Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill

A case study based on HLC Ltd development in Auckland

Mehrnaz Rohani, Ting Huang, Leon Hoffman, Mark Roberts and Barbara Ribeiro

July 2019 Technical Report 2019/009

RIMU Research and Evaluation Unit

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Executive summary

Sending construction and demolition (C&D) waste to landfill creates environmental problems for Auckland. Data on Auckland's waste volumes indicate that C&D waste (e.g. rubble, concrete, timber, plasterboard, insulation materials) together account for 40 per cent of all waste sent to landfills (Auckland Council, 2018b).

Auckland Council has a vision of "Zero waste by 2040" (Auckland Council, 2018a). To achieve this, the council has set a long-term target in its Waste Management and Minimisation Plan (WMMP) of reducing total waste to landfill by 30 per cent by 2027. As Auckland's single largest waste stream, with high tonnages going to landfill and high diversion potential, C&D waste has been identified by the council as a priority waste stream to achieve the WMMP's target.

As C&D waste is a source of commercial waste, the council has limited influence over the construction industry's behaviour of managing it. However, there is an opportunity to work with large-scale developers to support C&D waste diversion through wider uptake of deconstruction methods instead of demolition, and facilitating the recycle and reuse of materials.

This is a report on a high-level Cost Benefit Analysis (CBA) of two options proposed by Auckland Council's Waste Solutions Unit for C&D waste diversion from landfill. For each proposed option, expenditure is spread across a series of activities that relate to each of the broad areas of focus identified for C&D waste diversion, namely awareness, infrastructure, brokerage, regulatory controls, training, job and business opportunities.

The CBA in this study compares a 'current state' option (which is based on a continuation of current expenditure and practices of C&D waste management), referred to as the status quo or counterfactual, and two alternatives, Options A and B. The study measures the changes in costs and benefits under the proposed options relative to the status quo. Based on the modelling information provided by Waste Solutions, both Options A and B will result in significant additional C&D waste diversion compared to the status quo. Option A will achieve this by focusing more on partial recovery and recycling of waste. Option B will achieve this with stronger focus on minimising waste through reduction of waste generation and reuse of waste materials.

This study focuses on C&D waste from residential developments. To illustrate a comprehensive economic case of the two options proposed for C&D waste diversion, two analyses are undertaken. The main analysis is the economic CBA for Aucklanders (i.e. the broader society). It assesses the social, economic and environmental impacts for Auckland under each option compared to the status quo. In order to show the impacts of the proposed changes to the main stakeholder group, a financial CBA (distributional analysis) is also carried out to estimate the additional costs and benefits to developers under each option relative to the status quo. The scope of the study only applies to the removal of the existing houses (demolition, deconstruction or relocation) and waste management during the construction process. Remediation of house removal and building activities are not in scope because they are the same under the status quo and the proposed options.

There is no data available on the future levels of house demolition and house construction in Auckland. Therefore, a planned residential development by Housing New Zealand subsidiary, the Homes Land Community Alliance (HLC) is used as a case study to evaluate the effects of each C&D waste diversion option. The HLC development is expected to be completed by 2031. In total, over 7000 homes will be demolished and replaced with over 22,000 new homes across the five HLC development areas. This is expected to result in approximately 212,000 tonnes of demolition waste. The development of replacement homes on this development is likely to result in a further 91,000 tonnes of construction waste.

The CBA methodology used in this study is in accordance with guidance on CBAs provided by the New Zealand Treasury (2015) and Auckland Council's CBA primer (Auckland Council, 2017). For a policy option or investment to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than one. The study uses information and data obtained from various sources (e.g. insights from industry experts, previous case studies in Auckland and studies in the literature) with very conservative assumptions applied. Acknowledging the uncertainty in behavioural change in C&D waste management, the study adopts a pragmatic and conservative approach to avoid over-estimation of the potential benefits.

The study covers a 12-year period from 2019/20 and 2030/31 during which the HLC development will take place. Because the analyses are carried out based on the HLC development, the study assumes that the HLC development will be the driver of the investment under Options A and B. The results are summarised below.

Results of the economic CBA

The main costs to Auckland associated with the two C&D waste diversion options include the cost of investment attributed to the HLC development, cost of training additional workers employed onsite and offsite and the deadweight cost. Benefits considered in the economic CBA include social benefits associated with additional employment and obtaining training in employment, economic benefit from savings in construction materials, and environmental benefit associated with less greenhouse gas (GHG) emissions. Potential benefits associated with mitigation of disturbances and other negative impacts to the communities, flow-on impacts to family wealth and Māori cultural values associated with intergenerational resource sustainability are not included in the analysis. Both the costs and benefits in the economic CBA are informed by studies and insights within New Zealand and overseas.

The range of the estimated benefits (i.e. the extent to which society is better off as a result of the options) are $6.97 million and $14.46 million in present value terms for Options A and B respectively. These correspond to a BCR of 2.83 and 2.27. This indicates that the costs associated with either option are more-than offset by the benefits to society. This is even under conservative assumptions and with some potential benefits unquantified.

Scenario testing is undertaken to assess how results of the economic CBA would change with pessimistic (Worst Case) and optimistic (Best Case) assumptions. The scenario testing result in a range of BCR values between 0.75 and 5.79 for Option A, and 0.97 and 3.13 for Option B (Table A below). For both options, only the Worst Case scenario would result in negative NPVs and BCRs below 1 (less than 10 per cent chance that this may occur). Although compared to Option A, Option B's BCRs are smaller in the Most Likely and Best Case scenarios, however, this option will deliver greater net benefits to society.

Table A: Summary of the economic CBA results

	Option A ($_{2019}$ $million)			Option B ($_{2019}$ $million)		
	Worst Case	**Most Likely**	Best Case	Worst Case	**Most Likely**	Best Case
Total benefits	$2.86	**$10.78**	$21.70	$11.12	**$25.86**	$35.38
Total costs	$3.83	**$3.81**	$3.75	$11.41	**$11.40**	$11.31
Net benefits (NPV)	-$0.96	**$6.97**	$17.95	-$0.29	**$14.46**	$24.07
Benefit-cost ratio (BCR)	0.75	**2.83**	5.79	0.97	**2.27**	3.13

Note: a discount rate of four per cent is applied to calculate the present values as at 2019.

When controlling for each cost and benefit assumption in the sensitivity analysis, it is found that assumptions on the proportion of investment attributed to the HLC development and savings in construction materials have the greatest impact on the results for both Options A and B. However, the BCR values of both options stayed above 1 when each of the assumptions is adjusted to their Worst Case scenario values at a time. The range of estimated net benefits and BCRs of both options are stable when alternative discount rates (ranging from 2% to 10%) are applied.

The net economic benefit from materials saved due to relocation has the greatest impact on the results of both Options A and B. Removing this benefit would result in negative NPVs and BCRs less than 1 for both options.

Results of the financial CBA (distributional analysis)

For the developers, the cost items considered in the financial CBA relate to sorting waste onsite, recycling (transporting waste to material recovery facilities (MRFs) and gate fees paid to the MRFs for recycling), reusing, collecting waste (additional skips required to collect and send waste to various destinations) and designing out waste. Under both options, cost of sorting accounts for more than half of the estimated total cost. This reflects the fact that deconstruction is a more labour intensive approach to remove buildings compared to demolition.

The benefits measured in the financial CBA include revenues from selling salvaged materials, revenues from selling relocated dwellings, cost savings associated with landfill disposal (fees paid for landfill disposal and cost of transporting waste to landfill) and cost savings in purchasing new construction materials. Of these, the analysis shows that cost savings associated with landfill disposal and purchasing new materials make up a significant proportion of total benefits to the developers under both options.

Results of the financial CBA indicate that both Options A and B are essentially breakeven for the HLC developers, with corresponding BCRs of 1.01 and 0.97 respectively. This does not account for any potential gains for the developers if the intangible benefits associated with improved reputation and credentials can be realised.

In anticipating the future changes in New Zealand's waste levy which would subsequently change the fees paid for landfill disposal, the study considers two alternative waste levy scenarios ($20 per tonne from year 2020/21 and $90 per tonne from year 2020/21). Results indicate that, for both Options A and B, NPVs for the developers improve as the waste levy increases.

Keeping in mind the uncertainty in the assumptions made in the financial CBA, two alternative scenarios, namely 'Worst Case' and 'Best Case' scenarios, are developed for scenario testing. For the Worst Case scenario, values of the assumptions about costs are adjusted upward and assumptions about benefit values are adjusted downward. This is done conversely for the Best Case scenario. In this analysis, Option A's BCR ranges between 0.21 and 4.04, and Option B's BCR values vary between 0.26 and 2.80.

Sensitivity analysis is also undertaken to assess the individual effect of each cost and benefit assumption on the BCR results of the financial CBA. It is found that assumptions on the cost and benefit of designing out waste and assumption on the unit cost of sorting waste have the greatest impact for both Options A and B. In the sensitivity analysis of the discount rate, the BCRs of both options are approximately the same when two alternative discount rates, 6 per cent and 10 per cent are applied.

Discussion and conclusion

Results of the economic CBA support the view that Auckland can be better off with either of the two C&D waste diversion options proposed for the HLC development. A conservative approach to measure the benefits is adopted at all times. There are benefits that are not quantifiable and hence are not included in the analysis. Option B is the preferred option, although it has a lower benefit to cost ratio compared to Option A, it delivers significantly greater net benefits to society.

Results of the distributional analysis indicate that the developers would essentially breakeven from implementing C&D waste diversion from landfill. There may be additional gains for the developers if the intangible benefits (improved reputation and credentials from diverting C&D waste) can be realised. Net returns to the developers under either option would also increase as the waste levy increases. While both options give similar propositions on the business side, however, taking results of the economic CBA into account, Option B would be more beneficial than Option A given the wider Auckland would be better off under this option.

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1.0 Introduction

Sending construction and demolition (C&D) waste to landfills creates environmental problems for Auckland, including water and soil pollution (Building Research Association of New Zealand (BRANZ), 2014a). Although most C&D waste is sent to cleanfills and managed fill sites,[1] it has been estimated that C&D waste together accounts for 40 per cent of all waste to landfills in Auckland (Auckland Council, 2018a & 2018b). This issue is shared by many cities around the world.

Auckland Council has an aspirational vision for Auckland – '*Zero Waste (to landfill) by 2040 – taking care of people and the environment and turning waste into resources*' (Auckland Council, 2018a). At the heart of the Zero Waste vision is Te Ao Māori and the tradition of kaitiakitanga – the active obligation to sustain and restore our collective resources to enhance the mauri (essence) of taonga tuku iho (treasures of our heritage). To achieve this, the council has set a long-term target in its Waste Management and Minimisation Plan (WMMP) of reducing total waste to landfill by 30 per cent by 2027. As Auckland's single largest waste stream, with both high tonnages going to landfill and high diversion potential, C&D waste has been identified as one of the three non-domestic priority waste streams in the WMMP.[2]

The council is seeking ways to encourage the development of innovative solutions for reducing C&D waste as a commercial waste (rubble, concrete, timber, plasterboard, insulation materials etc.). For instance, better planning and onsite management can help the building industry to divert materials such as metal, plasterboard and timber from landfill, and save money. Deconstruction instead of demolition reduces damage to materials, which enables value of those materials to be retained and to be salvaged for further use.

Traditionally, Auckland Council and government agencies have focused on providing web information, fact sheets, planning advice and checklists, to increase the uptake of home deconstruction by developers, construction companies, builders and home owners. Although the council has limited influence over the behaviour of companies managing C&D waste, there is an opportunity to work with large developers, communities and iwi to support C&D waste diversion through wider uptake of deconstruction and facilitating the recycle and reuse of materials. Based on this

[1] Cleanfill is a type of landfill that accepts materials that, when buried, have no adverse effect on people or the environment. Managed fill is a disposal site requiring resource consent to accept well-defined types of non-municipal waste (e.g. low-level contaminated soils). Refer to the 2018 Auckland Waste Management and Minimisation Plan (Auckland Council, 2018a) for details.

[2] The other two priority waste streams are organic and plastic waste. Refer to page 62 of the 2018 WMMP (Auckland Council, 2018a).

notion, Auckland Council's Waste Solutions Unit have proposed two options for C&D waste diversion from landfill.

Central and local government must show value for money for any initiative or policy that requires public funding. To demonstrate that Auckland will be made better off from public investments, Cost Benefit Analysis (CBA) can be used to support the council's decision-making in choosing a policy proposal that could deliver a desirable outcome for Auckland and reflect better value for money.

This report presents a high-level CBA undertaken by Auckland Council's Research and Evaluation Unit (RIMU) for Waste Solutions' two options proposed for C&D waste diversion from residential developments. The first option focuses more on diverting C&D waste from landfill by partial recovery and recycling of waste. The second option has a stronger focus on reuse of materials and reducing waste and resource use from C&D activities. The study has two separate analyses:

- The main analysis, economic CBA, evaluates the social, economic and environmental impacts to Aucklanders under the proposed changes of each option compared to the status quo.
- A distributional analysis, financial CBA, looks at the additional costs and benefits to developers on their project under each of the proposed options compared to the status quo.

There is no data available on the future levels of housing demolition and construction in Auckland. Therefore, a planned residential development by Housing New Zealand subsidiary, the Homes Land Community Alliance (HLC) is used as a case study to evaluate the effects of each C&D waste diversion option. The study relies on industry data and information, previous case studies in Auckland and the wider literature. Constrained by amount of data and information available and timeframe of the study, it is not possible to measure all the potential impacts that would result from the activities under each proposed option. Therefore, in terms of the level of detail, this CBA falls somewhere between a 'preliminary' and 'indicative' assessment, while employing conservative assumptions at all times.

The report is structured as follows:

- Section 2 presents the context of C&D waste management, including an overview of the literature on the concepts that underpin economic evaluations of C&D waste diversion from landfill.
- Section 3 describes the current status of C&D waste and relevant C&D waste management practices in Auckland, and the proposed options for C&D waste diversion.

- Section 4 outlines the scope and the underlying assumptions of this study.
- Section 5 describes the methods used for estimating the costs and benefits to Aucklanders in the economic CBA, and presents the results under each proposed option (including results from scenario and sensitivity testing).
- Section 6 presents the financial CBA of C&D waste diversion from landfill, including the estimated costs and benefits to developers under each proposed option compared to the status quo.
- Section 7 provides a short discussion of the results with conclusions.

2.0 Concepts related to construction and demolition waste diversion from landfill

This section is a literature review on the concepts and practices related to C&D waste diversion from landfill. The review focuses on the 5Rs hierarchy of waste management, circular economy, designing out waste, and the involvement of social enterprises in C&D waste management. Most literature is found from outside of New Zealand.

2.1 The 5Rs hierarchy of waste management

The 5Rs Hierarchy of Waste Management is a well-established framework for waste minimisation across all sectors (Figure 1). The hierarchy is used by the Ministry for the Environment (MfE) and includes reduction, reuse, recycling, recovery and residual disposal. It provides a useful guide for managing C&D waste as it prioritises reduction in material use which is known to produce the most beneficial effect on natural systems (Holman, 2016).

Figure 1: Waste minimisation hierarchy

Source: Holman, 2016

Starting from the top of the hierarchy, 'reduction' is always the best option to minimise waste. There are three avenues for reducing waste – reduction of raw material extraction, reduction of materials to landfill, and reduction of a structure's life-cycle cost (Brennan et al., 2014). This can be implemented by, for example, designing structures for end-of-life disassembly (Rios, 2015), avoiding the purchase of overly-packaged material, or providing an accurate inventory of required materials to reduce oversupply (United States Environmental Protection Agency (US EPA), 2017).

Traditional demolition methods for taking down an old building produce large amounts of waste to landfill (and cleanfill). One way to minimise demolition waste is the reuse of component material, either in parts or as a whole (Brennan et al., 2014). Deconstruction, often referred to as the reverse of construction, is the process in which the material of a building is extracted in a way so that it can be reused (Rios, 2015). Materials and systems extracted from a deconstructed building can include doors and windows, fixtures, or timber.[3] They can be reused by both builders and owners, or sold for use in other projects (Building Research Association of New Zealand, 2008a). Further benefits of deconstruction are detailed in Section 2.4.

When the reuse of a component is not possible, it may still be possible to recycle it in whole or part (Brennan et al., 2014). Recycling refers to reprocessing the used materials to create something new. There are over 100 recycling centres in Auckland across all operational scales (Roberts, 2005). To reduce the landfill disposal costs, demolition contractors in Auckland are keen to recycle materials (Building Research Association of New Zealand, 2014a).[4] While most waste from demolishing residential buildings can be recycled, there are a number of constraints. These include facility proximity and priority, quality of materials, and time available (Building Research Association of New Zealand, 2008a).

Following the processes of reduction, reuse and recycling, materials may be recovered for energy production, for example, as a fuel for concrete manufacturing. Any remaining waste that cannot be recovered would then go to landfill for residual disposal, and this should be the last stage of waste management.

Currently, the construction industry in New Zealand still relies on recovery and residual disposal as waste management techniques, rather than reduction, reuse or recycling (Auckland Council, 2018b). However, the 5Rs hierarchy of waste management can be used as a tool to analyse each material extracted from end-of-life structures to determine the output destination for extracted building materials.

[3] See Appendix A for an expanded list of reusable building materials.

[4] See Appendix A for a list of demolition waste which can be recycled.

Using the hierarchy as the underpinning framework, this study estimates the potential impacts of the two C&D waste diversion options based on estimates of waste tonnages ending up at each level of the hierarchy.

2.2 The circular economy concept in construction and demolition waste management

The concept of a Circular Economy focuses on the reduction, reuse and recycle levels of the 5Rs hierarchy. The concept suggests that we should move away from the linear approach of 'take-make-dispose' (Antikainen et al., 2018) towards a system that aims to keep products, components and materials at their highest utility and value at all times (Ellen MacArthur Foundation (EMF), 2015a). By closing material and energy loops, for example, via long-lasting product design, reuse and recycling, the circular economy approach can help minimise resource use, waste and emissions (Geissdoerfer et al., 2017).

In 2018, The Sustainability Business Network (SBN) commissioned the Sapare Research Group to undertake a study on the circular economy opportunity for Auckland (Blick and Comendant, 2018). The study highlights construction as one of the most wasteful industries in Auckland, alongside with the food and the transport sectors. It estimates that the construction sector comprises over half (NZ$3.617 billion) of the potential value added of having a circular economy to Auckland's gross domestic product (GDP). A significant proportion of this comes from savings in materials and labour costs for the firms in the sector.

BRANZ have been researching ways to divert construction waste from landfill in a collaborative effort with the Auckland Council. Their work aligns with the Building Act 2014, which embeds waste minimisation as a core principle. This research has produced guides to help businesses in the transition to circular practices (e.g. Building Research Association of New Zealand, 2014a and 2014b).[5] Even though the practical advice found in these guides lack a 'circular' label, they often refer to terminology encountered in the circular economy literature (e.g. 'closing the loop of materials') (Jurgilevich et al., 2016; Toop et al., 2017). In addition to more generalisable recommendations, BRANZ have documented cases of enterprises that are committing to circular ways of doing business in the construction sector. These can be used to cast light on ways of enacting a more circular construction sector for Auckland by diverting C&D waste from landfill.

[5] These guides are available from BRANZ's website at: https://www.branz.co.nz/cms_display.php?sn=240&st=1&pg=12648.

Other studies in London, Helsinki and Copenhagen (to name a few) find that the construction sector's circular economy potential comes from cost efficiency, reduction in greenhouse gas (GHG) emissions and increased employability. However, scholars also highlight that only a few of those studies assess the whole life cycle of conventional buildings within a cradle to cradle approach instead of a 'take-make-dispose' perspective (including the design phase) (Ghisellini et al., 2018). Scaling up the circular economy would require radical change in business mind-sets and management commitment, as well as legislation and policy and support for infrastructure and social awareness (Antikainen et al., 2018).

2.3 Designing out waste

Drawing from the circular economy concept, it appears that there is broad consensus that strategies to reduce (C&D) waste should prioritise a top-down approach that focuses on the reduction of input material and reuse of output material. Ensuring such priorities gives rise to the practice of designing out waste (Tran, 2017; Osmani et al., 2008; Llatas and Osmani, 2016), which aims to eliminate or minimise potential waste produced at every stage of a construction project – design, construction and demolition.

One approach to designing out waste is to design for deconstruction (DfD). When buildings are designed with deconstruction in mind, they can be deconstructed more easily with less damage to materials, thus yielding higher material recovery rates (Tingley, 2012; Morgan and Stevenson, 2005) and even increasing the profitability of deconstruction (e.g. Storey et al., 2005; Ghisellini et al., 2018). Common DfD practices mentioned in the literature include use of prefabricated materials (Jaillon et al., 2009; Jaillon and Poon, 2014), steel connections (Guy et al., 2006; Akbarnezhad et al., 2014; Llatas and Osmani, 2016) and non-composite materials (Tingley, 2012). Guy et al., (2006) also suggest designs that minimise the types of building materials and components can simplify the disassembly and sorting process in deconstruction.

DfD can result in significant environmental and economic benefits. While structures built according to DfD frameworks may initially be more costly at the construction stage, they tend to cost less for maintenance and repair during their service life. Buildings that are designed for deconstruction also output less waste and provide an enhanced rate of material recovery (along with greater potential sales of recycled materials) at the end of the building's service life, leading to overall cost and energy saving (Morgan and Stevenson, 2005; Tingley, 2012). One case study based on a housing project in Singapore has estimated that DfD strategies could achieve a nine per cent reduction in the building's life cycle cost, between 34 and 37 per cent reduction in energy use, and between 37 and 40 per cent reduction in carbon emissions (Akbarnezhad et al., 2014). Similarly, a UK-based study by Tingley (2012) demonstrates that DfD strategies can reduce the carbon emissions contained in a building by a quarter over its life cycle.

However, there has been a low uptake of DfD (or design-out waste in general), with little interest from architects (e.g. Osmani et al., 2008; Kelly and Dowd, 2015). Studies in the UK, Ireland and New Zealand highlight that the main barriers to designing out waste are higher initial costs, lack of commitment from the client and lack of training (Morgan and Stevenson, 2005; Akinade et al., 2017; Osmani et al., 2008; Kelly and Dowd, 2015; Tran, 2017).

Economic incentives may also play a critical role in influencing the uptake of designing out waste or waste minimisation strategies (Akinade et al., 2017). In New Zealand, Tran (2017) finds that developers and project managers are more incentivised to invest in waste minimisation at the early design stages of a construction project if there is a 1500 per cent increase in the waste levy (from the current rate of $10 per tonne). Based on this finding, Tran's economic evaluations of two commercial construction projects in Auckland show that benefits outweigh costs when 71 per cent or more C&D waste is reduced by designing out waste.

2.4 Social enterprise involvement in construction and demolition waste management

International literature highlights the significance of social enterprise involvement in C&D waste management practices. According to Zizys (2008), a social enterprise is "an income earning business that seeks to meet one or more social goals" (p. 4). Within the deconstruction industry, social enterprises are found across a number of sectors including training and education, employment, retail, salvage and manufacturing.

Deconstruction provides a number of social and community benefits. These include: the alleviation of unemployment through work including disassembly, resource recovery, sorting, salvage and hauling (Bell, 2011); training for low- and un-skilled or marginalised individuals in tool, carpentry and building techniques (Kibert et al., 2000) which are marketable in the construction industry (Chini and Bruening, 2003); the fostering of small businesses and community orientated social enterprises including deconstruction services, used building material stores, salvage operations and small manufacturing centres (Kibert et al., 2000; Bell, 2011); the reduction of neighbourhood blight (Bell 2011); increased availability of typically unaffordable building materials in low-income areas (Chini and Bruening, 2003); community volunteering opportunities (Telander, 2014); and the preservation of community history through the repurposing of material (Hoag Jr, 2016). Deconstruction is also considered to be less upsetting to communities as it minimises disturbances created by demolition such as unwanted noise, increased traffic and the spread of pollutants (Hoag Jr, 2016). As such, the deconstruction industry provides ample opportunity for social enterprises to meet their social and community goals.

Zizys' (2008) publication *Feasibility Study for a Social Enterprise Deconstruction Business* highlights the value that a deconstruction social enterprise can have for individuals participating in it. These include acquiring job-related skills, acquiring employability skills, gaining skills and experience while getting an income, and advancing after participation in this program.

As well as benefiting individuals, social enterprises can also benefit the communities in which they are embedded. In her report *Deconstruction in Tāmaki*, Otter-Lowe (2018, p8) notes that a social enterprise in the deconstruction industry can support its community in a number of ways:

- Providing employment and training opportunities.
- Collaborating with others to create complementary social enterprise.
- Having a local procurement policy that keeps money circulating in the local economy.
- Providing low cost materials to low income families.
- By donating materials for community and creative initiatives.
- By creating a space at the salvage yard where innovation, collaboration and community come together.
- By ensuring that any profits generated by the enterprise are used for the benefit of the community.

With these individual and community benefits in mind, Appendix B summarises a number of deconstruction projects from around the world that involve the creation and/or use of social and community enterprises, and that undertake with the social benefits of deconstruction as a priority.

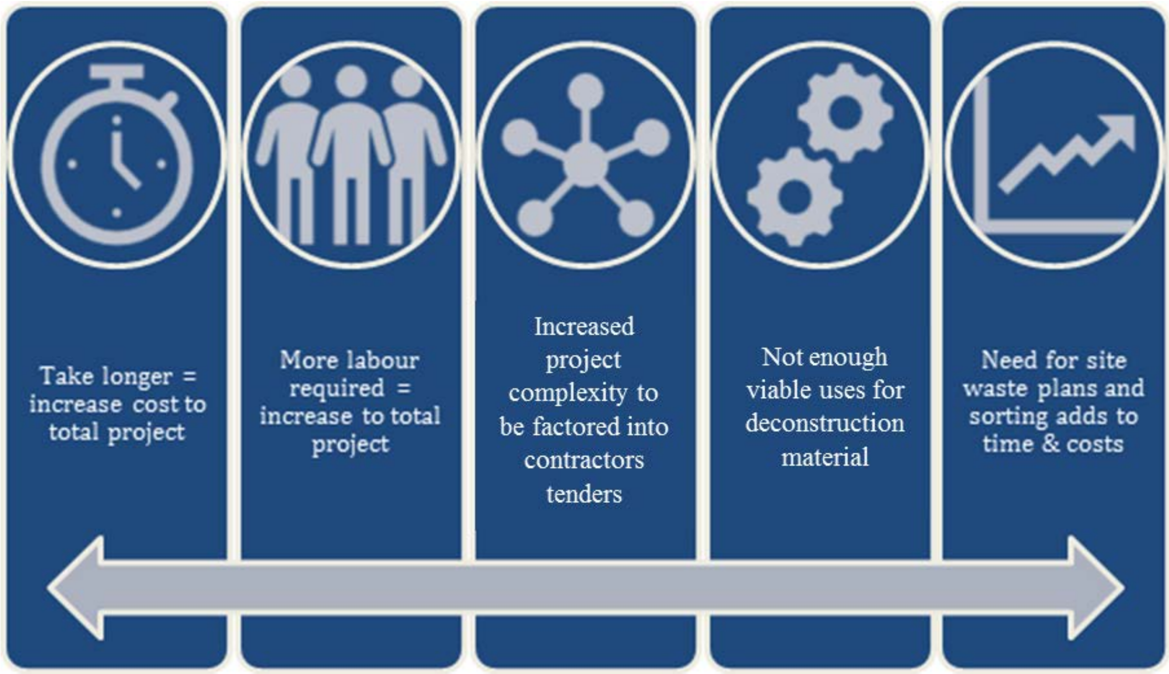
3.0 Construction and demolition waste management in Auckland

This section provides an overview of the current status of C&D waste and its management practices in Auckland. It highlights the central issue of increasing tonnages of C&D waste to landfill as Auckland evolves.

Auckland Council's Waste Assessment (2018b) indicates that around 700,000 tonnes of C&D waste is generated each year in Auckland. As Auckland experiences growth in development of housing and commercial properties, C&D waste generation is expected to grow. For example, HLC, the largest housing development Alliance in Auckland, will be demolishing more than 7000 homes over the next five years resulting in over 200,000 tonnes of demolition waste. The development of replacement homes on this project is likely to result in a further 90,000 or more tonnes of materials. Waste materials from these types of buildings typically end up in landfill or, at best, in a resource recovery facility.

While deconstruction is a proven method of decreasing waste from demolition (Tarkar, 2018), the economic case for this method is frequently questioned (Storey et al., 2005). As the construction industry is time and cost driven, developers (and construction project managers) typically favour demolition over deconstruction as they perceive it is the quickest and cheapest way to take down old buildings. Figure 2 depicts the current perceptions associated with deconstruction. These are mainly concerned with the complexity of deconstruction in terms of project management, site planning, commitment, skills required for the task and onsite waste sorting. Also, the uncertainty about demand for deconstruction materials often leads to developers to question the profitability of deconstruction.

Figure 2: Current common perceptions of limitations associated with deconstruction



3.1 Auckland's construction and demolition waste problem

It has been estimated in the recent Waste Assessment (Auckland Council, 2018b) that, in 2016, approximately 1.65 million tonnes of waste generated in Auckland were disposed to landfills.[6] This was a 40 per cent rise from 1.17 million tonnes in 2010. With seven per cent growth in Auckland's population during this period (from 1.46 million in 2010 to 1.56 million in 2016), the per capita tonnage to landfill increased to 1.05 tonnes from the 2010 baseline of 0.80 tonnes per capita. This per capita to-landfill tonnage figure for Auckland was also significantly higher compared to the New Zealand average (0.73 tonne per capita)[7] and the OECD average (0.52 tonne per capita).[8]

While Auckland Council has made an effort to reduce domestic kerbside waste to 144kg per capita between 2010 and 2016 (a 10% reduction from 160kg per capita),

[6] Currently there are five landfill sites where waste generated in Auckland is disposed at, namely Redvale Landfill (owned by Waste Management New Zealand Ltd), Hampton Downs (owned by Enviro New Zealand Ltd), Whitford Landfill (owned by Waste Disposal Services (WDS), Claris Landfill (located in Great Barrier Island, owned by Auckland Council), Puwera Landfill (partnership between Northland Council and Northland Waste Limited, operated by a subsidiary of Northland Waste).

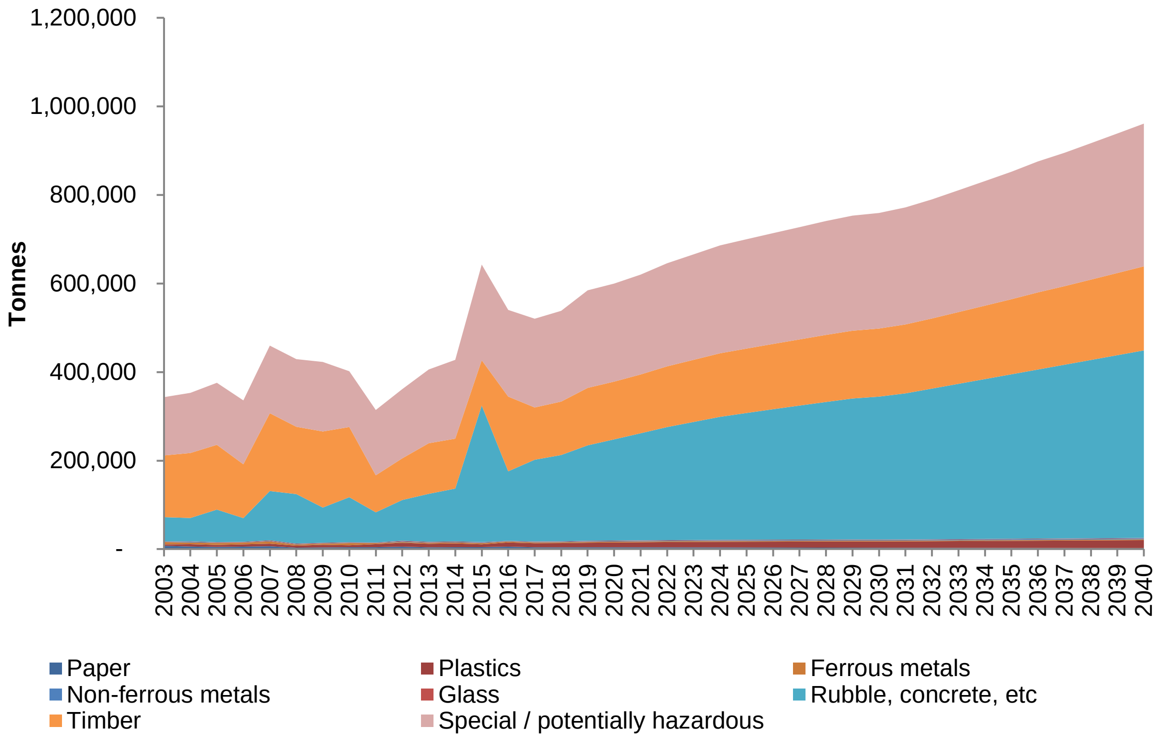
[7] See the Ministry for the Environment's website at http://www.mfe.govt.nz/waste/why-reducing-reusing-and-recycling-matter

[8] See the interactive data of Municipal waste indicator on OECD's website at https://data.oecd.org/waste/municipal-waste.htm

this reduction was outweighed by a significant increase in commercial waste (including C&D waste). According to the council's WMMP (Auckland Council, 2018a), commercial waste accounts for about 80 per cent of all waste sent to landfill, and the council has no control over how this source of waste is managed. It is estimated that in 2016, more than 1.40 million tonnes of commercial waste were sent to landfill, which was almost half million tonnes more than the tonnage of commercial waste to landfill in 2010 (0.93 million). Almost a third (29 per cent) of this increase was attributable to C&D waste.

C&D waste is the largest source of commercial waste in Auckland. The council's Waste Assessment (Auckland Council, 2018b) estimates that C&D waste could contribute up to 40 per cent of Auckland's total waste to landfill, and this does not taking into account the additional quantities sent to cleanfill and managed fill sites. As shown in Figure 3 below, rubble and concrete, timber, and special or potentially hazardous wastes present the three largest streams of C&D waste.

Figure 3: Estimated C&D waste to landfill by waste stream, 2003 to 2040

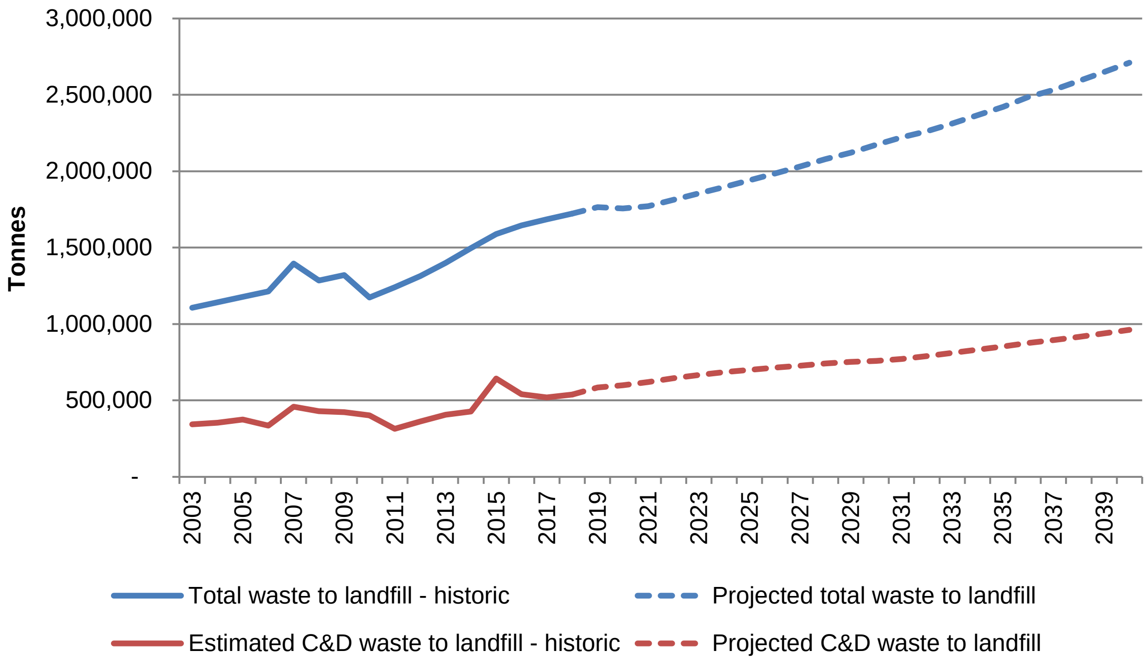


Source: Waste volume trend, Waste Solutions, Auckland Council

Trends also indicate that the significant increase in Auckland's landfill waste tonnage between 2010 and 2016 was largely due to the spike in C&D waste to landfill. This was primarily due to the growth of housing and infrastructure developments (e.g.

developments in Kumeu-Huapai, Hobsonville Point, Flat Bush, construction of the Waterview Tunnel). The positive relationship between C&D waste and total landfill tonnage is expected to continue for the next few decades (Figure 4).

Figure 4: Estimated total waste to landfill and C&D waste to landfill, 2003 to 2040

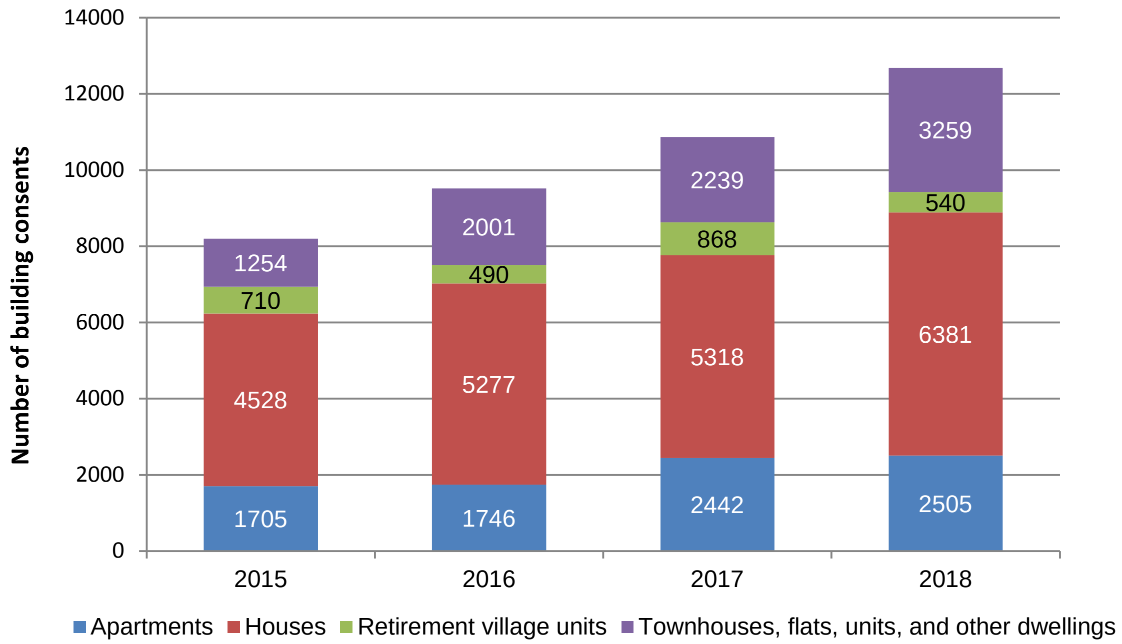


Source: Waste volume trend, Waste Solutions, Auckland Council

Auckland's population growth is a key driver for the increasing C&D waste. Based on a medium growth scenario, Auckland Council has projected that the region's population could exceed 2.1 million by 2040 (from nearly 1.6 million in 2016) (Auckland Council, 2018b).[9] With the number of building consents for residential buildings already on the rise (Figure 5), further increase in the number of residential developments is expected to address the pressure on demand for housing. This means more C&D waste will be generated as construction and demolition activities are expected to further increase.

[9] These figures are cited in Auckland Council's Waste Assessment 2017 (Auckland Council, 2018b, p91). The council does extensive modelling of regional population growth based on land use and transport corridor scenarios prescribed by the Auckland Regional Transport Model. The figures referenced here come from the results based on a medium growth scenario.

Figure 5: Number of building consents by dwelling type, 2015 to 2018

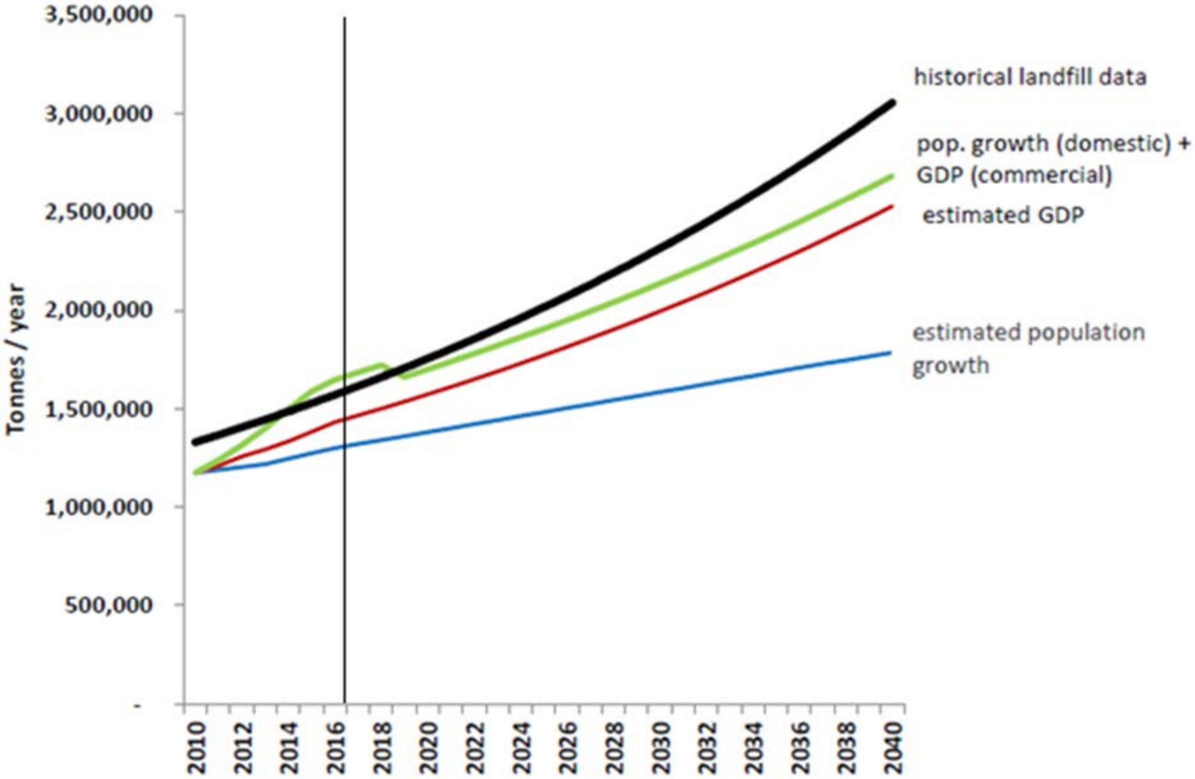


Source: Auckland Council, RIMU's customised building consent database

Another key factor affecting C&D waste is economic activity. Measuring GDP against waste generation finds a positive historical relationship which remains as of 2018 (Auckland Council, 2018b). This can be compared to elsewhere in the world, such as the UK, where waste tonnages (including C&D waste) have started to deviate away from this positive relationship (The Waste and Resources Action Programme, 2012).

The Waste Assessment (Auckland Council, 2018b) has made projections on Auckland's waste to landfill based on historic landfill data, population growth and GDP growth (Figure 6). These projections show a continued increasing trend in waste to landfill, even when accounting for new waste services responding to population and GDP growth.

Figure 6: Auckland's waste to landfill projections

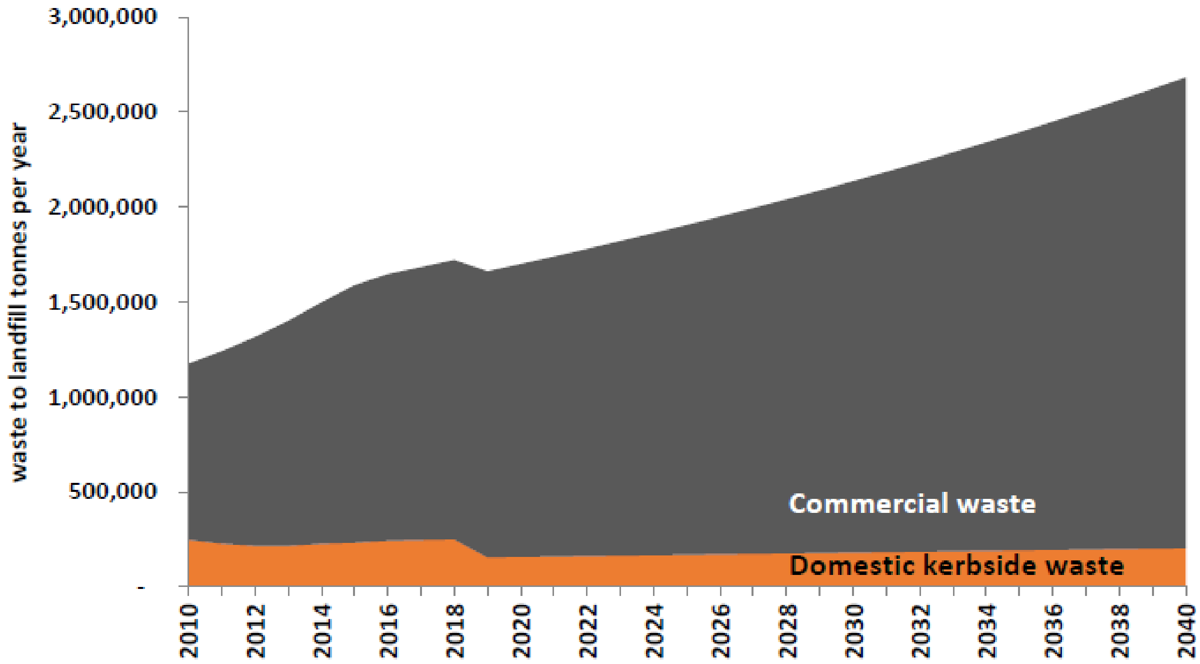


Note: The black line represent projections of waste tonnages to landfill based on Auckland Council's historical landfill data. The red and blue lines show waste generation predicted based on population growth and GDP growth. Historical landfill data, GDP and population growth factors are applied in isolation when producing these projections. The exception to this is the combined domestic population growth and GDP growth projection, as shown by the green line. This projection takes into account changes to average waste per capita when new waste services are introduced. These new services include a domestic kerbside food waste collection and standardised use pays charging regime.

Source: Adopted from Auckland's Waste Assessment 2017 (Auckland Council, 2018b)

The relative proportion of commercial waste is projected to rise continuously over the next two decades while domestic kerbside waste is projected to remain stable (Figure 7). With a number of significant developments (ongoing or planned) taking place across Auckland (e.g. City Rail Link, Commercial Bay Development, residential developments by HLC, development in the Future Urban Zones, etc.), the rising trend of C&D waste is expected to continue, with the relative proportion of rubble and concrete projected to increase (refer to Figure 3).

Figure 7: Projected relative split between Auckland's commercial and domestic waste to landfill



Source: Adopted from Auckland's Waste Assessment 2017 (Auckland Council, 2018b)

In recognising that C&D waste can be more easily diverted for reuse or recycling (e.g. rubble, concrete, metal, timber), the council in its WMMP (Auckland Council, 2018a) has identified C&D waste as one of the three waste streams to prioritise in achieving its waste minimisation target. As the council has limited influence over the behaviour of how commercial waste is managed by the private industries, the increasing tonnages of C&D waste presents a challenging issue for Auckland.

3.2 Deconstruction in Auckland

The practice of deconstruction is gaining momentum in Auckland as a method to divert C&D waste. By dismantling building components, this practice limits the damage to materials and allows them to be salvaged for further use. The practice enables the C&D industry to move up to higher levels in the waste hierarchy in their management of C&D waste, and promoting a circular economy.

A number of large-scale resource recovery plants have recently been established in Auckland by the private sector, providing a mix of manual and automated sorting within Material Reclamation Facilities. These sites provide an option for the processing of mixed C&D waste and recovery of selected material. The plants separate major C&D waste items such as metal, plasterboard and timber, diverting them for reuse and recycling.

However, in Auckland, when a structure comes to its end of life, the most popular approach to take it down is still demolition (Tarkar, 2018; Tran, 2017; Storey et al., 2005). This is largely due to the perceived higher costs of deconstruction associated with time, labour, complexity of the process, site waste plans, onsite sorting and higher degree of commitment (Tarkar, 2018; Tran, 2017) (also see Figure 2). Both the Waste Assessment (Auckland Council, 2018b) and Tran (2017) highlight that the landfill levy (i.e. waste levy) needs to increase in order to encourage C&D waste minimisation and diversion, as the current rate of $10 per tonne does not reflect the true cost of landfill disposal for most of the waste streams.

3.2.1 Case studies in Auckland

While deconstruction is not a common method in New Zealand, a number of deconstruction projects in Auckland show that this is not always the case.

As early as 2008, the deconstruction of nine 1960s state houses in Northcote, undertaken by Resource Efficiency in the Building and Related Industries (REBRI)[10] and Demolition 1, managed to divert 94 per cent of total volume of waste materials (855.3m^3) from landfill (Building Research Association of New Zealand, 2008b). Across similar state housing deconstruction projects, landfill diversion rates remain consistently high. A 1951 timber weatherboard, brick and tile house in Ōrakei had 88 per cent of its material diverted from landfill (Tarkar, 2018), while a recent deconstruction in Helensville undertaken by Envision and the Helensville Community Recycling Centre managed to salvage or recycle 87 per cent of a 1950s weatherboard and tile state house (Envision, 2019). Further, a recent pilot project undertaken by the Tāmaki Regeneration Company (TRC) found little difference in overall net costs when comparing the demolition and deconstruction (after the application of salvage credit) of state houses (Otter-Lowe, 2018). In fact, learnings from this project suggest that in some cases, for dwellings of certain typologies and conditions, the net cost of deconstruction can be lower than traditional demolition. This can even be the case when the need for expanded labour capacity is taken into account. Across these state housing deconstruction projects, crews ranged from three to nine employees who worked for between eight and 17 days.

[10] REBRI started in 1995 as a collaborative effort between local government in Auckland and BRANZ to undertake research and awareness of the issues of waste and efficient use of resources in C&D projects. Since 2003, the initiative extended with partnerships across councils, BRANZ, Recycling Operators of New Zealand and the Ministry for the Environment to undertake more research and develop national waste reduction guidelines. For more details about REBRI, refer to its website at: https://www.branz.co.nz/REBRI.

Typically, materials salvaged from the deconstruction of state houses include native timbers, windows, doors, metals and appliances such as ovens. Recyclable materials include concrete, plasterboard, metal (corrugated iron), hot water cylinders, pipes, glass and different timbers such as native and non-native weatherboards, flooring and joinery.

Deconstruction has also been used in removal of non-residential structures such as community and commercial buildings. Trow Group, an organisation that salvages and donates used building material has been involved in several non-residential building deconstructions. In 2017, Trow Group deconstructed a 1950s park building in Auckland's Whitford Domain over five days with five crew members, and 100 per cent of the waste was recycled or reused (Latu, 2017). Trow Group also partnered with private-sector demolition contractors Greenway to deconstruct a grandstand in Birkenhead (Greenway Ltd, 2018) and a large commercial building in Three Kings (Trow Group, n.d.). Deconstructing the grandstand took five days with four workers (Greenway Ltd, 2018), while the commercial building took 20 days with five workers (Trow Group, n.d.). Over 90 per cent of the waste materials from the grandstand was either recycled or reused (Greenway Ltd, 2018.).[11] In Ranui, Pratec was involved in deconstructing parts of the Ranui Community House which was undergoing renovation. This project took 20 days with 10 workers, and diverted 99 per cent of its waste from landfill. Of interest, much of the native timber was reused in the refurbished internal fit-out (Mawhinney, 2015).

Like residential deconstructions, materials salvaged from commercial projects include various timbers and metals, as well as doors and windows. Recycled materials include concrete, plasterboard, metals and glass and some native timber.

Table 1 below provides a summary of the deconstruction case studies in Auckland.

[11] There are no figures on the percentage of resource recovery for the commercial building

Table 1: Summary of deconstruction case studies in Auckland

Case study	Source	Property	Deconstruction	Demolition	Labour input	Material salvaged	Material recycled	Net cost
Tāmaki	Otter-Lowe (2018)	House; 1950s	Yes – deconstruction trial	No	3 workers; 20 days	Native timber Windows Doors Brass latches	Hot water cylinder Metals Concrete Plasterboard Mixed masonry materials Plastic	$12,402
Tāmaki	Otter-Lowe (2018)	Duplex; 1950s	Yes – deconstruction trial	No	6 workers; 17 days	Native timber Stainless steel benches Ovens Windows Doors Vanities	Hot water cylinder Metals	$40,780
Tāmaki	Otter-Lowe (2018)	House; 1950s	No	Yes – done as direct comparisons in the Tāmaki deconstruction trial	2 workers; 9 days			$18,300
Tāmaki	Otter-Lowe (2018)	Duplex; 1950s	No	Yes - done as direct comparisons in the Tāmaki deconstruction trial	2 workers; 10 days			$35,100
Helensville	Envision (2019)	House, 1950s	Yes	No	9 workers, 8 days	Windows Native timber Doors Fittings Cabinetry	Metals Concrete tiles Plasterboard	$18,000

Case study	Source	Property	Deconstruction	Demolition	Labour input	Material salvaged	Material recycled	Net cost
Ōrakei	Tarkar (2018)	House; 1951		Yes	3 workers; 8 days	Native timber Timber Windows Doors Appliances	Iron roof Concrete tiles Metals Concrete	
Whitford	Latu (2017)	Park building; 1950s	Yes	Yes	3 workers; 5 days	Timber framing Doors Door rails	Concrete Corrugated iron	
Three Kings	Trow Group (n.d.)	Commercial building; 1970s	Yes		5 workers; 20 days			$505,000
Birkenhead	Greenway Ltd (2018)	Grandstand; 1959	Yes		4 workers; 5 days	Doors Windows Tables Lights Timber Metal Sundries	Gypsum Metals Cardboard Woodchip Hardfill Joinery Native Timber	$136,680
Ranui	Mawhinney (2015)	Community house; 1960s			10 workers; 20 days	Timber Metal	Plasterboard	
Northcote	BRANZ (2008b)	9 apartment buildings; 1960s	Yes	Yes	Unknown	Building components	Plasterboard Ferrous metal Non-ferrous metal Concrete Glass	

3.3 Residential development by Homes Land Community (HLC)

As Auckland experiences increasing number of residential and commercial developments, generation of C&D waste is also expected to increase significantly. This is exemplified by the current and planned developments in Northcote, Mt Roskill, Māngere and Oranga by HLC. The HLC development projects are expected to complete in 12 years. In total, more than 7000 existing dwellings will be removed (mostly 1950s and 1960s state housing) to make way for over 22,000 new houses comprising a mix of state, affordable and open market homes. Across the four development areas, these homes will be built across a mixture of typologies including apartments, terraced homes, walk-ups and standalone homes, with sizes ranging from one to six-bedrooms. Table 2 below provides an overview of the projects of HLC's main development areas in Auckland.

Table 2: HLC project overview by development area

Development area	Houses to be removed	Total new houses	New state houses	New affordable houses	New market houses
Northcote	380	1500	450	1050	
Mt Roskill (Roskill South and Ōwairaka)	3000	10,000	3000	3500	3500
Māngere	2700	10,000	3000	3500	3500
Oranga	335	1000	400	330	270

Source: HLC websites[12]

3.3.1 Current stage of the HLC development

As at the time of writing this report, Stage 1 of the development project in Northcote was nearly complete. The development in Northcote began with the removal of 20 existing state houses. So far, 43 modern homes, ranging from two to four bedrooms have been replaced, and another 16 one-bedroom homes are to be replaced. Stage 2 is now underway, and will continue to replace the old state houses on Tonar Street, Fraser Avenue and Richardson place with modern homes.

In Mt Roskill South, Stage 1a of the project is currently underway. Twenty-five old state homes have been removed or demolished to build 81 new state homes.

[12] These are based on the information available at HLC's websites for each of the development area: Northcote (northcotedevelopment.co.nz); Mt Roskill (mtroskilldevelopment.co.nz), Māngere (mangeredevelopment.co.nz) and Oranga (orangadevelopment.co.nz).

Demolition and removal for Stage 2 of the project is also underway, with 90 older state homes to be replaced with around 300 modern homes – approximately 60 will be state homes. Construction work for Stage 2 is expected to start in the second half of 2019 (HLC, 2018a). The associated Ōwairaka development in Mt Roskill is in the planning stage; construction of the Stage 1 homes is expected to begin in early 2019 (HLC, 2018b).

Stages 1a to 1d of the Māngere development project are currently underway. To date, 35 old state houses on Bader Drive, McKenzie Road and Cessna Place have been removed to be replaced with 66 new state houses and a mix of 100 affordable and market homes. Construction of the first houses is expected to be complete in June 2019 (HLC, 2018c).

HLC's development project in Oranga is currently at its planning stage.

3.3.2 Current waste management approach by HLC

As noted, HLC will be demolishing over 7000 homes and building over 22,000 new homes. This is expected to result in approximately 212,000 tonnes of demolition waste. The development of replacement homes is likely to result in a further 91,000 tonnes of materials.

At the moment, HLC takes a relocation-or-demolition approach to reduce the material waste from removing the old houses (HLC, 2018a, 2018b, 2018c and 2018d). At the early planning stages, HLC identifies which of the existing houses are to be retained, relocated or recycled. Those houses that present significant heritage value are worked into the masterplan for retention. The remaining houses are tested for hazardous substances to confirm their suitability for relocation. Quality recyclable materials are then removed from those houses that are unsuitable for relocation and will be demolished. Once demolition takes place, materials from the demolished houses are then taken to Green Gorilla's materials recovery facility (MRF) for recycling (HLC, 2018a).

In the Northcote project, three quarters of all materials in the houses removed from Stage 1 have been saved for reuse. Timber from roofs has been sent to be reused in building projects in Samoa (HLC, 2018d). For Stage 2, some houses have already been relocated, and where possible, items such as bath tubs, sinks and native timber flooring are being stripped off. Currently, the contractors are achieving a resource recovery rate of 84 per cent through chipping of timber for incineration, crushing concrete to use as engineering fill, and the segregation of metals for recycling.

In the Mt Roskill development projects, around 85 per cent of wood, steel and plasterboard have been recycled by Green Gorilla's facility (HLC, 2018a). To date, three houses in the Ōwaikara development area have been identified as suitable for relocation (HLC, 2018b).

In anticipation of the number of significant construction projects taking place across Auckland, Waste Solutions at Auckland Council is seeking to expand the uptake of end-of-life building deconstruction. Given the success of deconstruction in the previously mentioned case studies, Waste Solutions believe that the HLC development can provide an opportunity to present an economic case for C&D waste diversion through deconstruction and other waste reduction strategies.

3.4 Construction and demolition waste diversion options

Auckland Council's WMMP (Auckland Council, 2018a) has identified C&D waste as a priority waste stream as the reduction of C&D waste will assist in achieving WMMP's target of a 30 per cent reduction in total waste to landfill by 2027. To do this, the council's Waste Solutions Unit has proposed the following options for diverting C&D waste from landfill, as outlined in Table 3.

Two separate Cost Benefit Analyses (CBAs) are undertaken to evaluate the impacts of each of the proposed options described compared to the status quo:

- an economic CBA to assess social, economic and environmental impacts of the two options for Aucklanders
- a distributional analysis to assess financial impacts of the two options for developers, as the main stakeholder group.

Table 3: Proposed options for C&D waste diversion

	Status Quo – No change in diversion by 2030	Option A: Recycling focused – readily available diversion options	Option B: Best case – for waste social, economic outcomes
Focus		Mid-range of the waste hierarchy – recycling/ diversion, not reuse	Higher up in the waste hierarchy – reuse, enabling a circular economy
Actions		Increased advocacy, ad-hoc waste brokering and limited civil share but limited structure (i.e. no deconstruction hub)	Increased advocacy, waste brokerage (both materials and training/education), and suitable infrastructure (i.e. development of a deconstruction hub)
Timeframe		Short to mid-term focus	Longer term focus
Target outcomes	➢ Total diversion 14% including: Recycling 5% Resource recovery (re-use) 5% Relocation 4% ➢ Soft strip 5%	➢ Total diversion 79% including: Recycling 61% Re-use 9% Relocation 9% ➢ Soft strip 66% **Maximum diversion target to be achieved by 2025/26**	➢ Total diversion 83% including: Recycling 39% Re-use 27% Relocation 16%[13] ➢ Soft strip 75% **Maximum diversion target to be achieved by 2029/30**

[13] This target is indicated by Piritahi Alliance, contractor working with HLC for house relocation. The figure is based on their experience in working in large-scale demolition projects. Refer to Appendix D for more details on the number of houses Piritahi is intending to remove by relocation each year.

4.0 Economic evaluation using CBA

CBA is widely used by Auckland Council in supporting its policy or investment decision-making. It is an economic assessment tool that helps council decision makers with understanding the economic/resource costs and benefits of a policy or investment proposal (Auckland Council, 2017). Results from CBAs are readily comparable across a range of policy, options and industry areas. This can assist council decision makers with determining the value for money and the most efficient project or option over others (Auckland Council, 2017)

In CBAs, the costs associated with implementing a policy option are compared with the anticipated benefits, relative to a ‘base case’, often referred to as the status quo. The status quo is when the current state continues as usual. In the context of this study, this is the case when neither of the proposed options for C&D waste diversion is pursued. For a policy or investment option to be considered worthwhile, it should have a Net Present Value (NPV) greater than zero, and a Benefit to Cost Ratio (BCR) greater than one (Auckland Council, 2017; New Zealand Transport Agency (NZTA), 2018; New Zealand Treasury, 2015).

The perspective of CBAs is on society as a whole, and not on particular groups, individuals or entities. This means that transfers of costs and benefits with no change to the underlying level of costs and benefits are not ‘counted’. The CBA measures the extent to which society would be better off (i.e. whether wellbeing is improved) as a result of a proposed policy or initiative.

A distributional analysis is often undertaken in addition to a CBA. It assesses the financial impacts across stakeholder groups, such as local government, producers, landowners, businesses, retailers, consumers and households. Such analysis differentiates between stakeholder perspectives and implications for society as a whole (New Zealand Treasury 2015).

The CBA method is also subject to limitations. Some include:

- A simplification of the complexity of markets – models can make simple, and at times misleading, assumptions about market behaviour (The Electric Energy Market Competition Task Force, 2006).
- Prediction of effects into the future is subject to estimation biases (Boardman et al., 2014). Optimism bias may arise when benefit estimates are overly optimistic and costs are underestimated. This bias can be mitigated by performing sensitivity tests on key benefit and cost assumptions (Auckland Council, 2017).

- Some intangible impacts that are identified as relevant and qualitatively described as they are difficult to quantify or monetise.
- There are often data limitations requiring assumptions that need to be tested through sensitivity analysis to ensure the robustness of the CBA results (The Electric Energy Market Competition Task Force, 2006).

The main take-away message from the critical review above is that the criteria for decision-making should in most cases be broader than the quantifiable results from the CBA. That is, the CBA is a useful and often necessary input into decision-making, but it should not be used as a sole determinant.

4.1 Economic evaluation studies of construction and demolition waste diversion through deconstruction

Over the last 20 years there has been an increasing amount of research into deconstructing rather than demolishing buildings. One area of focus has been the economic analysis and viability of deconstruction (e.g. Ajayi et al., 2015; Coelho and de Britto, 2011; Inglis, 2007). The following provides a short summary of some economic evaluations of building deconstruction.

In two economic comparisons of the demolition and deconstruction of houses in Italy and Portugal, Coelho and de Britto (2011 and 2013) find that although deconstruction requires more time and labour, the final costs, while more expensive, are relatively evenly spread between labour, equipment, transport and disposal. Conversely, demolition costs are almost solely dependent on the final costs of disposal only. To overcome the barrier of the extra cost of deconstruction, and to incentivise deconstruction, Coelho and de Britto (2011 and 2013) recommend that landfill fees should increase from 90 per cent up to 150 per cent to make deconstruction equally attractive to traditional demolition. This is a similar conclusion also reached by Tran (2017) in his economic evaluation of a commercial C&D project in Auckland.

These results are similar to those arrived at by Dantata et al., (2005), who have evaluated the deconstruction and demolition opportunities for residential buildings in Massachusetts. They note that while deconstruction costs remain higher than demolition costs, deconstruction will become “more favourable if productivity increases or lower wage rate or higher disposal cost applies” (p.14).

In an analysis of six deconstructed houses in Florida, Guy and McLendon (2000) find that “deconstruction can be more cost-effective than demolition when considering the reduction in landfill disposal costs and the revenues from salvage” (p. 24). They again note that raising tipping fees is the easiest way to encourage deconstruction. This is because salvage market arrangements are complex to navigate for best prices and controlling for quality material when deconstruction will always cost further labour time.

Leroux and Seldman (1999), in assessing the deconstruction of a building in Maryland, find that with maximum recycling and reuse, the average cost of deconstruction range from $4.50 to $5.40 per square foot. This compares to between $3.50 and $5 per square foot for traditional demolition. In Portland, Paruszkiewicz et al., (2016) calculate a single-family home to cost $10,300 in demolition costs and $18,800 in deconstruction costs. In San Francisco, Chini and Bruening (2003) find deconstruction of a 9180 square foot wooden building costs 44 per cent less than demolition, after taking into account the value of salvaged materials. More generally for the United States, Zahir (2015) notes that "deconstruction is more favourable in the West Coast because the labour cost is cheaper compared to East coast and mid-west and also the landfill tipping fees are higher in the west coast. Again this points to the importance of waste levies.

While the studies described above which have focussed on cost barriers of deconstruction, Inglis (2007) looks at cost savings of disposal involved with deconstruction. The study finds that there would be cost savings in disposal of materials through deconstruction, and benefits come from both the cost savings and higher recycling rates.

There are limited studies in New Zealand that evaluate the costs associated with deconstruction. Otter-Lowe (2018) assesses costs of demolition versus deconstruction for a number of mid-20th century state houses in Auckland. In an assessment of a single-storey weatherboard state house, Otter-Lowe (2018) finds that deconstruction is 32 per cent cheaper than demolishing a house of the same typology. However, for a similar duplex, Otter-Lowe's assessment shows deconstruction is 16 per cent more expensive than demolition.

The studies reviewed above do not quantify the actual costs of each aspect of demolition versus deconstruction. They have resulted in only a generalisation of examples rather than a financially definitive example for reference. This may be associated with commercial sensitivity in this area. With this issue in mind, this CBA study uses a range of primary and secondary sources to evaluate costs and benefits associated with each of the two options proposed for C&D waste diversion (refer to Table 3 in Section 3.4). The study adopts a pragmatic and conservative approach, using lower values when a range of benefits and higher values when a range of costs are specified.

4.2 Data and assumptions

This study focuses on C&D waste generated from residential developments. It consists of two separate CBAs: economic CBA for Aucklanders and financial CBA for developers. The scope of the study only applies to the removal of the existing houses (demolition, deconstruction or relocation) and waste management during the construction process. Remediation of house removal and building activities are not in scope because they are the same under the status quo and the proposed options.

As mentioned earlier, the planned HLC development is chosen as a case study for the CBAs due to lack of data on the future levels of housing construction and demolition in Auckland. The following are the main assumptions on the HLC development:

- The HLC projects are the main construction and demolition activities in Auckland.[14]
- The HLC development will take 12 years to complete, from 2019/20 to 2030/31.
- Across the five main HLC development areas (Northcote, Mt Roskill South, Ōwairaka, Māngere, Oranga), 7075 dwellings are to be removed and 22,797 dwellings are to be constructed.

Option A takes a moderate approach to deconstruction and focuses more on partial recovery and recycling of waste materials. Option B takes a full deconstruction approach and has a stronger focus on the top two levels of the 5Rs hierarchy (reduce and reuse). Due to the lack of existing data around C&D waste management practices in Auckland, the study uses various sources of information to estimate the associated costs and benefits. These include insights from the C&D industry, data from the costing model developed by the council’s Waste Solutions Unit, literature on C&D waste management and recent deconstruction case studies and trials in Auckland.

[14] RIMU’s Auckland monthly housing update (Auckland Council, 2019) suggests that the share of dwelling consents on Housing New Zealand owned land ranges from 11 per cent to 16 per cent of the total number of dwelling consented in Auckland between April 2018 and April 2019. Note that the average lag between a consent being issued and actual activity takes place is around six months (Wilson, 2014). Consents data on demolitions would significantly understate the level of demolition activities as a building consent is not required for demolishing a detached dwelling up to three storeys.

This study also considers the impact of designing out waste, however, only to the extent of construction waste. This is because the study only covers the 12-year project life of the HLC development but not the whole life span of the new builds. Hence, the approach of design for deconstruction for designing out waste is not feasible within the timeframe considered in the study. The assumption on the percentage reduction in construction waste as a result of designing out waste under each option relies on the ranges suggested in a New Zealand-based study by Tran (2017).

The additional tonnages of C&D waste that can be diverted under Options A and B relative to the status quo set the basis for estimating the costs and benefits of each option. The costing model developed by the council's Waste Solutions Unit provides inputs for estimating the additional C&D waste diversion through deconstruction and relocation. Tonnages of construction waste diverted under each option are calculated based on the assumed percentages of waste reduction as a result of designing out construction waste.

Table 4 outlines the assumptions used in this study for estimating tonnages of C&D waste diversions.

Table 4: Main assumptions used for estimating C&D waste diversions

Source	Assumption	Value
Waste Solutions, Auckland Council[15]	Waste produced as the result of each demolition	30 tonnes per house demolished
	Waste produced as the result of each construction	4 tonnes per house constructed
	Waste reduced as the result of each relocation	25 tonnes per house relocated
	Soft strip – Status Quo	5% of the houses removed
	Soft strip – Option A	66% of the houses removed
	Soft strip – Option B	75% of the houses removed
	Timeframe for achieving the maximum target diversion rate – Status Quo	14% throughout the 12-year project life
	Timeframe for achieving the maximum target diversion rate – Option A	79% diversion achieved by 2025/26
	Timeframe for achieving the maximum target diversion rate – Option B	83% diversion rate achieved by 2029/30

[15] Based on experts information about the industry.

Source	Assumption	Value
Tran (2017)[16]	Percentage of waste reduction through designing out waste – Option A	Level 5 – reduction of construction waste by 70%
	Percentage of waste reduction through designing out waste – Option B	Level 7 – reduction of construction waste by 95%

The estimated additional C&D waste diversion under each proposed option compared to the status quo are summarised in the sub-section below. Note that this excludes waste types such as top soil and asbestos, which need to be removed regardless whether demolition, deconstruction or relocation takes place. This means that tonnages of these two types of waste are the same under the status quo and the proposed options.

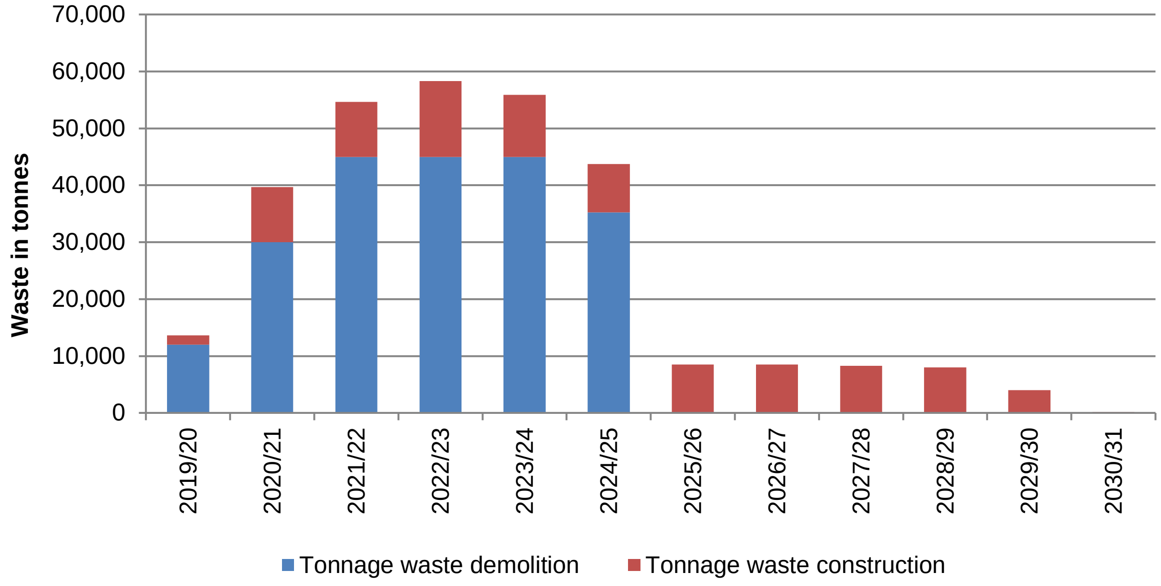
4.2.1 Additional construction and demolition waste diversion compared to the status quo

Based on the information provided by the industry's experts, an average demolition of each house produces 30 tonnes of waste and construction of each house creates four tonnes of waste. Therefore the HLC development could produce 212,250 tonnes of waste from demolition and 91,188 tonnes waste in construction in total over its 12-year project life (Figure 8).

With the static waste diversion rate of 14 per cent under the status quo (refer to Table 4), only 31,718 tonnes of the demolition waste would be diverted from landfill. As there would be no design-out waste strategies carried out under the status quo, all waste generated during constructing new homes in the HLC development would be sent to landfill.

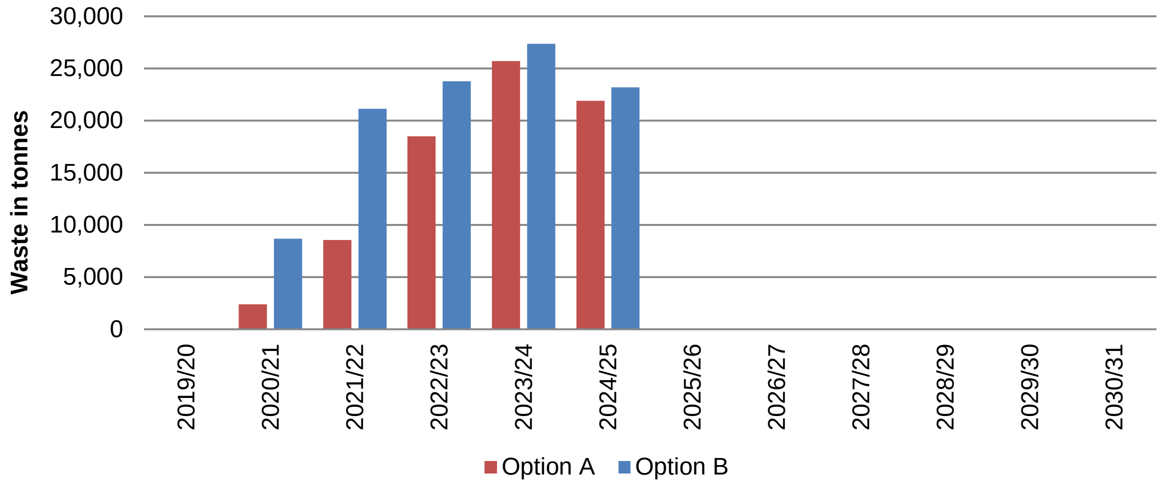
[16] In the economic evaluations of waste minimisation strategies for a commercial C&D project in Auckland, Tran (2017) considers several different levels of waste minimisation by designing-out waste, ranging from level 1 (disposing all waste to landfill) to level 7 (zero waste). The assumptions made in this CBA study on the percentage of construction waste reduction from designing out waste under Options A and B are based on possible outcomes from a level 5 design-out waste strategy (reducing waste by 51-70%) and a level 7 design-out waste strategy (reducing waste by 95% to zero waste).

Figure 8: Estimated tonnage of C&D waste of the HLC development



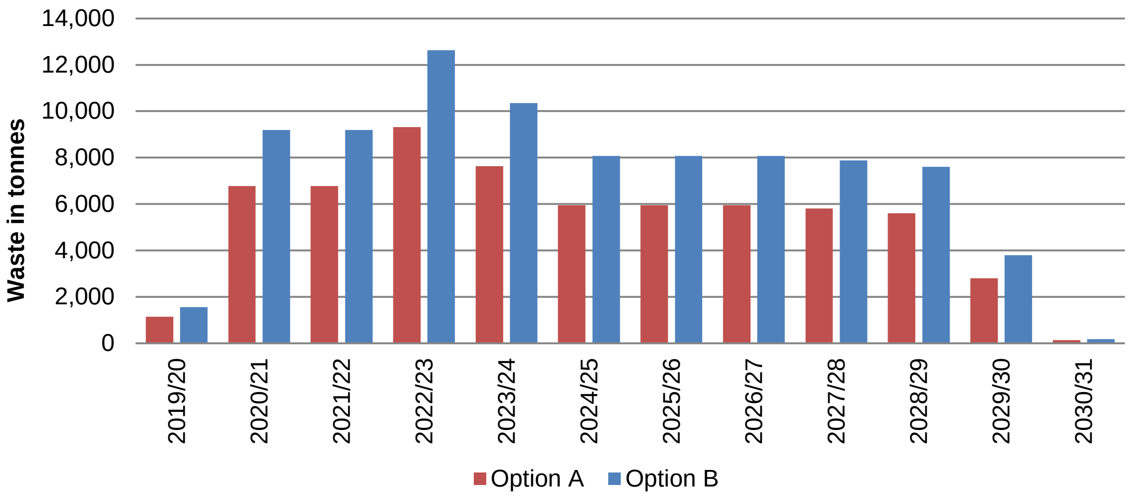
Figures 9 and 10 show the estimated additional diversion of waste from removal of old dwellings and construction under Options A and B compared to the status quo over the 12 years of the HLC development.

Figure 9: Estimated additional waste diverted compared to status quo – house removal



Source: Estimates based on Waste Solutions' costing model

Figure 10: Estimated additional waste diverted compared to status quo – construction



Source: Estimates based on Waste Solutions' costing model

Option A would divert 108,748 tonnes of waste generated by deconstruction and relocation, and 63,832 tonnes of construction waste by implementing a level 5 designing out waste strategy. This is an additional diversion of 142,862 tonnes from landfill compared to the status quo. As a result of a stronger focus on recycling under this option, almost half (48%, or 67,203 tonnes) of the additional diversion would be the result of recycling. The designing out waste strategy under this option would reduce construction waste by 70 per cent compared to the status quo.

Option B is estimated to divert 135,882 tonnes of waste during house removal and 86,629 tonnes during construction. Compared to the status quo, 190,793 more tonnes of C&D waste can be diverted under this option. While recycling is estimated to contribute 30 per cent (56,834 tonnes) of this additional diversion, reuse and relocation are estimated to contribute 13 per cent (25,401 tonnes) and 12 per cent (21,930 tonnes) of the additional diversion respectively. The designing out waste strategy under this option would reduce waste produced during construction by 95 per cent compared to the status quo.

4.3 Waste levy in New Zealand

A number of New Zealand studies highlight that the waste levy is an important factor for incentivising C&D waste diversion and minimisation because it is a part of the cost of landfill disposal (Tran, 2017; Tarkar, 2018; Eunomia, 2017). As the waste levy is introduced by the central government through Waste Minimisation Act 2008, Auckland Council has no influence over how the levy is applied (Auckland Council, 2018a and 2018b). The levy rate has remained at $10 per tonne since its introduction in 2008.

At the moment, the levy only applies to class 1 landfill disposal facilities (Eunomia, 2017). This narrow application of the levy gives the operators incentive to minimise or avoid levy obligations by migrating waste from levied sites to non-levy sites (Eunomia, 2017; Ministry for the Environment, 2014). Non-levied sites are more likely to have lower levels of monitoring and enforcement. Hence, it is more difficult to ensure that waste materials going to those sites are in the most appropriate form of disposal. Also, the current rate of $10 per tonne is too low for influencing behaviour change of waste disposal and encouraging activities that divert waste from landfill (Eunomia, 2017; Ministry for the Environment, 2017).[17] This is particularly the case for C&D waste. While much of the C&D waste, for example, rubble and concrete can be recovered, Eunomia (2017) suggests that the majority is disposed of at Class 4 facilities (cleanfills) which are non-levied sites. C&D waste diversion can be incentivised with a levy regime that includes all fill sites and sets a higher levy rate for landfill disposal.

In light of the limitations described above, the Ministry for the Environment (MfE) in its 2017 review of the waste levy recommends to explore the possibility of a new levy system that targets specific waste streams with a differentiated levy rate (Ministry for the Environment, 2017). Eunomia (2017) looks at four possible levy scenarios, with the standard levy rate ranging from $20 per tonne for low improvement to $140 per tonne for maximum recycling.[18] In anticipating the possibility of future changes in the waste levy for C&D waste, this study also considers how landfill disposal costs of Options A and B would change under some of the alternative waste levy scenarios considered in Eunomia (2017).

[17] Eunomia (2017) cites that a report by Hyder Consulting (2007) finds that waste to landfill quantities show a more elastic response at certain threshold values beyond which additional resource recovery activities become commercially viable.

[18]This study by Eunomia (2017) looks at the potential impacts of possible changes to New Zealand's waste levy structure. Four possible scenarios are modelled in the study, namely, the low improvement scenario, the enhanced recycling scenario, the minimal waste disposal scenario and the maximum recycling scenario. All scenarios have different rates for standard and inert waste, and the study applies a tax escalator over a seven-year period based on the notion that it takes around five to eight years to make infrastructural changes to the waste collection system to support increased recycling rates as a result of the levy increase. For each scenario, the levy would increase at a slow rate for the first three years (2018 to 2020). Then it would increase at a faster rate for the next four years and reach to the maximum target levy rate by 2024.

5.0 Results of the economic CBA

This section presents the economic, social and environmental impacts associated with C&D waste diversion proposed under Options A and B. The estimated impacts are relative to a counterfactual of the status quo.

Sections 5.1 to 5.3 present the methods and results of the economic CBA. The initial analysis is undertaken for the scenario considered as “Most Likely” and uses conservative assumptions to avoid under-estimation of costs and over-estimation of benefits.

5.1 Costs

This section presents the estimated costs associated with the investment under Options A and B. The cost components broadly consisted of:

- Cost of investment attributed to the HLC development.
- Costs of training attributed to the HLC development.
- Deadweight cost of Auckland Council’s contribution.

The method and proxies used to measure each of the cost components are described further in the subsections below.

5.1.1 Cost of investment attributed to the HLC development

The total investment cost of each Option (A and B) is the sum of additional Capital Expenditure (Capex) and Operational Expenditure (Opex) of a series of activities related to each of the broad areas of focus identified for C&D waste diversion – awareness, infrastructure, brokerage, regulatory controls, training and job and business opportunities. These expenditures are over and above the investment under status quo. An overview and description of the activities in the focus areas under Options A and B are outlined in Appendix C.

The HLC development is considered as the driver of the investment under either option as it is the development in Auckland that is going to implement the proposed changes under Option A and B. For this reason, the CBA only considers the investment cost that is attributed to HLC’s C&D waste management activities. Under either proposed option, all investment in the first year (i.e. 2019/20) is assumed to be made to the HLC development. To allow some capacity for other developments to use the new facilities and resources for diverting their C&D waste, the CBA assumes that the share of investment going into HLC activities would become 50 per cent from year two onwards. This is based on Waste Solutions’ observation that some demolition companies have already started switching to use MRFs to divert C&D waste.[19]

As estimated by the Waste Solutions' costing model for C&D waste diversion, the total cost of activities, except training, under Options A and B would be $4.29 million and $23.26 million respectively.[20] Of these costs, $4.29 million and $12.61 million are attributed to the HLC development under Options A and B respectively.

Of the total investment (except in training) attributed to the HLC development, Waste Solutions' costing model indicates that the private sector is expected to contribute 81 per cent (3.47 million) and half ($6.33 million) under Options A and B respectively.[21] The rest would be funded by Auckland Council. This also includes grants made by The Waste Minimisation and Innovation Fund (WMIF).

5.1.2 Cost of training

Another part of the cost associated with the investment under Options A and B is the cost associated with training for the new jobs created as a result of the proposed changes. These new jobs would be created both on the HLC development sites for deconstruction, relocation and soft strip, and at the destination sites for retrofitting the relocated dwellings.

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[19] For example, with some advocacy by Auckland Transport and Waste Solutions, the demolition operator at the AMETI (Auckland Manukau Eastern Transport Initiative) demolition site, have already started switching to use Green Gorilla's material recovery facilities (MRFs).

[20] Note that the supposed investment and the targets for waste sent to MRFs, resource recovery facilities and house relocations indicated in the costing model are not linked. That is, the investments are uncoupled from target landfill diversions. For more information on the background of the costing model, refer to Appendix D.

[21] Assumptions used in estimating private investment have been drawn from a range of sources:

- Recipients of Waste Minimisation and Innovation Fund (WMIF) and the Ministry for Environment Waste Minimisation Fund (WMF) grants are assumed to be making investments greater than that funding, for example, large waste companies investing in MRF plants. Waste Solutions have specific numbers on the funds.
- An expectation that waste companies who are active in processing C&D waste will continue to invest in those facilities to increase efficiency and capacity.
- Investment by demolition companies and contractors in salvage yards and deconstruction facilities and techniques that has been made known in discussion with those companies.

Refer to Appendix D for more details on the assumptions for assumptions applied in estimating public and private investment.

Information from RESET (a community enterprise) provides insights on the percentages of waste from removal of dwellings going to various destinations.[22] These percentages are used to establish the fundamental assumptions for estimating the additional employment onsite and at destination sites as a result of the proposed changes under Options A and B compared to the status quo. In the context of this CBA, it is considered that 79 per cent of the waste from dwellings deconstructed with partial recovery would be recycled or recovered at MRF,[23] and the rest would go to landfill. Fully deconstructed dwellings would yield a landfill diversion rate of 85 per cent, with 43 per cent going to be recovered for energy and/or recycled[24] and 42 per cent to be reused. All demolition waste from those dwellings that are too contaminated for any recovery would be directly sent to landfill.

To better distinguish between the three methods of removal described above, they are referred to as moderate deconstruction, full deconstruction and demolition respectively. Using the information described in the paragraph above, proportions of waste going to different destinations by each of the three removal methods are recalculated as follows:

- Dwellings removed by demolition, moderate deconstruction and full deconstruction respectively contribute 74 per cent, 15 per cent and 11 per cent of the total waste from removal ending up at landfill.
- 65 per cent and 35 per cent of the waste that goes to MRF comes from dwellings removed by moderate deconstruction and dwellings removed by full deconstruction respectively.
- All waste materials that are going to be reused come from dwellings removed by full deconstruction.

The estimated waste tonnages going to residual disposal, recover/recycle and reuse under the status quo, Options A and B (obtained from Waste Solutions' costing model) are allocated to demolition, moderate deconstruction and full deconstruction respectively. The allocated tonnages are then applied to the number of dwellings,

[22] This information is provided by RESET, a community enterprise that was developed between Envision NZ (an environmental and local economic development consultancy) and the Helensville Community Recycling Centre. The information is based on the experience of the Tāmaki deconstruction trial by the TRC and the deconstruction trial by RESET in Helensville in 2018.

[23] This includes 48 per cent recycling of metal, gypsum, cardboard (and a small proportion that went to cleanfill/ hardfill), and 31 per cent incinerated for biofuel.

[24] This includes recycling or recovered materials from deconstruction (37%), recycling of metal, gypsum, cardboard (and a small proportion going to cleanfill/ hardfill) (4%), and waste to energy (i.e. incineration) (3%) by the MRF. Note that about two per cent of the waste would also be disposed at landfill by the MRF.

based on production of 30 tonnes of waste. The number of dwellings allocated to relocation and soft strip are based on their respective percentage targets under the status quo and Options A and B.

RESET advises that, based on experience, there are 225 working days each year. Applying this information, changes in employment onsite under Options A and B compared to the status quo can then be estimated for each removal method. These are calculated as the differences in total labour input required for the removal method as a result of the differences in the allocated number of dwellings. The CBA uses information from various sources to make assumptions on the labour input required for each removal method.

The CBA assumes that each moderate deconstruction would require a crew of three members and eight days and each full deconstruction would take a crew of three members a total of 13 days. These are based on the Ōrakei deconstruction case study described by Tarkar (2018) [25] and the Tāmaki deconstruction trial (Otter-Lowe, 2018).[26] Interviews and communications with the demolition company at the AMETI demolition site suggests that demolition of one house would take three days and require a crew of two people – one supervisor and one machine operator. For relocation and soft strip, RESET suggests that relocating each dwelling at the origin site requires a crew of three people and two days and a crew of four people and one day for soft strip.

For relocation at destination sites, RESET advises that retrofitting of each relocated dwelling at the destination site would need a crew of four people and five days. Changes in employment at the destination sites of relocated houses are then estimated using the assumption that 60 per cent of the relocated houses from the HLC development sites would stay in Auckland. This percentage figure comes from market evidence provided by house relocation companies.

Note that this CBA only considers changes in employment required directly for each of the removal methods relative to the status quo. While there could be administrative or management support either at the HLC sites or at the destination sites of the relocated dwellings, employment associated with this role is not included in the CBA.

[25] Tarkar (2018), deconstruction had three crew members working for eight days to deconstruct an old wooden house in Ōrakei. Most of the removed materials ended up being recycled.

[26] Otter-Lowe, (2018), deconstruction in Tāmaki took one supervisor and five skilled labourers a total of 17 days to deconstruct two single-storey houses (Otter-Lowe, 2018). In applying the information from this deconstruction trial, the CBA considers it is more reasonable to assume that deconstruction of each house took 75 per cent of the labour time as the two houses were being deconstructed concurrently. This suggests that each house could take approximately 13 days to deconstruct.

This is to be conservative about estimation of job creation from the proposed changes under Options A and B.

Using the unit costs of training per worker per removal method as provided by RESET, the training costs attributed to the HLC development are estimated as $0.10 million under Option A and $0.14 million under Option B. While the areas of actions under each proposed option (see Appendix C) suggest that some of the activities related to training are expected to be paid for by public funding, the share paid by public funding under each option is unknown. It is considered reasonable to assume that half of the estimated training cost would be paid for by the public sector.

5.1.3 Deadweight costs

The additional investment by the council is intended to be paid for through the Auckland Council rates and the Ministry for the Environment's WMIF (funded through the waste levy). In economic theory, this is considered as a tax, and therefore the deadweight loss of such tax should be included in the CBA. Deadweight costs refer to the costs associated with the distortions that result from using tax to raise necessary funding for public projects. When a tax is in place, individuals would move away from consuming things that are taxed and towards things that are not taxed, resulting in reduction in economic welfare (Boardman et al., 2014).

For the purpose of this analysis, no distinction is made between taxes and rates. New Zealand Treasury (2015) recommends that 20 per cent of investment by the public sector funded through tax should be added to the project's cost in the absence of an alternative evidence base value. In this CBA, this deadweight cost is applied to Auckland Council's contribution to Capex and Opex, and half of the training cost.

5.1.4 Summary of costs

Under the Most Likely scenario, total cost of Options A and B attributed to the HLC development over the whole project life, are estimated at $4.56 million and $14.02 million respectively. A summary of costs for Options A and B is presented in Table 5 below.

Table 5: Estimated costs under Most Likely scenario, economic CBA

Cost component	Option A ($ million)	Percentage of total cost	Option B ($ million)	Percentage of total cost
Investment attributed to HLC development (except training)	$4.29	94.0%	$12.61	89.9%
Cost of training	$0.10	2.2%	$0.14	1.0%
Deadweight cost	$0.17	3.8%	$1.27	9.1%
Total cost	**$4.56**	**100.0%**	**$14.02**	**100.0%**

5.2 Benefits

This section presents the method used in the economic CBA for estimating benefits associated with Options A and B. For explanatory purposes, the benefits are presented in non-discounted terms. The estimates contained in this section relative to a counterfactual of the status quo.

We have identified a range of possible benefits. However, with the information and data available, the analysis only focuses on the following quantifiable benefits:

- Social benefit of moving from unemployment to employment.
- Social benefit of training in job.
- Net economic benefit of construction material saved as a result of increased relocations.
- Environmental benefit associated with reduction in greenhouse gas (GHG) emissions).

Next sub-section describes the potential benefits that are not included in the analysis. They are not measured due to data availability constraints.

5.2.1 Potential benefits not included in calculations

As mentioned earlier in Section 2.4, demolition creates disturbances to the surrounding communities, for example the unwanted noise, increased traffic and the spread of pollutants (Hoag Jr, 2016). Community-related costs arise when there is the need to address communities' concerns regarding those nuisances (Tran, 2017). In addition, as suggested by an industry expert, demolition can have significant psychological impact on community as local residents perceive their homes are being ‘smashed down’ by large machineries.[27] Deconstruction, relocation and designing out waste can mitigate those negative impacts caused by demolition and construction processes. However, there is no information or evidence available for measuring the potential benefit as a result of this mitigation.

It is known that deconstruction creates more jobs than demolition both directly in the process as well as the associated recycling and reuse industry (Otter-Lowe, 2018; Bell, 2011; Storey et al., 2005[28]). The employment and training opportunities enable people to acquire the skills and experience, develop career in the C&D industry and provide a more stable source of income. This in turn may contribute towards wealth generation for the individuals’ families, especially those currently with low household incomes. The evaluative framework for measuring this flow-on impact needs to be developed based on case studies, which is not available at the time of this CBA.

C&D waste from landfill is inherently linked with the specific cultural values and concepts of Māori (Storey, et al., 2005). For example, recycle and reuse materials from deconstruction aligns with the Māori concept of Te Ao Turoa (intergenerational resource suitability) of taonga tuku iho (sacred gifts passed down from one generation to the next).The concept stresses the kaitiakitanga role that people have for the environment and the next generation. It requires the exchange of these treasured resources to be passed from one generation to the next with an uplifted state of mauri (essence) of the environment, providing for the cultural practices that previous generations enjoyed. However, this cultural value is difficult to measure and monetise.

The following three sub-sections describe the steps taken in measuring each of the quantifiable benefits.

5.2.2 Social benefits of moving to employment and training in job

Employment opportunities are created onsite when more dwellings are removed by deconstruction and relocation. Additional jobs would be created at MRFs and resource recovery facilities as more tonnages of waste are sent to be recovered for energy use, recycled and reused. More relocation means more workers would be

[27] This is highlighted in a case involved a demolition of an old state house in Glen Innes in 2017. The tenant, who had lived in this house for 20 years, was left with a significant sense of loss when seeing large machinery turned the house into a pile of building materials shortly after she moved out. More details about the case can be read from the *New Zealand Herald’s* online news article “Glen Innes beneficiary's house demolished within days of her leaving” (Miller, 2017).at https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11939048.

[28] As cited in Storey et al., (2005), it has been estimated that there are 20 per cent more jobs in the recycling industry than in landfilling in New Zealand.

needed for relocation at the HLC sites and retrofitting at the destinations of the relocated dwellings. However, the number of jobs associated with demolition and landfill disposal would also reduce as more dwellings are removed by deconstruction and relocation instead of demolition. Therefore, the CBA calculates net changes in employment onsite and at destination sites under each option relative to the status quo. This is the first step for estimating the social benefits associated with additional employment and training in job.

Changes in the number of jobs required directly for demolition onsite are already calculated jointly with the cost of training (see Section 5.1.2). This is based on the number of dwellings allocated to the demolition method under the status quo, Options A and B, and the evidence that each demolition requires a crew of two and three days considering 225 working days each year. The CBA estimates that, in total, Options A and B would reduce 50 jobs and 68 jobs required directly for demolition onsite respectively. However, this reduction would be more-than offset by the additional employment created in deconstruction, relocation and soft strip of materials, resulting in a net of 241 and 307 more jobs created onsite under Options A and B respectively.

Changes in employment under Options A and B compared to the status quo are also calculated for the destinations where the demolition or deconstruction waste is sent off to – landfill for disposal, MRFs and other recycling operators for recover/recycle, and operators for reusable materials. This is done by multiplying the waste tonnages allocated to residual disposal, recover/recycle and reuse (as per the percentage targets set in the costing model), with the job creation factors associated with landfill, recycling, incineration and reuse.

The job creation factors are expressed as the number of jobs created per 10,000 tonnes. They are adopted from studies by the United States Environmental Protection Agency (US EPA) (2002) and Institute for Local Self Reliance (2002). The US EPA estimates that 10,000 tonnes of waste create six, 36 jobs and one job if they are landfilled, recycled or incinerated, respectively.[29] Institute for Local Self Reliance in a research in 1997 estimates that up to 296 jobs could be created from per 10,000 tonnes of waste recovered and reused.[30]

[29] These estimates were based on the findings of the Recycling Economic Information Study (United States Environmental Protection Agency, 2001) quantifies the economic value of waste recovery using input-output.

[30] A more recent report by Reuse and Recycling EU Social Enterprises network (RREUSE) (2015) suggested an even greater job creation potential of up to 800 jobs per 10,000 tonnes of waste reused. To be conservative, the smaller job multiplier for resource recovery and reuse is chosen for this CBA.

Adding the estimated additional employment at the destinations of relocated houses, it is estimated that Options A and B would create a net total of 156 and 921 more jobs, respectively, over the removal phase of the HLC development compared to the status quo.[31] While the proposed changes reduce the number of jobs at landfill (by 46 under Option A and 62 under Option B), this would be more-than offset by the additional employment created through increased recycling, reuse of waste materials and relocation of dwellings.

To estimate the social benefit of people moving to employment as a result of proposed options of C&D waste diversion, the net additional employment onsite and at destination sites are multiplied by a social value of moving into employment. A report by the UK's Housing Associations' Charitable Trust (HACT) (2014) documents a series of social values of community investment activities (including social values of employment) using the Wellbeing Valuation approach.[32] The social value for an unemployed individual moving into employment ranges from £1229 for part-time employment to £14,433 for full-time employment. To be conservative, the CBA considers that in the Most Likely scenario the additional jobs created would be part-time employment, with the corresponding social value of $2358 per additional part-time employment in NZ dollars.[33]

Over the project life of the HLC development, social benefit of moving into employment under Options A and B are estimated as $0.60 million and $0.72 million, respectively.

Another aspect of social benefit associated with additional employment relate to obtaining training in job. HACT (2014) suggests that the social value of an individual

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[31] These were calculated under the assumption that, under Option A, 60 per cent of the waste going to under recover/ recycle would be recycled and 40 per cent would be incinerated, and under Option B, 94 per cent of the waste going to recover/ recycle would be recycled and six per cent would be incinerated. These based on the proportions of waste that ended up being recycled and incinerated under moderate deconstruction and full deconstruction, as recalculated from the information provided by RESET.

[32] This report outlines how Wellbeing Valuation can be applied to community investment programmes. This approach measures the success of a project by how it impacts people's wellbeing through analysing existing datasets of national surveys which instead reveals effects on wellbeing in a robust way. By isolating the impact of a specific aspect of life on wellbeing in the analysis, its associated social value can be then measured by finding from the data the equivalent amount of money needed to increase someone's wellbeing by the same amount.
The values documented in the report were established through large-scale national surveys across the UK, and the datasets include people's responses to wellbeing questions, and questions on a large number of aspects and circumstances of their lives.

[33] The social values from HACT (2014) were converted to NZ dollar value using the online currency conversion tool at https://www.xe.com/currencyconverter/convert/?Amount=1&From=GBP&To=NZD.

getting training in employment is £807. Converting this social value to NZ dollar, the CBA estimates that social benefit of training in job is $0.40 million and $0.47 million under Options A and B, respectively.

As mentioned in Section 5.2.1, there are potential flow-on benefits to the wealth of the individuals' families associated with the increased employment and training opportunities as a result of the proposed changes. As the social benefits estimated above use social values that are established based on large-sample surveys of individuals' experience, those flow-on benefits are partially accounted for in the analysis.

5.2.3 Net economic benefit of materials saved due to increased relocations

Relocating the old dwellings contribute to C&D waste diversion by closing the material loop as the service life of the relocated dwellings extends. This practice is in line with the circular economy concept in the sense that resources are kept in use for as long as possible (Waste and Resources Action Programme, n.d., as cited in Blick and Commendant, 2018). In a circular economy setting, there would be less cost to Auckland's economy associated with producing new construction materials as more old dwellings would be relocated compared to the status quo.

To estimate the economic benefit from materials saved due to relocation, this CBA adopts the assumptions used by Sapere Research Group (Blick and Commendant, 2018) in their estimation of Auckland's circular economy potential. Blick and Commendant (2018) estimate that the construction sector could contribute more than 60 per cent (63%) of Auckland's circular economy potential, and reuse and high-value recycling alone could contribute more than a quarter (27%). This is estimated based on findings from Ellen MacArthur Foundation (EMF) (2015b). Firstly, EMF (2015b) finds that material costs and labour costs make up 35 per cent and 20 per cent of the total construction costs. EMF (2015b) also reports that a 70 per cent adoption rate of reuse and high-value recycling would correspond to a 30 per cent reduction in costs of new materials and five per cent reduction in labour costs.[34] In the context of relocation, this CBA assumes that because relocation also requires retrofit, 70 per cent of the materials from relocated houses considered to be saved, and this corresponds to a 30 per cent of reduction in material costs.

Figures from the QV Costbuilder report released in June 2018 reveals that the average cost of building a standard house in Auckland in the year to April 2018 was

[34] Blick and Commendant's (2018) in their study assumed an adoption rate of 60 per cent by 2030. Proportionately this would correspond to a 26 per cent reduction and four per cent reduction in material costs and labour costs respectively.

$281,750, [35] which increased by 2.9 per cent (Hargreaves, 2018, June 2018). Assuming that this rate of increase would hold between 2018 and 2019, the average cost of building house in 2019 is calculated as $289,921. Because this rate of increase in construction costs is unknown for future years, the CBA uses the 2019 figure for the average cost of building a house over the project life of the HLC development. This is to avoid overstating the economic benefits associated with construction materials saved.

Under the assumptions described above, it is calculated that materials diverted through each additional dwelling relocated could save material costs of $30,442 for Auckland's economy. Multiplying with the number of relocations based on the percentage targets in Waste Solutions' costing model, the CBA estimates that the additional relocations under Options A and B, compared to the status quo, would result in net economic benefits (associated with materials saved) of $8.64 million and $22.25 million respectively.

5.2.4 Environmental benefit

Options A and B enable Auckland to move toward a more circular economy as more C&D waste would be diverted through reusing materials, relocation and designing out construction waste. This is expected to reduce greenhouse gas (GHG) emissions associated with the landfill process (including transporting and transporting), benefiting Aucklanders through avoidance of the costs imposed by GHG emissions.

Reduction in GHG emissions are measured as reduction in emissions of carbon dioxide equivalent (CO_2e) (Blick and Commendant, 2018; Ellen MacArthur Foundation, 2012 and 2015; Green Industries South Australia; 2017). Blick and Commendant (2018) estimates that almost half of the reduction in carbon emissions from enabling a circular economy in Auckland is from carbon embodied in materials and resources, and half is from emissions generated from the use of materials and resources. Using two studies on carbon content of materials (Hammond and Jones,

[35] This refers to a standard 140m^2 house, with three bedrooms and one bathroom. The cost does not include: the cost of land; demolition of existing structures on the site; additional costs due to building code changes; increased structural requirements and external works such as landscaping, driveways and parking areas; utilities; balconies and covered ways; any loose furniture, fittings and equipment; professional, council and legal fees; GST. More details can be read from the news article by Hargreaves (2018, June 2018) at https://www.interest.co.nz/property/94378/latest-qv-costbuilder-report-shows-average-cost-building-home-main-centres-rose-34.

2008; Pratt and Lenaghan, 2015),[36] they estimate that each tonne of construction materials may cause between 0.07 and 0.22 tonne of carbon emissions.[37]

In the Most Likely scenario, it is conservatively assumed that 0.15 tonnes of CO_2e is contained in each tonne of waste reduced (through relocation and designing out waste) or materials reused. This is the mid-value of the range estimated by Blick and Commendant (2018). This value is multiplied with the additional waste tonnages diverted through reusing, relocation and designing out waste under Options A and B to calculate their impacts on GHG emissions. The CBA estimates that the total reductions in CO_2 emissions as a result of waste reused and reduced are 10,662 tonnes and 19,398 tonnes under Options A and B, respectively.

The CBA then uses the "social cost" of carbon (SCoC) to measure the environmental benefits associated with the estimated impacts on emissions. This social cost measures the damage cost avoided due to a marginal decrease in carbon dioxide (CO_2) emissions. It includes market and non-market impacts covering health, environment, crops and other property damage potential, as well as other wider social aspects.

In New Zealand, Covec (2010) suggests that the social cost of carbon in 2030 could be priced between $50 and $150 per tonne. The Ministry of Business, Innovation and Employment (MBIE) (2016) have conducted scenario analyses of electricity demand and generation using values ranging from $56 to $152 for per tonne price of carbon in 2030. New Zealand Transport Agency (NZTA) (2018) in its latest amendment of the Economic Evaluation Manual suggests a value of $65.58 per tonne, in prices as at June 2016, to reflect the damage costs of CO_2 emissions. This is based on the value (AUS $52.4 per tonne) suggested by Austroads (2012).

The CBA adopts the social cost value of CO_2 as suggested by NZTA (2018) and adjusted to $68.45 as in 2019 prices. Therefore, the total environmental benefits associated with reduction in GHG emissions are estimated as $0.73 million under Option A and $1.33 million under Option B.

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[36] Hammond and Jones (2008) provide a detailed estimate of carbon content per material type, and they used a carbon emission factor of 3.67. Pratt and Lenaghan (2015) estimate the embodied emissions factor for construction materials overall by dividing the total carbon impact to total weight of construction material.

[37] The Ministry for the Environment (2019) have provided carbon emissions factor associated with waste disposal using data from the 2016 calendar year. However, the carbon factor derived by the Sapere Research Group (Blick and Commendant, 2018) is used instead in this CBA because:

- their range of figures is specifically derived for construction materials
- their results are lower than the figures reported by MfE, which are considered more conservative.

5.2.5 Summary of benefits

In the Most Likely scenario, Options A and B are estimated to bring total benefits of $13.64 million and $32.63 million to Auckland, respectively, over the 12-year project life of the HLC development. Table 6 presents the estimated benefits by component.

Table 6: Estimated benefits under the Most Likely scenario, economic CBA

Benefit component	Option A ($ million)	Percentage of total benefit	Option B ($ million)	Percentage of total benefit
Social benefit of moving to (part-time) employment	$0.60	4.4%	$0.72	2.2%
Social benefit of training in job	$0.40	2.9%	$0.47	1.5%
Net economic benefit of materials saved as a result of relocation	$8.64	63.3%	$22.25	68.2%
Environmental benefit from reduction in GHG emissions	$0.73	5.4%	$1.33	4.1%
Terminal value of infrastructure	$3.27	24.0%	$7.85	24.0%
Total benefit	**$13.64**	**100.0%**	**$32.63**	**100.0%**

The CBA also includes the terminal value of the new infrastructure (buildings, plants and facilities for landfill diversion). It can be viewed as value generated by the investment asset over the project life (Jones et al., 2014). When economic life of the infrastructure is longer relative to the project life, the value of the infrastructure would be positive at the end of the project (CRA International, 2006).

Experts from Waste Solutions advise that the typical economic life of facilities that handle C&D waste (e.g. MRF plants) is 20 years. This is shorter compared to the life of many other industry plants because they are used to process heavy, hard, dusty, wet and irregular materials.

As a first step to calculate the terminal value, the difference between the economic life of the infrastructure and its remaining service life at any given year in the HLC development is divided by the economic life. This ratio is then multiplied with the capex on infrastructure in that year to obtain the value of the infrastructure for that year. The sum of those values over the 12 years of the HLC development will be realised as terminal value at the end of the development.

It is important to emphasis here that Table 6 above does not include all potential benefits to Auckland from the two options for proposed for C&D waste diversion (refer to Section 5.2.1).

5.3 Costs and benefits combined

Figures 11 and 12 present benefits and costs to Auckland under Options A and B for the Most Likely scenario. The graphs show when the costs occur and benefits are realised over the horizon of the HLC development, and they are in present value terms. The period of this analysis is 12 years, between 2019/20 and 2030/31. Consistent with the Auckland Council CBA Primer (Auckland Council, 2017), the discount rate applied is four per cent. Note that the two graphs are shown in different scales.

Figure 11: Option A – Most Likely Scenario Costs and benefits, economic CBA

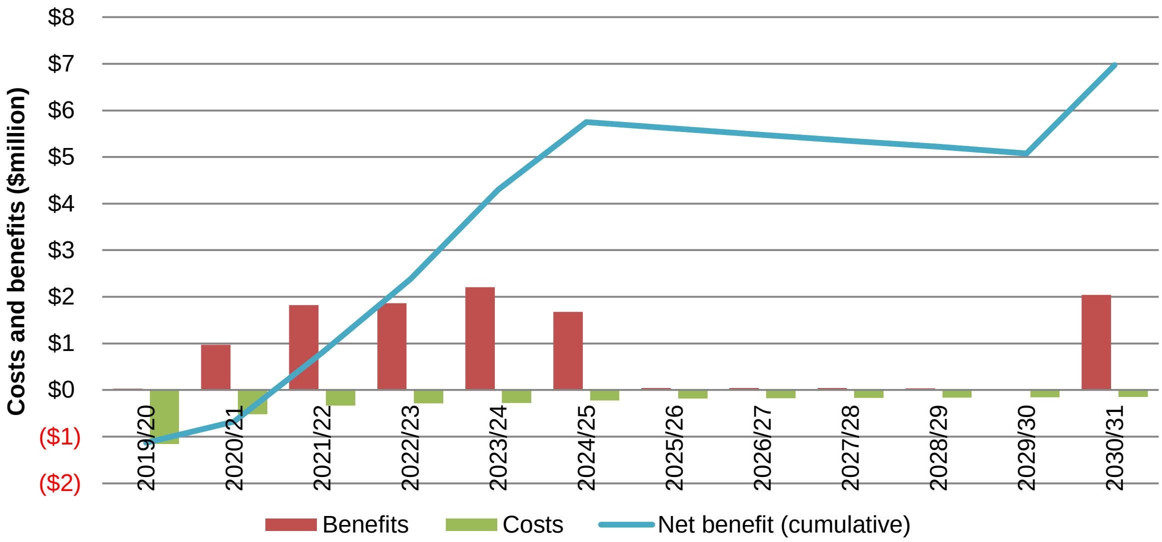
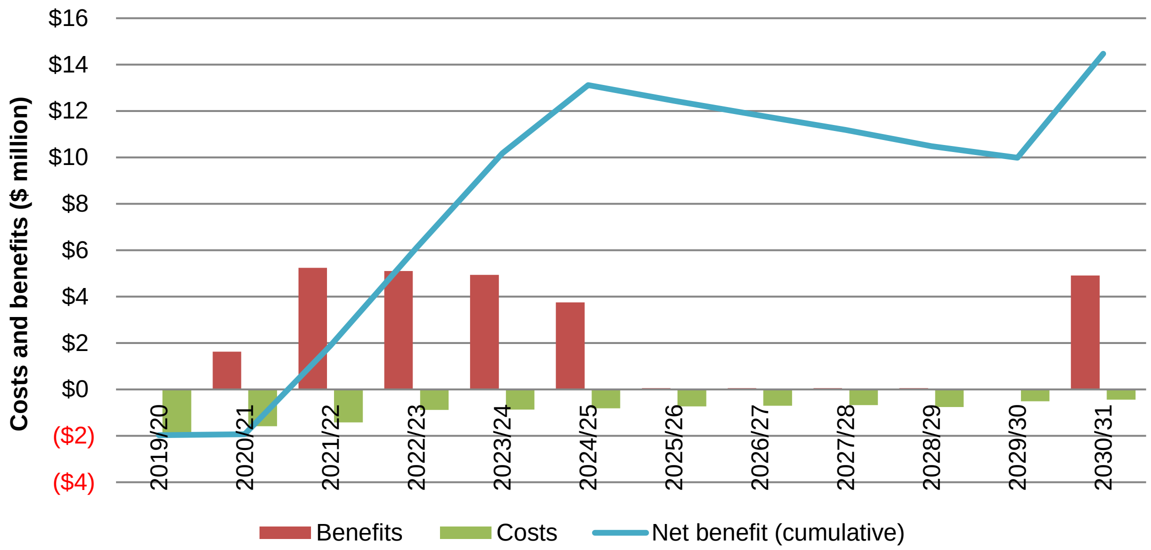


Figure 12: Option B – Most Likely Scenario Costs and Benefits, economic CBA



Patterns of how costs and benefits occur and are realised under Options A and B are similar. Most benefits are realised between 2020/21 and 2024/25, the period during which the removal work and the majority of construction that would take place. Under both options, net benefits become positive in the third year (i.e. 2021/22), and reach the first peak by the end of year six (i.e. 2024/25) when all the removal work is completed. Net benefits then decline between 2025/26 and 2029/30 because only the environmental benefits (as a result of designing out construction waste) would be realised in this period. In the final year (2030/31), net benefits would be the highest as the terminal value of infrastructure would be realised. In present value, the estimated net benefits under Options A and B are $6.97 million and $14.46 million, respectively. Note that these do not include those potential benefits that are not measured in the CBA.

5.4 Scenario and sensitivity analysis

In addition to the main analysis undertaken for More Likely scenario as described in sections 5.1 to 5.3 above, testing of alternative scenarios of the parameter values are undertaken. The impacts of changing the key inputs on the CBA results are also assessed through a series of sensitivity analysis. This is to curb any potential optimism bias resulting from over-estimation of benefits and/ or under-estimation of costs.

5.4.1 Alternative scenarios

Results of the economic CBA are tested under the Worst Case and the Best Case scenarios. The Worst Case scenario is a combination of more pessimistic assumptions on the key cost and benefit parameters for Options A and B, whereas the Best Case scenario uses more optimistic values on the parameters.

The parameters included in the analyses for the Worst Case and Best Case scenarios compared to the Most Likely scenario are summarised in Table 7. For the Worst Case scenario, values of benefit parameters are adjusted downward and cost parameters are adjusted upward. This is done conversely for the Best Case scenario. Note that values on parameters related to social value of employment, reduction in CO_2e and social cost of CO_2 emissions are adjusted based on the range obtained from the literature.

Table 7: Changes in the Worst Case and Best Case scenarios compared with the Most Likely scenario

Key parameters	Option A			Option B		
	Worst Case	**Most Likely**	**Best Case**	**Worst Case**	**Most Likely**	**Best Case**
Proportion of total investment attributed to HLC development from year two onwards	70%	**50%**	30%	70%	**50%**	30%
Proportion of dwellings to soft strip	50%	**66%**	75%	50%	**75%**	100%
Training cost per worker – soft strip	$666	**$513**	$154	$666	**$513**	$154
Training cost per worker – relocation (at development sites)	$769	**$592**	$177	$769	**$592**	$177
Training cost per worker – relocation (at destination sites)	$917	**$705**	$212	$917	**$705**	$212
Training cost per worker – deconstruction	$292	**$225**	$67	$292	**$225**	$67
Social value of moving to employment[38]	$1179	**$2358**	$27,693	$1179	**$2358**	$27,693
Social value of training in job[39]	$774	**$1548**	$2323	$774	**$1548**	$,323
Material cost saving as a result of diversion per additional relocation[40]	$9133	**$30,442**	$39,574	$9133	**$30,442**	$39,574
Percentage of construction waste reduced as a result of designing out waste	45%	**70%**	95%	85%	**95%**	100%
Reduction in CO_2e per tonne of waste reduced and reused[41]	7%	**15%**	22%	7%	**15%**	22%
Social cost of per tonne of CO_2 emissions[42]	$53	**$68.45**	$200	$53	**$68.45**	$200

[38] The Most Likely scenario uses the social value of moving from unemployment to part-time employment suggested by HACT (2014) as the proxy for social benefit of moving to employment. This value is halved for the Worst Case scenario. For the Best Case scenario the suggested social value of moving from unemployment to full-time employment in HACT (2014) is used.

[39]The main analysis for the Most Likely scenario applies the value suggested by HACT (2014) and adjusted to the NZ dollar value. For scenario testing, this value is adjusted downward by 50 per cent for the Worst Case scenario, and upward by 50 per cent for the Best Case scenario.

[40] The values are derived by assuming that in the Worst Case scenario, the share of material cost in total construction cost would be half of the 35 per cent figure that is suggested by Blick and Commendant (2018). For the Best Case scenario, the share would be 50 per cent greater (52.5%).

[41] The lower and the upper values of CO_2e emissions embodied in per tonne of construction materials estimated in the by Blick and Commendant (2018) are assumed for the Worst Case and the Best Case scenarios respectively.

[42] The social cost value for the Worst Case scenario is the suggested value in the previous release of NZTA's (2016) EEM adjusted to current price. The value for the Best Case scenario is the upper limit of Covec's best-guess estimate of the carbon price in 2020 (Covec, 2010).

To test the results of the economic CBA under each scenario, the values of all parameters are changed simultaneously. The analysis timeframe and the discount rate for the scenario analysis are the same as those in the main analysis for the Most Likely scenario (2019/20-2030/31; discount rate at 4%). Table 8 shows the range of total benefits, total costs, net benefits and BCRs estimated for the Worst Case, Most Likely and Best Case scenarios for Options A and B.

Table 8: Summary of economic cost-benefit analysis results – Worst Case, Most Likely and Best Case scenarios

	Option A ($_{2019}$ $million)			**Option B ($_{2019}$ $million)**		
	Worst Case	**Most Likely**	Best Case	Worst Case	**Most Likely**	Best Case
Total benefits	$2.86	**$10.79**	$21.70	$11.12	**$25.86**	$35/38
Total costs	$3.83	**$3.81**	$3.75	$11.41	**$11.40**	$11.31
Net benefits (NPV)	-$0.97	**$6.97**	$17.95	-$2.29	**$14.46**	$24.07
Benefit-cost ration (BCR)	0.75	**2.83**	5.79	0.97	**2.27**	3.13

Firstly, in the Most Likely scenario, Auckland would be made better off under both Options A and B. The range of estimated net benefits (i.e. the extent to which society is made better off because of the options) is $6.97 million and $14.46 million in present value for Options A and B, respectively. This corresponds to BCRs of 2.83 for Option A and 2.27 for Option B. The results indicate that cost of investing in HLC's C&D diversion activities under either option would be offset by the benefits resulting from implementing the proposed changes. This is even under conservative assumptions and with some potential benefits not included in the analysis. Option B would have a greater impact on society compared to Option A in terms of estimated net benefits.

With a range of pessimistic assumptions applied in the Worst Case scenario, both Options A and B would have costs outweighing benefits, resulting in BCRs less than 1 (0.75 and 0.97 respectively), indicating that society would be worse off. The extent to which society is made worse off would be smaller under Option A compared to Option B given its net present value (NPV) is less negative.

Under the Best Case scenario, the BCRs for both Options A and B are significantly greater compared to the Most Likely scenario (5.79 and 3.13 respectively). This indicates that under those assumptions, investing in either option would have a significant positive net effect on society. The estimated net benefit of Option B is more than 30 per cent greater than that of Option A ($24.07 million compared to $17.95 million).

5.4.2 Sensitivity analysis of net benefits using Monte Carlo simulations

Monte Carlo simulations are carried out to estimate the net benefits of Options A and B by adjusting the values of the parameters included in Table 7. The orders of magnitude of the estimated NPV for Option B is more variable compared to Option A given the greater range between its minimum and maximum NPV (see Table 9 below).

Results from Monte Carlo simulations also suggest that the Worst Case scenario shown in Table 8 would only occur with a very small chance – less than one per cent of the time for Option A and less than 10 per cent of the time for Option B.

Table 9: Distribution of estimated net benefit/ NPV results from Monte Carlo simulations

	Net benefit/ NPV ($_{2019}$ million)	
	Option A	**Option B**
Minimum	-$1.47	-$8.42
2.5th percentile	$0.95	-$3.43
5th percentile	$1.73	-$1.89
10th percentile	$2.66	$0.26
Mean	$6.13	$10.06
Median	$6.13	$9.68
95th percentile	$10.56	$21.58
97.5th percentile	$11.31	$22.96
Maximum	$14.39	$30.75

Note: These figures are the result of Monte Carlo simulations considering the probability of occurrence.

5.4.3 Sensitivity analysis of each key parameter

A series of sensitivity tests are undertaken to identify which of the parameters listed in Table 7 has the greatest impact on the BCR results. This is done by changing the value of one parameter at a time.

Results of the sensitivity tests show that assumptions on the proportion of investment attributed to the HLC development and cost saving of materials per additional relocation have the greatest impact on results for both Options A and B. However, none of the parameters tested would reduce the BCRs to lower than 1 when they are adjusted downward to their Worst Case scenario values.

A summary table of BCR's sensitivity to changes in each parameter is provided in Appendix E.

5.4.4 Sensitivity analysis of the discount rate

To assess the sensitivity of the CBA results to discount rate, a number of alternative discount rates are applied to see their impacts on the estimated net benefits and BCRs of Options A and B. As expected, the higher the discount rate the lower the net benefit and BCR.

For both Options A and B, the breakeven points (i.e. at where BCR=1) are above 90 per cent. Table 10 shows estimated net benefits and BCRs are stable when different discount rates are applied.

Table 10: Economic CBA results – alternative discount rates

	Option A		Option B	
	Net benefits ($\$_{2019}$million)	BCR	Net benefits ($\$_{2019}$million)	BCR
Base assumption 4%	**$6.97**	**2.83**	**$14.46**	**2.27**
2%	$7.93	2.91	$16.35	2.30
6%	$6.17	2.75	$12.86	2.24
8%	$5.48	2.68	$11.49	2.21
10%	$4.89	2.61	$10.32	2.18

5.4.5 Sensitivity analysis of main cost and benefit items

A sensitivity analysis of the major cost and benefit items is carried out to test the effect on each option's CBA results if assumptions on these items are changed.

As shown in Table 5 before (refer to Section 5.1.4), the investment cost attributed to the HLC development makes up most of the total cost under both Options A and B. This is dependent on the proportion of investment that is assumed to go into the HLC development. In the sensitivity analysis of this cost item, the impact of a range of alternative assumptions on this proportion are tested to compare with the results under the assumption used in the Most Likely Scenario (i.e. base assumption).

Results in Table 11 show that the estimated net benefits and BCRs decrease when a higher proportion of investment is assumed. Options A and B would still yield net benefits and BCRs greater than 1, even if all investment goes into activities in the HLC development. Also, Option B would still result in greater net benefit compared to Option A under all alternative assumptions tested. The ranges of BCRs in this sensitivity analysis are 1.69 to 6.12 for Option A, and 1.25 to 6.48 to Option B.

Table 11: Alternative assumptions on the proportion of investment attributed to the HLC development from year two onwards

	Option A		Option B	
	Net benefits ($\$_{2019}$million)	**BCR**	**Net benefits ($\$_{2019}$million)**	**BCR**
Most Likely scenario: 50%	**$6.97**	**2.83**	**$14.46**	**2.27**
10%	$9.02	6.12	$21.87	6.48
30%	$8.00	3.87	$18.16	3.36
70%	$5.95	2.23	$10.75	1.71
100%	$4.41	1.69	$5.20	1.25

The sensitivity analysis of main benefit items is undertaken for the net economic benefit of materials saved, the terminal value and the environmental benefit from reduction in GHG emissions. This is done by setting the result of each of these benefits to zero and reducing them by 50 per cent. The latter sensitivity analysis would highlight any over-estimation of any of these benefits.

The net economic benefit from materials saved due to relocation has the greatest impact on the results of both Options A and B (Table 12). Removing this benefit would result in negative NPVs and BCRs less than 1 for both options. Although both options would yield positive net benefit when the value of this benefit item is halved, the associated BCRs would decrease from 2.83 to 1.87 for Option A, and decrease from 2.27 to 1.44 for Option B.

Table 12: Impact of main benefit items on results of the economic CBA

		Option A		Option B	
		Net benefits ($\$_{2019}$million)	**BCR**	**Net benefits ($\$_{2019}$million)**	**BCR**
Most Likely Scenario		**$6.97**	**2.83**	**$14.46**	**2.27**
Net economic benefit of materials saved due to relocation	Zero	-$0.35	0.91	-$4.40	0.61
	Reduced by 50%	$3.31	1.87	$5.03	1.44
Terminal value	Zero	$4.93	2.29	$9.55	1.84
	Reduced by 50%	$5.95	2.56	$11.51	2.01
Environmental benefit from reduction in GHG emissions	Zero	$6.39	2.68	$13.38	2.17
	Reduced by 50%	$6.68	2.75	$13.92	2.22

6.0 Financial CBA for the developers

A financial CBA is also carried out to evaluate the impacts of the proposed changes to (the HLC) developers as a result of implementing the proposed options for C&D waste diversion. The estimated costs and benefits are relative to a counterfactual of the status quo.

6.1 Costs

This section presents the estimated costs to the HLC developers under Options A and B. For explanatory purposes, the costs presented here are not discounted. The estimates are on the assumptions of the Most Likely scenario.

The following cost components were quantified in this financial CBA:

- Cost of sorting waste onsite.
- Cost of recycling.
- Cost of transporting waste to MRF (e.g. Green Gorilla).
- Cost of reusing.
- Cost of collecting waste.
- Cost of designing out construction waste.

The method and proxies used to measure each of the cost components are described further in the subsections below.

6.1.1 Cost of sorting

As waste and materials are pulled down during demolition or deconstruction, they need to be sorted into various streams before sending them to different destinations (landfill, recover, recycle, and reuse). Because deconstruction aims for a higher rate of resource recovery, waste sorting in deconstruction is considered more labour intensive compared to demolition (Otter-Lowe, 2018).

A demolition industry practitioner advises that the typical labour cost of deconstructing a house is $10,000 and that there are six hours per working day on average. A crew typically consists of a supervisor and a number of labourers. The supervisor typically gets paid at $65 per hour and the labour work is paid at $45 per hour. This information is applied to derive the additional labour cost per tonnage of removed waste compared to the status quo – a proxy for the unit cost of sorting waste under each of the proposed options.

As a first step to derive the unit labour cost of sorting, the CBA uses the crew size and number of days assumed for demolition, moderate deconstruction and full deconstruction in the economic CBA (see Section 5.1.2) as the proxies for the average labour input and time taken for each dwelling under the status quo, Option A and Option B respectively.[43] Based on the labour cost advised by the demolition industry practitioner, it can be then calculated that the labour costs per dwelling are $1980 for the status quo, $7440 for Option A and $11,858 for Option B. Under the assumption that demolition of each house produces 30 tonnes of waste, Options A and B would have $186 more labour cost and $329 more labour cost for per tonne of waste respectively compared to the status quo.

The total waste to be sorted onsite includes the waste ended up being recovered/ recycled and reused, as well as the waste disposed at the landfill (including the portion sent directly to landfill and the residual disposed by MRF). Compared to the status quo, it is estimated that Options A and B would produce 8513 less tonnes of waste and 21,930 less tonnes of waste from deconstruction respectively. However, with significantly higher unit costs of sorting, the CBA estimates that the additional costs of sorting relative to the status quo are $22.09 million under Option A and $46.42 million under Option B.

6.1.2 Cost of recycling

With higher rates of recycling under Options A and B compared to the status quo, additional costs associated with recycling are also expected. The CBA assumes the main cost of recycling under Options A and B is the additional gate fees paid to the MRF for recycling. As the chosen MRF for the HLC development, Green Gorilla's gate fee for recycling per tonne of waste is used as the unit cost of recycling, which is assumed to be $80 per tonne.

Based on Waste Solutions' costing model, it is estimated that 77,815 tonnes of waste would be recycled under Option A and 67,446 tonnes would be recycled under Option B. This would result in an additional of 67,203 tonnes and 56,834 tonnes of recycled waste respectively compared to the status quo (10,613 tonnes). At the

[43] Although it is possible that not all dwellings would be removed by the same method, however, because there was no information on the labour input and time needed for per dwelling under the status quo, Options A and B, those figures were applied uniformly to the status quo, Options A and B respectively. This was also in line with the underlying assumptions that the status quo uses demolition as the main approach, Option A focuses more on partial recovery and recycling of waste with moderate deconstruction as the main approach, and Option B uses full deconstruction as the main approach with stronger focus on reuse of recovered materials.

assumed gate fee of $80 per tonne, the costs of recycling are estimated as $5.38 million under Option A and $4.55 million under Option B.

6.1.3 Transportation cost to MRF

Recycling also involves transporting the materials from the HLC development sites to the MRF. The cost associated with this transportation is affected by the travel distance and travel time between the development sites and the MRF.

It is reasonable to assume that a rational driver would always choose the closest route to travel to their destinations. Based on this, data on the approximate distances between each of the HLC sites and their closest landfill sites and the approximate distances to Green Gorilla are collected from Google Maps. The average travel time from each HLC development area to their closest landfill sites and Green Gorilla are then calculated using the road-specific speed limits information from Auckland Transport's Speed Limits Bylaw (Auckland Transport, 2019). [44] Taking into account the expected number of demolitions in each of the HLC sites, it is found that the total travel distances between the HLC sites and Green Gorilla are approximately 25 per cent of the total travel distance to their closest landfills.

Based on the finding above, the CBA assumes that transportation cost to MRF is 25 per cent of the transportation cost to landfill. Experts from Waste Solutions suggest that the unit cost of transporting C&D waste between the project sites and landfill range between $30 and $40 per tonne, but more likely to be towards the lower end of this range. To be conservative, the CBA assumes that the unit transportation cost to landfill is $35 per tonne. Using the earlier finding on the total travel distances between the HLC sites and Green Gorilla, the unit transportation cost to MRF would be $8.72 per tonne, which is 25 per cent of the unit transportation cost to landfill.

The transportation costs to MRF over the 12-year project life are estimated as $0.59 million under Option A and $0.50 million under Option B.

6.1.4 Cost of reusing

The CBA considers cost of time as the main part of the cost associated with reusing materials from deconstruction under the Options A and B, and this is already captured in calculating the cost of sorting waste. However, an additional cost of $1000 per deconstructed dwelling is assumed for other expenses related to reuse (e.g. additional processing) for both options. Applying the assumption that each

[44] Note that the CBA assumes heavy vehicles are used to transport C&D waste, therefore it is assumed that they can only travel at an average speed of 90km/h on a motorway with a speed limit of 100km/h.

demolition produces 30 tonnes of waste, the unit cost of reusing per tonne of materials from deconstruction would be $33.

Based on Waste Solutions' costing model, it is estimated that, 1315 tonnes more materials would be reused under Option A and 25,401 tonnes more would be reused under Option B compared to the status quo. This would result in an additional cost of $0.04 million associated with reusing under Option A and $0.85 million under Option B.

6.1.5 Cost of collecting waste

The CBA estimates the cost of collecting waste under Options A and B as the cost of additional skip bins used for transporting the deconstruction waste that is going to be reused or going to the MRF. This also includes the residual waste which is later disposed to landfill from the MRF.

A large MRF in Auckland suggests that one additional skip would cost $300. From here, the CBA further assumes that under Option A, collecting waste from one dwelling would hire one additional skip compared to the status quo. Because more waste materials can be recovered from full deconstruction than moderate deconstruction the CBA assumes that Option B would hire two additional skips per dwelling compared to the status quo. Therefore, the unit cost of collecting waste relative to the status quo would be $300 per dwelling under Option A and $600 per dwelling under Option B.

Cost of collecting waste under each option can be then estimated by multiplying the unit cost of collecting waste by the additional number of dwellings from which waste would be collected from relative to the status quo. The latter is derived by multiplying the number of expected demolitions with the expected percentage targets for reuse, recover/recycle and residual disposal under the status quo and each option as per Waste Solutions' costing model.

The total costs of collecting waste over the project life of the HLC development are estimated as $0.85 million under Option A and $2.89 million under Option B.

6.1.6 Cost of designing out waste

It has been widely recommended by studies in the international literature that the optimal waste minimisation strategy is to design out both waste from removing the buildings and waste from construction (e.g. Morgan and Stevenson, 2005; Osmani et al., 2008; Kelly and Dowd, 2015). However, because the project life of the HLC development is only 12 years and Options A and B have already identified the approaches for demolition waste diversion, the CBA only considers design-out waste for construction waste diversion.

As already outlined in Table 4 (see Section 4.2), the CBA assumes that 70 per cent of the construction waste would be reduced through designing out waste under Option A. This level of waste reduction is within the range of the target outcome of a Level 5 design-out waste strategy as described by Tran (2017). As Option B has a stronger focus on the top level of the waste hierarchy (i.e. reduce) than Option A, the CBA assumes a Level 7 design-out waste strategy for Option B, which would result in a waste reduction by 95 per cent.

In Tran's (2017) case study of a construction project in the Auckland CBD, it is estimated that a Level 5 design-out-waste strategy could cost $57,350 and a Level 7 strategy could cost $75,735. Due to the lack of information about design-out-waste practices in Auckland, the CBA uses this information as the basis for calculating the unit cost of designing out waste under Options A and B.

Further, Beacon (2015, p. 7) finds that the costs of design and professional services for a sample of 69 homes across Auckland are in the range between $11,000 and $26,000. This finding leads to the conclusion that "standardised design will deliver lower cost in both design and construction" (Beacon, 2015, p. 7). Considering the size of the HLC development, the CBA considers it is likely that every 100 dwellings constructed in the HLC development would have a standardised design. Using Tran's (2017) estimated cost of the design-out waste strategies, the CBA calculates that designing out waste from constructing one dwelling costs $573.75 under Option A and $757.35 under Option B.

With a total of 22,797 new dwellings to be constructed over the project life, the total costs of designing out waste are estimated as $13.08 million under Option A and $17.27 million under Option B.

6.1.7 Summary of costs

In the analysis for the Most Likely scenario, Options A and B are estimated to cost the developers $42.03 million and $70.54 million respectively over the 12-year project life of the HLC development. A summary of costs under each option is presented in Table 13.

Table 13: Estimated costs to the HLC developers under Option A and Option B, financial CBA

Cost item	Option A ($million)	Percentage of total cost	Option B ($million)	Percentage of total cost
Cost of sorting	$22.09	52.6%	$46.42	64.1%
Cost of recycling	$5.38	12.8%	$4.55	6.3%
Transportation cost to MRF	$0.59	1.4%	$0.50	0.7%
Cost of reusing	$0.04	0.1%	$0.85	1.2%
Cost of collecting	$0.87	2.0%	$2.89	1.4%
Cost of designing out waste (construction)	$13.08	31.1%	$17.27	23.8%
Total costs	**$42.03**	**100.0%**	**$72.47**	**100.0%**

Under both options, cost of sorting accounts for more than half of the total cost. This is largely due to the fact that deconstruction is a more labour intensive compared to demolition. The larger share of cost of sorting under Option B (64%) compared to Option A (53%) reflects their different approaches to deconstruction.

6.2 Benefits

This section presents the estimated benefits or cost savings to the HLC developers under Options A and B relative to the status quo. The benefits presented here have not been discounted, and they are estimated based on assumptions for the Most Likely scenario.

The following are the main benefit components included in the financial CBA:

- Revenue from selling salvaged materials from soft strip and deconstruction
- Revenue from selling houses to be relocated
- Cost savings in landfill disposal as a result of deconstruction and construction waste diversion
- Cost savings in transporting waste to landfill as a result of deconstruction and construction waste diversion
- Cost saving in purchasing construction materials.

There are also intangible benefits to the HLC developers resulting from implementing the proposed C&D waste diversion practices. As described by Tran (2017), developers and contractors can improve their reputation and credentials when they are committed to C&D waste diversion and minimisation. These can enhance their marketing/brand image which may in turn lead to opportunities for further business expansion. However, they are not included in the analysis as there is no information or data available for measuring and monetising them.

The method and proxies used to measure the quantifiable benefits are described in the following sub-sections.

6.2.1 Revenue from selling salvaged materials

Revenue from selling salvaged materials comes from soft strip and deconstruction. It is understood that the New Zealand Building Code (Ministry of Business, Innovation and Employment, 2014)[45] may limit the use of salvaged materials. However, Waste Solutions also advises that there are still outlets and high demand for those materials.[46] This is based on their experience in the C&D waste industry and evidence from a number of Auckland Council's deconstruction and resource recovery projects. It is therefore reasonable for this CBA to assume that demand for the salvaged materials matches the supply.

Communications between Waste Solutions and the developers suggest that currently soft strip collection is only done to five per cent of the dwellings removed. They are aiming to increase this rate to either 66 per cent under Option A or 75 per cent under Option B. While there is no data available on every single material collected from soft strip in Auckland, the common or main types of materials from soft strip are identified

[45] For example, there are provisions in the New Zealand Building Code that specifically require building materials and components to be sufficiently durable to ensure the building's functional performance throughout the life of the building.

[46] Waste Solutions suggests that:

- All common scrap metals are typically in high demand, however, their prices tend to fluctuate.
- Native timbers are in high demand for furniture and renovation use with good demand and high prices for new native timber floorboards moulded from recovered timber.
- Fittings and fixtures such as windows, doors, kitchens, plumbing and lighting have some demand from people doing renovations and repairs. This is evidenced by the numerous commercial demolition yards in Auckland and an active market on Trade Me.
- Community based organisations, social enterprises and social businesses such as the Resource Recovery Network, TROW Group and All Heart play a key role in developing new markets for recovered materials that are typically considered to only be useful as biofuel. An example is treated timber, which Community Recycling Centres report as having good demand when a supply is available.
- Deconstruction and recovery projects undertaken by Auckland Council have revealed accepted uses for recovered timber in Pacific countries.

from various deconstruction case studies in Auckland.[47] Using a mixture of information sources on the resell price of those items (e.g. TradeMe, Google, Bunnings Warehouse, Musgroves); it is found that the value of soft strip materials per dwelling could add up to $921.

Relative to the status quo, total revenues from selling soft strip materials are estimated as $3.97 million under Option A and $4.56 million under Option B.

The value of salvaged materials from deconstruction is calculated based on the information obtained from industry practitioners and a recent study on deconstruction in Auckland. A demolition company suggests that the typical salvage value of recovered materials from each house removed is $3000. A study by Envision (2017) estimates that the value of materials recovered from full deconstruction (including soft strip) of a one-storey native timber house built between 1940 and 1960 is $16,290. Excluding the soft strip materials, the suggested value of reusable materials recovered from a full deconstruction is $15,323 per house.

Because Option A takes a moderate deconstruction approach and Option B undertakes full deconstruction, the CBA applies the lower value (i.e. $3000) for return from salvaged materials per dwelling deconstructed under Option A, and the higher value (i.e. $15,323) under Option B. To calculate additional revenue from selling materials salvaged from deconstruction under each option compared to the status quo, return from salvaged materials per dwelling was multiplied with the additional number of dwellings that have materials for reuse (based on Waste Solutions' costing model).

Over the 12 years of the HLC development, total revenues from selling salvaged materials from deconstruction are estimated as $0.13 million under Option A and $12.97 million under Option B.

Note that the substantial difference in these estimated revenues between Options A and B is driven by the combined effect of the following three factors:

- Option B undertakes full deconstruction with stronger focus on reuse, whereas Option A undertakes moderate deconstruction that focuses more on partial recovery and recycling of waste materials. This is reflected by the higher value of recovered materials per dwelling under Option B compared to Option A.

[47] These materials include hot water cylinder, oven, stainless bench, clothesline (deconstruction trials in Tāmaki; Otter-Lowe, 2018), bath (information from Helensville deconstruction project by Envision), and bathroom vanity (Tarkar, 2018) and whole kitchen (communications with a demolition company involved in the Tāmaki deconstruction trial).

- Compared to the status quo, Option B has 847 more deconstructed dwellings from which waste materials are recovered for reuse, whereas this number is 44 under Option A.
- Deconstruction is expected to start in the year 2020/21 under Option B compared to 2022/23 under Option A.

6.2.2 Revenue from selling relocated houses

Options A and B would also result in additional revenues from selling more relocated houses compared to the status quo. Waste Solutions suggests that currently only four per cent of the old houses are removed by relocation. As indicated by the company working with HLC on housing relocation, this percentage is proposed to increase to nine per cent under Option A and 16 per cent under Option B.

Site visit interviews and other communications with demolition companies suggest that a relocated house could be sold at an average price of $8000, and this diverts 25 tonnes from demolition. An onsite interview with a demolition company involved in the AMETI demolition work advises that the gains from selling the houses for removal vary, ranging from $1 to $2500. To be conservative, the CBA assumes a value of $2500, as the value per relocated house. This is within the lower bound of the range of $1 to $8000 as described above. Based on the information that each sale of relocated houses diverts 25 tonnes of waste, the unit value of a relocated house in terms of waste tonnage would be $100 per tonne.

The contractor working with HLC for house relocation has confirmed that houses would only be relocated when their destinations are known. This means there is demand for every house being relocated. Based on this, the CBA estimates that increased relocation of houses result in a total revenue of $1.36 million under Option A and $3.51 million under Option B.

6.2.3 Cost savings in landfill disposal

Under both Options A and B, savings in landfill disposal costs result from increased waste diversion during removal (as a result of increased deconstruction and relocation instead of demolition), as well as from construction waste diversion as a result of designing out waste.

The CBA uses the cost of disposing per tonne of waste to landfill as the unit cost of landfill disposal. This charge also includes the waste levy to be paid by the disposal operators as under the requirement of the Waste Minimisation Act 2008. The current waste levy in New Zealand is at the rate of $10 per tonne. Also, according to Eunomia (2017), the landfill gate fees of disposing medium to large bulk waste vary significantly across New Zealand, ranging between $20 and $90 per tonne. While there is no Auckland-specific information available, to be conservative, the CBA assumes the highest landfill gate fee within this range ($90 per tonne). If the waste levy is to remain at its current rate at $10 per tonne over the project life of the HLC development, this adds up to a unit cost of landfill disposal at $100 per tonne.

Under the current waste levy rate, the additional waste diverted from landfill under Options A and B through deconstruction and relocation are estimated to save $7.70 million and $10.42 million in landfill disposal costs respectively. Savings in landfill disposal costs as a result of construction waste diversion are estimated as $6.38 million under Option A and $8.66 million under Option B.

6.2.4 Cost savings in transporting waste to landfill

The increased waste diversions under Options A and B would also result in cost savings in transporting waste to landfill. The CBA uses the value of $35 as the cost of transporting per tonne of waste to the landfill. This is based on the suggestion from Waste Solutions (refer to Section 6.1.3).

The estimated savings in transportation cost to landfill as a result of deconstruction and relocation are $2.70 million under Option A and $3.65 million under Option B. Cost savings in transportation to landfill as a result of construction waste diversion are estimated as $2.23 million under Option A and $3.03 million under Option B.

6.2.5 Cost saving in purchasing construction materials

Tran (2017) from his interviews with the experienced construction industry practitioners finds that the key consideration in designing out construction waste is materials. Therefore, it is expected that designing out waste could result in significant cost savings in purchasing construction materials under both Options A and B.

Because the list of the materials used for constructing new dwellings in the HLC development is unknown, the CBA uses the average cost of construction materials calculated in a case study by Tran (2017). Tran first aggregates the costs of purchasing per tonne of plasterboard, timber and steel, the materials of which cost information is obtainable from various sources. This aggregated value is then averaged across the materials identified from the construction waste, giving a value of $316.67 for the average cost of new materials.

Using $316.67 as the unit cost of per tonne of construction materials, cost savings in purchasing construction materials as a result of the construction waste diversion under Options A and B are estimated as $20.21 million and $27.43 million respectively.

6.2.6 Summary of benefits

In the analysis for the Most Likely scenario, Options A and B are estimated to result in total benefits of $44.70 million and $74.23 million to the developers respectively over the 12 years of the HLC development. A summary of the benefits by component under each option are in Table 14.

For both options, cost saving in purchasing construction materials presents the largest benefit component, making up 45 per cent and 37 per cent of the total benefits under Options A and B respectively.

While 17 per cent of the total benefit under Option B is estimated to come from revenue from selling materials salvaged from deconstruction, this source of benefit only contributes less than one per cent of the total benefit under Option A. This reflects the main difference between the two proposed options – Option A has a strong focus on recycling, whereas Option B focuses more on reuse.

Table 14: Estimated benefits to the HLC developers under Options A and B, financial CBA

Benefit component	Option A ($million)	Percentage of total benefits	Option B ($million)	Percentage of total benefits
Revenue from selling salvaged material – from soft strip	$3.97	8.9%	$4.56	6.1%
Revenue from selling salvaged material – from deconstruction	$0.13	0.3%	$12.97	17.5%
Revenue from selling relocated houses	$1.36	3.0%	$3.51	4.7%
Cost saving in landfill disposal (diversion through deconstruction and relocation)	$7.70	17.2%	$10.41	14.0%
Cost saving in transporting waste to landfill (diversion through deconstruction and relocation)	$2.70	6.0%	$3.65	4.9%
Cost saving in landfill disposal (construction waste diversion)	$6.38	14.3%	$8.66	11.7%
Cost saving in transporting waste to landfill (construction waste diversion)	$2.23	5.0%	$3.03	4.1%
Cost saving in purchasing construction materials	$20.21	45.2%	$27.43	37.0%
Total benefits	**$44.70**	**100.0%**	**$74.23**	**100.0%**

It is also important to emphasise that the benefits presented here do not include the intangible benefits associated with improved reputation and credentials for the developers from implementing C&D waste diversion from landfill. Those benefits are difficult to measure or monetise with the information and data available at the time of this CBA.

6.3 Costs and benefits combined

Figure 13 and Figure 14 illustrate how costs and benefits occur or are realised over the project life of the HLC development (2019/20 - 2030/31) under Options A and B respectively. The costs and benefits are in present value terms – using a discount rate of seven per cent. Note that the two graphs are shown in different scales.

Figure 13: Option A – Costs and benefits under the Most Likely scenario, financial CBA

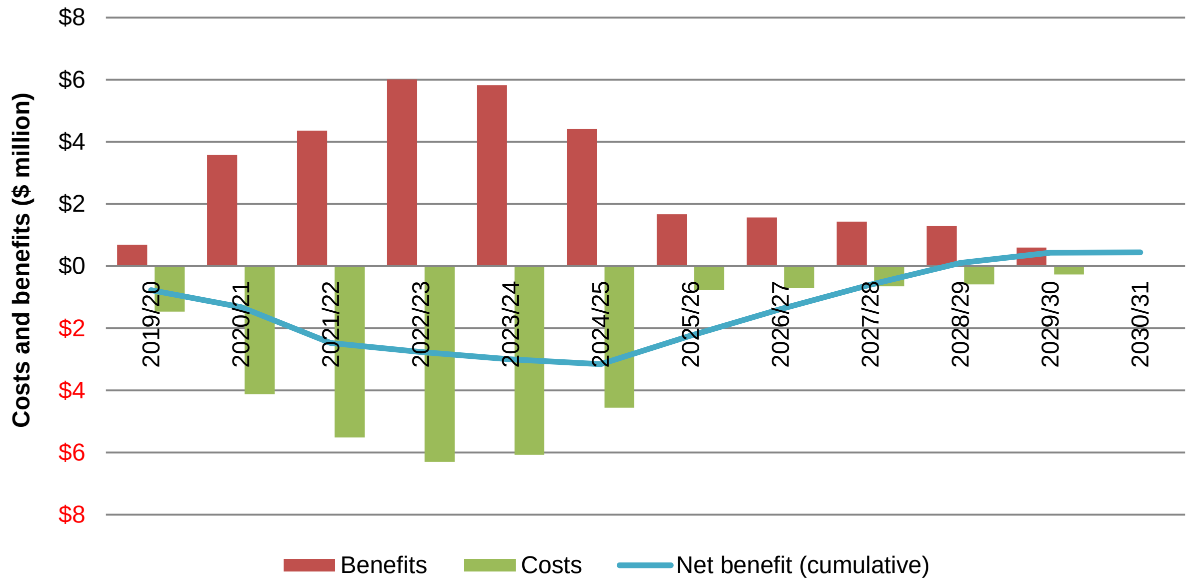
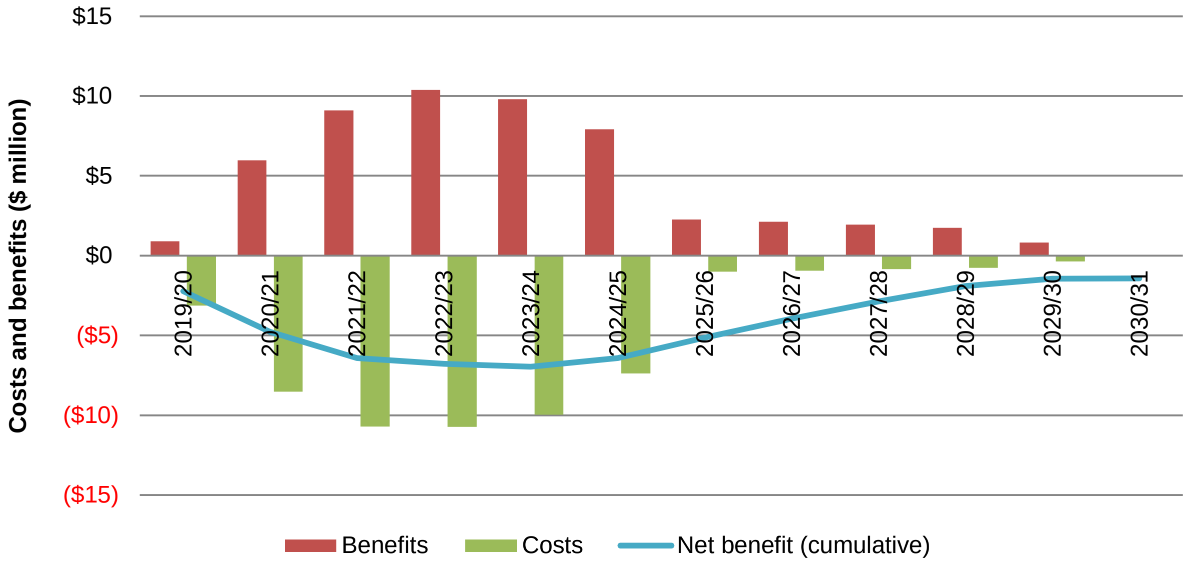


Figure 14: Option B – Costs and benefits under the Most Likely scenario, financial CBA



Under both Options A and B, most of the costs and benefits occur during the first half of the HLC development – between 2019/20 and 2024/25. This is the period where removal and the majority of construction work take place. Option A starts to accumulate net benefits in 2024/25, when all deconstruction work is completed. Its net benefits become positive by the end of 2028/29, with benefits slightly outweighing the costs. Option B starts to accumulate net benefits in 2024/25, however, its net benefits still remain negative by the end of the development, with costs slightly outweighing benefits. This is due to the conservative assumption that Option B is expected to achieve the maximum target diversion rate by 2029/2030, compared to 2025/26 assumed Option A.

The accumulation of net benefits shown in the two graphs above do not account for those intangible benefits associated with improved reputation and credentials. They may bring additional gains for the developers if they can be monetised and realised.

6.4 Scenario and sensitivity analysis

The preceding sections have presented the financial CBA under the assumptions made based on what was considered the Most Likely scenario. To obtain a robust analysis, Most Likely scenario is tested, given that there could be changes to New Zealand's waste levy system, and there are many uncertainties associated with the values of the parameters used in the CBA. Sensitivity analyses are also carried out to assess the impacts of each parameter used and the alternative discount rates on the CBA results.

6.4.1 Alternative waste levy scenarios

As highlighted in Section 4.1, fees paid for landfill disposal can affect the cost-effectiveness of C&D waste diversion through deconstruction. To take this into account, a scenario analysis is done to assess how results of the financial CBA may vary when the levy rate changes, using two of the alternative waste levy scenarios developed in Eunomia's (2017). The scenarios considered in this analysis are:

- Levy scenario 0: Levy stays at the current rate of $10 per tonne over the project life of the HLC development.
- Levy scenario 1 – increase to $20 per tonne by 2020/21.
- Levy scenario 2 – increase to $$90 per tonne by 2020/21.

At the assumed landfill charge fee of $90 per tonne, the unit cost of landfill disposal would be $100 ($90+$10 levy) per tonne in the first year of the development (2019/20) under all three levy scenarios. From year two (2020/21) onwards, the unit cost of landfill disposal would increase to $110 per tonne under Levy scenario 1 and $180 per tonne under Levy scenario 2.

Table 15 shows the range of benefits, costs, net benefits and benefit-cost ratios (BCRs) under the three waste levy scenarios for Options A and B.

Table 15: Summary of cost-benefit analysis results – waste levy scenarios

	Option A Present value ($_{2019}$$ million)			Option B Present value ($_{2019}$$ million)		
	Scenario 0	Scenario 1	Scenario 2	Scenario 0	Scenario 1	Scenario 2
Total benefits	$31.45	$32.44	$39.34	$52.97	$54.33	$63.82
Total costs	$31.01	$31.01	$31.01	$54.40	$54.40	$54.40
Net benefits (NPV)	$0.44	$1.43	$8.33	-$1.43	-$0.07	$9.43
Benefit-cost ratio (BCR)	1.01	1.05	1.27	0.97	1.00	1.17

Option A yields positive net benefits across all three waste levy scenarios, with estimated net benefits ranging between $0.44 million and $8.33 million in present value terms. This corresponds to a BCR range of 1.01 and 1.27. This means changes in the waste levy would not affect the outcome that Option A results in net gains for the HLC developers.

In comparison, Option B would only yield net gains for the HLC developers when the waste levy is set to increase to $90 per tonne. Under this scenario, the estimated net benefit is $9.43 million in present value terms, corresponding to a BCR of 1.17. Under the other two waste levy scenarios, the present value of Option B's benefits range between $52.97 million and $63.82 million and the cost at $54.40 million, resulting in negative benefits and BCRs of less than or just at 1. Therefore, a high waste levy is important for achieving net gains for the developers from an initiative that focuses more on resource recovery and reuse such as Option B.

6.4.2 Worst Case and Best Case scenarios

Keeping the waste levy unchanged, a range of the assumptions on the parameters used in the Most Likely scenario are adjusted downward to test the outcome when a Worst Case scenario is assumed. The Worst Case scenario is a combination of the most pessimistic assumptions for Options A and B. The parameters are also adjusted upward for the Best Case scenario, using a set of more optimistic values based on information from communications with the industry practitioners and the literature. Note that the Most Likely scenario uses lower range values for benefit parameters and higher range values for cost parameters.

The parameters included in the Worst Case and Best Case scenario analysis compared to the main scenario (Most Likely) are summarised in Table 16.

Table 16: Changes in the Worst Case and Best Case scenarios compared with the main scenario (Most Likely)

Key parameters	Option A			Option B		
	Worst Case	Most Likely	Best Case	Worst Case	Most Likely	Best Case
Unit cost of sorting waste ($ per tonne)	$237	**$182**	$127	$428	**$329**	$230
Unit cost of collecting waste ($ per dwelling)	$600	**$300**	$0	$1200	**$900**	$600
Unit transportation cost to landfill ($ per tonne)	$17	**$35**	$50	$17	**$35**	$50
Unit transportation cost to other destinations (e.g. MRF)	$12	**$9**	$5	$12	**$9**	$5
Unit cost of recycling ($ per tonne)	$100	**$80**	$60	$100	**$80**	$60
Unit cost of reusing ($ per tonne)	$67	**$33**	$0	$67	**$33**	$0
Unit cost of designing out waste ($ per dwelling)	$1148	**$574**	$287	$1515	**$757**	$379
Value of relocated house ($ per tonne)	$0	**$160**	$320	$0	**$160**	$320
Return from salvaged materials (deconstruction) ($ per dwelling)	$2000	**$3,000**	$4,000	$10,000	**$15,323**	$20,000

Key parameters	Option A			Option B		
	Worst Case	Most Likely	Best Case	Worst Case	Most Likely	Best Case
Unit cost of purchasing construction materials ($ per tonne)	$0	**$317**	$700	$0	**$317**	$700
Percentage of waste reduction as a result of designing out waste	45%	**70%**	95%	85%	**95%**	100%
Value of soft strip materials per dwelling	$0	**$921**	$1500	$0	**$921**	$1500
Proportion of dwellings to soft strip	50%	**66%**	75%	50%	**75%**	100%

Costs and benefits to the developers under Options A and B are estimated for the Worst Case and Best Case scenarios. The present values of total costs and benefits over the 12-year project life of the HLC development are calculated by discounting to the 2019 dollar values. The range of total benefits, total costs, net benefits and BCRs for the Worst Case, the Most Likely Case and the Best Case scenarios for Options A and B are presented in Table 17.

Table 17: Summary of financial cost-benefit analysis results – Worst Case, Most Likely and Best Case scenarios

	Option A (2019 $million)			Option B (2019 $million)		
	Worst Case	**Most Likely**	Best Case	Worst Case	**Most Likely**	Best Case
Total benefits	$10.49	**$31.45**	$66.62	$21.55	**$52.97**	$90.18
Total costs	$49.97	**$30.01**	$16.48	$82.45	**$54.40**	$32.21
Net benefits (NPV)	-$39.48	**$0.44**	$50.13	-$60.90	**-$1.43**	$57.96
Benefit-cost ration (BCR)	0.21	**1.01**	4.04	0.26	**0.97**	2.80

Under the Most Likely scenario, Option A has an estimated net benefit of $0.44 million in present value term for the developers, corresponding to a BCR of 1.01. For Option B, the estimated costs slightly outweigh the estimated benefits by $1.43 million, yielding a BCR just under 1 (0.97). This indicates that both options are essentially breakeven for the HLC developers. However, this does not account for any potential gains for the developers if intangible benefits associated with improved reputation and credentials can be realised.

When using pessimistic values for benefit parameters and higher values for cost parameters in the Worst Case scenario, costs significantly outweigh benefits under both Options A and B. In this scenario, both options would have BCRs below 1 (0.21

and 0.26), indicating loss for the HLC developers from implementing C&D waste diversion proposed under either option.

In the Best Case scenario, both Options A and B would yield higher BCRs compared to the Most Likely scenario (4.04 and 2.80), with net benefits (in present value terms) estimated as $50.13 million and $57.96 million respectively. This indicates that the developers would be better off under either option, when assumptions about costs and benefits are more optimistic.

6.4.3 Sensitivity analysis of each key parameter

Sensitivity analysis is also carried out to assess which parameter in Table 16 has the greatest impact on the BCR results for the HLC developers. This is done by changing one parameter to their Worst Case and Best Case values at a time while controlling for the other parameters.

It is found that that assumptions for estimating cost of and cost savings from designing out waste and assumption on the unit cost of sorting waste have the greatest impact for both Options A and B. When changing the assumptions on unit transportation cost to MRF, unit cost of reusing or return from materials salvaged from each deconstructed dwelling, Option A's BCR still stays above 1.

A summary table of BCR's sensitivity under Options A and B to changes in each parameter is provided in Appendix F.

6.4.4 Sensitivity analysis using alternative discount rates

The alternative discount rates applied in the sensitivity analysis of discount rate are 6 and 10 per cent.

The "break even" discount rates (i.e. where BCR=1) are around 9.4 per cent and 3.1 per cent for Options A and B respectively. Table 18 below shows the impact of changes in the discount rate on the BCR result of each option. For both options, their BCRs vary slightly when the alternative discount rates are applied. Option A yields a BCR at 1 or slightly above 1 when either alternative discount rate is applied. For Option B, its BCR remains just below 1 under either alternative discount rate.

Table 18: BCR results – alternative discount rates

	Option A (BCR)	Option B (BCR)
Base Assumption 7%	**1.01**	**0.97**
10%	**1.00**	**0.96**
6%	**1.02**	**0.98**

7.0 Discussion and conclusion

Results of the economic CBA support the view that Auckland is likely to be better off with either of the two C&D waste diversion options proposed for the HLC development. A conservative approach to measure the benefits is adopted at all times. There are benefits that are not quantifiable and hence are not included in the analysis. Option B is the more expensive option as it has a lower benefit to cost ratio (BCR=2.27) relative to Option A (BCR=2.83). However, it is considered the preferred option as its net benefits to society (NPV=$14.46 million) are more than double those under Option A (NPV= $6.97 million), reflecting a better value of money spent. With a stronger focus on reduce (through relocation and designing out waste) and reuse (through more uptake of full deconstruction), Auckland can enjoy greater economic benefits from savings in construction materials and environmental benefits from reduction in GHG emissions. Results of the economic CBA do not change materially when assumptions on the key parameters and discount rates are altered.

Results of the financial CBA indicate that developers would essentially breakeven from implementing the proposed changes for diverting C&D waste from landfill, with BCR of 1.01 under Option A and BCR of 0.97 under Option B respectively. There may be additional gains for developers from implementing C&D waste diversion if the intangible benefits (improved reputation and credentials from diverting C&D waste) can be realised. Results also indicate that under both Options A and B, net returns to developers increase as the waste levy increases. While both options give similar propositions on the business side, however, taking results of the economic CBA into account, Option B would be more beneficial than Option A given the wider Auckland society would be better off under this option.

It is important to note that these results do not include the benefits that are not measured due to data or information constraints. Our assessment is that the effect of including such impacts may raise net benefits to society and developers. Benefits not measured include benefits associated with mitigation of disturbances and negative social impacts to the surrounding communities, flow-on impact to family wealth, Māori cultural value associated with sustaining and restoring the essence of treasured resources, and intangible benefits to developers associated with improved reputation and credentials from implementing C&D waste diversion.

This CBA study on the HLC development is exploratory and indicative in nature and could be improved when more information is available.

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Appendix A Materials that can be salvaged, reused and recycled

Table 19: Reusable materials from deconstructed buildings

Materials	Description
Door and window	timber, steel or aluminium frames of doors and windows, mechanical closer, panic hardware, double glazing glass door, unframed mirrors, storage units, skylights, glass from windows or doors etc.
Fixtures	baths, sink toilet can be reused, taps and its metal can be recycled, and other materials which can reuse are light fixture, wiring and service equipment.
Hazardous material	fluorescent light ballasts contain PCBs, fluorescent lamp contain mercury, battery contain lead and mercury, paint solvent and other hazardous fluid, asbestos material and material with lead.
Insulation	fibreglass, polyester insulation, polystyrene rigid insulation and pellets.
Finishing	carpet, terracotta tiles, architraves skirting, scotia, timber panelling and joinery.
Timber products	engineered timber, native timber, hardwood timber, hardwood flooring, lamination beam and truss joists.

Source: BRANZ, 2008a

Table 20: Waste generated from houses which can be salvaged, reused and recycled

Acoustical ceiling tiles	Wood
Asphalt shingles	Window glass
Brick	Can, glass and plastic
Cardboard	Dirt
Drywall fluorescent light	Concrete
Insulation	Porcelain
Metal	Paint

Source: BRANZ, 2008a

Table 21: Types of demolition waste that can be recycled

Type of demolition waste	Additional information
Asphalt	Asphalt from demolition waste can be sorted by milling and recycling, then it is reused for road construction. Approximately 80% can be recycled.
Brick	Approximately 80 per cent of brick from demolition waste can be recycled. Whole brick can be use in fences, landscaping and construction. Broken brick can be crushed and reuse as hardfill.
Metal	Metal extracted from demolition site can reuse such as aluminium, cast iron, copper, lead, reinforcing bar, steel and zinc, structural steel etc. Approximately 80% of metal from demolition waste can be recycled.
Concrete	Concrete collected from demolition site can be reused anywhere such as loose on driveway, base of pathway, base of the foundation and in civil work as earth bunds, drainage channels and beds for pipe works. Ward resource recovery has been crushing the concrete for several years in Auckland (BRANZ, 2014). Approximately 80% of concrete from demolition waste can be recycled.
Plasterboard	Once the plaster board is crushed it can be sold as gypsum or in the powder form which later moulded and formed into pellets. Approximately 80% can be recycled.
Soil	Soil should be retained after construction so that nutrient can be returned.
Timber	Timber is the major reuse and recyclable from demolition site which includes all kind of timber – treated, untreated and engineered timber. Joinery, panels, pallets, lengths are wood which can be used directly from site whether by contractor or the owner. Approximately 80% can be recycled.

Source: BRANZ, 2008a

Appendix B Summary of social enterprise involvement in construction and demolition waste management

Area	Source	Year	Type of intervention	Organisations involved	Financial support	Labour hours/ jobs created	Policy/ legislation	Notes
Austria	RepaNet (2018); Hochreiter (2018); Wikipedia (2018)	2017	Deconstruction of decommissioned Coca-Cola factory; deconstruction of building in Vienna.	Deconstruction social enterprise (partnership between six social organisations).	Financing from the EU's European Social Fund; organisation can claim 60% of employee wages from government under a 'transit worker' scheme.	7600 labour hours	Austrian legislation requires that contractors undertaking demolition projects with waste outputs of over 750 tonnes and gross building volumes of more than $3500m^3$ must ensure the clean and accurate dismantling and sorting of reusable components	Enterprise employs and trains disadvantaged workers for environmental and associated work.
San Francisco Bay Area, California	Leroux & Seldman (1999); Thomas (2001); Galuszka (2001)	1996/ 97	Deconstruction of ex-military building at Port of Oakland.	Partnership between youth job-training, education and support organisation, and private-sector demolition contractor.	Total of $270,000 grant money from local/federal government, financial institutions, private industry.	4 supervisors, 15 youth in training		
San Francisco Bay Area, California	Walker (2001)	2000/ 01	Community wood mill	Non-profit community wood mill (partnership between social enterprises and organisations, private sector, local government, private foundation).	$500,000 from federal government; $241,000 from private foundation.			

Area	Source	Year	Type of intervention	Organisations involved	Financial support	Labour hours/ jobs created	Policy/ legislation	Notes
San Francisco Bay Area, California	Galuszka (2001)	2000	Various building deconstructions across California.	Partnership between non-profit recycling organisation and private-sector demolition contractor.	$10,000 from federal government; other grants project dependent (state government, non-profit social enterprise).	5+ workers depending on deconstruction		
Humboldt County, California	Hanchett (2001)		Deconstruction of barns on government land.	Community action agency and state government partnership; other partnerships with social organisations, local/state government.	$15,000 total from county/federal government; three training/employment salaries covered by social organisation; 50% foreman salary covered by private industry council.			
Eastern Madera County, California	Walker (2001)	1998	Deconstruction of closed wood mill.	Non-profit corporation, local government, educational organisation, carpentry union, private industry council, employment social enterprise.	$45,000 from federal government; $100,000 from local government; $35,000 from carpentry union.	14 individuals trained and involved in deconstruction.		Mill donated to Madera County Redevelopment Agency.

Appendix C Actions under each option proposed for construction and demolition waste diversion

Area	Description	Actions Option A	Actions Option B
Awareness	Raise profile of the C&D waste issue, informs and educates on the topic	Awareness investment is mostly devoted to interacting with specific projects such as HLC and large public projects	Investment continues over a longer period of time which allows for additional activities such as: • Engaging with media, social media (e,g, video case studies) • Engaging with industry conferences • Working with industry organisations • Developing new resources and templates for project managers • Greater presence of C&D on Auckland Council's website
Infrastructure	Development of buildings, plants and facilities that can divert waste to landfill. Examples – salvage distributors, MRF facilities, deconstruction hubs, community recycling centre (CRC)	Investment is mostly devoted to actions that are currently apparent but are assumed to be reacting to greater volumes of waste that are anticipated to emerge from minimisation measures taken by HLC and other large scale public projects: • Planned expansion of the CRCs as described in the 2018 WMMP, with 12 sites established and run by community trusts • Some short-term house relocation sites, but most likely shared with CRCs in informal arrangements • Private investment by Green Gorilla in new MRF facilities • Expansion of All Heart's (a social enterprise) operation into South Auckland with a focus on C&D waste • Some short-term investment by Piritahi Alliance in soft strip of houses and limited community development Anticipated increase in private investment in other privately owned C&D waste recovery facilities.	Investment with a longer-term vision that the waste minimisation actions prompted by projects such as HLC will spread to the industry in general. Main differences in activities compared to Option A include: • Some increased emphasis and capacity to take C&D waste by the CRC operators • Development of C&D deconstruction hub • Dedicated, long-term site(s) established, possibly utilising Council sites, closed landfills or leased properties • Increased community involvement through increased number of relocation of houses by Piritahi Alliance A larger level of private investment in C&D waste recovery facilities to allow for an increase of waste from HLC and similar developments, but also an anticipation that these types of facilities will capture a greater market share in the long term with encouragement from activity Waste Brokers and changes to the waste levy.

Area	Description	Actions Option A	Actions Option B
Brokerage	Resource devoted to connecting waste generators to recyclers and re-users of waste materials. It also includes development for project waste strategies, waste plans and research projects	No additional investment in brokerage activities compared to the status quo. Continue to use ad-hoc brokering focusing on currently known outlets and organisations and their capacity.	Investment made in: • resourcing Waste Brokers and associated marketing activity such as video and media • Deconstruction Hub Manager engaged to set up and run the site(s) • Research • Internal Auckland Council capital works projects and procurement • Influencing and building identity to develop the image of C&D waste minimisation and gain a greater interest in the topic Building community capacity in the C&D sector and commenting community to industry and public projects
Regulatory Controls	Measures that regulate for waste minimisation, including raising the waste levy and regulating for mandatory site waste plans	• Investment in resource to lobby for an increase in the waste levy Investment in resource to advocate for the use of voluntary site waste plans.	• Investment in resource to lobby for an increase in the waste levy at the same level as Option A Investment in resource to advocate for mandatory site waste plans to be introduces as part of the 2023 WMMP.
Training, job and business development opportunities	Activity that leads to social outcomes such as new jobs being created and new small to medium-sized businesses being formed from the diversion of waste from landfill	Leave it to the market to develop the skills required with advocacy from council	Full deconstruction focused accredited training and skills development and capacity building of social enterprises/ co-operative deconstruction businesses

Appendix D Costing model for construction and demolition waste diversion options

Background

The costing model is intended to provide two main areas of information:

- An indication of investment (capital and operational) that might be devoted to reducing and diverting C&D waste.
- Targets that would be required to be met that will increase the amount of waste to MRFs and resource recovery facilities as well as house relocations to a point that a significant amount of waste is diverted from landfill.

It should be noted that the supposed investment and the targets cited to reduce waste are not linked. There is no true indication of the capacity of any of the listed investments to produce a reduction in waste to landfill. In short, the investments are uncoupled from target landfill diversions.

Because the modelling is attempting to indicate what the effect of the current HLC developments and the processes they are considering would have if applied across Auckland, the modelling also covers calculations to determine what that diversion could look like.

The model allows for different levels of investment. It calculates the investment that would need to be applied under Options A and B, over and above status quo investment, to divert the waste associated with HLC.

Basic assumptions

The model uses basic assumptions such as the weight of a typical house (25 tonnes) and the number of houses being removed by the HLC development. There are 7075 houses that are currently proposed to be removed by HLC. The removals are due to be completed between 2019 and 2030, with the peak occurring between 2020 and 2022.

Piritahi Alliance, working with HLC, is intending to remove 16 per cent of these houses through relocation. The target number of relocations by year is indicated below.

Table 22: Number of relocations by year in the HLC development

2019/20	2020/21	2021/22	2022/23	2023/24	2024/25
400	2000	2000	1600	1000	75

Costing assumptions

Investment has been divided into three layers, Status Quo, Option A investment and Option B investment.

Status quo is investment that will go ahead regardless of any other intervention by Council or HLC. For example, companies who have obtained yards with a stated intention to invest in facilities to reduce waste to landfill.

Option A and B investment are additional investments that as being provoked by the type of activity the HLC is proposing in reducing waste from its project. An example would be Auckland Council developing a deconstruction Hub to receive materials from HLC with Option B providing a great level of investment in new facilities.

It should be noted that investment made for Status Quo, Option A and B is additional or equal investment on top of investment made at the previous level. The modelling prevents combinations of investment that is not over and above the previous level. For example it would not allow a scenario where investment was made at Status Quo and Option B but NOT Option A.

The source of investment is identified in the modelling, namely Council investment and private investment. Council investment is made by Auckland Council. This also includes grants made by The Waste Minimisation and Innovation Fund (WMIF).Private investment is investment made by the private sector, for example the investment made by Green Gorilla in increasing capacity in its MRF facility.

Assumptions used in estimates of public investment (capex and opex) have been determined by Waste Solutions, using known salary and overhead costs of engaging resources to activities such as waste brokering, introducing regulatory controls, marketing and communications. Investment in Community Recycling Centres is spending that has been approved by the Environment and Community Committee. This information informs the assumptions used in developing any proposed Deconstruction Hub. Investment provided from the Auckland Council Waste Minimisation and Innovation Fund (WMIF) and the Ministry for Environment Waste Minimisation Fund (WMF) has been calculated from publicly available records of grants made to construction and demolition related projects since 2014. The calculation assumes a continuation of this level of funding. It should be noted that these funding sources also expect a commensurate level of investment from the recipient of the grant.

Assumptions used in estimates private investment have been drawn from a range of sources:

- Recipients of WMIF and WMF grants are assumed to be making investments greater than that funding, for example, large waste companies investing in MRF plants.
- An expectation that waste companies who are active in processing construction and demolition waste will continue to invest in those facilities to increase efficiency and capacity.
- Investment by demolition companies and contractors in salvage yards and deconstruction facilities and techniques that has been made known in discussion with those companies.

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Appendix E Results of sensitivity analysis of key parameters in the economic CBA

Table 23: Sensitivity analysis of key parameters – Option A

	Most Likely		Worst Case		Best Case	
Key parameters	**Value**	**BCR**	**Value**	**BCR**	**Value**	**BCR**
Proportion of total investment attributed to HLC development from year two onwards	50%		70%	2.23	30%	3.87
Proportion of dwellings to soft strip	66%		50%	2.82	75%	2.84
Training cost per worker – soft strip	$513		$666	2.82	$154	2.85
Training cost per worker – relocation (at development sites)	$592		$769	2.83	$177	2.83
Training cost per worker – relocation (at destination sites)	$705		$917	2.83	$212	2.83
Training cost per worker – deconstruction	$225	2.83	$292	2.82	$67	2.85
Social value of moving to employment	$2358		$1179	2.76	$27,693	4.25
Social value of training in job	$1548		$774	2.79	$2323	2.87
Material cost saving as a result of diversion per additional relocation	$30,442		$9133	1.49	$45,663	3.41
Percentage of construction waste reduced as a result of designing out waste	70%		45%	2.78	95%	2.88
Reduction in CO2e per tonne of waste reduced and reused	15%		7%	2.75	22%	2.91
Social cost of per tonne of CO2 emissions	$68.45		$53	2.79	$200	3.13

Table 24: Sensitivity analysis of key parameters – Option B

Key parameters	Most Likely		Worst Case		Best Case	
	Value	BCR	Value	BCR	Value	BCR
Proportion of total investment attributed to HLC development from year two onwards	50%		70%	1.71	30%	3.36
Proportion of dwellings to soft strip	75%		50%	2.26	100%	2.27
Training cost per worker – soft strip	$513		$666	2.27	$154	2.27
Training cost per worker – relocation (at development sites)	$592		$769	2.27	$177	2.27
Training cost per worker – relocation (at destination sites)	$705		$917	2.27	$212	2.27
Training cost per worker – deconstruction	$225	2.27	$292	2.26	$67	2.28
Social value of moving to employment	$2358		$1179	2.24	$27,693	2.85
Social value of training in job	$1548		$774	2.25	$2323	2.29
Material cost saving as a result of diversion per additional relocation	$30,442		$9133	1.11	$45,663	2.76
Percentage of construction waste reduced as a result of designing out waste	95%		85%	2.26	100%	2.27
Reduction in CO2e per tonne of waste reduced and reused	15%		7%	2.22	22%	2.32
Social cost of per tonne of CO2 emissions	$68.45		$53	2.25	$200	2.45

Appendix F Results of sensitivity analysis of key parameters in the financial CBA

Table 25: Sensitivity analysis of key parameters – Option A

	Most Likely		Worst Case		Best Case	
Key parameters	**Value**	**BCR**	**Value**	**BCR**	**Value**	**BCR**
Unit cost of sorting waste ($ per tonne)	$182	1.01	$237	0.80	$127	1.38
Unit cost of collecting waste ($ per dwelling)	$300		$600	0.99	$0	1.04
Unit transportation cost to landfill ($ per tonne)	$35		$17	0.96	$50	1.06
Unit transportation cost to other destinations (e.g. MRF)	$9		$12	1.01	$5	1.02
Unit cost of recycling ($ per tonne)	$80		$100	0.98	$60	1.05
Unit cost of reusing ($ per tonne)	$33		$67	1.01	$0	1.02
Unit cost of designing out waste ($ per dwelling)	$574		$1148	0.79	$287	1.19
Value of relocated house ($ per tonne)	$160		$0	0.98	$320	1.05
Return from salvaged materials (deconstruction) ($ per dwelling)	$3000		$2000	1.01	$4000	1.02
Unit cost of purchasing construction materials ($ per tonne)	$317		$0	0.57	$700	1.55
Value of soft strip materials per dwelling	$921		$0.00	0.92	$1500	1.08
Percentage of waste reduction as a result of designing out waste	70%		45%	0.79	95%	1.24
Proportion of dwellings to soft strip	66%		50%	0.99	75%	1.03

Table 26: Sensitivity analysis of key parameters – Option B

	Most Likely		Worst Case		Best Case	
Key parameters	Value	BCR	Value	BCR	Value	BCR
Unit cost of sorting waste ($ per tonne)	$329		$428	0.78	$230	1.31
Unit cost of collecting waste ($ per dwelling)	$900		$1200	0.96	$600	0.99
Unit transportation cost to landfill ($ per tonne)	$35		$17	0.93	$50	1.01
Unit transportation cost to other destinations (e.g. MRF)	$9		$12	0.97	$5	0.98
Unit cost of recycling ($ per tonne)	$80		$100	0.96	$60	0.99
Unit cost of reusing ($ per tonne)	$33		$67	0.96	$0	0.99
Unit cost of designing out waste ($ per dwelling)	$757	0.97	$1515	0.80	$379	1.09
Value of relocated house ($ per tonne)	$160		$0	0.93	$320	1.02
Return from salvaged materials (deconstruction) ($ per dwelling)	$15,323		$10,000	0.91	$20,000	1.03
Unit cost of purchasing construction materials ($ per tonne)	$317		$0	0.63	$700	1.39
Value of soft strip materials per dwelling	$921		$0	0.91	$1500	1.01
Percentage of waste reduction as a result of designing out waste	95%		85%	0.92	100%	1.00
Proportion of dwellings to soft strip	75%		50%	0.95	100%	1.00

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