicate better outcomes. The analysis incorporates discounting calculations to take into account the time value of money, thereby allowing the comparison of projects with different time frames in a consistent manner. In all, CBA has significant potential to inform decision makers on key policy issues, and its use is widely endorsed by government agencies in most developed and developing nations.

The process undertaken for the CBA followed the process outlined through the training workshops over the period 12–16 May 2016. The key steps are shown in the figure below.

STEP 1: SUMMARISE THE EVIDENCE AND LOGIC OF THE PROJECT

STEP 2: FORMULATE COST–BENEFIT ANALYSIS QUESTIONS

STEP 3: IDENTIFY THE COSTS AND BENEFITS

STEP 4: VALUE THE COSTS AND BENEFITS

STEP 5: AGGREGATE THE COSTS AND BENEFITS

STEP 6: PERFORM SENSITIVITY ANALYSIS

STEP 7: CONSIDER DISTRIBUTIONAL EFFECTS

STEP 8: PREPARE RECOMMENDATIONS

FIGURE 1. THE CBA PROCESS

To undertake this CBA, we built a sophisticated CBA model that allows for the sensitivity testing of all 99 input parameters relevant to the CBA.[14] In addition, a simpler model was established for training purposes. This report is based on the outputs from the more sophisticated model, although it should be noted that the results of the simpler model are similar.

2.2 Valuation of unit costs and benefits

One of the major complexities in undertaking the CBA was the fact that many benefits and costs attributable to green waste management options are indirect or non-market in nature. That is, their values cannot be observed directly through market transactions. Therefore, a number of valuation techniques were necessary. Techniques used included:

- **market values.** For some inputs to the CBA, there are direct market prices. This factor includes items such as the cost of the new equipment, etc.;
- **the production function approach.** When a good or service is used as an intermediate input factor in some production process (e.g. compost made from mulch and pig dung), and the output of the production process can be sold in a market, the economic value of the input can be defined by the additional value (profit) that the input generates in isolation from other inputs and production technology (e.g. the value of the additional vegetable production when manure is used to treat poor soils);
- **avoided cost, delayed cost, replacement cost, and substitute cost methods.** These are related methods that estimate values of goods and services based on either the costs of avoiding damages due to lost services, the value of delaying expenditures, or the cost of providing substitute goods; for example, the value of delaying the need to secure a new landfill site; and
- **benefit transfer.** This method employs estimates of economic values from studies undertaken elsewhere to infer values for the project under consideration, such as the value of carbon abatement per tonne.

The major benefit and costs identified and assessed in this CBA report are shown in Table 6. The valuation approaches and data sources used for each of the major costs and benefits are outlined in Appendix A.

14 The more sophisticated model has been specifically designed to allow the CBA team to easily test “what if” sensitivity analysis scenarios using “drop-down boxes” in the spreadsheet to assist in the implementation of the broader project. It has also been designed to enable easy updates of input parameters as superior information is gathered through the monitoring and evaluation process.

TABLE 5. KEY COSTS AND BENEFITS

COST OR BENEFIT	DESCRIPTION
Costs	
Awareness programs	This is the financial cost of staffing and operating awareness programs that are designed to influence behaviour and use of green waste product. This is an ongoing cost.
Enforcement green waste laws	This is the financial cost of staffing and operating awareness programs that are designed to influence behaviour and use of green waste product. This is an ongoing cost.
Efficiency trials and M&E	This is the financial costs of designing and running efficiency trials and associate monitoring and evaluation. This includes expert technical assistance at market rates. This is a once-off cost at the beginning of the project.
Upgraded chippers	This is the financial cost of minor modification to wood chippers (e.g. changing to different blades). This is a periodical capital equipment cost.
Compulsory home compost use (awareness and regulation)	This is the financial cost of staffing and operating awareness/regulation programs that are designed to ensure greater home composting.
Cost or benefit	**Description**
Mobile wood chipping and disposal in situ (staff and fuel)	This is the additional staff and fuel costs required to undertake wood chipping in situ, as opposed to the current practice of chipping at the hanger. This is an ongoing operational cost.
Better product available for compost	This is the additional cost of operational activities to ensure the mulch product available is of a quality that is more attractive to the market. The major cost is additional labour inputs required for mulch preparation and addition fuel costs.
Commercial gardening costs including mulch and pig manure inputs	This is the financial cost of expanding horticultural production and using manure in the production process, including: Capital costs to establish garden beds, rainwater tanks etc. (capital cost incurred every 10 years). Additional variable production inputs such as seedlings, labour etc. (ongoing variable costs).
Use of mulch in dry pig waste management	This is the additional cost of underpinning changes in the pig management to a dry litter (compost piggery) approach. The majority of the costs are changes in labour inputs (practice change and operational).
Benefits	
Landfill	This is value of delaying the need to commission the new landfill site and the avoided cost of consuming landfill space at both the current and future site. The delay benefit is a once-off benefit, while the reductions in landfill consumption are an ongoing benefit.
Imports avoided (reductions in imported garden media)	This is the value of the additional cost of imported soil media (e.g. peat) avoided through the use of local composting products.
Service delivery efficiencies	This is the reduction in labour and other operational costs (fuel, etc.) from implementing identified efficiencies in SWAT operations.[15] This is an ongoing benefit.
Emissions	This is the value of estimated reduction in greenhouse gas emissions that would be emitted if the green waste went to landfill. This is an ongoing benefit.
Home gardens (additional output)	This is the value of the fruit and vegetable product yield increases attributable to the use of compost. This is an ongoing benefit.
Commercial gardens	This is the value of the fruit and vegetable product yield increases attributable to the use of compost. This is an ongoing benefit.
Sales and fees (sales of recycled green waste)[14]	This is the change in revenues attributable to growth in the sales of mulch.
Health (not valued)	These benefits would be attributable to the increase in fruit and vegetables available and the subsequent improvements to health. Note: there is insufficient information to establish quantitative estimates for these benefits. However, these benefits could be substantial.
Enhanced lagoon health (not valued)	These benefits would be attributable to the reductions in green waste going to landfill and the subsequent reductions in risks to the natural environment (e.g. less leachate). Note: there is insufficient information to establish quantitative estimates for these benefits. However, these benefits could be substantial.

15 Note: Some operational improvements were identified in the first in-country mission for this project that have already been implemented.

16 Note: Household green waste fees have not been included in the actual CBA modelling because they are a transfer between household and SWAT and would not impact in the net results of the CBA for each option. Fees are assessed in Section 4.3 of this report.

3. Cost benefit analysis results

This section briefly summarises the results of the CBA analysis for the four options. First, we summarise and compare the results of the analysis of the four options when the most likely parameters are used. Second, we have undertaken significant sensitivity analysis to test how the results change depending on the assumptions and input variables used. Finally, we assess some of the key distributional issues.

3.1 High level results

Table 7 summarises the key results of the analysis for the four options considered. The table outlines the present value of costs and benefits over the 10-year analysis period[17] for the key costs and benefit categories:

- costs: this includes all necessary capital purchases, all changes to fixed costs, and all changes to variable costs;
- benefits*:* these are the estimates of benefits by broad category; and
- CBA decision rules: this includes the results of the NPV and BCR analysis over the full 10 years of the project.

A real discount rate of 5.6% was used. Determination of an appropriate discount rate is outlined in Appendix C. The detailed CBA model outputs for each option are shown in Appendix D. In addition to the CBA analysis, we have also modelled the physical waste flows attributable to each option, particularly the potential demand for the recycled product. Only where the recycled product is consumed is the likelihood of green waste going to landfill actually eliminated.

The key findings from the analysis are:

- **Option 1.** While the investment in this option is relatively modest (less than AUD 400,000 in present value terms), the benefits achieved are less than AUD 140,000. We estimate that the NPV of this option is AUD –261,507, with a BCR of 0.32. Based on this analysis, Option 1 is *not* economically viable. We estimate this option could not create additional demand for mulched product, with only 10% of recycled product would be consumed. This will result in a continuation of a build-up of green waste at the depot.
- **Option 2.** The investment in this option is relatively modest (approximately AUD 450,000 in present value terms), and the benefits achieved are approximately AUD 205,000. We estimate that the NPV of this option is AUD –248,322, with a BCR of 0.45. Based on this analysis, Option 2 is *not* economically viable. Option 2 does not create sufficient additional demand for mulched product, with only 10% of recycled product would be consumed. This will result in a continuation of a build-up of green waste at the depot.
- **Option 3.** The investment in this option is significantly higher, and this option has a number of additional initiatives designed to increase the level of use of recycled mulch, primarily for horticultural production. The costs are approximately AUD 1,130,000 in present value terms, the benefits achieved are approximately AUD 1,630,000. We estimate that the NPV of this option is AUD 504,213, with a BCR of 1.45. Based on this analysis, Option 3 *is* economically viable. Because Option 3 does create additional demand for compost product, we estimate that all of the recycled green waste would be consumed, eliminating the build-up of green waste at the depot.
- **Option 4.** Similar to Option 3, the investment in this option is higher and has a number of additional initiatives designed to increase the level of use of recycled mulch. In addition, this option

17 A 10-year period was used for this analysis because this reflects the longest economic life of any capital infrastructure to be developed under any option. This also aligns with the period for the Green Waste Management Policy being developed.

also includes the augmentation of some pig pens with rainwater tanks to provide fresh water for cleaning. This adds to the capital cost of this option when compared to Option 3, while the benefits remain the same. The costs are approximately AUD 1,300,000 in present value terms, and the benefits achieved are approximately AUD 1,630,000. We estimate that the NPV of this option is AUD 327,586, with a BCR of 1.25. Based on this analysis, Option 4 *is* economically viable. This option would also result in full consumption of recycled green waste.

It should be noted that the benefits attributable to all options are underestimated because the reduction in environmental risk to the lagoon have not been quantitatively estimated due to a lack of data. The estimates of benefits for Options 3 and 4 are also significantly underestimated because the health benefits attributable to additional fruit and vegetable consumption are not estimated due to a lack of data.

TABLE 6. HIGH LEVEL RESULTS (THE RESULTS ARE IN PRESENT VALUE TERMS, AUD)

COST OR BENEFIT	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Costs				
Awareness programs (staff and operating costs)	$97,434	$97,434	$97,434	$97,434
Enforcement green waste laws (staff and operating costs)	$97,434	$97,434	$97,434	$97,434
Efficiency trials and M&E (staff costs)	$0	$9,473	$9,473	$9,473
Upgraded chipper (capital cost)	$0	$4,737	$4,737	$4,737
Compulsory home compost use (awareness and regulation)	$163,147	$163,147	$163,147	$163,147
Mobile wood chipping and disposal in situ (staff and fuel)	$40,925	$40,925	$40,925	$40,925
Better product available for compost (staff and fuel)	$0	$40,925	$40,925	$40,925
Commercial gardening costs including mulch and pig manure inputs	$0	$0	$562,446	$739,074
Use of mulch in dry pig waste management	$0	$0	$109,994	$109,994
Total costs	**$398,939**	**$454,075**	**$1,126,515**	**$1,303,142**
Benefits				
Landfill (reduced consumption of landfill space)	$66,003	$66,003	$66,003	$66,003
Imports avoided (reductions in imported garden media)	$11,834	$11,834	$11,834	$11,834
Service delivery efficiencies (reduction of SWAT costs)	$0	$48,229	$48,229	$48,229
Emissions (reductions in greenhouse gas emissions)	$41,049	$41,049	$41,049	$41,049
Home gardens (additional output)	$18,546	$38,638	$38,638	$38,638
Commercial gardens (additional output)	$0	$0	$1,262,614	$1,262,614
Sales and fees (sales of recycled green waste)[6]	$0	$0	$162,361	$162,361
Total benefits	**$137,432**	**$205,753**	**$1,630,728**	**$1,630,728**
Net present value	–$261,507	–$248,322	$504,213	$327,586
Benefit cost ratio	0.32	0.45	1.45	1.25

A comparison of the options shows that Options 1 and 2 are not economically viable because their

18 Note: Household green waste fees have not been included in the actual CBA modelling because they are a transfer between household and SWAT and would not impact in the net results of the CBA for each option. Fees are assessed in Section 4.3 of this report.

costs are greater than their benefits. Furthermore, they would not generate sufficient demand for recycled green waste by end users. This would result in continued stockpiling of mulch at the depot or additional costs to SWAT to dispose of the mulch on public land or in the landfill site.

Options 3 and 4 are economically viable, and both should result in sufficient demand for recycled product. However, Option 3 achieves the same benefits at a lower cost and has a superior BCR (1.45 compared to 1.25 for Option 4). Therefore, Option 3 is considered superior.

It should be noted that for green waste strategies to be economically viable, they do need to generate recycled product (mulch) that is actually used by end users. In effect, any implementation of the Green waste Policy will also require complementary initiatives to expand horticultural production and the consumption of manure. This will also provide significant nutritional benefits to the community and reduce the need for importation of less nutritious food.

Key findings

- Options 1 and 2 are not economically viable, and they do not generate sufficient demand for recycled green waste. This will result in stockpiling of green waste.
- Options 3 and 4 are economically viable, and both should result in sufficient demand for recycled product. However, Option 3 achieves the same benefits at a lower cost and has a superior BCR (1.45 compared to 1.25 for Option 4). Therefore, Option 3 is considered superior.
- Net benefits for all options will be underestimates because the benefits of reduced environmental risks to the lagoon have not been estimated due to the lack of data. Furthermore, the health benefits attributable to increased fruit and vegetable consumption have not been estimated for options 3 and 4 due to data limitations.
- Any implementation of the Green waste Policy will also require complementary initiatives to expand horticultural production and the consumption of manure. This will also provide significant nutrition-based health benefits to the community.

3.2 Sensitivity analysis

A number of key parameters relating to the CBA modelling were identified that are worthy of assessment within the sensitivity analysis component of the CBA.[19] We tested the sensitivity of the result, particularly any change to the preferred option (Option 3) and whether any option become viable or not viable based on changes to key input parameters.[20] Table 8 summarises the key findings from the sensitivity analysis for key parameters that do not materially impact on the findings of the CBA. The column on the left shows the element of the CBA tested through the sensitivity analysis. The column on the right documents the findings of the sensitivity testing for that element.

19 Parameters relating to units estimates of costs and benefits are shown in Appendix A.

20 The full CBA model developed for this project has 99 input parameters, any of which can be changed through a sensitivity analysis process.

TABLE 7. OUTCOMES FOR SENSITIVITY ANALYSIS

ELEMENT OF CBA TESTED THROUGH SENSITIVITY ANALYSIS	RESULTS FROM SENSITIVITY TESTING
Green waste flow volumes	No major change to outcomes for Options 1 and 2. They are still not viable. Significantly higher green waste volumes do increase the risks that Options 3 and 4 cannot meet the objectives of the Draft Waste Policy because there are limits on the demand for recycled green waste from increased garden production. This was tested by changing the estimated waste volumes and examining the ability of each option to adsorb the additional waste.
Element of CBA tested through sensitivity analysis	Results from sensitivity testing
% of green waste that is segregated	No material and realistic change for any options because current levels of segregation are already quite high due to the change attributed to recent programmes.
Fuel costs	No material change for any options. These variable costs are too insignificant to have a material impact on the findings of the CBA.
Maintenance and replacement costs	No material change for any options. These variable costs are too insignificant to have a material impact on the findings of the CBA.
Lifespan of the equipment	No material change for any options providing equipment is maintained. The exception would be if equipment is damaged by cyclones. Climate sensitivity is assessed separately below.
Health benefits	Not tested.
Yield gains from using compost on gardens	No major change to outcomes for Options 1 and 2. They are still not viable. For Options 3 and 4, reducing yield gain to zero does reduce net benefits. However, both options are still viable.
Cost of new landfill site	Results are significantly impacted by the assumed cost of a new landfill site, but only where an extremely high cost is adopted (i.e. based on land reclamation). For example, the BCR for Option 3 increases from 1.45 to 2.15. Where more likely future landfill costs are adopted, including paying a premium rent on the currently proposed site, they are not materially different to the initial estimates. Because the new site is required in the very near future, the feasible range of delays tested did not materially change the results.

Key finding

- Of the issues identified for inclusion in sensitivity analysis, many do not have a material impact on the outcomes of the CBA modelling.

There are a number of issues that require more detailed sensitivity analysis. These issues are outlined below.

3.2.1 CLIMATE CHANGE AND DISASTER RISK

Tuvalu is one of the most vulnerable countries in the Pacific to climate change and climate variability. Climate change and disaster risk are a key issue for sensitivity analysis. In this section, we look at the sensitivity of the findings to climate change, specifically the frequency of major drought and the frequency of cyclones. The results presented here discuss the impacts on Option 3 only because that is the superior option.

A major component of the benefits is attributable to growth in horticulture production and the use of mulch as a key input for horticultural production. Where prolonged droughts occur, water (rainfall and rainwater tank yield) for horticulture will be limited, horticultural production will be scaled back, and demand for green waste mulch will temporarily cease. Under these circumstances, the costs of green waste management (e.g. collection and mulching) will continue, while the benefits from horticultural development will cease. We modelled the potential risks of climate-induced frequency of drought by testing different drought frequencies on the benefit cost ratio.[21] This is shown in Table 9. The analysis found that a severe drought would need to occur approximately 1 in every 2 years before Option 3 was not economically viable. This would appear unlikely even under the most extreme climate change predictions and is a significantly worse drought than any on record (see Appendix B).

The key disaster risks relate to the frequency of cyclones damaging infrastructure (for green waste management and gardening) and the temporary loss of the benefits from gardening (i.e. no horticultural production). We modelled the sensitivity of Option 3 to the frequency of cyclones and found that the frequency of cyclones would need to be less than 1 in every 4 years before Option 3 is no longer viable (Table 9). The cyclone frequencies tested are significantly greater than those indicated by current climate change scenario modelling outlined in Appendix B.

TABLE 8. OUTCOMES FOR SENSITIVITY ANALYSIS ON OPTION 3 – IMPACTS ON BENEFIT COST RATIO

	FREQUENCY OF MAJOR CLIMATE RISK				
Risk assessed	1 in 2 years	1 in 3 years	1 in 4 years	1 in 5 years	Base case for CBA
Drought	1.03	1.21	1.29	1.37	1.45
Cyclones	0.85	0.98	1.12	1.27	1.45

Key findings

- The economic viability of Option 3 is resilient to the possible climate change risks assessed.
- Option 3 is economically viable even assuming drought conditions occurred 1 on every 2 years or Funafuti was hit by a cyclone 1 in every 1 years. These frequencies of climate events are significantly worse than data for historical climate events indicate and significantly worse than any climate scenario modelling suggest are possible.

3.2.2 THE EFFECTIVENESS OF AWARENESS PROGRAMS

Many of the benefits of the options rely on behaviour change as a result of awareness programs. Even where awareness programs are highly effective, Options 1 and 2 are not viable because they still do not address the low use of recycled mulch.

Option 3 is highly reliant on the efficacy of awareness of programs to change pig pen management to a deep litter approach (to avoid contamination with salt water). Without this behaviour change, there will be insufficient clean manure to mix with the mulch. This will ultimately constrain the demand for recycled green waste, unless fresh water is provided for washing pig pens. We assessed a number of potential consequences of awareness campaigns that are not successful:

- Option 4 represents this scenario where up to 30 pig pens would need to be supplied with fresh

21 To test this frequency, we ran the model with different drought frequencies where costs continue, but benefits from horticultural production for that year are $0.

water.[22] This represents approximately 5% of the households that have pigs. Economically, the difference between Option 3 and Option 4 represents an upper bound for the risk of insufficient households changing their pig management regime. However, even under these circumstances, the green waste Policy is still economically viable.

- If the awareness campaign for modified pig management is only partially successful (e.g. pig owners occasionally use salt water for cleaning and manure is contaminated), this will reduce the yield gains in horticultural production attributable to manure use. We tested this risk by progressively reducing the yield gains attributable to the use of manure, and the subsequent BCR for Option 3. Even where yield gains were significantly diminished, Option 3 is still economically viable. Yields would need to drop by approximately 30% before Option 3 would no longer viable.
- It should also be noted that discussion with pig owners during consultation indicated that the effort to collect and use the mulch is likely to be lower than the current effort required to collect and use seawater. This will particularly be the case once the SWAT depot is moved to a site adjacent to the bulk of the pig pens. Testing this assumption is also a specific recommendation for implementation.

Key finding

- The sensitivity analysis has found that the economic viability of Option 3 is resilient to limitations in the success of awareness programs.

3.2.3 THE UPTAKE OF RECYCLED PRODUCT

There is evidence to suggest there would be sufficient demand for vegetables grown locally given the level of imports. This was partially confirmed through an 'exit survey' of customers at the Taiwan garden project undertaken on 20 May 2016, where:

- 68% of customers interviewed indicated that they visited the market twice a week;
- only 14% of customers have a home garden; and
- 100% of respondents said they would purchase more vegetables if they were available (68% even at current prices, 32% if prices were lower).

These findings are consistent with the views of Senior Managers at the Taiwan garden project.

To test the sensitivity of the results to the uptake of the use of product, we modelled the expansion of the commercial garden area (as the main consumer of mulch), and the subsequent impact on the BCR (Option 3 only) (Figure 2).

22 Here, we have assumed that each pig pen holds the average number of pigs per family from the Census and that a mix of 1 part pig dung to 3 parts mulch is the likely compost mix (advised by the Taiwan Garden Project).

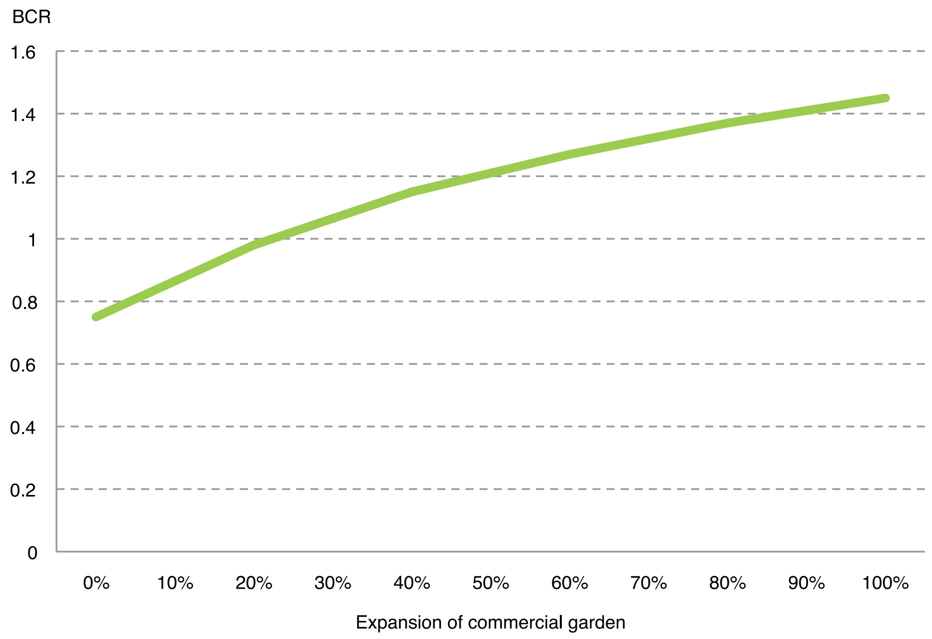


FIGURE 2: SENSITIVITY ANALYSIS – IMPACT OF COMMERCIAL GARDEN EXPANSION ON BCR (OPTION 3)

The sensitivity analysis found that the results of the CBA are particularly sensitive to the uptake of recycled production. Even for the superior option (Option 3) to be economically viable, it is necessary to double the use of mulch on existing commercial gardening and expand the production area by at least 20% above historical production areas.[23] To ensure the Waste Policy volumetric objectives are achieved, commercial gardening would need to expand by 80% to absorb the available mulch.

Other results from this sensitivity analysis include:

- to ensure the Waste Policy objectives are achieved (i.e. close to 100% green waste recycled, used, and diverted away from landfill by 2026), commercial gardening would need to expand by 80%; and
- the results are not materially impacted by changes in assumed use of mulch for composting toilets or on existing home garden areas.

Key findings

- The outcomes of the CBA are most susceptible to assumptions of the capacity for growth and consumption of horticultural products because horticulture is the major source of demand for mulch.
- For Option 3 to be economically viable, it is necessary to double the use of mulch on existing commercial gardening and expand the production area by at least 20%.
- To ensure the Waste Policy volumetric objectives are achieved, commercial gardening would need to expand by 80% to absorb the available mulch.

23 It is understood from anecdotal information that the area of production has been reduced in 2016, but primarily due to limitations in the availability of suitable manure.

3.3 Distributional consequences

It is useful to understand the likely equity and distributional impacts of the potential options being considered under the CBA. Table 10 shows the outcomes of the workshop exercise to identify and understand some of the key impacts. A + indicates that that stakeholder group is positively impacted by the distributional impacts, – shows a negative impact, and (+) indicates that the distributional impact is indirect and positive. These have been further assessed for each of the three major stakeholder groups (households and the Taiwan garden project, waste service providers, and the Government of Tuvalu).

TABLE 9. DISTRIBUTIONAL IMPACTS[24]

COST OR BENEFIT	HOUSEHOLDS/ TAIWAN GARDEN PROJECT	SERVICE PROVIDERS	GOVERNMENT
Cost: Extra effort for segregating and using compost	–	+	+
Cost: Performing conversion to mulch and compost		–	–
Benefit: Efficiencies in collection	(+)[23]	+	+
Benefit: Use of mulch and compost	+	+	+
Benefit: Reduced landfill	(+)[23]	+	+
Benefit: Improved environmental quality	+	+	+
Benefit: Health benefits	+	+	+

An analysis of the different categories of costs and benefits enables a quantitative estimate of the distributional impacts of each option. The key points to note from the analysis are:

- For Option 1, approximately 22% of benefits flow directly to households in the form of increased home garden production, but only for houses that already have a home garden. Approximately 78% of the benefits accrue directly and indirectly to the community in the form of lower green waste management costs, lower consumption of landfill and broader benefits such as lower CO_2 emissions. The direct costs of this option are imposed largely on SWAT, but these costs will be passed onto the community in the form of fees and/or lower levels of government services elsewhere.
- The distribution of benefits for Option 2 is similar to Option 1, with approximately 25% of benefits flow directly to households in the form of increased home garden production, but only for houses that already have a home garden. The distribution of costs is also similar to Option 1.
- For Option 3, approximately 81% of benefits flow directly to households in the form of increased home garden production and the availability of additional horticultural produce through commercial gardens. Approximately 19% of the benefits accrue directly and indirectly to the community in the form of lower green waste management costs, lower consumption of landfill and broader benefits, such as lower CO_2 emissions. A high proportion of the direct costs of this option are incurred in the production and increased use of manure. However, it should be noted that these costs will be embedded into the price of vegetables sold and are therefore ultimately met by the community.
- The distribution of benefits for Option 4 is essentially the same as for Option 3. However, the costs are higher, resulting in a greater funding for SWAT that would ultimately be borne by a mix of the community and donors. The distribution of costs for this option are similar to Option 3.

24 Through reduced fees and more funds to spend on other priorities such as education and health.

Key findings

- For Options 1 and 2, the bulk of the direct benefits accrue to the community, while the costs are largely borne by the community.
- For Options 3 and 4, a significantly higher proportion of the benefits accrue to the community in the form of additional garden production when green waste is used in conjunction with other inputs. A significant portion of the direct costs are attributable to the production and use of the mulch as an intermediate input for horticulture production. However, these costs would be recovered through the price of vegetables sold.

3.4 Conclusions from CBA

The CBA has found that there are economically viable options for green waste management in Funafuti that are also likely to meet the objectives of the Waste Management Policy. Of the options assessed, Option 3 was superior as it provides both the highest ratio of benefits to costs and meets the Waste Management Policy objectives. However, Option 3 is highly reliant on derived demand for green waste mulch, particularly from the commercial gardening sector, and the availability of suitable pig dung for mixing with the mulch.

The sensitivity analysis found that the results of the CBA are particularly sensitive to the uptake of recycled production. Even for the superior option (Option 3) to be economically viable, it is necessary to double the use of mulch on existing commercial gardening and expand the production area by at least 20% above historical production areas.[25] To ensure the Waste Policy volumetric objectives are achieved, commercial gardening would need to expand by 80% to absorb the available mulch. There is evidence to suggest there would be sufficient demand for vegetables grown locally given the level of imports.

To achieve the objectives of the Waste Management Policy being developed, proactive actions will need to be taken to create demand for mulch via increased garden production. This will require a joint initiative between SWAT, the Department of Agriculture, and the Taiwan garden project. This is discussed more in Section 4 of this report.

3.4.1 KEY RESEARCH QUESTIONS ANSWERED

During the design of the CBA, several key research questions were established. These were separated into key stakeholder groups. These stakeholder groups, their interests in the CBA, the key research questions, and the answers provided from the CBA are shown in Table 11.

25 It is understood from anecdotal information that the area of production has been reduced in 2016, but primarily due to limitations in the availability of suitable manure.

TABLE 10. KEY RESEARCH QUESTIONS

STAKEHOLDER	KEY INTERESTS IN CBA	KEY QUESTIONS	CORRESPONDING ANSWERS
SWAT	Input to the design of the main policy	Which option meets the waste management targets? What are the benefit and costs of each option and which one is most efficient? What are the budgetary implications and the potential for cost recovery?	Only Options 3 and 4 are economically viable *and* meet the waste management targets. Benefits and costs are outlined in Section 3.1. Option 3 is superior. Options 3 and 4 both require additional SWAT resources.
Permanent Secretary and Minister for Home Affairs	Good policy and efficient service delivery	Same question as SWAT plus: What are the broader benefits and costs and what is their relative importance? What are the opportunities for efficiency gains or commercializing of SWAT's operations (including revenues)?	The major benefit streams relate to increased agricultural production attributable to the use of mulch (less imported food and better nutrition). Options 3 and 4 will also significantly increase the life of the new landfill site. Efficiency gains are possible for SWAT and revenues from mulch sales should increase. However, the budget requirement will increase.
Cabinet	Whole of Government perspective	Same as Permanent Secretary and Minister Plus: Distribution of benefits and costs?	The bulk of the direct costs are borne by SWAT (ultimately passed onto the community) and purchasers of mulch, while the bulk of the direct benefits accrue to the community from additional vegetable availability.
Households	Green waste management at home	How much green waste can I use at home and what are the benefits? What are the potential benefits and cost at the household scale? If services are commercialized, what might the charges be?	Green waste use for home garden production could double, providing significant benefits in terms of increased garden yields. Yield gains could be worth up to AUD 70 per year for an average home garden (12 m^2). See Section 4.3 of this report.
Kaupule	Impact on Kaupule business	How will recommendations and their implementation impact on Kaupule waste management services?	Awareness and regulatory actions to reduce the levels of contaminated green waste will require cooperation from the Kaupule.
PERMU	Effectiveness and cost-efficiency of waste management services	What is the efficient cost of providing waste management services? Would it be possible to fund just the revenue shortfall of a commercial (if any) of a service provider?	This issue is partially covered in Section 4.3 of this report. Yes. That would be a more efficient way to fund waste management services.
Farmers	Production and value of production	What yield gains are possible from the use of compost? Will the project reduce my cost of production? Will the project provide compost at an appropriate quality and at an affordable price?	While there is uncertainty in the data and trials are ongoing, yield increases up to 25% should be achievable. Use of green waste mulch and pig dung should be cheaper than imported soil treatments. If properly implemented, the quality of compost available should improve.
Donors	Ensuring donor investment is efficient	Does the project represent 'value for money'? Is it possible to establish a sustainable commercial service for green waste that doesn't require ongoing development assistance?	Options 3 and 4 present value for money for donors, particularly due to the multiple types of benefits (including enhancing food security benefits). This would require significantly higher prices for mulch sold which could be inconsistent with other waste management policy objectives and broader development goals.

4. Recommendations, program design and implementation, financing

The CBA has found that green waste management Options 3 and 4 are economically viable under almost all circumstances assessed. They provide significant net benefits to the community. This section briefly outlines the high-level recommendations from this CBA study and provides insights for green waste policy design and implementation.

4.1 High-level recommendations

Key recommendations from the CBA project are:

- the Waste Policy should include actions similar to Option 3 outlined in this report. Option 3 is both economically viable and should meet the objectives of the Waste Management Policy;
- SWAT will need to work jointly with other stakeholder organisations to ensure the objectives of the Waste Management Policy are achieved;
- proactive actions must be taken to create demand for mulch via increased garden production and to ensure pig waste is of an appropriate quality to mix with mulch for gardening inputs (see Table 12); and
- Tuvalu should establish an effective monitoring and evaluation Policy for green waste management that covers physical waste flows, the effectiveness and costs of service provision, and community behaviour and use of recycled product.

4.2 Program design and implementation

There are a number of issues that will need to be considered for the program design and implementation phases of the green waste Policy over the next 10 years. These are briefly outlined in Table 12.

TABLE 11. PROGRAM DESIGN AND IMPLEMENTATION ACTIONS

ISSUE	ACTIONS	RATIONALE
Green waste flow volumes still uncertain	Undertake a baseline survey of *all* waste streams building on the existing system of log books. Analyse data to establish improved estimates of waste flow volumes. Analyse SWAT head office activities to enable the allocation of costs across different waste streams and locations.	This information is vital to establishing and refining operational and strategic waste-management strategies.
Monitoring and evaluation (regulations, compliance, service delivery, outcomes)	Monitor the oversight, delivery, and compliance of relevant green waste-management regulations and policies. Establish a monitoring and evaluation programme for green waste including advice from PERMU to ensure data is relevant for any future financial/ownership structures for waste management. This should cover physical and financial aspects of waste management.	To ensure waste-management services are delivered efficiency and at the lowest net cost to the community.

ISSUE	ACTIONS	RATIONALE
SWAT corporate management	Review and evaluate capital equipment holdings and establish an asset register. Establish proper accounting to ensure funds are available for asset replacement when necessary. Instigate a more rigorous and properly funded maintenance program to reduce the likelihood of equipment failure and service disruptions. Review the corporate structure and financing of waste management, including all waste streams. Undertake analysis to identify the efficient costs of service delivery and transition to a community service obligation framework for budget funding (or similar). Further evaluate the potential for sustainable service charges for green waste management and mulch products. This should consider interactions and the complimentary of green waste with other waste streams, and the need to incentive use of mulch.[26] Note: These actions can be undertaken irrespective of SWAT's corporate structure. Once the actions above are completed and SWAT is operating in a more efficient manner, it would also be prudent to identify and review options for the long-term corporate model for waste management service delivery. This would include options such as maintaining the status quo (SWAT delivers services, service provision by a third party under contract, or privatisation of the waste management business).	To ensure that SWAT activities are both efficient and financially sustainable in the long-term.
Awareness programs	Instigate awareness programs, particularly focusing on deep litter management for pigs and the use of mulch in conjunction with pig dung as a soil conditioner. These awareness programs would be designed around required practice changes, impediments to practice change, and the benefits to households and businesses from implementing practice change.	Focusing on these areas through awareness programs will deliver greater outcomes (more consumption of recycled green waste).
Deep litter approach to pig pen management	Run trials and demonstrations of deep litter pig pen management. Monitoring and evaluation of results (including levels effort required, levels of contaminants, and suitability of manure for use in gardens). Promote findings. Promote the use of manure developed through deep litter pig pen management based on the outcomes of trials and monitoring and evaluation. Assess options and ensure the economic incentives for litter management are appropriate and provide continuous incentives for the continuous use of the practice. This would include operational matters such as: • the location and availability of mulch (impacts on the time and effort of using mulch compared to salt water) • the pricing of mulch; • the location of payments (currently the Government offices); • value adding such as pre-bagged mulch, or a delivery system; • policies to only collect suitable quality compost from pig owners; and • a combination of measures that ensure pig pen management objectives are met.	This initiative is vital as an intermediate production process of manure suitable for use in gardening.
Agriculture expansion	Undertake a comprehensive demand study for horticultural output, including consumers' unsatisfied demand and willingness/ability to pay for additional output. Establish a detailed agricultural development and expansion Policy. This should be done in conjunction with the Taiwan gardening project and the Department of Agriculture. This would also include key crop and plot trials to better understand productivity gains and changes in input costs associated with the use of soil conditioning that uses green waste. Establish a business case to expansions for consideration by donor agencies. Implement expansion, including the use of mulch from green waste and clean pig manure from deep litter approaches as the basis of soil conditioning and improvement. It should be noted that this action will need to be undertaken in coordination with the current expansion of the garden on Vaitapu because any expansion of commercial horticulture on Funafuti will reduce the need for imports from Vaitapu.	Demand for mulch is a derived demand. Waste Policy targets cannot be achieved without agricultural expansion to consume mulch.

26 It should be noted that the generation of green waste cannot be avoided (unlike other waste streams), and pricing/charging structure needs to incentivise the use of mulch.

4.3 Financing green waste management

Typically, waste management services incur household charges based on the recovery of efficient costs of service delivery. This has not yet been considered for green waste in Tuvalu. A number of approaches can be used to establish efficient costs as a basis for service charging. All approaches require an estimate of the assets consumed to provide the service and the efficient operational and maintenance costs.

Table 13 shows our indicative estimate of the value of capital used for green waste management on Funafuti based on historical funding proposals. Note, these estimates are very rough and included here for illustrative purposes.

Because assets typically last for several years, it is common to work out the annual value of assets consumed (used) as a basis for any charging. Based on the data outlined in Table 13, this would total approximately AUD 31,600 per year.

TABLE 12. INDICATIVE CAPITAL COSTS (AUD)

ITEM	CAPITAL VALUE	ECONOMIC LIFE (YEARS)	ANNUAL ASSET CONSUMPTION
3 x chippers	$165,000	10	$16,500
3 x trailers	$84,000	10	$8,400
Other vehicles	$120,000	10	$12,000
Buildings	$200,000	30	$6,667
Total	**$569,000**		**$43,567**
Return on capital (if included)			$31,625

Source: Based on data in previous proposals for capital equipment

It is then important to understand what are the efficient annual overhead, operational, and maintenance costs incurred to provide the green waste service. These costs are shown in Table 14 (based on SWAT budget data from 2016). We have made assumptions about the percentage of total SWAT costs that are attributable to green waste management in Funafuti and have also reduced the total annual cost to reflect efficiency gains already identified in this project.

Based on the data available, we estimate that the efficient annual operating costs of green waste management in Funafuti are probably approximately AUD 73,000.

TABLE 13. INDICATIVE ANNUAL OVERHEAD AND OPERATING COSTS (CURRENT GREEN WASTE MANAGEMENT ON FUNAFUTI) (AUD)

COST ITEM	ESTIMATES ANNUAL COST	% OF TOTAL SWAT COST ATTRIBUTABLE TO GREEN WASTE
Salaries & on-costs	$62,625	40%
Equipment maintenance	$370	40%
Vehicle maintenance	$4,452	40%
Fuel	$7,743	60%
Electricity	$3,300	60%
Protective gear	$578	40%
Less efficiencies already identified	*$6,416*	
Efficient annual operating costs	$72,652	

Source: Based on SWAT budget for 2016

Previous work has identified alternative approaches to estimate the costs of service provision and establish funding for state-owned entities such as SWAT based on the concept of a community service obligation. Estimation approaches include:

- the Long Run Avoidable Cost (LRAC) method, which includes all costs associated with the provision of the service that would be avoided if the service was not carried out; and
- the Fully Distributed Cost (FDC) method which also includes all fixed and variable costs directly pertaining to the service. This includes a proportion of the common fixed costs and common overhead costs. In many developed countries, this will include a rate of return on the assets employed to deliver the service as this provides an incentive for private sector provision of the service in the long run without the need for future government/donor funding.

Table 15 shows the indicative cost of providing green waste services on Funafuti under current arrangements using the LRAC and FDC approaches. We have also calculated the FDC approach incorporating a commercial return on assets.

TABLE 14. INDICATIVE ANNUAL OVERHEAD AND OPERATING COSTS (CURRENT GREEN WASTE MANAGEMENT ON FUNAFUTI) (AUD)

	LRAC	FDC	FDC + RETURN ON CAPITAL
Cost of running green waste activities	$72,652	$109,803	$141,428
Less avoided landfill consumption cost	–$6,037	–$6,037	–$6,037
Less sales revenue	–$5,040	–$5,040	–$5,040
Net cost of service	$61,576	$98,726	$130,351
Net cost per household	**$63**	**$99**	**$127**

Source: Based on SWAT budget for 2016

While these data are very indicative and are not sufficiently robust to form the basis of any service pricing mechanism, the net annual cost of green waste services in Funafuti is between AUD 61,600 and AUD 130,000 depending on the approach used. This translates to an annual cost per household between AUD 63 and AUD 127 which could be used as a basis for any community service obligation policy. Generally speaking, charges set using the FCD approach should ensure the business could continue in a commercial fashion without the need for further external donor funding.

References

Anonymous (2011) 3R Action Plan of Lautoka City Council developed in November 2011 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands

Anonymous (2011) 3R Promotional Manual developed in 2012 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands

Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014

Bernard K (2013) How men and women use their time in Tuvalu: A time use study. SPC Women in Fisheries Information Bulletin #23 – December 2013

Bourke RM and Harwood T (eds) (2009) Food and Agriculture in Papua New Guinea. ANU E Press, The Australian National University, Canberra

Buncle A (2016) Community Service Obligation Policy Framework for the Solomon Islands

Buncle A (2016) Community Service Obligation costing guidelines

DuPonte M and Fischer D (2012) Most Frequently Asked Questions on the IDLS Piggery, The Natural Farming Concept: A New Economical Waste Management Stem for the Small Family Swine Farms in Hawaii, 2012, Livestock Management., Sept., LM-23

FAO (undated) Tuvalu. Situation Analysis and Agriculture Sector Overview

Freeman A, Taufatofua P, Rodoni B (2010) Impact of climate change on food security and biosecurity in small Pacific nations

Government of Tuvalu (2010) Household Income and Expenditure Survey 2010

Government of Tuvalu (2012) Tuvalu national population and housing census

Government of Tuvalu (2014) The poverty lines, the incidence and characteristics of poverty in Tuvalu

Kawai K and Tasaki T (2015) Revisiting estimates of municipal solid waste generation per capita and their reliability. Journal of Material Cycles and Waste Management. January 2016, Volume 18, Issue 1, p 1–13

Kruger I et al. (2006) Deep-litter housing for pigs

MainStream Economics and Policy (2015) Use of biogas as an alternative energy source in Tuvalu. Preliminary cost-benefit analysis report

MainStream Economics and Policy (2016) Green waste management in Funafuti. Background, identification of options, CBA workplan and contextual information

Pacific Climate Futures Version 2 was developed as part of the Pacific-Australia Climate Change Science and Adaptation Planning programme (http://www.pacificclimatechangescience.org) with funding from the Government of Australia.

Reid JB, Hunter D, Eaqub M, and Aiono L (2009) Improving yields and fertilizer efficiency in the South Pacific

Secretariat of the Pacific Community in conjunction with CSIRO (2011) Food security in the Pacific and East Timor and its vulnerability to climate change

Sinclair P (2011) Rapid drought assessment Tuvalu

Singh S (undated) Market Waste Composting in Lautoka City Council

Tary R (2014) Waste Management in Port Vila Municipality. Market waste compost pilot project – Evaluation report

Templeton D (ed) (2012) Food security in East Timor, Papua New Guinea and Pacific island countries and territories. ACIAR Technical Reports No. 80. Australian Centre for International Agricultural Research: Canberra

Telakau S (2015) Sixth Regional 3R Forum in Asia and the Pacific “3R as an Economic Industry – Next Generation 3R Solutions for a Resource Efficient Society and Sustainable Tourism Development in Asia and the Pacific”. Malé, Maldives, 17–19 August 2015

World Bank (2016) Country database (Tuvalu).

APPENDIX A
Valuation of input parameters

Table A1 shows the valuation methodology, valuation range, data source(s), and reliability for the key cost and benefits estimates used in the CBA. Generally, the mid-point of the range was used as the estimate for CBA, with the extreme of the range used for sensitivity analysis except where otherwise indicated. Note: Figures have been rounded.

TABLE A1. KEY COSTS AND BENEFITS

COST OR BENEFIT	VALUATION METHODOLOGY	VALUATION RANGE (AUD)	DATA SOURCE(S)	RELIABILITY
Costs				
Awareness programs	Market values including all staff overheads and operational costs of existing programs	\$22,300–\$29,000 per year (full time equivalent person)	SWAT budget	
Enforcement green waste laws	Market values including all staff overheads and operational costs of existing programs	\$22,300–\$29,000 per year (full time equivalent person)	SWAT budget	
Efficiency trials and M&E	Market values for technical assistants (including per diem and allowance for return flights from Australia/NZ)	\$800–\$1,200 (per day)	Market insight from Technical Advisor	
Upgraded chippers	Market values (includes allowances for freight and installation)	\$1,000–\$5,000	Based on discussions with suppliers (parts only)	
Compulsory home compost use (awareness and regulation)	Market values including all staff overheads and operational costs of existing programs	\$22,300–\$29,000 per year (full time equivalent person)	SWAT budget	
Mobile wood chipping and disposal in situ	Production function based on specific model of chipping operations plus transport fuel.	\$1.90–\$3.70 m^3 (processed product)	SWAT staff logbooks, relevant staff hourly wages, equipment manufacturer fuel use specifications, fuel prices, advice from operators on volumes.	
Better product available for compost	Production function based on specific model of chipping operations.	\$1.40–\$3.00 m^3 (processed product)	SWAT staff logbooks, relevant staff hourly wages, equipment manufacturer fuel use specifications, fuel prices, advice from operators on volumes.	
Commercial gardening costs including mulch and pig manure inputs	Production function modelling of expansion and operation of commercial gardening including all relevant inputs	\$38–\$46 m^2 (establishment) \$18–\$22 m^2 (annual operational costs)	Taiwan Garden Project annual accounts.	
Use of mulch in dry pig waste management	Market values for trials (once off cost) and awareness (ongoing)	\$22,300–\$29,000 per year (full time equivalent person) \$800–\$1,200 (per day)	SWAT budgets. Market insight from Technical Advisor	

COST OR BENEFIT	VALUATION METHODOLOGY	VALUATION RANGE (AUD)	DATA SOURCE(S)	RELIABILITY
Benefits				
Landfill (delay)	Delayed cost based on estimated acquisition costs of next site (lease costs), estimated change in remaining landfill consumption, and monthly discount rate.	$1,100–$2,100 per month (based in lease costs) $44,300 per month (based on land reclamation)	Volume and lease estimates provided by SWAT. Land reclamation cost based on cost of beach adjacent to hotel.	
Landfill (reduced consumption)	Avoided cost based on estimated landfill acquisition and operating costs.	$7.20–$7.80 m^3 (based in lease costs) $140 m^3 (based on land reclamation)		
Imports avoided (reductions in imported garden media)	Avoided costs of imported garden media	$28–$36 per bag	Taiwan Garden Project financial data	
Service delivery efficiencies	Avoided costs using production function	$10,600 to $14,400 per year	SWAT staff logbooks, relevant staff hourly wages, equipment manufacturer fuel use specifications, fuel prices, truck/trailer capacities.	
Emissions	Avoided cost using benefit transfer	0.3 tonnes per m^3 of landfill $4:40–$44.70 per tonne	Volumes advised by SPREP. Prices based on a review of market prices.	
Home gardens (additional output)	Production function modelling	Yield gains 5%–25% $33–$49 m^2	Review of data from previous studies. Consultation with Department of Agriculture & Taiwan Garden Project. Survey of shops for vegetable prices as proxy for import substation price.	
Commercial gardens	Production function modelling	Yield gains 5%–25% $44–$54 m^2	Taiwan Garden Project. Survey of shops for vegetable prices as proxy for import substation price.	
Sales and fees (sales of recycled green waste)	Production function modelling	Input volumes per m^2 of garden (current and potential) $1–$3 per bag	Taiwan garden Project and SWAT	
Health (not valued)	Not quantitatively valued			
Enhanced lagoon health (not valued)	Not quantitatively valued			

LEGEND: ESTIMATE RELIABILITY

Highly reliable **Somewhat reliable** **Relatively poor**

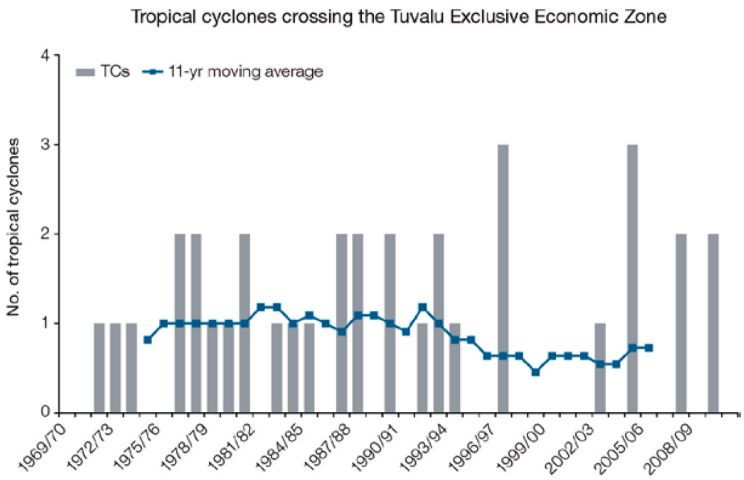
APPENDIX B
Climate and climate change

It is important to note that the green waste-management options and their respective risks, benefits, and costs will be impacted by climate risks and climate change in the longer term. This appendix summarises some of the key climate and climate change risks relevant to the assessment of options.

CYCLONES

Cyclones and other extreme weather events will create physical risks to waste-management infrastructure as well as significantly increasing the volume of green waste immediately after major weather events. Figure B1 shows the frequency of cyclone activity in the Tuvalu Exclusive Economic Zone since 1969. Cyclones are more likely during an El Niño event.

FIGURE B1. TIME SERIES OF THE OBSERVED NUMBER OF TROPICAL CYCLONES DEVELOPING WITHIN AND CROSSING THE TUVALU EEZ PER SEASON. THE 11-YEAR MOVING AVERAGE IS IN BLUE



Source: Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014

In the period 1969 to 2010, 31 tropical cyclones passed within 400 km of Funfuti. However, it would appear that major damage has only occurred on land twice during that period (Cyclone Bebe in 1972 and Cyclone Pam in 2015). While the frequency of cyclones is expected to decrease under climate change, the intensity of cyclones is expected to increase (BOM and CSIRO, 2014).

SEA LEVEL RISE AND INCREASED STORM SURGE RISK

Sea level rise scenarios for Tuvalu are shown in Figure B2. It is the inter-annual levels that are of most interest to this analysis because these levels provide some indication of the extremes that would significantly exacerbate storm surge. These extremes are shown by the grey dashed line[27].

27 95% confidence intervals based on the modelled outcomes.

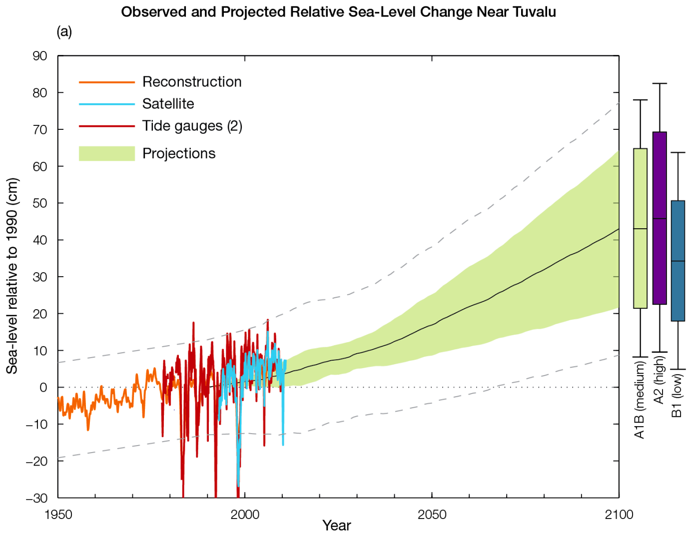


FIGURE B2. TUVALU SEA LEVEL RISE SCENARIOS

Source: Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014

Figure B2 indicates that by approximately 2045, maximum sea level heights could be 30 cm higher than 1990 levels during high tide events. Storm surges are already a problem in some low-lying areas of Tuvalu, and this risk will incrementally increase under climate change.

RAINFALL AND DROUGHT

One of the key benefits from composting and mulch from green waste is soil retention in home and commercial gardens. Monthly rainfall data (mean, lowest on record, highest on record) for Funafuti is shown in Figure B3. The 2011 drought is shown by the brown dashed line.

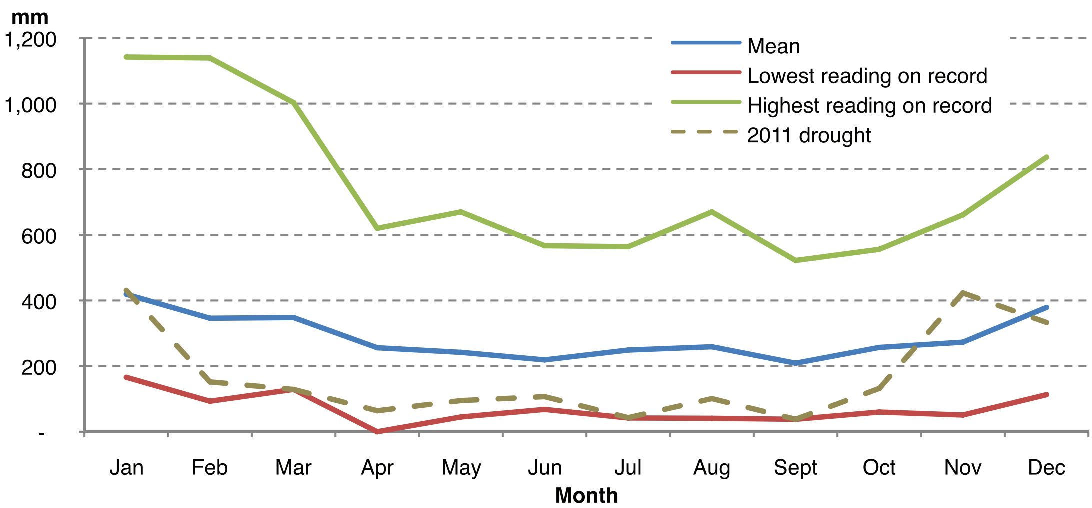


FIGURE B3. MONTHLY RAINFALL – FUNAFUTI

Source: Tuvalu Met Office

Figure B4 shows the historical and range of simulated annual rainfall for Tuvalu under various climate change assumptions. It generally shows an expectation for a slight increase in annual rainfall, while even under the more pessimistic assumptions and modelled outputs, reductions are relatively minor during the 30-year period of this analysis. Furthermore, the likelihood of droughts is expected to decline.

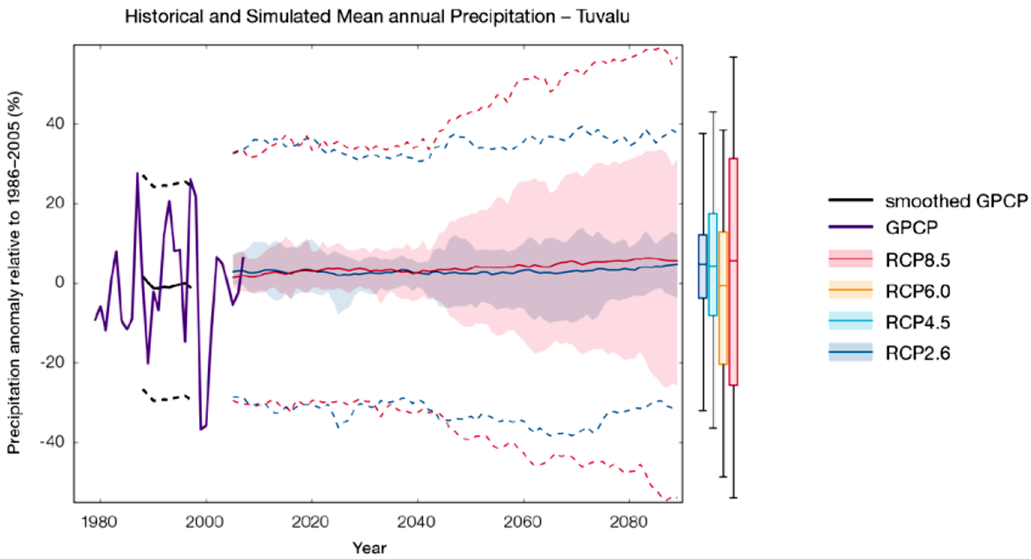


FIGURE B4. HISTORICAL AND SIMULATED ANNUAL AVERAGE RAINFALL TIME SERIES FOR THE REGION SURROUNDING TUVALU

Source: Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014

APPENDIX C
Economic information

This appendix outlines a number of economic input parameters and information relevant to the analysis.

DISCOUNT RATE

To conduct a CBA, a discount rate must be used to enable the assessment of all future costs and benefits as present values (today's values). There is no official Government bond rate (or similar) to determine a discount rate in Tuvalu, nor is there any formalised equity market to provide guidance. Therefore, we used a real discount rate based on existing nominal lending rates less inflation.

Both the National Bank of Tuvalu (NBT) and the Tuvalu Development Bank (TDB) offer loan facilities. Interviews conducted with bank management revealed commercial rates charged by the NBT range from 6.5% per year (secured low-risk lending) to 9.5% per year (unsecured or more risky lending). The TDB charges higher rates but has a more risky loan portfolio due to the high proportion of business loans. However, the TDB is charged a rate of 6.0% per year for capital provided by Government. This rate is similar to a risk-free lending rate. Interviews revealed interest rates do not fluctuate greatly, although rates in recent years have been relatively lower.

Analysis of World Bank implicit price deflators for Tuvalu for the latest ten year period indicates an annual average inflation rate of 2.2%.

Based on the information above, the range of discount rates used in this report ranges from 3.8 to 7.3% per year, with a mid-point rate of 5.6%.

TRENDS IN INTERNATIONAL DEVELOPMENT ASSISTANCE

While Tuvalu has benefited from significant growth in overseas development assistance (ODA) in recent years, this goes against the trend in the region (see chart below). Consideration of waste-management options needs to consider the long-term funding arrangements. Based on regional ODA trends, it would be wise to consider some form of cost sharing between users (household and businesses) and green waste service providers.

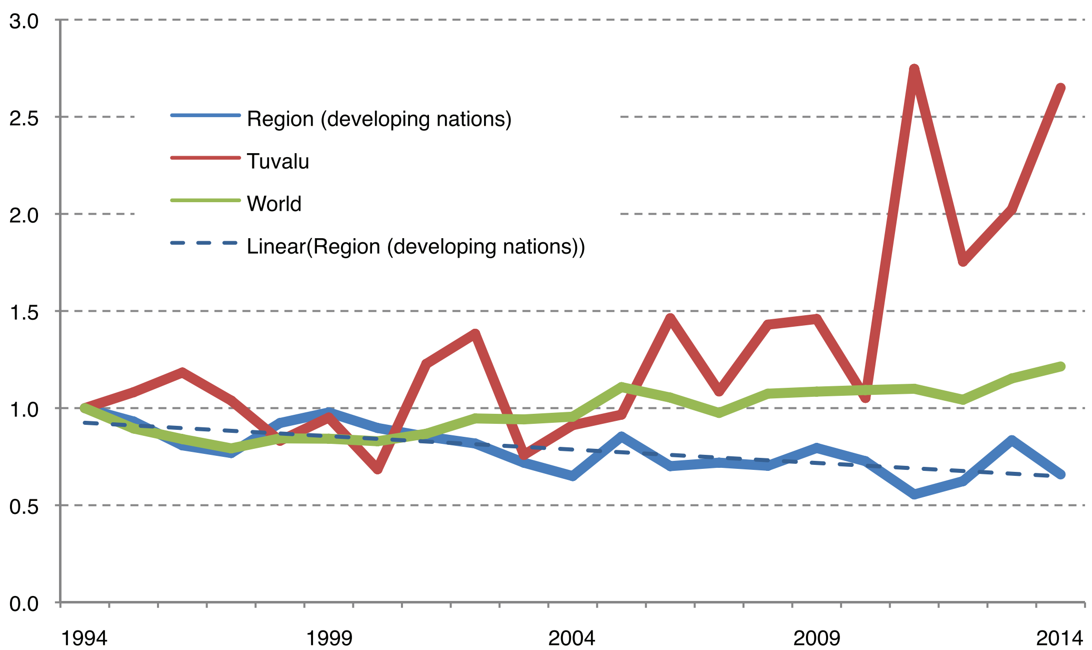


FIGURE C1. INDEX OF OFFICIAL DEVELOPMENT ASSISTANCE PER CAPITA (CONSTANT USD)

Source: World Bank

APPENDIX D
CBA model outputs

TABLE D1. OPTION 1 CBA MODEL OUTPUTS ($ = AUD)

	Present value ($)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Greenwaste volumes before new actions											
Number of households		974	998	1,023	1,049	1,075	1,102	1,129	1,157	1,186	1,216
Greenwaste left for collection (m3)		2,422	2,482	2,544	2,608	2,673	2,740	2,808	2,879	2,951	3,024
Greenwaste suitable for conversion (m3)		2,180	2,234	2,290	2,347	2,406	2,466	2,528	2,591	2,656	2,722
Conversion rate (%)		33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Greenwaste after conversion (m3)		719	737	756	775	794	814	834	855	876	898
Economic costs of actions											
Sub-objective one											
Basic awareness program											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Comprehensive awareness program											
Salaries		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operation costs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Demonstration fale (establishment cost)		$0									
Total costs	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Household bins											
Household bins (assumes variable collection costs are the same)	*$0*	$0									
Enforcement greenwaste laws											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Sub-objective two											
Efficiency trials and monitoring and evaluation of service provider											
Technical expert (assume SWAT inputs are in-kind)	*$9,473*	*$10,000*									
Service fees											
Administration / collection officer	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Upgraded chipper											
Upgrade one of the existing chippers	*$4,737*	*$5,000.00*									
Sub-objective three											
Compulsory home compost use for small greenwaste materials (houses with home gardens only)											
Salaries (additional staff for awareness / compliance)	*$163,147*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*
Mobile woodchipping and disposal of large greenwaste in situ											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Converted product available for compost											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Woodchips available for compost toilets											
No additional cost of production											
Mulch production for commercial horticulture and/or sale (exploiting current excess clean dung supply)											
No additional cost of production											
Manure production for commercial horticulture and / or sale (augmenting clean dung inputs supplies)											
Capital cost of farm expansion		$125,160									
Conversion of pig pens to clean water use (number of pens)		$186,445									
Additional operating cost of commercial garden ($)		$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00
Total	*$739,074*	*$370,656.64*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*
Use of mulch in dry pig waste management											
Technical input days to assist with efficiency trials		$30,000									
Awareness / extension officer (self pick up of material)		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Total	*$109,994*	*$40,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*
Total cost of option	***$1,303,142***	**$485,027.23**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**
Economic benefits of actions											
Landfill											
Avoided cost of landfill consumption		$5,507	$5,645	$5,786	$5,930	$6,079	$6,231	$6,386	$6,546	$6,710	$6,877
Delayed needs for purchase of new site		$21,254									
Total	*$66,003*	*$26,761*	*$5,645*	*$5,786*	*$5,930*	*$6,079*	*$6,231*	*$6,386*	*$6,546*	*$6,710*	*$6,877*
Imports avoided											
Reduction in bags of soil	*$11,834*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*
Service delivery efficiencies											
Reduction in variable costs of collection ($/% gain)	*$48,229*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*
Emissions											
Value of CO2e ($/tonne)	*$41,049*	$4,928	$5,051	$5,178	$5,307	$5,440	$5,576	$5,715	$5,858	$6,005	$6,155
Home gardens											
Annual value of home garden production ($/m2)	*$38,638*	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140
Commercial gardens											
Annual increase in yield in existing operations	*$164,689*	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910
Annual value of production from additional area	*$1,097,925*	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065
Sales and fees											
Sales of bags (shouldn't strictly include without reversing out of users' surplus)	*$162,361*	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600
Household collection fees	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$1,630,728**	**$234,395**	**$213,401**	**$213,669**	**$213,943**	**$214,224**	**$214,512**	**$214,807**	**$215,110**	**$215,420**	**$215,738**
Net present value	**$327,586**										
Benefit-cost ratio	**1.25**										

TABLE D2. OPTION 2 CBA MODEL OUTPUTS ($ = AUD)

	Present value ($)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Greenwaste volumes before new actions											
Number of households		974	998	1,023	1,049	1,075	1,102	1,129	1,157	1,186	1,216
Greenwaste left for collection (m3)		2,422	2,482	2,544	2,608	2,673	2,740	2,808	2,879	2,951	3,024
Greenwaste suitable for conversion (m3)		2,180	2,234	2,290	2,347	2,406	2,466	2,528	2,591	2,656	2,722
Conversion rate (%)		33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Greenwaste after conversion (m3)		719	737	756	775	794	814	834	855	876	898
Economic costs of actions											
Sub-objective one											
Basic awareness program											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Comprehensive awareness program											
Salaries		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operation costs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Demonstration fale (establishment cost)		$0									
Total costs	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Household bins											
Household bins (assumes variable collection costs are the same)	*$0*	$0									
Enforcement greenwaste laws											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Sub-objective two											
Efficiency trials and monitoring and evaluation of service provider											
Technical expert (assume SWAT inputs are in-kind)	*$0*	*$0*									
Service fees											
Administration / collection officer	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Upgraded chipper											
Upgrade one of the existing chippers	*$0*	*$0.00*									
Sub-objective three											
Compulsory home compost use for small greenwaste materials (houses with home gardens only)											
Salaries (additional staff for awareness / compliance)	*$163,147*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*
Mobile woodchipping and disposal of large greenwaste in situ											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Converted product available for compost											
Variable cost (manpower and fuel)	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Woodchips available for compost toilets											
No additional cost of production											
Mulch production for commercial horticulture and/or sale (exploiting current excess clean dung supply)											
No additional cost of production											
Manure production for commercial horticulture and / or sale (augmenting clean dung inputs supplies)											
Capital cost of farm expansion		$0									
Conversion of pig pens to clean water use (number of pens)		$0									
Additional operating cost of commercial garden ($)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	*$0*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Use of mulch in dry pig waste management											
Technical input days to assist with efficiency trials		$0									
Awareness / extension officer (self pick up of material)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Total cost of option	***$398,939***	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**	**$53,073.70**
Economic benefits of actions											
Landfill											
Avoided cost of landfill consumption		$5,507	$5,645	$5,786	$5,930	$6,079	$6,231	$6,386	$6,546	$6,710	$6,877
Delayed needs for purchase of new site		$21,254									
Total	*$66,003*	*$26,761*	*$5,645*	*$5,786*	*$5,930*	*$6,079*	*$6,231*	*$6,386*	*$6,546*	*$6,710*	*$6,877*
Imports avoided											
Reduction in bags of soil	*$11,834*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*
Service delivery efficiencies											
Reduction in variable costs of collection ($/% gain)	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Emissions											
Value of CO2e ($/tonne)	*$41,049*	$4,928	$5,051	$5,178	$5,307	$5,440	$5,576	$5,715	$5,858	$6,005	$6,155
Home gardens											
Annual value of home garden production ($/m2)	*$18,546*	$2,467	$2,467	$2,467	$2,467	$2,467	$2,467	$2,467	$2,467	$2,467	$2,467
Commercial gardens											
Annual increase in yield in existing operations	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual value of production from additional area	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sales and fees											
Sales of bags (shouldn't strictly include without reversing out of users' surplus)	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Household collection fees	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$137,432**	**$35,731**	**$14,738**	**$15,005**	**$15,279**	**$15,560**	**$15,848**	**$16,143**	**$16,446**	**$16,756**	**$17,074**

Net present value	**$261,507**
Benefit-cost ratio	**0.34**

TABLE D3. OPTION 3 CBA MODEL OUTPUTS ($ = AUD)

	Present value ($)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Greenwaste volumes before new actions											
Number of households		974	998	1,023	1,049	1,075	1,102	1,129	1,157	1,186	1,216
Greenwaste left for collection (m3)		2,422	2,482	2,544	2,608	2,673	2,740	2,808	2,879	2,951	3,024
Greenwaste suitable for conversion (m3)		2,180	2,234	2,290	2,347	2,406	2,466	2,528	2,591	2,656	2,722
Conversion rate (%)		33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Greenwaste after conversion (m3)		719	737	756	775	794	814	834	855	876	898
Economic costs of actions											
Sub-objective one											
Basic awareness program											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Comprehensive awareness program											
Salaries		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operation costs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Demonstration fale (establishment cost)		$0									
Total costs	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Household bins											
Household bins (assumes variable collection costs are the same)	*$0*	$0									
Enforcement greenwaste laws											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Sub-objective two											
Efficiency trials and monitoring and evaluation of service provider											
Technical expert (assume SWAT inputs are in-kind)	*$9,473*	*$10,000*									
Service fees											
Administration / collection officer	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Upgraded chipper											
Upgrade one of the existing chippers	*$4,737*	*$5,000.00*									
Sub-objective three											
Compulsory home compost use for small greenwaste materials (houses with home gardens only)											
Salaries (additional staff for awareness / compliance)	*$163,147*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*
Mobile woodchipping and disposal of large greenwaste in situ											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Converted product available for compost											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Woodchips available for compost toilets											
No additional cost of production											
Mulch production for commercial horticulture and/or sale (exploiting current excess clean dung supply)											
No additional cost of production											
Manure production for commercial horticulture and / or sale (augmenting clean dung inputs supplies)											
Capital cost of farm expansion		$0									
Conversion of pig pens to clean water use (number of pens)		$0									
Additional operating cost of commercial garden ($)		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total	*$0*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*	*$0.00*
Use of mulch in dry pig waste management											
Technical input days to assist with efficiency trials		$0									
Awareness / extension officer (self pick up of material)		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Total cost of option	***$454,075***	**$73,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**	**$58,518.31**
Economic benefits of actions											
Landfill											
Avoided cost of landfill consumption		$5,507	$5,645	$5,786	$5,930	$6,079	$6,231	$6,386	$6,546	$6,710	$6,877
Delayed needs for purchase of new site		$21,254									
Total	*$66,003*	*$26,761*	*$5,645*	*$5,786*	*$5,930*	*$6,079*	*$6,231*	*$6,386*	*$6,546*	*$6,710*	*$6,877*
Imports avoided											
Reduction in bags of soil	*$11,834*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*
Service delivery efficiencies											
Reduction in variable costs of collection ($/% gain)	*$48,229*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*
Emissions											
Value of CO2e ($/tonne)	*$41,049*	$4,928	$5,051	$5,178	$5,307	$5,440	$5,576	$5,715	$5,858	$6,005	$6,155
Home gardens											
Annual value of home garden production ($/m2)	*$38,638*	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140
Commercial gardens											
Annual increase in yield in existing operations	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Annual value of production from additional area	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sales and fees											
Sales of bags (shouldn't strictly include without reversing out of users' surplus)	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Household collection fees	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$205,753**	**$44,820**	**$23,827**	**$24,094**	**$24,369**	**$24,649**	**$24,937**	**$25,233**	**$25,535**	**$25,845**	**$26,163**
Net present value	$248,322										
Benefit-cost ratio	0.45										

TABLE D4. OPTION 4 CBA MODEL OUTPUTS ($ = AUD)

mainstream
economics and policy

	Present value ($)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Greenwaste volumes before new actions											
Number of households		974	998	1,023	1,049	1,075	1,102	1,129	1,157	1,186	1,216
Greenwaste left for collection (m3)		2,422	2,482	2,544	2,608	2,673	2,740	2,808	2,879	2,951	3,024
Greenwaste suitable for conversion (m3)		2,180	2,234	2,290	2,347	2,406	2,466	2,528	2,591	2,656	2,722
Conversion rate (%)		33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Greenwaste after conversion (m3)		719	737	756	775	794	814	834	855	876	898
Economic costs of actions											
Sub-objective one											
Basic awareness program											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Comprehensive awareness program											
Salaries		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operation costs		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Demonstration fale (establishment cost)		$0									
Total costs	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Household bins											
Household bins (assumes variable collection costs are the same)	*$0*	$0									
Enforcement greenwaste laws											
Salaries		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Operation costs		$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110	$2,110
Total costs	*$97,434*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*	*$12,962*
Sub-objective two											
Efficiency trials and monitoring and evaluation of service provider											
Technical expert (assume SWAT inputs are in-kind)	*$9,473*	*$10,000*									
Service fees											
Administration / collection officer	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
Upgraded chipper											
Upgrade one of the existing chippers	*$4,737*	*$5,000.00*									
Sub-objective three											
Compulsory home compost use for small greenwaste materials (houses with home gardens only)											
Salaries (additional staff for awareness / compliance)	*$163,147*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*	*$21,705*
Mobile woodchipping and disposal of large greenwaste in situ											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Converted product available for compost											
Variable cost (manpower and fuel)	*$40,925*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*	*$5,445*
Woodchips available for compost toilets											
No additional cost of production											
Mulch production for commercial horticulture and/or sale (exploiting current excess clean dung supply)											
No additional cost of production											
Manure production for commercial horticulture and / or sale (augmenting clean dung inputs supplies)											
Capital cost of farm expansion		$125,160									
Conversion of pig pens to clean water use (number of pens)		$0									
Additional operating cost of commercial garden ($)		$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00	$59,052.00
Total	*$562,446*	*$184,212.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*	*$59,052.00*
Use of mulch in dry pig waste management											
Technical input days to assist with efficiency trials		$30,000									
Awareness / extension officer (self pick up of material)		$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852	$10,852
Total	*$109,994*	*$40,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*	*$10,852*
Total cost of option	***$1,126,515***	**$298,582.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**	**$128,422.58**
Economic benefits of actions											
Landfill											
Avoided cost of landfill consumption		$5,507	$5,645	$5,786	$5,930	$6,079	$6,231	$6,386	$6,546	$6,710	$6,877
Delayed needs for purchase of new site		$21,254									
Total	*$66,003*	*$26,761*	*$5,645*	*$5,786*	*$5,930*	*$6,079*	*$6,231*	*$6,386*	*$6,546*	*$6,710*	*$6,877*
Imports avoided											
Reduction in bags of soil	*$11,834*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*	*$1,574*
Service delivery efficiencies											
Reduction in variable costs of collection ($/% gain)	*$48,229*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*	*$6,416*
Emissions											
Value of CO2e ($/tonne)	*$41,049*	$4,928	$5,051	$5,178	$5,307	$5,440	$5,576	$5,715	$5,858	$6,005	$6,155
Home gardens											
Annual value of home garden production ($/m2)	*$38,638*	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140	$5,140
Commercial gardens											
Annual increase in yield in existing operations	*$164,689*	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910	$21,910
Annual value of production from additional area	*$1,097,925*	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065	$146,065
Sales and fees											
Sales of bags (shouldn't strictly include without reversing out of users' surplus)	*$162,361*	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600	$21,600
Household collection fees	*$0*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$1,630,728**	**$234,395**	**$213,401**	**$213,669**	**$213,943**	**$214,224**	**$214,512**	**$214,807**	**$215,110**	**$215,420**	**$215,738**
Net present value	**$504,213**										
Benefit-cost ratio	**1.45**										

The **Pilot Program for Climate Resilience: Pacific Regional Track (PPCR-PR)** is a regional program which aims to strengthen integration of climate change and disaster risk considerations into 'mainstream' policy making and related budgetary and decision-making processes (i.e. 'climate change and disaster risk mainstreaming').

The PPCR-PR is implemented by the Secretariat of the Pacific Regional Environment Program (SPREP) and Asian Development Bank (ADB) and is funded through the Climate Investment Funds (CIF).

SPREP
Secretariat of the Pacific Regional Environment Programme