Report prepared for the Sustainable Business Network

A circular economy for Auckland - scoping the potential economic benefits

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sapere research group

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Glossary

BAU	Business as usual
CE	Circular economy
CAGR	Compound annual growth rate
EV	Electric vehicle
GDP	Gross domestic product
EECA	Energy Efficiency and Conservation Authority
ICE	Internal combustion engine
ITF	International Transport Forum
MoT	NZ Ministry of Transport
OECD	Organisation for Economic Co-operation and Development
R & D	Research and Development

Executive summary

This report provides a view on the potential economic benefits of a more circular economy for Auckland. It has been commissioned by the Sustainable Business Network to inform its report on the circular economy opportunity for Auckland. The estimates provided here are intended to provide an initial indication of the "size of the prize". As a first attempt at examining the potential of the circular economy in a New Zealand setting, this report is also intended to be a stepping stone for more detailed analyses in future.

The circular economy is an umbrella term that has been attracting attention…

One recent definition describes a circular economy as a regenerative system in which resource inputs, waste and emissions are minimised by slowing and closing material and energy loops, for example, via long-lasting product design, repair and reuse, remanufacturing or recycling. Simply put, a circular economy involves keeping resources and products in use for as long as possible, extracting the maximum value from them while in use, and then recovering and regenerating products and materials at the end of each service life. The concept is contrasted with the dominant linear economy which follows a "take, make and dispose" model of production in which materials end up in landfills or incinerators.

Economy-wide modelling studies collectively point to a transition to a circular economy as being compatible with positive macroeconomic outcomes…

The OECD has reported that, among the modelling studies it reviewed, most economic models find these shifts to a circular economy to have an impact on aggregate macroeconomic outcomes that ranges from being insignificant to positive. Accordingly, the OECD's main finding is that lower rates of resource extraction and use can be achieved with associated increases in aggregate economic output.

Results from prior studies point to a circular economy for Auckland potentially being worth an additional $0.8 - 8.8 billion in GDP in 2030…

We begin by considering the potential impact on Auckland's GDP from a transformation to a circular economy, by drawing on the estimates produced in country-level studies elsewhere. The focus is on the impact on GDP from four prior studies from 2015 with the modelling timeframes vary from 2025 to 2035. The estimated range varies from 0.8% of GDP (Ellen MacArthur Foundation report on Denmark) to 7.0% of GDP (McKinsey report on the EU).

A simple translation of these estimates to an Auckland context suggests that Auckland's GDP could be between $0.8 and $8.8 billion higher in 2030 than may otherwise be the case. These figures are obtained by applying the prior estimates of impact to a counterfactual projection of Auckland's GDP in 2030, derived using recent trend growth in real GDP. As such, we refer to this as a "top-down" approach to estimating the potential benefits.

A "bottom-up" approach to estimation implies an additional $6.3 - 8.8 billion in GDP for Auckland in 2030 – towards the upper end of the "top-down" range…

We investigate sector-level impacts to get a sense of the potential scale of benefits in key sectors of interest. The attention here is on three sectors nominated by the Sustainable Business Network as "focus sectors" because of the expected opportunities for circular economy activities: the food chain, transport and construction. Together, these three sectors accounted for 15% of Auckland's GDP in 2017. These sectors correspond to the areas where prior studies have tended to focus, for instance, the McKinsey report on Europe.

This "bottom-up" approach is more detailed and grounded in Auckland-specific data. We identified individual opportunities across the three focus sectors, based on the examples identified in the literature, the availability of Auckland data on material use and waste, and adoption rates drawn from other studies. The method focuses on estimating the total economic benefit (value added) from a transformation to a circular economy by 2030. The raw result of the opportunities across the three sectors is $4.6 billion in value added in 2030. This result excludes any rebound effect and the cost of transition, which means that the net benefit from these opportunities is likely to be materially lower. Still, this estimate represents opportunities for cost savings among firms and households in aggregate; there is also new added value for new products (i.e. resulting from organic waste diversion).

We produced this estimate to get a sense of the magnitude and the specific opportunities with more potential. We next take a fairly simple approach to relating this bottom-up estimate (total economic benefits) with the initial top-down range (additional economic benefits). There are three steps involved.

- *Conversion from total to net benefits* – we approximate the costs (including transition costs) to be up to 30% of total benefits estimated in the sectoral estimate above. This ratio is based on analysis of the total and net benefits published in the McKinsey report. Other research suggests that the intermediate costs faced by firms are typically around 50% of total output. Depending on which of these assumptions is used, an approximate net benefit of $2.3 -3.2 billion in value added by 2030 is obtained.
- *Conversion of value added to GDP* – our net benefit estimates for Auckland are partly based on the examples in the McKinsey work and so we derive an implied GDP multiplier of 1.5-1.6 from that report, depending on whether rebound effects are included. This implies that every dollar of value added results in 1.5-1.6 dollars of GDP. This estimate is consistent with findings from the EMF case study on Denmark, which reported a multiplier range of 1.3-2.5. Using a multiplier of 1.5 implies a potential GDP contribution of $3.5 - 4.8 million from the sector-specific opportunities included in the bottom-up estimation approach.
- *Scaling the estimated value added to the full potential* – we estimate that the results of our bottom-up approach may only reflect 55% of the full economic benefit from circular economy opportunities, based on sector-specific results of the McKinsey work. This perspective implies that the total potential contribution of the circular economy to Auckland's GDP in 2030 could be in the range of $6.3 - 8.8 billion.

This result suggests that the potential net benefits from circular economy opportunities in Auckland are towards the upper end of the range of the top-down estimates of $0.8 to $8.8 billion. However, we would like to caution that our method is based on several assumptions, which means that the results come with a high level of uncertainty.

The take-away message from our analysis is that the net benefits from the transformation to a circular economy in Auckland are likely to be positive in aggregate and, potentially, significant in scale in the medium term. This is consistent with the findings of the literature.

1. Purpose and approach

1.1 Purpose of this report

This report provides a view on the potential economic benefits of a more circular economy for Auckland. It has been commissioned by the Sustainable Business Network to inform its report on the circular economy opportunity for Auckland.

The purpose is to consider whether the transition to a more circular economy is likely to have a net economic benefit for Auckland. We provide some estimates, within the resources and time available for this work, as an initial indication of the "size of the prize". As a first attempt at examining the potential of the circular economy in a New Zealand setting, this report is also intended to be a stepping stone for more detailed analyses in future.

The work has been extended to include an estimate of the associated impact on carbon emissions – an extension commissioned by the Ministry for the Environment.

1.2 Approach to undertaking this work

This report comprises four parts. The first part considers the concept of the circular economy and the second part looks at the approaches and findings of international studies into the economic potential benefits of a circular economy. Part 3 estimates the potential economic benefits from Auckland making a transformational shift to a circular economy under defined scenarios, while Part 4 considers the potential impact on greenhouse gas emissions (GHG).

This work has involved the following steps:

- identifying prior economic studies and reports on the impact of a circular economy in other jurisdictions;
- appraising the body of prior work to draw out common themes with respect to methods and findings;
- undertaking estimation of the potential economic benefit using "top-down" and "bottom up" estimation approaches that make use of prior studies and Auckland-specific data; and
- sharing the draft report for feedback from a steering group of stakeholders convened by the Sustainable Business Network.

2. Circular economy as a concept

This chapter provides an overview of the concept of a circular economy.

2.1 Description of the concept

The idea of a circular economy is attracting attention from governments, policymakers, businesses, not-for-profit organisations and academia. Despite this, there is no single widely-accepted definition of the term. One recent definition, based on a systematic review of the literature, describes a circular economy as a regenerative system in which resource inputs, waste and emissions are minimised by slowing and closing material and energy loops, for example, via long-lasting product design, repair and reuse, remanufacturing or recycling.[1] Simply put, a circular economy involves keeping resources and products in use for as long as possible, extracting the maximum value from them while in use, and then recovering and regenerating products and materials at the end of each service life.[2] The concept is contrasted with the dominant linear economy which follows a "take, make and dispose" model of production in which materials end up in landfills or incinerators.[3]

Transitioning to a more circular economy has been promoted by a number of government, business and not-for-profit organisations – notably the Ellen MacArthur Foundation – as a response to resource constraints and negative environmental impacts. Proponents typically focus on case studies of emerging circular activities and the opportunities for business-led innovations to redefine products and services to "design waste out", to use products more intensively (e.g. the sharing economy) and to extend the lifespan of a product and its parts.

Overall, the circular economy can be seen as an "umbrella concept" in that it brings together existing concepts related to waste and resource management (e.g. resource life-extending strategies such as servitisation, reuse, recycling as well as waste-to-energy conversion) to catalyse interest and action from business leaders, policymakers and the public.[4] In doing so, the circular economy concept highlights the importance of material cycles – often referred to as "loops" – and shows the possibilities of the emerging sharing economy in contributing to a more sustainable production-consumption culture. As such, the concept has been able to attract the business and policy-making community to sustainable development work.[5]

1 Geissdoerfer, Martin; Savaget, Paulo; Bocken, Nancy M. P.; Hultink, Erik Jan (2017) "The Circular Economy – A new sustainability paradigm?" *Journal of Cleaner Production*. 143: 757–768.

2 A definition used by WRAP (Waste and Resources Action Programme), a UK-based non-for-profit http://www.wrap.org.uk/about-us/about/wrap-and-circular-economy

3 See the Ellen MacArthur Foundation https://www.ellenmacarthurfoundation.org/circular-economy

4 Blomsma, F. and Brennan, G. (2017) "The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity". *Journal of Industrial Ecology*, 21: 603–614.

5 Korhonen, Jouni & Honkasalo, Antero & Seppälä, Jyri. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*. 143. 37-46.

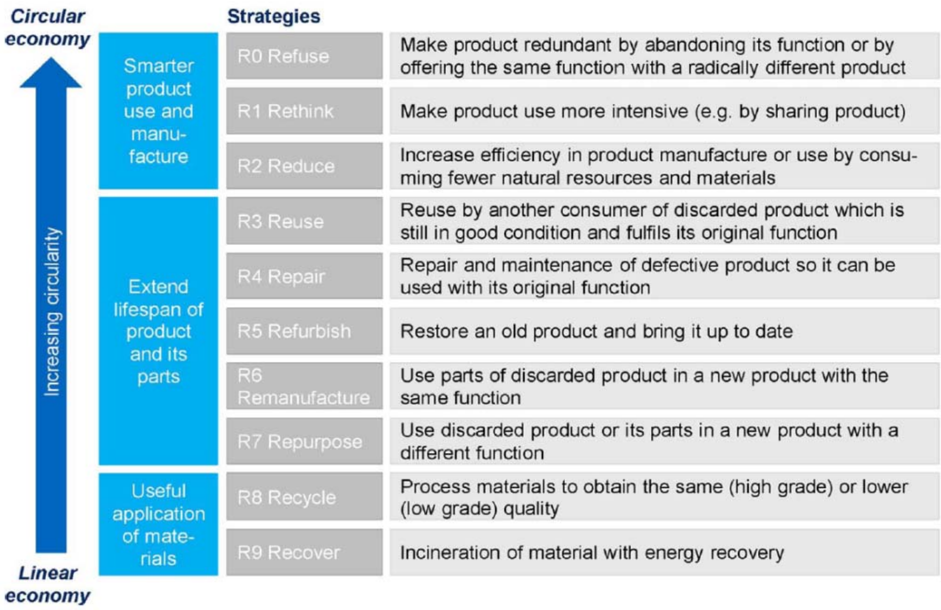
2.2 Frameworks for circular activities

A number of frameworks have been used to categorise circular economy activities. A systematic assessment of the literature undertaken in 2017 identified various 'R frameworks', with the 3R framework being most common – i.e. Reducing materials need and waste, Reusing products and product parts and Recycling materials.[6] Kirchherr et al (2017) offer a comprehensive 9R framework which we find useful for defining many of the terms that are commonly used. Figure 1 reproduces the 9R framework and shows how the various 'R' strategies are grouped under three broad categories:

- Smarter product use and manufacture;
- Extending the lifespan of products and their parts; and
- Useful application of materials (including recycling and recovery of energy from waste).

The RESOLVE framework used by the Ellen MacArthur Foundation offers a similar approach – i.e. Regenerate, Share, Optimise, Loop, Virtualise, and Exchange. Another approach is a system-level framework, which is used to highlight that a circular economy involves a fundamental shift at macro, meso and micro levels of the economy. The macro perspective highlights the need to adjust the structure of the economy, with the meso level focusing on regions and the micro perspective considering what needs to happen to increase circularity at the level of individual products, enterprises and consumers.[7]

Figure 1: The 9R framework



Source: Kirchherr et al (2017) adapted from Potting et al. (2017)

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6 Kirchherr, Julian; Reike, Denise; Hekkert, Marko (2017) "Conceptualizing the circular economy: An analysis of 114 definitions." *Resources, Conservation and Recycling.* 127: 221-23.

7 ibid

2.3 Economic perspectives on the concept

The OECD has noted that although the various definitions of the circular economy involve different processes and assumptions, they share a similar focus: increased resource efficiency or, in other words, the decoupling of natural resource extraction and use from economic output. An improvement in resource efficiency describes a situation where more value is being produced with a given amount of resource (or fewer resources being used).[8] Three main mechanisms for reduced demand are often highlighted.

- **Creating material loops** – involving the substitution of secondary materials (i.e. derived from the recycling of industrial or household waste) as well as second-hand, repaired, or remanufactured products for those derived from virgin resources.
- **Slowing material flows** – the emergence of products which can remain in use in the economy for longer, usually due to more durable product design. Products that are designed to be robust and more easily repairable will last longer and slow the introduction of new natural resources into the economy.
- **Narrowing material flows** – more efficient use of natural resources, materials, and products, either through the development new production technologies, increased utilisation of existing assets, or shifts in consumption behaviour away from goods and services that are material intensive.[9]

It is sometimes suggested that the activities that will drive the transformation to a circular economy could also become significant drivers of job creation and economic growth. Opportunities could include secondary material production, repair and remanufacture, the services sector, and the sharing economy. Further, early adopting countries could realise additional benefits by becoming exporters of circular economy expertise and technology.[10]

Much of the focus is on specific opportunities to close material cycles. At the level of the firm, these may make sense from a business perspective in that they help to reduce costs (e.g. more efficient design or production processes that reduce raw material inputs) or to increase revenue from developing new products (e.g. waste conversion to biofuels). Cost reductions or revenue growth lead to increases value added (i.e. revenue less intermediate consumption) at the level of the firm and its sector.

From a household or consumer perspective – lower prices may mean increased demand and/or some spending being diverted into other products. Meeting the demand for these additional products will in turn require further resource in production and result in waste output. This represents a partial offset of the potential benefit and is sometimes referred to as the rebound effect.[11]

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8 OECD (2017) "The macroeconomics of the circular economy transition: a critical review of modelling approaches", p.11

9 ibid p.8; see more detail in Bocken et al (2016) "Product design and business model strategies for a circular economy" in *Journal of Industrial and Production Engineering*,33(5)

10 For example, see Stegeman (2015), The Potential of the Circular Economy; Wijkman et al (2016) *The Circular Economy and Benefits for Society Jobs and Climate*… A report prepared for the Club of Rome.

11 See McKinsey and EMF (2015). *Growth within: A circular economy vision for a competitive Europe.*

3. Overview of prior studies

This chapter looks at the approaches and findings in literature on the economic potential benefits of the circular economy.

3.1 Approaches taken

The OCED, in a review of modelling approaches, has noted that most studies have used ex ante simulations to assess the economic impacts of a transition to a circular economy – because the policy mixes that are typically suggested have not been widely implemented historically. The models can be grouped within two broad approaches.[12]

- **Accounting modelling** – sector-specific scenarios are developed around material circularity or technological progress, drawing on expert opinion and typically involving higher recycling, remanufacturing, repair, or re-use rates. These changes are modelled autonomously (i.e. not linked to policy change) and the resulting benefits – such as cost savings achieved through reduced material use – are estimated and scaled to a sector.[13] In some studies, the changes in final demand and in production in sectors are used to calculate indirect effects throughout the economy (e.g. using input-output tables).
- **Economy-wide quantitative models** – these comprise computable general equilibrium (CGE) and macro-econometric (ME) models. Despite making different assumptions about agent behaviour, the OCED notes that these models share advantages over accounting models, for example, they represent the role that relative prices play in determining supply and demand for products, commodities, and ultimately, natural resources. This is important in the context of resource efficiency; increased output from secondary material sectors may reduce demand for natural resources, but this is likely to be partially offset by the lower prices that this entails.

A number of high-profile studies have attempted to quantify the economy benefits of a circular economy, for example, those by the Ellen MacArthur Foundation (for Denmark), McKinsey (for the EU). The approach involves estimates based on data from a representative product or firm that are then scaled up to an aggregate level, for example, using input-output multipliers, while other approaches involve more complex modelling approaches, such as CGE models. Although such studies tend to report net economic benefits from a transition to a circular economy, the reports themselves (and some critiques) note that the results provide a rough indication of magnitude while being imperfect, given the simplifications (e.g. with respect to behavioural responses) and data shortcomings.[14]

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12 OECD (2017) The macroeconomics of the circular economy transition: a critical review of modelling approaches, pp.12-13

13 This type of approach is advocated by the Ellen MacArthur Foundation within its circular economy toolkit for policymakers: *Delivering the circular economy – a toolkit for policymakers* (2015)

14 For example, see Wijkman et al (2016) *The Circular Economy and Benefits for Society Jobs and Climate.* General shortcomings are commented on in: European Academies' Science Advisory Council (2015) "Circular economy: a commentary from the perspectives of the natural and social sciences." EASAC, November 2015.

The OECD notes that the complexity of the envisaged circular economy transition – affecting large parts of the economy with the likelihood of rebound effects – mean that economy-wide quantitative models are the most suitable for analysis. Although accounting models can provide detailed insight into the likely costs and benefits of increased material or product circularity, they tend to do so for specific products, and without feedbacks associated with changing prices. While this offers some insight into impact of the supply shock in other sectors, there is no price mechanism and so economic feedback processes are not fully reflected.

3.2 Reported findings

Economy-wide modelling studies collectively point to the transition to a circular economy as being compatible with positive macroeconomic outcomes…

The OECD reported that, among the modelling studies it reviewed, most economic models find a shift to a circular economy would have an impact on aggregate macroeconomic outcomes that ranges from being insignificant to positive. Accordingly, the OECD's main finding is that lower rates of resource extraction and use can be achieved with associated increases in aggregate economic output.

> *…the current literature indicates that a transition to a (broadly defined) circular economy – with the associated reductions in resource extraction and waste generation – could take place with potentially significant positive (or at least without negative) consequences for economic growth or overall employment.*

Some caution is advisable, for, as the OECD notes, the robustness of this key conclusion crucially depends on assumptions about the enabling policies implemented, and about mechanisms in the models themselves.

However, it seems probable that the transition to a circular economy will involve spill-over and interaction effects between sectors, leading to structural shifts across the economy across sectors and regions. Accordingly, the OECD also finds that existing modelling studies highlight the potential reallocation effects that the introduction of circular economy enabling policies could have.

- Material intensive sectors – natural resource extraction and certain types of manufacturing – will probably decline in competitiveness (and so workers, regions, and countries specialising in these activities may be worse off in transition).
- Waste management and recycling, remanufacturing and repair, and services more generally will probably expand as their output becomes relatively more affordable (e.g. owing to greater economies of scale).

There are several high-profile reports on the potential benefits of the circular economy that have involved considerable investment in analysis and modelling expertise and business leader input. These studies have advantages in the level of detail that is provided and the relevance to the approach being adopted in this report. We consider the results four studies that produce estimates of the impact on GDP of a transformation to a circular economy – to identify the range of plausible values. The economies and authors are:

- EU-27 (McKinsey, 2015)
- Denmark (Ellen McArthur Foundation, 2015)
- Netherlands (Stegeman, 2015)
- United Kingdom (University College, 2015)

These reports all acknowledge the uncertainty involved and it is worth noting the following statement by the Ellen MacArthur Foundation in the Denmark case study.

> *…no matter how diligently the data gathering and impact quantification is carried out, predicting the impact of circular economy opportunities on multi-year time frames will always at best be a well-informed estimate that relies on important assumptions.*[15]

Table 1: Summary of estimated GDP impacts in selected prior studies

Economy (study)	Approach	Reported GDP impacts
EU-27 (McKinsey, 2015)	Quantified impacts of opportunities in 3 sectors (mobility, food systems, and the built environment) were input into a computable general equilibrium model.	An increase in GDP of 7 percentage points by 2030 relative to the current development scenario
Denmark (Ellen McArthur Foundation, 2015)	Quantified impacts of opportunities in 5 sectors (food & beverage, construction & real estate, machinery, packaging and hospitals) were input into a computable general equilibrium model.	An increase in GDP of 0.8-1.4% by 2035.
Netherlands (Stegeman, 2015)	The method is based on calculating and reasoning the potential effects of the transition to a circular economy for a limited number of sectors, after which the results obtained are scaled up to the economy as a whole.	The size of the economy, as measured by GDP, would increase by 1.4% after 15 years of transitioned to a circular economy (i.e. ~2030).
United Kingdom (University College, 2015)	The contribution to GDP from transitioning to a circular economy, was based on a series of circular economy strategies: landfill diversion; the commodity value of materials reused and imports replaced; the energy value from materials not reprocessed into commodities (e.g. food, animal, vegetal waste); deriving value from chemical by-products, steam or heat; recovering value by switching from buying/disposing of products to selling them as part of a service.	Using resources in a closed loop system has the potential to contribute £29 billion (1.8%) of GDP in 10 years (i.e. ~2025).

Sources: McKinsey (2015); Imperial College (2015); Stegeman (2015); EMF (2015)

15 Ellen MacArthur Foundation (2015) *Toolkit for policymakers*, p.60

3.3 Circular economy potential at city level

A city with a growing population – such as Auckland – has to deal with increases in consumption, waste volumes and the associated negative environmental impacts. As such, the limits of a linear economy may be most apparent in an urban context. Equally, cities are also likely to play a leading role in the transition to a circular economy due to their:

- proximity – the concentration of resources, capital, data and talent means that circular economy activities may be more viable, for example reverse logistics (i.e. moving goods from their typical final destination for the purpose of capturing value or for proper disposal); and
- scale – most of the population lives in cities and this means sufficient scale for new business models to emerge – given a large and varied supply of materials and high potential demand for goods and services.[16]

Furthermore, there is the potential for policy influence within cities – local government and central government have an ability to shape urban planning settings, transport system design, urban infrastructure – in a way that supports circular economy principles.

The Ellen McArthur Foundation has posited that a circular city would likely include the following elements:

- a built environment that is designed in a modular, flexible manner, built with efficiency construction techniques that minimise virgin material use, and is highly utilised;
- an urban mobility system that is accessible, affordable and effect – comprising a multi-modal approach that includes public transformation with on-demand cars as a flexible last-kilometre solution; and
- energy systems that are renewable and allowing effective energy use.

A number of cities have developed route maps to support their transition to a circular economy, for example, Amsterdam, Glasgow and London. In the case of London, the benefits have been estimated to be worth £1.2 to £7.8 billion in GDP annually by 2036.[17]

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16 Ellen MacArthur Foundation (2017) *Cities in the Circular Economy: an initial exploration*

17 Amec Foster Wheeler (2017) *Circular economy Route Map economic analysis. Final report.* Prepared for the London Waste and Recycling Board, June 2017.

4. Estimating the economic benefit

This chapter provides estimates of the potential economic benefits for Auckland.

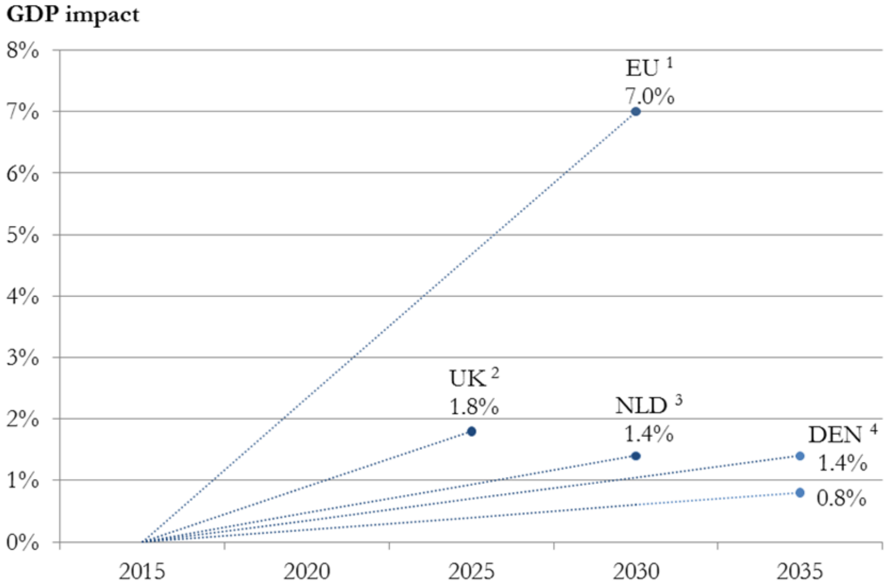
4.1 Top-down estimation

Results from prior studies point to a circular economy potentially being worth an additional $0.8 - 8.8 billion in GDP for Auckland in 2030…

We begin by considering the potential impact on Auckland's GDP from a transformation to a circular economy, by drawing on the estimates produced in prior country-level studies. Figure 1 shows the point estimates of impact on GDP from four prior studies from 2015, with the modelling timeframes for the transformation to a circular economy varying from 2025 to 2035. Focusing on 2030, the estimated range varies from 0.8% of GDP (Ellen MacArthur Foundation report on Denmark) to 7.0% of GDP (McKinsey report on the EU).

A simple translation of these estimates to an Auckland context suggests that Auckland's GDP could be between $0.8 and $8.8 billion higher in 2030 than may otherwise be the case. These figures provide an initial sense of the potential "size of the prize" for Auckland. They are obtained by applying the estimates of GDP impact to a counterfactual projection of Auckland's GDP in 2030, derived using trend growth in real GDP in the decade to 2017.[18]

Figure 2: Estimates of GDP impacts in selected prior studies



Sources: (1) McKinsey (2015); (2) Imperial College (2015); (3) Stegeman (2015); (4) EMF (2015)

18 ATEED's Auckland Index provides a series, by Infometrics, that estimates Auckland's GDP at $90 billion in 2017 with a 10-year compound annual growth rate of 2.6% https://www.aucklandnz.com/auckland-index

The wide range is attributable to the fact that the studies have differences in method and in the assumptions being made. While these studies tend a sector-level perspective on a transformational shift to a circular economy, they differ in the number and type of focus sectors (as noted in Table 1), the treatment of rebound effects, and the translation of the benefits from sectors to the wider economy.

It must be emphasised that this "top down" approach is fairly crude in that it makes the assumption that the opportunities identified in other studies also exist in Auckland and would affect GDP in a similar way. To begin with, it must be acknowledged that the impacts estimated in prior studies are somewhat imperfect. These studies offer a partial view as they focus on selected sectors based on known opportunities and data availability, and so these estimates may not represent the full potential of a circular economy. Secondly, the modelling may not fully capture the dynamic impacts across other sectors of the economy.

Furthermore, a simple translation of these estimated impacts to Auckland's GDP does not take into account the specifics of the Auckland economy. Auckland likely has a different set of circular economy opportunities because it has a different starting point, for example:

- scale – Auckland, as a city, is smaller in scale than the economies of focus in the prior country or region-level studies; and
- structure – Auckland has a different mix of economic activity (i.e. being focused on services and some manufacturing, within a relatively isolated national economy that has a focus on primary resources).

Nevertheless, while we acknowledge the shortcomings of this top-down approach, these broad estimates are a useful "scene setter" in that they show that the economic impact of a circular economy is potentially material for Auckland.

4.2 Bottom-up sectoral analysis

Our "bottom-up" approach is more detailed and more grounded in Auckland-specific data. We investigate the potential impacts within specific sectors, with the attention being on three sectors nominated by the Sustainable Business Network as "focus sectors" because of the expected opportunities for circular economy activities. We characterise these as the food chain[19]; transport and the built environment. Together, these three sectors accounted for 15% of Auckland's GDP in 2017.[20] These sectors also correspond to the areas where prior studies have tended to focus, for instance, the large and resource-intensive value chains of food, mobility and the built environment examined in the McKinsey report on Europe.

We identified individual opportunities across the three focus sectors, based on the examples identified in the literature, the availability of Auckland-specific data and waste, and adoption rates drawn from other studies. Given this, these opportunities likely represent only a sub-set of the full circular economy potential in Auckland.

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19 In our estimates, this sector includes all organic waste.

20 Broadly ,these focus sectors correspond to the sectors of: food & beverage; transport, logistics & distribution; construction & engineering – as defined in ATEED's Auckland Index (data by Infometrics) https://www.aucklandnz.com/auckland-index

4.2.1 Summary of approach

Our approach to estimating the economic benefits from a circular economy in Auckland involved the following steps.

- Identify opportunities within the three focus sectors, drawing on international studies and available data
- Identify a baseline od economic and demographic developments in Auckland to the year 2030. These developments are classified as 'business as usual' or 'BAU'
- Import CE opportunity assumptions for the identified opportunities based on international and NZ studies. These assumptions are overplayed onto the BAU parameters
- Estimate the total economic benefit from CE opportunities in terms of cost savings or new product value created.

4.2.2 Overview of opportunities examined

Table 2 below lists the circular economy opportunities examined for the purpose of estimating benefits and GHG emissions reduction potential. Table 3 then describes the adoptions (or uptake) rates assumed for each opportunity and the sources used as a basis for these rates.[21] Note that for some opportunities, we estimated either the economic benefit or the emissions reduction due to data limitations; this is also shown in Table 3.

Table 2: Description of circular economy opportunities examined

CE opportunity	Description
The food chain	
Food waste minimisation	Food waste can be minimised through various strategies: • Reducing consumer food waste, e.g. through awareness raising and behavioural change • Reducing losses in retail, e.g. through better estimate of demand, lowering aesthetic requirements for fruit and vegetables, donating food surplus before the 'best before' date • Reducing losses in the food supply chain, e.g. during storage and transportation
Organic waste diversion	New value can be extracted from organic waste through bio-chemical extraction and bio-gas production. Different organic waste streams can be used to generate new products, such as sugars, proteins and fibre.[22]
Transport	

[21] By adoption rate we mean the extent to which a CE opportunity is taken up in 2030.

[22] See Bastein et al (2013) for de tailed description of different new products that could be produced form biotic waste streams.

CE opportunity	Description
Car and ride sharing	Thanks to smartphones and big data, mobility services and vehicle-sharing businesses are thriving. The different modes by which vehicles could be shared include: • Car sharing through a fleet operator, offering on-demand and short-term rentals • Peer-to-peer car-sharing, which is a variation of the fleet model, whereby users share their own cards on an online platform • App-enabled car-pooling, which links non-professional drivers with passengers to fill empty sets.
Electrification	Although EVs cost more upfront today than ICE vehicles, prices are falling rapidly towards parity.[23] EVs cost less to operate since electricity is much cheaper than petrol. Furthermore, EVs are much more environmentally friendly – they produce at least 80% fewer GHG emissions than a petrol vehicle when used in NZ (EECA, 2015).
Vehicle refurbishment	Exchanging components responsible for the degradation of light commercial vehicle performance may extend the vehicle's life or productivity. This exchange could be enabled through improved vehicle design and establishing professional refurbishing systems.
The built environment	
Material reuse & recycling	Material reuse and recycling in the construction sector can be improved through better design (e.g. modularity, design for dismantling, efficient material use), smarter use of materials and stock (e.g. leasing of materials / components, building life-time extension through re-purposing), and improved end-of-life processes (e.g. selective sorting of materials, material exchange platforms, material recycling & recovery).
Industrialised processes and 3D printing	These processes involve moving construction towards factory-based industrial processes, which can shorten delivery times by at least 50%.[24]
Passive homes	Passive homes are ultra-low energy consumers thanks to natural air circulation and reinforced insulation. They can achieve heating and cooling energy savings of up to 90%, with an average upfront investment of only 10% more than tradition construction.
Retrofitting	Retrofitting an existing building into a passive house is difficult, but there are other ways to reduce energy consumption by 20-30% in existing houses, such as though better insulation and smarter homes.

23 Some analysts predict that EVs may reach cost parity with comparable ICE vehicles by 2029-2030 (BNEF, 2017 ; IEA, 2017)

24 Woetzel et al (2014).

Table 3: Circular economy opportunities examined for Auckland 2030

CE opportunity	Source used to select the adoption rate	Economic benefit estimated?	Emissions reduction estimated?
The food chain			
50% reduction in food waste compared to 2030 BAU waste volumes	Deloitte (2016) Reflects the UNDP objective to halve per capita food waste at the retail and consumer levels by 2030. The target is consistent with the finding that about 54% of NZ household food is avoidable (WasteNot Consulting, 2015)	✓	✓
Diversion from landfill of 30% of 2030 BAU organic waste volumes	Reflects Auckland Council's target in its Waste Management and Minimisation Plan	✓	✓
Transport			
33% of the 2030 number of light private vehicles are used at full capacity due to car sharing, leading to car displacement	Consistent with the target in McKinsey, EMF and SUN (2015) that mobility on demand will cover 33% of car-km in 2030	✓	
33% or taxis are ride shared resulting in 92% utilisation			✓
20% of light private vehicles are EVs	Auckland Council's 2014 Low Carbon Strategic Action Plan		✓
30% of the 2030 number of light commercial vehicles are refurbished	EMF (2013)		✓
Congestion is reduced so that the opportunity cost of congestion drops by 45%	Consistent with the findings by ITF and OECD that congestion in Auckland could be reduced by 61% by 2040.	✓	
The built environment			
80% of construction waste to landfill is diverted	Within the range reported by Deloitte 2016 (of 70%) and CCC 2011 (of 86.9%)		✓
60% of new projects (residential and non-residential) in 2030 use new processes for reducing construction waste (material reuse and high-value recycling)	Consistent with the 70% adoption rate by 2035 as per EMF (2015)	✓	

CE opportunity	Source used to select the adoption rate	Economic benefit estimated?	Emissions reduction estimated?
50% of new projects (residential and non-residential) in 2030 use industrialised production processes	McKinsey, EMF and SUN (2015)	✓	
14% of new projects (residential and non-residential) in 2030 use 3D technology	Consistent with the 25% adoption rate by 2035 as per EMF (2015)[25]	✓	
7% of the 2030 demand for new non-residential space is met by multi-purposing and space sharing	Consistent with a 9.5% decline in demand for new buildings by 2035 as per EMF (2015)	✓	
80% of new residential buildings use passive home technology to improve energy use. The 2030 stock of new residential buildings includes developments from 2018	Consistent with the energy efficiency target in Arup (2014)	✓	✓
65% of old residential buildings are retrofit. The 2030 stock of old buildings includes developments up to 2018	Arup (2014)	✓	✓

4.2.3 Total economic benefits

This method for estimating benefits focuses on *total* economic benefit (value added) from a transformation to a circular economy by 2030. In other words, our estimates include all benefits associated with circular economy developments, regardless of whether some of these benefits could arise under business-as-usual (BAU).

Table 4 shows the BAU assumptions for Auckland in 2030, which underlies this estimation of total economic benefits. Appendix 1 details the other assumptions used in the estimation.

25 The adoption rate of 14% was estimated based on a CAGR of 12% derived based on Denmark's uptake of 3D printing in construction currently and in 2035.

Table 4: BAU assumptions for estimating total benefits

2030 BAU assumption	Source
The food chain	
Waste to landfill grows at a CAGR of 2.9 during 2019-2040	Based on projections from the 2017 Auckland Waste Assessment Report
Starting with 2017, avoidable food waste grows at the same rate as GDP – i.e. 2.6%	GDP growth rate estimated based on ATEED/Infometrics data
Organic waste to landfill grows at a CAGR of 2.5% % during 2019-2040	Based on projections from the 2017 Auckland Waste Assessment Report
Transport	
The utilisation rate of light passenger vehicles is 2.5 people per care (compared to 1.51 today)	Current utilisation rate is as per ITF and OECD (2017)
The number of Auckland households grows at 1.7% p.a.	NZ Stats, 2013 Census
Average number of cars per Auckland household is the same as in 2012, i.e. 0.94	NZ Stats, 2013 Census
The mix of light vehicles in Auckland is the same as in NZ in 2017	Ministry of Transport
Emissions intensity by car type is the same as in 2017	Ministry of Transport
The number of light commercial vehicles in Auckland grow at 3% p.a.	CAGR based on MoT data for 2012 and 2016 is 8.7%. We assume a much more conservative growth rate
The cost of congestion grows at the same as rate as Auckland population p.a. – i.e. 1.6%	Auckland population growth rate is based on projections from NZ Stats 2013 census data
The built environment	
Investments in new residential and non-residential buildings in Auckland grow at a rate of 2.8% and 3.6% respectively	Data from MBIE's National Construction Pipeline Reports suggest a 5.6% and 7.2% CAGR for gross fixed capital formation in the residential and non-residential sectors respectively during 2015-2022. We assume a conservative growth rate of 50% of those values
The number of Auckland households grows at 1.7% p.a.	NZ Stats, 2013 census

Table 5 describes the 2030 CE scenarios for each sector, and the nature of the economic benefits being estimated.

Table 5: 2030 CE opportunities and total economic benefits

2030 CE opportunity	Total economic benefits ($ billion)	The nature of economic benefits
The food chain		
50% reduction in food waste compared to 2030 BAU waste volumes	If implemented together $0.299 If implemented separately: food waste reduction – $0.299b diversion of organic waste – $0.003b. (i.e. $2m of new added value is lost if food waste is minimised in the first instance)	Food cost savings
Diversion from landfill of 30% of 2030 BAU organic waste volumes		New value from biochemical extraction and bio-energy production
Transport		
33% of the 2030 number of light private vehicles are used at full capacity due to car sharing, leading to car displacement	$1.050	Total car ownership cost savings
30% of the 2030 number of light commercial vehicles are refurbished	$0.575	Vehicle purchase cost savings
Congestion is reduced so that the opportunity cost of congestion drops by 45%	$0.175	Cost savings from operating light passenger vehicles
The built environment		
60% of new projects (residential and non-residential) in 2030 use new processes for reducing construction waste (material reuse and high-value recycling)	$0.973	Material and labour cost savings
50% of new projects (residential and non-residential) in 2030 use industrialised production processes	$1.000	Material and labour cost savings
14% of new projects (residential and non-residential) in 2030 use 3D technology	$0.155	Material and labour cost savings
7% of the 2030 demand for new non-residential space is met by multi-purposing and space sharing	$0.199	Material and labour cost savings

2030 CE opportunity	Total economic benefits ($ billion)	The nature of economic benefits
80% of new residential buildings use passive house technology to improve energy use. The 2030 stock of new residential buildings includes developments from 2018	$0.527	Energy cost savings by households
65% of old residential buildings are retrofit. The 2030 stock of old buildings includes developments up to 2018	$0.763	Energy cost savings by households

The raw result of the opportunities estimated across the three sectors is $4.6 billion in value added in 2030. This result excludes any rebound effects and the costs of transition and so the net benefits from these opportunities are likely to be materially lower.

We produced this estimate to get a sense of the magnitude and the specific opportunities with more potential. We caution against drawing conclusion regarding the relative sector-specific benefits, as we only looked at specific opportunities within each sector. This is underlined by the fact that in the McKinsey report, net benefits suggest the food sector has the most potential whereas the result here points to the built environment.

Having developed the bottom-up estimates, we wanted to get a sense of the potential scale of the CE opportunities that we did not quantify. We estimated this in three main steps. First, for each sector we identified a CE opportunity that is common to the McKinsey and our bottom-up analysis. Second, we derived a set of scale factors between the common opportunity and the other opportunities within the same sector. And finally, we then applied these scale factors to our own estimate of the common opportunity.

Based on this analysis, we estimate that there is potential for up to $3.8 billion in additional total economic benefits. In other words, our estimates cover approximately 55% of the potential scope of CE opportunities (as modelled in the McKinsey report on the EU).

Furthermore, the analysis suggests that most of the opportunities not quantified lie in the food chain and the built environment sectors. Additional opportunities include:

- the built environment – renewable energy use, energy efficiency in non-residential buildings, and travel cost savings due to tele-working
- the food chain – regenerative and healthy food chain, and resource efficient agricultural products; and
- transport – EVs and renewable energy, and public transport, cycling and walking as modes of choice.

Figure 3 summarises our estimates for the individual opportunities in each sector. Figure 4 places these results in the context of an estimate of the fuller potential (drawing on the results of the McKinsey report on the EU).

Figure 3: Estimates of total economic benefits for specific opportunities

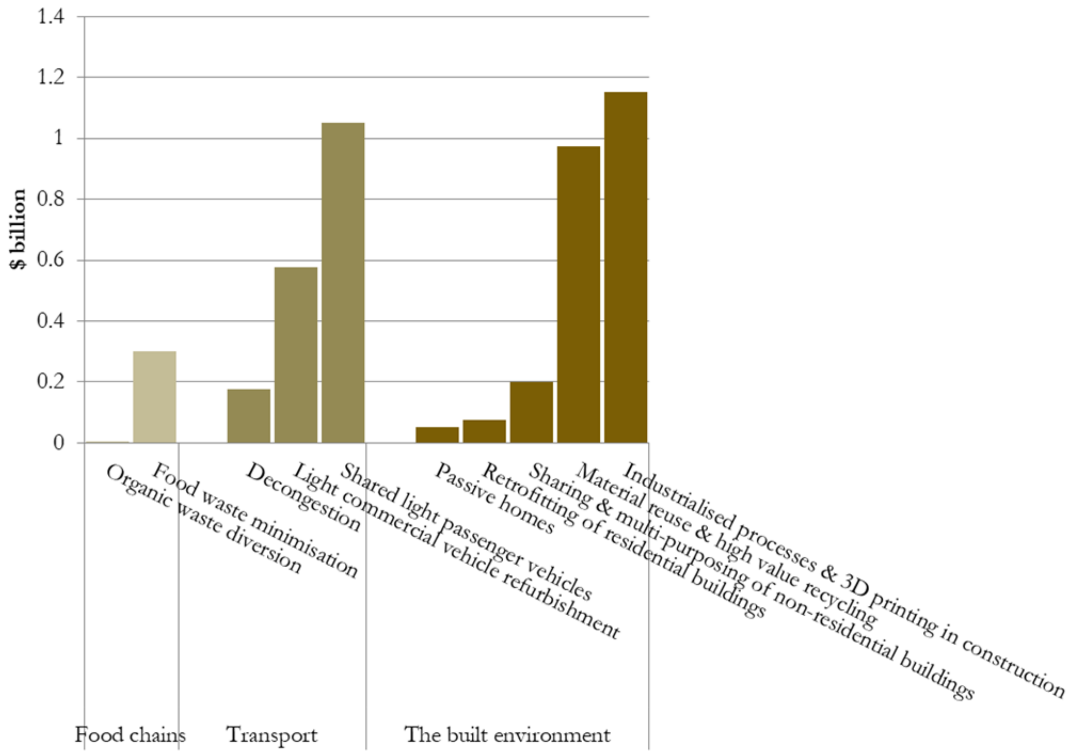
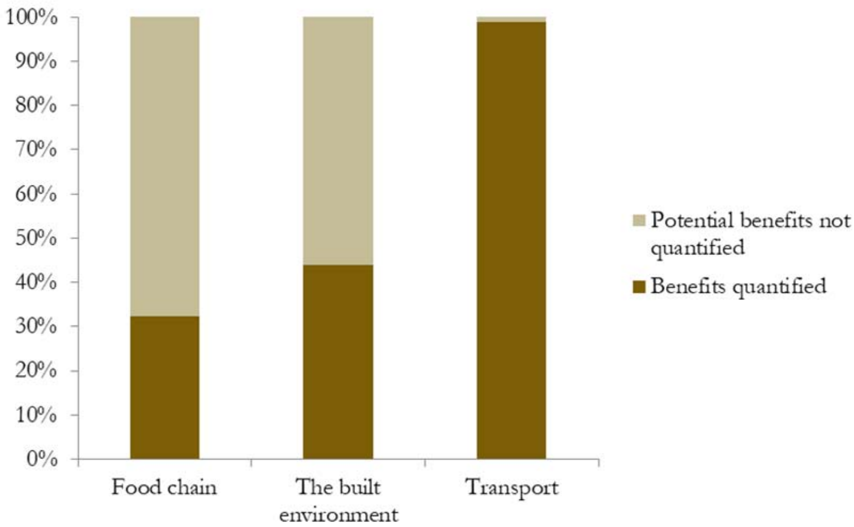


Figure 4: Total economic benefits: quantified benefits vs full potential



4.3 Reconciling the top-down and bottom-up estimates

The results of this "bottom-up" estimation imply an additional $6.3 - 8.8 billion in GDP for Auckland in 2030 – towards the upper end of the "top-down" range…

We now turn to whether our bottom-up estimates of total benefits from specific circular economy opportunities in Auckland can help us narrow down the broad range identified via the top-down estimates.

The benefits that can be achieved at a sector level can have a knock-on effect through the wider economy as a result of freeing up resources which can be spent more productively elsewhere, or by employing existing resources to produce new added value. In our bottom-up estimates, most of the benefits are in the form of monetary savings, with the assumption of new products being created via the organic waste diversion opportunity.

A micro-level analysis of how freed up resources can be used to produce more output per unit would have to account for various consumer and producer interactions with the Auckland economy, and is beyond the scope of this report. Instead we take a fairly simple approach of connecting the bottom-up and top-down estimates via the use of circular economy-specific induced GDP multiplier. There are three steps involved.

- **Conversion from total to net benefits** – we approximate the cost of transition to be up to 30% of total benefits estimated in the sectoral estimate above. This ratio is based on some scaling of the net results published in the McKinsey report (see the previous section). This is below the figure typically cited in research that the intermediate costs faced by firms are around 50% of total output. Using a range of 30 - 50% in transition costs, we estimate the net benefit to be approximately $2.3 - 3.2 billion in value added in 2030.
- **Conversion of value added to GDP** – based on the net benefits in GDP terms, as estimated in the McKinsey report, we derive an implied GDP multiplier of 1.5-1.6, depending on whether rebound effects are included. This implies that every dollar of value added results in 1.5-1.6 dollars of GDP. This estimate is consistent with findings from the EMF case study on Denmark, which reported a multiplier range of 1.3-2.5. Using a multiplier of 1.5 implies a potential GDP contribution of $3.5 - 4.8 billion from the sector-specific opportunities included in the bottom-up estimation approach.
- **Scaling the estimated value added to the full potential** – in the previous section we mention that our estimates may only reflect 55% of the full economic benefit from circular economy opportunities**.** This perspective implies that the total potential contribution of the circular economy to Auckland's GDP in 2030 could be in the range of $6.3 - 8.8 billion.

This result suggests that the economic benefits from circular economy opportunities in Auckland are towards the upper end of the range of the top-down estimates of $0.8 to $8.8 billion in terms of GDP contribution. However, we would like to caution that our method is based on several assumptions, which means these results come with a high level of uncertainty.

4.4 Key messages from the estimation

We have used two approaches to consider the size of the potential of a more circular economy in Auckland in 2030, following a transformational change in the economy.

- **A top-down approach** – based on importing assumptions from prior studies undertaken overseas, points to Auckland's GDP being higher by $0.8 - 8.8 billion in 2030, than would otherwise be the case.
- **A bottom-up approach** – a more detailed look at specific opportunities that uses Auckland data – produces an estimate of total benefits in 2030, in value added terms. We convert this to a GDP figure by factoring estimates of transition costs and the multiplier for induced GDP. The result of $4.6 billion may only account for slightly over half of the full CE potential, which may be in the range of $6.3 - 8.8 billion – towards the upper end of the range of the top-down estimate.

The take-away message from this analysis is that the net benefits from the transformation to a circular economy in Auckland are likely to be positive in aggregate and, potentially, significant in scale in the medium term. This is consistent with much of the literature.

It should also be noted that GDP alone does not sufficiently capture the several key dimensions of the circular economy, for example, the impact of the circular paradigm on consumer surplus, wealth distribution beyond averages, depletion of resources, unpaid activities like commuting, environmental costs externalities, depreciation, and the value of leisure time.

5. Emissions reduction potential

This chapter considers the impact of selected circular economy activities on greenhouse gas emissions in Auckland, as measured by kilo-tonnes of carbon dioxide equivalent (CO_2e).

5.1 Summary of approach

Our approach to estimating potential emissions reduction from a circular economy in Auckland involved similar steps as for estimating the total economic benefit.

- Identify opportunities within the three sectors based on international studies and available data.
- Identify a baseline on economic and demographic developments in Auckland to the year 2030. These developments are classified as 'business as usual' (i.e. BAU).
- Import CE opportunity assumptions for the identified opportunities based on international and NZ studies. These assumptions are overplayed onto the BAU parameters. Note that some CE opportunities may differ from those estimated in terms of total economic benefit.
- Estimate the potential for reducing embodied or generated emissions.

Table 6 below presents the business as usual (BAU) assumptions used for these estimates, and Appendix 2 provides more detail on method and other input assumptions.

Table 6: BAU assumptions for estimating emissions reduction

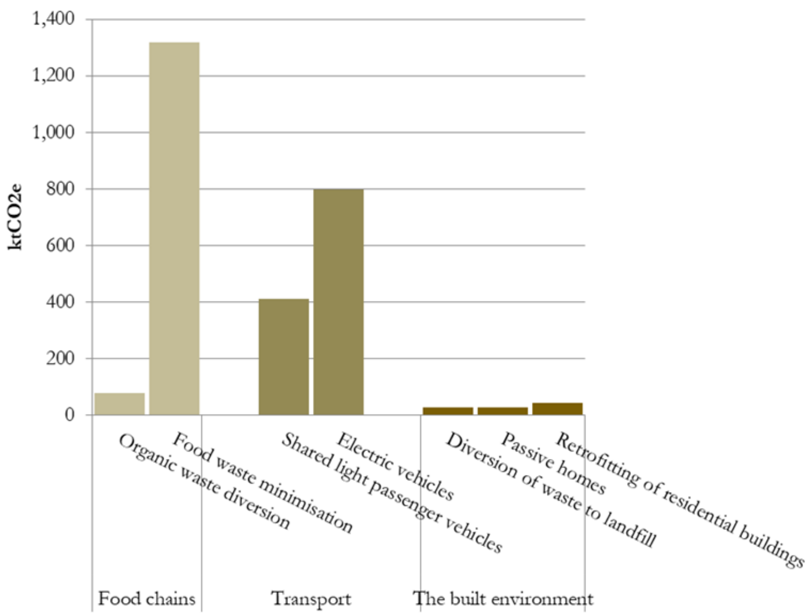
2030 BAU assumption	Source
Food chain	
Waste to landfill grows at a CAGR of 2.9 during 2019-2040	Based on projections from the 2017 Auckland Waste Assessment Report
Starting with 2017, avoidable food waste grows at the same rate as GDP – i.e. 2.6%	GDP growth rate estimated based on ATEED/Infometrics data
Organic waste to landfill grows at a CAGR of 2.5% % during 2019-2040	Based on projections from the 2017 Auckland Waste Assessment Report
Transport	
The utilisation rate of light passenger vehicles is 2.5 people per care (compared to 1.51 today)	Current utilisation rate is as per ITF and OECD (2017)
The number of Auckland households grows at 1.7% p.a.	Statistics NZ 2013 census
Average number of cars per Auckland household is the same as in 2012, i.e. 0.94	Statistics NZ 2013 census

2030 BAU assumption	Source
The number of taxis grows at the same rate as the Auckland population – i.e. 1.6% p.a.	Auckland population growth is based on projections from Statistics NZ 2013 Census
The mix of light vehicles in Auckland is the same as in NZ in 2017	Ministry of Transport
Emissions intensity by car type is the same as in 2017	Ministry of Transport
The built environment	
The number of Auckland households grows at 1.7% p.a.	Statistics NZ 2013 census
Emissions intensity of energy use for space heating and cooling per household is the same as in 2012	EECA
Rubble and concrete waste to landfill grows at a CAGR of 4.2% during 2019-2040	Based on projections from the 2017 Auckland Waste Assessment Report

5.2 Overview of results

Figure 5 and present the results by circular economy opportunities in 2030. Similar to total economic benefits, we would like to highlight that our estimates of emissions reduction represent only a sub-set of the wider potential from CE opportunities, given the limited scope of our study. Furthermore, the results present only a snapshot as at 2030, i.e. they exclude emissions reduction that would take place prior to 2030 as the adoption rates of different CE opportunities gradually increase.

Figure 5: 2030 CE opportunities and GHG emissions reduction



Note: the construction waste to landfill figure is an average of the range provided in the table below

Table 7 below shows the reductions estimated for these opportunities total 2,700 ktCO_2e. Approximately half of this reduction is from emissions embodied in materials and resources and half is from emissions generated from the use of materials and resources. Achieving the estimated reduction in generated emissions would be equivalent to taking approximately 288,000 cars off the road in Auckland.

These figures should be treated as high-level estimates only as they relate to the specific opportunities examined in this work. Therefore, it is likely that this estimate represents only a fraction of the potential emission reductions from a circular economy in Auckland.

Table 7: CE opportunities and GHG emissions reduction in 2030

2030 CE opportunity	Emissions reduction (ktCO_2e)	The nature of emissions reductions
Food chains		
50% reduction in food waste compared to 2030 BAU waste volumes	1,093	Reduction in emissions embedded in total food waste
	225	Reduction in emissions generated from food waste
Diversion from landfill of 30% of 2030 BAU organic waste volumes	77	Reduction in emissions generated from organic waste to landfill. The lower figure is in the scenario where 50% food waste is avoided in the first instance
Transport		
33% of the 2030 number of light private vehicles are used at full capacity due to car sharing, leading to car displacement	411.1	Emissions reductions due to lower number of light private vehicles on roads
33% of taxis are ride shared resulting in 92% utilisation		
20% of light private vehicles are EVs	676.5 - 769.6 ktCO_2e. The lower figure is in a scenario where, in the first instance, cars are displaced due to shared mobility	Emissions reductions due to uptake of electric vehicles
The built environment		
80% of construction waste to landfill is diverted	16.8 - 34.9	Reduction in emissions embodied in construction waste to landfill

2030 CE opportunity	Emissions reduction ($ktCO_2e$)	The nature of emissions reductions
80% of new residential buildings use passive house technology to improve energy use. The 2030 stock of new residential buildings includes developments from 2018	26.6	Emissions reduction due to improved energy efficiency for space heating and space cooling
65% of old residential buildings are retrofit. The 2030 stock of old buildings includes developments up to 2018	44	Emissions reduction due to improved energy efficiency for space heating and space cooling

5.3 Key messages from the estimation

Most of the emissions reduction quantified lies in the food and transport sectors…

The largest emissions reduction potential is due to avoided emissions embodied in food waste, followed by EV uptake. The potential for reducing emissions from waste in the food and construction sectors is at least 1,334.8 $ktCO_2e$, with most of this figure being due to food waste minimisation. Note that our estimate for the construction sector is based on a derived carbon factor in the range of 0.07-0.22 of tons CO_2e per ton of material (see Appendix 2), which may be on the low side. Future work could assess this factor for Auckland specifically.

There may be a greater potential in the transport sector…

Based on the GHG emissions reported by Xie (2015) for on-road transportation (scope 1)[26] in Auckland, and assuming that these emissions would rise at the same rate as the Auckland population (i.e. 1.6%), we estimate that our quantified emissions reduction potential in the transport sector would represent 13% of total emissions in 2030.

McKinsey, EMF and SUN (2015), on the other hand, estimate that the emissions reduction potential of the circular economy in the transport sector could be of 40% (including the rebound effect) or 55% (excluding the rebound effect).[27] The opportunities where these additional emissions reduction may come from include material evolution and transport system integration.

There may also be a greater potential in the built environment sector…

Based on the GHG emissions reported by Xie (2015) for residential buildings (scope 2)[28] in Auckland, and assuming that these emissions would rise at the same rate as the Auckland population (i.e. 1.6%), we estimate that our quantified emissions reduction potential in the

26 4,034 $ktCO_2e$ in 2015.

27 Compared to today.

28 402 $ktCO_2e$ in 2015.

residential sector would represent 14% of total emissions in 2030. We suspect that the there is greater potential for emissions reduction in the built environment, as our estimates focus on space heating and cooling in the residential sector. For example, a report on the potential benefits of the circular economy in South Australia has found that most GHG emission reduction are achieved though efficient and renewable energy measures.[29]

Further CE opportunities – in addition to those estimated here – include retrofitting non-residential buildings and applying higher energy efficiency standards for new non-residential buildings. Arup (2014) reports that there are significant opportunities for transforming energy usage in the manufacturing and industrial sectors. For the residential sector, we focus on the energy efficiency of space heating and cooling because these are the direct benefits from passive houses. The definition of CE opportunities could potentially be extended to include other energy efficiency measures such as those relating to energy use by appliances and for water heating.

29 See Lifecycles et al (2017).

6. Reflections on policy issues

A key question is whether the transformation to a circular economy will occur in Auckland, given the competitive forces of the market and the propensity of firms to innovate, or whether there are barriers that may require some policy intervention. Assessing the feasibility for Auckland to make a transformational shift to a circular economy requires primary research, which is beyond the scope and resourcing for this work. However, we offer some general reflections on the potential barriers and enablers from a public policy perspective by drawing on observations from international studies and circular economy route maps.

To begin with, it must be acknowledged that there are relevant initiatives already under way in Auckland…

It is important to acknowledge that there are some initiatives under way in Auckland that are consistent with a shift towards a more circular economy. The diversion of organic material from landfill, for example, is a fundamental aspect of Auckland's Waste Management and Minimisation Plan, which sets the target for a 30% reduction in kerbside waste to landfill.[30] Food waste currently accounts for 40% of domestic waste and organic material is the largest contributor to GHG emissions of all waste sent to landfill. Therefore, efforts to reduce kerbside waste to landfill will significantly contribute to improving Auckland's waste emissions profile – for example, through a user pays organic collection service.

Auckland's Energy Resilience and Low Carbon Action Plan also promotes circular economy-relevant opportunities in the transport sector and the built environment.[31] The Plan includes actions that would help meet the 2030 targets of electrifying 20% of the vehicle fleet and ensuring that 65% of new buildings achieve high sustainable design standards.

Additionally, there are numerous examples of circular economy -compatible business models and initiatives currently under way in Auckland, as can be seen in the report by the Sustainability Business Network on the topic.[32]

Internationally, a growing number of cities and countries are taking more of a systems view to achieving a circular economy…

While individual initiatives will contribute to a more circular economy for Auckland, a growing number of cities and counties are recognising that a transformation to a circular economy will involve structural changes within and across sectors of the economy.[33] Taking this systems view involves a unified approach that:

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30 https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/Pages/waste-management-minimisation-plan.aspx.

31 Auckland Council (2014) *Low Carbon Auckland* https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docslowcarboncopy/low-carbon-strategic-action-plan-full.pdf

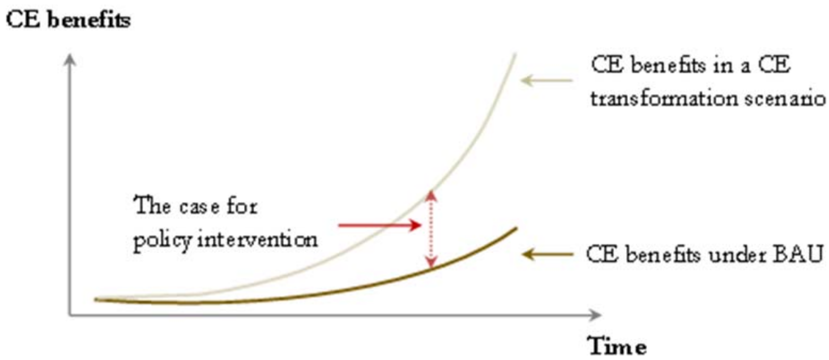
32 See https://sustainable.org.nz/the-circular-economy-resource/.

33 Examples of cities with circular economy route maps include London, Glasgow, Amsterdam and Helsinki.

- provides leadership in form of a strategy that articulates a clear vision for a circular economy;
- considers the barriers to making a transformational shift; and
- takes a coordinated approach to policy interventions.

The work done on the circular economy in other jurisdiction suggests that policy will play a key role in ensuring that the transformation to a circular economy can occur. Strategies developed in other cities typically make a case for policy intervention to help ensure that essential new technologies are developed and scaled and that initiatives aimed at barriers are integrated effectively.[34] Figure 6 below provides a conceptual illustration of the role that policy could play in the circular economy transformation. The darker line illustrates the benefits from CE-compatible activities under the current development path (i.e. an extension of business as usual) whereas the lighter line illustrates the benefits under a circular economy transformation scenario.

Figure 6 The role of policy in the circular economy transformation[35]



A number of barriers to a transformation to a circular economy have been cited in reports from other jurisdictions…

Previous studies have cited a range of potential barriers that can restrict the uptake and the scale-up of circular economy approaches. We categorise these barriers into four groups:

- economic and market-related barriers that, in the main, arise from market failures;
- legal and regulatory barriers that arise from government settings that, for example, may have unintended consequences;
- behaviour and social barriers with respect to consumers/households and firms;
- technology and innovation-related barriers – mainly related to under-investment in innovation. needed to support the circular economy transformation

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34 This integration would need to also occur *between* some systems, e.g. energy systems (not discussed in this report and the transport system.

35 This figure is for illustration only. The circular economy transformation may not necessarily follow the shape of the path suggested here.

Collectively, leaving these market failures unaddressed is likely to lead to under-investment in innovation, resulting in new technologies not being available at scale on a cost-effective basis. Table 8 summarises examples of these barriers within each grouping.

Table 8: Categorisation of potential barriers to a more circular economy

Type of barrier	Examples of barriers cited
Economic and market related barriers	• Unpriced negative externalities – for example environmental cost of food production is not reflected in food prices, or the environmental cost of producing construction material is not reflected in the cost of materials and therefore in the cost of buildings. • Imperfect information – e.g. consumers are unaware of the difference between 'best before' and 'use by' for food products, or are uncertain about the total cost of ownership of an EV. Literature suggests that imperfect information can hamper the diffusion of new technologies. • Split incentives – agents along the supply chain may have split incentives, e.g. producers have an incentive to shorten 'best before' dates to increase turnover (and reduce liability) whereas retailers have an incentive to sell more. • A high cost of capital – poor access to capital can affect the early uptake or the scale-up of new technologies. This is relevant across the three sectors studied, and particularly for closed nutrient loops, shared mobility and industrial processes & 3D printing. • Inadequate public good infrastructure – e.g. the absence of optimal waste separation infrastructure in municipalities or infrastructure to support multi-modal transport systems.
Legal and regulatory barriers	• Poorly defined targets and objectives – can provide insufficient or skewed direction to an industry • Weak or absent frameworks – with respect to the use of new technologies, e.g. the absence of a legal framework to ensure that the 3D-printing technology in construction has a positive impact in terms of environmental and technical performance, as well as health of building occupants. • Unintended consequences – existing regulations can hamper the adoption of circular practices, e.g. food safety regulations may restrict trade in bio-refinery products, or approaches to electricity pricing may restrict the uptake of electric vehicles (see Concept Consulting, 2018).

Type of barrier	Examples of barriers cited
Behaviour and social barriers	• Consumers lack sufficient knowledge about, and experience with, circular approaches, e.g. how to best store produce, how to evaluate produce freshness or how to prepare food with minimum waste. • Households may not be aware of the impact that their decisions may have on resource availability and the environment. The convenience of current routines such as having immediate access to a personal car may hinder the uptake of CE opportunities like shared /pooled vehicles. • Existing custom and habits – e.g. consumers may reject 'odd-looking' produce and may prefer longer use dates, or homebuyers may be unwilling to trust non-traditional building approaches. • Incumbents are unwilling to change their long-established operational practices. A prominent example of this is the construction sector, where business models rely on extensive sub-contracting, resulting in over-specialisation and fragmented knowledge. This barrier is related to the path-dependency barrier discussed for innovation further below.
Technology and innovation-related barriers	• R&D stage – under-investment in research & development may occur because individual firms cannot fully internalise the social benefits of their investments (positive externality) or they anticipate reaping costless benefits to be gained from the investment of other firms. • Demonstration stage – the high cost of exploring and creating new markets may not be recoverable as later entrants may reduce profit margins. As a result, early movers may not be willing to take on the risk, leading to exploration of new opportunities being lower than otherwise. • Deployment stage – past technology choices can create inertia with respect to rolling out new technologies. This path dependence means the market is unable to switch technologies despite the knowledge that the incumbent technology is inferior to the alternative.

Interventions to address barriers to a circular economy…

Each part of society – firms, government and consumers – can play a role in addressing the barriers to a transformation to a circular economy. Firms have a leading role in developing innovations across the product life cycle, from design to production process to business models to end-of-life options (e.g. reverse logistics). The role of government spans the provision of leadership and information to raise awareness and encourage change through to regulatory and expenditure interventions. Consumers can be more conscious of their actions from a circular economy perspective and voluntarily adjust their purchasing, consumption and disposal behaviours – in addition to responding to any incentives or requirements put in place by government.

The role for government is highlighted as the critical platform for enabling, encouraging, incentivising and requiring transformative change across firms and consumers. While there are many ways to categorise roles of government, we offer the following high-level typology covering four dimensions of the government role: leadership, information provision, regulatory intervention and public expenditure. These roles are summarised in Table 9 with examples of policy interventions from road maps in other jurisdictions. This is intended be illustrative to show the breadth of the government's roles and provide examples of actions being proposed or adopted elsewhere.

Table 9: Enabling a circular economy – policy instrument typology and examples

Leadership	Information	Regulation	Expenditure
Can involve • a strategy with a vision, measurable targets, immediate priorities and actions • a commitment to monitor progress • a commitment to assess and deploy policy instruments • a commitment to work in partnership with industry/firms.	*Can involve* • public information campaigns to raise awareness and change behaviour • targeted information to encourage firms to innovate or to help firms adapt.	*Can involve* • removal of regulatory barriers • improving or creating new regulations • use of pricing instruments, including taxation, levies, and cap & trade schemes.	*Can involve* • purchasing enabling services, such as specialist advisory services to work alongside firms • providing capital / co-financing to SMEs to enable piloting of innovation • public ownership of infrastructure.
Selected examples of interventions being proposed or adopted elsewhere			
• city-level road maps, e.g. Amsterdam, London, Glasgow; • country-level strategy, e.g. Finland that articulates priorities and piloting of initiatives in partnership.	• include information on nutrition, food preservation in school curriculum; • knowledge centres providing information for businesses • promote communal food production, new ownership models.	• energy efficiency and carbon ratings for buildings; • weight-based charging schemes for household waste (Danish city-level); • create a market for organic recycled nutrients; • minimise food waste by eliminating regulatory barriers.	• concessionary financing in nascent industries, e.g. UK Green Investment Bank has developed loan products; • bold development of public transport in urban areas; • public procurement focuses on solutions that support a circular economy.

Some types of interventions may be more suited to address certain types of barriers. Information-based interventions tend to be suited to changing consumer behaviour and addressing market failures such as information asymmetries. Regulation-based interventions may be best suited to addressing firm-level behaviours (e.g. changing business models) and market failures such as unpriced negative externalities. Expenditure may necessary for the provision of public infrastructure or in providing access to capital (e.g. for small and medium enterprises, start-ups) where traditional forms of finance may not be accessible. Leadership in the form of a well-thought out strategy enables these interventions to be prioritised into a coherent package that takes a long-term view. Taking a proactive long-term systems view allows cost-effective opportunities to be identified across sectors and across time – and ensures that any dependencies or sequencing issues can be addressed.

It is also useful to distinguish between the roles of central and local government. Some interventions may be suited at a national level, for example, setting a country-level vision or dealing with national regulatory frameworks. Local government is likely to be closer to local constraints and opportunities and is therefore better able to reflect these in a set of practical priorities in a city or regional-level strategy for a circular economy.

7. Concluding remarks – and potential next steps

This work provides an initial view on the potential economic benefits of a more circular economy for Auckland. The estimates are necessarily based on a number of assumptions and come with a high level of uncertainty. Therefore, the take-away message from this analysis is that the net benefits from the transformation to a circular economy in Auckland are likely to be positive in aggregate and, potentially, significant in scale in the medium term. This is consistent with much of the existing body of research and commissioned studies.

While a more in-depth piece of work could result in a different estimate of the potential of a circular economy in Auckland, perhaps the more pressing questions relate to how well Auckland is positioned to take-up the opportunity of the circular economy. In particular:

- What is Auckland's comparative advantage – which sectors or sub-sectors are innovating and/or offer the most potential?
- What barriers are there to realising this potential, from Auckland perspective?
- What might need to be done to address those barriers?

Work undertaken by the Sustainable Business Network highlights numerous examples of innovative business models and private sector initiatives in Auckland that are already displaying circular economy characteristics.

Further research could focus on the barriers that firms may face to adopting more circular economy practices. This would provide further insights into the preparedness of firms to innovate or adopt technological advancements from elsewhere. The behaviours and views of households would also need to be researched to understand how they may respond to different incentives, which would inform the design of policy interventions.

Alongside these insights from firms and households with respect to the opportunities and barriers, research should assess the extent to which the current mix of policy interventions is likely to enable a transformational shift to a circular economy. The outcome would be a better understanding of what is likely to happen through innovation, behavioural change and current policy support from local and central government – and what else may be necessary to enable a transformational shift to a circular economy in Auckland.

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Appendix 1: Detailed assumptions for estimating total economic benefits

The food chain

Food waste minimisation

- Estimates of total avoidable food waste for New Zealand are provided by WasteMINZ (2015) for the residential sector, and by Reynolds (2016) for the residential and non-residential sectors. For the residential sectors, the estimates in the two studies are similar.
- Estimates of the unit cost of avoidable food waste are also provided by the two studies above. However, WasteMINZ reports the figures in terms of consumer prices, whereas Reynolds et al (2016) – in terms of basic purchase prices, before taxes and other costs such as transport are added. We adopt the figures from WasteMINZ to get a better view of the total costs involved.
- To derive the value of non-residential food waste in terms of consumer prices, we apply the ratio of residential vs non-residential tons estimated based on Reynolds et al (2016). The ratio is 2.17.

Organic waste diversion

- We assume that 50% of diverted organic waste can be used for bio-chemical extraction, and the rest of 50% - for biogas production.
- The per-unit economic values from bio-chemical extraction and biogas are taken from the Denmark report, adjusted for the NZ-EUR exchange. The estimates are of $119/ton and $40/ton respectively.

Transport

Shared cars

- We estimate the number of cars that could be displaced at a given utilisation rate of shared cars.
- We take the current utilisation rate to be 1.51 people per car, as per ITF OECD (2017) estimates based on 2011/2012-2013/2014 Household Travel Survey. We assume that by 2030 car utilisation rate can increase by 1 person (i.e. to 2.5 people per car). In 2030, increasing utilisation rate from 2.5 to full occupancy implies a car displacement factor of 57%.
- Total car ownership costs for Auckland are estimated at the household level based on data from the Household Expenditure Statistics 2016. Detailed Auckland data was scaled from NZ data based on the total weekly transport expenditures by an Auckland household relative to an average NZ household.

Refurbishment of light commercial vehicles

- Net benefit from refurbishing light commercial vehicles is estimated in terms of new vehicle cost savings as per EMF (2013). We take the conservative assumption that the discount on refurbished vehicles is 50% of new vehicle's sales price (and not lower). The net benefit is estimated to be of $7,313 per vehicle in 2030.

Decongestion

- The opportunity cost of congestion is estimated based on Auckland economic decongestion benefits as per Leung et al (2017).
- We focus on the costs associated with light private vehicles. We assume that decongestion benefits are proportionate to ratio of light private vehicle users out of total road users (79%).

The built environment

Industrialised production processes and 3D printing

- We assume that material costs and labour costs constitute 35% and 20% respectively out of total construction costs, as per EMF (2015).
- McKinsey, EMF and SUN (2015) estimate that a 50% adoption rate of industrialised processes can lead to a 30% reduction in total construction costs compared to on-site construction. We assume the 30% reduction applies to material and labour costs.
- EMF (2015) estimate that a 25% adoption of industrialised processes can lead to a 25% reduction in material costs and 40% reduction in labour costs. Proportionately, for a 14% adoption rate this implies an 14% and a 22% in material and labour cost reduction respectively.

Passive homes and retrofitting of residential buildings

- The focus is on energy use for space heating and cooling. Data is taken from EECA for 2012, and we derive the proportion of energy use for space heating and cooling out of total household energy use. This rate is 32%.
- To derive household cost of energy for space heating and cooling, we apply 32% to the average electricity per Auckland household, which was $2,175 in 2017.[36]
- We estimate that by 2030, there will be 104,563 new households in Auckland compared to 2018, i.e. 16% of total households in 2030 will have been built between 2018 and 2030.

[36] See https://www.stuff.co.nz/business/industries/92920513/infographic-what-is-the-average-new-zealand-power-bill.

Sharing and multi-purposing of non-residential buildings

- We assume that material costs and labour costs constitute 35% and 20% respectively out of total construction costs, as per EMF (2015).

Reuse and high-value recycling

- We assume that material costs and labour costs constitute 35% and 20% respectively out of total construction costs, as per EMF (2015).
- According to EMF (2015), a 70% adoption rate corresponds to 30% and 5% reduction in material and labour costs respectively. Proportionately, this means that at a 60% adoption rate, material and labour costs savings are 26% and 4% respectively.

Appendix 2: Detailed assumptions for estimating GHG emissions reductions

The food chain

Food waste minimisation

- A key input parameter is the projected volume of food waste to landfill by 2030. We assume that this will constitute 13% of total waste to landfill. The 13% figure reflects the share of food waste out of total waste in New Zealand in 2011, as per Reynolds et al (2016).
- We estimate that total waste to landfill will amount to 1.3 million tons in 2030. This number was derived using the CAGR for estimated waste to landfill during 2019-2040. The forecast for waste to landfill was sourced from the 2017 Auckland Waste Assessment Report.
- Two emissions reduction measurements were applied to food waste minimisation: avoidance of embodied emissions and avoidance of emissions generated from food waste. In contrast to the latter indicator which measures emissions produced from waste, the former indicator measures emissions embodied in *producing* the food that is wasted.
- To estimate the potential for avoiding embodied emissions, we derive an embodied emissions factor (tons of embodied CO_2e/ton of food waste) based on the NZ-level findings by Reynolds et al (2016). We estimate this factor to be 12.96.
- To estimate the potential for avoiding emissions generated from food waste, we use the 2.66 emissions factor (tons CO_2e generated per tons of food waste), as reported by the National Food Waste Prevention Project.

Organic waste diversion

- We apply the estimation approach used by C40 Cities (2017) to estimate net emissions reductions from diverting organic waste from Auckland landfills. Note that organic waste here includes timber alongside putrescibles.
- We assume that the quantity of waste sent for composting or anaerobic digestion is 30% of total organic waste sent to landfill. The C40 report assumes 50,000 tons of food waste diverted in 2020, which represents 26% out of total organic. So we assume a slow increase in the rates of diversion.

Transport

Shared cars

- By 2030, 1 shared car displaces 1.3 cars. This is calculated based on the current car utilisation rate (people per car) in Auckland (1.51) as per ITF and OECD (2017), and an assumption that the utilisation rate of shared cars in 2030 will be 2.5.
- It is assumed that the utilisation rate of ride-shared cars is 32% higher than that of taxis by 2030. This is based on the finding that currently UberX can already achieve between 4-40% higher utilisation rates (see Transport and Environment, 2017)
- Emissions are reduced due to cars being displaced. Emission reductions are estimated using two sources of emission factors. This gives us a range:
  - The first set of emissions factors is estimated for different types of cars based on data from the Ministry of Transport's New Zealand Transport Outlook (2018)
  - The second emissions factor is assumed to be 4.7 tons CO2e from a typical passenger vehicle, as per US Environmental Protection Agency (2014).

Electric vehicles

- The fleet mix in Auckland is the same as overall for NZ as per MoT's NZ Transport Outlook Report
- Emissions intensity per vehicle type is as per 2017 base case in MoT's NZ Transport Outlook report. The data suggests that the emissions intensity of EVs is 89% lower than that of petrol cars.

The built environment

Construction waste reduction

- We use two sources to estimate embodied carbon factors in construction materials. This gives us a range
  - The first source is Hammond and Jones (2008) who provide a detailed estimate of carbon content per material type. To convert to CO2e estimate, a 3.67 factor is used.
  - The second source is Pratt and Lenaghan (2015) who estimate the carbon content of material flows in Scotland. The embodied emissions carbon factor is estimated overall for construction materials by dividing the total carbon impact to total weight of construction material.

  Based on the above, we estimate emissions carbon factors for construction material to be between 0.07 and 0.22 (tons CO2e/ton material)
- To apply the emissions factor from Hammond and Jones (2008), we assume that 80% of construction waste to landfill is cement, and 20% is rubble.

Passive houses

- We assume that energy reduction due to improved standards for new buildings is 60%. Arup (2014) notes that kWh reduction for a 6-star home is 69%.
- The date on end-use energy consumed and CO2e emitted is sourced from EECA's energy end-use database.
- We estimate that residential emission intensities of space heating and cooling in 2012 were 0.42 and 0.002 tons CO2e/household respectively.

Retrofitting of residential buildings

- The proxy for the number of residential buildings is the number of Auckland households as projected by NZ Stats.
- The date on end-use energy consumed and CO2e emitted is sourced from EECA's energy end-use database.
- Using NZ Stats data on the number of Auckland households, we estimate emissions per household in 2012 and then apply this number to projected number of households in 2018 in order to estimate total projected emissions from space heating and cooling for existing residential buildings as at 2018
- We estimate that residential emission intensities of space heating and cooling in 2012 were 0.42 and 0.002 tons CO2e/household respectively.
- We assume that energy reduction as a result of retrofitting is 30%, based on McKinsey. Arup (2014) assume a 50% reduction in kWh consumed.