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# Cost benefit analysis of options for an e-waste landfill ban in Western Australia

Report to the Department of Water and Environmental Regulation (DWER)

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# Contents

# Figures and Tables

# 1 Introduction

Waste electrical and electronic equipment (e-waste) has been identified as one of the fastest growing waste streams globally.[1] This trend is primarily driven by continuous advancements in electrical product (e-product) technology, which makes e-products become out-dated quicker and cheap to replace. E-products are therefore being replaced earlier in their lifecycle and entering the waste stream sooner.

E-waste is commonly defined to be[2]:

> "waste electrical and electronic equipment, and includes components, subassemblies and consumables which are part of the original equipment at the time of discarding".

This definition includes products that are powered by an electrical cord or that are battery powered.

## 1.1 Background

In Western Australia, approximately 70,000 tonnes of e-waste is generated each year (equivalent to around 25 kg per capita), with only 27% of this being recycled[3]. It is likely the remainder may be disposed to landfill. Projections from a recent study by Encycle Consulting[4] indicate that while e-waste presently only accounts for 1.2% of all waste generated in the state (by weight), the volumes are forecast to increase at three times the rate of general household waste. By 2030, it has been estimated that the total annual tonnage of e-waste generated in Western Australia will grow to 86,000 tonnes[5], or 1.5% of total waste output.

The relatively low recycling rates for e-waste (for example, compared to construction and demolition waste, for which over 80% is recycled) together with growing volumes of e-waste being generated has prompted the State Government to announce a proposed ban on disposal of e-waste to landfill by 2024, together with $14 million in funding for implementing the new regulations. The intent of the ban is to promote increased collection of e-waste for recycling.

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1 Golev, A., 2016, *Where next on e-waste in Australia?* Waste Management, 58, 348-358.

2 Bontinck PA, Bricout J, Grant T and Legoe G (2021) *E-product stewardship in Australia: Evidence report*. A report prepared for the Commonwealth Department of Agriculture, Water and the Environment by Iceni Group and Lifecycles, Sydney, Australia.

3 Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*, prepared for the Department of Water and Environmental Regulation, 8 September 2021 (the 70,000 tonnes excludes batteries and photovoltaics).

4 ibid

5 Excludes batteries and photovoltaics

The landfill ban, accompanied by government financial support to help build the necessary collection and processing infrastructure, is designed to catalyse the e-waste recycling industry in the state. This will not only generate commercial benefits and employment, but also lead to improved environmental and public health outcomes. A ban also aligns with actions to meet national targets, identified under the *National Waste Policy Action Plan 2019*[6].

Victoria and South Australia have legislated a ban on e-waste disposal to landfill. The Australian Capital Territory has banned computers and televisions from disposal to landfill, in a non-legislative approach. The Queensland Government is currently partnering with the E-Waste Watch Institute to co-design an E-Products Action Plan to address waste and other impacts from end-of-life electrical and electronic products[7].

## 1.2 Rationale for intervention

The McGowan government made an election commitment to ban e-waste to landfill by 2024. Factors and issues that support this commitment are summarised as follows:

- **Lost resources and income** – e-waste typically contains a range of materials and minerals that are both valuable and that otherwise require extraction from non-renewable resources (i.e. via mining). When e-waste is disposed to landfill these resources are lost, resulting in ongoing reliance on raw materials.

- **Environment and health risks** – e-waste often contains a range of materials that can be toxic and harmful. If not appropriately handled, processed or disposed, these materials may pose risks for human health and the environment.

- **Potential for employment opportunities** – previous economic modelling by Access Economics has estimated that 9.2 persons are employed for every 10,000 tonnes of waste recycled, which is considerably higher than the estimated two persons employed if that same volume of waste was landfilled[8]. Given the high level of manual processing often required for e-waste, it is possible that the employment needed for e-waste recycling may be even higher[9].

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6 Department of the Environment and Energy, 2019, *National Waste Policy Action Plan 2019*, Canberra.

7 Queensland E-Products Action Plan: accessed on https://ewastewatch.com.au/queensland-eproducts-action-plan/

8 Access Economics, 2009, *Employment in waste management and recycling*, Report by Access Economics Pty Limited for the Department of the Environment, Water, Heritage and the Arts, 2 July 2009.

9 While recycling may increase total jobs in the waste sector, these may not necessarily represent a net increase in employment across the economy if other sectors experience job losses due to higher costs imposed by a landfill ban.

- **Community expectations** – previous research has shown that the community values increased recycling of e-waste, with the average Australian previously estimated to be willing to pay $0.50 per e-waste item for every percentage point increase in recycling[10]. In the same study, Perth residents were estimated to pay a slightly higher $0.55 per item. These preferences for increased e-waste recycling may be attributable to community values for reduced environmental risks and a circular economy.

- **Market failures** – the prevailing high rates of e-waste disposal to landfill would indicate that the costs of collecting, segregating and processing e-waste generally outweigh the commercial value of materials recovered. However, a portion of these costs may reflect the impact of market failures, including:
  - information costs for waste generators – not knowing where e-waste can be taken for recycling;
  - co-ordination costs - the costs of aggregating and collating e-waste that is characterised by irregular and dispersed generation; and
  - economies of scale - having sufficient quantities of e-waste to make collection and reprocessing economically feasible.

  Where market failures exist and the likely cost of government action to address those market failures is less than the potential benefit of doing so, government actions are warranted.

## 1.3 This report

Synergies Economic Consulting (Synergies) has been engaged by DWER to assess the financial and economic costs and benefits associated with three proposed implementation options to ban e-waste disposal to landfill:

- Option 1 – Voluntary landfill ban
- Option 2 – Regulatory ban with voluntary elements
- Option 3 – Regulatory ban with extensive obligations

A cost benefit analysis (CBA) is used to evaluate the relative net economic benefits of each option against a base case scenario in which the Western Australian government does not invest in promoting additional e-waste recovery. In addition to the CBA, the financial impacts of each option on key stakeholder groups is quantified.

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10 URS 2009, *Willingness to Pay for E-Waste Recycling*, Final Report, Prepared for Environment Protection and Heritage Council, 23 June

The analysis is designed to inform policy considerations about the relative advantages and disadvantages of each option and to identify a preferred option for managing the implementation of an e-waste to landfill ban in Western Australia.

The remainder of this report is set out as follows:

- Section 2 sets out the volumes of e-waste generated in Western Australia and how it is currently managed;
- Section 3 describes at a high level the approach used to conduct the analysis;
- Section 4 details the base case and implementation options that were assessed;
- Sections 5 and 6 set out the benefits and costs (respectively) that were modelled in the CBA, including their supporting assumptions;
- Section 7 summarises the results from the cost benefit analysis (including sensitivity analysis); and
- Section 8 presents the financial impact of the proposed implementation options on key stakeholders.

Technical details of the modelling and assumptions are contained in the Appendices.

# 2 Current e-waste generation and management

In 2021 DWER engaged Encycle Consulting to prepare a Material Flow Analysis (MFA) which developed estimates on the rates of e-waste generation and recovery in Western Australia (as at 2019-20), including supporting services and infrastructure. This section presents key statistics from this study to build a picture of the current situation in relation to e-waste in the state.

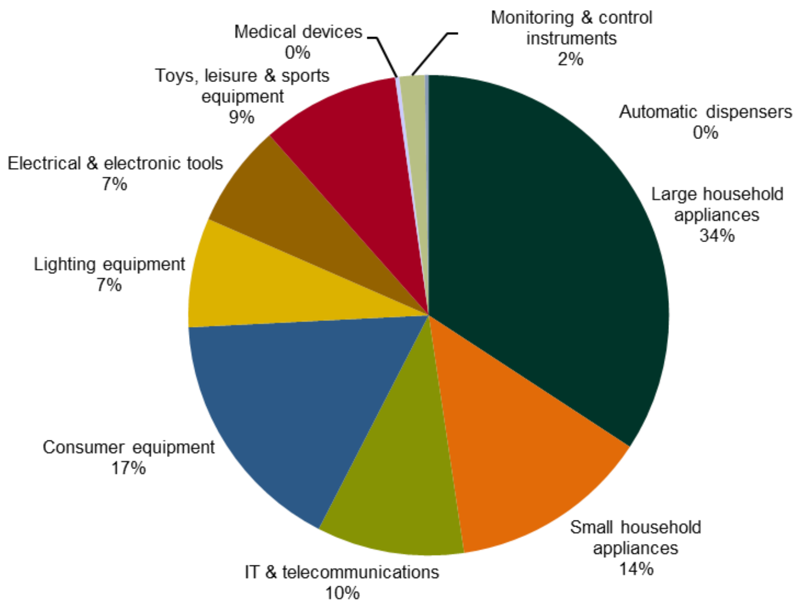
Synergies has also drawn on data from other sources to identify the volume of waste batteries and photovoltaic systems (PVs) which are estimated to be generated each year in Western Australia (noting that these categories of e-waste did not form part of Encycle's analysis).

## 2.1 Current generation and recycling rates

### 2.1.1 E-waste generation

The total volume of e-waste generated in Western Australia in 2019-20 (excluding batteries and PVs) was estimated by Encycle to be 68,663 tonnes. Figure 1 shows a breakdown of this waste by e-product type.

**Figure 1 E-waste generation in Western Australia by e-waste category, 2019-20**




**Data source:** Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*, report prepared for the Department of Water and Environmental Regulation, September 2021.

Large household appliances account for the largest share (34%) and includes fridges, washing machines, clothes dryers, dishwashers and cookers. This was followed by consumer equipment (17%) – which includes music instruments, speakers and cameras. Small household appliances account for 14% (eg vacuum cleaners, irons, kettles and toasters), while IT and telecommunications (eg computer equipment, televisions and mobile phones) account for 10%.

### 2.1.2 Recovery (recycling) rates

Of the total 68,663 tonnes of e-waste 18,737 tonnes was estimated to be recycled, equivalent to a 27% recovery rate overall (to avoid confusion, throughout this report the term 'recovery rate' refers to the tonnes of e-waste recycled as a percentage of e-waste generated. It does not refer to the tonnes of materials recovered as a percentage of the tonnes collected).

E-waste recovery data from DWER[11] indicates that approximately one third of e-waste recovered in 2020-21 came from commercial sources, with the other two thirds from the residential sector.

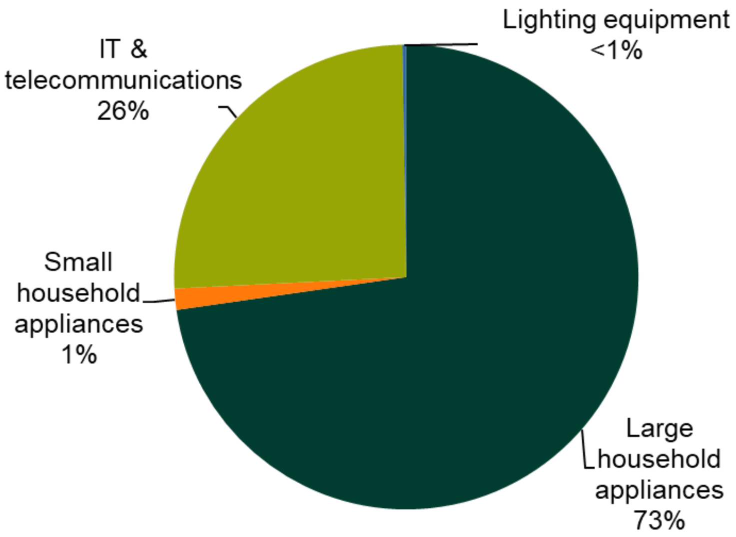
Some types of e-waste have higher recovery rates than others, as illustrated in Figure 2 which shows the share of each type of e-waste recovered relative to the total volume recovered in 2019-20. For example,

- 58% of large household appliances were recycled, which represents to 13,629 tonnes and accounts for 73% of all e-waste recovered; and
- 70% of IT and telecommunications products were recycled, which represents 4,782 tonnes and accounts for 26% of all e-waste recovered.

Small household appliances and lighting products have much lower recovery rates, each at just 1% or less.

[11] This data is based on the proportion of e-waste within the commercial and industrial (C&I) waste stream relative to e-waste within the Municipal Solid Waste (MSW) stream. The data is current for the 2020-21 local government waste reporting period.

**Figure 2 E-waste recovery in Western Australian by e-waste category, 2019-20**




**Data source:** Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*, report prepared for the Department of Water and Environmental Regulation, September 2021.

### 2.1.3 Waste batteries and photovoltaics

While the Encycle MFA includes detailed modelling and forecasting for 10 different e-waste categories, it does not include waste generation or recycling estimates for PVs. In the case of batteries, volumes currently generated are estimated but recycling rates are not included in the MFA.

Synergies used what information was available in the MFA for batteries and PVs and combined this with other data to model current e-waste generation tonnages and recovery rates for these two additional categories. This included data from a Commonwealth Department of Agriculture, Water and the Environment model and report on e-product stewardship in Australia[12] and 2020-21 waste recovery data from DWER.[13]

Using this additional data, batteries currently account for a significant proportion (18%) of total e-waste generation[14], while PVs presently account for just 2% of e-waste generation, by weight.

[12] Bontinck PA, Bricout J, Grant T and Legoe G (2021) *E-product stewardship in Australia: Evidence report.* A report prepared for the Commonwealth Department of Agriculture, Water and the Environment by Iceni Group and Lifecycles, Sydney, Australia.

[13] Department of Water and Environmental Regulation (2022) *Recovered tonnes in WA 2019-20, 2020-21*

[14] Includes all types of batteries, including lead-acid

## 2.2 Current e-waste services and infrastructure

A key determinant of Western Australia's e-waste recycling performance and capability is the collection network, processing services and infrastructure for receiving and managing e-waste for recycling and material recovery.

The current status of e-waste services and infrastructure in the Perth metropolitan area and regional areas is described below.

### 2.2.1 Collection services and infrastructure

The e-waste collection network in Western Australia includes fixed drop-off locations, pick-up services and periodic collection events.

Many metropolitan and some regional waste transfer stations have drop-off facilities for household and commercial e-waste. Such waste transfer stations may be required to hold a Category 62 solid waste depot licence under the *Environmental Protection Regulations 1987*, depending on the activities on the premises and the threshold of production or design capacity on that premises. There are currently 167 licensed Category 62 solid waste depot premises in Western Australia comprising:

- 88 in the Perth-Peel region;
- 19 in major regional centres (as identified in the Waste Strategy); and,
- 60 in regional areas.

Encycle identified thirteen transfer stations in the Perth-Peel region, six in the south-west region and a further five in other regional locations (York, Karratha, Geraldton, Kalgoorlie-Boulder and Esperance) that accept e-waste for recycling. It may be likely that a higher number of the 167 Category 62 premises across Western Australia accept e-waste for recycling. Such facilities would likely be a key focus for establishing a network of e-waste collection infrastructure to support the ban on e-waste to landfill disposal.

Encycle noted that e-waste currently dropped off at local government waste transfer stations is primarily computers, televisions and other small household appliances, which are then recycled (to the extent possible subject to recycling capacity and markets for the recovered materials).

E-waste may be collected by local governments at fixed drop-off locations such as community drop-off or bulk aggregation point, recycling facilities, libraries/council buildings or disposal sites. A fee per item is sometimes charged for acceptance and for degassing where required (eg fridges, freezers, air conditioners). The categories accepted may include large household appliances that yield value for metal, items under the National Television and Computer Recycling Scheme (NTCRS) and lead acid batteries.

Fixed drop-off locations also exist at retail shop fronts for e-waste covered under NTCRS[15]. Many of these services are in the Perth-Peel region, however regional outlets also exist in Broome, Ashburton, Narrogin, Karratha, Port Hedland, Esperance, Geraldton and Carnarvon.

Some local governments also provide a pick-up service that collects e-waste placed on household vergesides[16]. Vergeside pick-up services include general bulk-waste vergeside collection services (in which e-waste can be put out for collection with other bulk-wastes) or separate 'on-call' vergeside collection services (also referred to as 'valet' service).

Periodic and ad-hoc drop-off collection events for e-waste are a further mechanism by which e-waste is collected. These events provide an opportunity for large amounts of e-waste to be collected at once, sometimes for a number of localities combined. Many only cover NTCRS related e-waste and event locations vary year to year.

Data reported to DWER by local governments under regulation 18C of the *Waste Avoidance and Resource Recovery Regulations 2008* provides an indicative snapshot of the relative importance of the various types of local government e-waste collection services, in terms of volumes of waste collected through each channel[17]. Local governments report on the recovery of categories of waste that are relevant to e-waste: "electric and electronic goods", "whitegoods" and "batteries". While the reported data may be subject to some quality issues, due to unit measurement conversion errors, it nevertheless provides a reasonable picture of typical volumes of e-waste collected by local government[18].

For electric and electronic goods reported as recovered by Perth and Peel local governments in the 2020-21 financial year, drop-off services and vergeside services were roughly equal as a source of recovery, with each service accounting for roughly 700 tonnes of recovered waste. For non-metropolitan local governments, virtually all recovery of electric and electronic goods was via drop off services, with 342 tonnes recovered via drop off services compared to 11 tonnes from vergeside services.

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[15] DAWE provides details on organisations approved to provide recycling and collection services under NTCRS at https://www.awe.gov.au/environment/protection/waste/consumers/recycling-drop-off

[16] Consistent with the Waste Authority's approach, vergeside services in this report are assumed to involve the collection of bulk waste from household verges, which is distinct from kerbside bin services (for comingled recycling and green-waste).

[17] Permission granted by DWER to publish data, which was self-reported to DWER by local governments under regulation 18C of the Waste Avoidance and Resource Recovery Regulations 2008

[18] Personal communication, Policy Officer, DWER.

For whitegoods reported as recovered, vergeside services accounted for the majority of recovery reported by local governments in the Perth metropolitan region (ie. 1,772 tonnes or 96% of total whitegoods collected, by weight). The opposite was true for non-metropolitan areas, with 262 tonnes (89%) of whitegoods recovered sourced from drop off, reflecting the relative lack of vergeside services available in regional areas.

For batteries reported as recovered, 955 tonnes were recovered via resident drop-off in 2020-21, with no battery waste reported as collected via vergeside collection services. Of this total, 560 tonnes (59%) were collected in the Perth metropolitan region, and 46 tonnes (5%) collected in the Peel region. The remaining 349 tonnes (36%) were collected in non-metropolitan areas.

Data on periodic e-waste drop-off events is captured under drop-off services. As a result, it is difficult to identify the relative contribution of periodic drop-off events to e-waste recycling in Western Australia relative to fixed drop-off services and vergeside services.

*Adequacy of e-waste collection infrastructure*

A detailed audit of existing infrastructure capacity for collecting, handling and temporarily storing specifically "e-waste" at various locations in the state has not been undertaken. The number of drop-off points and handling capacity has increased over time but some areas are better serviced than others on a per capita basis. To support an e-waste to landfill ban, upgrading the existing and providing new collection infrastructure is required.

### 2.2.2 Recycling infrastructure and processing services

E-waste generated in Western Australia is recycled by commercial e-waste specialist recyclers and scrap metal recyclers, either locally in Western Australia or exported to other states for further processing.

The largest e-waste specialist recycler in Western Australia is located in Welshpool, which services the entire state. While licensed to process 4,000 tonnes[19], it reported processing 2,906 tonnes of waste over the year ending April 2021[20]. The facility offers waste generators a processing service for items covered in the NTCRS; and services a number of local governments and private industry. It uses both manual- and machinery-based processing, which includes the use of shredders, magnets, a hammer mill, an eddy current separator, and a recently acquired optical sorter (to better recover capture copper

19 https://www.der.wa.gov.au/component/k2/item/download/10078_6b133b4f9b62a6ce2b97dba774ba3e26

20 Annual Audit Compliance Form, available at: https://www.der.wa.gov.au/images/documents/our-work/licences-and-works-approvals/aacr/L9227-2019-1_01MAY20-30APR21_Redacted.pdf

wire and circuit boards)[21]. It also resells and reuses units and componentry that are still functional[22]. The recycler has recently announced a partnership with a large-scale European based e-waste recycler which will likely see its processing capacity expand in future[23].

According to Encycle Consulting, there are an additional three specialist e-waste recyclers located in the Perth-Peel region. Encycle also identified an additional six recyclers that provide services focused on items with high metal composition, predominantly large household appliances and to a lesser extent small household appliances, monitoring instruments and automatic food/drink dispensers.

While battery recycling infrastructure in Western Australia was not specifically discussed as part of Encycle's analysis, a Western Australian based lithium battery producer recently purchased the only B-cycle stewardship scheme accredited and EPA permitted battery recycler based in Victoria[24]. This is likely to represent further potential for expansion in recycling capacity in Western Australia.

Finally, the Department of Jobs, Tourism, Science and Innovation is undertaking ongoing work into the development of a downstream battery manufacturing industry in Western Australia, which includes the creation (and updating) of the Future Battery Industry Strategy Western Australia. The work explores the future demand for batteries in Western Australia, as well as the resulting battery waste and the options for battery recycling facilities in Western Australia.

## 2.3 Current management of e-waste

Western Australia's current legislation and policy framework sees e-waste managed consistent with other categories of waste. This is primarily under the *Waste Avoidance and Resource Recovery Act 2007* (WARR Act) and the *Environmental Protection Act 1986* (EP Act). Waste avoidance, recovery and environmental protection are also encouraged under the *Waste Avoidance and Resource Recovery Strategy 2030*.

While the disposal of e-waste to landfill is currently not prohibited, it is disincentivised through the waste levy which applies to all waste disposed to landfill. Despite the waste levy, in some cases it continues to be cheaper for e-waste to be disposed of to landfill

21 https://www.totalgreenrecycling.com.au/optical-colour-sorter/

22 https://www.totalgreenrecycling.com.au/recycling/computer-and-mobile-devices/#1485933555107-f9703b0b-ee1c4d0e-37a5

23 https://www.totalgreenrecycling.com.au/total-green-recycling-joins-forces-with-scipher-to-future-proof-e-waste-recycling/

24 https://envirostream.com.au/lithium-australia-now-fully-owns-strategic-battery-recycling-asset-envirostream/

rather than diverted for recycling, as is evidenced by the high proportion of e-waste that is estimated to end up in landfill.

Environmental protection from e-waste is primarily achieved through generic obligations for all waste outlined in the EP Act and its subsidiary regulations for operators of landfills, recycling facilities and waste transfer stations. While there are limited environmental protection obligations relating specifically to e-waste, three categories of batteries are identified as controlled wastes under the *Environmental Protection (Controlled Waste) Regulations 2004*. This requires these products be transported by licenced transporters and managed appropriately by anyone holding these items.

E-waste management in Western Australia is also influenced by several national product stewardship schemes. Product stewardship is an approach to managing the impacts of different products and materials. It acknowledges that those involved in producing, selling, using and disposing of products have a shared responsibility to ensure that those products or materials are managed in a way that reduces their impact, throughout their life cycle, on the environment and on public health and safety[25].

The most significant e-waste product stewardship scheme in Western Australia is the NTCRS. It covers televisions and computers (including printers, computer parts and peripherals) and has been in place since 2011. The scheme includes a national e-waste recovery target of 80% by 2026-27[26]. Other product stewardship arrangements in place in Western Australia include MobileMuster (for mobile phones, related componentry, network connectivity and smart devices), B-Cycle (for batteries, established in February 2022) and Fluorocycle (for mercury containing lighting). While these schemes are generally proving effective at encouraging greater recycling, they do not cover all categories of e-waste.

[25] https://www.wasteauthority.wa.gov.au/images/resources/files/Strategic_Direction_Waste_Avoidance_and_Resource_Recovery_Strategy_2030.pdf

[26] Department of the Environment (2015), National Television and Computer Recycling Scheme – Operation of the Scheme, available at: https://www.dcceew.gov.au/sites/default/files/documents/factsheet-national-television-and-computer-recycling-scheme-operation.pdf.

# 3 Methodology

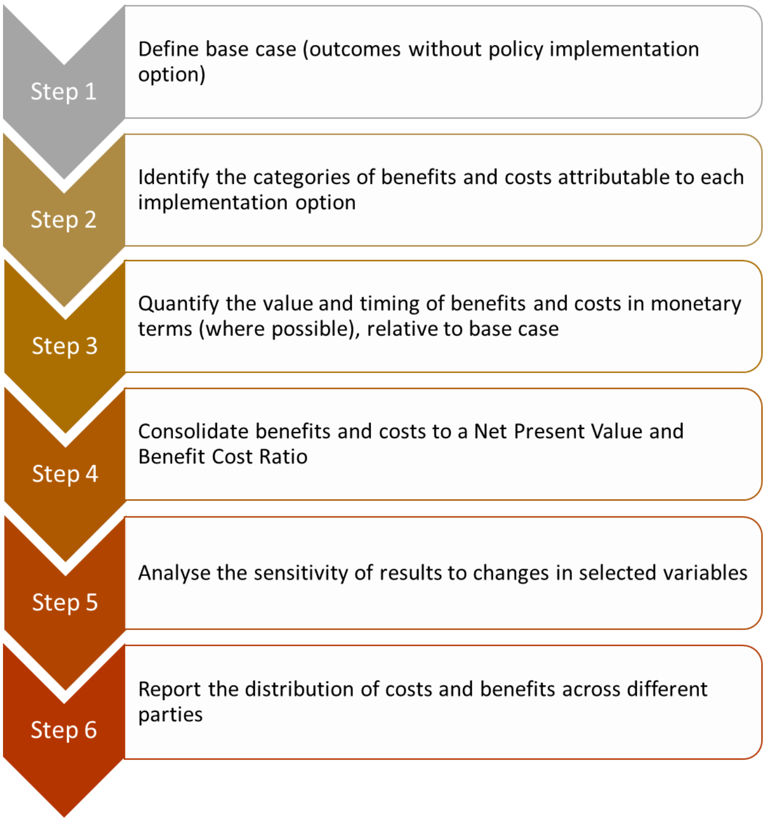
This section outlines the approach applied in undertaking the assessment and modelling of options for an e-waste landfill ban in Western Australia and the primary data and information sources that informed the analysis.

For the purpose of the analysis we assessed costs and benefits over a 20-year timeframe, commencing in 2023 with the first expenditure on program design, and with the ban first coming into effect in 2024. The 20 year timeframe allows adequate time for the full costs and benefits of the implementation options to be captured.

## 3.1 Cost benefit analysis framework

The net economic benefit of three e-waste implementation options was assessed using a high-level CBA. The analytical framework comprises a six-step process, as shown in Figure 3. Each step is described in further detail below

**Figure 3 CBA steps**




**Data source:** Synergies

### 3.1.1 Define the base case

The base case forms the basis against which the impacts of implementation options are described, measured and assessed. Drawing on an understanding of current arrangements for e-waste in Western Australia as well as current e-waste flows, the base case was defined in terms of the outcomes that would eventuate over the next 20 years without a ban on e-waste. This primarily focused on quantifying anticipated e-waste generation, recovery and landfill rates but also considered likely 'organic' growth in the e-waste collection services and recycling industry over time (partly attributable to the introduction of new product stewardship schemes). See section 4.1 for a description of the base case.

### 3.1.2 Identification of costs and benefits under each implementation option

The three e-waste ban options were identified by DWER that would meet government policy objectives and also meet the State Government's election commitment (see section 4.2 for a description of the options).

Having defined the options, the types of costs of benefits of each option were identified, all relative to base case. These impacts are summarised in Table 1.

**Table 1 Categories of costs and benefits**

| Costs | Benefits |
|---|---|
| Collection and transport costs | Commercial benefit from materials recovered |
| Collection infrastructure upgrade costs | Heath and environmental benefits |
| Processing centre upgrade costs | Avoided landfill costs |
| Stockpiling and unlawful disposal cost | |
| Industry reporting costs | |
| Government monitoring and enforcement costs | |
| Education and communication costs | |
| Start-up government implementation costs | |

**Note:** 2043 has been selected as the last year in the analysis to give a snapshot as to the total amounts of waste recovered per year under the different options.

### 3.1.3 Quantify the value and timing of benefits and costs

This step involves two modelling exercises. One is the physical modelling of the volumes of e-waste generated, collected, recycled and landfilled. The other is an economic model that applies monetary values to the impacts arising through the management, processing and sale of recycled products.

*The stock and flow model*

A high-level 'stock and flow' model was developed to quantify and forecast over the next 20 years the annual volumes of e-waste being generated, collected, recycled, and stockpiled (or illegally disposed) under each of the implementation options and base case. This is done at a disaggregated level of each of 10 categories of e-waste.

The annual volume of e-waste generated is assumed to be the same across all three implementation options and the base case. The three possible 'fates' for e-waste are:

- disposal to landfill;
- recovered and recycled/reprocessed;
- stockpiled (for a prolonged period) or unlawfully disposed outside of a licensed facility.

Recovery rates are assumed to increase over time under the base case due to progressive improvement in community awareness and 'organic' growth in the recycling industry, but more slowly compared to the implementation options. Maximum possible recovery rates are capped at 90% or below , reflecting the fact that it is impracticable to recycle every tonne of e-waste generated. However, we assume relatively higher maximum recovery rates for the implementation options with greater levels of enforcement, as outlined in Appendix B.

*Economic model*

The economic model is used to estimate the annual cost and benefits of the activities depicted in the stock and flow model. All costs and benefits are measured relative to base case. The economic model draws on price information for a wide variety of relevant inputs and outputs.

### 3.1.4 Consolidate benefits and costs

At this step, the annual costs and benefits are consolidated over the 20-year forecast period using discounted cashflow analysis, which produces a Net Present Value (NPV) and Benefit Cost Ratio (BCR). This is done separately for each of the implementation options for comparison.

A discount rate of 7% was used (with sensitivity tests performed at 4% and 10% rates). This is consistent with the Office of Best Practice Regulation's guidance on the discount rate to use for regulatory interventions.

### 3.1.5 Sensitivity analysis

The sensitivity of net economic benefits to changes in key input parameters were examined through a sensitivity analysis. The choice of parameters for sensitivity testing were informed by an assessment of each parameter's relative level of uncertainty as well as its relative contribution to costs or benefits.

## 3.2 Financial impact analysis

The purpose of a CBA is to assess the net economic benefit of policy interventions from a societal perspective. It does not reveal how different stakeholder groups will be affected financially by the implementation options. This is because many financial impacts are 'transfer payments' – that cash payments made by one stakeholder group is a cost to that group, but an equal financial gain to another – thus cancelling out of the CBA as there is not net change in economic outcome.

In order to provide an indication of how different stakeholders will be impacted financially, a financial impact module has been incorporated into the modelling. The results of this analysis are presented in Section 8.

## 3.3 Key data sources

The analysis has used a number of data sources to inform the stock and flow modelling and valuation of costs and benefits. The key sources are listed below. Appendix C contains a complete listing of all information sources.

- Encycle's Material Flow Analysis[27], which summarises current and forecasted e-waste flows (generation, recovery and landfill) by category of e-waste and also provides information on current infrastructure and services. The categories of e-waste and detailed examples of items included within each category are shown in Appendix B. This data was used to map out the anticipated generation, landfill and recovery of e-waste over the analysis period. While the MFA data only gave estimates of e-waste generation to 2030, the trends were extrapolated to 2043 to cover the 20-year modelling period.

- Marsden Jacob Associates[28] recent cost benefit analysis of an e-waste ban in Victoria, to support assumptions around:

[27] Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*, report prepared for the Department of Water and Environmental Regulation, September 2021.

[28] Marsden Jacob Associates (2017) *Cost Benefit Analysis of Options to Reduce E-Waste from Landfill*, prepared for the Department of Environment, Land, Water and Planning, Victoria, Revised Report

  - E-waste collection and processing costs
  - Revenues earned from the recovery of materials from e-waste
  - Avoided landfill operating costs and environmental costs.

- Federal E-stewardship reports and data[29], which were used to obtain estimates of the current and forecast volumes of waste PVs being generated (Encycle did not include waste flow estimates for PVs).
- DWER's register of licensed waste facilities, by capacity, type and location.
- Data and information requested from DWER to support quantification of:
  - the anticipated cost of regulation design, implementation and enforcement under each implementation option (e.g. staff time and salary)
  - the current availability of relevant infrastructure to support an e-waste landfill ban (i.e. drop-off points, transfer stations, recyclers and landfills)
  - anticipated education and communication campaign costs.

[29] Bontinck PA, Bricout J, Grant T and Legoe G (2021) *E-product stewardship in Australia: Evidence report.* A report prepared for the Commonwealth Department of Agriculture, Water and the Environment by Iceni Group and Lifecycles, Sydney, Australia.

# 4 Base case and implementation options

This section defines the base case and the three implementation options.

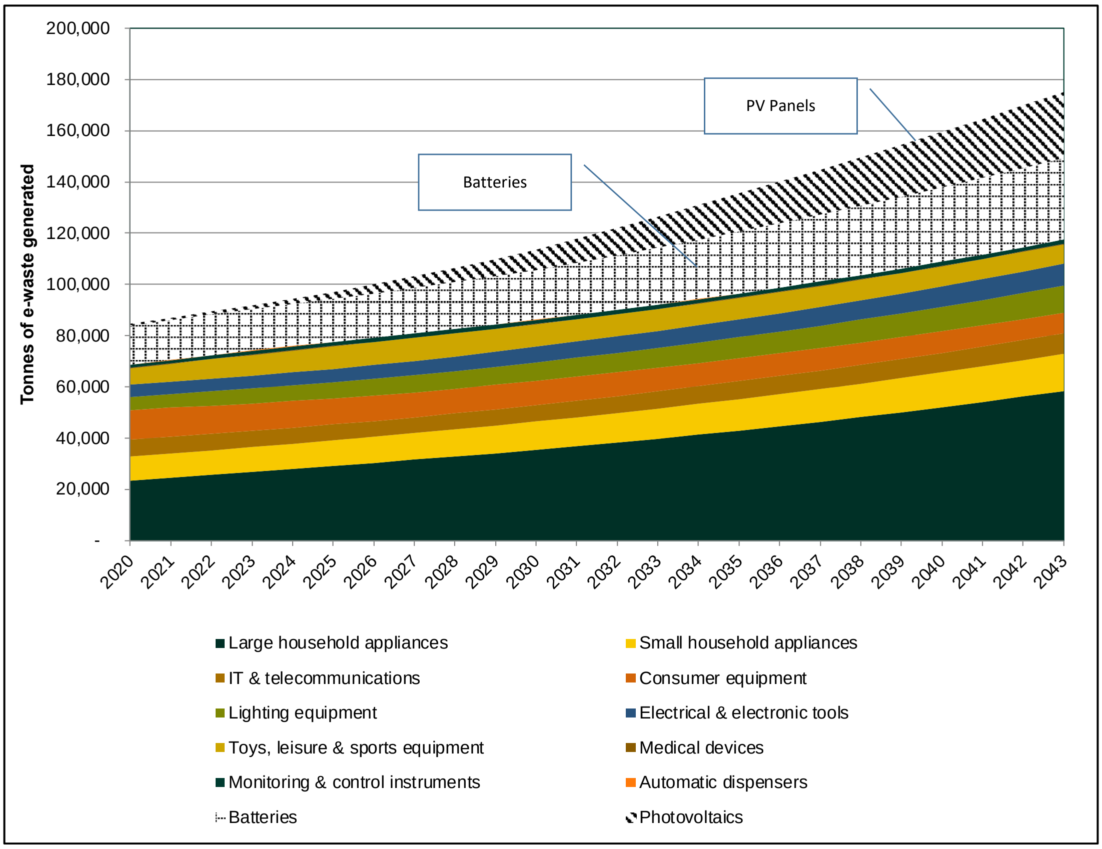
## 4.1 Base case

The base case defines the profile of outcomes that are expected to occur over time if government does not proactively intervene in the market to incentivise additional e-waste collection and recycling, either through financial or regulatory means. That is, we assume that DWER continues to apply its existing approach to the regulation of e-waste under its broader waste legislative and regulatory framework. Importantly, the base case is not a static outcome as discussed below.

### 4.1.1 Tonnes generated

Over the next 20 years, the annual amount of e-waste generated is forecast to increase from 69,000 tonnes to 117,000 tonnes (excluding PVs and batteries) (Figure 4).

**Figure 4 Forecast volumes of e-waste generated in WA from 2023 to 2043**



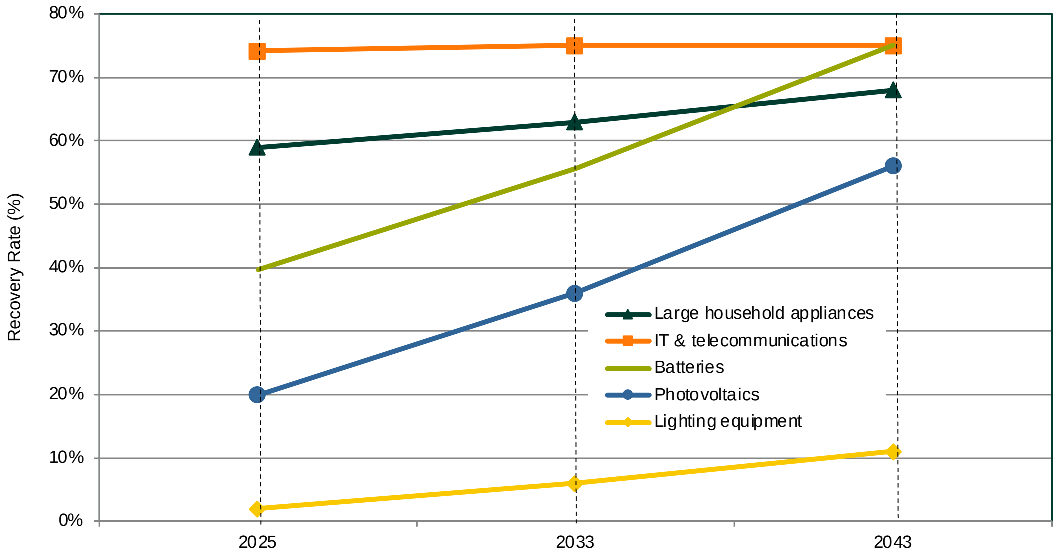

**Data sources: (1)** Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*; (2) Forecasts for PVs sourced from *E-product stewardship in Australia: Evidence report.* A report prepared for the Commonwealth Department of Agriculture, Water and the Environment (2021). (3) Forecasts Data beyond 2030 are Synergies' assumptions.

Once PVs and waste batteries are included, total annual tonnes generated by 2043 are estimated to be 175,000 tonnes.

### 4.1.2 Recovery rates

The analysis assumes that recovery rates for some categories of e-waste will rise gradually over time, even in the absence of a landfill ban (see Figure 5).

**Figure 5 E-waste recovery rates under base case, 2023 to 2043**




**Data source:** Encycle Consulting, 2021, *Western Australia E-Waste Material Flow Analysis*. Data beyond 2030 reflects Synergies assumptions.

The base case uses forecast recovery rates specified in Encycle's MFA report out to 2030. Synergies has extrapolated the trends beyond that date to the end of the analysis (2043). The rising recovery rates in Figure 5 reflect progressive improvement in community awareness about the benefits of recycling, gradual improvement in the economics of recycling, and also the introduction of a product stewardship scheme for PVs in June 2023.

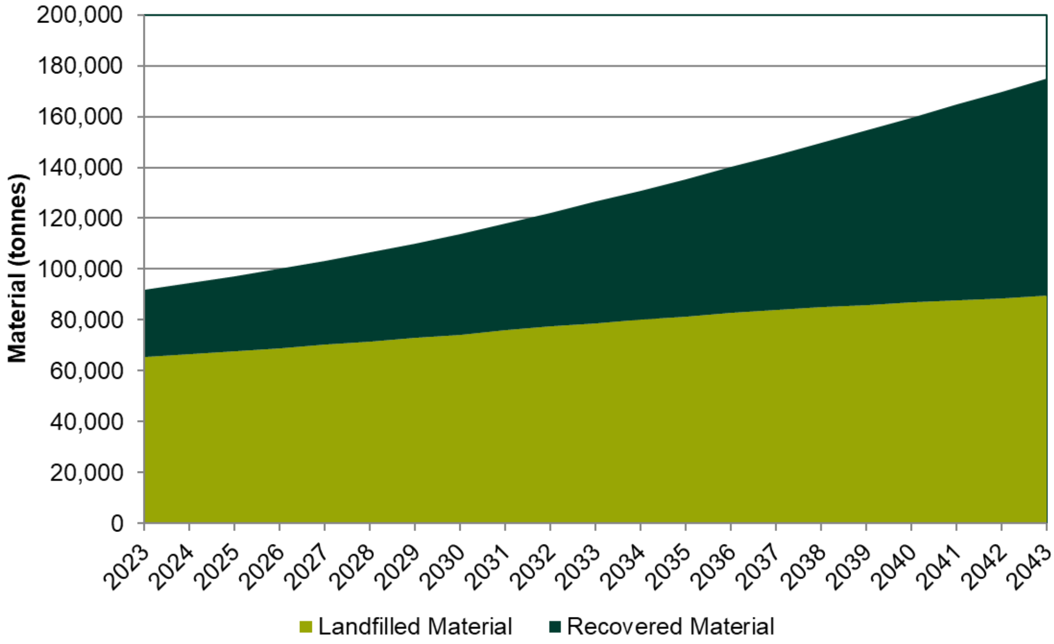
The recovery rates also assume that e-waste categories currently covered by a product stewardship scheme (ie the NTCRS, B-cycle for batteries, MobileMuster, and Fluorocycle) are assumed to continue and scheme recovery rate targets are assumed to be met.

## 4.1.3 Tonnes recovered

The total volumes of e-waste recovered under base case is calculated by multiplying the projected recovery rates by the estimated tonnes generated. This is shown in Figure 6, together with the projected volumes going to landfill.

We make the simplifying assumption that under base case there is no e-waste stockpiled or being disposed unlawfully outside of a licensed facility. Therefore, generated waste is either recovered or disposed to landfill.

**Figure 6 Tonnes of e-waste recovered and landfilled in WA under the base case, 2023 to 2043**




**Data source:** Synergies calculations using base data presented in Figure 4 and Figure 5.

## 4.1.4 Collection and recycling capacity

Under base case it is expected that there would be some growth in infrastructure capacity and associated capital investment in response to higher volumes of e-waste being recovered. However, the CBA does not make an explicit assumption around the size of this change as we are only interested in assessing the net increase in infrastructure investment under each of the implementation options (ie over and above what would occur in base case).

## 4.2 Implementation options

The implementation options represent differing levels of intervention and regulatory effort on the part of State Government, which is assumed to have a commensurate impact on e-waste recovery rates. The key design variables for each option are:

- legislative and regulatory measures;
- financial incentives (ie grants for infrastructure); and,
- government investment in community education and awareness.

A number of the benefits and costs modelled in the CBA are directly linked to the amount of e-waste recovered under each option. E-waste not recovered is assumed to either be landfilled, stockpiled for an extended period or disposed unlawfully. Higher levels of regulatory enforcement of the landfill ban are assumed to (perversely) incentivise stockpiling and unlawful disposal.

Further details on the distinguishing features of each option are summarised below.

### 4.2.1 Option 1: A voluntary ban

Option 1 involves the least amount of change relative to the base case and assumes a voluntary ban would be implemented with:

- no new legislative or regulatory obligations on stakeholders[30];
- financial incentives from State Government in the form of grant funding for infrastructure (up to $10 million in aggregate, CBA model assuming matching funding from the grant recipient) would be open to applications from all stakeholders to support the collection and processing/recycling of e-waste;
- a three-year investment from State Government (valued at $1,260,400) to initially support community education and engagement initiatives, to promote e-waste recycling.

The voluntary nature of this ban means that Option 1 is associated with the lowest amount of e-waste recovery, with an annual recovery of 99,563 tonnes by the end of the analysis (2043).

[30] Stakeholders being all participants in sector, including household and commercial e-waste generators, transport contractors, councils, waste transfer station operators, recyclers, and landfill operators

#### 4.2.2 Option 2: Regulatory ban with voluntary elements

The key features of Option 2 are:

- making new regulations that interact with the EP Act and/or WARR Act (and subsidiary regulations) that support e-waste being banned from disposal to landfill, which may place regulatory obligations (with penalties) for:
  - damage, spoilage and disposal of e-waste and non-compliance reporting obligations for commercial e-waste generators, collection networks (private, not-for-profit, local government), and waste managers (transport contractors, transfer stations, recycling facilities, landfill operators); and,
  - performance data reporting obligations for commercial e-waste generators and recycling facilities;
- financial incentives from State Government in the form of grant funding for infrastructure (up to $10 million in aggregate, CBA model assuming matching funding from the grant recipient) would be open to applications from all stakeholders to support the collection and processing/recycling of e-waste;
- a three-year investment from State Government (valued at $1,260,400) to initially support community education and engagement initiatives to promote e-waste recycling.

With increased regulatory obligations and improved education and engagement efforts, annual e-waste recovery over the 20-year period is assumed to be higher in Option 2 relative to Option 1 at 114,770 tonnes per annum by 2043.

#### 4.2.3 Option 3: Regulatory ban with extensive obligations

Implementation Option 3 imposes the most extensive regulatory obligations, and involves:

- making new regulations that interact with the EP Act and WARR Act (and subsidiary regulations) that prescribe obligations with penalties and regulatory reporting obligations on all stakeholders as specified in Option 2 (thus resulting in additional time cost burden for regulated entities);
- financial incentives from State Government in the form of grant funding for infrastructure (up to $10 million in aggregate, with the CBA model assuming matching funding from the grant recipient) would be open to applications from all regulated parties and liable persons and entities;

- a three-year investment from State Government (valued at $1,260,400) to initially support community education and engagement initiatives to promote e-waste recycling).

Under Option 3, increased regulation is assumed to result in the highest level of e-waste recovery at 121,495 tonnes per annum by 2043. However, it also generates the highest quantities leakage in the form of stockpiling and/or illegal disposal at 8,755 tonnes.

Table 2 below summaries the different waste flow scenarios under each of the implementation options, while Figure 7 tracks recovery rates for each option over time.

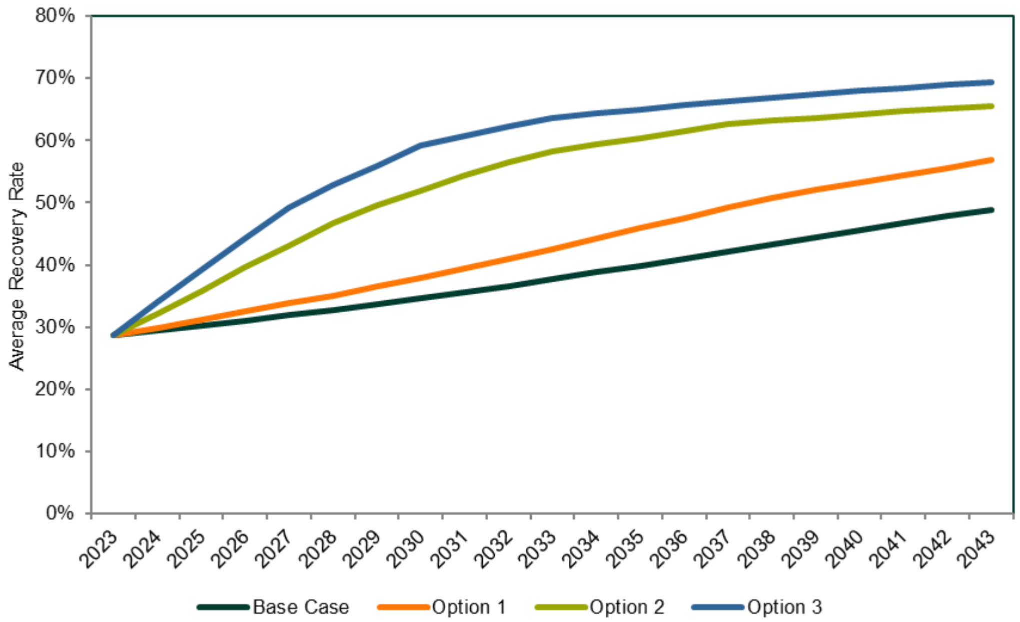
**Table 2 E-waste recovered in 2043**

| | E-waste recovered | E-waste landfilled | E-waste stockpiled or illegally disposed |
|---|---|---|---|
| **Base case** | 85,508 | 89,599 | 0 |
| **Option 1 – voluntary** | 99,563 | 75,544 | 0 |
| **Option 2 – regulatory with voluntary elements** | 114,770 | 55,959 | 4,378 |
| **Option 3 – regulatory extensive obligations** | 121,495 | 44,856 | 8,755 |

**Note:** 2043 has been selected as the last year in the analysis to give a snapshot as to the total amounts of waste recovered per year under the different options.

**Source:** Synergies modelling

**Figure 7 E-waste recovery rates over time for base case and each implementation option**




**Note:** This is an average recovery rate across all categories – that is, total tonnes recovered as a percentage of tonnes generated

**Data source:** Synergies modelling

# 5 Benefits

The benefit streams under each of the three implementation options are as follows:

- Commercial benefit from materials recovered
- Heath and environmental benefits
- Avoided landfill costs

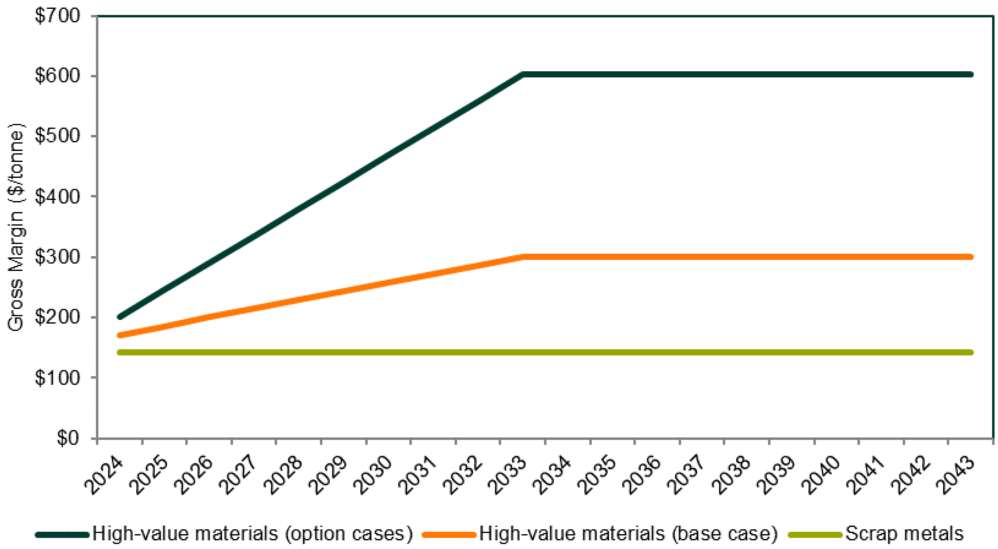
Each of these benefits is further detailed below.

## 5.1 Commercial benefit from materials recovered

This benefit captures the commercial returns earned from increased tonnages of recovered e-waste material under each of the implementation options. The modelling uses estimates of gross margin returns from recycling, defined as the per-tonne sale value of recovered materials minus the per-tonne operating cost of processing the e-waste. Capital costs of recycling are accounted for separately in the cost side of the ledger (see section 6).

Commercial returns are calculated separately for (1) Large Household Appliances (which largely constitute scrap metal) and (2) all other e-waste items, which typically contain higher-value materials. The gross margins assumed for the analysis vary over time, as illustrated in Figure 8 and discussed further below.

**Figure 8 Gross margins for e-waste recycling, by product type**




**Data source:** Synergies modelling based on data from Marsden Jacob Associates (2017) *Cost Benefit Analysis of Options to Reduce E-Waste from Landfill*

### *Large Household Appliances (scrap-metals recovery)*

Large household appliances include mostly whitegoods that contain considerable amounts of useful and readily recoverable metals such as steel and copper. As previously indicated, metal recovery from large household appliances is already well established in Western Australia. As a result, the calculation of gross margins on material recovered from large household appliances was assumed to be constant over the full analysis period at $143 per tonne (in real terms, adjusting for inflation impacts) using estimates from previous analysis by Marsden Jacobs Associates.[31] This margin was multiplied by the total tonnes of large household appliances recovered under each option.

### *All other e-waste (high-value material recovery)*

For all other e-waste categories affected by each of the implementation options, we assume a gross margin that is initially 40% higher than scrap metal recycling (ie $202 per tonne), but increasing over the analysis period to reach a maximum of $602 per tonne by 2033[32]. The $602 figure is a Victorian estimate. In that state, the e-waste recycling

[31] Marsden Jacob Associates (2017) *Cost Benefit Analysis of Options to Reduce E-Waste from Landfill*, Prepared for the Department of Environment, Land, Water and Planning, Victoria

[32] Drawing on analysis from Marsden Jacob Associates (2017) *Cost Benefit Analysis of Options to Reduce E-Waste from Landfill*, Prepared for the Department of Environment, Land, Water and Planning, Victoria, Revised Report

industry is more mature than Western Australia, with greater volumes of throughput and established markets for outputs. The lower starting value of $202 per tonne for Western Australia is based on an assumption that industry in this state does not enjoy the same economies of scale and access to markets. It will take time to attain the same gross margins as those states with a more developed e-waste recycling industry.

Under the base case, the same starting gross margin is used (for 2023), but is capped at a lower maximum at just $301 per tonne.

## 5.2 Health and environmental benefits

Many e-products contain hazardous materials such as mercury, lead and cadmium. When e-waste is landfilled, there is a risk that these hazardous materials will be released into the environment and cause detrimental impacts to public health and the environment. Thus, any reduction in the amount of e-waste directed to landfill represents a benefit to society.

We equate the value of this benefit to the damage cost that would otherwise have been incurred had e-waste been disposed to landfill. For simplicity, the analysis focuses on mercury as the key hazardous material and utilises an average mercury-equivalent composition for e-waste. We assume an environmental damage cost of $30 per tonne of e-waste, which are sourced from an analysis by Marsden Jacob Associates (2017) and Spadoro and Rabl (2008).

## 5.3 Avoided landfill costs

This benefit accrues due to lower tonnages of e-waste being disposed to landfill, which therefore creates savings in terms of avoided landfill costs. These costs include a combination of land, labour and capital costs of providing a landfill service. Perth metropolitan landfills typically charge around $170 per tonne for receival of bulk general waste[33], which is inclusive of the $70 per tonne landfill levy. The landfill levy does not represent an economic cost because it is a financial transfer between parties. Therefore, the CBA uses $100 per tonne as an indicative estimate of the economic cost of landfill – which can be avoided if e-waste is instead recycled. We make the simplifying assumption that there is no residual waste product from the recycling process that is returned to landfill.

[33] Based on 2020-23 schedules of charges published by the Eastern Metropolitan Regional Council, Western Metropolitan Regional Council, and Millar Road Landfill Facility (Rockingham City Council)

# 6 Costs

If introduced, an e-waste to landfill ban would give rise to a range of additional costs for consumers, industry, local governments and State Government. Eight cost-categories are identified and quantified in the CBA:

- Collection and transport costs (variable operating cost)
- Collection infrastructure upgrade costs (fixed capital cost)
- Processing centre upgrade costs (fixed capital cost)
- Stockpiling and unlawful disposal cost (variable cost)
- Industry reporting costs
- Government monitoring and enforcement costs
- Education and communication costs
- Start-up government implementation costs

These costs are described further in this section. The methods and assumptions used to quantify each cost are also documented.

## 6.1 E-waste collection and transport

With increased amounts of e-waste being diverted from landfill, there will be additional costs associated with collecting, handling, sorting, and transporting e-waste along the waste supply chain (eg via transfer stations) to an e-waste processing (recycling) facility.

Collection and transport costs (a variable operating cost) are estimated using a single $ per tonne amount that is applied to the tonnes of e-waste recovered. This is calculated by weighting calculated costs for both residential and commercial e-waste sources.

For residential e-waste collection, a two-stage collection process is assumed. All e-waste directed for recycling is first collected from household e-waste generators and transported to an aggregation and storage point (such as a waste transfer station or an e-waste collection shop front). The second stage sees the e-waste transported from the storage point to a recycler.[34]

[34] While there is currently some amount of e-waste being collected directly by the largest e-waste recycler from residents via vergeside services, we have taken a conservative approach in our analysis and assumed a transport model that is associated with higher costs.

For the first stage, residential and commercial collection costs are calculated separately. For household residential waste generated, two e-waste collection paths are assumed:

- drop-off - whereby the household transports their e-waste to a drop-off location such as a transfer station, recycler or collection partner (eg an electronics retailer); or
- vergeside collection – whereby households can put e-waste (eg fridge, large TVs) out on the verge and have it collected as part of existing council vergeside collection rounds.

For commercial collection, a single $ per tonne amount was applied.

These two costs were then weighted according to the current proportion of Commercial and Industrial (C&I) to Municipal Solid Waste (MSW) sourced e-waste reported in recovery data to DWER.

For the second stage, a $100 per tonne cost is assumed for the transport of e-waste from aggregation points to a recycler.

All costs draw on the assumptions of Marsden Jacob Associates (2017), which have been adjusted for the Western Australian context. See Appendix C for a detailed description of the calculations and assumptions applied.

## 6.2 Collection network upgrading

Under the e-waste to landfill ban options, there will be a need to upgrade existing collection infrastructure due to greater volumes of e-waste collected in Western Australia. For example, this may include building additional storage and sorting facilities (such as a shed and space for sorting) on existing premises with a Category 62 license under the *Environmental Protection Regulations 1987*. These sites that are classified under the regulations as a: "Solid waste depot: premises on which waste is stored or sorted, pending final disposal or re-use."

For the purpose of the CBA it is assumed that 40% of these premises will require collection network upgrades (or new builds) to provide Western Australian residents with access to e-waste drop-off facilities and ensure sufficient capacity for e-waste to be sorted, stored, and transferred to recovery centres. The 40% aligns with the proportion of premises that were found to require upgrading in Victoria as part of that state's introduction of an e-waste ban.

The suite of facilities that will need to be built or upgraded will vary in size, and hence cost. We draw on Victoria's recent experience, which found that small-scale transfer stations typically cost around $75,000 to upgrade and larger stations cost around

$150,000. The CBA uses a bottom-up approach to calculate the total, aggregate cost of upgrading the network with reference to the number of small and large licensed waste depots in Western Australia. This cost is calculated to be $4,830,015 (before discounting). We assume the same nominal cost for all implementation options but vary the time over which the capital is spent on infrastructure upgrades so as to align to the different volumes of e-waste that will be diverted from landfill as a result of each option. The investment timeframes are: Option 1 (15 years), Option 2 (10 years) and Option 3 (5 years).

## 6.3 Processing centre upgrading

This is the capital cost of upgrading existing processing infrastructure and/or building new infrastructure to recycle additional volumes of e-waste collected under each of the implementation options. This investment would be made by the private sector with a contribution from State Government through the grant program.

Based on Synergies' review of the literature, the capital costs required per tonne of e-waste recycling capacity varies depending on the type of processing technology employed. For the purpose of the CBA we use a recent Australian study published by UTS Institute of Sustainable Futures which estimates the capital cost of constructing a facility for recycling PV panels to be $1.5 million per kilotonne of processing capacity[35]. This estimate is selected as being reasonable for the CBA as a high proportion of the additional e-waste that will be collected over the next 20 years will constitute PVs.

Our analysis determines a total capital cost based on the amount of processing capacity that will be needed to recycle the additional volume of e-waste collected under each of the implementation options by 2043. However, the costs are expended over time in approximate alignment with the profile of annual increases in volumes collected under each option with (ie. spread over 15 years for Option 1, 10 years for Option 2, and 5 years for Option 3).

## 6.4 Stockpiling and illegal dumping

A negative side-effect of imposing a landfill ban is the possibility of e-waste being stockpiled for lengthy periods of time and/or illegally dumped. To the extent that this occurs, it will give rise to a range of costs, including increased fire risk (stockpiles), health and environmental risk (stockpiles), and the cost of removing unlawfully dumped

35 UTS Institute of Sustainable Futures & Equilibrium Consulting (2020) *Scoping study for photovoltaic panel and battery system reuse and recycling fund*

waste. Cost estimates for these impacts are taken from a previous Synergies study, and documented in Appendix C.

## 6.5 Industry reporting

The landfill ban will impose greater record keeping and reporting obligations on industry participants. This will impact various stakeholders including commercial e-waste generators, local governments and e-waste collection premises. A full description of the reporting obligations involved is contained in Appendix C.

The cost of record keeping and reporting obligations is estimated as an assumed number of additional days per year required under each implementation option. This is estimated separately for various stakeholders based on advice from DWER, and is converted to an FTE equivalent and multiplied by an assumed salary rate ($90,000).

## 6.6 Government monitoring and enforcement

The Government will undertake monitoring and enforcement activities to ensure the implementation of the ban is effective. This is expected to require additional resources at a cost to the State Government.

It is assumed the level of monitoring and enforcement will vary under the three options, with Option 1 requiring no additional monitoring and enforcement, Option 2 requiring medium levels and Option 3 requiring elevated levels of additional monitoring and enforcement.

Typical activities may include officers visiting sites to audit for industry compliance with the new legislation, administration officers checking submitted reports to ensure compliance with reporting obligations (such as analysing collated data for any outliers) or issuing notices to stakeholders found to be non-compliant with the new legislation.

Additional FTEs required to undertake the above activities was estimated and then staff time was multiplied by a Level 5 Western Australian Government salary[36], indicative of the pay grade of personnel that would perform these functions.

## 6.7 Education and communication

This is the cost of educating the community and industry about the landfill ban and/or desired voluntary behaviours through different communication mechanisms. These costs were budgeted for in the 2021-22 Western Australian State Budget. The exact

[36] Available at: https://downloads.wairc.wa.gov.au/agreements/pub058.pdf

mechanisms by which information about the landfill ban will be communicated has not been confirmed, however the estimate from the State budget can be considered adequate for the purposes of this CBA.

## 6.8 Initial Government Administration costs

The initial implementation of the ban will result in additional administration costs to Government. These costs would include activities such as additional staffing time for legislative amendments, development of policy guidelines or setting up the systems for ongoing reporting and data collation. They are assumed to be spread across the first three years of the ban and were budgeted for in the 2021-22 Western Australian State Budget. On advice from DWER, the analysis assumes no ongoing additional administration costs to Government as any additional tasks that will be required will likely be folded into existing responsibilities of staff (such as processing reports and data).

# 7 Results

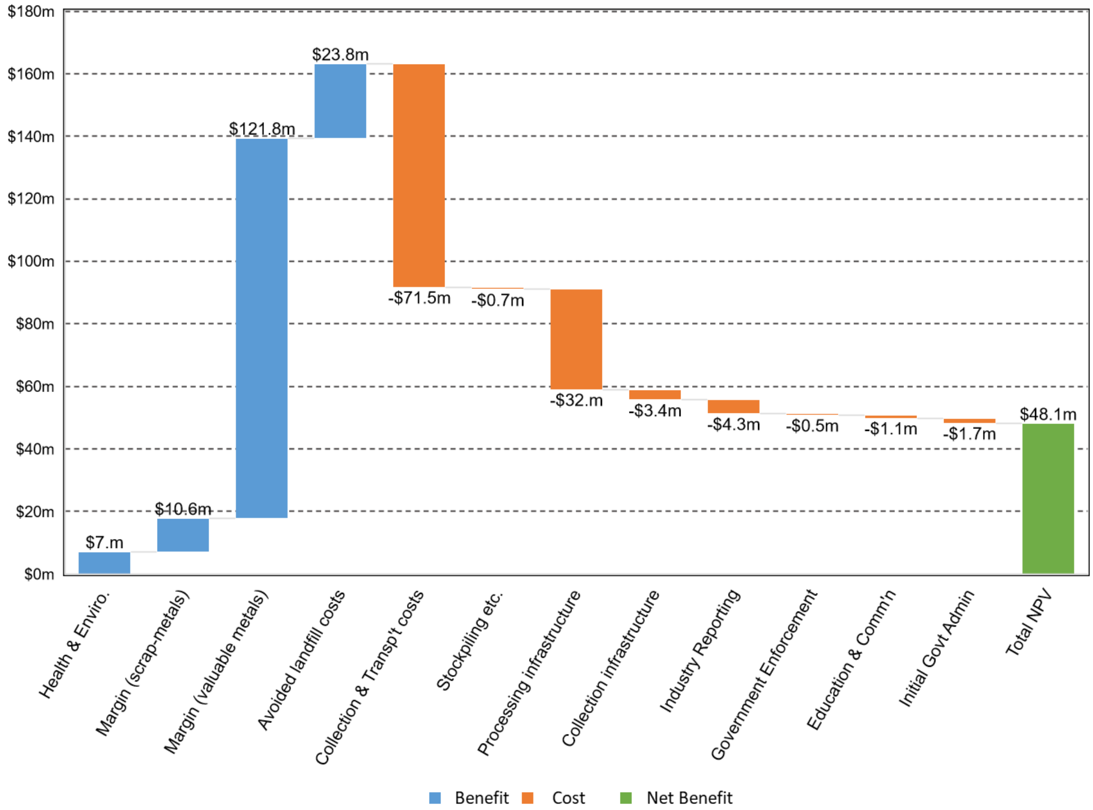
All three implementation options yield a positive net economic benefit (that is, NPV is greater than zero). Of the three options, Option 2 produces the highest NPV ($48 million), followed by Option 1 ($44 million) and then Option 3 ($36 million).

BCRs are all greater than one, meaning that the present value of benefits exceed present value costs under all implementation options. Option 1 yields the best BCR at 2.08, followed by Option 2 at 1.42.

## 7.1 Breakdown of benefits and costs

For illustrative purposes, Figure 9 below shows the composition of benefits and costs that make up the $48 million of net benefit estimated for Option 2.

**Figure 9 Option 2 Costs and Benefits**




**Data source:** Synergies modelling

The most significant benefit driving the results is the gross margin derived from the sale of recovered materials, particularly from high-value material processing. In total, this benefit component is estimated to be $122 million. Avoided landfill costs are also an important contributor to benefits, accounting for $24 million.

On the cost side of the ledger, the most significant costs are collection and transport costs ($72 million) and the capital costs involved in developing additional recycling infrastructure ($32 million). The cost of upgrading the collection network ($3.4 million) is a minor contributor to costs, as is the additional regulatory cost burden on industry ($4.3 million).

The following table summarises the results for each implementation option.

**Table 3 Summary of modelling results (7% discount rate)**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| **Benefits** | | | |
| Health & Environmental benefit | $1.7m | $7.0m | $9.8m |
| Gross margin (from scrap-metal recovery) | $2.7m | $10.6m | $13.8m |
| Gross margin (from high-value material recovery) | $74.8m | $121.8m | $140.8m |
| Avoided landfill costs | $5.8m | $23.8m | $33.3m |
| **Costs** | | | |
| Collection & Transport costs | $20.2m | $71.5m | $93.3m |
| Stockpiling & Unlawful Disposal cost | $0.0m | $0.7m | $1.4m |
| Processing Centre Upgrade costs | $13.3m | $32.0m | $45.9m |
| Collection Network Upgrade costs | $2.9m | $3.4m | $4.0m |
| Annual Industry Reporting costs | $1.7m | $4.3m | $7.6m |
| Annual Government Monitoring and Enforcement | $0.1m | $0.5m | $6.6m |
| Education & Communication costs | $1.1m | $1.1m | $1.1m |
| Initial Government Administration costs | $1.7m | $1.7m | $1.7m |
| Total Benefit | $85.1m | $163.2m | $197.6m |
| Total Cost | $41.0m | $115.1m | $161.5m |
| **Net Benefit (NPV)** | **$44.1m** | **$48.1m** | **$36.1m** |
| Benefit-Cost Ratio (BCR) | 2.08 | 1.42 | 1.22 |

**Note:** All values are in Present Value terms.

## 7.2 Sensitivity analyses

A sensitivity analysis was performed on the following input variables:

- Discount rate (4% and 10%)
- E-waste recovery rates (slower annual increase, but no change to maximum)

- Commercial gross margin for high-value materials recovery (+/- 20%)
- Processing infrastructure capital cost (apply a lower bound cost of $280,000 per kilotonne)

In summary, all the implementation options remain net positive even under a 10% discount rate. Reducing the effectiveness of the implementation options in terms of recovery rates did not have a material impact on the NPV results, and the relativities between the options remain the same.

The results are sensitive to changes in the commercial gross margin for recycling. For example, Option 2 NPV increases from $48 million (under standard assumption) to $72 million when the $ per tonne gross margin is increased by 20%. On the other side, a 20% lower gross margin reduces the NPV for Option 2 to $24 million.

In the case of processing infrastructure costs, our standard model assumed a capital cost of $1.5 million per kilotonne. However, we found alternative estimates in the literature that indicated capital costs could be as low as $280,000 per kilotonne. If this lower cost is adopted, the NPV for Option 2 increases to $74 million.

We also examined the threshold upper limit of processing infrastructure costs that would cause the implementation options to only just break even (that is produce an NPV of zero). This upper limit is around $100 million. This is a nominal figure, and is spread across 15, 10 and 5 years for Options 1, 2 and 3 respectively.

### 7.2.1 Discount rates

Table 4 presents the NPV results of each option under 4% and 10% discount rates. Under each discount rate adopted as a sensitivity test, Option 3 is the worst performing option, while Option 2 is still predominantly the best performing option.

Under the 4% discount rate, the size of the net benefit increases, although the relative differences between the options does not materially change. This reflects a higher present value of the future benefits of recovered material and the lower present value of up-front costs associated with the implementation options, such as infrastructure and admin costs.

Under the 10% discount rate, the NPV under all options is significantly reduced, including Option 1 performing marginally better than Option 2. Conversely to Option 1, this is because the future benefits of increased recovery of waste (like the sale of valuable metals) are discounted heavily, while the higher front capital costs are front-loaded in the first few years.

**Table 4 Sensitivity results (4% and 10% discount rate)**

| | 4% Discount Rate | | | 10% Discount Rate | | |
|---|---|---|---|---|---|---|
| | **Option 1** | **Option 2** | **Option 3** | **Option 1** | **Option 2** | **Option 3** |
| Total Benefit | $123.5m | $231.1m | $264.4m | $60.3m | $118.5m | $145.1m |
| Total Cost | $54.2m | $149.3m | $204.1m | $32.0m | $91.3m | $131.7m |
| **Net Benefit (NPV)** | **$69.3m** | **$81.8m** | **$60.3m** | **$28.3m** | **$27.1m** | **$13.4m** |
| Benefit-Cost Ratio (BCR) | 2.28 | 1.55 | 1.30 | 1.89 | 1.30 | 1.10 |

### 7.2.2 Effectiveness of implementation options on lifting recovery rates

In this sensitivity test, we examined the impact on NPVs if the rate of increase in recovery rates is slower than forecast under the standard assumptions. For Options 2 and 3 we held the maximum recovery rate the same (as per the standard assumption) but deferred the time till the maximum is reached by reducing the rate of increase. For Option 1 we set recovery rates equal to base case. These changes to the model had negligible effect on the NPV results and the relativities between the options remain the same.

**Table 5 Sensitivity results (ban has a minor effect on recovery rates)**

| | **Option 1** | **Option 2** | **Option 3** |
|---|---|---|---|
| Total Benefit | $56.0m | $141.0m | $183.2m |
| Total Cost | $21.7m | $100.2m | $150.8m |
| **Net Benefit (NPV)** | **$34.2m** | **$40.8m** | **$32.4m** |
| Benefit-Cost Ratio (BCR) | 2.58 | 1.41 | 1.21 |

### 7.2.3 Gross margin of high-value materials recovery

Given the degree of uncertainty around the gross margin of high-value materials recovery, we tested the sensitivity of results to varying the gross margin by +/- 20%. The results are presented below.

**Table 6 Sensitivity results (Low and high gross margin of high-value materials)**

| | Low estimate (-20%) | | | High estimate (+20%) | | |
|---|---|---|---|---|---|---|
| | **Option 1** | **Option 2** | **Option 3** | **Option 1** | **Option 2** | **Option 3** |
| Total Benefit | $70.2m | $139.4m | $170.4m | $99.9m | $187.0m | $224.9m |
| Total Cost | $41.0m | $115.1m | $161.5m | $41.0m | $115.1m | $161.5m |
| **Net Benefit (Cost)** | **$29.3m** | **$24.3m** | **$8.9m** | **$59.0m** | **$71.9m** | **$63.4m** |
| Benefit-Cost Ratio (BCR) | 1.72 | 1.21 | 1.05 | 2.44 | 1.62 | 1.39 |

### 7.2.4 Processing infrastructure capital cost

There is some uncertainty around how much capital investment would be required to expand Western Australia's e-waste recycling facilities to process the additional waste collected as a result of the implementation options. While our standard model assumed a capital cost of $1.5 million per kilotonne, we found alternative estimates in the literature that indicated capital costs could be as low as $280,000 per kilotonne[37]. If this lower estimate is adopted, NPVs across all three options are higher.

**Table 7 Sensitivity results (Low estimate - $279,000/kt)**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Total Benefit | $85.1m | $163.2m | $197.6m |
| Total Cost | $30.1m | $88.9m | $123.8m |
| **Net Benefit (Cost)** | **$55.0m** | **$74.3m** | **$73.8m** |
| Benefit-Cost Ratio (BCR) | 2.83 | 1.84 | 1.60 |

The following table provides the results of an analysis which determined the capital cost of processing infrastructure which would return a $0 NPV in our analysis. We find that, across the four options, roughly $100m of processing capital expenditure would be required across the three options to reduce to a breakeven result.

**Table 8 Breakeven analysis results (7% discount rate)**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Processing Infrastructure Upgrade cost to Breakeven | $95m | $114m | $100m |

[37] https://www.business-standard.com/article/companies/merpl-to-process-over-200-000-tonnes-of-e-waste-annually-to-invest-25-mn-121091701014_1.html

# 8 Financial impacts

This section examines the financial impact of the implementation options on stakeholders, including:

- reduced revenue to landfill operators due to volumes of e-waste being diverted from landfill;
- reduced landfill waste levy revenue to the State Government; and
- additional waste collection rates to households and commercial businesses to fund the additional costs of collecting and handling e-waste (to the extent that these costs are not funded by Government or are unable to be passed on to recyclers), less financial cost savings due to reduced payments to landfill operators to dispose e-waste and reduced levy payments to Government.

These impacts are not specified in the CBA model because they are 'financial transfers' as opposed to economic costs. For example, the total cost of collecting and handling e-waste is identified in the CBA but the model does not specify 'who pays'.

## 8.1 Landfill operators

Reduced revenue to landfill operators is calculated by multiplying the tonnage of e-waste diverted from landfill under each option (relative to base case) by the typical charge in the Perth metropolitan area for disposing general bulk waste to landfill, which is $100 per tonne (after subtracting the $70 per tonne landfill levy)[38]. This approach assumes that in the absence of the policy interventions, e-waste would have been mixed with general waste, and would therefore attract the general waste disposal charge.

Annual revenue impacts for landfill operators in aggregate are shown in Table 9.

**Table 9 Financial impact of implementation options on landfill operators**

| | Annual revenue loss ($ million) | |
|---|---|---|
| | **2033** | **2043** |
| **Option 1 – voluntary** | $0.6m | $1.4m |
| **Option 2 – regulatory with voluntary elements** | $3.0m | $3.4m |
| **Option 3 – regulatory extensive obligations** | $4.0m | $4.6m |

**Note:** Revenue losses are in 'dollars of the day'. They have not been discounted to present values

**Source:** Synergies analysis

38 Based on 2020-23 schedules of charges published by the Eastern Metropolitan Regional Council, Western Metropolitan Regional Council, and Millar Road Landfill Facility (Rockingham City Council)

The impacts are calculated for two points in time – at year 10 after introduction of the implementation options (ie 2032) and at year 20 (ie 2042). Revenue losses increase over time as progressively larger volume of e-waste are diverted from landfill.

## 8.2 State Government

Diversion of e-waste from landfill will reduce the amount of revenue collected through the waste landfill levy, which is currently $70 per tonne.

Reduced levy revenue to State Government is calculated by multiplying the tonnage of e-waste diverted from landfill under each option (relative to base case) by the waste levy. Revenue impacts are summarised in Table 10.

**Table 10 Reduced waste levy revenue to State Government under each implementation option**

| | Annual revenue loss ($ million) | |
|---|---|---|
| | **2033** | **2043** |
| **Option 1 – voluntary** | $0.4m | $1.0m |
| **Option 2 – regulatory with voluntary elements** | $2.0m | $2.4m |
| **Option 3 – regulatory extensive obligations** | $2.7m | $3.1m |

**Note:** Revenue losses are in 'dollars of the day'. They have not been discounted to present values
**Source:** Synergies analysis

## 8.3 Households and commercial waste generators

The implementation options all involve higher collection and handling costs than would otherwise be incurred under base case. For the purposes of this financial analysis, the CBA assumes that a 50% share of the capital cost of upgrading collection infrastructure will be funded by State Government. The other 50% share of capital costs, together with the additional e-waste handling costs, will need to be met through one or a combination of methods:

- absorbed by councils;
- passed onto recyclers (ie there could be scope for councils to recyclers for e-waste feedstock); and
- passed onto households and commercial businesses through higher waste disposal rates.

The market and individual circumstances of councils will ultimately determine how the unfunded costs will be recovered. For the purpose of this analysis we present a scenario in which all unfunded costs are recovered through higher council rates to households and commercial e-waste generators.

However, the net financial impact needs to also consider the financial savings from reduced landfill charges and reduced landfill levy payments.

The net financial impost on households and commercial e-waste generators is calculated in five steps, as outlined below.

*Step 1: Unfunded collection infrastructure costs incurred by councils*

The capital cost of upgrading collection facilities for recovering additional volumes of e-waste is estimated to be $4.0 million (whole of state), which is assumed to be expended in the first five years of the e-waste landfill ban being introduced (see section 6.2 for details). Assuming infrastructure grants will be made available on a matching basis, the amount outstanding that would need to be funded by councils is $2.0 million.

When amortised over 15 years, this equates to an annuity of $217,000 per year.

*Step 2. Additional operating costs of handling e-waste*

Additional costs are borne by local governments to collect and handle e-waste before transporting waste to recovery facilities. The handling cost of additional e-waste being collected and recovered due to the implementation options is estimated to be $81 per tonne (see section 6.1 for details), and this is applied to the additional tonnages of e-waste collected.

*Step 3: Reduced payments to landfill operators*

While councils will incur costs to upgrade infrastructure, they will also make cost savings on landfill charges due to e-waste being diverted from landfill. We assume that these savings are passed onto households and commercial waste generators. The value of these savings is equivalent to the revenue losses to landfill operators, which were calculated in sub-section 8.1.

*Step 4: Reduced landfill levy payments to State Government*

The volumes of e-waste diverted from landfill will no longer be subject to the landfill waste levy. We assume that the financial savings would ultimately pass through to households and commercial waste generators. The value of these reduced levy payments was calculated in sub-section 8.2.

*Step 5: Net additional cost to households and commercial waste generators*

The final step in the analysis is to calculate the net financial impact (ie increase or decrease, relative to current day) to e-waste generators by summing each of the above impact components.

Table 11 presents the results in the analysis. Financial impacts under each implementation option are shown for year 10 of the forecast period, being 2033.

**Table 11 Financial impact of the implementation options to households and commercial e-waste generators (as at 2033)**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| **Cost increases** | | | |
| Unfunded infrastructure costs (capital) | $0.2m | $0.2m | $0.2m |
| Additional collection and handling costs (operating) | $0.3m | $1.3m | $1.7m |
| **Cost decreases** | | | |
| Reduced payments to landfill operators | $1.1m | $5.0m | $6.7m |
| Reduced landfill levy to State Government | $0.4m | $2.0m | $2.7m |
| **Net financial benefit** | **$1.0m** | **$5.6m** | **$7.5m** |

**Note:** Revenue losses are in 'dollars of the day'. They have not been discounted to present values
**Source:** Synergies analysis

The results demonstrate that e-waste generators will be financially better-off under the implementation options due to cost savings on landfill charges and the landfill levy outweighing the additional costs of infrastructure upgrades and handling costs. It is important to note however that this does not include any out-of-pocket costs incurred by e-waste generators in transporting their e-waste to drop off centres or waste transfer stations. This cost, which includes vehicle operating costs and time costs, is included in the CBA but not in the financial analysis.

In order to get an appreciation of the potential scale of impact on household waste charges, we take the financial impacts shown in Table 11 and apportion the impact to households and businesses on a pro rata basis using tonnages of e-waste collected from the residential and commercial sector, respectively.

**E-waste recovery data from DWER[39] indicates that approximately one third of e-waste recovered in 2020-21 came from commercial sources, with the other two thirds from the residential sector.**

Table 12 contains the results of this analysis. We find that on average, households would experience a reduction in waste charges, ranging from $0.50 per year per household under Option 1 through to $4.20 per year under Option 3.

[39] This data is based on the proportion of e-waste within the commercial and industrial (C&I) waste stream relative to e-waste within the Municipal Solid Waste (MSW) stream. Data are current for the 2020-21 local government waste reporting period.

**Table 12 Breakdown of financial impact of the implementation options by e-waste generator (as at 2033)**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Households e-waste generators | $569,642 | $3,896,031 | $4,825,789 |
| Commercial e-waste generators | $284,821 | $1,948,016 | $2,412,894 |
| Net financial benefit per household | $0.50 | $3.39 | $4.20 |

**Note:** Revenue losses are in 'dollars of the day'. They have not been discounted to present values. The number of households assumed in WA is 1,150,257, as of the 2021 Census.

**Source:** Synergies analysis

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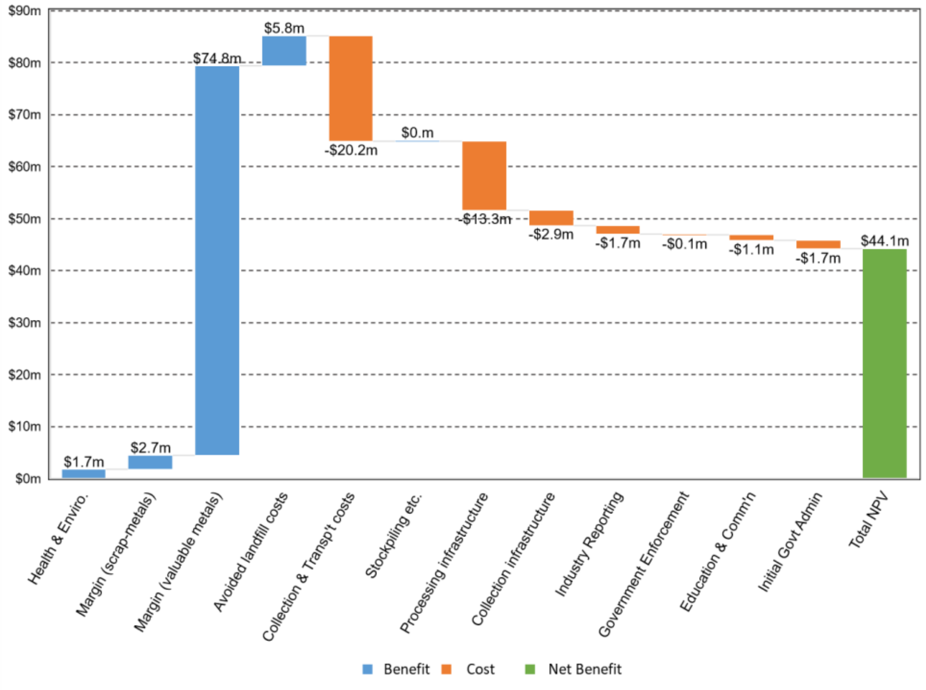
# A. Detailed results

**Table A.1 Summary of modelling results (7%, 4% & 10% discount rate)**

| | 7% | | | 4% | | | 10% | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Option 1** | **Option 2** | **Option 3** | **Option 1** | **Option 2** | **Option 3** | **Option 1** | **Option 2** | **Option 3** |
| **Benefits** | | | | | | | | | |
| Health & Environmental benefit | $1.7m | $7.0m | $9.8m | $2.5m | $9.6m | $13.3m | $1.2m | $5.3m | $7.5m |
| Gross margin (from scrap-metal recovery) | $2.7m | $10.6m | $13.8m | $4.0m | $14.4m | $18.5m | $1.9m | $8.1m | $10.6m |
| Gross margin (from high-value material recovery) | $74.8m | $121.8m | $140.8m | $108.7m | $174.6m | $200.1m | $53.0m | $87.2m | $101.7m |
| Avoided landfill costs | $5.8m | $23.8m | $33.3m | $8.4m | $32.6m | $32.6m | $4.1m | $17.9m | $25.3m |
| **Costs** | | | | | | | | | |
| Collection & Transport costs | $20.2m | $71.5m | $93.3m | $29.2m | $98.5m | $127.0m | $14.4m | $53.4m | $70.5m |
| Stockpiling & Unlawful Disposal cost | $0.0m | $0.7m | $1.4m | $0.0m | $0.9m | $1.9m | $0.0m | $0.6m | $1.1m |
| Processing Centre Upgrade costs | $13.3m | $32.0m | $45.9m | $16.2m | $36.9m | $49.8m | $11.1m | $28.0m | $42.4m |
| Collection Network Upgrade costs | $2.9m | $3.4m | $4.0m | $3.6m | $3.9m | $4.3m | $2.4m | $3.0m | $3.7m |
| Annual Industry Reporting costs | $1.7m | $4.3m | $7.6m | $2.2m | $5.5m | $9.8m | $1.4m | $3.4m | $6.1m |
| Annual Government Monitoring and Enforcement | $0.1m | $0.5m | $6.6m | $0.1m | $0.6m | $8.4m | $0.1m | $0.4m | $5.3m |
| Education & Communication costs | $1.1m | $1.1m | $1.1m | $1.2m | $1.2m | $1.2m | $1.0m | $1.0m | $1.0m |
| Initial Government Administration costs | $1.7m | $1.7m | $1.7m | $1.8m | $1.8m | $1.8m | $1.6m | $1.6m | $1.6m |
| Total Benefit | $85.1m | $163.2m | $197.6m | $123.5m | $231.1m | $264.4m | $60.3m | $118.5m | $145.1m |
| Total Cost | $41.0m | $115.1m | $161.5m | $54.2m | $149.3m | $204.1m | $32.0m | $91.3m | $131.7m |
| **Net Benefit (Cost)** | **$44.1m** | **$48.1m** | **$36.1m** | **$69.3m** | **$81.8m** | **$60.3m** | **$28.3m** | **$27.1m** | **$13.4m** |
| Benefit-Cost Ratio (BCR) | 2.08 | 1.42 | 1.22 | 2.28 | 1.55 | 1.30 | 1.89 | 1.30 | 1.10 |

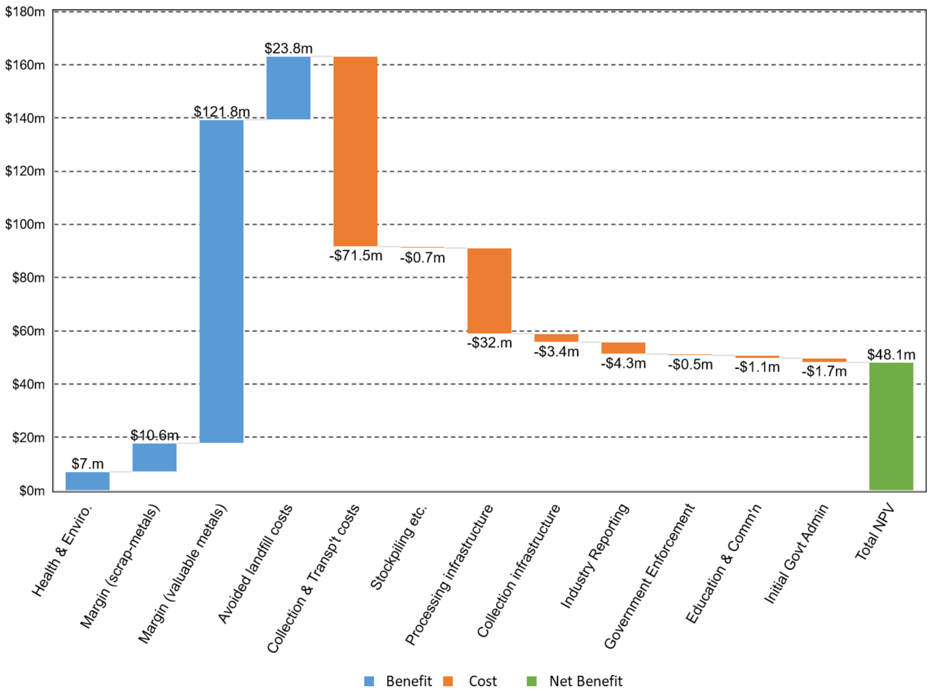
**Note:** All values are in Net Present Value (NPV) terms.

## Figure A.1 Option 1 Costs and Benefits



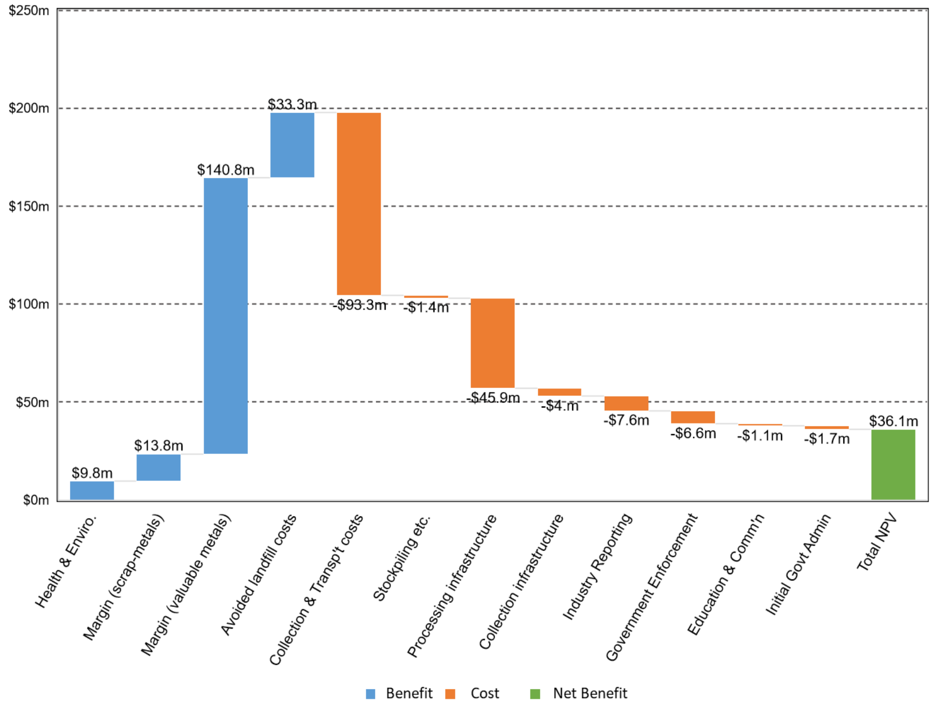

**Data source:** Synergies modelling

## Figure A.2 Option 2 Costs and Benefits




**Data source:** Synergies modelling

## Figure A.3 Option 3 Costs and Benefits




**Data source:** Synergies modelling

# B. E-waste categories and recovery rates

**Table B.1 Examples of items in Material Flow Analysis e-waste categories**

| Category | Description |
|---|---|
| 1. Large household appliances | Fridges, Washing machines, Driers, Dish washers, Cookers, Micro-waves, Electric fans, Air conditioners |
| 2. Small household appliances | Vacuum, cleaners, Irons, Electric shavers, Kettle, toasters, Coffee machines, Hair dryers, Watches |
| 3. IT & telecommunications | Monitors, Laptops, Printers, Computers, TVs, Mice, keyboards, Remote controls, Mobile phones |
| 4. Consumer equipment | Music instruments, speakers, cameras |
| 5. Lighting equipment | Fluorescent lights, Compact fluorescent, High intensity, Discharge lamps, Lamps, LEDs |
| 6. Electrical & electronic tools | Drills, Saws, Sewing machines, Lawn mowers, Batteries |
| 7. Toys, leisure & sports equipment | Electric trains or car racing sets, Consoles, Hand-held video games, Radios, Musical instruments, Amplifiers, Electric bikes, Rowing machines |
| 8. Medical devices | Medical devices / lab devices |
| 9. Monitoring & control instruments | Monitoring and control, Smoke detector, thermostats |
| 10. Automatic dispensers | Automatic food / drinks dispensers |
| 11. Batteries | Alkaline, Lead acid, Lithium ion, Lithium primary, Nickel cadmium, Nickel metal hydride, other types of batteries |
| 12. Photovoltaics | Solar panels (PVs) |

**Source:** Encycle MFA

**Table B.2 Recovery rates by year, category and option**

| | Base Case | | | Option 1 | | | Option 2 | | | Option 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2025 | 2033 | 2043 | 2025 | 2033 | 2043 | 2025 | 2033 | 2043 | 2025 | 2033 | 2043 |
| 1. Large household appliances | 59% | 63% | 68% | 60% | 68% | 78% | 68% | 85% | 85% | 73% | 90% | 90% |
| 3. IT & telecommunications | 74% | 75% | 75% | 76% | 80% | 80% | 80% | 85% | 85% | 90% | 90% | 90% |
| 5. Lighting equipment | 2% | 6% | 11% | 3% | 11% | 21% | 21% | 85% | 85% | 26% | 90% | 90% |
| 8. Medical devices | 1% | 5% | 10% | 2% | 10% | 20% | 20% | 85% | 85% | 25% | 90% | 90% |
| 10. Automatic dispensers | 1% | 5% | 10% | 2% | 10% | 20% | 20% | 85% | 85% | 25% | 90% | 90% |
| 11. Batteries | 40% | 56% | 75% | 42% | 66% | 80% | 46% | 85% | 85% | 51% | 90% | 90% |
| 12. Photovoltaics | 20% | 36% | 56% | 22% | 46% | 76% | 26% | 66% | 85% | 31% | 90% | 90% |

**Note:** Maximum recovery rates were modelled by Synergies at 75% under base case, and 80%, 85% and 90% for Options 1, 2 and 3 respectively.

**Source:** Synergies Modelling

# C. Modelling assumptions and data sources

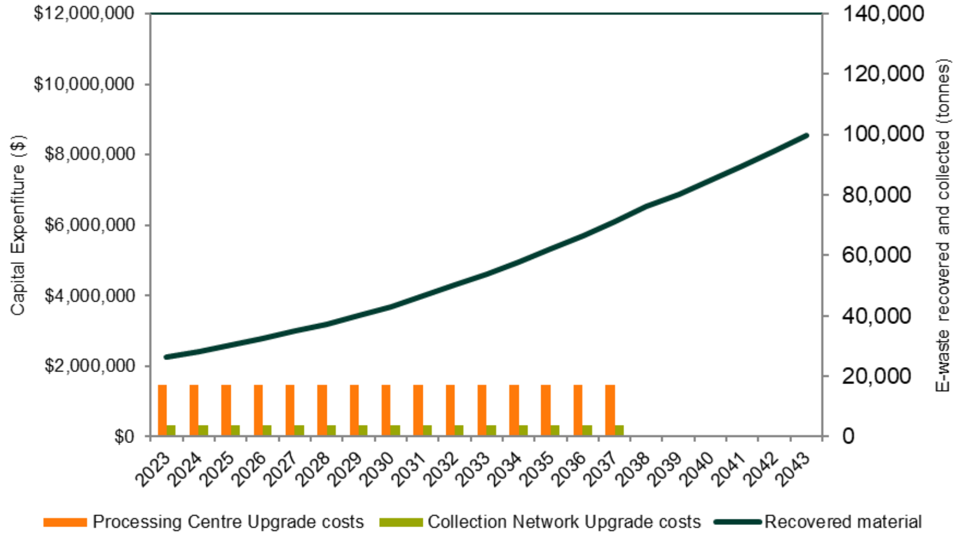
**Table C.1 Detailed description of cost and benefit calculations and assumptions**

| Cost/ Benefit | Sources | Description of calculation and assumptions |
|---|---|---|
| **Costs** | | |
| Initial Government Administration Costs<br>Education & Communication Costs | WA State Government Budget 2022-23 | The WA State Government budgeted a set amount ($3.15m) to be spent over three years on administration and an education & communication campaign.<br>On advice from DWER, this was split at 60% for administration and 40% communication, and spread across the three years in accordance with the budget. |
| Collection Network Upgrade Costs | DWER (2022) Waste Infrastructure Register<br>Marsden Jacobs Associates (2017) *Managing e-waste in Victoria: Policy Impact Assessment* | The Marsden Jacobs Victorian PIA estimate a small transfer station upgrade was estimated to cost $75,000 and a large station costing $150,000.<br>According to DWERs internal Waster Infrastructure register, there are 167 premises with a category 62 license, and these were assumed to be capable of receiving a transfer station upgrade that would allow them to collect and sort e-waste. Of these 167 premises, 32 received over 50,000 tonnes of waste per year (treated as 'large' premises), while 135 received under 50,000 tonnes (treated as 'small' premises).<br>The number of these category 62 premises that were assumed to require upgrading to meet reasonable collection standards was 39%, based on this proportion of transfer stations that needed upgrading in the Victorian PIA. This meant an approximated 54 'small' category 62 premises would need upgrading around WA (at $75,000 each, plus 15% inflation to account for increased construction costs), and 13 'large' premises would require upgrading (at $150,000 each, plus 15%).<br>The total figure of $4.8m roughly aligns with what DWER had budgeted for with grants to be awarded for collection infrastructure upgrade costs ($10m for all infrastructure upgrade grants, which also includes recyclers).<br>This upgraded collection infrastructure spend was estimated to be spread over the first 15, 10 and 5 years of the analysis for Options 1, 2 and 3 respectively, to account for varying speeds of e-waste industry development.<br>See Figure C.1, Figure C.2 and Figure C.3 for an illustration of these costs over time. |
| Collection and transport costs | Marsden Jacobs Associates (2017) *Managing e-waste in Victoria: Policy Impact Assessment*<br>Department of Water and Environmental Regulation (2022) *Recovered tonnes in WA 2019-20, 2020-21* | To calculate the cost of residential e-waste collection, it was assumed that 54% of e-waste collected would be via drop-off and 46% would be via verge collection, based on the proportion of Category 1 Large Household Appliances (verge collection) to the other categories of e-waste (drop-off participation) recovered.<br>The drop-off cost was taken from the Marsden Jacobs Victorian PIA as the non-metro residential e-waste drop-off (participation) amount, which was $178/tonne. An additional $81/tonne cost for the sorting and handling of e-waste was added to this figure.<br>The verge collection cost was assumed to be only $81/tonne, given it was assumed verge collections by local governments would continue as usual (to the same extent as the base case) with only an additional cost to handle and sort the waste at a transfer station.<br>For commercial collection costs, a $312/tonne cost was taken from the Marsden Jacobs Victorian PIA with an additional $81/tonne estimated for handling and sorting.<br>The residential e-waste collection cost was weighted at 67% of the total collection cost per tonne, while commercial costs were weighted 33%, which reflected the relative proportion of MSW to C&I sourced e-waste recovered in the 2020-21 reporting period to DWER.<br>Finally, there was also a cost to transport the waste from the transfer station to an e-waste processor, which was estimated at a high level from the Marsden Jacobs Victorian PIA (converted to the WA context) as $100/tonne.<br>This produced an estimated $357/tonne to collect, handle and transport e-waste through the waste system. |

| Cost/ Benefit | Sources | Description of calculation and assumptions |
|---|---|---|
| Processing Centre Upgrade Costs | UTS Institute of Sustainable Futures & Equilibrium Consulting (2020) *Scoping study for photovoltaic panel and battery system reuse and recycling fund* | A data point that matched the capital cost of an e-waste recovery facility ($7m AUD) to the annual throughput capacity (4,500 tonnes) was used to estimate this cost ($1.5m/kt). The kilotonnes of e-waste recovered in our model in 2043 (14kt for Option 1, 29kt for Option 2 and 36kt for 3) was used to calculate a $21.9m (Option 1), $45.5m (Option 2) and $56m (Option 3) capital construction cost.<br>This processing infrastructure spend was estimated to be spread over the first 15, 10 and 5 years of the analysis for Options 1, 2 and 3 respectively, to account for varying speeds of e-waste industry development.<br>See Figure C.1, Figure C.2 and Figure C.3 for an illustration of these costs over time. |
| Annual Government Monitoring and Enforcement | DWER Assumptions | With a change to legislation and regulations, the State Government will need to increase its monitoring and enforcement to ensure compliance with the landfill ban. Under Option 1 (with no change to the legislation), it is assumed an additional 0.1 FTE will be required per year, while under Option 2 it is assumed 0.5 FTE will be required. Under Option 3, it is assumed local Governments will be responsible for compliance monitoring and is assumed to be equal to 0.05 FTE per LGA (138 LGAs in WA).<br>All FTE are assumed to cost $90,000 p.a. This results in a $9,000, $45,000 and $621,000 cost per annum for Options 1, 2 and 3 respectively. |
| Annual Industry Reporting costs | DWER Assumptions<br>ABS (2022) *8165 Counts of Australian Businesses, including Entries and Exits, June 2017 to June 2021* | The annual industry reporting costs are calculated by multiplying the number of entities by the additional FTE equivalent reporting burden for each option, for each of the following stakeholders:<br>• Commercial entities<br>• Private entities<br>• Not-for-profit (e.g., charitable recyclers)<br>• Local government collections<br>• Transport contractors<br>• Transfer stations<br>• Recycling facilities<br>• Landfill operators<br>For a full list of the number of entities and the additional reporting burden per entity, see **Table C.2** below. |
| Stockpiling and Unlawful Disposal | Synergies Economic Consulting (2021) *Economic assessment of waste reform options* | The cost per-tonne of stockpiling and unlawful disposal was taken from a previous Synergies study. This study estimated the economic impact of A: stockpiling and B: Unlawful disposal (such as illegal dumping) of C&D waste. The cost of stockpiling was based on the risk of stockpile fires, the risk of abandonment and associated clean-up and the operating cost of stockpiling. The cost of unlawful disposal includes clean-up, transport and land costs.<br>For the purposes of this high-level study, an average of these two costs were taken and applied to the total tonnes assumed to be stockpiled/unlawfully disposed of in the model. |
| **Benefits** | | |
| Gross margin (from high-value material recovery) | Yang, Wan-Dong & Sun, Qing (2021) *Cost-benefit analysis of metal recovery from e-waste: Implications for international policy*.<br>Marsden Jacobs Associates (2017) *Managing e-waste in Victoria:* | The gross margin (from high-value material recovery) per tonne is calculated by subtracting the operating cost of processing one tonne of e-waste from the average value of the metals extracted from one tonne of e-waste.<br>For the purpose of this CBA and for simplicity, it was assumed all categories of e-waste *other than Category 1 Large Household Appliances* would be processed for high-value material recovery if diverted from landfill.<br>The value of these materials depends on market conditions and fluctuates over time, but was estimated based on average quantities of valuable materials present in e-waste from the Marsden Jacobs Victorian PIA. This was estimated at $900 per tonne.<br>The cost of processing one tonne of e-waste was estimated from Yang, Wan-Dong & Sun, Qing (2021) *Cost-benefit analysis of metal recovery from e-waste: Implications for international policy*. This was the cost of metals recovery from |

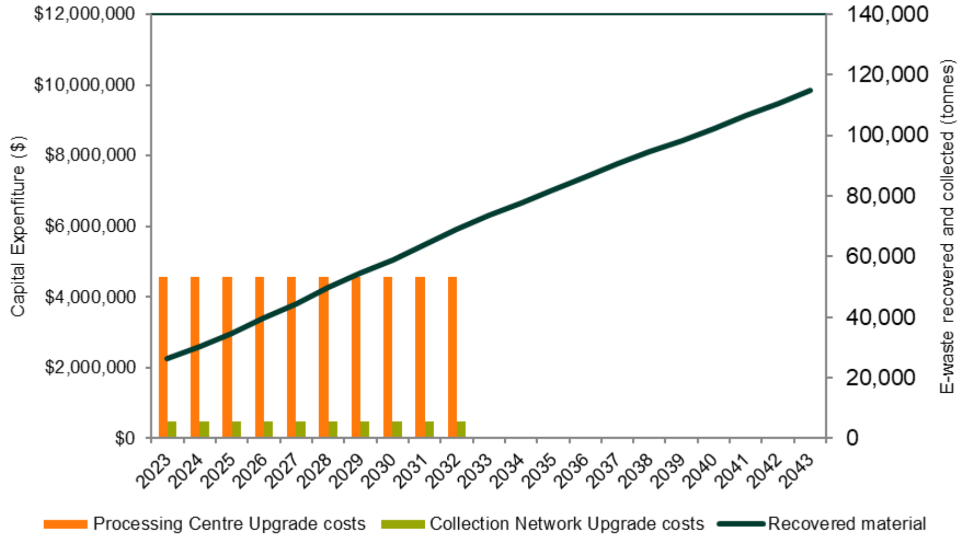
| Cost/ Benefit | Sources | Description of calculation and assumptions |
|---|---|---|
| | *Policy Impact Assessment* | e-waste (taken from the European context) which equalled 183 Euros/tonne in 2016, and converted to 2022 Australian dollars as $298/tonne.<br>This results in a gross margin of $602/tonne for the processing and sale of e-waste. Note that this does **not** include any fixed capital costs, and hence is considered a gross margin per tonne rather than a net profit per tonne.<br>Finally, the full gross margin calculated in this method was assumed to be reached over time as recycling centres reach efficient scale. As such, the original margin per tonne is assumed to be 40% higher than the gross margin for scrap metal recycling (at $202/tonne) and then grow over 10 years to reach $602/tonne by 2033. This was assumed under Options 1, 2 and 3.<br>The gross margin for e-waste recovered under the base case was assumed to grow to 50% of the full margin under the project cases, to $301/tonne by 2033. This assumes that, under the base case, there is less development and 'activation' of the e-waste recycling industry in Western Australia and as such, does not foster the required efficiency and scale to reach the gross margins available in other more established industries, such as in Victoria.<br>See Figure 8 for an illustration of the gross margin for high-value recovered materials over time. |
| Gross margin (from scrap-metal recycling) | Marsden Jacobs Associates (2017) *Managing e-waste in Victoria: Policy Impact Assessment*<br>Marsden Jacob Associates (2019) *Evaluation of shredder floc reduction and concessional waste levy* | The gross margin (from scrap-metal recycling) per tonne is calculated by subtracting the operating cost of processing one tonne of scrap metal from the average value of the metal recovered from the waste.<br>For the purposes of this CBA and for simplicity, it was assumed all Category 1 Large Household Appliances would be processed through scrap metal recycling. This assumption is based on the high amounts of metals contained in large household appliances (for example, whitegoods such as fridges or washing machines).<br>The value of the sale of scrap metals was derived from an approximation of steel and copper recovered from one tonne of Large Household appliances. Based on Marsden Jacob Associates (2019) *Evaluation of shredder floc reduction and concessional waste levy* and other desktop research, it was assumed 97% of recovered material was steel (valued at $110/tonne) and 3% of recovered material was copper (valued at $3,625/tonne). This resulted in the value of recycled scrap metal of $215/tonne.<br>The cost of recycling scrap metals was taken from the Marsden Jacobs Victorian PIA and estimated at $73/tonne.<br>As such, the gross margin for scrap metal recycling was estimated as $143/tonne. |
| Health & Environmental benefit | Marsden Jacobs Associates (2017) *Managing e-waste in Victoria: Policy Impact Assessment* | The previous report by Marsden Jacobs associates conducted detailed analysis into the health and environmental impact of landfilled e-waste. This analysis estimated the levels of hazardous substances (converted to a mercury-equivalent) contained in different categories of e-waste. The total amount of mercury equivalent substances in these e-waste items was then costed using the damage mercury poses to human health and the environment.<br>While the detailed analysis in the report was made at a category level (and therefore applied per-tonne to specific e-waste categories), for the purposes of this CBA we have taken the average cost per-tonne of *all* e-waste that is disposed to landfill. This figure came to $30/tonne.<br>This $30/tonne was then applied to the tonnes of e-waste diverted from landfill under each of the options, which produced a net benefit. |
| Avoided landfill costs | Desktop review of landfill gate fees<br>Marsden Jacobs Associates (2017) *Managing e-waste in Victoria: Policy Impact Assessment* | The cost of operating a landfill to dispose of one tonne of waste was estimated from a review of landfill gate fees in Perth with the waste levy ($70/tonne) subtracted. This resulted in an estimate of the cost of landfilling e-waste as $102/tonne, and was roughly cross checked with figures from the Marsden Jacobs Victorian PIA.<br>This $/tonne figure was multiplied by the tonnes of e-waste diverted from landfill to produce a net benefit under the implementation options. |

**Figure C.1 Capital expenditure (processing and collection infrastructure): Option 1**



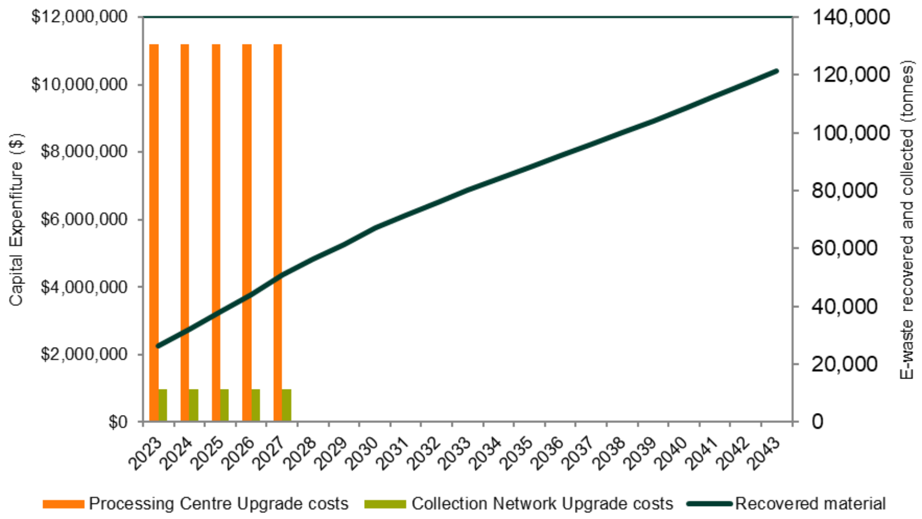

**Data source:** Synergies modelling

**Figure C.2 Capital expenditure (processing and collection infrastructure): Option 2**




**Data source:** Synergies modelling

**Figure C.3 Capital expenditure (processing and collection infrastructure): Option 3**




**Data source:** Synergies modelling

**Table C.2 Industry compliance (recording and reporting) costs**

| Additional reporting burden (days per year) | Option 1 | Option 2 | Option 3 | Number of Entities | Assumption on number entities |
|---|---|---|---|---|---|
| **E-waste generators** | | | | | |
| Households | — | — | — | 0 | No reporting required from households |
| Commercial entities | — | 1.5 | 1.5 | 414 | Businesses with over 200 employees in WA have to record and report their bulk e-waste disposal from ABS Business Counts data. |
| **Collection network** | | | | | |
| Private entities | — | 1.0 | 6.0 | 10 | Estimate |
| Not-for-profit (e.g., charitable recyclers) | — | 1.0 | 6.0 | 10 | Estimate |
| Local government collections | 1.0 | 1.0 | 6.0 | 138 | Western Australia's Local Government Association (WALGA) represents 138 local government areas in WA |
| **Waste management** | | | | | |
| Transport contractors | — | 4.0 | 12.0 | 15 | Estimate |
| Transfer stations | 1.0 | 1.0 | 1.0 | 167 | Any facility with Category 62 license |
| Recycling facilities | 1.0 | 2.0 | 2.0 | 10 | 4 e-waste recyclers and 6 scrap metal companies in Perth |
| Landfill operators | 1.0 | 1.0 | 1.0 | 145 | Category 89 facilities plus category 64 facilities (that don't also have a category 62 license) |

**Note:** Data based on assumptions from DWER on level of reporting burden required per stakeholder. Number of entities data from ABS Business counts, DWER Waste Infrastructure Register, WALGA and desktop research.

**Table C.3 Additional sources used in the CBA**

| Source | Usage |
|---|---|
| Bontinck PA, Bricout J, Grant T and Legoe G (2021) *E-product stewardship in Australia: Evidence report.* A report prepared for the Commonwealth Department of Agriculture, Water and the Environment by Iceni Group and Lifecycles, Sydney, Australia.<br>Renew Economy (2016) *Australia's top solar states and suburbs*. Accessed at https://reneweconomy.com.au/australias-top-solar-states-and-suburbs-23048/ | PV waste arising forecasts to 2030.<br>These forecasts were at the Australian level and multiplied by 13% to convert to WA figures, based on Western Australia accounting for 13% of PV uptake in Australia. |
| Department of Water and Environmental Regulation (2021) *Waste Recovery Data 2020-21* | Estimate of current percentage of battery recovery.<br>The Encycle MFA data estimated generation statistics for batteries in 2019-20, while the DWER recovery data reported tonnes of batteries recovered. The proportion of recovered batteries to waste batteries generated was used as the starting point for recovery percentage (36%) in the model. |

**Note:** Data based on assumptions from DWER on level of reporting burden required per stakeholder.