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TECHNICAL RESEARCH REPORT:
METHODS FOR MEASURING WASTE PREVENTION OUTCOMES

Prepared for the Australian Government Department of Climate Change, Energy, the Environment and Water v1.0

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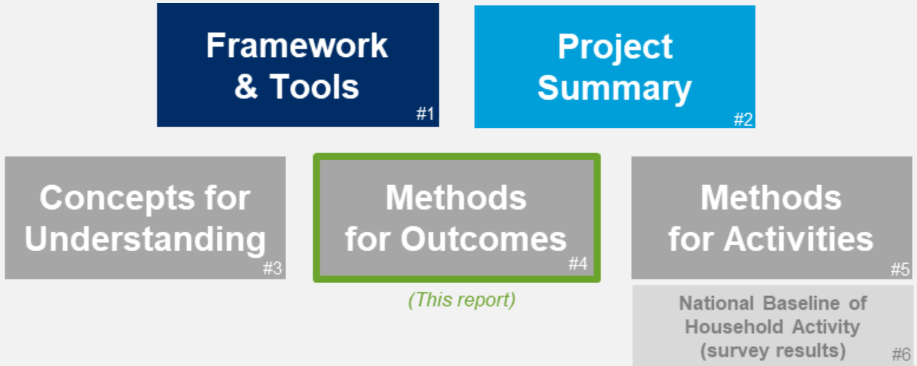
Conflict of interest

The authors have no conflicts to declare.

CONTENTS

This report is the second of three underlying pieces of research that support the development of feasible methods to measure waste prevention at national, state/territory and more local scales. The aim for these methods is to feed into Australia's national waste reporting, and in particular, support tracking of progress against Target 2 of the National Waste Policy & Action Plan: *Reduce total waste generated in Australia by 10% per person by 2030*. These methods are contained in the Guidance document, *Understanding, measuring and communication waste prevention*.

Summary of project outputs available on the Department website



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INTRODUCTION

Every tonne of waste prevented is a ton of material which does not need to be managed and is a win for the environment. A challenge in the current information environment is that it is not clear which activities, decisions and system changes are likely to lead to the greatest value to society from waste prevention

The objective of this research is to *propose one or more methods for measuring overall waste prevention outcomes across the national economy, including the public, private and third sectors*.

Waste prevention includes a wide range of activities, as illustrated in Figure 1 below which articulates key waste prevention activities by Users.

This report presents an integrated model for Waste Prevention Measurement (herein 'the integrated model') which comprises:

- 1a. Measurement of **aggregate waste prevented by weight** (including breakdown of changes in waste generated by key sector and waste stream)
- 1b. Measurement of reductions in **pollution emissions** attributable
- 2a Multiple measures of **waste prevention outcomes** by key activities across the entire product lifecycle
  - a. Measurements of **waste eliminated** by key waste avoidance opportunities and activities
  - b. Measurements of **waste delayed and eliminated** attributable to extending the life of products, components and substances
- 3. Measurement of changes in **awareness, values beliefs and attitudes** related to waste prevention opportunities and activities
- 4. Relevant changes to **policy, economic and technology context**.

The conceptual method is complimented by a general formula to estimate waste prevented which provides framing for the various proxy measures proposed. We also share suggestions for a set of measurement indicators which are informative about the level of waste prevention related to the conceptual method.

The model developed is sufficiently pliable in its design so as to be suitable for adaption to a variety scales, such as at the national and state level, and with some adjustment at more granular levels including organisational and local government.

This report was commissioned in response to a number of key challenges to waste prevention measurement which have been identified, namely:

a) perceptions by some stakeholders that waste prevention is too hard to measure

b) a lack of consensus on what waste prevention is (that is, what ought to be measured, given what is already measured)

c) uncertainty surrounding the methods for collecting, organising and reporting on data to enable measurement of waste prevention outcomes.

The project is part of a larger project on *Measuring Waste Prevention* which is a collaboration between BehaviourWorks Australia (Monash University) and the University of Technology Sydney, funded by the Australian Government Department of Climate Change, Energy, the Environment and Water.

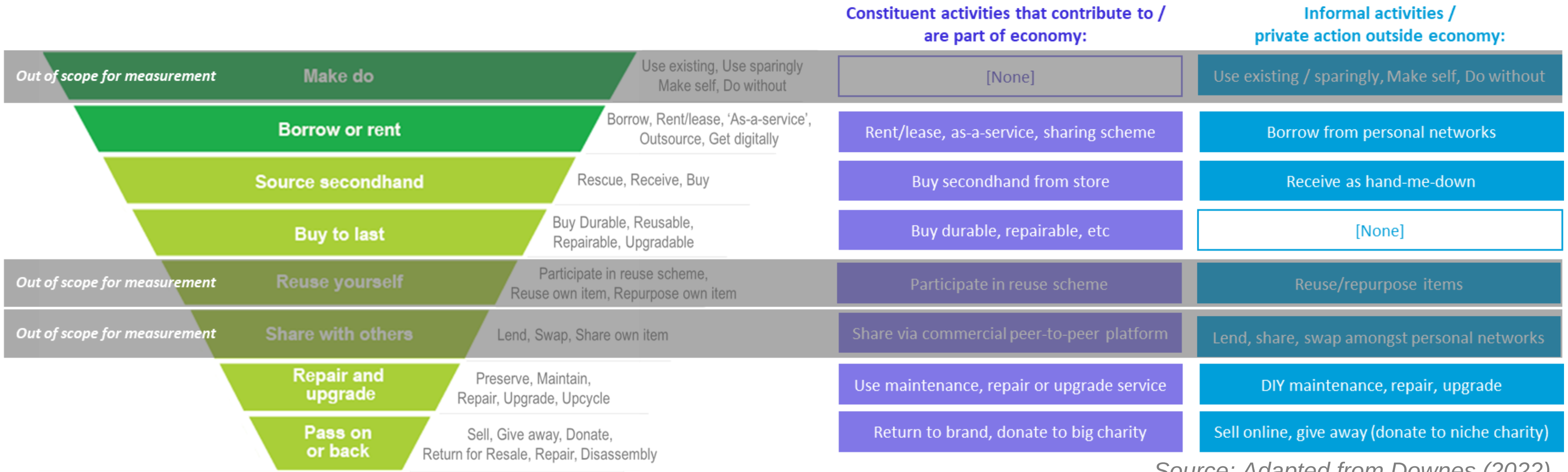
The proposed method is based on:

1. A review of data collection and reporting methods on waste prevention both for Australia and internationally
2. A review of the academic literature on waste prevention reporting
3. An exploratory consultation and co-design process involving *semi-structured interviews* with 18 experts and stakeholders in waste prevention, including national and state governments, civil society and industry; and a *group consultation* with 22 experts and stakeholders in waste prevention from state government
4. Expertise in performance measurement from the design team including expertise in accounting, economics and integrated measurement techniques
5. Detailed work in stage one of this project by BehaviourWorks Australia, developing a typology of waste prevention as well as defining and prioritising waste prevention activities
6. Guidance and feedback from the Department of Climate Change, Energy, the Environment and Water.

The project aligns with the *National Waste Policy Action Plan 2019*, in which waste avoidance is framed as a national priority, in tandem with resource recovery and associated waste management practices.

The proposed method is not the end of the conversation, but rather the beginning of a broader conversation about where we aspire to be.

Figure 1: Expanded waste hierarchy and activities which are the focus of measurement for Phase 3 of this project



Source: Adapted from Downes (2022)

BACKGROUND

UNPACKING WASTE GENERATION AND PREVENTION

Critical to the measurement of waste prevention, is clarity on what is meant by the term waste prevention. As the literature review and stakeholder conversations suggest, waste prevention is a term that is often understood in a variety of ways, with different stakeholders foregrounding different aspects of waste prevention depending on their context.

As a way of providing clarity to this plethora of views on waste prevention, we adopt the following definitions to the terms waste, waste generation and waste prevention; noting that waste prevention is typically defined in reference to waste and waste generation. Waste prevention initiatives are measured directly by what is achieved, that is waste prevented through deliberate acts of reducing existing resource use from becoming waste that previously were entering into the waste management system.

Defining waste

While there is some nuance in the term waste, the definition put forth by the Australian Bureau of Statistics (ABS) (2020) is indicative of the set of views we observed in both the literature and from stakeholder interviews. The ABS define waste as:

1. *any substance that is discarded, emitted or deposited in the environment in such volume, constituency or manner as to cause an alteration in the environment*
2. *any discarded, rejected, unwanted, surplus or abandoned substance*
3. *any otherwise discarded, rejected, unwanted, surplus or abandoned substance intended for sale or for recycling, reprocessing, recovery, or purification by a separate operation from that which produced the substance.*

A common observation from the stakeholders consulted is that the term waste can hide the multifaceted nature of waste being generated. For example, waste can be viewed as a resource, a burden, or inert material.

Defining waste generation

A key contextual factor relevant to measuring overall waste prevention outcomes in the Australian context is predicated on how waste generation is defined. The 2019 National Waste Policy Action Plan defines waste generation as:

"[t]he process of producing waste. For data and reporting purposes, waste generation is the sum of the quantities of waste taken to waste management facilities or added to on-site stockpiles. Measures of the total amount of waste generated include the waste recycled as well as the waste sent to landfill." (p. 36)[1]

The 2019 National Waste Policy Action Plan also details a national target to reduce total waste generated in Australia by 10% per person by 2030.

While this is a key definition, there is more to waste generation than the waste industries activity, as there will be more waste actually generated than is visible in the data about material flows to facilities in the waste sector. Therefore, waste prevention outcomes may be achieved but not visible in data collected at facilities.

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[1] A number of stakeholders interviewed as part of this project explained their understanding of waste as being a resource that is recyclable. They suggest the terms 'waste' could be revised to better reflect that waste includes a range of material, of which some has value. It is beyond the scope of this project to re-define waste; however, we note that further consultation and discussion is warranted between key stakeholders on the relation and terminology used for describing and classifying waste, in particular where it intersects with the actual or potential circular economy.

Defining Waste Prevention

In our earlier report waste prevention *was defined to be any action taken (i.e. measures, activities, changes) or any planned action (i.e. strategies, or programmes) that aims to stop items from entering the waste stream (p.4)*.

During the stakeholder consultations and analysis, it became evident that waste prevention extends beyond deliberate actions to reduce waste. It includes decisions to reduce consumption. It became evident that waste prevention also includes the effect of system changes that limit consumption / production choices that in turn have the effect of reducing waste serendipitously. System level changes could include things like regulation (domestic or international) and changes in technology.

It was also observed that planned action which is not enacted is not waste prevention, but rather a potential precursor to waste prevention. In the same way as planning to save is not the same as saving. Notwithstanding this clarification, any decisions (on that is fulfilled) about not purchasing a product or service is an example of waste prevention without a specific action; as the outcome of the decision is a reduction in the quantum of material demanded from supply chains and is therefore waste prevention.

Waste prevention is not just about waste prevention activities of individual or organisations. It may also include taking decisions and outcomes of system changes including regulation that result in a reduction of waste.

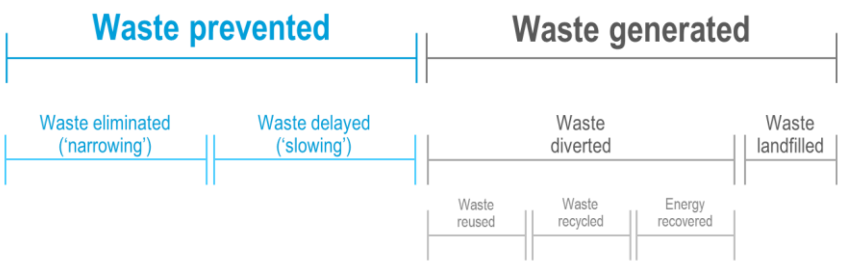
This can be contrast with the definition of waste prevention most commonly cited in the literature (and which also aligns with some of the views expressed during our stakeholder interviews) from the 2008 European Union 'Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives', that defines waste prevention as:

> *"prevention' means measures taken before a substance, material or product has become waste, that reduce:*
>
> *(a) the quantity of waste, including through the re-use of products or the extension of the life span of products;*
>
> *(b) the adverse impacts of the generated waste on the environment and human health; or*
>
> *(c) the content of hazardous substances in materials and products"*

The definition we adopt detailed below includes insights from the perspectives obtained from the review of the literature and our consultation with stakeholders. It considers waste prevention approaches to include actions and/or decisions of individuals or groups with a view to preventing waste, as well as system level measures for waste prevention such as regulation. Accordingly, we refine our earlier definition for waste prevention in the Australian national context to be as follows:

Waste Prevention Definition: *Any, action (i.e. measures, activities, changes) or system changes prior to an item becoming waste that stops material (i.e. products, substances) from entering waste management systems. These can include deliberate actions taken (i.e. strategies or specific programmes) or unintended actions (i.e. system changes not deliberately designed to reduce waste).*

Figure 2: Classification of waste prevented and waste generated



Source: Downes, J. (2022) Understanding waste prevention research report.

ILLUSTRATING WASTE PREVENTION MEASUREMENT STAGES

The longer we (re)use items, the longer we delay disposal and avoid waste

In this section we present the importance of considering the various points across the material supply chain for exploring opportunities for measuring waste prevention. The extent of waste prevention in a given supply chain is influenced by attitudes and values, policy, technology and other relevant contexts.

A review of the literature identified that waste prevention measurement typically occurs at all stages of the material supply chain as illustrated in Figure 3a. Simply put, raw material is drawn from the natural environment and from a recycled waste stream and goes through a process of transformation through to use and re-use. At each iteration, this material may become non-recyclable waste or circulated back into production for recycling (as illustrated by the blue collection of material flows from each stage of production in the centre of the circle).

Our analysis suggests that there are at least three key stages where waste prevention measurement can occur within a supply chain. Figure 3b illustrates the relationship between these three key elements of waste prevention measurement (the outer circle) and the lifecycle of materials (the inner circle).

The outer circle represents 3 related waste prevention measurement stages:

- **waste generated:** the ultimate outcome of waste prevention is to reduce what potentially would otherwise enter the waste management stream, which at an aggregate level is reflected in reductions in waste generated
- **waste eliminated by reducing the number of products / amounts of material:** the primary mechanism of waste prevention is resource use being reduced or eliminated entirely. This can occur at any stage of a production system, but predominantly at the design, input, production and distribution stages, and to some extent in the use (consumption) stage when decisions are made to not purchase a product, or substitute digital or service in lieu of physical product.
- **waste delayed and eliminated attributable to extending the life of products, components and substituting for new purchases:** once material is in use as part of a product or component of a product, the timing of it entering a waste stream can be delayed though activities such as delays in purchasing, reuse activities and otherwise extending its life span; thus temporarily preventing waste from entering waste streams. A second order effect of this delayed waste is waste eliminated via the avoidance of alternative product or material which would have otherwise been used in lieu of, had the life and use of product and components not been extended. It is worth noting that any substance that is abandoned or discarded but stored (or not collected) can effectively become stored waste prior to entering a waste stream, rather than waste delayed and eliminated).

Figure 3a: Material flow in typical supply chain

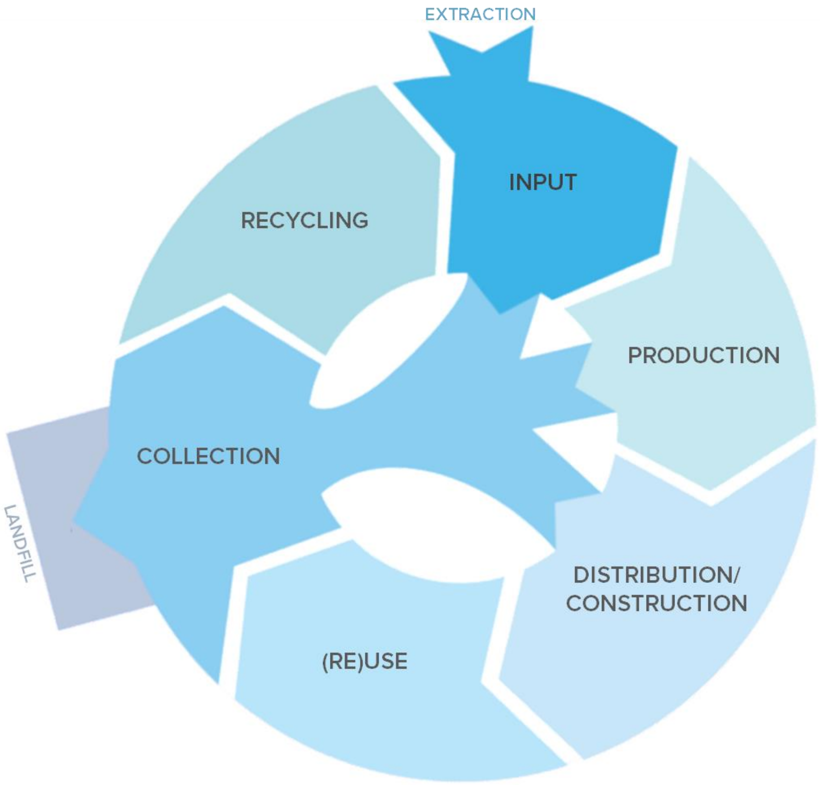
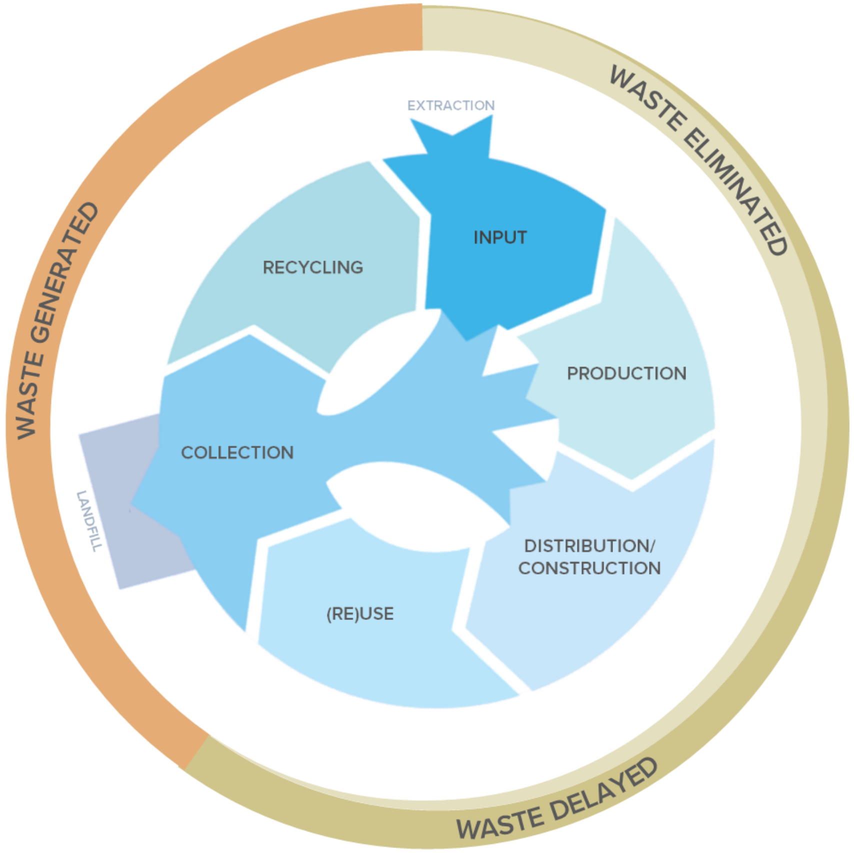


Figure 3b: Relation between waste prevention measurement stages and material flow in a typical supply chain



Source: Iterated version of stakeholder engagement input.

OVERALL MODEL FOR MEASURING WASTE PREVENTION

AN INTEGRATED METHOD FOR MEASURING OVERALL WASTE PREVENTION OUTCOMES

Waste prevention as part of a lean strategy is core to many successful organisations competitive advantage through less material utilized and lower costs. Why not the same for households and the country?

It has been long recognised by management accountants and others that a single measure of performance is rarely, if ever, sufficient to provide a representation of performance in most areas of activity. This in part explains the plethora of measurement methods identified in the literature review (Brown et al., 2021), as different methods are chosen based on data availability and cost, as well as the aspect of performance being focused on.

In the context of Australia's national and state reporting, we propose that an integrated modelling approach be adopted, whereby multiple measures of waste prevention activities and outcomes are collected and reported, with date grouped into key thematic areas, or categories. An integrated model aims to address key challenges to waste prevention measurement, including:

- limited data availability at sufficient granularity;
- practical challenges to measuring the quantum of waste that would have been generate had the action or system change not taken place for all key waste streams; and
- practical challenges to matching (i) changes in the level of waste generated to actions and (ii) system changes attributable to waste prevention.

These reasons indicate that it is unlikely that a single measurement method is likely to give a complete measure of waste prevention in the short term.

An integrated modelling approach provides an alternative means for measuring waste prevention, since multiple measures are used at different levels of granularity. These are presented by key categories so as to jointly give a reflection of overall waste prevention outcomes across the national economy, including the public, private and third sectors.

Figure 7 presents the integrated model illustrating a method for measuring overall waste prevention outcomes. The light blue box contains the key measures of waste prevention outcomes, while the two orange boxes are necessary disclosures to enable people to understand and contextualize the blue box measures.

Table 5 (Panels A and B) define each of the measurement and context categories presented in Figure 7, and provide some indicative metrics.

With a view to linking the proposed model with extant practices for waste prevention measurement, Appendix 2 contains a summary of some methods identified in a literature and practice review (Brown et al., 2021) which align with Figure 7 and Table 5.

The integrated model illustrates the key categories which together provide a representation of overall waste prevention outcomes.

Measurement of aggregate waste prevented is at the core of the model. It provides an informative, but also an incomplete measure of overall waste prevention. Accordingly,

1. As illustrated by 1a and 1b, the aggregate measures are broken down into more granular measures such as for national reporting: state level data by key waste streams (e.g. MSW, C&I, C&D), as well as by sector and by waste material categories (e.g. material type, recyclability). It is critical that these measures be adjusted for factors that impact waste generation, including population, number of households and their composition, level of economic activity and any other salient factors, which in combination can increase the level of waste generated despite increases in waste prevention levels.
2. As illustrated by 2a and 2b, available date on waste prevention outcomes and activities is presented. This information is also necessary to gauge the magnitude and performance of waste prevention and illuminate opportunities for new value-adding policy measures targeting waste prevention.
3. To the extent to which data and methods allow, the measures in 2a and 2b should be quantified as tonnes of waste prevented, and linked to linked to the measures of aggregate waste prevention (1a and 1b).
4. As illustrated by 3 and 4, changes to contextual factors are necessary to interpret the waste prevention measures.

RATIONALE FOR INTEGRATED MODEL DESIGN

The design of the conceptual model was informed by interviews with stakeholders and a review of national and international literature and practices for waste prevention measurement. Here we present a summary of the rationale for the proposed approach.

A review of the literature reveals that different methods are informative for different aspects of waste prevention outcomes. Rather than propose a 'shoehorning' of methods together or the dropping of informative measures of waste prevention outcomes, we propose that disaggregate measures be taken, but reported in relation to each other.

Enables observation of causal links between waste prevention strategies (including policy and private sector) and measurement, and links to aggregate waste generation and prevention levels. The method is flexible in that it allows for flexibility in what is presented to better enable fit between the information provided and the needs of users over time, and makes the link between various initiatives with aggregate waste prevention performance explicate time.

Mix of lead and lag indicators to better represent the outcomes of a system in flux. End users of the reporting on waste prevention have a range of information needs, including how well we are tracking to the target, and what sectors are performing well or could be enhanced. A mix of lead and lag measures allows users to focus on the element of waste prevention most salient to them.

Conceptual method has some consistencies with current approaches to measurement. Our approach can be enacted in the short term by adapting current approaches to measurement and existing data, and complementing these measures with additional measurement as new data and methods become available. For example, the most recent National Waste Report contains a mix of data and qualitative disclosures to provide an indicator of waste prevention outcomes.

Lower and flexible cost for data collection. The framework is sufficiently pliable to enable extant data which is currently available or in planning to be reported, and then evolved over consecutive periods as the system evolves

Figure 7: Integrated model for measuring overall waste prevention outcomes across the national economy, including the public, private and third/voluntary sectors

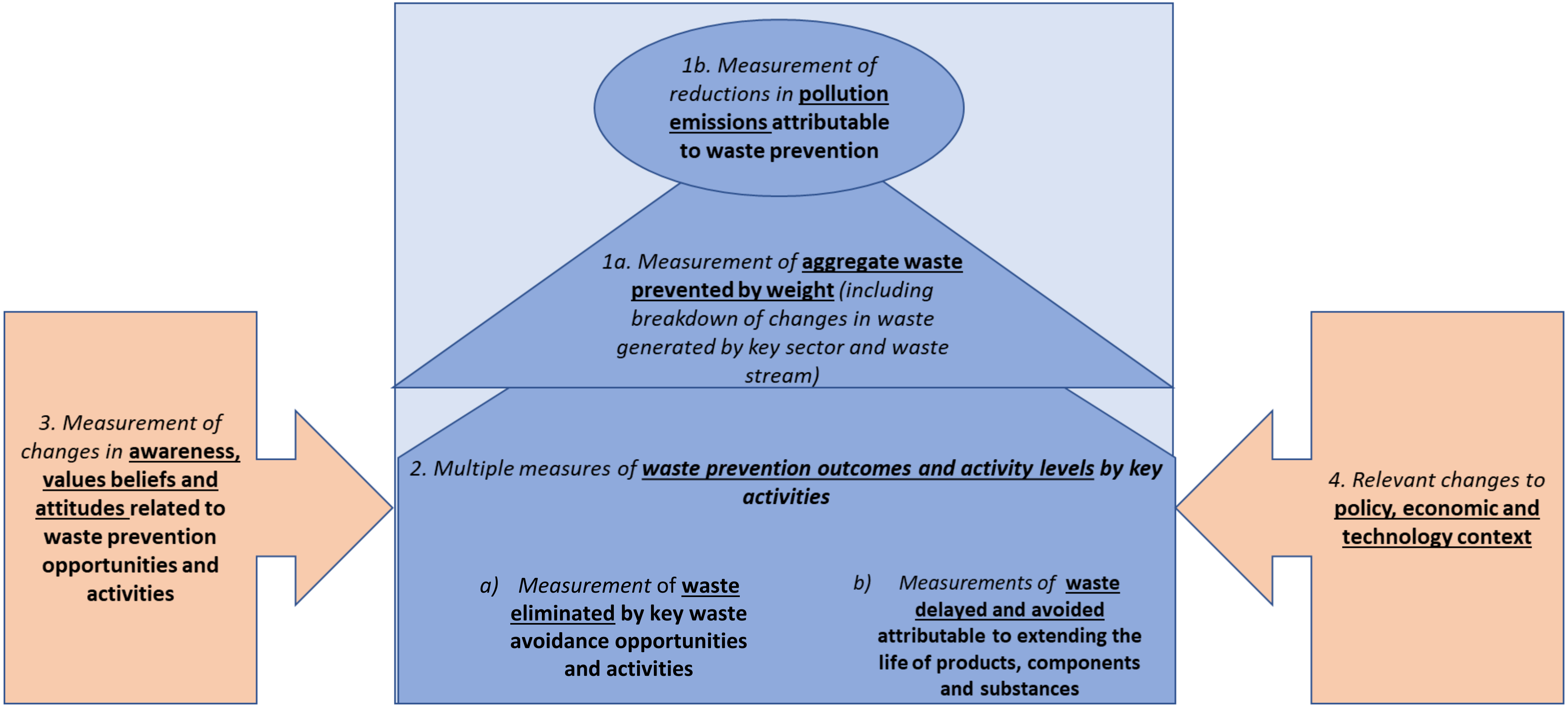


Table 5: Defining Waste prevention measurement and context categories with indicative metrics

Panel 5A: Waste prevention measurement categories

Waste prevention measurement and context category	Indicative metrics and / or methods
1a and 1b. Measurement of **aggregate waste prevented by weight** (including breakdown of changes in waste generated by key sector and waste streams) The outcome of waste prevention is a reduction in levels of waste entering waste streams such as landfill, recycling or conversion to energy. Measurements of reductions in waste generated are lagging indicators of waste prevention activities, as measurement and reporting happens after the waste prevention.	• Quantity in tonnes of actual waste generated compared to a compared to a baseline representing business as usual waste generation. The baseline can be the expected level of waste generation estimated from the previous time period adjusted for factors that may influence generation levels such as changes in population and broader economic trends. This measure can be presented on a per capita, GDP or similar basis • The measures of aggregate waste prevented should be complemented by a set of more granular measures which are causally linked, such as breakdown by sector and waste stream. • Measurement of reductions in pollution emissions attributable to waste prevention to complement the waste prevention measurement • Compilation waste prevention measures for of a set of more granular waste streams, which have been prioritised for waste prevention policy and which have substantial potential for waste prevention

2. Multiple measures of **<u>waste prevention outcomes</u> by key activities**
 	
a Measurement of **<u>waste eliminated</u> by key waste avoidance opportunities and activities**
 	
Where resource use is reduced or eliminated at any stage of a production system, predominantly at the design, input, production and distribution stages, and to some extent in the use (consumption) stage when decisions are made to not use a product or substitute digital or 2. service in lieu of a physical product.
	• Estimates of reduction in quantum of virgin and recycled material embedded in produce / service design by key classes of products or an index; accompanies by an estimate of the level of waste prevented.
	  - These estimates would include measures designed to give a picture of the adoption and outcomes of practices such as light-weighting of product and packaging
	• Reduction in process waste from production and distribution activities
	• Level of adoption and diffusion of innovative and new technologies enabling service and / or digital substitution; accompanies by an estimate of the level of waste prevented
	• Estimates of waste prevented from key programs targeting waste prevention
	• Estimates of levels and changes in avoidance activities and an estimate of the level of waste prevented. These activities include:
	  - Reusing
	  - Making do
	  - Sharing with others
	• Estimates of relevant commercial activity (e.g. number of businesses, transactions, economic value of activity, etc.) and consumer activity (e.g. including number of people, organisations, items; changes in the level and/or composition of consumption, etc); accompanies by an estimate of the level of waste prevented

Waste prevention measurement and context category	Indicative metrics and / or methods
2. Multiple measures of **<u>waste prevention outcomes</u> by key activities** b Measurement of **<u>waste delayed and eliminated</u> attributable to extending the life of product, components and substances** Once material is in use as part of a product or component of a product, the timing of it entering a waste stream can be delayed though reuse activities and otherwise extending its life span, thus preventing waste from entering waste streams. Further, if the product / material substitutes for purchasing / consumption of new product/material there is a second order waste avoidance effect through reduced consumption. Note: Any substance that is abandoned or discarded can effectively become stored waste prior to entering a waste stream, which is different to delayed.	• Level of activity and estimate of quantum of waste prevented reported by key activities such as: - Building / Buying to last - Obtaining items second hand - Repairing - Passing on or back - Borrowing or renting • Estimates of levels and changes in the average life of classes of products, potently in the form of indexes, accompanied by an estimate of the quantum of wasted prevented • Estimates of waste prevented from key programs targeting waste delay and prevention • Estimates of relevant commercial activity (e.g. number of businesses, transactions, economic value of activity, etc.) and consumer activity (e.g. including number of people, organisations, items; changes in the level and/or composition of consumption, etc); accompanied by an estimate of the level of waste prevented

Panel 5B: Waste prevention context categories

Waste prevention context category	Indicative metrics and / or methods
3. Measurement of **awareness, values beliefs and attitudes** Changes in awareness, values, beliefs and attitudes are generally precursors to waste prevention, and accordingly are leading indicators of waste prevention.	• Representative surveys of key populations where waste prevention is theoretically and practically possible • Magnitude and characteristics of changes in awareness, values, beliefs and attitudes from key programs and initiatives • Awareness of where and how to prevent waste (ie. infrastructure)
4. Relevant changes to **policy, economic and technology context** Changes to and the outcomes of policy and technology related to waste prevention are leading indicators of waste prevention and are informative about system changes driving waste prevention.	• Quantum and characteristics (including key mechanisms and scope) of relevant policy, regulation and programs, in comparison with domestic and international reference cases • Quantum and characteristics (including key mechanisms and scope) of relevant technology and investment, in comparison with domestic and international reference cases

Note: While the focus of this report is on measurement outcomes of waste prevention activities, the measurement of outcomes necessitates some level of measurement of activities. Activity data can be augmented with estimates of typical outcomes per activity, estimated or simulated data to provide an outcome measure. Depending on various factors; data collection may, inter alia, take the form of (i) representative or targeted surveys, (ii) observational studies or data collected (e.g. garage sale data where information is collected by local councils, (iii) point-of-sale data, (iv) voluntary disclosures by key organisations.

A GENERAL MEASURE OF WASE PREVENTION

Waste prevented is the outcome of an action or system state whereby waste that would have resulted from some activity is lessened or eliminated.

In this section we present a general method for measuring waste prevention which is consistent with how waste prevention is defined and understood by key stakeholders. We include present a set of illustrative examples at an activity level to help expose challenges and opportunities for measuring waste prevention outcomes at an aggregate level (which is explored in the next section).

The ultimate outcome of waste prevention is a reduction in material waste that under current conditions would enter the waste management stream. This outcome is reflected in wide use of reductions in waste generated as a measure of waste prevention.

Logically, following on from how waste prevention is widely understood, measurement of waste prevention requires:

1. knowledge of an action or system change in terms of the time period and waste stream(s).
2. a measure of what resulted in terms of what waste was generated as a result of the action or system change; and
3. a measure of what waste would have been generated had the action or system change not taken place.

Accordingly, a measure of waste prevented can be expressed as the *difference between* the actual level of waste for a given period of time resulting from an action or system change which has been made (and the expected level of waste had no action or system change has been made (which we label Business as Usual waste).

The following equation presents the measure more formally:

$$\begin{aligned} &Waste\ Prevented \\ &= Business\ as\ usual\ waste\ generation \quad - Actual\ Waste\ generated \end{aligned}$$

where

$Business\ as\ Usual\ waste\ generation$ is the quantum of waste that would have been generated had the action or system change not occurred (business as usual, or ‘expected waste’ if you will);

$Actual\ Waste\ generated$ The quantum of relevant waste generated as a result of an action or system change intended to prevent waste.

This equation is helpful as a guide for undertaking measurement, as captures some key elements which have been elusive in earlier efforts to measure waste prevention, and provides a reference point to calibrate and expand upon when undertaking or evaluating waste prevention measurement endeavours.

The following illustrative examples provide various scenarios that make explicit the existence of and hypothetical measurement of counterfactual Business as Usual waste generation. Additional scenarios for durable goods are included in the Appendix.

WORKED EXAMPLES

The following examples, and those in the appendix, illustrate how to apply the formula and interpret the results for different types of activities. Each example is based on a single activity, as might be calculated by an individual or organisation.

Note: The results are not intended to be *comparative* across scenarios (that is, to determine if Scenario 1 has more waste potential than Scenario 2) as they have not been designed with comparable numbers of activities, households, items and uses, in mind. The numbers here and below are for illustrative purposes only.

Scenario 1 Do without (waste eliminated)

This first scenario describes waste prevention as a result of foregoing some level of existing consumption. Here we illustrate an example in the context of coffee consumption, specifically foregoing the purchase of an amount of takeaway coffee.

Arabella goes to the coffee shop twice a day, every weekday, for her flat white. She decides to trim her coffee spend and intake, so forgoes one coffee a day. Every time she does without, 15g of waste are prevented.

Table 1: Forgoing purchasing one takeaway coffee in a disposable cup

Formula	Working	Notes:
Business as usual waste generation	15g	Expected waste is one disposable coffee cup (10g) into waste Organic food waste from coffee beans (5g)
Less: Actual waste generated	0g	Actual waste is zero grams of waste were generated
= Waste Prevented	15g	

Note: numbers are for illustrative purposes only.

Scenario 2 Buy Reusable (waste delayed and eliminated):

The second scenario describes 'Buy to last' waste prevention, which has the effects of both avoiding waste over the life of the product each time reusable product is used in lieu of a disposable alternative, and also delaying waste from entering a waste stream (as the produce is more durable). This is illustrated in the context of substituting the disposable coffee cup for a more durable product/service.

Ella usually makes her coffee at home in the mornings. However, on the weekend she has a takeaway coffee on the way back from the beach or gym. She decides to purchase a reusable coffee cup, which only lasts about 1 year. At the end of the year she disposed of the coffee cup into recycling, and decides to purchase a more durable reusable coffee cup. Over the course of the year, Ella avoids 1,000g of waste. At the end of its life, the disposable coffee cup is disposed of, causing waste of 100g, which results in a net waste avoidance of 900g. Notably, Ella could have delayed disposal of her coffee cup, and in doing so avoided additional waste.

Table 2: Substituting purchasing takeaway coffee in a disposable cup with the purchase of a reusable coffee cup (100 coffees)

Formula	Working (when purchased)	Working (end of life)	Notes:
Business as usual waste generation	10g	1,000g	Expected waste is one disposable coffee cup (10g) into waste immediately, plus another 99 if the reusable cup substitutes for **100 takeaway coffees**
Less: Actual waste generated	0g	100g	the time of purchase, and at the end of life waste is generated upon disposal of the reusable cup (100g)
= Waste Prevented	10g	900g	

Note: numbers are for illustrative purposes only.

Reductions in aggregate waste generated (Scenario 1 and 2)

While scenario 1 and 2 are helpful to understand the level of waste prevention for two activities, and two people, it is helpful to consider how they relate to changes in waste generation per capita. In Table 3 we estimate waste for the year before Arabella and Ella act to prevent some of their coffee consumption waste.

Table 3: Main effect of scenario 1 and 2 on level of waste generated (assuming BAU of 100 takeaway coffees per year)

Formula	Year 0	Year 1	Year 2	Notes:
Scenario 1 (Arabella)	3,750g	0g	0g	Waste is assumed to be 15g per takeaway coffee, Arabella avoids 250 coffees per year in years 1 and 2.
Scenario 2 (Ella)	1,500g	600g	500g	Waste is assumed to be 15g per takeaway coffee, which reduces to 5g each time the reusable cup is used. Ella avoids 100 coffees per year in years 1 and 2, and disposes of one reusable coffee cup (100g) at the end of year 1, and purchases a more durable reusable cup.
Total per year	5,250	600g	500g	Total waste generated for year

Note: numbers are for illustrative purposes only.

There are three key observations from table 3:

1. Changes in behaviour / activities influence the level of waste generated each year.
2. Arabella completely avoids waste. Ella reduces waste considerably, but due to her continued consumption of coffee still causes waste to be produced, with the reusable cup eventually becoming waste.
3. There is a link with productivity, in that Arabella does not purchase 500 coffees over years 1 and 2, so there is less economic activity and Arabella misses out on delicious coffee. Alternatively, Ella spends the same in each year as in year 0 (assuming no inflation), gets the value from consuming coffee.

ADDITIONAL CONSIDERATIONS

Direct vs indirect waste prevention

For the purpose of simplicity, these scenarios have largely been restricted to direct waste prevention as a result of specific waste prevention activities. However, it is also possible to include (some aspects of) indirect waste. For example, in addition to direct waste as a result of the coffee cup and any substitutes, there may be indirect waste such as:

Residual coffee in the cup: this would be disposed of with the cup. This would be avoided in the Scenario 2, but still present in all other scenarios.

Packaging waste (for disposable and reusable cup): The apportioned amount of packaging waste per disposable cup would be avoided in the Do Without scenario, and eliminated in the Reuse scenario though likely offset at least to some extent by any packaging of the substitute reusable items. The offset amount would likely differ between the Borrow and Buy/Use Reusable, as the coffee supplier providing items for borrowing would likely source their cups wholesale and in bulk and therefore have less packaging per cup, than in the Buy/Use Reusable where each consumer would purchase their cup individually and the items would likely be in packaging designed for promotional/marketing purposes as well as product protection.

Depending on the activities and items, such calculations can be important in determining the true waste prevention impact of any activity.

Role of durability and intensity of use

The intensity of use of an item, before measurement is taken (or calculated) can influence the calculations on waste eliminated. It is therefore important to measure/appropriately estimate this variable.

For more durable goods, product lifespan and point of measurement interact to influence measurement/estimation of waste prevention, as demonstrated across scenarios A4 to A9 in the Appendix.

MEASURING WASTE PREVENTION OUTCOMES

CHALLENGES TO AND OPPORTUNTIES FOR IMPROVING AGGREGATE MEASUREMENT

Waste prevention is the outcome of an action or system state whereby waste that would have resulted from some activity is not generated.

Sections before show how we can measure waste prevention outcomes at the level of individual changes (such as not purchasing coffee, or reusing coffee cups). A key challenge is how to scale up measurement, either to all reuse in a country or for a state, or all the different kinds of waste prevention activities together (reuse with repair etc).

As presented in the introduction, the current approach is to not measure waste prevention outcomes in aggregate directly, but rather to measure indirectly at the stage of changes in per capita waste generation. This approach has some limits and issues, such as:

1. Factors other than waste prevention are related to changes in per capita waste generations, including changes in consumption demand, general economic conditions, population growth, digitization, urban development and the growth of the business sector, particularly the relative growth of different business sectors (e.g. services and building and construction).
2. Positive waste prevention outcomes in different sectors and waste streams may be hidden due to negative waste prevention outcomes in other sectors and waste streams
3. There are practical challenges to matching changes in aggregated measures of waste generated with (i) changes in classes of specific actions and (ii) system changes.
4. Business as usual waste generation is not visible due to a lack of data on waste prevention activities and outcomes
5. Changes in waste generation is a lagging measure of waste prevention (tells you what happened in the past, what waste was prevented), and there is a paucity of leading indicators of waste prevention (tells you what is likely going to happen), which are indicative of trends and opportunities for waste prevention.

Our analysis has revealed a number of ideas and opportunities to improve the measurement of aggregate waste prevention outcomes at the country or state scale, building off the earlier literature review and stakeholder consultations. These are:

1. Continue to utilise the indirect approach utilising changes in waste per capita, but improving its validity via adjusting for contributing factors beyond population growth, like digitisation and light-weighting. This suggestion is expanded on in the next section.
2. When presenting changes in waste per capita, also include a set of more granular measures which are causally linked, such as breakdown by sector and waste stream. These additional measures will be helpful to understand and interpret changes in aggregate waste generation.
3. Collecting data on and reporting on indicators of disaggregated waste prevention activities are necessary to complement aggregate measures of waste prevention, to better represent the trends in overall waste prevention outcomes being measured. To do so, assessments are needed of component activity outcome measures for materiality, feasibility, cost and intelligibility/demonstration value, using the results to prioritise proxy measurement choices. The collection of additional data on waste prevention activities and outcomes will be informative both for the performance and potential for waste prevention in ways which are currently inaccessible.
4. Add up whatever tonnes prevented you can find across prevention sources, and repeat this in a standardised and controlled way over time, to show trends.
5. Consider compiling an index of various waste prevention activities or outcomes to track changes over time (similar to a CPI Index)

6. Where data on waste prevention outcomes is not available:
    a. data on activities or economic value of activities may be combined with deemed values to construct accounts of waste prevention.
    b. qualitative disclosures will be informative to promote greater understanding, as well as support discussion of what additional data could be used to better gauge waste prevention.
7. Disclosures of other factors which are relevant to explaining waste prevention outcomes will be informative for users of the waste prevention measures. Consider the value of:
    a. attitudinal measurement to complement outcomes measurement
    b. disclosure of contextual factors relevant to waste prevention such as material changes in technology and policy initiatives

A NOTE ON ACTIVITIES, OUTCOMES AND OUTPUTS

An alternative to more conventional measurement of waste, material flows and economic factors, is a theory of change perspective. The theory of change approach to measurement has become a dominant method for project and program evaluation. James Connell and Anne Kubisch in 1998 trace the genesis of the theory of change approach to Carol Weiss's 1972 book *Evaluation Research: Methods of Assessing Program Effectiveness*, where she advocates for testable models for programs which articulate the objectives, activities and outcome with a view to evaluating the effectiveness of programs in the short to medium term. As data is collected on the outcomes of activities, hypothesis and activities can be revised accordingly. More modern articulations of the theory of change (*c.f.* OECD, 2010) involve the specification of a causal chain, representing the 'theory' of a program in the form of:

inputs → activities → outputs → outcomes → impacts

This approach makes a lot of sense for waste avoidance projects and programs, where specific activities are taken with a view to stimulate certain activities, which are expected to drive certain outcomes. However, this approach is less helpful for the measurement of waste prevention more generally in aggregate, which aligns more closely with how activity bases management / costing or Life Cycle Analysis is enacted.

Table 4: Illustrating the link between actions and outcomes

Case 1: Person purchases a reusable cup from an existing vendor	Case 2. Cafe owner decides to offer and promote reusable cups	Case 3: As part of its sustainability strategy, a university decides to promote the benefits of reusable cups to students and staff
	Cafe owner offers reusable cups and offers discount for reusable coffee cup owners (action)	On campus signage extoling the benefits of reusable cups (action)
Purchase of reusable cup (action)	Purchase of reusable cup (outcome)	Purchase of reusable cup (outcome)
Less disposable cups demanded, reducing waste (outcome)	Less disposable cups demanded, reducing waste (outcome)	Less disposable cups demanded, reducing waste (outcome)
Less waste to be managed by waste and recycling facilities (impact)	Less waste to be managed by waste and recycling facilities (impact)	Less waste to be managed by waste and recycling facilities (impact)

In an activity-based management / costing or Life Cycle Assessment approach, activities and outcomes are viewed as being tightly connected: outcomes are estimated by multiplying the activity by a proxy or measure of outcome per unit of activity. This enables the conversion of the quantity of activity to be used in estimating the level of outcome. So in the cases in Table 4, the impact of all three cases could be estimated by multiplying a measure of the number of reusable cups by an estimate of the waste prevented per cup, which in all three cases would be an estimate of waste prevention.

ESTIMATING AGGREGATE WASTE PREVENTION OUTCOMES

Estimate of waste prevention may be gleaned from estimates of waste generation, adjusting for other factors which also explain fluctuations in waste generated

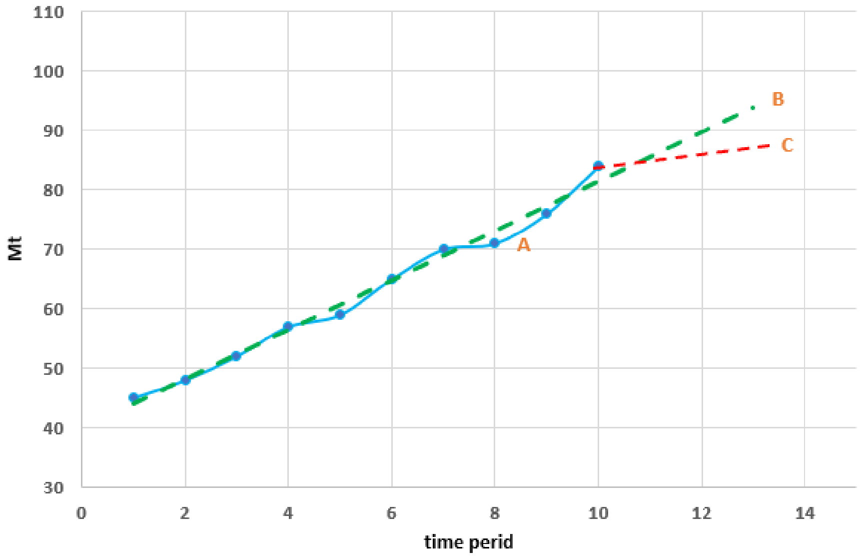
MEASUREMENT OF WASTE PREVENTED AT AN AGGREGATE LEVEL

The illustrative examples presented earlier provide a context for developing measures of waste prevention. At the same time, these examples (including those in the appendix) illustrate the complexity of constructing aggregate measures of waste prevention given that an extremely large number of possibilities exist. With some adjustment, a more generalised aggregate measure of producing estimates of waste prevention may, in the first instance, provide a good indicator of waste prevention. Such an example in provided in Figure 4.

Figure 4 provides a scenario using hypothetical data on waste generation measured in Mt over 10 time periods. The time series data on waste generation is illustrated by the blue line. Over this period, waste generation has increased consistently to 85 Mt by time period 10. During this period, the waste generated is influenced by a series of factors including changes in consumption demand, general economic conditions, population growth, digitization, urban development and the growth of the business sector, particularly the relative growth of different business sectors (e.g. services and building and construction).

If we assume 'business as usual', the blue line (line A) (representing waste generation) will undoubtedly continue to grow into the future. As we do not have data beyond the current period (period 10), we can forecast the projected level of waste generation taking into account factors such as those noted earlier that influence the level of waste generation. In this forecast we assume that the business / production practices continue unaltered and consumers' attitudes to reducing waste remains unchanged (which can include a positive attitude towards reducing waste). In other words, the forecasting model has these factors incorporated into the model, with the exception that the variables are updated with data from periods 11 and 12 to produce the 'business as usual' estimate of waste generation.

Figure 4: Estimating Waste Prevention using aggregate generated waste data



Without illustrating the econometric method by which this forecast is made, we present the results of this forecast in Figure 4 as the green dotted line (line B) extending beyond the blue line. By period 12, the forecasted waste generation is estimated at 90Mt, an addition of 5Mt from the level in period 10.

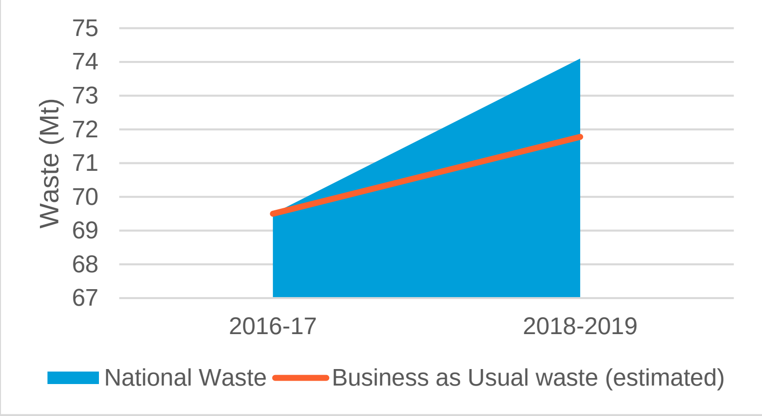
As our focus is on measuring waste prevention and not measuring the effects of policies changes designed to encourage greater waste prevention, our method of measurement is dependent on tracking the observed changes in waste generation against the levels of waste generation that are forecasted using the forecast model (assuming 'business as usual').

In the example given in Figure 4, we assume that over time periods 11 and 12, the actual level of waste generation is denoted by the red dotted line (line C). The same factors noted above that were used in the forecast (line B) are the same actual values determining the actual level of waste generation given by the red dotted line (line C). The gap between the two lines (lines B and C) is explained by something other than the factors noted earlier. This could include business decisions to introduce technology to bring about productive efficiency and lead to significant waste prevention. It may also include changes in consumer consumption habits which are a change to the 'business as usual' typical of the previous period and that which was assumed in the forecasting model. This gap could be considered an estimate of waste prevention because the activities of consumers and businesses that changed over this period (periods 10 and 11) were different to the 'business as usual' from the earlier periods.

As an illustration, the blue shaded area in Figure 5 utilises actual data from the Waste report for the period 2017-18 to 2018-19, which saw a rise from 69.5 to 74.1 Mt of waste generated. Adopting a simplified version of the proposed model from Figure 4, a forecast estimate of the 'business as usual' case is illustrated by the orange line. The gap between the line and the actual level of waste generation in 2018-19 provides an approximation for the level of waste prevention over this period. (In this illustration, the model actually shows waste *appreciation* rather than prevention.) Forecast for the following year would assume the state of play in 2018-19 becomes the 'business as usual' case, assuming any efficiency gains in production and consumer habits remain unchanged into the next period. A comparison between the actual and forecasted value provide a new estimate of the level of waste prevention for the next period.

While the measure in Figure 5 can inform about overall waste prevention, it masks the performance of the various sectors of the economy which drive waste generation. Figure 6 over the page presents the disaggregated MSW, C&I, C&D as Ash and Other; with the proposed method of estimating waste prevention repeated for each of the constituent parts. In this illustration, Quadrants A and B show that even when the level of MSW remains similar and C&IW increases, there is actually evidence of some (C&I) or substantial (MSW) waste prevention. It also illustrates how such waste prevention can be masked by substantially waste *appreciation* in the C&D sector.

Figure 5: Illustration of proposed method, comparing estimated BAU against Total National waste generated using 2017-18 to 2018-19 data



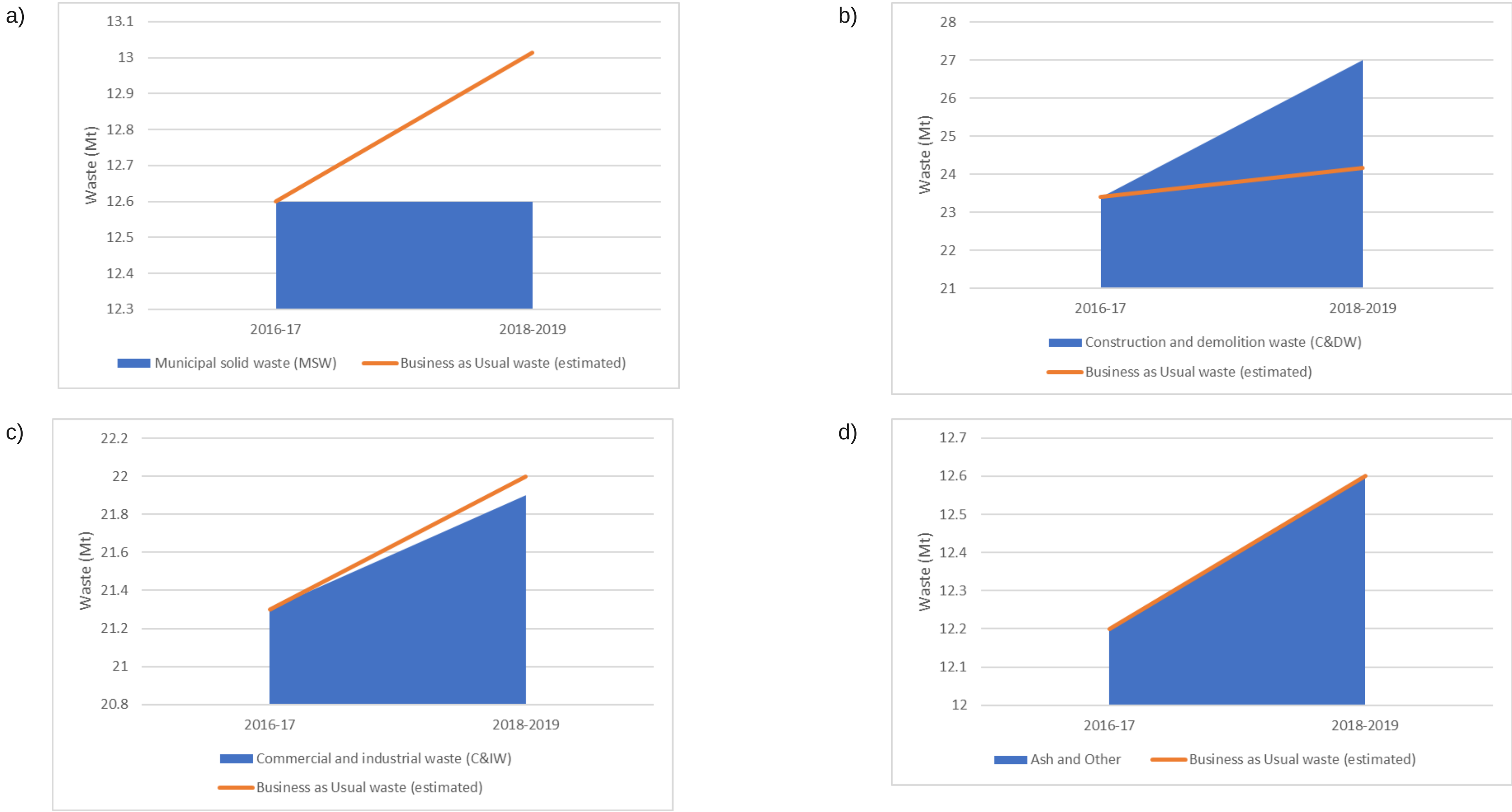
While further work is needed to calibrate this modelling for real use, the examples in Figures 4, 5 and 6 illustrate:

- that the current practice for aggregate measurement can be improved to increase the validity of this measure
- how such an approach can enable sectors of the economy which are preforming well (or poorly) to be identified and better understood.

The information presented here is complimented by an academic working paper which contains in-depth and technical elaboration on the model and links to the literature.

Readers can request of a copy of the working paper (and provide feedback on the approach summarised here) by contacting: paul.j.brown@uts.edu.au

Figure 6: Illustration of proposed method comparing estimated BAU to actual waste generated by sector, using 2017-18 to 2018-19 data



CONCLUSION AND RECOMMENDATIONS

Our analysis reveals a number of opportunities for improving the measurement of waste prevention outcomes, which are presented here as recommendations:

Investigation and collation of data currently available or forthcoming to produce a pilot measurement report on the level of overall waste prevention outcomes at the national level. This investigation to include a gap analysis of the desired and available data: We propose that detailed work be conducted to map existing data as well as collaborate and consult with state and local government, and industry stakeholders to produce a pilot report. This pilot measurement report would adapt the proposed model in this report to the extant information environment and evaluate gaps and opportunities for improved reporting.

National database of deemed waste prevention outcomes: To lower the cost involved in measuring waste prevention outcomes, we propose that a similar approach to Life Cycle Analysis be pursued. We propose that multiple studies be conducted to estimate average waste prevention outcomes of key waste prevention activities, and that these be collated and maintained in a publicly available database. These estimates may then be used as 'deemed outcomes' for key activities, which would enable individuals and organisations to match measures of activities and decisions to these deemed values to estimate the level of outcome. Also, such a database could include financial and other data to enable the matching of aggregate financial data back to activities and outcomes where plausible. For example, total Gross Value Add for the repair sector could be combined with a deemed value based on average waste prevented from the cost of repair activities. The deemed waste data would also be informed by the representative surveys that may be implemented at some designated frequency (for the purposes of updating the currency of the deemed data).

Identification and classification of key waste prevention opportunities in terms of ease of adoption and / or magnitude of opportunity: At present there is no clear hierarchy of what waste avoidance actions and system changes are likely to have the greatest impact on waste reduction. To address this recommendation we propose:

1. **Representative surveys and interviews be conducted across key sectors including households, for the purpose of identifying what actions and policy measures are plausible and desirable and at what magnitude:** This work would include measurement of key waste avoidance activities and self-estimates of actual waste generation outcomes, and self-estimates of the quantum of waste that would have been generate had the action or system change not occurred. This data could be combined with other measures of waste prevention activities and outcomes to provide a method to aggregate activities and extrapolate to a broader context.
2. **The conduct and collation of targeted studies investigating the outcomes of plausible waste prevention actions, decisions and policy interventions:** This recommendation is linked to the previous one in that, at present it is not clear which policy interventions are likely to have the greatest impact on waste prevention. We suspect that some interventions would be prioritised, if such data was available. The outcome of these studies would be helpful in justifying policy choices and promoting informed debate and action across industry and society more broadly.

APPENDICES

APPENDIX 1 ADDITIONAL ILLUSTRATIVE EXAMPLES OF MEASURING WASTE PREVENTION

The following examples extend Scenario 1 and 2 on coffee cups (see p.18 above) and illustrate how to apply the formula and interpret the results for different types of activities. Each example is based on a single instance of an activity, as might be calculated by a single individual or organisation. These examples are not meant to be exhaustive, but rather are useful to explore the characteristics of waste avoidance measurement for different types of activities.

In general, the results are not designed to be *comparative* across scenarios (ie. to determine if Scenario 1 has more waste potential than Scenario 2) as they have not been designed with comparable numbers of activities, households, items, uses, etc. Instead, their purpose is to illustrate how the method works across a range of waste prevention activities.

Scenario A1: Substituting purchasing of a product or service by purchasing a more durable product / service

Here we illustrate the level of waste prevented as a result of substituting the disposable coffee cup for a more durable product/service, where that durable alternative is used more or less intensely. (Scenario 2 can be contrasted with this example.)

Table A1: Substituting disposable cup with reusable cup (more durable and / or more intense use)

Formula	Day of purchase	10 uses	100 uses	200 uses	Notes:
Business as usual waste generation	10g	100g	1,000g	2,000g	Expected waste is one disposable coffee cup immediately, plus another 9, 99, or 199 for each subsequent coffee.
Less: Actual waste generated	0g	100g	100g	100g	Actual waste is 100g whenever reusable cup is actually discarded
= Waste Prevented	10g	0g	900g	1,900g	While the reusable cup initially saves 10g of waste, if it is not used a sufficient number of times (in this case 10) it can actually increase waste generation.

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A2: Renting service: Increase the number of users of a product through lending, renting, swapping

This scenario illustrates the waste prevention levels as a result of renting a reusable coffee cup rather than purchasing them. [2] Here the estimations are from the perspective of the system, rather than a specific individual.

Table A2: Renting disposable coffee cup

Formula	Working (end of life)	Notes:
Business as usual waste generation	10,000g	Expected waste from one disposable coffee cup avoided (10g), times the number of disposable cups avoided (1000 in this example)
Less: Actual waste generated	120g	As a result of renting coffee cups, the use of disposable coffee cups is completely avoided. At the end of life waste is generated upon disposal (100g). There is additional waste generated by the administration of the renting operations (20g)
= Waste Prevented	9,880g	

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A3: Redesign of product / service

This simplified scenario illustrates that this method can be utilised across the entire product lifecycle, such as during production. In this example, the production of the coffee cups (whether made using foam, cardboard or plastic) would entail a level of 'offcut' material wastage in production. A redesign of the production process or upgrades in the technology for producing coffee cups could significantly reduce the level of waste by reducing the amount of offcuts material wastage in production.

Table A3: Production efficiency in producing disposable coffee cups (for 10,000 coffee cups)

Formula	Working (end of life)	Notes:
Business as usual waste generation	200g	Expected offcuts in the production of one coffee cup is 2% of material used. The amount of offcut by weight for a 10g disposable coffee cup is 0.2g per cup
Less: Actual waste generated	100g	As a result of improvements in capital equipment, the coffee cup manufacturer was able to reduce the level of inefficiency in production by 50% to 1% of material used. This means that the amount of offcut by weight for a 10g disposable coffee cup decreases to 0.1g per cup
= Waste Prevented	100g	

Note: This is a simplified example and numbers are for illustrative purposes only.

There are many ways in which the redesign of product / service may result in both up and downstream waste prevention.

[2] An actual example of such a renting scheme is Green Caffeen: (https://greencaffeen.com.au/) a Kiama based Australian coffee cup swap-and-go service for reusable takeaway coffee cups.

The following scenarios switches to illustrating the method for activities relevant to durable items, using a lawnmower as the example, generally from the perspective of one or two individual households.

Scenario A4: Buy durable lawnmower

A standard lawnmower has an expected lifespan of ~4 years from purchase. A household buying their first lawnmower specifically chose to reduce waste by investing in a higher quality, more durable lawnmower, which lasts 2x as long (8 years instead of 4 years) as a standard lawnmower.

Formula	End Of Life	Notes:
Business as usual waste generation	300kg	Expected waste over 8 years is disposal of 2 lawnmowers (two standard purchases that each last 4 years)
Less: Actual waste generated	150kg	Actual waste is 1 lawnmowers over 8 years (the durable purchase that lasts 8 years)
= Waste Prevented	150kg (eliminated)	

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A5: Buy/sell second-hand lawnmower

Household A's old lawnmower breaks. Instead of buying a new lawnmower, Household A buys an unwanted lawnmower off Household B (Household B), who no longer needs it because they have downsized (Household B sells lawnmower instead of discarding it).

Formula	At time of purchase	End Of Life	Notes:
Business as usual waste generation	300kg	450kg	Expected waste *initially* is Household A's broken lawnmower and Household B's unwanted lawnmower. Expected waste *eventually* is Household A's broken and new lawnmowers, and Household B's unwanted lawnmower
Less: Actual waste generated	150 kg	300kg	*Actual* waste *initially* is Household A's broken lawnmower. Actual waste *eventually* is Household A's initial broken lawnmower, and later discard of Household B's unwanted lawnmower (now owned by Household A) when it eventually breaks
= Waste Prevented	150kg (delayed)	150kg (eliminated)	Initially, Household A's purchase of Household B's unwanted lawnmower delayed 150kg waste because Household B didn't discard it at that time. Eventually, by not initially purchasing a new lawnmower Household A eliminated 150kg because there is one less lawnmower in total to discard.

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A6: Borrow / lend lawnmower (amongst neighbours)

Instead of buying their own lawnmower, Household A borrows a lawnmower owned by Household B whenever they need to mow their lawn.

Formula	End Of Life	Notes:
Business as usual waste generation	300kg	*Expected* waste is two lawnmowers (one for Household A, and one for Household B)
Less: Actual waste generated	150kg	*Actual* waste is one lawnmower (one for Household B)
= Waste Prevented	150kg (eliminated)	(Household A does not have a lawnmower to discard)

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A7: Repair lawnmower

When a Household's old lawnmower breaks after 4 years, they invest in getting it repaired which increases lifespan by another 50% (from 4 to 6 years). The same thing happens with their next lawnmower.

Formula	At year 4	At year 12	Notes:
Business as usual waste generation	150kg	450kg	Expected waste at 4th year is one lawnmower Eventual expected waste at 12th year is three lawnmowers
Less: Actual waste generated	0kg	300kg	Actual waste at 4th year is zero. Actual waste at 12th year is two lawnmowers.
= Waste Prevented	150kg (delayed)	150kg (eliminated)	While HHs eventually discards initial lawnmower, they have one less lawnmower in total to discard.

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A8: Return lawnmower for parts

When a Household's old lawnmower breaks after 4 years they return it to the retailer who harvests parts to be kept in inventory for repairs.

Formula	At year 4	Notes:
Business as usual waste generation	150kg	Expected waste is one lawnmower
Less: Actual waste generated	80kg	Salvaged parts weigh approx. 70kg. Actual waste is residual material of lawnmower that can't be salvaged for reuse.
= Waste Prevented	70kg (eliminated and delayed)	Waste is eliminated when salvaged parts are used in lieu of new parts.

Note: This is a simplified example and numbers are for illustrative purposes only.

Scenario A7: Borrow lawnmower from Sharing Scheme

This final scenario is from the perspective of a single organisation with multiple households as customers.

An organisation provides Lawnmowers through a subscription sharing scheme. Each subscribed household gets the lawnmower one day each month. Between 15 (50% uptake) - 30 (100% uptake) local households subscribe. In this example the subscription lawnmower is much more durable than a typical household mower and therefore last the standard 4 year period despite the substantially increased intensity of use.

Formula	50% uptake	100% uptake	Notes:
Business as usual waste generation	4,500kg	4,500kg	Expected waste is one lawnmower per each of 30 households in area
Less: Actual waste generated	2,400kg	150kg	At 50% uptake of scheme, actual waste is one lawnmower for the scheme, and one lawnmower for each of 15 HHs not subscribed (ie. 16 lawnmowers). At 100% uptake, actual waste is one lawnmower for scheme.
= Waste Prevented	2,100kg (eliminated)	4,350kg (eliminated)	(Between 15 – 30 HHs avoid owning and therefore disposing of a lawnmower.)

Note: This is a simplified example and numbers are for illustrative purposes only.

APPENDIX 2: INDICATIVE INDICATORS FROM REVIEW OF LITERATURE AND PRACTICE

A comprehensive review was conducted (Brown et al., 2021) to identify what measurement was being used in national and international reporting, and literature. We identified over 100 different measures. We conducted a thematic analysis of them to identify key measurement methods in practice and theory. In exhibit A1 we present those which have some relation to each of the waste prevention measurement methods and context presented in Figure 2. A notable observation from this exercise is that while there is some overlap, there is a substantial gap between the metrics and indicators in practice and what we propose.

Exhibit A.1: Summary of Waste Prevention Measurement metrics and information sources

Panel A1.A: Waste prevention measurement categories

Waste Prevention Measurement Categories	Waste Prevention Measurement Metrics and Indicators	Measurement Definition	Indicative information / Data Source Examples
1a. *Measurement of* <u>**aggregate waste prevented by weight**</u> *(including breakdown of changes in waste generated by key sector and waste stream)*	Reduction in waste managed [reduction in waste generated]	Reduction in the amount [tonnage] of waste entering waste facilities Reduction in the amount [volumetric] of waste entering waste facilities Reduction in the composition of waste entering waste management facilities	<u>Waste Processing Facilities:</u> [Baseline weight of waste entering a facility] - [Weight of waste entering a facility at a later date] May be divided by GDP (or similar) or population to give a per GDP or person metric
	Unprocessed resources recovered from managed waste	The amount of resources recovered from landfill after disposal, such as gleaner.	<u>Waste Processing Facilities:</u> [Weight of waste collected during recovery activities over time]
	Reduction in organisational waste	Reduction in the amount and composition of waste generated by an organisation including bin audits, self-reported and other methods	<u>Manufacturing & Construction:</u> [Baseline weight of waste exiting a facility] - [Weight of waste exiting a facility at a later date]
	Reduction of waste present in the environment	Over time change in the waste present in the environment. Reporting based on data collected about the volume and composition of waste collected from the environment (pollution) and enters the formal waste management system. e.g. data collected over time from clean up Australia day.	<u>Government:</u> [Waste material audit in sample areas of total physical space] <u>Community Organisation/Event:</u> [Baseline number of waste items collected from a physical space] - [Number of waste items collected from a physical space at a later date]

Waste Prevention Measurement Categories	Waste Prevention Measurement Metrics and Indicators	Measurement Definition	Indicative information / Data Source Examples
1b. Reductions in pollution emissions attributable to waste prevention	Reduction in greenhouse gas (GHG) emissions from landfills	Reduction in the volume and composition of greenhouse gas (GHG) emitted from landfill	Waste Processing Facilities: [Baseline quantity of greenhouse gases collected by filters at a facility] - [Quantity of greenhouse gases collected by filters at a facility at a later date] [Baseline type/composition of greenhouse gases collected by filters at a facility] - [Type/composition of greenhouse gases collected by filters at a facility at a later date]
	Emissions reduction from recycling		Waste Processing Facilities: [Baseline quantity of greenhouse gases measured at a facility] - [Quantity of greenhouse gases measured at a facility at a later date after recycling processes have been implemented]
2a. Measurements of waste eliminated by key waste avoidance opportunities	Reduction in resource use through design	Observable changes to pre-production design of products to be resource efficient regarding: (i). reduction in resources required to produce the products, (ii). product life and use over time, and (iii). repair, repurposing or recycling options	Existing Product Redesign: [Baseline weight of raw materials entering a facility] - [Weight of raw materials entering a facility at a later date] New Product Design: [Baseline weight of raw materials typically used in typical products existing in the market] - [Weight of raw materials used in newly designed products]
	Reduction in resource use through substitution	The number of alternative products or services used to reduce resource consumption by specific category, such as physical to digital services or adoption of waste reducing technology.	Manufacturing & Construction: [Baseline weight of raw materials entering a facility] - [Weight of raw materials entering a facility at a later date after substitution has been implemented] Homes: [Baseline of self-reported consumption behaviours] - [self-reported consumption behaviours at a later date after substitution has been implemented]
	Theoretical waste eliminated (i.e. replacement of single use by reusable / durable)		
	Reduction in raw material use	Reduction in the amount of raw material used in the economy. May be estimated at an economy or sector level, such as raw material relative to GDP, or may be measured at a product or other level such as weight of product or packaging.	Manufacturing & Construction: [Baseline weight of raw materials entering a facility] - [Weight of raw materials entering a facility at a later date]

Waste Prevention Measurement Categories	Waste Prevention Measurement Metrics and Indicators	Measurement Definition	Indicative information / Data Source Examples
2b. Measurements of life of products and components extended (waste delayed) by key waste delay and avoidance opportunities	Level of reuse, repair or leasing activity	The level of reuse, repair or leasing activity may include estimates of the volume, type and/or financial value of activities at different levels of aggregation including by sector. May include resources used in production processes prior to entering the system.	Reuse, Repair or Leasing Organisation: [Baseline number of transactions or customers] - [Number of transactions or customers at a later date] Homes: [Baseline of self-reported reuse, repair or leasing activities] - [Self-reported d reuse, repair or leasing activities at a later date]
	Changes in the level and composition of consumption.	Observable changes to consumer behaviour sourced from 'Point of Sales', and other data collected by organisations (e.g. a retail or grocery store)	
	Volume of [resource / waste] repurposed	The amount of resources that were recovered and repurposed in the system, prior to disposal to landfill.	Homes: [Baseline of self-reported repurposing activities] - [Self-reported repurposing activities at a later date]

Source: Modified from Brown et al. (2021)

Panel A1.B: Waste prevention context categories

Waste Prevention Context Categories	Waste Prevention Measurement Metrics and Indicators	Measurement Definition	Indicative information / Data Source
3. Changes in awareness, values beliefs and attitudes related to waste prevention opportunities (leading indicators)	Awareness of waste prevention possibilities		Representative survey/interview of key populations enquiring scale/level of awareness of core related topics/ideas/terms
	Values, beliefs and attitudes regarding waste prevention		Representative survey/interview of key populations enquiring about the participants relationship and value of waste prevention as a concept, and as a practise
4. Relevant changes to policy, economic and technology context	Expenditure on waste prevention technology and programs	The amount of money spent on waste prevention technology and programs.	Community Organisation/Event: [Baseline cost of waste prevention technology or program execution] - [Cost of waste prevention technology or program execution at a later date]
	Number of organisations and programs involved in waste prevention	The number of organisations actively engaged with resource use reduction (e.g. programs and initiatives)	Community Organisation/Event: [Baseline number of industry partners in a waste prevention program] - [Number of industry partners in a waste prevention program at a later date]
	Level of waste prevention activities by participating organisations	The number of resource reduction activities in a program or within an organisation	Community Organisation/Event: [Baseline number of waste prevention activities self-reported by an industry partner] - [Number of waste prevention activities self-reported by an industry partner at a later date]

Source: Modified from Brown et al. (2021)

APPENDIX 3: STAKEHOLDERS ENGAGED

Stakeholders consulted	Number of individuals
Interviews	
Department of Climate Change, Energy, the Environment and Water	2
Data Stakeholders	2
Peak Industry and Civil Society Groups	2
State Government	6
Research organisations	6
Total Interviews	*18*
Group consultation (State Government)	
Total Consulted	22
Total stakeholders	*39*

Note: One stakeholder for the group consultation was also included in the interview group.
Due to human research ethics guidelines at UTS, individuals have been de-identified.

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