Potential environmental benefits of ICT e-waste recycling in Aotearoa New Zealand

FY23 update

Undertaken by Lifecycles for the TechCollect NZ pilot programme

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1 Introduction

1.1 Context

TechCollect NZ (TCNZ) is an industry leader in product stewardship – helping the technology sector manage the life cycle of its products. TCNZ provides a free national collection and recycling service for information and communication technology (ICT) e-waste in Aotearoa New Zealand (NZ). TCNZ only partners with local service providers who meet stringent health, safety, and environmental standards.

TCNZ contracted Lifecycles to explore the potential benefits of its national programme, building on the initial study conducted in 2022, and assessing a full year of operation.

This report presents the updated environmental data for FY2023, covering the benefits of e-waste recycling on climate change, water and energy use, and particulate emissions.

1.2 Life Cycle Assessment

LCA is a methodology for assessing the full 'cradle-to-grave' environmental benefits of products and processes by assessing environmental flows (i.e. impacts) at each stage of the life cycle. LCA aims to include all important environmental impacts for the product system being studied. In doing so, LCA seeks to avoid shifting impacts from one life cycle stage to another or from one environmental impact to another.

The framework and principles of LCA are described in the international standard ISO 14040 [1]. The general structure of the LCA framework is shown in Figure 1. Each stage of the LCA interacts with the other stages which makes LCA an inherently iterative process. The specific requirements for LCA are defined by ISO 14044 [2].

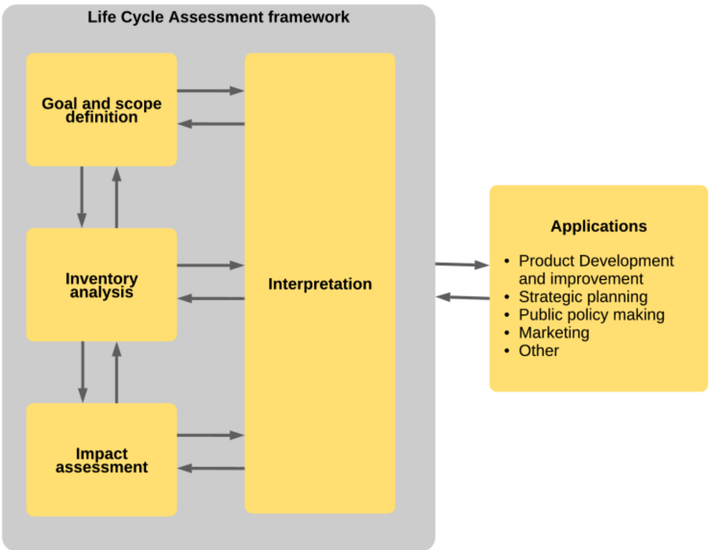

Figure 1 Framework for Life Cycle Assessment.

- The first stage (**goal and scope**) describes the reasons for the LCA, scenarios, boundaries, indicators and other methodological approaches used.
- The second stage (**inventory analysis**) builds a model of the production systems involved in each scenario and describes how each stage of the production process interacts with the environment.
- The third stage (**impact assessment**) assesses the inventory data against key indicators to produce an environmental profile of each scenario.
- The final stage (**interpretation**) analyses the results and undertakes systematic checks of the assumptions and data to ensure robust results.

2 Goal and scope

2.1 Reason for the study

This analysis aims to answer two questions, as detailed below.

1. **What are the environmental effects associated with the reprocessing of ICT waste collected through TCNZ's programme?**
   The recycling of e-waste into secondary materials relies on a complex system of processes used to separate and refine individual material fractions. These can range from simple processes (e.g. magnetic separation) to sophisticated processes requiring significant energy inputs (e.g. pyrometallurgy).
2. **What are the environmental benefits associated with recovered secondary materials from the recycling of e-waste?**
   Electrical and electronic products are manufactured using a broad range of materials, many of which can be recovered as secondary materials. The model is built under the assumption that the production of secondary materials will displace the use of an equivalent amount of primary materials. This analysis aims to quantify the mass of recovered material, the primary material it displaces, and the environmental benefits associated with avoiding the production of those primary materials.

2.2 Intended audience

Though this report will remain an internal document, information resulting from the analysis will be made available to the general public, through TCNZ's publications.

2.3 Functional unit

The functional unit (FU) is the basis for the comparison of alternatives in LCA. It describes the service delivered by the processes being studied. The primary intention of the study is to analyse the environmental effects associated with the e-waste recycling programme operated by TCNZ. Thus, the functional unit has been defined as:

"the collection and recycling of one tonne of mixed ICT waste collected and recycled by TCNZ in NZ, during financial year 2023".

2.4 System boundaries

The system boundary diagram reported in Figure 2 illustrates the boundary considered for the study, which includes the collection and recycling of e-waste collected through TCNZ.

A description of the steps considered within the system boundary are reported in Section 2.4.1, while excluded processes are identified in Section 2.4.3. As outlined by the functional unit and information provided in this section, the scope of this analysis is cradle-to-gate. Because their inclusion would not provide support in answering the research question, the manufacture and use of the products, as well as their transport to the drop-off site, were not considered in this analysis.

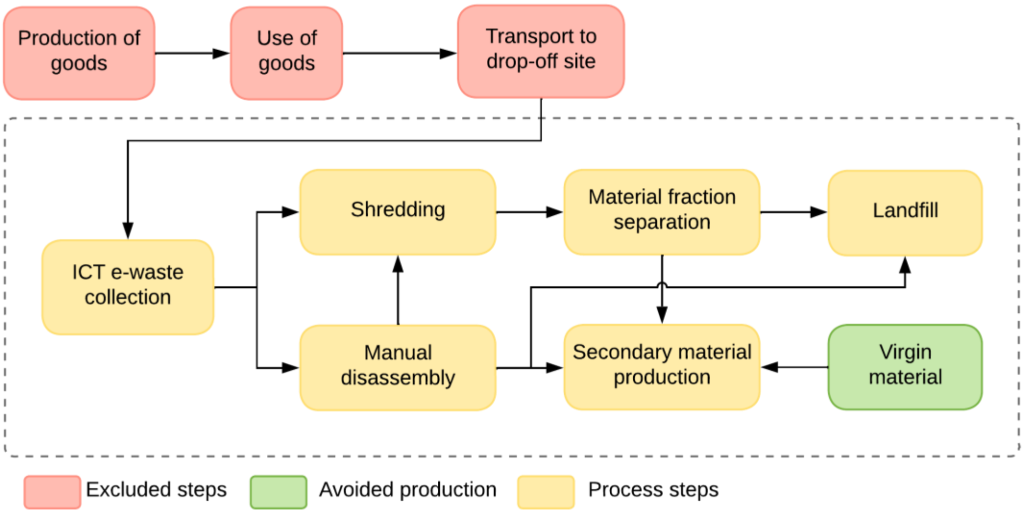

Figure 2 System boundaries

2.4.1 Included processes

This analysis covers all relevant steps of the e-waste collection and recycling systems as described below.

- Transport of e-waste from the point of collection (or drop-off site) to The Recycling Group's facilities.
- Processing of e-waste at The Recycling Group, including disassembly and initial separation of major material fractions.
- Transport of separated fractions to a downstream processor, domestically and overseas.
- Further dismantling of specific components and specialist recycling processes.

The boundaries of the system end at the point where a secondary material is ready to be used as an input to a new product. An example might be a clean stream of aluminium separated using an eddy current process, which is sold to a furnace.

2.4.2 Cut-off criteria

Any excluded flows must fall below the cut-off threshold for this study (below one per cent of total greenhouse gas emissions). The system boundary reported in Figure 2 is simplified. Though not all steps and processes used in the management of e-waste are shown, they are included in the analysis. The model built for this analysis relies on ecoinvent v3.9.1 and AusLCI v1.42. These systems are built with no cut-off, meaning that all flows are considered, including capital formation.

2.4.3 Excluded processes

Within the cradle-to-gate boundary of the system, the analysis excludes several flows, as defined below.

- Transportation of employees to and from the site, as well as any catering on-site.
- Manual disassembly of incoming waste.
- Non-material services associated with recycling operations (e.g. insurance, finance, etc).

2.5 Flows included in the Life Cycle Assessment

A Life Cycle Assessment aims at measuring the exchange between the natural world (the '*biosphere*') and human activities (the '*technosphere*'), either via the extraction of natural resources or the emissions of pollutants to air, water and soil. The measurement is done at the level of the system analysed, which is broken down into a series of unit processes leading to the delivery of the functional unit, as defined in the goal and scope. A single unit process is illustrated in Figure 3. It includes flows to and from the '*biosphere'* as well as flows to and from the '*technosphere'*.

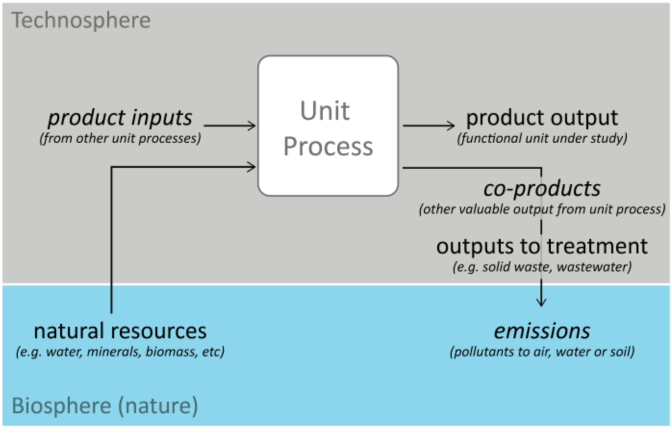

Figure 3 Inputs and outputs of a unit process in CFP.

2.6 Allocation procedures

Multi-functionality occurs when a single process, or group of processes, produces more than one usable output, or 'co-product'. ISO 14044 [3] defines a co-product as *'any of two or more products coming from the same unit process or product system'*. A product is any good or service, with value for the user. This is distinct from a '*waste*', which ISO defines as *'substances or objects which the holder intends or is required to dispose of'*, and therefore has no value to the user.

As LCA identifies the impacts associated with a discrete product or system, it is necessary to separate the impact of co-products arising from multifunction processes. The ISO 14044 standard provides a four-step hierarchy for solving the issue of multi-functionality (adapted from text in [4]):

1. **Avoid allocation by subdividing systems –** wherever possible, allocation should be avoided by dividing the unit process into sub-processes.
2. **Avoid allocation by system expansion** – expanding the product system to include the additional functions related to the co-products.
3. **Allocation by underlying physical relationships** – the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them.
4. **Allocation between co-products** – the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, data may be allocated between co-products in proportion to the economic value of the products.

One allocation was required in the foreground, with regards to printed circuit board recycling. The model used to represent the metallurgical process includes a mix of scrap copper and printed circuit board. The environmental impact of the pyrometallurgical process was allocated to the two waste streams based on the economic value of the material recovered, which was calculated based on the estimated content, recovery rate, and material value.

2.7 Characterisation model

In LCA, the impact assessment stage relates the inventory flows to the indicators selected. This is done by classifying which flows relate to this impact category and selecting a characterisation model that quantifies the relationship of each inventory type to the indicator in question. The calculation of the category indicator result is the sum of all inventory flows multiplied by their relevant characterisation factors.

The indicators chosen for this analysis are expected to be the most relevant to the recycling industry, with the exception of human and ecotoxicity indicators which are not included due to large uncertainties in the models and background data used in the study. A summary of the impact category selected for the study can be found in Table 1.

Table 1 Impact categories and characterisation models of the study.

Indicator	Description	Characterisation model
Climate change	Radiative forcing as Global Warming Potential (GWP100) Expressed in kg CO_2 eq. This is governed by the increased concentrations of gases in the atmosphere that trap heat and lead to higher global temperatures. Gases are principally carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).	(IPCC 2013) IPCC model based on 100-year timeframe + some factors adapted from EF guidance.
Resource use (energy carriers)	Abiotic resource depletion – fossil fuels. Expressed in MJ lower heating value. Depletion model based on use-to-availability ratio. Full substitution among fossil energy carriers is assumed. It includes all energy resources extracted and used in any way. It does not include renewable energy, energy from waste or nuclear energy.	(Guinée et al., 2002) CML 2002 and van Oers et al. 2002.
Particulate matter	Measured in g $PM_{2.5}$. This impact category looks at the health impacts from particulate matter for PM_{10} and $PM_{2.5}$. This is one of the most dominant immediate risks to human health as identified in the global burden of disease.	(Humbert et al. 2011) World impact plus method.
Water scarcity	User deprivation potential. Expressed in m^3 world eq. Represents the relative Available WAter REmaining (AWARE) per area in a watershed, after the demand of humans and aquatic ecosystems has been met. The calculations are based on deprivation-weighted water consumption numbers.	(AWARE) Available WAter REmaining as recommended by UNEP, 2016

2.8 Limitations

This study, like any Life Cycle Assessment, has limitations. It is worth pointing out that a life cycle assessment is a model, and as such it relies on assumptions and approximations. The ability to use these assumptions and approximations is what allows us to complete a Life Cycle Assessment. We rely on their robustness to provide the closest representation possible of the system under study.

In this case, there is a certain level of uncertainty associated with the downstream processes which are used to recover secondary material. Our model attempts to model these in as much detail as the available literature and existing background model allows. In addition, there are some uncertainties on the material fraction recovered throughout the year, as the study relies on a sampling campaign conducted outside the temporal boundaries of the study (FY23).

3 Inventory

Inventory analysis is the stage of the LCA in which the system being studied is broken up into unit processes, which are modelled by quantifying relevant inputs and outputs. These unit processes are linked to create a system that produces the functional unit of the study, as illustrated in Figure 4. They can be categorised into foreground unit processes and background unit processes:

- **Foreground processes** are those for which specific data are collected for the study. This includes primary data collected from facilities, secondary data from published papers and modified background processes from LCA databases.
- **Background processes** are those for which data are typically sourced from pre-existing databases. The background data are either less important to the study outcomes or are already well-characterised in the existing data sets and therefore do not warrant specific modelling. Background processes are used to connect the model during an analysis with their complete supply chain, so that a full cradle-to-grave assessment can be conducted. Here, AusLCI v 1.42 [5] and ecoinvent v3.9.1 [6] are used as the databases of reference. Both libraries uses economic allocation throughout.

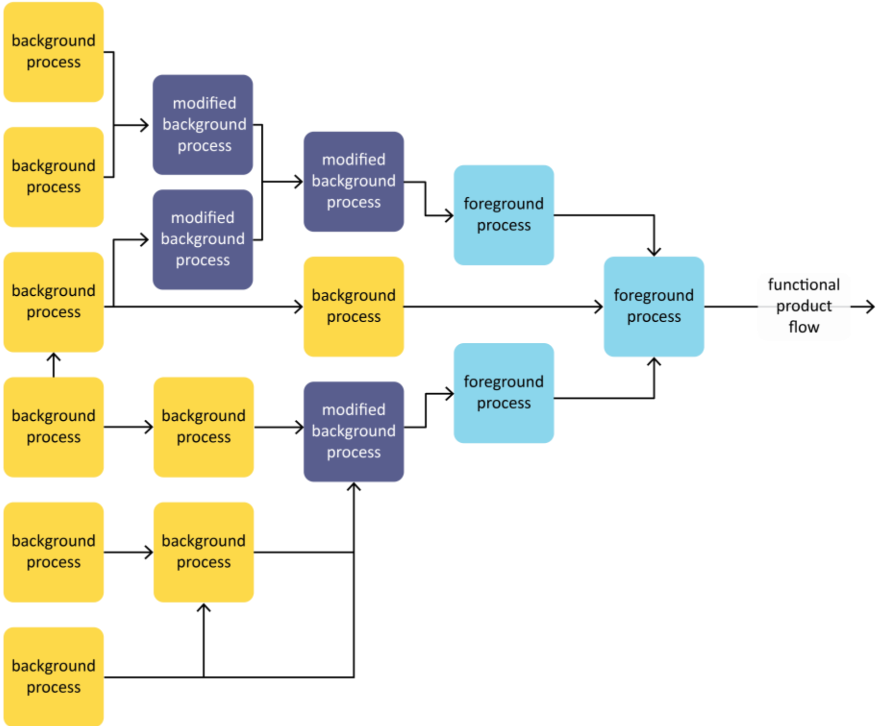

Figure 4 Linking unit processes in a carbon footprint to produce the functional unit.

The following sections outline the sources of the background and foreground inventory data.

3.1 Foreground data

3.1.1 Inbound e-waste logistics

Freight efforts are modelled using a tonne.km unit, which represent the requirements of moving one tonne of goods over one kilometre.

The Recycling Group is the sole recycler involved in the programme to date. Its main operation is in Auckland, though some pre-processing takes place at a second site in Christchurch. This second site is also used to consolidate ICT waste collected from the South Island, before transportation to Auckland. The distance and mass of each shipment was calculated using information shared by TCNZ.

As reported in Table 2, the use of road and sea freight is almost equally distributed, with approximately 53% of the logistics effort being allocated to road freight and the rest to sea freight.

Table 2 Inventory table – total freight effort required to transport e-waste.

	Unit	Value
Road freight	t.km	21,104
Sea freight	t.km	18,739
Average road distance per tonne of waste	km	219

3.1.2 Pre-processing at initial recycler

Upon delivery to The Recycling Group, the e-waste will undergo an initial pre-processing step. Two processes can typically take place:

1. *Manual disassembly*: the e-waste is disassembled to separate clean fractions (e.g. ferrous metals, non-ferrous, plastics, etc.), or specific components (e.g. batteries, printed circuit boards, toner cartridges, hard-drives, etc.). This is process is conducted manually, using handheld power tools. The environmental burdens associated with this process is assumed to be negligible and has therefore been excluded from the analysis.
2. *Mechanical pre-processing*: at The Recycling Group, specific components or material fractions are further treated through a mechanical process before being shipped downstream. This is the case for some printed circuit boards and for clean plastic grades, which are granulated at 10mm. Using conservative assumptions, this analysis assumes that 29% of the material received will go through size reduction step before leaving the site.

The mechanical pre-processing step was modelled using data from the ecoinvent background database [6], modified to use electricity from the NZ grid.

3.1.3 Exported material fraction

Once the initial separation step is conducted, each material fraction is distributed to downstream recyclers, domestically and abroad, for further processing. The information reported by The Recycling Group allows us to establish the final destination of each material fraction.

Based on the information collected, approximately 64% of the e-waste collected via TCNZ is treated in NZ. This includes ferrous and non-ferrous metals, clean glass, and non-recyclables going to landfill. Once secondary materials are obtained, these are generally sold on the global market.

Of all destinations considered, Malaysia represents by far the largest export fraction, comprising 83% of all exports. This is because all clean plastic grades and toner powder are shipped to Malaysia for recycling. Other exports streams are linked to material fraction which require specialist processes that are not currently domestically available. This is the case for PCBs, which are treated in Japan using a pyrometallurgical process. A summary of the exported fraction is reported in Table 3.

Table 3 Inventory table – exported fraction in FY23.

	Proportion	Mass exported (kg)	Typical material export
Malaysia	83%	28,899	Plastics (95%), and toner (5.3%)
Japan	13%	4,532	Printed circuit boards (100%)
South Korea	2%	867	Batteries (100%)
Australia	1%	487	Lead glass (100%)
TOTAL		**34,785**	

3.1.4 Material fractions in e-waste

A critical aspect of e-waste recycling is the breakdown of materials found in a tonne of product. E-waste recycling is environmentally beneficial if it can recover valuable material fractions. When recovered, these can replace virgin materials, thus avoiding their production.

The broad range of materials in e-waste includes various metals, plastics, and glass. Ferrous and non-ferrous metals such as aluminium and copper are often a focus for recovery, as they represent a high proportion of the waste, can be recovered using relatively simple processes, and have a high resale value. More complex processes are required to recover valuable material fractions from specific components, and some businesses have developed a particular expertise in specific streams.

In this study, information on the typical composition of the waste managed through the TCNZ programme was estimated through sampling, conducted in September 2023. This allowed identification of the proportion of different material fractions, as well as specific components such as PCBs, CRT screens etc. The analysis relies on a 2.3 tonne sample of ICT waste processed by The Recycling Group, as a representation of the entire stream.

Precious metal fractions in printed circuit boards were estimated based on the literature [7]. The list of materials provided in Table 4 and Figure 5 is limited, as they were drawn from the material being recovered, rather than from an estimate of the composition.

Variations from the previous exercise can be observed in Table 4 and Figure 5, the most significant of which are described below.

1. A 15% reduction in the fraction of ferrous metal and aluminium, compared to the previous model.
2. Silver and gold fractions have significantly increased, by 43% and 860% respectively. This is because the PCB recycling model has been reviewed and is now calibrated based on the typical gold and silver content of PCBs as reported in the literature [7].
3. A 22% reduction in the fraction of glass, primarily driven by a reduction in the fraction of lead glass.
4. A 38% increase in the fraction of plastic, which is mostly related to an increase in clean plastic grades.

These variations highlight the importance of developing a sound approach to estimating the material fractions found in ICT waste collected by TCNZ.

Table 4 Estimated material fraction in e-waste.

Material fraction		Mass kg / t	Ratio %
Metal		**584**	**58%**
	Iron	513	51%
	Aluminium	25	2.51%
	Copper	43	4.32%
	Silver	0.027	0.0027%
	Gold	0.0130	0.0013%
	Other metal	2.46	0.25%
Glass		**32**	**3%**
	Clean glass	27	2.72%
	Lead glass	5	0.50%
Plastics		**298**	**30%**
	Mixed plastics	41	4.15%
	Clean plastic grades (ABS / PC / PS)	257	25.68%
Other		**86**	**9%**
	Batteries	61	6%
	Toner	9	0.90%
	Other	16	1.60%

The material breakdown reported in Table 4 is summarised in Figure 5.

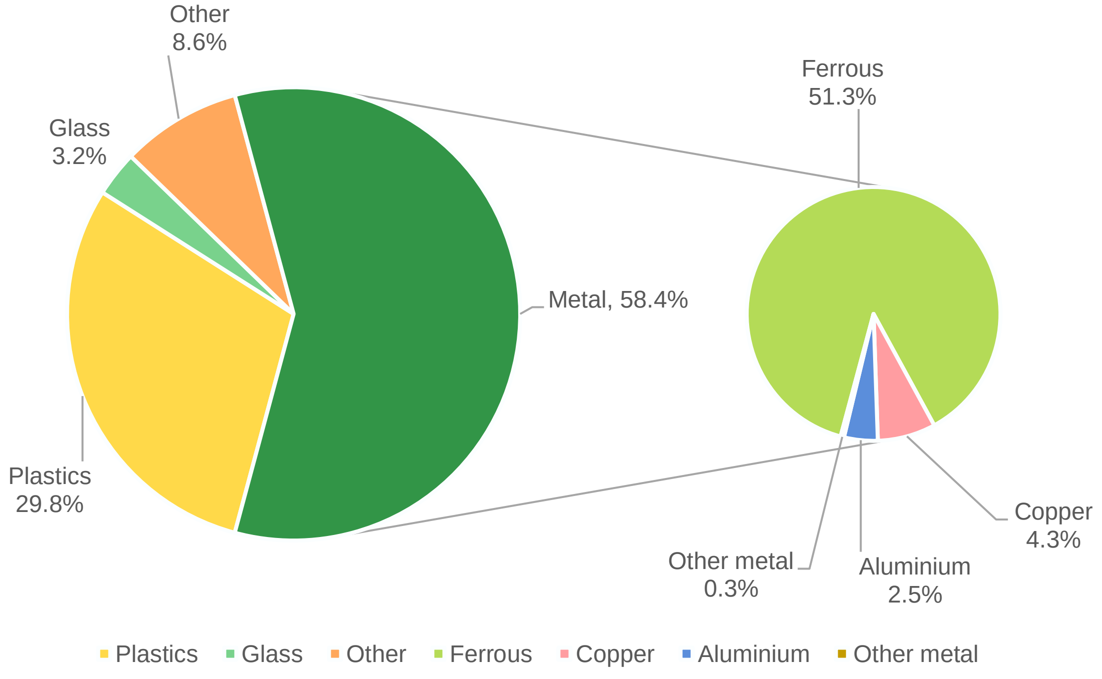

Figure 5 Estimated material fractions in e-waste.

3.1.5 Material reprocessing

Printed circuit board reprocessing

The precious metal fraction of e-waste is typically found in electronic components. As such, the reprocessing of printed circuit boards has been the subject of much research in the past decade.

Metallurgical processes have been used extensively to recover precious metals from printed circuit boards. In this case, a pyrometallurgical process is used by the Japanese downstream recycler, which is replicated here from the literature. As modelled, the process allows for recovery of copper, silver and gold scrap from the PCBs.

The model used to represent the pyrometallurgical process is based on the literature and replicates the management of PCBs through a copper smelter. The copper is extracted through a smelting and electro-refining process, while silver and gold are recovered through an additional precious metal refining stage. From one kg of PCB, the process extracts the following metals.

- 166g of copper (assuming a copper content of 17.75% and a recovery rate of 93.4%).
- 0.28mg of silver (assuming a silver content of 0.058% and a recovery rate of 47.8%).
- 0.14mg of gold (assuming a gold content of 0.028% and a recovery rate of 48.9%).

Table 5 Inventory for the reprocessing of PCBs through a copper smelter [7-9].

	Unit	Amount	Comment
Waste input			
PCB scrap	kg	5.94	Assuming a copper content of 17.7%, gold content of 0.0277% and silver content of 0.0585%, as per [7].
Copper scrap	kg	6	Assuming a copper content of 70%, as reported in Table 1 of Ghodrat M. et al. (2016) [9].
FCS Slag	kg	0.42	
Process input			
Coal	kg	1.88	Coal and carbon inputs to the reduction and oxidation furnaces respectively, as reported in Figure 3 of Ghodrat M. et al. (2016) [9].
Oxygen	kg	11.9	Oxygen enriched air inputs to the reduction and oxidation furnaces respectively, as reported in Figure 3 of Ghodrat M. et al. (2016) [9]. Matches the total amount of oxygen reported per kg of copper output in Table 6 of Ghodrat M. et al. (2017) [8]
Sulfuric acid	kg	2.82	Represents the input of electrolyte to the electro refining process, as reported in Figure 3 of Ghodrat M. et al. (2016) [9]. The use of sulphuric acid was ascertained via Table 6 of Ghodrat M. et al. (2017) [8].
Compressed air (700 kPa)	m^3	89	Used to represent the input of ‘Air 2’ to the Fire refining process, as reported in Figure 3 of Ghodrat M. et al. (2016) [9]. Assuming a density of 9.37 kg/m3 based on a 6.89 bar pressure and 21°C temperature.
Electricity	kWh	10.1	Electricity demand reported in Table 7 of Ghodrat M. et al. (2017) [8], per mass of copper output, pro-rated to the total copper output.
Natural gas	MJ	40.1	Used to represent the input of ‘Hydrocarbons’ to the Fire refining process, as reported in Figure 3 of Ghodrat M. et al. (2016) [9].

	Unit	Amount	Comment
Waste output			
Slag	kg	6.6	Represents the output of slag, as reported in Table 6 of Ghodrat M. et al. (2017) [8], per mass of copper output, pro-rated to the total copper output.
Treatment residue	kg	0.045	Represents the output of treatment residue, as reported in Table 6 of Ghodrat M. et al. (2017) [8], per mass of copper output, pro-rated to the total copper output.
Electrolytic steam	m^3	0.0028	Represents the output of electrolytic steam, as reported in Table 6 of Ghodrat M. et al. (2017) [8], per mass of copper output, pro-rated to the total copper output.
Air emissions			
Carbon dioxide	kg	6.2	Estimated assuming 90% carbon in coal and full release of all carbon as CO_2.
Carbon monoxide	kg	10.4	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.
Sulfur dioxide	kg	0.00052	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.
Dinitrogen monoxide	kg	0.0087	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.
Particulate (<2.5 um)	kg	0.0042	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.
Particulate (>10 um)	kg	14.5	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.
Particulate (>2.5 um and <10 um)	kg	0.022	As reported in Table 7 of Ghodrat M. et al. (2017) [8], pro-rated to total copper output.

Other recovery processes

The material recovery process includes the treatments all other waste fractions go through to recover secondary material. Our model stops at the creation of a secondary stream, which is then sold on the global commodity market. A summary of high-level modelling assumptions is provided for each fraction in Table 6.

The total fraction of waste which is exported for further treatment was estimated based on information provided by recyclers on the downstream recycling steps. Of the total volume of material collected in FY23, approximately 36% was exported for further treatment. This is larger than in the previous exercise and is mainly associated with the larger fraction of plastics estimated in this analysis. Exported fractions include plastics, printed circuit boards, batteries, and lead glass.

The Recycling Group provided information on the breakdown of materials sent for further processing, including their destination and fate. This information was used to model the collection and management of e-waste in the year.

Table 6 Summary of material recovery models used throughout the analysis.

Fraction	Location	Data source	Comments
Ferrous metal	NZ	Modified AusLCI recycling process.	Process modified to use the NZ energy mix. Material offset is represented by the global supply.
Non-ferrous	NZ	Modified AusLCI recycling.	Process modified to use the NZ energy mix. Material offset is represented by the global supply.

Fraction	Location	Data source	Comments
Plastics	MY	Modified Australasian LCI database.	Energy from Grant et al. [10] adjusted to the energy mix in Malaysia. Material offset is represented by the global supply.
Toner	MY	Previous LCA work.	Toner reprocessing, as conducted in Malaysia, is represented by previous work conducted by Lifecycles on a process taking place in Australia, modified to use the energy mix of Malaysia.
Batteries	KR	Previous LCA work.	Adaptation of work conducted at Lifecycles on the recycling of cell phones [11]. The model assumes that lithium batteries would form the vast majority of the chemistry collected.
PCB	JP	Pyrometallurgy process modelled from Ghodrat et al. [8, 9], with metal content sourced from Oguchi et al [7]. Mechanical process modelled from existing models, with metal content sourced from Oguchi et al. [7] and recovery rate of mechanical systems from [12].	Process estimated from the available literature, with outputs aligned with typical metal content of PCBs and typical reported efficiencies.
Glass	NZ	Modified Australasian LCI database.	
Lead glass	AU	Modified ecoinvent lead smelting process.	Ecoinvent [13] model, modified using data from Nyrstar.
Landfill	AU	AusLCI landfill process.	Unmodified.

4 Results and interpretation

4.1 Evolution of results over time

Lifecycles first conducted this analysis in 2022. A comparison between this year and the previous year is provided in Table 7, showing the effects of incremental improvements on the underlying model, as well as changes in the material composition of the waste.

Table 7 Characterisation results of the management of e-waste, as reported over time.

	Cimate change *kg CO_2e*	Energy demand *MJ NCV*	Particulate matter *g $PM_{2.5}$-eq*	Water scarcity *m^3-eq*
FY23	-2,475	-36,664	-3,250	-296.8
2022	-2,052	-28,347	-3,026	-7.4

Overall, we see a significant increase in benefits, particularly with regards to climate change (+21%) and energy demand (+29%). This change is largely linked to the modifications in the underlying model, which significantly affect the benefits associated with printed circuit board reprocessing. In previous years, the metallurgical model was sourced from a study on pyrometallurgy applied to e-waste as a whole, rather than focusing on PCBs. This means that the precious metal content was significantly underestimated. In the updated version of the model, we combine a more recent pyrometallurgical model with an estimate of the metal content in PCBs from the literature, and efficiency rate of the process. This should give a more representative picture of the quantity of precious metals recovered from PCBs in a pyrometallurgical process.

Secondly, the impact assessment method used to model effects on water scarcity was updated to use the more recent method AWARE [14]. This means that this year's results cannot be compared to last year's.

4.2 Climate change

Recycling one tonne of ICT e-waste collected by the TCNZ programme in NZ saved 2,475 kg CO_2e from being emitted to the atmosphere. This is equivalent to planting 41 trees [1].

The burden of transporting and processing the different e-waste material streams is entirely offset by the benefits associated with avoiding the production of virgin materials within the economy.

Most impacts are linked to downstream reprocessing, which far outweigh the emissions associated with the logistics of running the waste management system.

NZ has the advantage of a highly decarbonised grid, with a significant fraction of power sourced from renewable energy (hydropower, geothermal and wind). This means that processes such as metal separation and pre-processing, which mainly rely on electrical input, will result in low carbon emissions when taking place domestically.

Ferrous metals, aluminium and plastic recovery provide 54% of the environmental benefits associated with recycling. The metal fractions can easily be segregated using manual processes and current technologies, such as magnetic separators or eddy current separators. They also have good resale values, well-established recovery routes, and replace a material that requires significant amount of energy to be produced from raw ore. The plastic fraction is manually segregated by The Recycling Group and are exported as a clean stream with minimal processing.

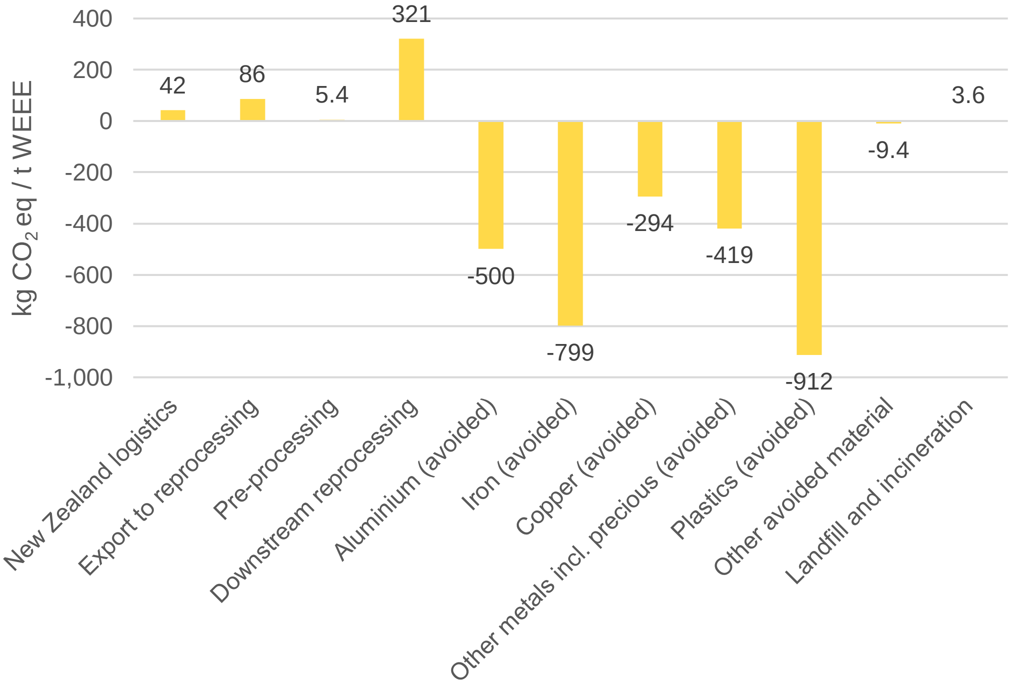

Figure 6 Climate change characterisation results, broken down by steps.

[1] Based on modelling assumptions developed by the U.S. EPA in their Greenhouse Gases Equivalencies Calculator, **https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references**

4.3 Energy

Recycling one tonne of ICT e-waste collected by the TCNZ programme in NZ saved 36,664 MJ. This energy could supply electricity to an average NZ household for 539 days[2].

As with climate change, most of the energy use lies in the downstream reprocessing of the various waste fractions – including the recycling processes associated with the various metals, plastics and glass. Overall, this step represents 68% of the total energy use. Comparatively speaking, the logistics associated with collecting waste represent 11% of total energy consumption.

This effect is entirely offset by the benefits associated with avoiding the production of virgin materials. Iron and aluminium provide significant benefits in terms of energy savings, with 32% of the total benefits when combined. Both materials are present in substantial amounts in the e-waste, and their production from raw material requires significant amounts of energy.

The largest contributor is the recycled plastic, which by itself represents 47% of the total benefits. This is because the production of plastic relies on a petrochemical feedstock, which is captured here as an energy source. The benefits associated with plastic recycling have significantly increased in 2023, reflecting a larger fraction of plastic being recycled, mostly as specific polymers.

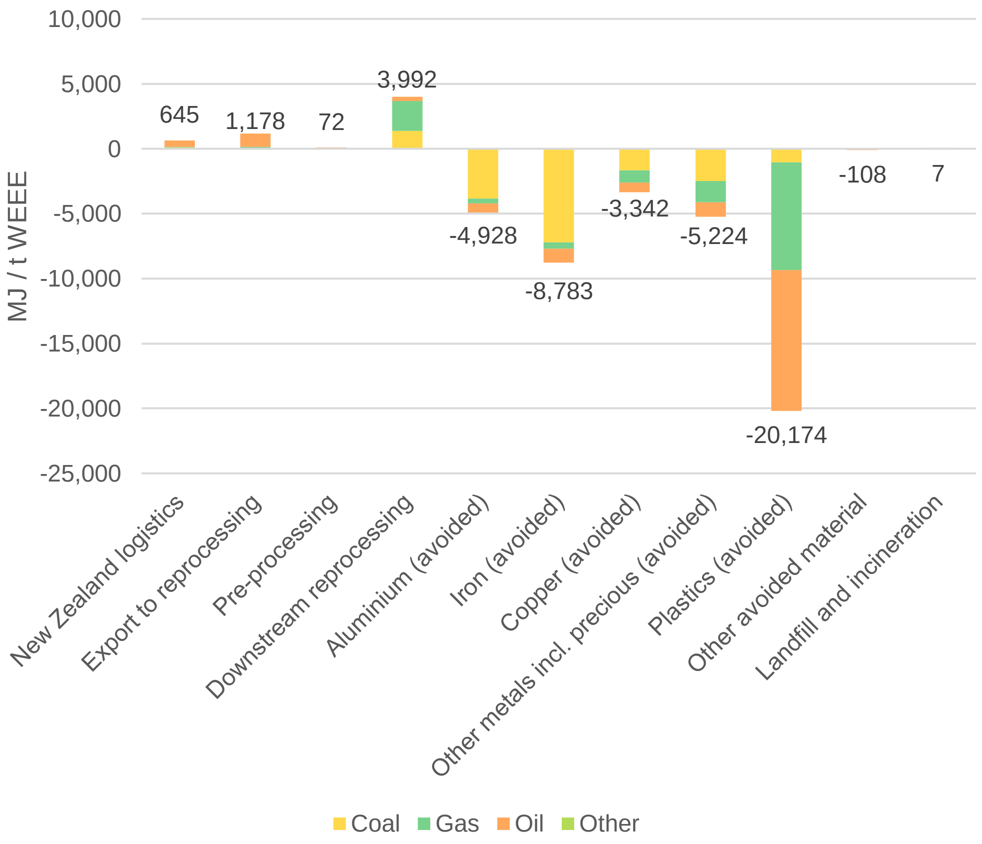

Figure 7 Energy demand characterisation results, broken by steps.

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[2] Based on 13,412 GWh of electricity being consumed by households in 2022 (**energy statistics**), and a total of 1,943,000 households (**population statistics**).

4.4 Particulate matter

Recycling one tonne of ICT e-waste collected by the TCNZ programme in NZ saved 3,250 grams of particulate matter. This is equivalent to removing over 3,279 km of truck travel[3].

The emission of particulate matter, globally, has significant health consequences. This is particularly the case in densely populated areas, and in countries with lower emission controls.

The energy input from downstream reprocessing is responsible for the majority of particulate matter emissions. As with other impact categories, these burdens are more than offset by avoided materials, the most significant of which are copper and iron, which together represent 62% of the total savings.

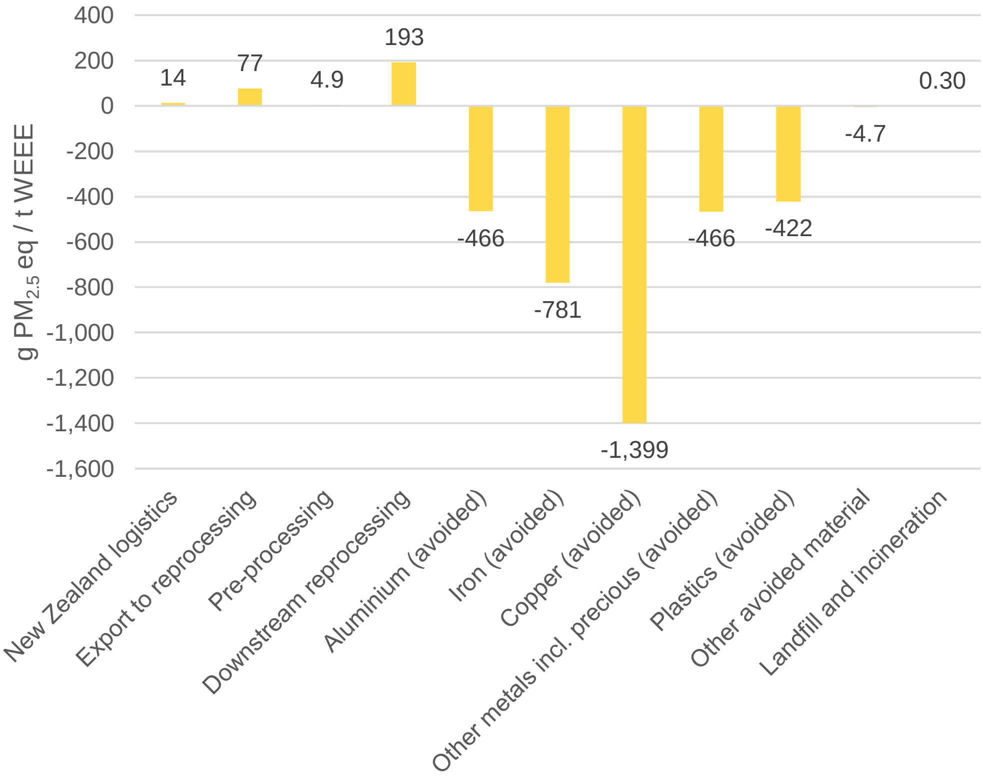

Figure 8 Particulate matter characterisation results, broken down by steps.

[3] Based on an EURO3 diesel truck emission as modelled in ecoinvent 3.5.

4.5 Water footprint

Recycling one tonne of ICT e-waste collected by the TCNZ programme in NZ saved 297 m^3 eq. of water. This is equivalent to 83 days of household water use[4].

The water footprint takes account of the relative water stress in catchments where water is extracted. The analysis of water usage and savings shows that downstream reprocessing drives the impacts on water scarcity, representing 66% of the total impacts. These effects are offset primarily by the recovery of precious metals and copper, which together represent 61% of the total benefits.

The impact assessment method used to characterise water scarcity impacts has been changed this year, to reflect recent developments and the globally accepted AWARE method has been implemented [14]. This means this year's results cannot be compared to results from previous years.

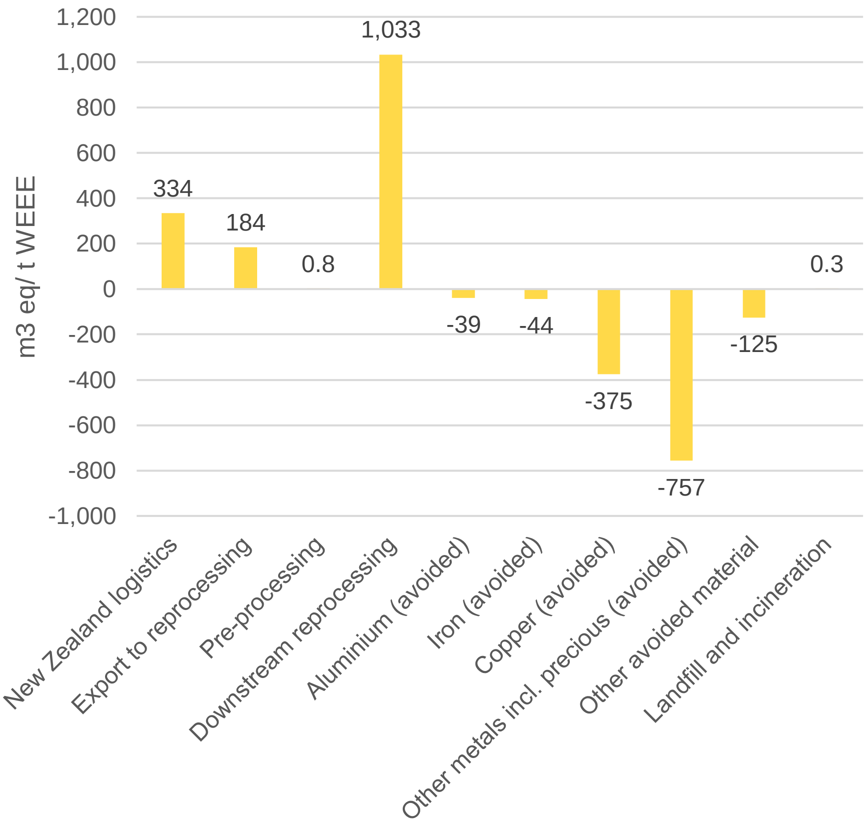

Figure 9 Water scarcity characterisation results, broken down by steps.

[4] Based on an estimate of 543 litre consumed by household per day, based on recent research on residential water use, associated with a water scarcity factor of 6.61 m^3-eq / m^3 as per the AWARE method [14].

5 Conclusions and recommendations

Recommendations

As e-waste recycling is becoming more established, and TCNZ grows its coverage and volume of waste managed, we would recommend changing the approach used to estimate the material fraction in the waste. Given that TCNZ represents a small fraction of the waste managed by The Recycling Group, we would recommend conducting regular sampling campaigns – perhaps once a quarter, from a range of geographical sources, so that a more representative sample can be obtained.

The plastic supply chain remains difficult to clearly replicate in our models, due to the lack of information on the use of secondary material. One key issue with plastic is to determine what the recovered material is truly displacing on the market. If the quality of the recyclate is high and it effectively replaces an equivalent polymer, the environmental benefits are high – for instance ABS recyclate being used for the same application as 100% virgin ABS. But if the recyclate is used for lower quality applications, the environmental benefits would decrease. We would recommend conducting audits of the current plastic recycling system, to better understand how the recyclate is currently being used, and the type of virgin polymer it is replacing. Alternatively, a more cost-effective approach may be to collect information from the downstream recycler on the typical industries which purchase the recyclate.

Finally, it is worth pointing out that as new recycling processes and facilities are launched, there may be several viable solutions to specific components. For instance, PCB recycling is now growing in Australia, with the recent launch of Mint Innovation, which uses a hydrometallurgical and bioleaching process to recover copper, gold and silver from PCBs [15].

Conclusions

This update of the Life Cycle Assessment acts as a strong reminder of the beneficial environmental effects associated with TCNZ's work. Though this analysis could be further improved, it provides a scientifically robust argument in favour of e-waste recycling, through the transparent use of in-depth primary data collected from The Recycling Group and by leveraging the existing scientific literature.

The study also highlights the inherent advantages of running a recycling scheme in New Zealand and maximising the fraction of e-waste managed domestically. Recycling e-waste relies largely on machinery running on electrical power to shred and separate specific waste fractions. As the New Zealand electrical grid is largely decarbonised, the environmental impact associated with recycling processes conducted domestically are minimal.

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