Cost Benefit Analysis Of an Organic Waste Collection Service in Auckland

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Internal Report

Executive summary

This report contains an indication of the likely economic costs and benefits associated with a weekly food waste collection service (the Service) for urban households in Auckland. The service covers all food waste and on average over the 30 year study period, the service is expected to divert almost 50,000 tonnes of food waste per year from landfills.

The kerbside food waste collection service was proposed under the Waste Management and Minimisation Plan (WMMP) (2012) to divert food waste from landfill to reduce the harm from waste.

The service is due to commence in March 2018, with further roll-out planned in the 2018-2020 period. It is designed with the target of reducing household refuse per person from 160 to 110 kilograms and the overarching goal of zero waste to landfill by 2040. In addition, the service could assist in the achievement of Auckland Council commitments under the Low Carbon Action Plan to reduce carbon emissions associated with waste.

A range of potential benefits is possible as a result of the service, including avoided costs associated with landfill operation and commissioning, greater soil yields from composting, better local air quality and less groundwater contamination. Given the scope and relevant time period for this initial analysis, we focussed on two benefits that were most likely to be material and that had a relatively high likelihood of occurring. These benefits relate to a gain in consumer welfare and the avoided social costs associated with a reduction in greenhouse gas emissions as a result of the service.

The cost categories used in the analysis relate to material collection, transport and processing, administrative and rollout costs, and the economic costs of public expenditure on the service. Both the costs and benefits used in this study were informed by studies and insights from within New Zealand and overseas.

We compared the economic effects of the service against the status quo of no service, using a 30 year assessment period and a discount rate of four per cent. We estimate that society would be better off by between $64 million and $402 million on a present value basis as a result of the service. Benefits exceed costs by between 19 per cent and 109 per cent.

This range of figures represents “upper bound” and “lower bound” estimates, based on key assumptions and parameters including household use of the service, the willingness of households to pay for the service and the social cost of greenhouse gas emissions. There was insufficient reliable data to calculate a robust central or medium estimate, but a simple midpoint would suggest net benefits of $233 million would accrue (over the 30 year study period) and benefits would outweigh costs by around 65 per cent (i.e. a benefit-cost ratio of 1.65).

Results	Upper bound	Lower bound
Total benefits ($m)	$771.02	$410.17
Total costs ($m)	$369.19	$345.82
Net benefits ($m)	$401.83	$64.35
Benefit-cost ratio (BCR)	2.09	1.19

The vast majority (around 98 per cent) of estimated total benefits relate to consumer welfare. We estimated this benefit using survey data from a previous New Zealand study on the value households would be willing to pay for organic recycling. While not perfect, this study represents the best available evidence relevant to the service. We also drew on survey data following food waste trials in Auckland to calculate the proportion of households that would be willing to pay for the service. Importantly, willingness to pay is not strictly related to actual use of the service; people are frequently willing to pay for things that they may never use themselves, with National Parks being a common example.

Sensitivity analysis revealed that the willingness to pay input had the greatest effect on overall results. Adjusting a key parameter that relates changes in willingness to pay to changes in income allows us to model different values for willingness to pay (see table below). Assuming that household willingness to pay for the service has remained unchanged since 2007 suggests that society would, in the worst case scenario, be made worse off by around $52 million from the service (although a simple midpoint of the lower and upper bounds suggests net benefits of around $73 million and benefits exceeding costs by around 20 per cent) .

Income elasticity of willingness to pay	0 (2007 values)		0.5		1 (2017 values)	
	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound
Net benefits/NPV	$199.29	-$51.90	$300.56	$6.23	$401.83	$64.35
Benefit- cost ratio	1.54	0.85	1.81	1.02	2.09	1.19

Altering the discount rate used had predictable effects, given upfront capital costs and ongoing benefits. With a discount rate of 12 per cent, the “lower bound” scenario sees society being made slightly worse off from having the service as opposed to no food waste collection service being in place (see table below). Altering the time period for the analysis (i.e. truncating the analysis to 10-year and 20-year periods respectively) had similar results. Altering the remaining parameters, predominantly around waste volumes and rates of household service use, did not materially change the positive results achieved. This is largely due to the willingness to pay benefits category being invariant to such changes, while costs change proportionally.

Discount rate	2%		4%		7%		12%	
	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound
Net benefits ($m)	$563.48	$104.27	$401.83	$64.35	$252.23	$28.20	$126.52	-$0.88
Benefit-cost ratio	2.16	1.23	2.09	1.19	1.97	1.12	1.77	0.99

While the study is indicative in nature, it supports the view that society is likely to be made better off from a food waste collection service than the alternative of no service. As is common in 'exploratory' studies of this nature, the precision with which estimates of costs and benefits can be made could increase with further more detailed work.

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1.0 Introduction

A kerbside food waste collection was proposed under the Waste Management and Minimisation Plan (WMMP), Auckland Council (2012), to divert around 40,000 tonnes of waste from landfill, contributing to the WMMP objectives to send less waste to landfill and reduce the harm from waste.

The service is due to commence in March 2018, with further roll-out planned in the 2018-2020 period. It is designed to divert food waste from landfill, particularly with the target of reducing household refuse per person from 160 to 110 kilograms and the overarching goal of zero waste to landfill by 2040. In addition, the service could assist in the achievement of Auckland Council commitments under the Low Carbon Action Plan to reduce carbon emissions associated with waste.

Auckland Council (the council) is interested in better understanding the costs and benefits of a collection service for organic/food waste in Auckland (the service).

The council's interest is motivated by "value for money" concerns associated with public expenditures. That is, are ratepayers/society made better off from the council investment in such a service. The council commissioned a cost-benefit analysis (CBA) to address this question.

As a result, this report provides an indication of the likely economic costs and benefits associated with the service. In terms of the level of detail, this analysis falls somewhere between a 'preliminary' and 'indicative' assessment, using the taxonomy of analysis levels employed by PHARMAC (2004) and others.

The report is structured as follows:

- Section 2 describes the service in more detail.
- Section 3 outlines the nature of costs and benefits relevant to this analysis.
- Section 4 details the estimated effects of the service and explains the basis of those estimates, including the base case, caveats and assumptions.
- Section 5 discusses the likely net effect of the proposal.

2.0 The proposal

This section provides an overview of the food waste collection service, using the most up-to-date information available.

2.1 Operational factors

The food waste collection service will operate in a similar manner as the existing recycling and household refuse services. The "three-bin" system will be in place by 2020, whereby households would collect food waste in a six-seven litre caddy in their kitchen and then empty that caddy into a bespoke designed larger 23 litre bin that would be put at their kerbside. Collection would be on a weekly basis, using specialist vehicles.

In addition to the specialist collection vehicles needed for collection and transport of food waste, there are also physical capital needs in terms of processing facilities. Historically, the lack of appropriate organic waste processing facilities has been one of the key barriers to greater recovery of organic waste in most parts of New Zealand (WasteNot Consulting and Eunomia, 2010). A range of generic processing methods is possible, including in-vessel composting, windrow composting, vermicomposting, anaerobic digestion, pyrolysis, and gasification.

The costs and other requirements associated with processing facilities are influenced by factors such as who will be procuring the facilities, and how they will be procured (e.g. models such as DBO: design-build-operate, BOOT: build, own, operate, transfer at end of contract, CCO: council-controlled organisation). In addition, the consideration of proprietary technologies is relevant.

We understand that while existing transfer stations could be used for some functions (e.g. bulking), the remaining collection, transport and processing requirements as a result of the food waste service would be additional to current availability. The costs used in this analysis reflect the limited current capacity for processing food waste (i.e. all estimated operational costs are treated as incremental in nature).

2.2 Range of food waste included

All food waste would be included in the service. This includes:

- vegetable and fruit scraps;
- meal leftovers, including meat and fish scraps, bones and shellfish cases;
- bread, pasta and rice;

- paper towels and tissues;
- dairy products and egg shells;
- coffee grounds, tea leaves and tea bags; and
- indoor cut flowers.

At present, food waste makes up around 45 per cent of household waste sent to landfill.[1] This material would be diverted away from landfill through the new collection service and processed for re-use (e.g. as compost). Any fuel produced from the process, in the form of methane, can be turned into electricity or used in vehicles.

2.3 Governance

The service would fall under the auspices of the council in the same manner as existing kerbside recycling and refuse collections services. As such, the council would take a decision to tender contracts with private providers or use in-house providers for collection services. No direct role is envisaged for central government. The nature and length of the contracts is not known at this time, but the working assumption used in the analysis is that contracts would roll over on the same terms upon expiry. This simplifying assumption means we can apply annual contract costs across each year in our study period (i.e. assume a single contract for the entire study period).

2.4 Why Cost Benefit Analysis?

A cost benefit analysis (CBA) systematically compares the costs associated with undertaking a policy option with the anticipated benefits, relative to the 'base case.' The 'base case' or status quo is the expected costs and benefits if the policy option is not pursued. The comparative exercise determines whether the policy is expected to deliver net benefits to society and/or which of a range of options is best (Marsden Jacob Associates, 2014).

CBA is valued by decision-makers as it produces a clear understanding of the economic (resource) costs and benefits of particular proposals (i.e. whether society will be better off from the proposal). In addition, the results of CBAs are readily comparable across a range of policy and industry areas, enabling comparison (and prioritisation) of initiatives in a manner that is consistent and coherent.

[1] http://ourauckland.aucklandcouncil.govt.nz/articles/news/2017/05/three-bin-rollout-coming-to-papakura/

The relevant perspective taken in a CBA is that of society as a whole, as opposed to particular groups or individuals or entities. This means that transfers (of costs and/or benefits) with no change to the underlying level of costs or benefits are not ‘counted’ in the analysis. What CBA does count is the extent to which society is made better off (well-being/welfare is improved) as a result of a policy proposal or action.

A distributional analysis is often undertaken in addition to a CBA. Distributional analysis focuses on the financial impacts across various stakeholder groups, such as local government, producers, retailers and consumers. Such analysis considers in more detail the transfers between parties. The clear separation of efficiency and distributional issues is important for ensuring that stakeholder perspectives are not confused with implications for society as a whole.

CBA is also subject to limitations. A review of cost-benefit studies in the electricity industry by the Electric Energy Market Competition Task Force (2006) provides the following generalisable insights:

- Assessments often overemphasised the benefits with little discussion of the costs of restructuring proposals.
- Models are gross simplifications of the complexity of markets and make simple and at times misleading assumptions about market behaviour.
- There are often data limitations necessitating assumptions, which can drive the results of the modelling. Sensitivity analysis of assumptions made is important.
- Often some of the most significant benefits are difficult to quantify (and monetise) and are therefore omitted form the studies (and reported results).

The main take-out from the review is that the criteria for decision-making should in most cases be broader than the quantified information available from the CBA. In other words, CBA is a useful (and often necessary) input into decision-making, but should not be the sole determinant.

2.5 Experience elsewhere

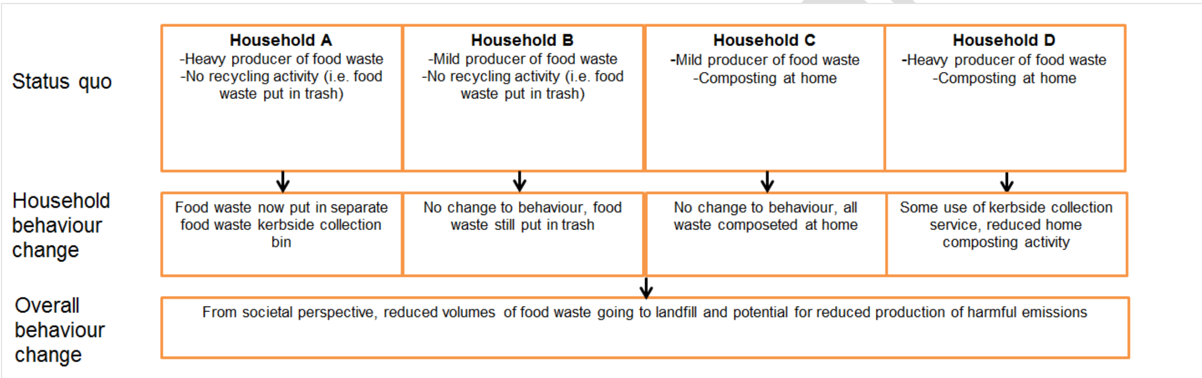
We have reviewed a number of studies that discuss costs and benefits of food/organic waste collection systems. We conclude that there is a relative dearth of economic CBA studies that can be readily drawn from. Most of the studies reviewed do not establish key costs and benefits in an economic sense, and appear to have “too many claims chasing too few facts.” That is, the evidential basis in support of impacts (however defined or described) is somewhat patchy. Hence, while the available studies were useful for background and context, we rely on ‘related’ studies (e.g. an economic CBA of recycling) and our own enquiries for key insights.

3.0 Impact descriptions and basis

This section introduces the key impacts (costs and benefits) likely to result from the introduction of a food waste collection service. The major factor driving these impacts is behaviour change; specifically moves to separate food waste from general refuse into kerbside collection. A stylised depiction of such behaviour change is presented below with reference to four archetypal households (see Figure 1).

Overall, a reduction in the volume of food waste going to landfill is posited. Obviously, for this to occur, the number of households (and consequently the amount of food waste produced, given their current behaviour) in categories A and D would need to exceed those in categories B and C. Resulting cost and benefit impacts are described more fully further below.

Figure 1 Stylised behaviour change from the service



Source: Sapere

3.1 Taxonomy of costs and benefits

There are myriad costs and benefits that could be included in the analysis, with differing levels of granularity. Our approach is to focus on those costs and benefits that are most relevant (i.e. are "universal" in nature as opposed to relying on specific design features), and where there is useful data or proxies that improve robustness.

Overview descriptions and comments on the main cost components for the proposed food waste collection service are outlined in

Table **1**. Detail on the calculation basis and cost estimates is included further below, but it is clear that costs associated with provision of infrastructure for processing and collection of food waste material are the major cost components of the service.

Table 1 Cost descriptions

Costs	Components/drivers	Comment
Collection costs	Upfront capital costs for: • Kerbside bins and kitchen caddies • Trucks Operating costs of the collection service	Kerbside collection costs essentially bundled into single collection rate per tonne (i.e. no separation of capital and operating costs) Capital costs for provision of bins and kitchen caddies (including renewal) identified separately
Processing costs	Capital (plant) and operating (inputs) costs resulting from a new service Consolidation costs associated with aggregating material in most efficient manner	Capital costs separated from fixed and variable operating costs Uniform constant cost per tonne used for consolidation costs
Transport costs	Haulage costs associated with moving tonnages of consolidated material from processing facility	Weighted average cost per tonne across regional areas used
Administrative costs	Implementation/roll-out costs, including marketing and education materials Staff time involved in administration and oversight	High-level, guesstimate basis used
Deadweight costs	Costs associated with distortions due to raising of public funds used for proposal	Nets out private costs associated with capital provision

Source: Authors

The potential categories of benefit for the food waste collection service are shown in

Table **2** below. This table is largely expositional, designed to outline possible beneficial impacts. Unlike the cost categories above, not all of the benefits listed are fully estimable, in terms of quantification and monetisation, either through lack of data or imprecision. Nevertheless, for completeness, we include those benefit components here and discuss them qualitatively further in the report.

Table 2 Benefit descriptions

Benefits	Components/drivers	Comment
Avoided social costs	Reduced greenhouse gas emissions, including from transport Reduced incidence of ground water contamination Reduced costs of landfill construction and management	Both direct and indirect impacts estimated in some categories (i.e. externalities are included to the extent possible) Market (paid) and non-market (volunteer) costs included
Welfare gains	Households' willingness to pay for food waste collection	Estimate derived from 2007 study for the Ministry for the Environment
Value of materials collected and processed	Food waste collected and processed has value in use as compost	Market conditions for compost and fertiliser need to be clearly understood to determine incremental impact from the new service
Indirect and/or co-benefits	More efficient source of energy production as a result of methane capture Lower collection volumes for general refuse	Energy supply not main purpose of food waste collection Only efficiency gains to service providers are relevant to the analysis.

Source: Authors

3.2 Baseline context

In any CBA a strong understanding of the 'counterfactual' is required. The 'counterfactual' is essentially what would happen in the absence of a food waste collection service. It can be thought of as the status quo or baseline option. Incremental effects (costs and benefits) of the proposed service are measured against this 'counterfactual' situation.

At present there is no kerbside collection service specifically for domestic/household food waste in Auckland. The vast majority of such food waste is collected as part of the kerbside refuse collection system, for disposal at landfills in the region. However, some food waste is composted at home by householders. While we are not able to identify with any precision the extent of such activity, this is not a major concern given the assumptions used in the analysis. In particular, we assume that home composting activity continues after the introduction of the kerbside collection service, but that there is some use of the dedicated kerbside collection service by home composters at times (i.e. the kerbside collection system and home composting are complements as opposed to substitutes). This is consistent with results from previous food waste collection trials for North Shore, Papakura and Manurewa in 2014.

3.2.1 Predicted food waste amounts diverted

The main source of our estimates of food waste diverted from landfill is the 2014 trials mentioned above, and subsequent research on the trial undertaken in 2016. These sources gave rise to a range of parameters used in this analysis. In particular, the:

a) rate at which households use the service was originally 72 per cent, rising to 80 per cent two years later;

b) rate at which households indicated they *would* use the service in future was 90 per cent;

c) average weekly weight of food waste put out by households using the service was 3.8 kilograms; and

d) rate at which households set out their bin each week was 50 per cent.

The number of households (eligible properties) is the other factor in the calculation of potential food waste amounts diverted from landfill. These numbers, which relate specifically to urban households for our analysis, were derived using the medium projections from the Auckland Transport Model, growth scenario I11.

Table 3 calculates the total predicted food waste that would be collected by the new service (and hence diverted from landfill) on an annual basis. It shows that, on average, around 49,000 tonnes of food waste would be collected on an annualised basis, starting from almost 39,000 tonnes in 2020 and rising to almost 59,000 tonnes in 2049.[2] As there is no current food waste collection service, these figures represent the incremental effect of the new service.

[2] Note that this table presents annualised figures, assuming full operation of all collection and processing facilities. More realistic figures are used further in the analysis to reflect timing of facilities completion and speed of take-up assumptions.

Table 3 Predicted food waste amounts diverted (tonnes thousand) on annualised basis 2020- 2049

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Total households	491,405	500,465	509,593	518,720	527,848	536,976	546,103	555,249	564,394	573,540
Households participating	393,124	400,372	407,674	414,976	422,278	429,581	436,883	444,199	451,515	458,832
Average bins set out	196,562	200,186	203,837	207,488	211,139	214,790	218,441	222,100	225,758	229,416
Tonnage collected	**38,841**	**39,557**	**40,278**	**41,000**	**41,721**	**42,443**	**43,164**	**43,887**	**44,610**	**45,333**

Source: Auckland Transport Model, Gravitas (2016) and Authors' estimate

Table 3 Predicted food waste amounts diverted (tonnes thousand) on annualised basis 2020- 2049 (continue)

	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Total households	582,685	591,831	600,924	610,018	619,112	628,206	637,300	646,664	656,028	665,392
Households participating	466,148	473,464	480,740	488,015	495,290	502,565	509,840	517,331	524,823	532,314
Average bins set out	233,074	236,732	240,370	244,007	247,645	251,283	254,920	258,666	262,411	266,157
Tonnage collected	**46,055**	**46,778**	**47,497**	**48,216**	**48,935**	**49,653**	**50,372**	**51,112**	**51,852**	**52,593**

Table 3 Predicted food waste amounts diverted (tonnes thousand) on annualised basis 2020- 2049 (continue)

	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
Total households	674,756	683,336	691,242	699,238	707,328	715,511	723,788	729,703	735,666	741,678
Households participating	539,805	546,669	552,993	559,391	565,862	572,408	579,030	583,762	588,533	593,342
Average bins set out	269,902	273,335	276,497	279,695	282,931	286,204	289,515	291,881	294,266	296,671
Tonnage collected	**53,333**	**54,011**	**54,636**	**55,268**	**55,907**	**56,554**	**57,208**	**57,676**	**58,147**	**58,622**

4.0 Estimated effects

This section presents estimates of the costs and benefits relevant to the analysis. When estimating these costs and benefits we acknowledge that the annualised predicted volumes of material diverted from landfill identified above will take time to be fully realised. For relevant costs and benefits we apply a ramped approach over four years (following the first year in the study, which is exclusively construction-related) to cost and benefit accrual. In particular, we assume that achievement of predicted collection volumes (and the resulting costs and benefits associated with such volumes) is as follows:

- 2020 30% (however, given the construction period, 15% is assumed)
- 2021 50%
- 2022 70%
- 2023 100%

4.1 Cost

This section presents the estimated costs of the proposed service. The costs in this section are presented in non-discounted (actual) terms. All of the estimates contained in this section are relative to a counterfactual of “no food waste kerbside collection.” The majority of costs used in the analysis come from a costing model developed by Auckland Council, with key inputs from private providers of key aspects of the proposed service. ***As such, this report contains information that is commercially sensitive and therefore is not to be made public.***

4.1.1 Collection costs

Collection costs as we have characterised them entail two separate costs- kerbside collection costs of private service providers and the provision of bins to households to essentially ‘store’ collected material and transfer that material to the kerbside for collection. A seven litre kitchen caddy as well as a larger 23 litre kerbside bin (into which the caddy is emptied as required) will be provided to households.

The kerbside collection costs are calculated by multiplying the tonnage collected by the cost per tonne of collection estimated by service providers in a process undertaken by Auckland Council. A contingency of 20 per cent is added to this estimate to reflect uncertainty.

As mentioned earlier, the cost per tonne is effectively a 'bundled' rate. It does not identify capital costs (e.g. costs of purchasing vehicles) as distinct from operating costs such as labour, fuel and the like. Nor does the cost rate used distinguish fixed and variable costs. Nevertheless, we are confident that the information used is the best available at this time and that the use of such information does not materially detract from, or call into question the robustness of the results of this analysis.

Based on the tonnages estimated in the previous section and the constant unit cost assumed of $273.08 per tonne ($227.57 per tonne plus the contingency of 20 per cent), total annualised kerbside collection costs for the 30-year study period were estimated to be around **$387 million** (annualised kerbside collection costs start at $10.61 million in 2020 and total $15.88 million in 2048). Additional detail, including the actual costs per year used in the overall calculations taking into account the assumed phase-in period are contained in further sections below.

The second element of cost relates to the kitchen caddy and disposal bin being supplied to households by the council. The kitchen caddy is a small bin to be used inside the home to collect food waste, before transferring the waste to a larger bin that then gets set out on the kerbside for weekly collection. The key assumptions and parameters used to calculate capital and distribution costs for bins and kitchen caddies are as follows:

- Unit price for kitchen caddies is $3.68 ($3.20 plus a contingency of 15%)
- Unit price for kerbside collection bin is$17.25 ($15.00 plus contingency of 15%)
- Costs to distribute bin and kitchen caddy is $5.11 per household
- Kerbside collection bins and kitchen caddies have a useful life of 10 years
- Kerbside collection bins and kitchen caddies require replacement for loss and/or damage at a rate of 3 per cent per year
- All kerbside collection bins and kitchen caddies will be replaced after 10 years[3]
- Kerbside collection bins and kitchen caddies have no net residual value once replaced[4]

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[3] We understand that the costs of tracking which bins have been replaced and their date for replacement is prohibitive. Thus, all bins, regardless of age will be replaced at the same time.
[4] Implicitly this assumes that any disposal costs for the replaced bins equals any residual value that the bins would have at the time of replacement.

Based on these assumptions and inputs, annualised capital and distribution costs for kerbside collection bins and kitchen caddies are estimated to total around $62.2 million over the 30-year study period, comprising:

- $12.8 million in 2020
- $15.2 million in 2030
- $17.6 million in 2040

Replacement costs of around $0.638 million on average per year in the intervening years ($0.566 million initially, rising to $0.648 million at the end of the study period).

4.1.2 Offsetting reduction in refuse collection costs

Overseas jurisdictions where a food waste collection service is in place suggest that cost savings may arise with respect to general kerbside refuse collection services, as operators are collecting far less refuse in total once food waste has been diverted. To the extent that there are cost savings to the council that are reflected in the contracting arrangements they are able to negotiate with service providers, there is an offsetting reduction in revenue to such providers. From an economic perspective, that process is essentially a transfer between parties and thus is not relevant to a CBA.

However, if the diversion of food waste material as a result of the introduction of a food waste collection service gives rise to productivity improvements (i.e. efficiency-based impacts), those effects are relevant and should be included in the CBA.

While we acknowledge the potential for offsetting reductions in refuse collection costs to come about as a result of a new food waste collection service (e.g. through route re-optimisation, and better resource utilisation and allocation as well as the potential for less frequent collection) we do not have the necessary information at hand to estimate the existence and magnitude of such impacts. Therefore, at this stage, reductions in collection costs elsewhere in the economy are not included in the analysis.

4.1.3 Processing costs

Processing costs are comprised of both capital and operating elements. Capital costs are largely 'one-off' in nature and relate to the provision of buildings, plant and bins, while operating costs are ongoing in nature. The life span of buildings is assumed to be 30 years, meaning there is no residual value at the end of the study period. Plant renewal (e.g. machines to move waste) is captured in the respective unit costs used through the study period and no residual value is assumed.

Operating costs have fixed and variable elements. The former do not change with volumes of food waste processed and typically include salaries for permanent employees, ground lease, repairs and maintenance, corporate overhead/administration and the like. Variable costs do change based on the volume of material processed and include electricity and other fuel costs, casual labour costs and production supplies.

While economic CBA does not distinguish between capital and operating expenditures (i.e. costs are costs if they consume resources that have a value in use elsewhere), what is important is the timing of such costs. Capital costs to construct buildings or buy plant and machinery are incurred prior to actual processing operations taking place and are usually incurred in a short space of time. Operating expenditures occur throughout the course of processing activity.

Processing costs (including consolidation) are calculated by multiplying the expected amount of food waste collected (i.e. tonnage diverted from landfill) by the combined fixed and variable costs of processing. Using the tonnages contained in Table 3 above and a combined processing cost of $23.55 per tonne results in a total annualised cost across the study period of around **$33.36 million**, from an initial cost in 2020 of around $0.915 million to around $1.37 million in 2048.

Upfront capital costs of **$38.2 million** arise in years 2019 and 2020 (i.e. before the service is fully operational). For simplicity, we assume these costs are split evenly across the two years.

Consolidation costs are estimated to be $10 per tonne, which results in total annualised costs across the 20-year study period of almost **$14.2 million**, from an initial annualised cost in 2020 of around $0.39 million to around $0.58 million in 2048.

4.1.4 Haulage costs

Haulage costs are estimated separately in the relevant cost modelling so we present them separately in this report. Again, the basic calculation involves multiplying tonnages by the cost of haulage per tonne. Doing so yields an estimate of total annualised costs across the 30-year study period of **$30.3 million**, from an initial cost in 2020 of around $0.83 million to around $1.11 million in 2048.

4.1.5 Administration costs

There are costs associated with the roll-out of the food waste collection service, marketing and education around the service and the council staff time costs for monitoring, enforcing and reviewing the operation of the scheme. On an annualised basis, we estimate costs relating to roll out and marketing/education of **$15.7 million** across the 30-year study period. This cost is comprised of an initial $1million roll out cost and almost $0.68 million marketing cost in the first year of operation, and an on-going marketing cost of $0.5 million annually.

Staff time costs have not yet been specifically included in the analysis. Anecdotally, these costs are thought to be in the range of $100,000 per year (half of which relates to consent compliance and monitoring and the other half to oversight and contract negotiation). It is thought that the rollout and marketing cost estimates (which are not granular in nature) are sufficient to capture the possibility of such staff costs, so no specific allowance is made at this stage.

4.1.6 Deadweight costs

Deadweight costs, otherwise known as the 'excess burden,' are costs associated with the distortions that result from a tax being in place to raise necessary funding for public projects. In the absence of a tax, consumption choices would differ from what they would be with a tax. That is, people move away from things that are taxed and towards things that are not. This reduces economic welfare.

For the purposes of this analysis, no distinction is made between taxes and rates. The Treasury recommends that 20 per cent be added to project costs that are funded by taxation and we apply this deadweight cost to all costs funded from public sources. As the initial capital outlay of $38.2 million is to be half-funded by the private sector, we deduct $19.1 million from project costs for which deadweight costs apply.

Annualised deadweight costs across the entire 30-year study period are estimated to total **$112.3 million**, comprising:

- $1.9 million relating to the initial capital outlay of $9.7 million in 2019
- $7.4 million in the following year
- $6.16 million in 2030
- $7.11 million in 2040
- $3.45 million on average in the intervening years ($2.8 million initially, rising to $4.0 million at the end of the study period)

Table 4 shows the total estimated costs by category by year. The figures are presented on an annualised basis (i.e. not taking into account the projected ramp-up of volumes until full realisation in year four).

Table 4 Total costs ($m) on an annualised basis 2019- 2048

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Capex	$19.11	$31.90	$0.57	$0.57	$0.58	$0.59	$0.59	$0.60	$0.60	$0.61
Processing cost- total		$0.91	$0.93	$0.95	$0.97	$0.98	$1.00	$1.02	$1.03	$1.05
Haulage		$0.83	$0.85	$0.86	$0.88	$0.89	$0.91	$0.92	$0.94	$0.95
Consolidation		$0.39	$0.40	$0.40	$0.41	$0.42	$0.42	$0.43	$0.44	$0.45
Collection cost		$10.61	$10.80	$11.00	$11.20	$11.39	$11.59	$11.79	$11.98	$12.18
Other costs- marketing, rollout		$1.68	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
Deadweight costs	$1.91	$7.35	$2.81	$2.86	$2.91	$2.95	$3.00	$3.05	$3.10	$3.15
TOTAL	**$21.02**	**$53.67**	**$16.85**	**$17.14**	**$17.43**	**$17.72**	**$18.02**	**$18.31**	**$18.60**	**$18.89**

Source: Information provided by Auckland Council's waste solutions department and authors' calculations

Table 4 Total costs ($m) on an annualised basis 2019- 2048 (continue)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Capex	$0.62	$15.17	$0.63	$0.63	$0.64	$0.65	$0.65	$0.66	$0.67	$0.68
Processing cost- total	$1.07	$1.08	$1.10	$1.12	$1.14	$1.15	$1.17	$1.19	$1.20	$1.22
Haulage	$0.97	$0.98	$1.00	$1.02	$1.03	$1.05	$1.06	$1.08	$1.09	$1.11
Consolidation	$0.45	$0.46	$0.47	$0.47	$0.48	$0.49	$0.50	$0.50	$0.51	$0.52
Collection cost	$12.38	$12.58	$12.77	$12.97	$13.17	$13.36	$13.56	$13.76	$13.96	$14.16
Other costs- marketing, rollout	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
Deadweight costs	$3.20	$6.16	$3.29	$3.34	$3.39	$3.44	$3.49	$3.54	$3.59	$3.64
TOTAL	**$19.18**	**$36.94**	**$19.77**	**$20.06**	**$20.35**	**$20.64**	**$20.93**	**$21.22**	**$21.52**	**$21.82**

Table 4 Total costs ($m) on an annualised basis 2019- 2048 (continue)

	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Capex	$0.68	$17.57	$0.68	$0.66	$0.67	$0.68	$0.69	$0.70	$0.64	$0.64
Processing cost- total	$1.24	$1.26	$1.27	$1.29	$1.30	$1.32	$1.33	$1.35	$1.36	$1.37
Haulage	$1.12	$1.14	$1.16	$1.17	$1.18	$1.20	$1.21	$1.22	$1.23	$1.24
Consolidation	$0.53	$0.53	$0.54	$0.55	$0.55	$0.56	$0.57	$0.57	$0.58	$0.58
Collection cost	$14.36	$14.56	$14.75	$14.92	$15.09	$15.27	$15.44	$15.62	$15.75	$15.88
Other costs- marketing, rollout	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50
Deadweight costs	$3.69	$7.11	$3.78	$3.82	$3.86	$3.90	$3.95	$3.99	$4.01	$4.04
TOTAL	**$22.12**	**$42.68**	**$22.67**	**$22.90**	**$23.16**	**$23.42**	**$23.69**	**$23.95**	**$24.07**	**$24.26**

5.0 Benefits

This section presents the estimated benefits of the food waste service. The benefits in this section are presented in non-discounted (actual) terms. The estimates contained in this section are relative to a counterfactual of “no food waste kerbside collection.”

We have identified a range of possible benefits (see

Table **2** and **Error! Reference source not found.**). However for reasons of tractability and efficiency of effort, for this high-level/initial CBA, we have focussed on two major benefit categories:

- the avoided cost of greenhouse gas emissions; and
- the gains in welfare to householders

Before detailing our calculation process and resulting estimates, we first describe the range of possible benefits not included in the analysis.

5.1 Potential benefits not included in calculations

This section discusses some of the main benefits that we didn't analyse due to their relative immateriality and/or data availability constraints.

5.1.1 Landfill cost saving

The kerbside food waste collection service could potentially extend the life of current landfills by diverting food waste from landfill. This could potentially result in avoidance of costs associated with creating a new landfill were existing capacity to be exhausted within the time period of the analysis. The food waste collection service could also save some of the operational cost of managing any closed landfill(s) in the study period as well.

The result of the primary consultation with waste management experts indicated that while this benefit could have a high magnitude impact, it would have a moderate likelihood of occurring. Auckland Council has a policy to progressively achieve zero waste by 2040 and available information does not suggest there would be a lack of capacity by then (see Table 5). Further, we understand that the amount of food waste diverted from landfills from the service would represent less than five per cent of total waste to landfill in a given year.

In relation to the potential for cost savings as a result of lower costs of managing closed landfills, there is insufficient evidence available for us to make a determination. Therefore, we have not included any potential benefits relating to landfill requirements and/or management in the analysis.

Table 5 Auckland's Landfill lifespan

Landfill	Opening date	Closing date	Comment
Redvale Landfill (Waste Management)	1993	2028	WMNZ[5] applied for extension until 2049,but this was declined (on appeal), so 2028 date stands, with stricter air discharge conditions
Hampton Downs (EnviroWaste)	2005	2030	Waikato Regional Council website states it obtained a 25 year consent in 2005, though EnviroWaste states it will operate for 100 years, therefore it could operate well beyond 2040
Whitford Landfill (WDS)	1970s?	2024	It has recently been extended to 2041 and will likely only continue to take relatively small quantities of municipal waste.
Claris Landfill (The council)	Informally >50 years	2027	Old unsanitary landfill. Only takes small amount of waste from Great Barrier Island
Puwera landfill (Northland Waste)	2003	2038	35 year consent obtained in 2003, though likely to get an extension beyond 2040

Source: Information provided by Auckland Council's waste solutions department

5.1.2 Energy production

Methane is produced from decomposition of organic waste at landfills. The methane can be collected and used as biogas for generation of electricity (or used directly as a fuel in motor vehicles). In New Zealand, landfill is the source of about 70 per cent of utilised biogas used for electricity generation[6] (Bioenergy Association of New Zealand, 2011). Table 6 shows the key landfills biogas sites in Auckland and their power ration in 2015.

The anaerobic digestion (AD) process, which would be used in the food waste plants, is the most common method of biogas production to generate electricity. While it is mandatory that landfills be designed to capture methane and it is estimated that between 50 to 90 per cent of the gas is captured, it is likely that the net generated electricity as the result of the service is minor.

[5] Waste Management New Zealand

[6] Captured methane could be upgraded to natural gas quality and can substitute for reticulated natural gas used by residential, commercial and vehicles.

Table 6 Landfill biogas generation sites in Auckland (2015)

Landfill	Owner	Power Rating kW
Greenmount	EnviroWaste services	1,200
Rosedale	EnviroWaste services	500
Redvale	Transpacific Industries	12,000
Whitford	Transpacific Industries	3,000

Source: Bioenergy association of New Zealand (2015)

5.1.3 Compost benefits

Organic compost is the final product of both compost and AD processes. There would be some benefits associated with compost production including the reduced need for chemical fertilisers, higher crop yields and revitalization of poor soils, United States Environmental Protection Agency (EPA), (2013).

The nature and the characteristics of nutrient release of chemical fertilisers and compost are different, and each type of fertilizer has its advantages and disadvantages with regard to crop type and soil fertility. Hence, the value of compost is contingent on many unknown factors such as the quality of the finished compost, the type of crop and soils quality, the degree to which fertilisers are used in agriculture, and the proportion of fertilisers that could be replaced by compost in order to maintain crop production levels.

5.1.4 Groundwater pollution

Organic waste in landfills is one of the main sources of toxic leachate, as it can dissolve after rain. This toxic leachate collects at the base of the landfill and any leakage can result in serious contamination of the local groundwater, albeit that the risk is longer-term rather than more immediate in nature. Auckland landfill owners have stated that their monitoring shows that there is little/no groundwater penetration. Given the 30-year timeframe for this study, we do not include any potential benefit from a reduction in groundwater pollution in this study.

5.1.5 Cultural benefits

Measuring and monetising intangible benefits is difficult. However, the way the project will help maintain separation between waste streams and the food chain is another source of potential benefit from cultural perspectives. For example; it contributes to the cultural importance Māori place on human health and well-being (Pauling and Atria, 2010). It is this holistic view that upholds the obligation of kaitiakitanga for te Taiao (the environment); through guardianship of these taonga tuku iho (sacred gifts passed down from one generation to the next) the mana (authority) of the iwi, hapu or whanau is retained within their rohe (region).

Te Ao Turoa (intergenerational resource sustainability) of taonga tuku iho requires the exchange of these treasured resources to be passed from one generation to the next with an uplifted state of mauri of the environment, providing for the cultural practices that previous generations enjoyed. Another example of this is the Para Kore ki Tamaki is a Māori initiative with a vision for all marae to be working towards zero waste by 2020.

5.2 Welfare gains from a food waste collection service

We use the concept of consumer's surplus to estimate the gain in welfare households would receive from the presence of a food waste collection service (relative to the 'counterfactual' of there being no such service). Consumer surplus is often used to measure changes in societal well-being from proposed changes to policy and regulatory settings in industries such as electricity, aviation (particularly airports), and more generally in competition matters.

A consumer surplus is the benefit someone derives in excess of the price they would willingly have paid for the good or service that they use. As indicated above, the willingness of householders to pay for a food waste collection service is integral to estimation of consumer surplus.

Available survey evidence suggests that in 2007, New Zealand households were willing to pay $1.50 per week per household (i.e. $78 per year) for an organic waste collection service (Covec, 2007). This is an average value across all households nationwide, including those who already composted. Households were asked to consider how much it would be worth to them to ensure their garden and kitchen waste was recycled in an environmentally responsible way.

As some households already composted, the question was prefaced in a way to elicit an estimate of the marginal willingness to pay of these households by considering the situation where they could not do it themselves, and had to pay a separate charge, what would it be?

The question was worded this way in an attempt to better understand whether survey respondents were reading the question as being additional to, or instead of, what they already did (by way of recycling food waste in an environmentally responsible way). For households that do not already compost, that question is less relevant (as they do not currently pay for, or undertake activities consistent with, environmentally responsible recycling of food waste). However, the costs of sorting waste would need to be subtracted from their identified willingness to pay (see further below for how we estimated these sorting costs). For households that compost already, the situation is less clear. That is, we are not able to tell the extent to which such respondents answered the question thinking that the service meant they no longer used their own compost bin or whether it was additional to their own bin. Other survey evidence from trials in Auckland suggests that the service would be a complement to existing household composting activities (see explanation further below).

The same study provided the basis for an estimate of willingness to spend time on relevant recycling activity over and above the time they currently spend as a means of determining a measure of willingness to pay. Households were prepared to spend an additional 10.1 minutes per week on recycling over and above the time currently spent on such activities, which translates to a value of $0.88 per household per week (i.e. $45.76 per year) using an opportunity cost of time spent on such activity of $5.20 per hour, Eunomia (2010).

Determining what respondents actually meant (or how they thought in relation to the question asked) is obviously crucial in determining willingness to pay estimates.[7] While the main author of the study acknowledges that the survey could have been improved (in order to better understand the exact meaning and thought process of survey respondents in relation to their willingness to pay),[8] we are comfortable that the figures used represent the best available evidence of willingness to pay for the service. In particular, using the estimated values as an upper bound (as opposed to a central estimate), and the use of willingness to spend time recycling organic matter figure, which is a familiar and commonly understood metric for householders, as a lower bound appropriately avoids spurious accuracy concerns.

We wish to express the $1.50 per week per household derived in 2007 in 2017 dollar terms. We did this by adjusting the value in accordance with changes in wages between 2007 and 2017. Wages are a proxy for incomes, and income is known to be influential (though not necessarily the sole or most important determinant) in peoples' willingness to pay. The Reserve Bank of New Zealand inflation calculator showed that wages of $1 in the second quarter of 2007 would be $1.31 in the second quarter of 2017 (i.e. there was a 31.5% change in the period). For convenience, we assume that the willingness to pay figure adjusts in direct proportion to changes in wages.[9]

This means that the 2007 figures of $1.50 and $0.88 per household per week equate to $1.97 and $1.19 per household per week in 2017, respectively. Annual figures per

[7] Personal communications with main author of the study.

[8] Personal communications with main author of the study. Also, see section 4.2 of Covec (2012).

[9] That is, unit elasticity in the willingness to pay with respect to income.

household are therefore $102.57 and $60.17 respectively. Given the importance of these figures in the calculation of benefits, we consider the effects of different values, including the possibility that the dollar values do not change between 2007 and 2017, in the sensitivity analysis further below.

As there is no household kerbside food waste collection service that would recycle waste in an environmentally responsible way at present, consumers do not currently pay anything. In such circumstances, the whole willingness to pay can be considered as consumer surplus (Covec 2007). However, in order to gauge the actual/true consumer surplus, an estimate of time that would be spent on the activity is needed (i.e. the consumer surplus, a direct benefit to consumers, is the difference between the time costs of participating in the service and the willingness to pay).

Despite some disagreement in the literature around whether or not to include the costs to households of participating in the service (i.e. sorting food waste and placing their bin at the kerbside and then recovering it when emptied), our preference is to account for such costs as much as possible. Our approach is to follow that taken in the Covec (2007) analysis to determine a value of time used in relevant activity. Key assumptions/parameters used are:

- the value of time spent participating is $7.08 per hour;
- households spend on average four minutes per week on food waste collection (around 20 seconds per day sorting, six days per week, and two minutes per week setting out and retrieving the kerbside bin), leading to costs of $0.47 per week or $24.54 per year per household;
- the proportion of households willing to pay for food waste collection services is 92 per cent;
- the rate at which households use the service is 80 per cent; and
- the rate at which participating households set their bin out each week is 50 per cent.

The value of time spent participating comes from the Economic Evaluation Manual published by the New Zealand Transport Agency. It refers to a passenger in a car or motorcycle undertaking travel for a non-work purpose. In essence, by spending time sorting food waste, transferring the waste from the kitchen to the bin and then setting out and retrieving their kerbside bin, householders give up the opportunity to partake in a 'drive in the country' which is worth $5.20 an hour. This is the value used by Covec and Eunomia studies cited earlier.

We wanted to express this value in 2017 dollar terms, as the $5.20 figure was derived in July 2002. The Reserve Bank of New Zealand's inflation calculator for general inflation (CPI) showed that a basket of goods and services that would have cost $5.20 in the second quarter of 2002 would cost $7.08 in the second quarter of 2017 (i.e. there was a 36.2% change in the period). CPI was chosen as the most general category of change, given the general nature of the value of time under study.

The assumption that 92 per cent of households would be willing to pay for a food waste collection service is based on survey results following the trials mentioned earlier in this report. In particular, follow-up surveys revealed that 93 per cent of the feedback was positive, and that only eight per cent of respondents thought that not continuing with the service was a good/very good idea. Furthermore, in 2014 just eight per cent of respondents indicated they were unlikely to/definitely wouldn't use the service in future; this proportion rose to 10 per cent in 2016 (Gravitas, 2016).

Importantly, willingness to pay is not necessarily related to actual utilisation. People are often willing to pay for services (usually those of a public good nature such as national parks) that they themselves may never use. The willingness to pay is based on a preference for something to be present rather than not be (i.e. an existence value) and/or a desire for that thing to be available for use by future generations (i.e. a bequest value) or for use by others now (i.e. an altruistic value).

Using the array of assumptions and parameters and the household numbers shown earlier we estimate direct consumer benefits (surplus) of **$1,515.3 million** on an annualised basis over the entire 30-year study period. Willingness to pay totalled $1,691.3 million on an annualised basis, while participation costs totalled $176.0 million on an annualised basis (see Table 7 for further details).

Obviously these impacts are significant, and we note that willingness to pay surveys have been brought into question in terms of producing over-stated benefits. It has been claimed that respondents either do not fully understand the context of the question and more importantly claim values that are greater than what they would actually pay as they don't believe there is a strong possibility that they will be faced with having to pay. Primary research, by way of a survey, is not feasible for this study. In the absence of this additional insight, we have been conservative in how we measure and reflect such willingness to pay estimates.

A further question that has been raised in relation to the type of direct consumer benefits under study here is whether they are additional to the other benefits. Covec (2007) questioned whether there is a benefit that households are receiving that is not accounted for elsewhere? Their view was that there is and that including the consumer surplus (the difference between their willingness to pay and current costs of litter reduction) can be added to other avoided cost-related benefits. On the basis of this, and the analysis of the survey used in the Covec (2007) analysis, we are comfortable with both the inclusion of such benefits and the estimation process used to measure them.

Table 7 Estimated consumer surplus benefits on an annualised basis ($m) 2019- 2048

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Total households		491,405	500,465	509,593	518,720	527,848	536,976	546,103	555,249	564,394
Relevant households WTP		452,093	460,428	468,825	477,223	485,620	494,018	502,415	510,829	519,243
WTP total at $102.57 per annum		$46.37	$47.23	$48.09	$48.95	$49.81	$50.67	$51.53	$52.40	$53.26
Participation costs (80% participation, 50% weekly set out, $24.54 cost per annum)		$4.82	$4.91	$5.00	$5.09	$5.18	$5.27	$5.36	$5.45	$5.54
Total consumer surplus benefits		**$41.55**	**$42.31**	**$43.08**	**$43.86**	**$44.63**	**$45.40**	**$46.17**	**$46.94**	**$47.72**

Source: Auckland Transport Model, Authors' calculations

Table 7 Estimated consumer surplus benefits on an annualised basis ($m) 2019- 2048 (continue)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Total households	573,540	582,685	591,831	600,924	610,018	619,112	628,206	637,300	646,664	656,028
Relevant households WTP	527,656	536,070	544,484	552,851	561,217	569,583	577,950	586,316	594,931	603,546
WTP total at $102.57 per annum	$54.12	$54.98	$55.85	$56.71	$57.56	$58.42	$59.28	$60.14	$61.02	$61.91
Participation costs (80% participation, 50% weekly set out, $24.54 cost per annum)	$5.63	$5.72	$5.81	$5.90	$5.99	$6.08	$6.17	$6.26	$6.35	$6.44
Total consumer surplus benefits	**$48.49**	**$49.26**	**$50.04**	**$50.81**	**$51.58**	**$52.34**	**$53.11**	**$53.88**	**$54.67**	**$55.47**

Table 7 Estimated consumer surplus benefits on an annualised basis ($m) 2019- 2048 (continue)

	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Total households	665,392	674,756	683,336	691,242	699,238	707,328	715,511	723,788	729,703	735,666
Relevant households WTP	612,161	620,776	628,669	635,942	643,299	650,741	658,270	665,885	671,327	676,813
WTP total at $102.57 per annum	$62.79	$63.67	$64.48	$65.23	$65.98	$66.75	$67.52	$68.30	$68.86	$69.42
Participation costs (80% participation, 50% weekly set out, $24.54 cost per annum)	$6.53	$6.62	$6.71	$6.79	$6.86	$6.94	$7.02	$7.11	$7.16	$7.22
Total consumer surplus benefits	**$56.26**	**$57.05**	**$57.77**	**$58.44**	**$59.12**	**$59.80**	**$60.49**	**$61.19**	**$61.69**	**$62.20**

5.3 Reduction in emissions

Any reduction in greenhouse gas (GHG) emissions is beneficial to society through the avoidance of costs that are imposed by GHGs. These costs usually include market and non-market impacts and cover health, environment, crops and other property damage potential and wider social aspects. Thus, the calculation of benefits for this analysis requires an estimate of the possible impact on GHG emissions as a result of the food waste collection service and an estimate of the social cost of GHG emissions. The product of these two factors is the benefit to society.

The ways through which a kerbside food waste collection service could change the level of GHG emissions, relative to the 'counterfactual' situation of no service can be summarised as follows:

- *Landfill:* Diverting food waste from disposal avoids potential methane emissions. This is beneficial even if landfills have bio-gas capture systems.
- *Transport:* Food waste collection trucks are smaller than refuse collection trucks because food waste could be more compacted and in total takes less space in the collection trucks. The smaller trucks and most likely hybrids would produce less GHG emissions.

5.3.1 Estimating the volume of GHG emissions avoided

A four-step process was used to derive estimates of GHG emissions avoided as a result of the introduction of a kerbside food waste collection service.

Step 1: The net change in the landfill GHG level was estimated using the potential landfill production of GHG under both the status quo and when the food waste collection service was in place. We also accounted for GHG that would be produced in the process of either 100 per cent compost or 100 per cent anaerobic digestion (AD). The emission factors (tonne CO2e/tonne waste) for landfill, compost and AD were used to estimate the GHG level before and after the intervention. Table 8 shows the data used for estimating emission factors and the data sources.

Step 2: emissions produced by food waste were calculated using the tonnage of food waste and the emission factor for each of the landfill, composting and AD for each year of the project life.

Step 3: net changes in GHG production was calculated for composting and AD separately by subtracting GHG produced by each of them from the net landfill's GHG production.

Table 8 Data assumptions and sources for GHG emissions reduction estimation

Factor	Measure	Source
R factor (Fraction recovered CH4)	0.75	R factor of 75% based on maximum methane capture rate achieved in best practice landfills in Europe. UK Department for Environment Food and Rural Affairs (2014).[10]
DOC (degradable organic carbon)	0.15	MfE (2016)
DOCF (fraction of DOC dissimilated)	0.5	
F (fraction of CH4 in landfill gas)	0.5	
Ox (oxidation factor)	0.1	
GWP of methane CH4	28	
Carbon to CO2 convertor	16/12	
Emission factor for landfill (tCO2e/t waste)	**1.26**	Estimated using MfE (2016) formula: CO2-e emissions (kg) = ((MSWT x DOC x DOCF x F x 16/12) x (1– R) x (1-OX)) x 28 [11]
Emission factor for compost (tCO2e/t waste)	**0.19**	C40: Adapted from IPCC (2006), default values
Emission factor for AD (tCO2e/t waste)	**0.056**	C40: Adapted from IPCC (2006), default values

[10] Landfill operators report 90% and MfE suggests New Zealand average of 61%.

[11] Where: MSWT = total Municipal Solid Waste (MSW) generated (kg); DOC = degradable organic carbon (0.15 for garden and food waste); DOCF = fraction of DOC dissimilated (0.5); F = fraction of CH4 in landfill gas(0.5); R = fraction recovered CH4 (0.606 where landfill gas systems are in place otherwise 0 ; OX = oxidation factor(0.1); 28 = GWP of methane (CH4). 16/12 converts carbon to CO_2.

Step 4: reduction in GHG in each year of the project life as the result of the reduced number and trip frequency of heavy diesel trucks due to the use of smaller hybrid trucks, estimated based on the potential food waste that would be diverted from landfill to the processing plant. The reduction in the level of GHG as a result of waste transport was calculated using on the following equation:

$$Net\ GHG\ Reduction, transport = NT_L \times VKT_L \times CO_2e_L - NT_P \times VKT_P \times CO_2e_P$$

Where:

NT_L = Reduction in annual number of round trips to landfill as the result of potential reduction in the refuse tonnage after the food collection service compared to status quo

VKT_L= Vehicle kilometre round trip to landfill

CO_2e_L = Emission factor per kilometre travelled by heavy diesel trucks (>17 tonnes)

NT_P = Number of round trips to plant to deliver the annual tonnage of food waste

VKT_P = Vehicle kilometre round trip to plant

CO_2e_P = Emission factor per kilometre travelled by hybrid vehicles

Table 9 summarises the key data assumptions and parameters used in relation to the reduction in GHG emissions from transport.

Table 9 Key data for measurement of transport-related GHG emissions reduction

	Option 1	Option 2	Source
Tonnage of total waste per vehicle before and after policy	8.00		Auckland Council, Infrastructure and Environmental services
VKT per round trip (km)	100		Auckland Council, Infrastructure and Environmental services
CO2e emission factor tonne per km (Diesel HCV >17 t)	0.000583	0.00094	Option 1_ VEPM5.2.1 (Diesel HCV 20-25 t)=583.17 g/km Option 2_ C40: For HGV (all diesel) Rigid (> 17 tonnes) 50% laden (assuming trucks are empty on the way back (Defra, 2014)
Tonnage of food waste per vehicle after policy	2.75		Auckland Council, Infrastructure and Environmental services
VKT per round trip (km)	60		Auckland Council, Infrastructure and Environmental services
CO2e emission factor tonne per km (Diesel HCV <7 t)	0.000070		VEPM5.2.1 (Hybrid)=70.05g/km

Table 10 shows that across the entire 30-year study period, on an annualised basis we estimate total net GHG emissions reductions to be 37,621 tonnes.

Table 10 Estimated net GHG reduction from food waste collection service (000's) 2019- 2048

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Number of trips to land fill before policy		64.7	65.6	66.6	67.5	68.5	69.4	70.4	71.3	72.3
GHG before policy (transport to landfill) tonne		6.1	6.2	6.3	6.3	6.4	6.5	6.6	6.7	6.8
Number of trips to land fill after policy		54.9	55.7	56.5	57.3	58.0	58.8	59.6	60.4	61.1
GHG after policy (transport to landfill) tonne		5.2	5.2	5.3	5.4	5.5	5.5	5.6	5.7	5.7
Number of trips to plant after policy		28.2	28.8	29.3	29.8	30.3	30.9	31.4	31.9	32.4
GHG after policy (transport to plant) tonne		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Net GHG Reduction, Tonne		**1.0**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.2**	**1.2**

Source: Information provided by Auckland Council's waste solutions department and authors' calculations

Table 10 Estimated net GHG reduction from food waste collection service (000's) 2019- 2048 (continue)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Number of trips to land fill before policy	73.2	74.2	75.1	76.1	77.1	78.0	79.0	80.0	80.9	81.8
GHG before policy (transport to landfill) tonne	6.9	7.0	7.1	7.2	7.2	7.3	7.4	7.5	7.6	7.7
Number of trips to land fill after policy	61.9	62.7	63.4	64.2	65.0	65.8	66.6	67.4	68.1	68.8
GHG after policy (transport to landfill) tonne	5.8	5.9	6.0	6.0	6.1	6.2	6.3	6.3	6.4	6.5
Number of trips to plant after policy	33.0	33.5	34.0	34.5	35.1	35.6	36.1	36.6	37.2	37.7
GHG after policy (transport to plant) tonne	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Net GHG Reduction, Tonne	**1.2**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**	**1.4**	**1.4**

Table 10 Estimated net GHG reduction from food waste collection service (000's) 2019- 2048 (continue)

	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Number of trips to land fill before policy	82.7	83.6	84.4	85.1	85.8	86.6	87.3	88.0	88.5	88.9
GHG before policy (transport to landfill) tonne	7.8	7.9	7.9	8.0	8.1	8.1	8.2	8.3	8.3	8.4
Number of trips to land fill after policy	69.5	70.2	70.9	71.4	72.0	72.6	73.2	73.7	74.1	74.4
GHG after policy (transport to landfill) tonne	6.5	6.6	6.7	6.7	6.8	6.8	6.9	6.9	7.0	7.0
Number of trips to plant after policy	38.2	38.8	39.3	39.7	40.2	40.7	41.1	41.6	41.9	42.3
GHG after policy (transport to plant) tonne	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Net GHG Reduction, Tonne	**1.4**	**1.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**

5.4 Estimating the value of avoided emissions reductions

The economic damage caused by a tonne of carbon dioxide emissions is often referred to as the “social cost” of carbon (SCoC). It could be measured through damage cost avoidance of the marginal decrease in GHG emission as a result of the service in its life span.[12] As indicated above, the GHG social cost usually includes market and non-market impacts and covers health, environment, crops and other property damage potential and wider social aspects.

A wide range of values have been estimated for the SCoC, In the New Zealand context, Covec (2010) suggest $50 per tonne of GHG as the best guess for 2020.[13] MBIE (2016) used a range of $56 to $152 per tonne of GHG for a 2030 scenario in its electricity demand and generation scenario analysis. NZTA (2016) suggests a $40 per tonne value, in 2004 prices.

International estimates from a review of available literature by Dobes et al. (2016) show a range between USD4.4 to USD126.6 with mean and median of USD56 and USD39 respectively. The results covered five European countries, Japan, UK, USA, Australia and New Zealand.

An US government study in 2013 concluded, based on the results of three widely used economic impact models, that an additional tonne of carbon dioxide emitted in 2015 would cause a range between USD11 to USD109 worth of economic damages. These damages are expected to take various forms, including decreased agricultural yields, harm to human health and lower labour productivity, all related to climate change.

In this report, the primary SCoC we use is $63/tonne , based on figures used in Austroads (2012) and Rohani and Kuschel (2017).[14] We also use$53/tonne which is the value suggested by NZTA (2016) adjusted to 2017 prices.

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[12] There are three other approaches to measure the carbon cost including abatement cost (cost of achieving a given level of CO2, e.g. under Paris agreement, New Zealand has to reduce its GHG emissions by 30% down 2005 levels in 25 years.), market price of carbon (the cost that is used to inform policy decision and is usually less that actual social cost of carbon due to political considerations) and willingness to pay estimates that use revealed or stated preference methods.

[13] Under ‘Medium Ambition’ when there are international agreements for at least some countries in the world to stabilise GHG levels in the atmosphere at 550 ppm CO2-e.

[14] This is a figure converted to NZD 2017 from Australian dollar using change in CPI in Australia and New Zealand and exchange rate from following sources respectively:
http://www.rba.gov.au/calculator/annualDecimal.html
http://www.xe.com/currencyconverter/convert/?Amount=483%2C392.89&From=AUD&To=NZD
http://www.rbnz.govt.nz/monetary-policy/inflation-calculator

Multiplying the predicted reductions in emissions by the SCoC results in annualised total benefits across the entire 30-year study period of **$36.98 million** (see **Table 11**). Consistent with the Covec (2007) national cost-benefit analysis of recycling, we treat these benefits as additional to the direct consumer welfare benefits. It is possible that household responses in the willingness to pay survey used to determine the direct consumer welfare benefits above accounted for the possible GHG impact (and consequent benefits). If that is the case, including reduction in GHG emissions as a separate benefit would be double counting.

There are arguments for and against the 'double counting' hypothesis. There is not sufficient evidence to determine whether or not survey respondents had such GHG emission reductions in mind when indicating their willingness to pay. We examine the possibility that the willingness to pay includes householders' expectations of GHG emissions reductions in sensitivity analysis below. That is, we show the impact on our results from removing the GHG emissions reduction benefit from our calculations.

Table 11 Estimated avoided emission benefits on an annualised basis ($m) 2019- 2048

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Greenhouse gas reduction, compost		$0.65	$0.67	$0.68	$0.69	$0.70	$0.71	$0.73	$0.74	$0.75
Greenhouse gas reduction, AD		$0.74	$0.75	$0.76	$0.78	$0.79	$0.80	$0.82	$0.83	$0.85
Greenhouse gas reduction waste transport		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total GHG benefits, compost		$0.65	$0.67	$0.68	$0.69	$0.70	$0.71	$0.73	$0.74	$0.75
Total GHG benefits, AD		**$0.74**	**$0.75**	**$0.76**	**$0.78**	**$0.79**	**$0.80**	**$0.82**	**$0.83**	**$0.85**

Source: Authors' calculations

Table 11 Estimated avoided emission benefits on an annualised basis ($m) 2019- 2048 (continue)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Greenhouse gas reduction, compost	$0.76	$0.78	$0.79	$0.80	$0.81	$0.82	$0.84	$0.85	$0.86	$0.87
Greenhouse gas reduction, AD	$0.86	$0.87	$0.89	$0.90	$0.91	$0.93	$0.94	$0.96	$0.97	$0.98
Greenhouse gas reduction waste transport	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total GHG benefits, compost	$0.76	$0.78	$0.79	$0.80	$0.81	$0.82	$0.84	$0.85	$0.86	$0.87
Total GHG benefits, AD	**$0.86**	**$0.87**	**$0.89**	**$0.90**	**$0.91**	**$0.93**	**$0.94**	**$0.96**	**$0.97**	**$0.98**

Table 11 Estimated avoided emission benefits on an annualised basis ($m) 2019- 2048 (continue)

	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048
Greenhouse gas reduction, compost	$0.89	$0.90	$0.91	$0.92	$0.93	$0.94	$0.95	$0.96	$0.97	$0.98
Greenhouse gas reduction, AD	$1.00	$1.01	$1.02	$1.04	$1.05	$1.06	$1.07	$1.08	$1.09	$1.10
Greenhouse gas reduction waste transport	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Total GHG benefits, compost	$0.89	$0.90	$0.91	$0.92	$0.93	$0.94	$0.95	$0.96	$0.97	$0.98
Total GHG benefits, AD	**$1.00**	**$1.01**	**$1.02**	**$1.04**	**$1.05**	**$1.06**	**$1.07**	**$1.08**	**$1.09**	**$1.10**

6.0 Net effects

This section compares the benefits to the costs over the study period, in order to derive the net benefit to society from the proposed food waste collection service. In order to make this information most useful for decision-makers, costs and benefits are expressed in present value terms. The time period for this analysis is 30 years. Consistent with available Auckland Council CBA Primer, the discount rate applied is 4%.

A four year phase-in period is assumed for the majority of costs and benefits, except for capital costs associated with the kerbside bins and kitchen caddies, which apply straight away, with replacement/replenishment of the kerbside bins at 3 per cent per year and full replacement of bins after 10 years. In addition the capital costs of required plant and buildings accrue in two years (half in each of the first two years) and no replacement is included in the timeframe for the analysis.

Table 12 shows that the range of estimated net benefits (i.e. the extent to which society is made better off as a result of the service) is around $401 million in present value terms. Benefits are over twice the costs.

It is important to note that these results do not include indirect or qualitative impacts. Our assessment is that the effect of including such impacts would be to raise the net benefits.

Table 12 Summary CBA results

	Present value ($m)
Total benefits	$771.02
Total costs	$369.19
Net benefits	$401.83
Benefit-cost ratio (BCR)	**2.09**

Source: Authors' estimates

7.0 Sensitivity and scenario analysis

In addition to the summary results shown above, this section considers the impacts of adjusting key assumptions and testing alternative scenarios. This is particularly important when the benefit estimate is heavily reliant on a single impact, in this case welfare gains. We also derive alternative scenarios based on known parameter values that differ from those used in the main analysis. All other factors remain the same.

7.1 Alternative scenarios

While somewhat conservative in nature overall, the results above might reasonably be considered "upper bound" in nature, as a range of assumptions and parameters have known values that are different (lower) than those used above.

Table 13 Alternative parameters

Parameter	Current	Alternative
Participation rate (proportion using service)	80%	72%
Annual replacement rate for bins	3%	5%
Households willing to pay for service	92%	90%
Willingness to pay per household per week	$1.97	$1.16
CO_2 Emissions factor	0.00094	0.000583
Social cost of carbon per tonne	$63	$53
R Factor (proportion of CH_4 recovered)	0.75	0.90

Source: Authors' estimates

To derive what might be considered "lower bound" estimates (and hence a range when considered alongside the "upper bound" estimates) we make use all of the alternative parameters at once. **Table 14** shows that society would still be made better off by around $64 million and benefits exceed costs by 19 per cent after introducing a food waste collection service with the alternative parameters used in the analysis. Clearly, benefits were more adversely affected by the alternative parameter values. Benefits dropped by around 47 per cent, while costs were around six per cent lower.

Table 14 "Lower bound" CBA results, using alternative parameters

	Present value ($m)
Total benefits	$410.17
Total costs	$345.82
Net benefits	$64.35
Benefit-cost ratio	**1.19**

Source: Authors' estimates

The results on the existing "upper bound" estimates of using the alternative parameter values individually are contained in Table 15. Not surprisingly, it shows that the willingness to pay parameter is the biggest driver of the reduction in the BCR using the combined alternative parameters. On its own, the alternative value of $1.16 per household per week (as opposed to $1.97) is enough to reduce the BCR from 2.09 to 1.14. The combined effect of the other parameters combined is to raise this to the level shown in Table 14.

For interest, the "break even" willingness to pay value (i.e. the willingness to pay value that results in a BCR equal to one, while holding all else constant) is $1.0351 per household per week (or $53.83 per household per year).

Table 15 Individual impacts of alternative parameters (PV, $m)

Parameter	Total benefits	Total costs	Net benefits	BCR
Existing "upper bound"	***$771.02***	***$369.19***	***$401.83***	***2.09***
Participation rate	$778.47	$341.31	$437.16	2.28
Annual replacement rate for bins	$771.02	$373.70	$397.32	2.06
Households willing to pay for service	$752.64	$369.19	$385.45	2.04
Willingness to pay per household per week	$421.52	$369.19	$52.34	1.14
CO_2 Emissions factor	$771.02	$369.19	$401.83	2.09
Social cost of carbon per tonne	$768.89	$369.19	$399.70	2.08
R Factor (proportion of CH_4 recovered	$762.96	$369.19	$393.78	2.07

Source: Authors' estimates

There was insufficient reliable data to calculate a robust central or medium estimate, but a simple midpoint would suggest net benefits of $233 million would accrue (over the 30 year study period) and benefits would outweigh costs by around 65 per cent (i.e. a benefit-cost ratio of 1.65).

7.2 Sensitivity analysis

In addition to the known alternative value changes above, we also undertake more traditional sensitivity analysis by altering key inputs and assumptions, such as the:

- discount rate used;
- amount of waste set out by households;
- timeframe for the analysis;
- rate at which households set out their bins weekly;
- proportion of households who would be willing to pay for the service;
- ramp-up period to full effect;
- time period for the study;
- amount that households would be willing to pay for the service; and
- removal of GHG emissions reductions.

We show the effect of these changes for both the "upper bound" and "lower bound" cases.

7.2.1 Discount rate

The effect of altering the discount rate is shown in Table 16. As expected, the higher the discount rate the lower the net benefit and BCR. The "break even" discount rate (i.e. where the BCR=1) for the upper bound case is around 38 per cent, while the equivalent in the lower bound case is around 11.6 per cent. Neither of these discount rates are plausible in the context of (largely-public) investments of this nature, though for many years from 1971through to 2008 the discount rate for public projects was 10 per cent (Young, 2002).

Table 16 Alternative discount rates (PV, $m)

Discount rate	2%		4%		7%		12%	
	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound

Discount rate	2%		4%		7%		12%	
Net benefits/NPV	$563.48	$104.27	$401.83	$64.35	$252.23	$28.20	$126.52	-$0.88
Benefit-cost ratio	2.16	1.23	2.09	1.19	1.97	1.12	1.77	0.99

Source: Authors' estimates

7.2.2 Amount of waste set out

The effect of altering the average amount of food waste produced by households using the service from the existing 3.8 kilograms per week is shown in Table 17. We continue to use the "upper bound" and "lower bound" labels, despite the fact that altering the assumed food waste volume essentially creates new bounds. It is obvious from the table that a reduction in food waste set out by households improves the BCR and net benefit to society, regardless of the scenario.

This somewhat counterintuitive finding is a function of the cost structure of collecting and processing food waste in the model. Given a unit cost of collection and processing, the greater the volume set out the higher the costs. However, the benefits are only marginally affected, as household willingness to pay (and consequently consumer surplus benefits) is invariant to changes in volume of household waste. Only the emissions side of the benefits equation changes with food waste volumes and the share of benefits accounted for by emissions reductions is modest.

Table 17 Alternative food waste volumes (PV, $m)

Food per HH per week	1.9kg		3.8kg		7.6kg	
	Upper bound	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**
Net benefits/NPV	$534.51	$187.76	$401.83	$64.35	$136.49	-$182.48
Benefit- cost ratio	3.33	1.85	2.09	1.19	1.21	0.69

Source: Authors' estimates

7.2.3 Weekly bin set-out rate

When we look at the rate at which households set out their bins on a weekly basis we see a similar pattern, although the magnitude of changes is less than that relating to food waste volume (see **Table 18**). Again, the overwhelming majority of benefits included in the analysis are invariant to changes in the kerbside bin set out rate. Costs however, change directly in line with the set out rate (by virtue of collection and processing costs being related to volume, which in turn is related to set out rate).

Table 18 Alternative household set-out rates (PV, $m)

Weekly set out rate	40%		50%		60%	
	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound
Net benefits/NPV	$472.50	$129.55	$401.83	$64.35	$331.17	-$0.85
Benefit- cost ratio	2.51	1.44	2.09	1.19	1.78	1.00

Source: Authors' estimates

7.2.4 Proportion of households willing to pay

We saw above that the dollar amount households are willing to pay has a material influence on the results of the analysis. It is the main driver of estimated benefits, and is likely to remain in that position even if we were to quantify and monetise further benefit categories. We based our estimation of the willingness to pay on known survey results.

Similarly, the proportion of households assumed to be willing to pay for the service (regardless of whether or not they intend to use the service) was based on survey data. However, the assumption was made that only those eight- ten per cent of households who expressed the sentiment that stopping the trial service was a good or very good idea would not be willing to pay. As well as the 81 per cent of households who said they thought stopping the service was a poor or very poor idea, there was also up to 11 per cent who were either unsure or neutral about stopping the trial service.

Here we test the sensitivity of the study results to the assumption about including those households who would be willing to pay for the service. In particular, we assess the results assuming that all of the neutral/unsure group would not be willing to pay for the service. That is, we assume that only 81 per cent would be willing to pay for the service, rather than the 92 per cent used in the original case. For completeness we also look at the case where 100 per cent of households would be willing to pay.

Table 19 shows that while the proportion of households willing to pay for the service has a relatively strong influence on the overall results, even in the lower bound situation, benefits still outweigh costs following the strong assumption that all those households who were neutral or unsure about stopping the trial service would not be willing to pay for the service.

Table 19 Proportion of households willing to pay for the service (PV, $m)

Proportion of HH's willing to pay	81%		92%		100%	
	Upper bound	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**
Net benefits/NPV	$300.73	$15.82	$401.83	$64.35	$475.36	$118.27
Benefit- cost ratio	1.81	1.05	2.09	1.19	2.29	1.34

Source: Authors' estimate

7.2.5 Ramp-up to full effect

As mentioned earlier, we assume that operations take some time to achieve their maximum potential. This means costs and benefits manifest over time rather than instantaneously, reflecting the need to account for the construction period for new facilities and plant as well as a gradual take-up of a new service by households. The profile of costs and benefits included in the calculations assumes full service would not be achieved until 2023. It was:

- 2020 30% (however, given the construction period, 15% is assumed)
- 2021 50%
- 2022 70%
- 2023 100%

The effect of a more aggressive assumption in relation to the time to full effect is shown in Table 20. The new profile maintains the 2020 proportion but assumes that 75 per cent of the costs and benefits would accrue in 2021, and 100 per cent in 2022. There is very little difference in all the key metrics from a more aggressive ramp-up, as the adjustment applies equivalently to costs and benefits. This suggests the choice of the ramp-up to full operations is best made by reference to what is more realistic.

Table 20 CBA results, aggressive ramp-up (PV, $m)

	Upper bound	Lower bound
Total benefits	$791.83	$421.24
Total costs	$377.05	$352.96

	Upper bound	Lower bound
Net benefits	$414.78	$68.29
Benefit-cost ratio (BCR)	2.10	1.19

Source: Authors' estimate

7.2.6 Time period for the study

The effect of truncating the time period is to reduce the estimated net benefits of the service, largely reflecting the profile of "upfront" and "one off" costs associated with capital infrastructure, although some of that impact is mitigated by the avoidance of kerbside bin replacement costs which occur in the year immediate following (see

Table 21).

Table 21 Alternative time periods (NPV, $m)

	10 Years		20 Years		30 Years	
	Upper bound	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**
Total benefits	$259.65	$138.13	$548.04	$291.55	$771.02	$410.17
Total costs	$152.11	$144.43	$274.80	$258.28	$369.19	$345.82
Net benefits/NPV	$107.54	-$6.30	$273.24	$33.28	$401.83	$64.35
BCR	**1.71**	**0.96**	**1.99**	**1.13**	**2.09**	**1.19**

Source: Authors' estimate

7.2.7 Value of willingness to pay

The weekly value for households'' willingness to pay for the service was adjusted to reflect 2017 values using changes in wages (income). For convenience, we assumed that the income elasticity of willingness to pay (i.e. the percentage change in willingness to pay relative to percentage changes in income) is one. This means that the willingness to pay moved in direct proportion with changes in income. **Table 22** shows the effect of lower values for this elasticity, including the case where it is zero (i.e. there is no change in willingness to pay from the 2007 values). We hold all other variables constant. The results confirm the previously made observation around the materiality of the willingness to pay value. The effect of using the 2007 values for willingness to pay is to turn the lower bound estimate of net benefits from positive to negative.

Table 22 Value for willingness to pay for the service (PV, $m)

Income elasticity of willingness to pay	0 (2007 values)		0.5		1 (2017 values)	
	Upper bound	**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**Lower bound**
Net benefits/NPV	$199.29	-$51.90	$300.56	$6.23	$401.83	$64.35
Benefit- cost ratio	1.54	0.85	1.81	1.02	2.09	1.19

7.2.8 Removal of GHG emissions reduction benefits

As mentioned earlier, there is a possibility that the willingness to pay estimates used to derive direct consumer benefits included the potential for GHG emissions reductions. That is, householders accounted for the possibility that the service would reduce GHG emissions (and hence the avoided social costs of such emissions) in their willingness to pay figure, and therefore to include such effects separately would overstate the benefits by double-counting.

There are arguments for and against the 'double counting' hypothesis and the available evidence does not allow to determine which is correct. Consistent with the treatment of GHG emissions reduction impacts (and consequent benefits) in the Covec (2007) source study, we include such benefits in the core analysis, but examine the impact of removing them on our overall results here.

The effect of removing the GHG emissions reduction benefit estimate is shown in **Table 23**. As might be expected the effect is negligible in both scenarios. Total benefits (and net benefits, given costs do not change) are reduced by $4.07 million in the lower bound scenario and $13.43 million in the upper bound scenario. The BCR remains strong in both scenarios.

Table 23 CBA results, removing GHG emissions reduction benefits (PV, $m)

	Upper bound	Lower bound
Total benefits	$757.59	$406.10
Total costs	$369.19	$345.82

	Upper bound	Lower bound
Net benefits	$388.40	$60.28
Benefit-cost ratio (BCR)	2.05	1.17

Source: Authors' estimate

8.0 Conclusion

The assessment of likely economic costs and benefits associated with a weekly food waste collection service for urban households in Auckland shows that society would be made better off as a result of the service.

While a range of potential benefits are possible as a result of the service, our initial analysis focussed on two benefits that were most likely to be material and that had a relatively high likelihood of occurring. These benefits relate to a gain in consumer welfare and a reduction in greenhouse gas emissions as a result of the service. While we acknowledge the possibility of double counting (i.e. that the willingness to pay of households already factors in possible reductions in greenhouse gas emissions (and the associated benefits), we follow the practice of the source material used and include both benefit estimates in our totals. We consider the impact on our results of removing the reductions in greenhouse gas emissions from benefit estimates in the sensitivity analysis.

The cost categories used in the analysis related to material collection, transport and processing, administrative and rollout costs, and the economic costs of public expenditure on the service. Both the costs and benefits used in this study were informed by studies and insights from within New Zealand and overseas.

Over a 30 year assessment period, using a discount rate of four per cent, we estimate that society would be better off by between $64 million and $402 million on a present value basis as a result of the service. Benefits exceed costs by between 19 per cent and 109 per cent.

This range of figures represents "upper bound" and "lower bound" estimates, based on key assumptions and parameters including household use of the service, the willingness of households to pay for the service and the social cost of greenhouse gas emissions. There was insufficient reliable data to calculate a robust central or medium estimate, but a simple midpoint would suggest net benefits of $233 million would accrue (over the 30 year study period) and benefits would outweigh costs by around 65 per cent (i.e. a benefit-cost ratio of 1.65). The vast majority (around 98 per cent) of estimated total benefits relate to consumer welfare.

Sensitivity analysis revealed that:

- The willingness to pay input had the greatest effect on overall results. The main driver of the lower net benefits in the "lower bound" scenario was the change in willingness to pay per household per week from $1.97 ($1.50 adjusted to 2017 dollars) to $1.16 ($0.88 adjusted to 2017 dollars). The proportion of households willing to pay for the service is also influential.

- Altering the discount rate used had predictable effects, given upfront capital costs and ongoing benefits. With a discount rate of 12 per cent, the “lower bound” scenario sees society being made slightly worse off from having the service as opposed to no food waste collection service being in place.
- Altering the time period for the analysis (i.e. truncating the analysis to 10-year and 20-year periods respectively) had similar results.
- Altering the remaining parameters, predominantly around waste volumes and rates of household service use, did not materially change the positive results achieved. This is largely due to the willingness to pay benefits category being invariant to such changes, while costs change proportionally.
- Removing the benefits associated with reductions in greenhouse gas emissions had a negligible effect on the overall results.

9.0 References

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Appendix A : Overview and initial assessment of benefits

Stakeholders	Benefits/ Dis-benefits	Benefits description	Significance (materiality)		Reason for significance		Indicator		Proxy	
			Likelihood	Magnitude	Likelihood	Magnitude	unit	source	unit	source
Auckland Council	+Cost saving	+ Extending the life of current landfills. Management cost of landfill goes down	Moderate	High	Depends on the capacity of the current landfills and estimate of future waste (based on population growth)	A new landfill is a major cost for the city.	A new landfill (in the future of the project life)		Cost of a new landfill in future (in the project period)	
Households	- Time	- Time is spent to separate the waste	High	Moderate to low	households have to spend some time to make sure their organic food is separated, sorted into relevant container and taken to kerbside	It is not major because as soon as they get used to it they would sort it out without spending much of their time.	Minutes spent to get organic waste to kerbside less any time saving from less time spent on general waste			
	+ Improved soil	+ Home composting would increase	High	Low	When households have to pay for their organic waste to be collected they will be encouraged to save some money by composting the waste rather than putting it in the kerbside.	They would use the compost in their gardening that means greener and healthier garden without spending for any fertiliser. But this benefit is not significant in magnitude compared to other benefits.				

Stakeholders	Benefits/ Dis-benefits	Benefits description	Significance (materiality)		Reason for significance		Indicator		Proxy	
			Likelihood	**Magnitude**	**Likelihood**	**Magnitude**	**unit**	**source**	**unit**	**source**
	+Cost savings	Households would have lower volumes of general refuse as a result of diversion of organic waste	Low	Moderate	Pure "pay as you throw" model does not exist (i.e. targeted rate is not based on volume)	Need to cover fixed costs so weight-based portion would not operate on total volumes-reducing the impact in non-linear manner				
	+ Welfare gain	Consumer surplus from increased recycling volume relative to status quo	Moderate	Moderate to high	Some debate on inclusion of such effects in CBA	Lack of specific data means conservative approach preferred	Willingness to pay for additional recycling	Covec (2007); Australian studies for CDS in 2012.		
Aucklanders (including the local environment components)	- Congestion	- More heavy vehicles on road	Low	Low	The collection could be done off-peak.	Even if the collection is on-peak, the new vehicles would be substituted with some of the waste collection vehicles compared to counterfactual.				
	- Decrease Local air quality	- More heavy vehicles on road	Low	Low	They would be substituted with some of the waste collection vehicles compared to counterfactual.	They would be substituted with some of the waste collection vehicles compared to counterfactual.	Particulate matter (PM_{10} and $PM_{2.5}$) Oxides of nitrogen (NO_x – includes NO_2 and NO)	Vehicle Emission Prediction Model (VEPM), from Emission Impossible, RIMU		

Stakeholders	Benefits/ Dis-benefits	Benefits description	Significance (materiality)		Reason for significance		Indicator		Proxy	
			Likelihood	Magnitude	Likelihood	Magnitude	unit	source	unit	source
	+ Avoided transport cost (air quality/ congestion) to new land fill in the future	+ The current landfill capacity will be freed out. There is no need to add a new landfill site (in the project life). A new landfill is further away and has higher transport external costs for Aucklanders	Moderate	Low	A new landfill has to be built outside of Auckland region but it depends to the capacity of the available landfills.	Additional air quality and congestion cost would not be significant compared to other benefits and costs of the project.				
	+ Less groundwater contamination	+ Less use of chemical fertiliser	Moderate	Low to moderate?	High volume of cheaper fertiliser (compost) compared to chemical fertiliser would be available in market especially for rural Auckland it very likely to be substituted.	The magnitude depends on the impact of the chemical fertiliser vs. compost on waterbodies (literature)				
		+ Less Leachate	Moderate	Low to moderate?	Food waste is the main source					
Landfill operators/owners	- Less energy Produced	- They would lose the main source of energy.	Moderate	??						
Refuse collectors	+ Efficiency benefits	+Productivity and capital utilisation opportunities as a result of lower volumes of refuse being collected (time savings from fewer trips to empty, less labour input required, extended vehicle life)	Moderate	Moderate	Existing contracts in place may negate the possibility of significant change in timeframe of analysis	Collection contracts not based on volumes at present. In addition, changes to frequency of collection could offset any potential gain (i.e. gain		Commercially sensitive material may not be released	General proportion of cost savings possible could be inferred from CDS work and other studies	

Stakeholders	Benefits/ Dis-benefits	Benefits description	Significance (materiality)		Reason for significance		Indicator		Proxy	
			Likelihood	Magnitude	Likelihood	Magnitude	unit	source	unit	source
						is predicated on existing conditions continuing)				
Council or private organic waste collectors	+ Energy produced	+ They could produce energy	High	High						
	+ Compost and mulch production	+ They could produce compost and mulch	High	High						
Environment	+ Greenhouse gas reduction	+ Reduction in CO_{2-e}	High	High	It is the most significant result of the service	The service would have a significant impact on greenhouse gas reduction.	0.72t CO_{2-e}/ t Organic waste	MfE (2006) New Zealand's Greenhouse Gas Inventory 1990 – 2004 The National Inventory ? Covec (2007)	$60? (a couple of scenarios)	MfE?

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