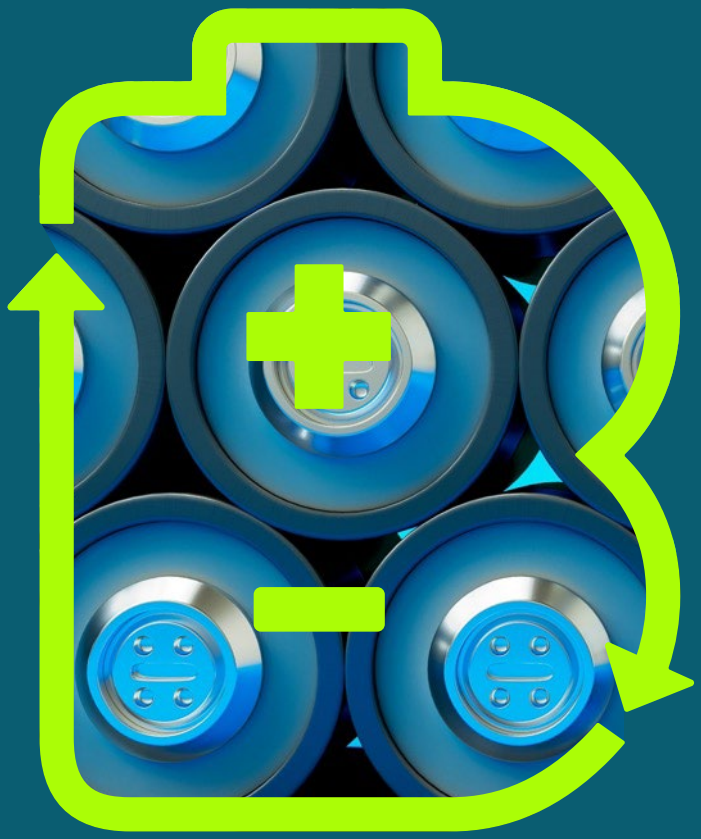
BatteryStewardshipCouncil



Battery Market Analysis

The latest market data for the battery industry in Australia

October 2023

A B-cycle benchmarking project conducted by UTS

UTS Institute for Sustainable Futures

B-cycle Battery Recycling

Acknowledgements

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Research team

Rusty Langdon, Elsa Dominish, and Helen Lara.

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About the authors

The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 in helping governments, organisations, businesses, and communities achieve change towards sustainable futures.

For further information visit: www.isf.uts.edu.au.

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Institute for Sustainable Futures
University of Technology Sydney
PO Box 123 Broadway, NSW, 2007
www.isf.uts.edu.au

B-cycle Battery Recycling
Battery Stewardship Council

www.bcycle.com.au

Forward

Batteries play an important role in the transition to a post fossil fuel economy and circularity. With a vast array of battery applications continuing to grow, a significant reserve of battery raw materials, and a desire to invest in a local battery industry, Australia's future for batteries and associated technologies is strong.

Having clear and consistent projections about the growth of battery sales by chemistry, market sector, and application is critically important for supporting sound investment into technologies and infrastructure for reuse, refurbishment, or recycling.

This report is the latest research into the Australian battery market and builds on previous research undertaken in 2018. It brings new insight to aid in the ongoing discussion and development of stewardship for the growing battery market. The general trajectory of the battery market being forecast in this 2023 report mirrors that of the 2018 report and indicates a consistent and strong forward projection for the industry.

In the handheld battery sector, sales of Lithium-ion batteries continue to outstrip the growth of Alkaline batteries in alignment with both current and past projections. A new addition to the 2023 report is the inclusion of a breakdown of the B-cycle in-scope batteries as a sub-sector of the handheld battery market.

This report not only draws out insight into battery sales but also projects stocks and flows and identifies the scale of the quantity of batteries that will reach their End-of-Life (EoL) over the coming decades. Such EoL projections in the report only consider a first life application, the report does not take into consideration the impact and possible lifecycle extension that may be realised by any second life application.

A good example of a second life application would be the repurposing of an electric vehicle (EV) battery for use in a stationary storage application once it is no longer viable for a traction application. Such activity has the potential to extend the useful life of the battery, delaying its end-of-life and need for recycling.

At this time, second life applications are in their infancy, but we are aware of work being done in this space by players in the EV sector. As markets for these applications grow and technologies and standards are introduced it is anticipated that safe and effective second life markets will flourish.

The Battery Stewardship Council's (BSC) mission is to support the battery industry at all stages of the life cycle. We hope that this research aids in the growth and prosperity of the industry.

Libby Chaplin
Chief Executive Officer
Battery Stewardship Council

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REF: Battery MA Report FINAL 20230927

Glossary of terms

Term	Definition
Battery stocks	Batteries in currently in use
End-of-Life arisings	Batteries reaching End-of-Life each year
Primary materials	Materials sourced from mining and extraction
Secondary materials	Materials sourced from recycled products
Thermal runaway	Accelerating increase in temperature which in turn releases energy that further increases temperature, causing fire in batteries

Table of acronyms

Acronym	Definition
ACCC	Australian Competition and Consumer Commission
ACT	Australian Capital Territory
Ag_2O	Silver Oxide
AGM	Absorbed Glass Mat
AHECC	Australian Harmonised Export Commodity Classification
BESS	Battery Energy Storage System
BSC	Battery Stewardship Council
DER	Distributed Energy Resources
EBUs	Equivalent Battery Units
EEE	Electric or Electronic Equipment
EoL	End-of-Life
EVs	Electric Vehicles
GWP	Global Warming Potential
GBSC	Global Battery Supply Chain
HHCC	Hazardous Household Chemical Collection
HTISC	Harmonised Tariff Item Statistical Classification
ICE	Internal Combustion Engine
ISF	Institute for Sustainable Futures
LAB	Lead Acid Battery
$Li_4Ti_5O_{12}$	Lithium Titanate Oxide (also Li-titanate or LTO)

Acronym	Definition
$LiCoO_2$	Lithium Cobalt Oxide (also Li-cobalt or LCA)
$LiFePO_4$	Lithium Iron Phosphate (also Lithium Ferro Phosphate or LFP)
$LiFeS_2$	Lithium Iron Disulfate
Li-ion	Lithium-ion
$LiMn_2O_4$	Lithium Manganese Oxide (also Li-manganese, LMO or Lithium Manganese Spinel)
$LiNiCoAlO_2$	Lithium Nickel Cobalt Aluminium Oxide (also NCA)
$LiNiMnCoO_2$	Lithium Nickel Manganese Cobalt Oxide (also NMC)
Li-S	Lithium Sulphur
MFA	Material Flow Analysis
NiCd	Nickel Cadmium
NiMH	Nickel Metal Hybrid
NSW	New South Wales
NT	Northern Territory
SA	South Australia
SES	Storage, Emergency and Standby
SLAB	Sealed Lead Acid Battery
SLI	Starting, Lighting and Ignition batteries
SSLAB	Small Sealed Lead Acid Battery
Tas	Tasmania
Vic	Victoria
WA	West Australia

1. Executive summary

1.1 Introduction

This report presents the findings from a benchmarking project commissioned by the Battery Stewardship Council (BSC), undertaken by the Institute for Sustainable Futures (ISF) at the University of Technology Sydney. The research will inform future performance evaluation of the BSC B-cycle Scheme.

The research comprises an analysis of the Australian battery market, for the calendar year 2021, and a fate mapping, or Material Flow Analysis (MFA) of stocks (batteries in use) and flows for battery sales, consumption, and End-of-Life (EoL) collection and reprocessing, by battery chemistry, format or size, and application.

1.1.1 Methodology

This study began with a literature review to gather available data for 2021 on battery market characteristics, battery sales (imports and exports), specifications (size, weight, and chemistry of batteries for individual product categories) and recycling rates. This was supplemented with responses from a survey and interviews with 27 stakeholders.

This research builds on the Australian Battery Market Analysis report, prepared by Envisage Works for the BSC in 2020, historic time series data from 2013 to 2020 has been adapted from the Envisage study to produce projections to 2050 (Envisage Works, 2020). The classification framework, terminology, and reporting format from the previous Envisage Works study has been adopted to aid the BSC in future time series analysis. Data in the MFA model classifies batteries by their market segment, application area, chemistry group, battery size and weight range, level of integration in products and end-user type.

1.1.2 Overview of the Australian battery market

The global battery supply chain is a complex web of mining, refining, manufacturing, collection and recycling processes. Australia's participation in the battery supply chain is predominantly in battery material mining and refining, with a smaller share of domestic battery recycling capacity. Battery recycling will play an increasingly important role in supporting the supply of minerals and materials for battery production, particularly with many of these materials listed as 'critical minerals' globally.

By the end of 2022, the Council of the European Union announced new regulation on batteries, requiring that at least 16% of cobalt, 85% of lead, 6% of lithium and 6% of nickel in industrial, Starting, Lighting and Ignition (SLI) and Electric Vehicle (EV) batteries are recycled with appropriate documentation (European Parliament, 2023). Although, Australia's current share of battery recycling is small compared to the global scale, there is great potential to increase Australia's capacity to contribute to a circular battery supply chain and balance the demand on constrained regions.

The key battery supply chain stages include mining and refining; electrochemical manufacture; battery cell manufacture; battery pack assembly; battery use; EoL; collection; and recycling. Once batteries reach the EoL they have the potential to be recycled into materials that provide secondary products such as fertilisers or steel, or the material can feed back into battery material manufacturing[1].

The battery recycling process can be broken up into several key stages:

+ **Drop Off** – A consumer drops off used batteries at a 'Drop Off' or collection point for the intent for it to be recycled;
+ **Collection** – A collection (e.g. transport) company picks up the batteries from the 'Drop Off' point and delivers the batteries to a recycling facility;
+ **Sorting** – Sorters (currently these are primarily the recycling companies in Australia) sort batteries into their specific chemistry groups;
+ **Recycling** – Recyclers discharge sorted batteries where necessary, mechanically shred batteries, and separate materials into metals, plastics, and black mass groups.

From this point, processed material can feed directly into the refining stages of the supply chain. Alternatively, if hydrometallurgical or pyrometallurgical processes are used at the recycling stage, there is potential for purified battery grade material to feed directly into the electrochemical processing phase of the battery manufacturing process. Although industry feedback indicates that this level of circularity is currently in the prototype stage.

Australia is a key participant in the mining and refining stages of the global battery supply chain, particularly for battery materials in high demand globally, such as lithium, nickel, cobalt, and manganese. In terms of global battery supply chain participation, China holds the largest share of battery component manufacturing, followed by Japan. Japan is a key player in battery pack assembly, and China holds the market share of battery cell recycling (refer to Figure 10 in the main report for more details on market share by supply chain stage).

[1] The potential for materials to feed back into battery manufacturing depends on the purity achieved during the recycling process.

1.2 Australian battery market analysis and fate mapping

1.2.1 Total Australian battery flows

Total battery flows represent an estimate of all batteries[2] currently sold, in use, and recycled on the Australian market and include a large portion of batteries that currently sit outside the B-cycle Scheme scope. A large percentage of these batteries already have established EoL solutions in Australia (such as Lead Acid batteries); however, an analysis of total battery sales is useful to understand which battery types have the potential to be included within the B-cycle Scheme in the future. Note below that all figures in this summary includes Lead Acid batteries that are not in-scope of B-cycle due to an existing high recovery of this product.

The results of MFA modelling of total Australian battery flows are presented in Figure 1, results are aggregated across all market and product classifications and total flows are presented by battery chemistries. Based on these results, the following was observed.

- A total of 737 million batteries were sold onto the Australian market in 2021, which represents 8,313 million Equivalent Battery Units (EBUs) and equates to just over 200,000 tonnes of batteries.
- It is estimated that almost 500,000 tonnes of batteries were in use in Australia in 2021 and just over 180,000 tonnes of batteries reached the end of their life.
- A total of 156,000 tonnes of batteries were estimated to be collected for recycling in 2021, which equates to a collection rate of 87% across all battery sizes[3].
- A total of 545 million batteries sold in Australia in 2021 would have been within the scope of B-cycle. B-cycle in-scope batteries represent just over 10% of the tonnage of batteries sold, at 21,785 tonnes. Of these, 1,258 tonnes of batteries were estimated to be collected for recycling in 2021, which equates to a collection rate of 7.2%.

The results indicate an increase in collection rate for Handheld batteries under 5kg[4] from 11% in 2018 (Envisage Works, 2020) to 16% in 2021. However, the Envisage report did not provide an estimated collection rate for batteries within the scope of B-cycle.

The estimated collection rate for batteries within the scope of B-cycle can therefore form the basis of a benchmark for B-cycle to improve on moving forward.

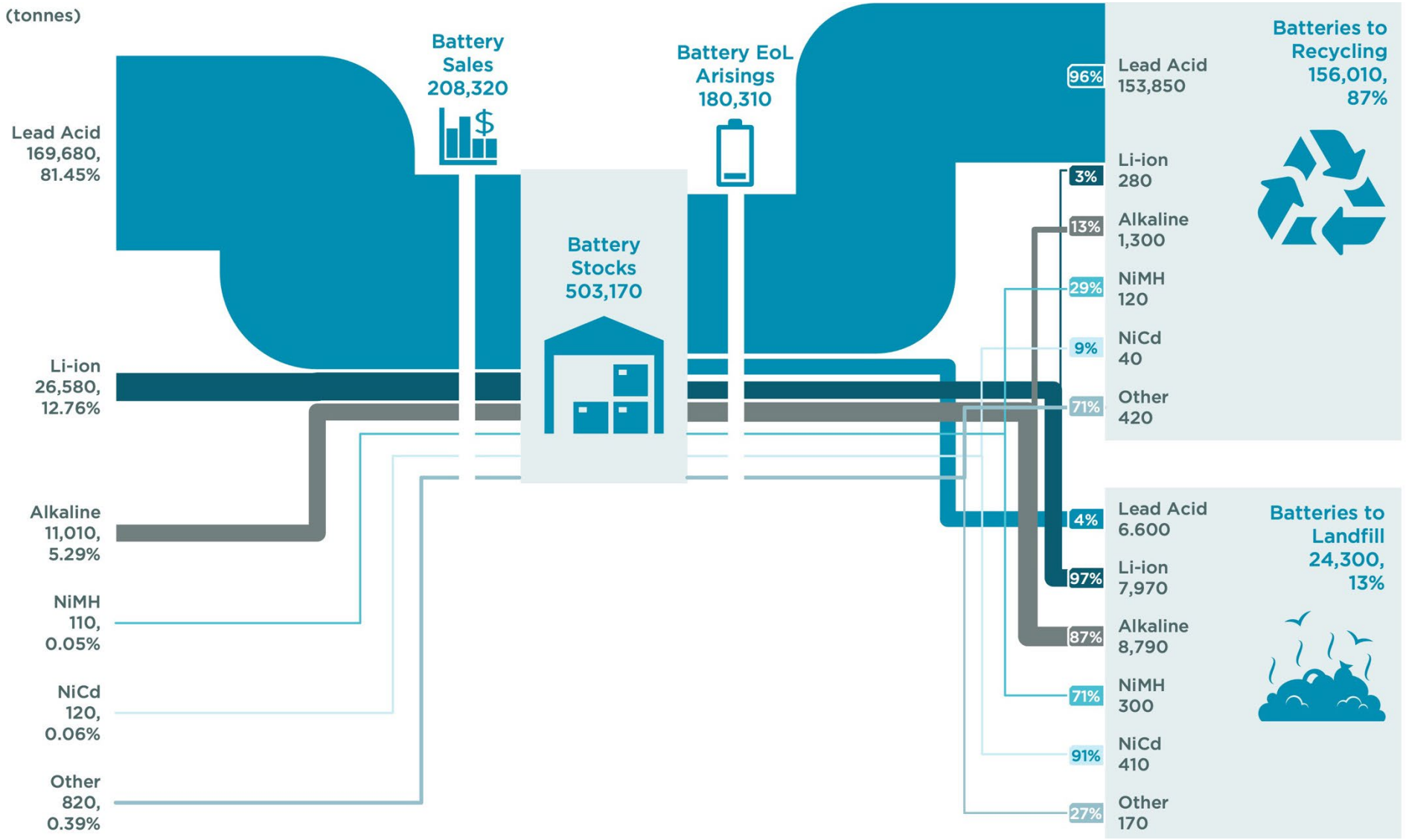
[2] Batteries = Single batteries sold either as a battery pack or as a battery cell; EBU = Equivalent Battery Units calculated based on battery cell weight only. Total battery weights quoted in tonnes include both cell weight and battery pack weight where relevant.

[3] This calculation includes batteries outside the scope of the B-cycle Scheme.

[4] Note that a share of Handheld batteries fall outside of the scope of B-cycle, such as mobile phone batteries, laptop batteries, and Lead Acid batteries.

B-cycle Battery Recycling

Figure 1. Australian battery flows (2021)[5]



[5] 'Others' includes a mixture of battery chemistries not able to be disaggregated for the purpose of this analysis.

1.2.1.1 Australian battery flows by market segment

In the next section, a more detailed characterisation of the Australian battery market is established, this is achieved by breaking up battery uses into key market segments. The Australian battery market consists of four overarching market segments, these segments have been previously defined by Envisage and the BSC and are re-established (with BESS and EV disaggregated as separate market segments) in this study as follows.

- **Handheld batteries (<5kg)** – All batteries under 5kg, including e-bicycle batteries, and Lead-Acid batteries.
- **Battery Energy Storage System (BESS) batteries** – BESS are those systems that provide stationary energy storage, examples include residential behind-the-meter batteries, and off-grid commercial systems (not utility-scale systems)[6] replacing diesel generators.
- **Electric Vehicle batteries (EV)** – EV batteries are used in vehicles powered by an electric or hybrid-electric motor.
- **Starting Lighting and Ignition (SLI) batteries and other industrial batteries (≥5kg)** – Predominantly Lead Acid batteries equal to or more than 5kg. These include batteries used in Internal Combustion Engine (ICE) vehicles for engine starting, other traction and industrial applications.

Based on the MFA modelling by market segment (refer to Table 1) the following is observed.

- A total of 29,110 tonnes of Handheld batteries were sold onto the Australian market, 63,460 tonnes were estimated to be held in stocks (in use), and 23,310 tonnes of Handheld batteries were estimated to reach EoL in 2021. Note that not all Handheld batteries <5kg are included in B-cycle scope currently and that the B-cycle Scheme did not commence battery collections until February 2023.
- The collection rate of Handheld batteries was much lower than the total average, at only 16%, with an estimate of almost 20,000 tonnes of batteries for this category assumed to end up in landfill in 2021.
- A total of 21,785 tonnes of B-cycle in-scope batteries were sold onto the Australian market prior to Scheme commencment, with 47,490 tonnes in stocks, and 17,440 tonnes estimated to reach EoL. B-cycle in-scope batteries reached a 7.2% collection rate in 2021, with 1,258 tonnes of batteries collected for recycling.
- SLI and other industrial batteries are estimated at a high recycling rate of 98% due to the mature nature of the Lead Acid recycling industry in Australia.

[6] Note that the BESS data used is for residential and commercial distributed energy resources (DER) only and does not include utility-scale BESS. Accurate historic installed capacities for utility-scale batteries will be needed for the inclusion of this battery type in future analysis.

+ A total of 1,200 tonnes of BESS batteries and 470 tonnes of EV batteries are estimated to reach EoL in 2021, with an estimated recycling rate of less than 1% for BESS and 32% for EVs.[7]

Table 1. Overview of Australian battery flows by market segment (2021)

Market Segment	Battery Sales			Battery Stocks (tonnes)	EoL Arising (tonnes)	Collected Recycling (tonnes)	Collection Rate (%)
	Weight (tonnes)	Number ('000)	EBUs (million)				
Handheld (<5kg)	29,110	728,500	1,060	63,460	23,310	3,620	16%
B-cycle In-scope(1)	21,785	545,190	800	47,490	17,440	1,258	7.2%
BESS	1,170	10	30	12,710	1,200	10[8]	1%
EV	13,080	100	350	38,650	470	150	32%
SLI and Other Industrial	164,960	8,960	6,870	388,350	155,330	152,230	98%
Total	**208,320**	**737,570**	**8,310**	**503,170**	**180,310**	**156,010**	**87%**

(1) Data is from a period prior to B-cycle commencement.

1.2.1.2 Australian Handheld under 5kg battery flows

Figure 2 illustrates the flow of Handheld batteries under 5kg in Australia in 2021 prior to the introduction of the B-cycle Scheme, Handheld batteries are also represented in the first row and second rows of Table 1. Handheld batteries are those batteries under 5kg and consist of batteries from a range of product categories and levels of integration (ease of removability from a product). Based on the overview of battery flows presented in Figure 2, the following observations are made.

+ A total of 29,110 tonnes of batteries under 5kg were sold onto the Australian market in 2021. B-cycle in-scope batteries represent 75% (21,785 tonnes) of Handheld batteries sold onto the market in 2021.
+ Lithium-ion batteries make up the major share of battery sales for this category at 43%, highlighting the increasing market dominance of this chemistry for rechargeable applications.
+ Alkaline batteries follow at just over 38% of sales, reflecting the dominance of the alkaline chemistry in single use applications requiring Stand-alone batteries.
+ Just over 63,000 tonnes of Handheld batteries were estimated to be in use in 2021.

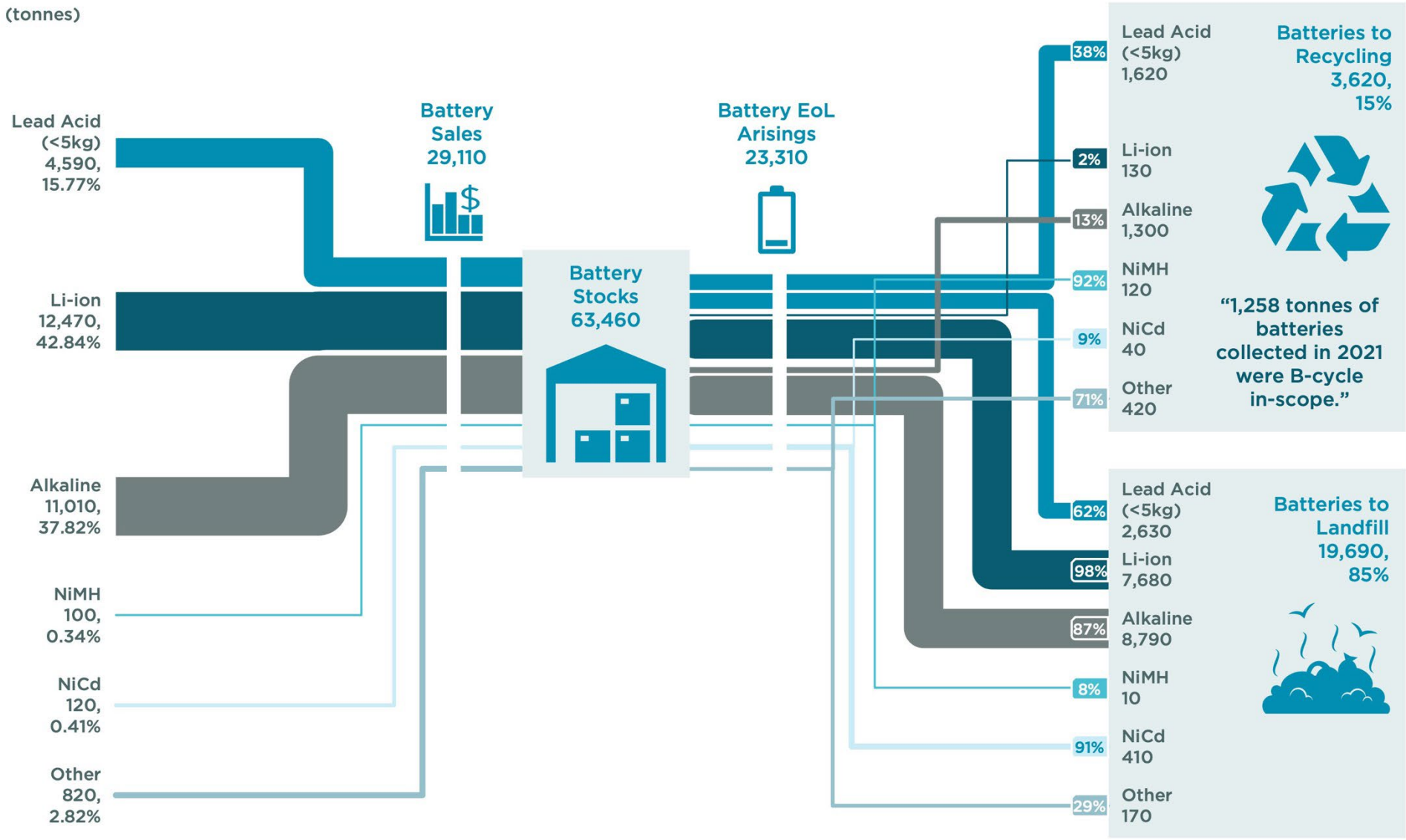
[7] The researchers have a low confidence in the estimate of recycled batteries for BESS and EV product categories. Data provided by recyclers did not disaggregate by battery type or size and reports indicate that some EV batteries may be directed to EV manufacturers for EoL handling. Information on recycling rates for these product categories should take this into consideration when relying on information presented in Table 1.

[8] Important note: Data provided by collectors and recyclers did not disaggregate by battery type or size. This estimate is therefore based on a combination of share of battery sales by product category, chemistry, and total collections by chemistry. Confidence in the results on collections and collection rate for this category is very
low. It is recommended that this data is improved by working with collectors to collect data on BESS battery collection rates.

- A total of 23,310 tonnes of Handheld batteries reached EoL in 2021, and an estimate of 3,620 tonnes of Handheld batteries were collected for recycling.
- Alkaline batteries represented the largest share of recycled batteries by battery type at 1,300 tonnes of batteries recycled in 2021.

Based on estimates, 309 million more Handheld batteries under 5kg were sold onto the Australian market in 2021 compared to 2018, which represents an increase of 7,260 tonnes of batteries or 150 million EBUs.

Figure 2. Handheld under 5kg battery flows (2021)[9]



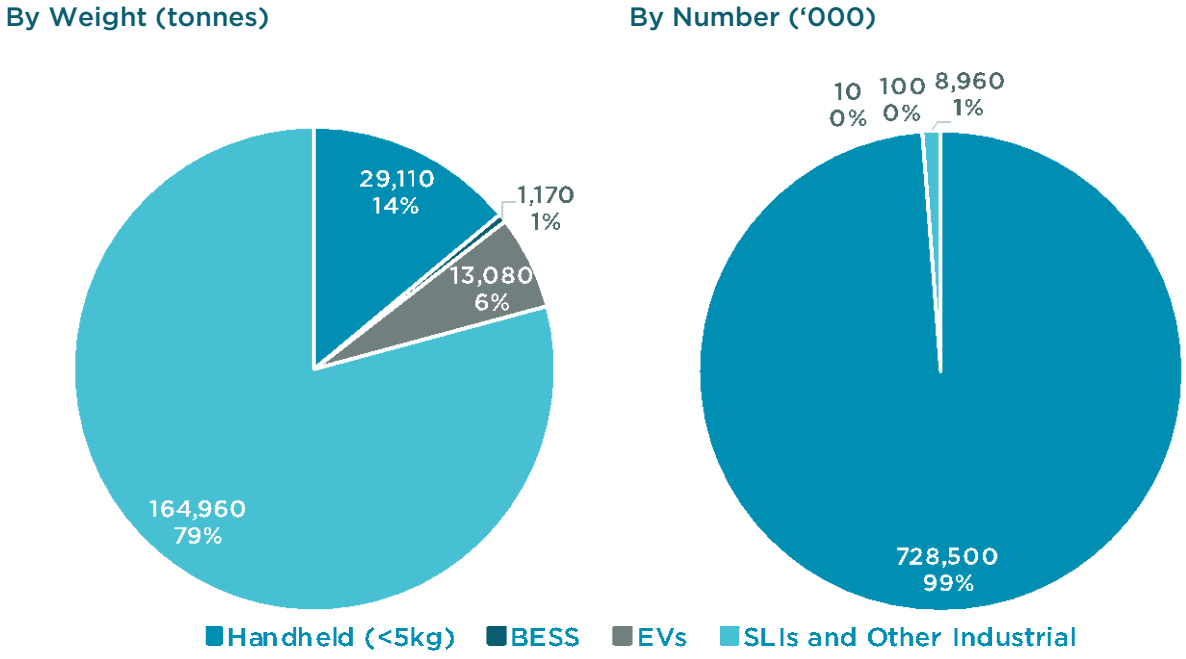
[9] 'Others' includes a mixture of battery chemistries not able to be disaggregated for the purpose of this analysis.

1.2.2 Australian battery sales

An overview of total Australian battery sales is presented in Figure 3, battery sales have been disaggregated by market segment for the year 2021. Based on the results of modelling, the following can be observed.

- SLI and other industrial batteries over 5kg dominate total sales by weight (164,960 tonnes) despite their smaller share by number (8 million batteries), this is due to their continuing prominence as engine starting batteries and larger weight share per battery compared to other market segments such as Handheld batteries.
- A total of 10,000 BESS batteries were sold onto the Australian market in 2021, a smaller share compared to other market segments, but with the size of this market segment expected to grow over the next 25 years.
- A total of 100,000 EV batteries were sold, represent less than 1% of batteries sold in 2021, and 6% of batteries by weight at 13,080 tonnes.
- A total of 728 million Handheld batteries were sold in 2021, representing 99% of batteries sold, and 14% of batteries sold by weight (29,110 tonnes).

Figure 3. Total battery sales by market segment by weight, and by unit number (2021)



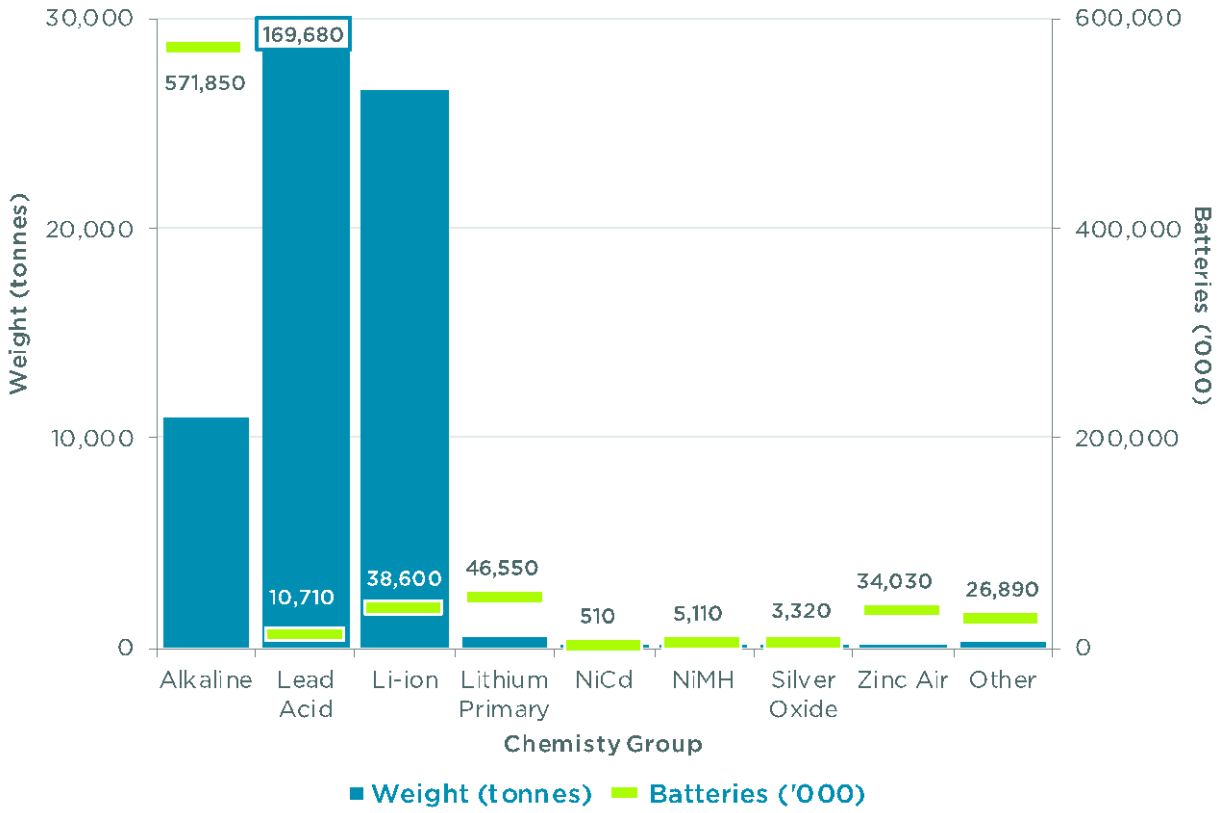
1.2.2.1 Total battery sales by chemistry group

Figure 4 shows the total number of batteries sold, broken down by chemistry and weight. Based on the results shown here the following is observed for 2021.

- Lead Acid batteries are the major Australian market share of sales in weight at just over 169,000 tonnes. These batteries are predominantly made up of SLI batteries for vehicles.

- Alkaline batteries are the largest share of battery sales by number at just over 570 million batteries sold.
- Lithium-ion batteries are the second largest share of battery sales in weight at just over 26,000 tonnes of batteries sold, and the third highest in number of batteries sold at just over 38 million batteries.
- Zinc Air batteries (button cells) are the fourth largest share of battery sales by number, at just over 34 million batteries sold, however their market share by weight is much lower due to the size of these batteries, at just 20 tonnes sold in 2021.

Figure 4. Total battery sales by chemistry group by weight, and by unit number (2021)



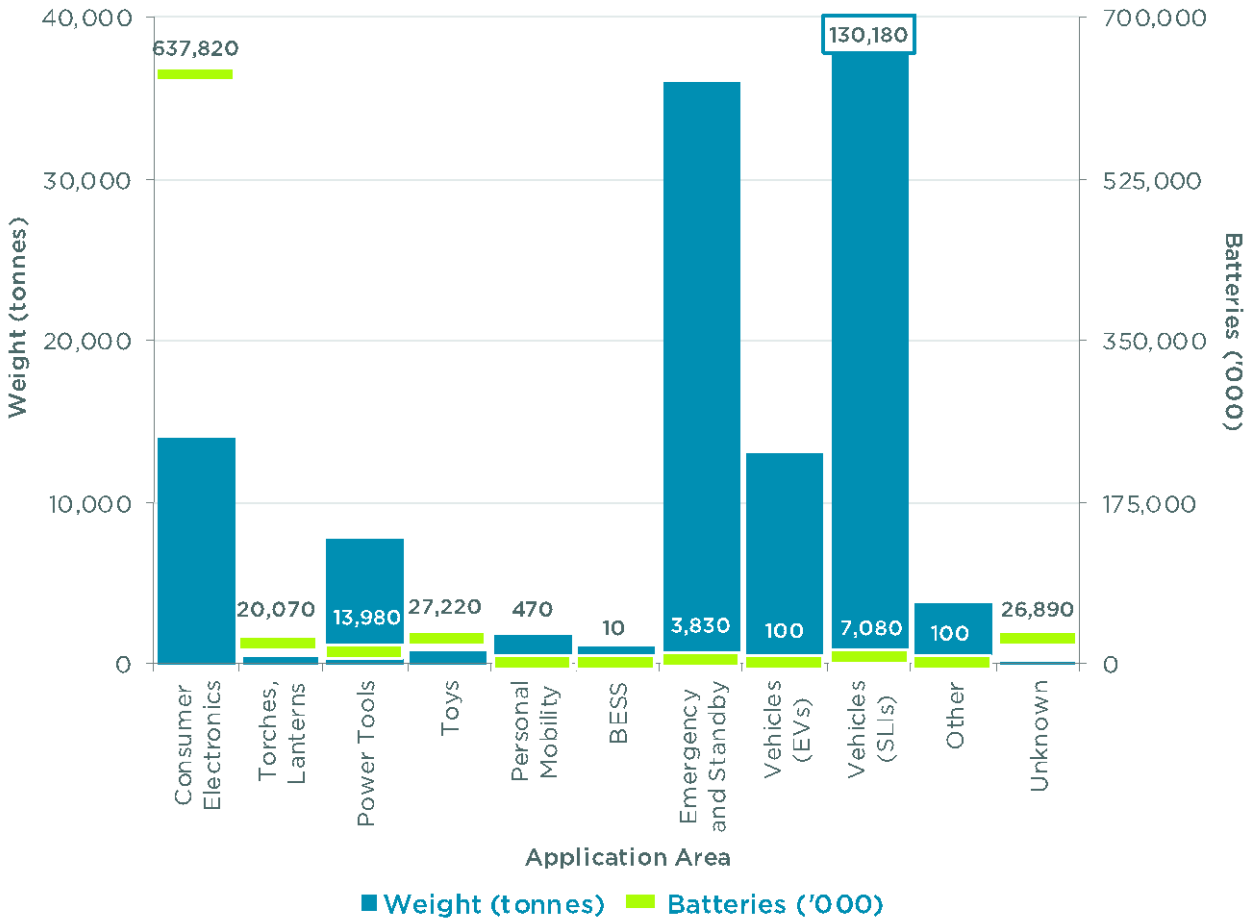
1.2.2.2 Total battery sales by application

Figure 5 provides an overview of battery sales in Australia in 2021 by application. Based on this cross section of battery sales the following is highlighted.

- Consumer electronics represent the largest share of battery sales by number at around 637 million batteries sold and contribute a significant share of batteries sold by weight at almost 14,000 tonnes.
- Internal Combustion Engine (ICE) vehicles were responsible for the major share of batteries by weight (130,180 tonnes), due to their larger battery size and weight for this application. These are Lead Acid batteries for SLI.

- Storage, Emergency and Standby (SES) also generated a significant share of battery sales by weight at around 35,000 tonnes sold in 2021.
- Power tools were the next application to drive a high volume of battery sales with a total of just under 8,000 tonnes of batteries sold in 2021 for this application, all Lithium-ion chemistries.

Figure 5. Total battery sales by application (2021)



1.2.2.3 Handheld batteries under 5kg and B-cycle in-scope battery sales

This section estimates sales of batteries that fall within the scope of B-cycle prior to the launch of the Scheme. In 2021, batteries could be removed from battery powered devices by consumers and taken to one of 1,000 battery collection points around Australia (BSC, 2022). Batteries accepted by B-cycle (launched in 2022) include batteries that are under 5kg, loose or stand-alone, or easily removed by the consumer. B-cycle does not include Lead-Acid batteries or batteries already covered by other stewardship schemes, such as laptop or mobile phone batteries, even if they fit under the under 5kg category. By estimating those batteries falling within the scope of B-cycle, a benchmark for the year 2021 is established, that can be used by the BSC to monitor the progress of B-cycle.

Batteries within the B-cycle scope are estimated by creating a breakdown of batteries under 5kg by 'level of embeddedness' or 'removability'[10] represented in Table 2 below. Batteries considered falling under the scope of B-cycle features a bright green border.

For those batteries considered falling under the scope of B-cycle, the following can be observed:

- A total of 21,785 tonnes of batteries under 5kgs, are within the current scope of B-cycle. This represents 75% of all batteries under 5kgs;
- Alkaline batteries represent the large share of batteries within this scope at 11,010 tonnes (51% of sales in scope;
- Of the B-cycle in-scope batteries, Lithium-ion batteries represent the second largest share of battery sales at 9,750 tonnes (45% of sales in scope).

Table 2. Handheld under 5kg battery sales by level of integration and chemistry group (2021)[11]

Chemistry Group	Battery Sales (Handheld <5kg)			Total
	Stand-alone	Part of EEE (Easily Removeable Battery)	Part of EEE (Embedded Battery)	
Alkaline	10,010	1,000	0	11,010
Lithium-ion	0	9,750	2,720	12,470
Lithium Primary	560	10	15	585
Nickel Cadmium	120	0	0	120
Nickel Metal Hybrid	90	10	0	100
Silver Oxide	5	0	0	5
Zinc Air	20	0	0	20
Other	210	0	0	210
Lead Acid	3690	740	160	4 590
Total (All Batteries <5kg)	**14,705**	**11,510**	**2,895**	**29,110**
Total (B-cycle Scope)	**11,015**	**10,770**	**0**	**21,785**

[10] Embeddedness describes the degree to which a battery can be easily removed from an electronic device. 'Embedded batteries' are not easily removed by the consumer and require specialist care or skills to remove the battery. 'Easily removable batteries' can be removed by the consumer either by hand or with a simple tool such as a screwdriver.

[11] Batteries considered to be within the B-cycle scope are highlighted with bright green border.

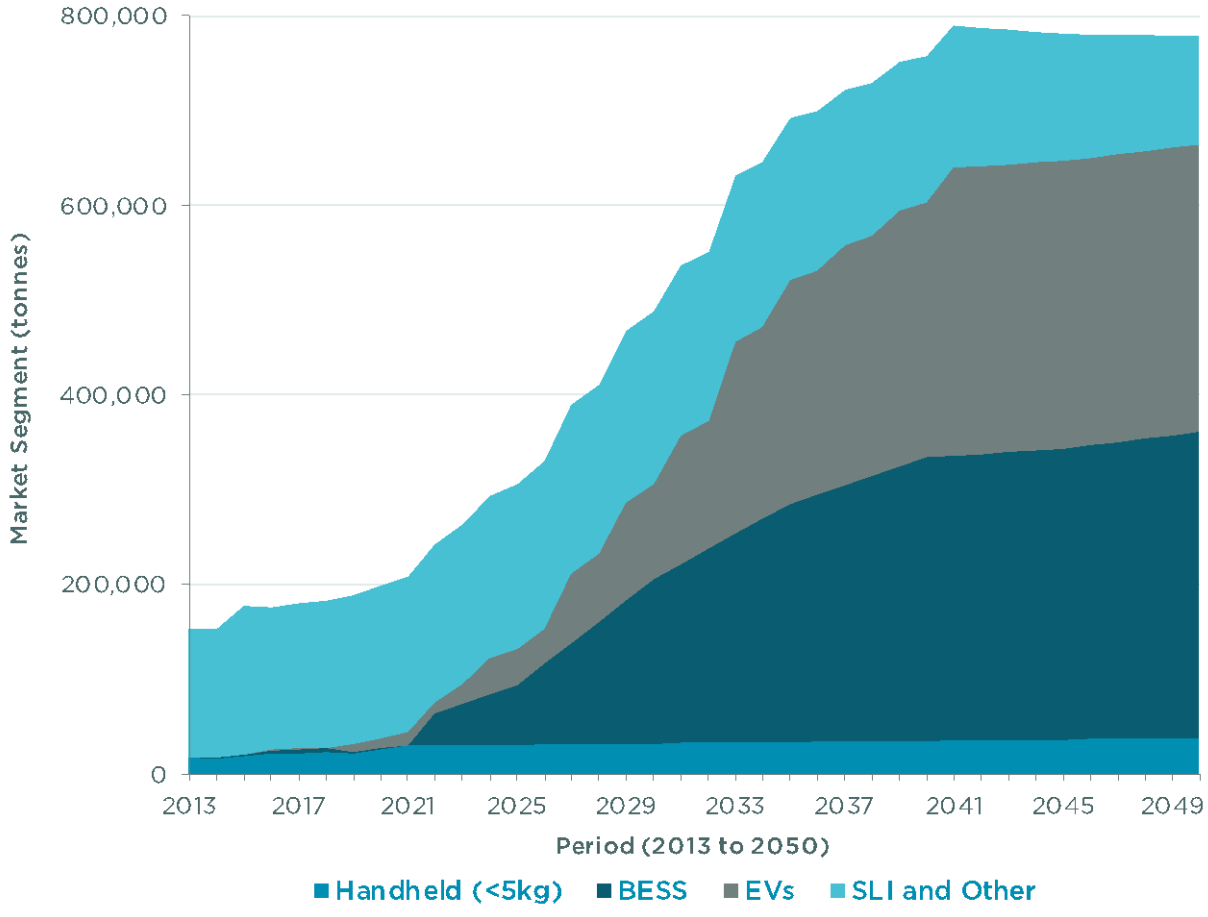
1.2.2.4 Australian battery sales projections

MFA modelling integrates historic data on total sales per year between 2013 and 2021 and then projects sales to 2050 based on available projections for individual product markets[12]. The result is a projection of sales by market segment shown in Figure 6 on the following page.

According to these results the following from MFA projections is observed.

- The tonnage of Handheld batteries sold onto the Australian market has increased by around 33% between 2018 and 2021, with a much smaller year on year growth rate of 1%–2% projected until 2050.
- The total tonnage of BESS and EV batteries sold is projected to grow between 10% and 40% year on year until 2030.
- SLI battery sales only increase 1% year on year, peaking in 2030 and then start to decline in line with increased EV market share.

Figure 6. Projected battery sales from 2021 to 2050 by market segment (2013–2050)[13]



[12] Sales projections for BESS and EV are estimated based projections in (Energeia, 2019), all other projections are based on population growth rate prorated to applications by market share.

[13] Figure adapted from Envisage (2020).

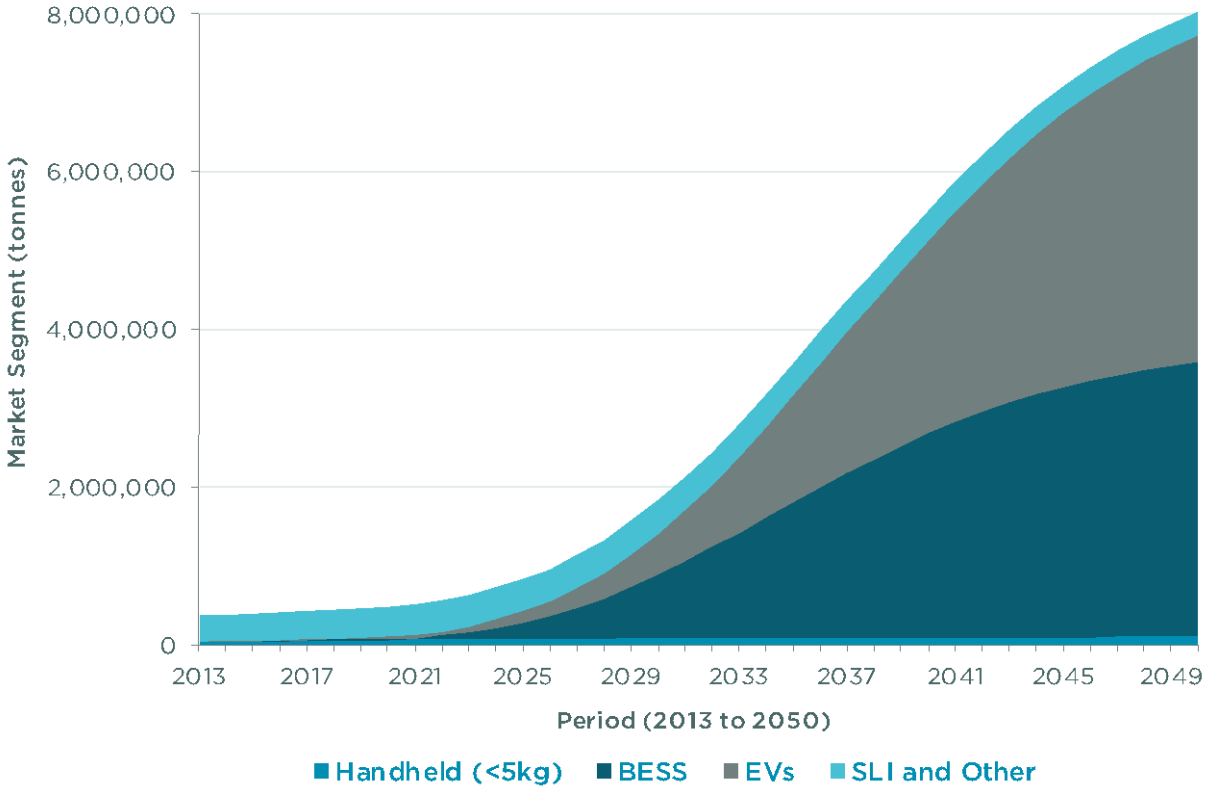
1.2.3 Battery stocks

Batteries held in stocks are those batteries in use in any given year between 2013 and 2050. Stocks are calculated based on battery sales and estimated cumulatively using technical information on battery lifetimes. The MFA calculates projections of batteries in use each year to 2050 and the results are presented in Figure 7 on the following page.

Based on these projections, the following is estimated.

- Total battery stocks are projected to reach around 8 million tonnes of batteries by 2050.
- Stocks of EV batteries are projected to reach just over 600,000 tonnes in 2030 and just over 4 million tonnes by 2050.
- Stocks of BESS batteries are projected to reach around 800,000 tonnes in 2030, 3.4 million tonnes by 2050.
- Stocks of Handheld batteries are projected to reach just over 195,000 tonnes by 2030 and just over 260,000 tonnes by 2050.
- SLI batteries will stay relatively constant to 2030 reaching around 430,000 tonnes and then decline to just over 300,000 tonnes by 2050.

Figure 7. Total projections of battery stocks from 2021 to 2050 by market segment (2013–2050)[14]



[14] Figure adapted from Envisage (2020).

1.2.4 End-of-Life (EoL) arisings

EoL arisings are estimated based on a combination of historic data on battery sales and technical information on battery lifetimes. Based on MFA modelling results the following for batteries reaching EoL in 2021 (refer to Table 3) is estimated.

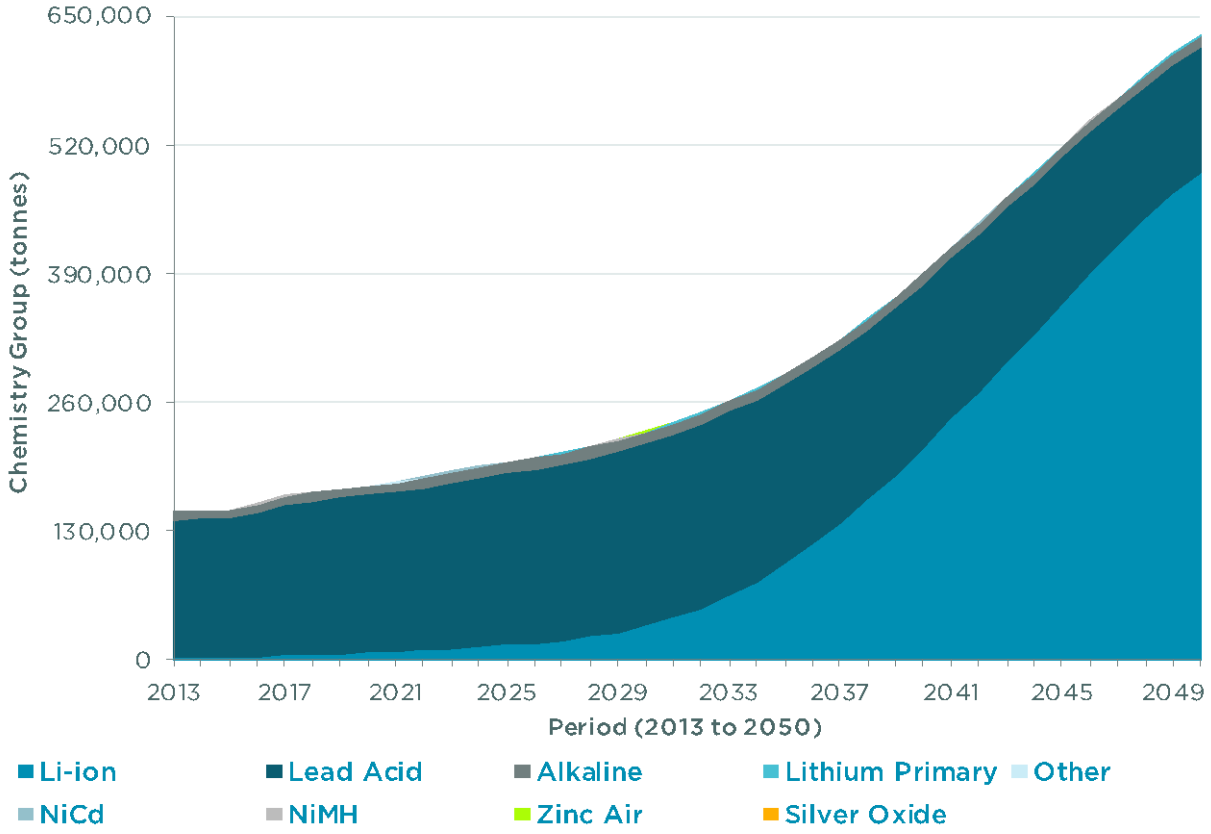
- A total of 180,310 tonnes of batteries reached the EoL in 2021.
- A total of 89% of batteries that reached EoL were Lead Acid batteries.
- 5.6% of batteries reaching EoL were Alkaline chemistries.
- 4.5% of batteries reaching EoL were Lithium-ion chemistries.

Table 3. Total battery EoL arisings by chemistry group (2021)

Chemistry Group	EoL Arisings (tonnes)	EoL Arisings (%)
Alkaline	10,090	5.6
Lead Acid	160,510	89
Lithium-ion	8,250	4.5
Nickel Cadmium	450	0.2
Nickel Metal Hybrid	420	0.2
Other	590	0.3
Total	**180,310**	**100**

Lithium-ion batteries dominate future sales projections, as a result of the increase of Lithium-ion batteries on the market, this chemistry is expected to contribute up to 80% of EoL arisings by 2050. Currently, Lead Acid batteries hold the market share for EoL arisings at just over 160,000 tonnes in 2021. As product markets such as BESS and EV start to increase their share of battery demand over the next decade, Lithium-ion EoL arisings will increase as these batteries reach EoL in 15 years to 20 years.

Figure 8. Projections of total battery EoL arisings from 2021 to 2050 by chemistry group (2013–2050)[15]



1.2.5 Australian collections and recycling

The following analysis gives a breakdown of batteries that have been collected and processed in Australia for the calendar year 2021. Lead Acid batteries less than 5kg have been excluded from this analysis as they are assumed to be collected and recycled via mature and established Lead Acid recycling markets.

Surveys and interviews with Australian collectors and recyclers provided an overview of collection and recycling processes in 2021, and these insights have been used to present recycling flows in Figure 9.

Batteries were collected from roughly 1,000 collection points in states and territories around the country (BSC, 2022). Batteries were then sorted, shredded, and separated into key material groups including metals, plastics, and black mass for further downstream processing. Most of this material was sent to the domestic materials market, except for lithium black mass and some Nickel Metal Hybrid and Nickel Cadmium batteries which were exported. Lead Acid batteries that ended up in this collection channel were sorted and then sent directly to domestic Lead Acid recyclers in Australia.

[15] Figure adapted from Envisage (2020).

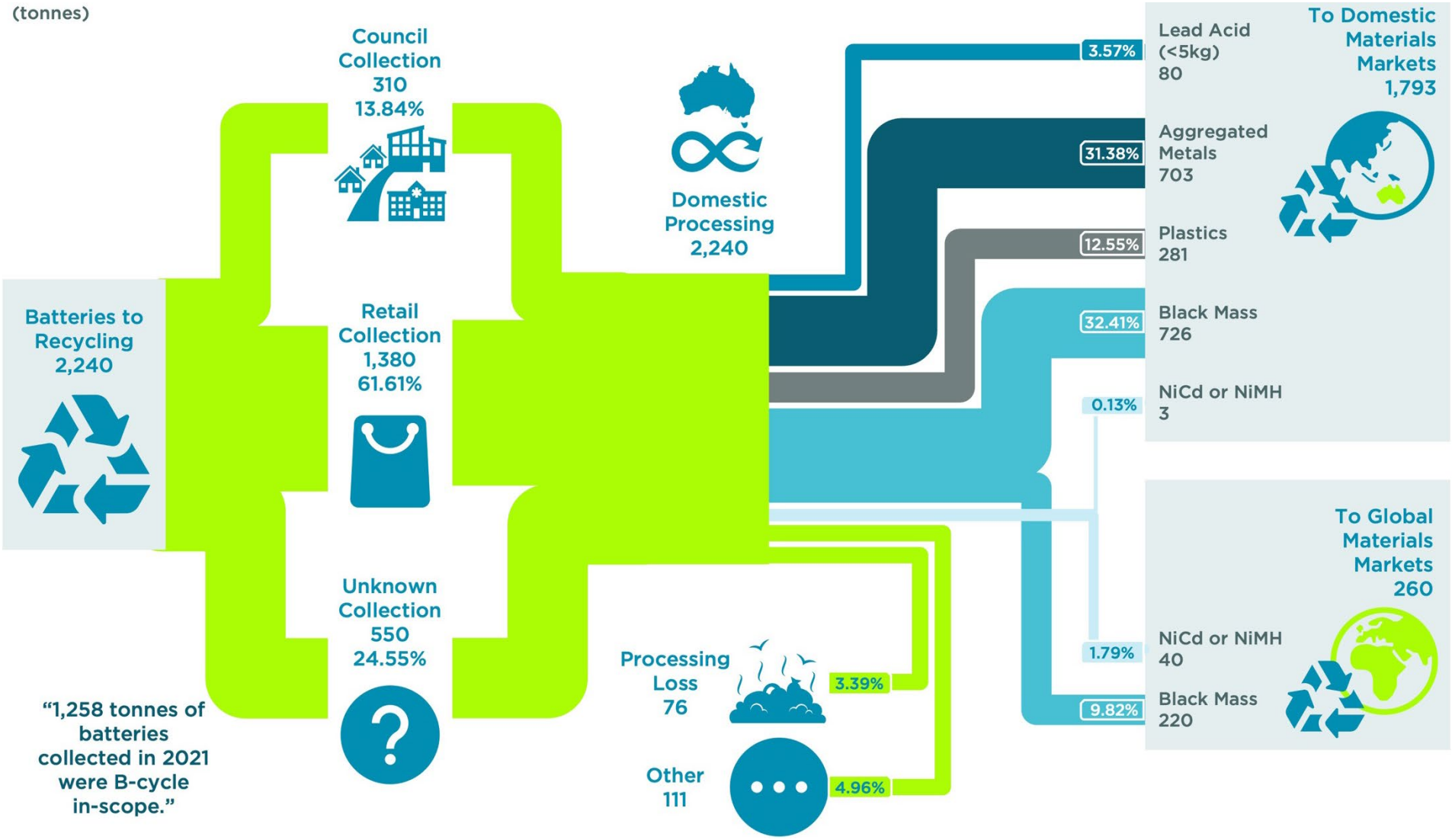
Key observations are made based on Australian battery recycling sector flows identified in Figure 9.

- A total of 2,240 tonnes of batteries (1,258 tonnes of B-cycle in-scope batteries) were collected in Australia in 2021 by survey and interview participants.
- A total of 60% of the batteries collected in 2021 were dropped off at retail collection points. A total of 14% of batteries collected were dropped at a council collection point. A data gap exists on the remaining batteries collected as this detailed information was not provided by some collectors.
- 76% of total batteries collected in Australia by collectors and recyclers were mechanically shredded and the battery materials were supplied to domestic materials markets such as plastics recyclers, metal recyclers, and downstream material processers.
- A smaller amount, 11% of material recovered, was exported to global materials markets which includes black mass from Lithium-ion batteries and some Nickel Cadmium and Nickel Metal Hybrid batteries.
- A total of 76 tonnes or around 3.5% of material recovered is lost during the recovery process and assumed to end up in landfill (domestic landfills).
- A total of 111 tonnes of material, almost 5% of processed material, was reported as other or out of scope material and is assumed to be made up of mixed battery material and mixed electronics waste. The fate of this material is not known.

Refer to following Figure 9 for a visual representation of total battery collections, total tonnage of batteries processed, battery material flows and battery material fates.

B-cycle Battery Recycling

Figure 9. Handheld under 5kg batteries (excluding Lead Acid batteries) recycling fates (2021)[16]



[16] The figures above do not include collection figures for a significant portion of Lead Acid battery collection. However, a small portion of Lead Acid batteries find their way into this collection stream but predominantly, Lead Acid battery collections and recycling markets fall outside the focus of this analysis.

1.2.6 Estimate of battery collection rates

The following battery collection rates are for all batteries reaching EoL on the Australian market in 2021. This includes a large portion of Lead Acid batteries, for which there is an established recycling market. The total collection rate for all batteries in Australia is 87%, however, for key battery types with projections of substantial market growth (e.g. Lithium-ion), collection rates are much lower.

According to the estimates of batteries reaching EoL and information provided by Australian collectors and recyclers, the results from the MFA of current collection rates for all battery chemistries are presented in Table 4.

+ Nickel Metal Hybrid batteries feature the highest collection rate at 29%.
+ Alkaline batteries follow closely at 13%.
+ Nickel Cadmium battery collection rate is 9%.
+ Lithium-ion features by far the lowest collection rate at 3% of EoL arisings.

The last column presents data for collection of batteries that today falls in the scope of B-cycle Scheme. In exclusion of Lead Acid batteries, the collection of in-scope batteries in 2021 represented 58% of all collected batteries (1,258 out of 2,160 tonnes) and 5% of all batteries reaching their EoL (1,258 out of 24,090).

Table 4. Battery collection rates by chemistry group (2021)

Chemistry Group	EoL Arisings (tonnes)	Collection to Processing (tonnes)	Collection Rate (%)	In-scope Collection (tonnes)
Alkaline	10,090	1,300	13%	757
Lithium-ion	8,250	280	3%	163
Nickel Cadmium	450	40	9%	23
Nickel Metal Hybrid	420	120	29%	70
Other and Mixed Chemistries	590	420	71%	245
Lead Acid	160,510	153,850	96%	0
Total	**184,600**	**156,010**	**87%**	**1,258**

2. Fate mapping and material flow analysis of Australian batteries

2.1 Introduction

Australia ranked tenth in the world for battery consumption in 2021[17]. As an affluent nation with a population that is geographically dispersed, Australia depends on batteries for consumer devices, for energy security in homes and businesses, and to power an increasing share of electric vehicles on roads.

Lithium-ion battery demand, particularly in Australia, is expected to grow fourfold by 2030 (FBI CRC, 2021). However, the primary sourcing of battery materials features several challenges, including annual mine production limits, commodity price volatility, environmental impacts, human rights abuses and social license risks such as inadequate community consultation. The essential battery materials that feed into Lithium-ion batteries, such as cobalt, lithium, and manganese are listed as Australian critical minerals.

Batteries are an amazing and enabling technology, however, batteries (even Rechargeable batteries) don't last forever. Without an efficient collection and recycling network, batteries can end up stockpiled in homes and businesses where certain battery types and chemistries contribute to increased fire risk or become choke hazards for children. Batteries often end up in landfill, where their contents such as cadmium, nickel, mercury, and lead have the potential to leach into and negatively impact the surrounding environment.

It is therefore critically import to understand the current collection rate of Australia's batteries, as this information will enable policy makers to guide industry innovation and contribute to the de-risking of battery supply over the next decade and beyond. Improvements can be made through sector wide target setting and performance management, however, it is essential that strategies account for product specific issues and prioritise management options that account for specific battery waste streams.

In 2022, the BSC commissioned this study to quantify the recycling efficiency of Australia's battery recycling sector, particular focus is placed on Handheld batteries, as a large portion of these batteries fall under the current scope of the B-cycle Scheme. This study benchmarks Australia's participation in battery sales, collection, and recycling.

[17] Source: https://about.bnef.com/blog/u-s-narrows-gap-with-china-in-race-to-dominate-battery-value-chain/

2.1.1 Objectives of this report

B-cycle is Australia's official product stewardship Scheme for batteries, run by the BSC. It was launched in early 2022 and is authorised by the Australian Competition and Consumer Commission (ACCC).

A battery collection network is being built by parties interested in participating in the B-cycle Scheme. This network is coordinated by BSC and accredited under B-cycle accreditation protocols. A main objective of B-cycle is to measure how Australia sustainably handles batteries at EoL, from collection to reprocessing and, in the future, repurposing.

The BSC identified the need for a benchmark study that would provide the baseline for measuring the Scheme performance against established targets. BSC commissioned a benchmarking project, which was undertaken by a partnership between Circular Australia, the Institute for Sustainable Futures (ISF) at the University of Technology Sydney and Nicki Hutley economics.

The benchmarking project includes three elements: market analysis and fate mapping, life cycle analysis, and economic analysis. This report presents the findings from the market analysis and fate mapping study which has been undertaken by ISF. The report presents findings on the current market characteristics for batteries and the fate of batteries at EoL.

This study comprises an analysis of the Australian battery market, for the year 2021, and a fate mapping of battery flows, including battery sales, stocks (batteries in use), and EoL collection and reprocessing, by battery chemistry, format or size and application.

The objectives of this study are to:

- Provide an overview of the battery market including a characterisation of country of origin for batteries sold on the Australian market;
- Quantify Australian battery sales for the year 2021 including the proportion of single use vs rechargeable;
- Quantify total Australian batteries in stocks (batteries in use);
- Quantify batteries reaching EoL, characterise their fates (i.e. whether they go to recycling or landfill), and estimate a collection rate;
- Provide a visual diagram of Australian battery sales (batteries sold onto the Australian market), battery stocks (batteries in use), batteries reaching EoL, and fates (the destination of battery materials).

2.2 Methodology

This study began with a literature review to gather available data for 2021 on battery sales (imports, exports), specifications (size, weight, and chemistry of batteries for individual product categories) and collection rates. This was supplemented with responses from a survey and interviews with 27 industry stakeholders.

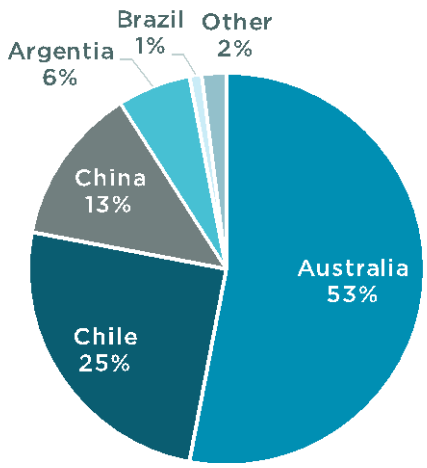
A Material Flow Analysis (MFA) was undertaken to provide a projection of the volumes of batteries reaching EoL. The MFA for this project is focused on the Australian battery market, including imports and exports as border flows, and sales, stocks or usage, collection, reprocessing and recycling as internal flows. The time boundary is the year 2021, chosen as baseline for future performance evaluation of B-cycle.

2.3 Overview of Australia's Participation in the Global Battery Supply Chain (GBSC)

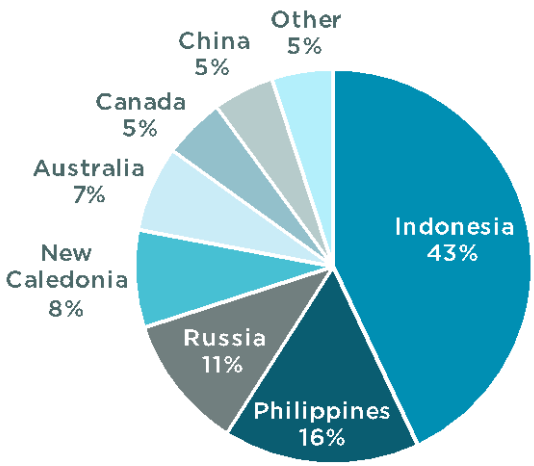
Australia's participation in the battery supply chain is predominantly in battery material mining and refining (as shown in Figure 10), with a smaller share of domestic battery recycling capacity.

Figure 10. Australia's market participation in the battery material mining and refining supply chain (2022)

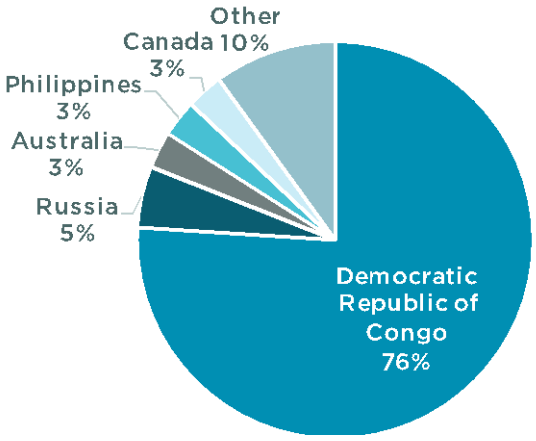
Lithium



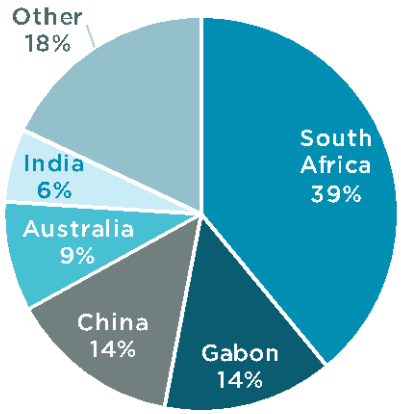
Nickel



Cobalt



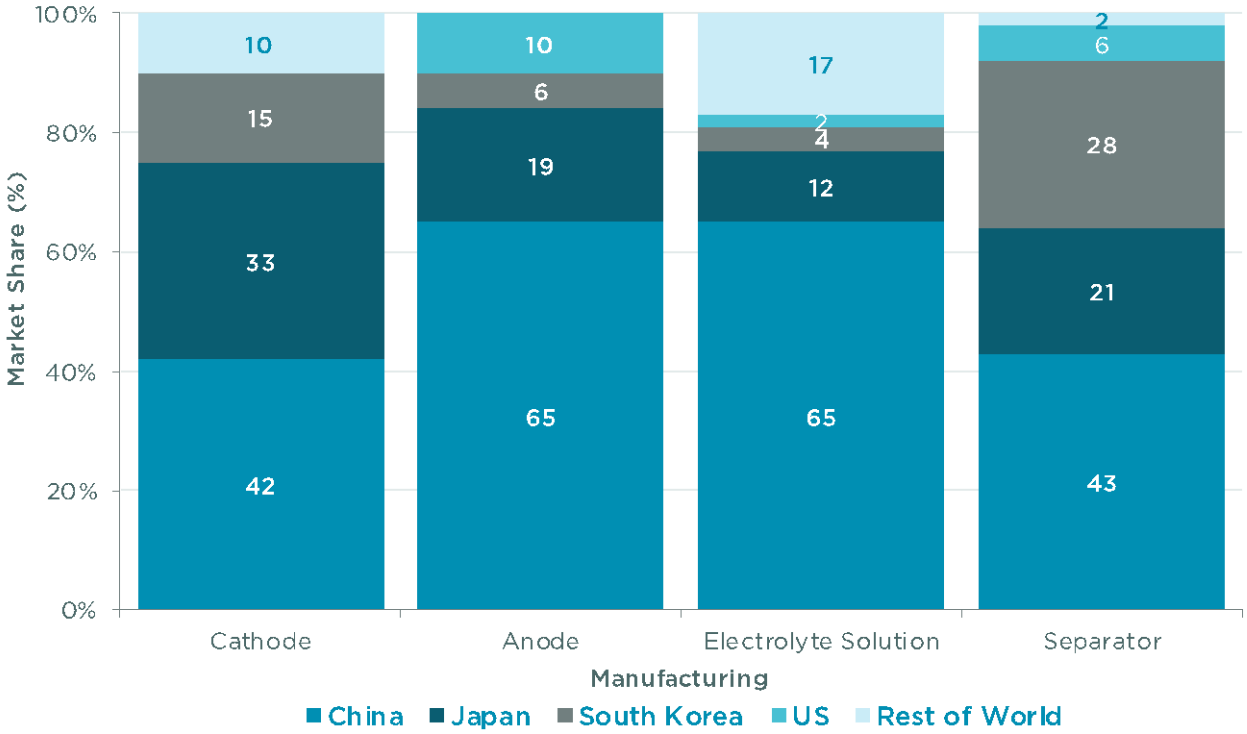
Manganese



Source: (Statista & US Geological Survey, 2022b, 2022a, 2022c, 2022d).

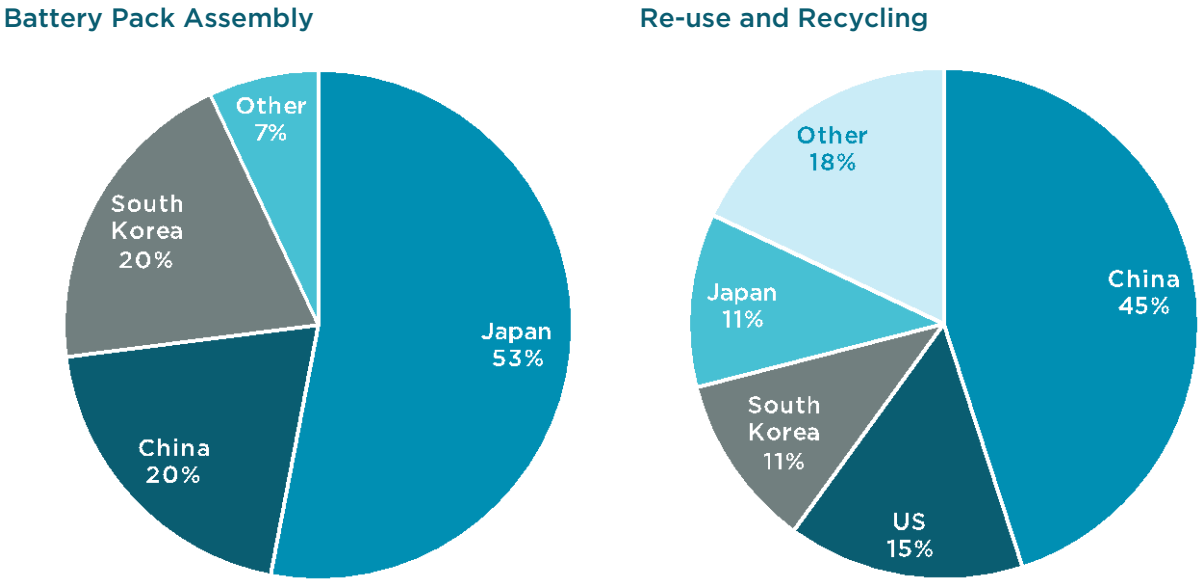
In terms of GBSC participation, China holds the largest share of Lithium-ion battery component manufacturing, followed by Japan (Figure 11). Japan is a key player in battery pack assembly, and China holds the market share of battery cell recycling (Figure 12).

Figure 11. Global participation in Lithium-ion battery component manufacture by market share (2019)



Source: (Statista, 2019).

Figure 12. Global participation in Lithium-ion battery pack assembly and battery reuse and recycling, by market share (2021)



Source: (FBI CRC, 2021).

However, as an affluent country, Australia contributes significantly to global battery consumption, therefor an understanding of Australia's impact on and participation in the battery supply chain is essential for guiding appropriate policy responses.

An overview of the battery supply chain is presented in Figure 13 on the following page. The GBSC is a complex web of mining, refining, and manufacturing processes. The key supply chain stages are as follows.

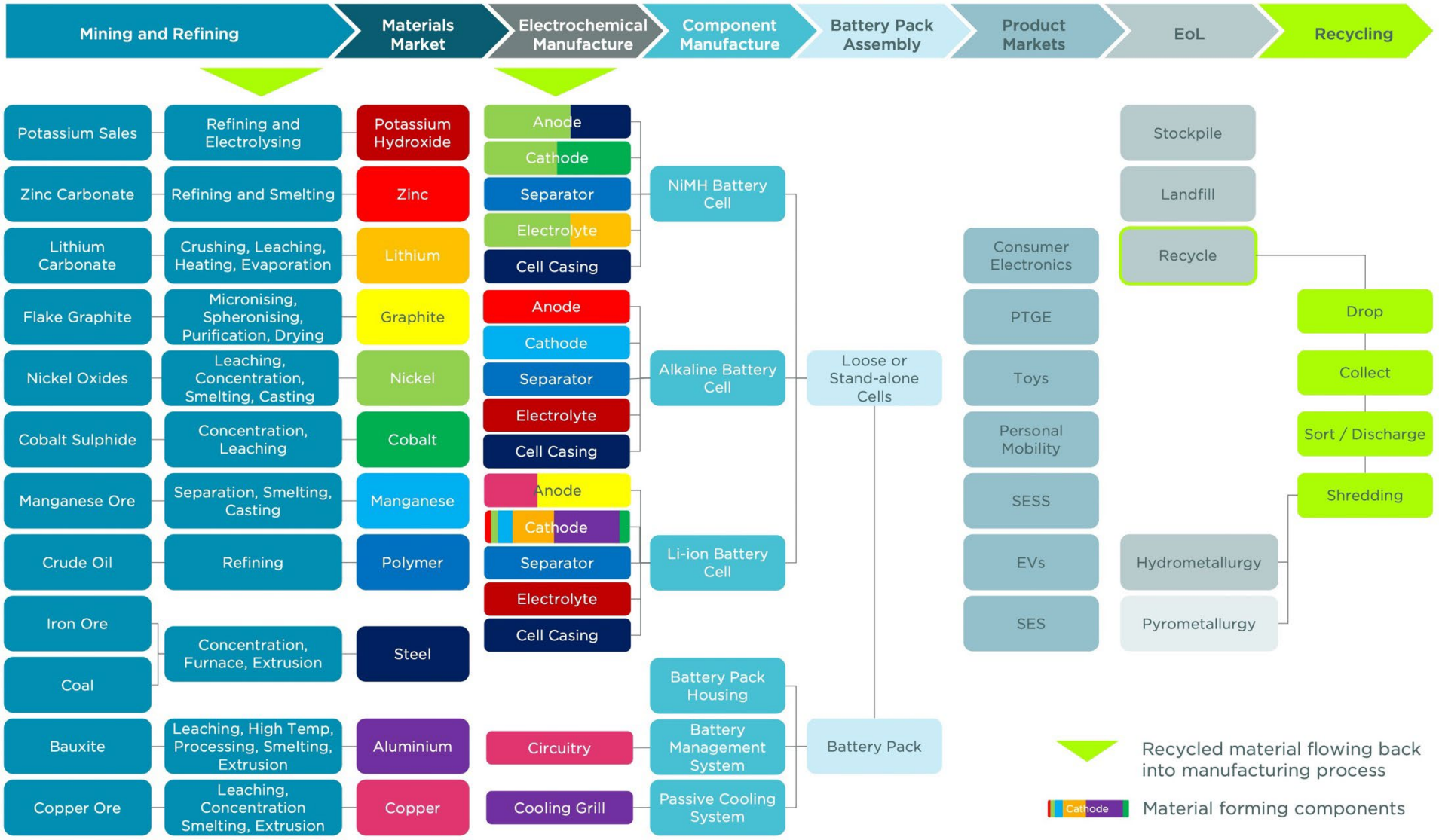
- **Mining and refining** – Minerals are mined and refined to a highly purified 'battery grade' material.
- **Electrochemical manufacture** – Highly purified material is manufactured or 'activated' into anode, cathode, separator, and electrolyte during the electrochemical manufacturing stage.
- **Battery manufacture** – Battery cell components are manufactured into cells.
- **Battery pack assembly** – Battery cells can be used as a loose or stand-alone battery in a product or assembled into larger battery packs.
- **Battery use in product markets** – Several common examples of products using batteries are presented in the product market column in Figure 13, including key growth markets such as power tools, personal mobility, stationary energy storage, and electric vehicles (EVs). Battery lifetimes can be difficult to estimate and are influenced by the power demand of a product, the product owner's usage style, and the battery size but range from approximately one year up to 20 years or more.
- **Battery EoL** – When batteries reach EoL they can be stockpiled (either at the home or in commercial facilities), discarded to landfill, or recycled.

The battery recycling process can be broken up into several key stages.

- **Drop Off** – A consumer drops off used batteries at a 'Drop Off' or collection point for the intent for it to be recycled.
- **Collection** – A collection (e.g. transport) company picks up the batteries from the 'Drop Off' point and delivers the batteries to a recycling facility.
- **Sorting** – Sorters (primarily battery recycling companies in Australia) sort batteries into their specific chemistry groups.
- **Recycling** – Recyclers discharge sorted batteries where necessary, mechanically shred batteries, and separate materials into metals, plastics, and black mass groups.

From this point, processed material can feed directly into the refining stages of the supply chain, indicated by the first green arrow in Figure 13. Alternatively, if hydrometallurgy processes are used at the recycling stage, there is potential for highly purified material to feed directly into the electrochemical processing phase of the battery manufacturing process, indicated by the second green arrow under electrochemical manufacture in Figure 13.

Figure 13. Battery supply chain for Nickel Metal Hybrid, Alkaline and Lithium-ion batteries[18]



[18] This diagram has been adapted from Briggs, C., Gill, J., Atherton, A., Langdon, R., Jazbec, M., Rutovitz, J., Cunningham, R., Wright, S., Nagrath, K., Walker, T., & Youren, M. (2021). Employment, skills, and supply-chains: renewable energy in New South Wales.

3. Results

3.1 Battery classifications

The scope of B-cycle currently includes three battery categories:

- **Loose batteries** – Imported without a product, such as AA, AAA, C, D, etc.;
- **Proprietary batteries imported with product and easily removeable** – Imported within a product that can be removed and/or replaced by the consumer, and that are specifically designed for that product, such as digital cameras, e-bicycles, power tools, etc.;
- **Loose batteries imported with product** – Loose batteries that are imported with a product that can be removed by the consumer and are not specifically designed for that product, such as toys, scales, remote controls, torches, etc.

Batteries that already have a viable recycling market or are included in other schemes are not within the B-cycle scope, this includes Lead Acid batteries, and batteries from laptops, phone batteries, etc. However, they are still analysed by this study because they represent a significant share of the battery market.

This study has adopted the classifications provided in a previous study by the BSC and Envisage (Envisage Works, 2020), and the same terminology and reporting format has been adopted to aid future time series analysis. The classification list is presented in Table 5. Data in the MFA model classifies batteries by their market segment, application area, chemistry group, battery size and weight range, level of integration in products and end-user type.

Table 5. Classifications by market segment, application area, chemistry, size, level of integration and end user type

Market Segment and Applications	Chemistry Group	Battery Size or Weight Range	Level of Integration in Products	End User Type
Handheld Batteries (<5kg) + Consumer Electronics (camera, wireless speakers, drones) + Torches, Lanterns + Power Tools and Garden Equipment + Toys + Personal Mobility <5kg (e-bicycles, e-scooters) + Storage, Emergency and Standby <5kg (lighting, fire, security) + Starting, Lighting and Ignition batteries <5kg (small traction applications, motorcycles)	+ Alkaline + Lead Acid + Lithium-ion + Lithium Primary + Nickel Cadmium + Nickel Metal Hybrid + Sliver Oxide + Zinc Air + Other Chemistries	+ AA + AAA + Button Cell + C + D + Lantern (6v) + 9v + Laptop + Mobile Phone + Tablet + Power Tool	+ Standalone batteries + Part of EEE (Easily removeable) + Part of EEE + (Embedded battery) + Other	+ Household and Commercial + Large and Industrial + Other End User Types
Battery Energy Storage Systems (BESS) + Storage, Emergency and Standby (UPS, data centers, hospitals, telecommunications) + Portable Energy Storage (recreational, deep cycle) + Residential Energy Storage (behind-the-meter) + Grid Scale Energy Storage (front-of-meter)		+ <10g + 10g–49g + 50g–99g + 100g–499g + 500g–999g + 1000g–4999g + 5kg–10kg + 10kg–50kg + 50kg–100kg + >100kg + Other		
Electric Vehicles (EVs) + Commercial EVs (trucks, buses, mining equipment) + Passenger EVs (under 3.5 tonnes)				
Starting, Lighting, and Ignition (SLI) and Other industrial (>5kg) + Starting, Lighting and Ignition + Personal Mobility >5kg (golf carts, wheelchairs) + Other Applications (industrial and other traction applications)				

3.2 Data sources and gaps

Data was sourced from a combination of desktop research, stakeholder surveys, and interviews. A detailed breakdown of data sources, data gaps and an assessment of data quality is provided in Table 6 below.

Table 6. Data sources, quality, and gaps assessment

Report Section	Data Type	Description	Source	Quality	Gaps
Battery Sales	Import Data	Ten-digit Harmonised Tariff Item Statistical Classification (HTISC data sourced from the Australian Bureau of Statistics, in units and weight.	(ABS, 2021b)	High	No import code for e-scooters and drones
	Export Data	Eight-digit Australian Harmonised Export Commodity Classification (AHECC data sourced from the Australian Bureau of Statistics, in units and weight.	(ABS, 2021a)	High	No export code for e-scooters and drones
	BESS Installed Capacity	Australian installs of residential and commercial Battery Energy Storage Systems (BESS) in 2021[19].	(AEMO, 2021)	High	Grid-scale BESS
	Lead Acid Battery Local Sales	Data could not be collected on local sales of Lead Acid batteries via interviews for the year 2021. To fill this gap, data collected by Envisage for 2018 was used.	(Envisage Works, 2020)	Low	Unable to source 2021 data from market
Battery Sales (EoL)	Battery Specifications	Data on the size, weight, and chemistry of batteries for individual product categories was collected from fact sheets and product specification sheets for common products currently on the market.	Various, refer to references for full list	Medium	None identified
Australian Battery Recycling Sector	Interview Data	Data was collected from recyclers on total kgs of batteries collected, sorted, and processed in 2021. Information was also collected on the current fates of recycled battery material. Information provided by the recyclers that did participate was extrapolated across the sector to fill data gaps.	Interviews (UTS, 2022)	High	Collection points

[19] Note: The BESS data used is for residential and commercial Distributed Energy Resources (DER) only and does not include utility-scale BESS. Accurate historic installed capacities for utility-scale batteries will be needed for the inclusion of this battery type in future analysis.

Report Section	Data Type	Description	Source	Quality	Gaps
Market Projections	Literature	Information on a select group of specific product markets was collected to understand and validate market trend calculations in the MFA model.	(Coulter, 2022; CWANZ, 2021; Electric Vehicle Council, 2020; Energeia, 2018; Energy Matters, 2022; FBI CRC, 2021; Global Battery Alliance, 2019; Huisman & Bobba, 2021; Mobile Muster, 2021; Mordor Intelligence, 2020; Statista, 2021; Zhao et al., 2021)	Medium	Drones, e-scooters, power banks, military vehicles.

3.3 Australian battery sales, stocks, collections, and fates

This section provides an overview of all batteries flowing through the Australian market in 2021. Total battery sales, total battery stocks (batteries in use), and EoL arisings (batteries reaching the end of their life in 2021) are estimated. Results are presented as follows.

+ **Total batteries** – All batteries on the market (which includes a significant portion of batteries outside the scope of B-cycle), presented in Figure 14.
+ **Handheld batteries (<5kg)** – Smaller batteries (a percentage of these batteries currently fall under the scope of B-cycle, the remaining share are batteries that could be considered for inclusion in B-cycle in the future), presented in Figure 15.

3.3.1 Total battery sales, stocks, EoL arisings, collections, and recycling

The results of MFA modelling of total Australian battery flows are presented in Figure 14, these flows represent all batteries across all market and product classifications (within the scope of this research). Results are aggregated across all market and product classifications and total flows are presented by battery chemistries.

Based on these results, the following points are highlighted.

+ A total of 737 million batteries were sold onto the Australian market in 2021, which equates to just over 200,000 tonnes of batteries.
+ Almost 500,000 tonnes of batteries are estimated to have been in use (stocks) in Australia in 2021 and just over 180,000 tonnes of batteries reached EoL.
+ A total of 156,000 tonnes of batteries were estimated to be collected for recycling in 2021, which equates to a recycling rate of 87% across all battery sizes[20].

[20] This calculation includes batteries outside the scope of the B-cycle Scheme.

3.3.2 Handheld under 5kg battery sales, stocks, EoL arisings and recycling

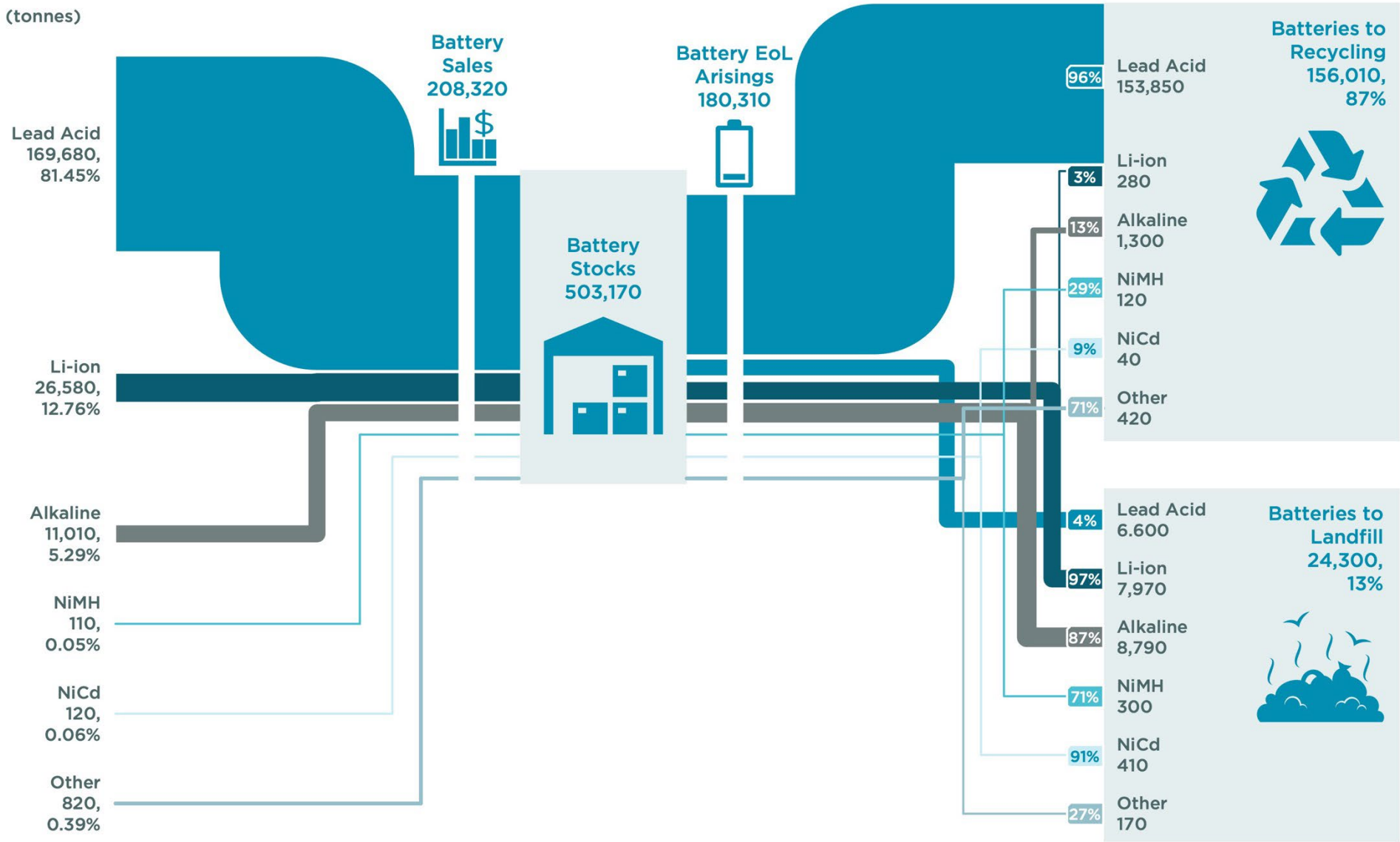
Figure 15 illustrates the flow of Handheld batteries in Australia in 2021. Handheld batteries are those batteries under 5kg and consist of batteries from a range of product categories and levels of integration (ease of removability from a product)[21]. Based on the overview of battery flows presented in Figure 15, the following observations are made.

- A total of 29,110 tonnes of batteries under 5kg were sold onto the Australian market in 2021.
- Lithium-ion batteries make up the major share of battery sales for this category at 43%, highlighting the increasing market dominance of this chemistry for rechargeable applications.
- Alkaline batteries follow at just over 38% of sales, reflecting the dominance of the Alkaline chemistry in single use applications requiring Stand-alone batteries.
- Just over 63,000 tonnes of Handheld batteries were estimated to be in use (stocks) in 2021.
- A total of 23,310 tonnes of Handheld batteries reached EoL in 2021, and an estimate of 3,620 tonnes of Handheld batteries were collected for recycling.
- Alkaline batteries represented the largest share of recycled batteries by battery type at 1,300 tonnes of batteries recycled in 2021.

[21] Handheld battery flows include a share of batteries currently within the scope of B-cycle, as well as a share of batteries that are not currently in-scope but could be considered in the future.

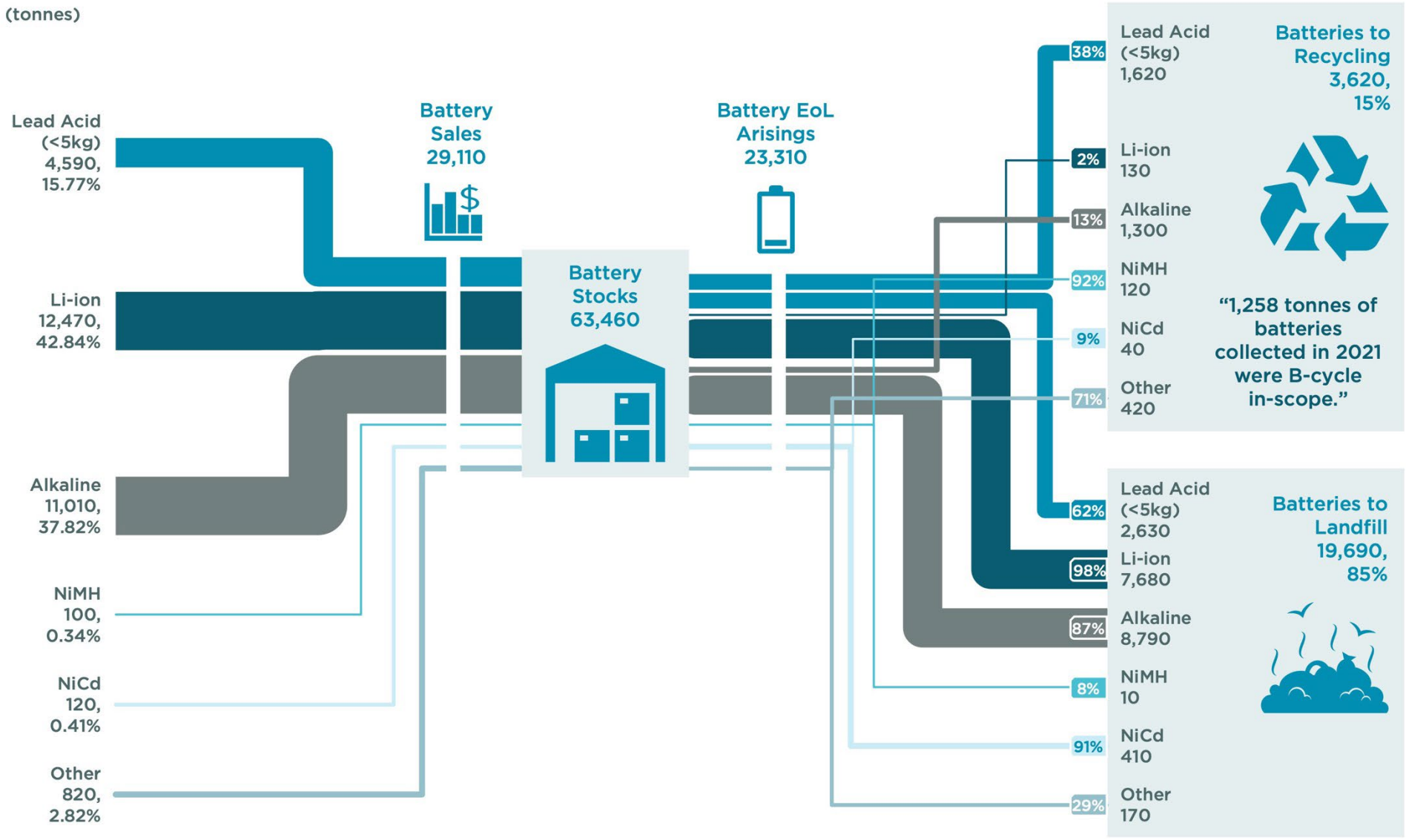
B-cycle Battery Recycling

Figure 14. Total battery flows by weight, and by chemistry group (2021)



B-cycle Battery Recycling

Figure 15. Handheld under 5kg battery flows by weight, and by chemistry group (2021)



3.4 Australian battery sales

The Australian battery market consists of three overarching market segments, these segments have been previously defined by Envisage and the BSC (Envisage Works, 2020) and are re-established in this study as follow.

- **Handheld batteries (<5kg)** – All batteries under 5kg, including e-bicycle batteries, and Lead Acid batteries.
- **Battery Energy Storage System (BESS) batteries** – BESS are those systems that provide stationary energy storage, examples include residential behind-the-meter batteries, and off-grid commercial systems replacing diesel generators. Portable BESS such as RVs are also included in this product category. This market segment does not include grid-scale batteries currently due to limited availability of historic data for these applications.
- **Electric Vehicle (EV) batteries** – EV batteries are used in vehicles powered by an electric or hybrid-electric motor.
- **SLI and other industrial batteries (≥5kg)** – All Lead Acid batteries equal to or more than 5kg. These include batteries used in Internal Combustion Engine (ICE) vehicles for engine starting and other traction and industrial applications.

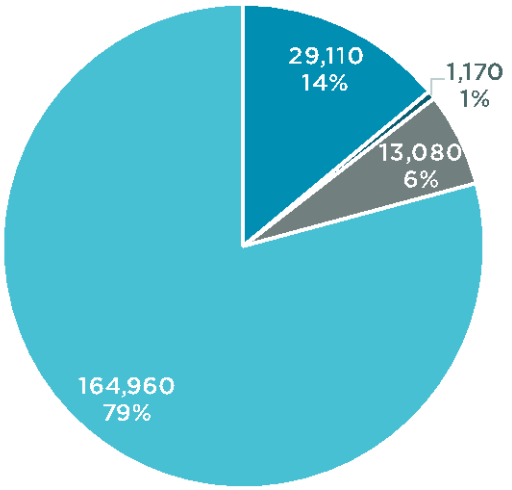
Battery sales results are presented in the next section as a total for all batteries and for batteries under 5kg and analysed by market segment, application area, chemistry group, and level of product integration.

3.4.1 Total battery sales by market segment in 2021

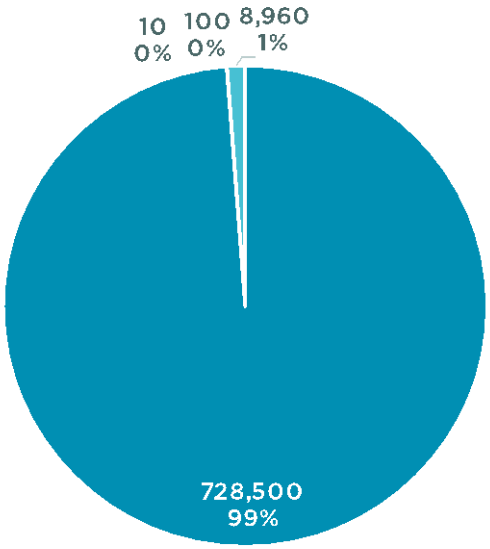
Total Australian battery sales by market segment for the year 2021 as shown in Figure 16 and Table 7. SLI and other industrial batteries over 5kg dominate total sales by weight (164,960 tonnes) despite their smaller share by number (8 million batteries), this is due to their continuing prominence as engine starting batteries and larger weight share per battery compared to other market segments such as Handheld batteries. Handheld batteries make up 99% of the share of batteries by unit number, and 14% of the share of batteries by weight, at 29,110 tonnes. BESS and EVs represent less than 1% of batteries by unit number with 110,000 units sold in 2021, and 7% of batteries by weight at 14,250 tonnes sold in 2021.

Figure 16. Total battery sales by market segment (2021)

By Weight (tonnes)



By Number ('000)



Handheld (<5kg) BESS EVs SLIs and Other Industrial

Table 7. Total battery sales by market segment (2021)

Market Segment	Battery Sales			Battery Stocks (tonnes)	EoL Arisings (tonnes)	Collected Recycling (tonnes)	Collection Rate (%)
	Weight[22] (tonnes)	Number[23] ('000)	EBUs[24] (million)				
Handheld (<5kg)	29,110	728,500	1,060	63,460	23,310	3,620	16%
BESS	1,170	10	30	12,710	1,200	10	1%
EV	13,080	100	350	38,650	470	150	32%
SLI and Other Industrial	164,960	8,960	6,870	388,350	155,330	152,230	98%
Total	**208,320**	**737,570**	**8,310**	**503,170**	**180,310**	**156,010**	**87%**

[22] Weight quoted in tonnes is inclusive of both the battery pack and cell weight.

[23] This unit is representative of the number of batteries (which in some cases is a battery pack and other cases is just a battery cell) sold per product.

[24] The calculation of EBUs is based on cell weight only.

1.1.1. Battery sales by application area in 2021

Total Australian battery sales by application area are provided in Figure 17 below and Table 8 on the following page. Consumer electronics dominate sales with over 637 million batteries sold for consumer electronics applications in 2021. This is followed by toys with just over 27 million batteries sold. Power tool sales totalled just over 13 million batteries sold. Personal mobility totalled 470,000 batteries sold, with a large share of around 300,000 electric bicycles containing batteries of around 5kg each. Approximately 100,000 EVs were sold in 2021 and BESS battery sales totalled 10,000.

By weight, SLI batteries for vehicles far outweigh any other product category at 130,180 tonnes, this is due to the larger size of this battery per unit (typically a Lead Acid battery with an average weight of around 20kg per battery). Emergency and standby batteries also feature a large percentage share by weight at 34,830 tonnes. The next highest product categories by weight are consumer electronics at 14,020 tonnes, and power tools at 7,810 tonnes. Sale of EV batteries totalled 13,080 tonnes and BESS totalled 1,170 tonnes (driven by large batteries sizes in this product category, for example the 14kWh Tesla Powerwall system features a battery weight of around 100kg).

Figure 17. Battery sales by application area (2021)

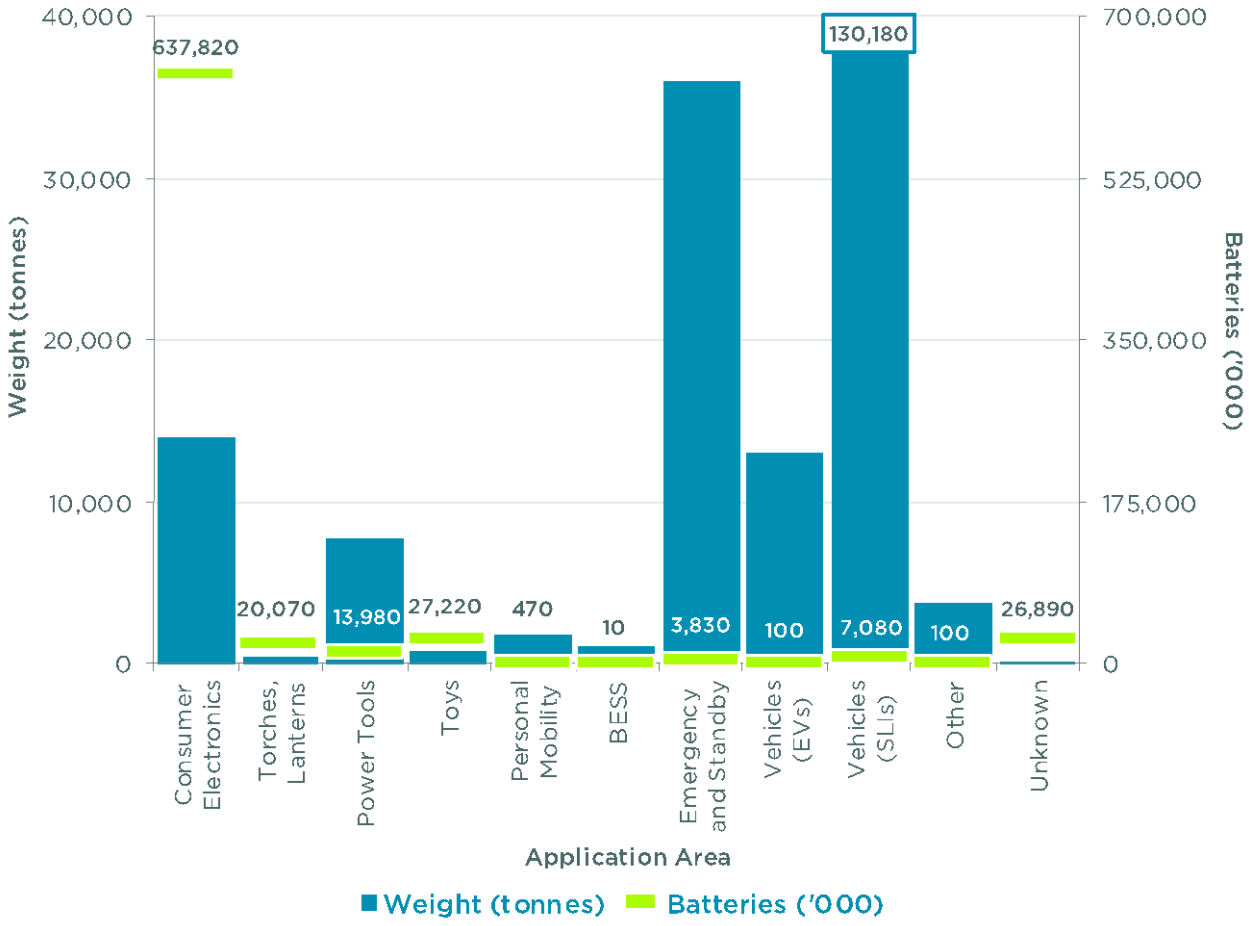


Table 8. Battery sales by application area (2021)

Application Area	Sales	
	Weight (tonnes)	Number ('000)
Consumer Electronics	14,020	637,820
Torches, Lanterns	440	20,070
Power Tools and Gardening Equipment	7,810	13,980
Toys	900	27,220
Personal Mobility	1,850	470
Battery Energy Storage System	1,170	10
Storage, Emergency and Standby	34,830	3,830
Vehicles (EV)	13,080	100
Vehicles (SLI)	130,180	7,080
Other Application Area	3,820	100
Unknown	220	26,890
Total	208,320	737,570

3.4.1.1 Battery sales, consumer electronics applications in 2021

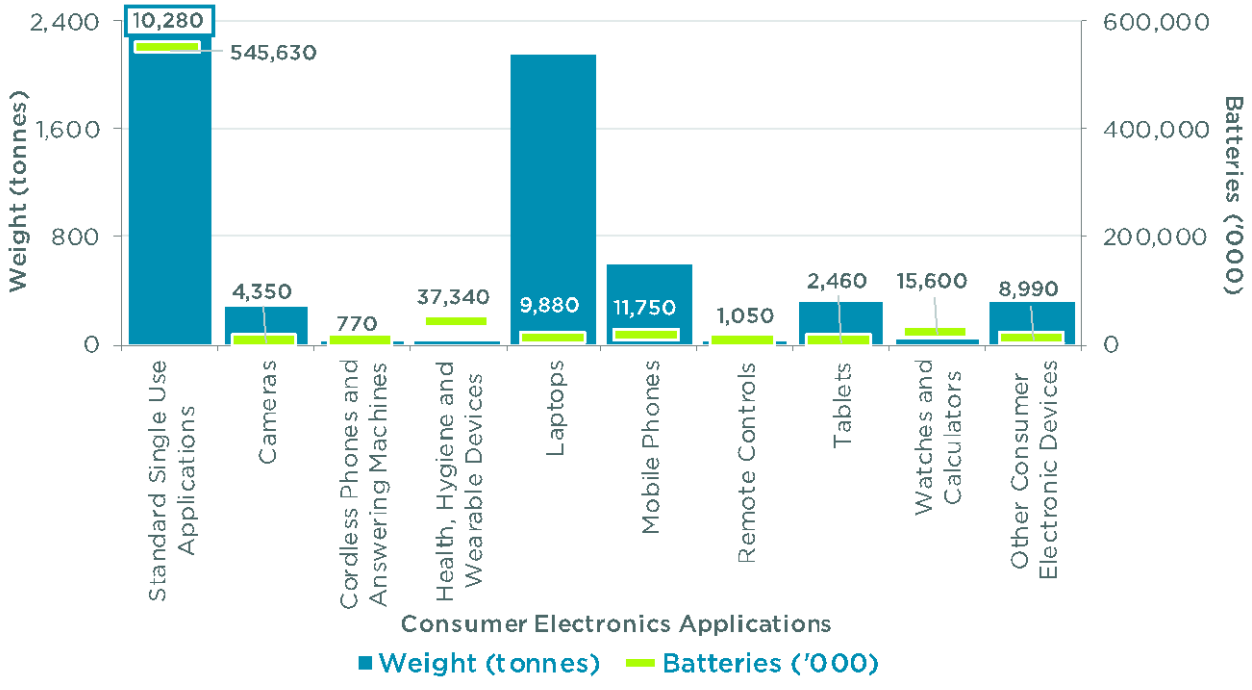
Table 9 and Figure 18 show that standard single use applications make up the major share of consumer electronics applications at 85% of battery sales (545 million) and 73% of battery sales by weight, almost entirely composed of Alkaline batteries.

Laptops are the next largest share at 15% of sales by weight (2,150 tonnes). Health, hygiene and wearable devices feature the second largest share of battery sales (37 million) however the weight of each silver oxide or zinc air button battery for these devices is much smaller than other product categories, so the product category equates to just 20 tonnes of sales.

Table 9. Battery sales by consumer electronics applications (2021)

Application Area	Sales		Comments
	Weight (tonnes)	Number ('000)	
Standard Single Use Applications	10,280	545,630	+ Almost entirely Alkaline batteries
Cameras	270	4,350	+ Lithium-ion batteries
Cordless Phones and Answering Machines	10	770	+ Nickel Metal Hydride batteries
Health, Hygiene and Wearable Devices	20	37,340	+ Silver Oxide and Zinc Air cells
Laptops	2,150	9,880	+ Lithium-ion and Lithium Primary (CMOS) batteries
Mobile Phones	590	11,750	+ Lithium-ion batteries
Remote Controls	20	1,050	+ Alkaline batteries
Tablets	320	2,460	+ Lithium-ion batteries
Watches and Calculators	40	15,600	+ Lithium Primary and Alkaline Batteries
Other Consumer Electronic Devices	320	8,990	+ Mostly Nickel Metal Hydride and Lithium Primary batteries
Total	14,020	637,820	

Figure 18. Battery sales by consumer electronics applications (2021)



3.4.1.2 Battery sales by power tools and gardening equipment applications in 2021

The battery powered tools and gardening equipment market has exploded over the last few years with total battery sales in 2021 reaching just over 13 million. Table 10 and Figure 19 show the breakdown of sales by number of batteries sold and their associated battery weight.

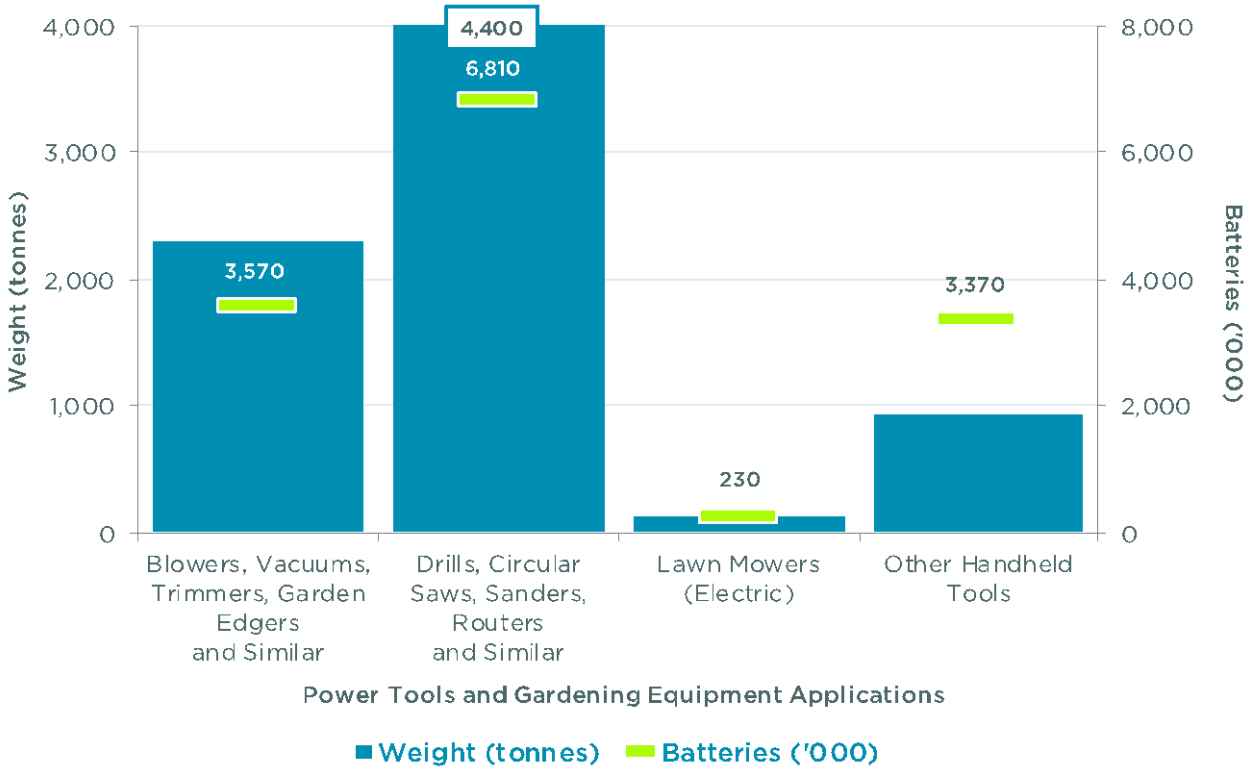
Battery powered hand tools such as drills, circular saws, sanders, and routers account for the biggest share of sales, at 57% of all battery powered tools by weight, a total of 4,440 tonnes. Based on market research it Is assumed that all batteries now sold with battery powered tools are predominantly Lithium-ion chemistries, this is the dominant market choice due to the fast-charging characteristics and long service life. The homogenous nature of batteries used for power tools across brand segments results in a consistent battery weight to unit ratio across most product segments (refer to Figure 19).

Table 10. Battery sales by power tools and gardening equipment applications (2021)[25]

Application Area	Sales		Comments
	Weight (tonnes)	Number ('000)	
Blowers, Vacuums, Trimmers, Garden Edgers and Similar	2,300	3,570	+ Lithium-ion batteries
Drills, Circular Saws, Sanders, Routers and Similar	4,440	6,810	+ Lithium-ion batteries
Lawn Mowers (Electric)	140	230	+ Predominantly Lithium-ion batteries for consumer market, some Lead Acid batteries in commercial models
Other Handheld Tools	930	3,370	+ Lithium-ion batteries
Total	**7,810**	**13,980**	

[25] The weight of the battery pack has been used to estimate the total weight of power tool battery sales. This is consistent with the scope of data received from recyclers at EoL which includes the weight of battery cells, BMS, casings, and electronics contained within battery packs. The approximate weight of battery cells for this product category is 65% of the battery pack weight.

Figure 19. Battery sales by power tools and gardening equipment applications (2021)



3.4.1.3 Battery sales by personal mobility applications in 2021

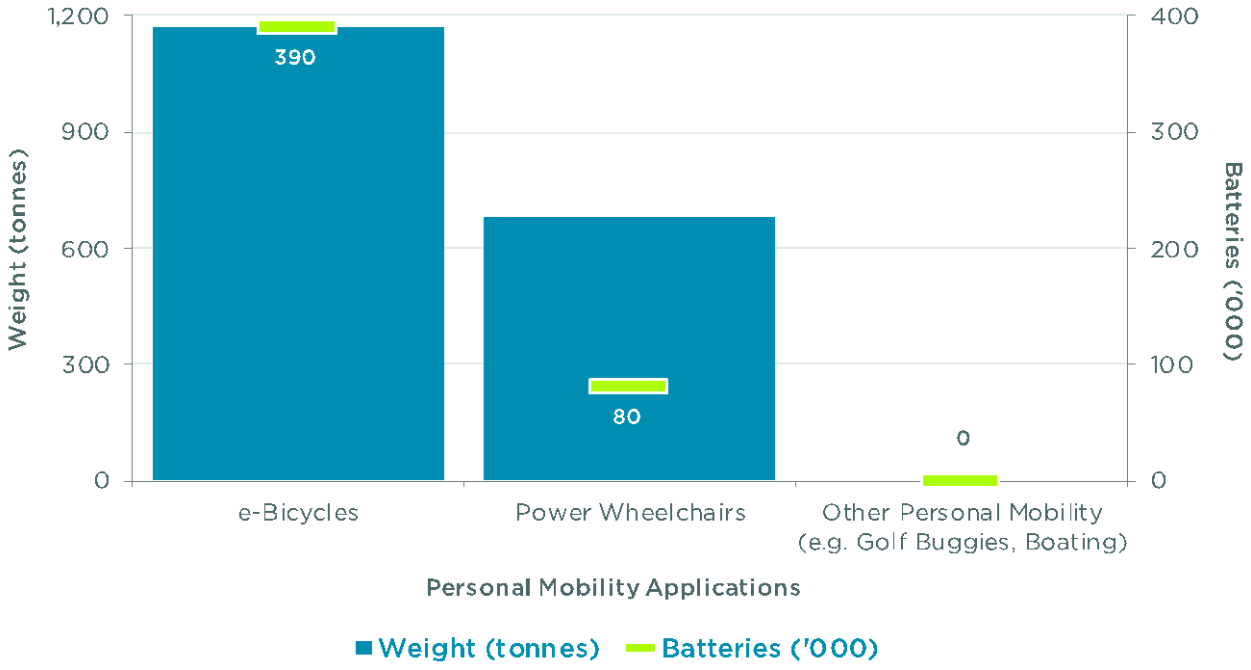
Sales of electric bicycles (e-bicycles) boomed in 2021, with previous reports the market had tripled between 2017 and 2019 (Else Kennedy, 2019), the trend is continuing in 2021 for this product market. According to market research, 2021 e-bicycle sales are expected to grow fourfold by 2030 (Mordor Intelligence, 2021). A total of 390,000 e-bicycle (and associated batteries) were recorded as imported into Australia in 2021, represented here as sales in Table 11 and Figure 20.

A total of 1,170 tonnes of e-bicycle batteries were sold onto the Australian market in 2021. E-bicycle batteries represents a key area for integration into B-cycle scope. Batteries are easily removeable by the consumer, however bicycle market experts noted complications with collection and recycling due to the size of the batteries and the potential for 'thermal runaway' while stored for collection. Due to the easily removeable nature of e-bicycle batteries these have been reclassified these to the Handheld category rather than the BESS and EV category as in the previous BSC report (Envisage Works, 2020).

Table 11. Battery sales by e-bicycles, wheelchairs, and other personal mobility applications (2021)

Application Area	Sales		Comments
	Weight (tonnes)	Number ('000)	
e-Bicycles[26]	1,170	390	+ Lithium-ion batteries
Power Wheelchairs	680	80	+ Lead acid and Lithium-ion batteries
Other Personal Mobility	0	0	+ Lithium-ion batteries
Total	1,850	470	

Figure 20. Battery sales by personal mobility applications (2021)



3.4.2 Total battery sales by chemistry group in 2021

Total battery sales by chemistry group are presented in Table 12 and Table 21. Based on the MFA, the following points are highlighted.

+ Lead Acid batteries are the major Australian market share of sales in weight at just over 169,000 tonnes. These batteries are predominantly made up of SLI batteries for ICE vehicles but also contain a share of smaller battery sizes for a range of applications.

[26] The weight of the battery pack has been used to estimate the total weight of e-bicycle battery sales. This is consistent with the scope of data received from recyclers at EoL which includes the weight of battery cells, BMS, casings, and electronics contained within battery packs. The approximate weight of battery cells for this product category is 60% of the battery pack weight.

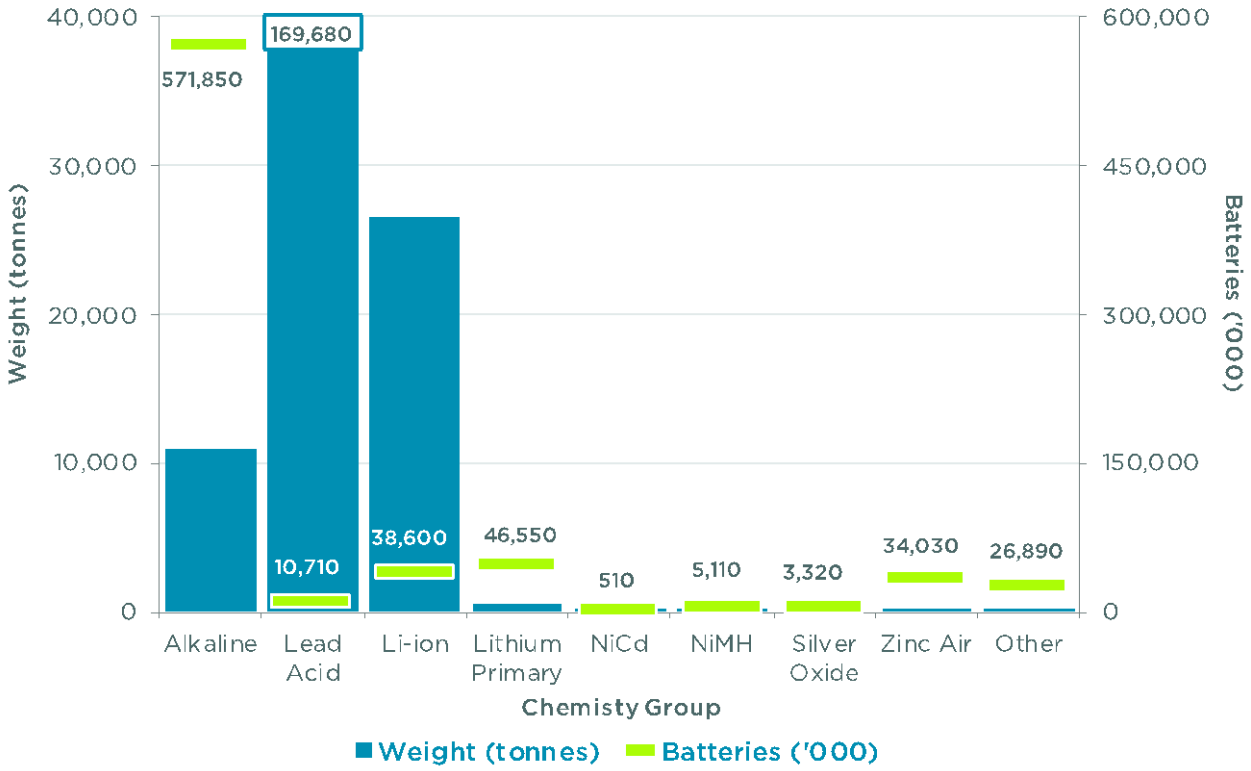
- Alkaline batteries are the most sold chemistry group at 571 million batteries sold in 2021, these batteries are common in AA and AAA Stand-alone battery range.
- Lithium-ion batteries make up the second largest share in weight, at over 26,000 tonnes, driven by new demand for fast-charging rechargeable technologies in product categories such as EVs, residential BESS, e-bicycles, and power tools.
- Zinc Air batteries (button cells) are the fourth largest share of battery sales, at just over 34 million batteries sold in 2021, however their market share by weight is much lower due to the size of these batteries, at just 20 tonnes sold in 2021.

Table 12. Total battery sales by chemistry group (2021)[27]

Chemistry Group	Sales	
	Weight (tonnes)	Number ('000)
Alkaline	11,010	571,850
Lead Acid	169,680	10,710
Lithium-ion	26,580	38,600
Lithium Primary	580	46,550
Nickel Cadmium	120	510
Nickel Metal Hydride	110	5,110
Silver Oxide	0(1)	3,320
Zinc Air	20	34,030
Other	220	26,890
Total	**208,320**	**737,570**

[27] Model is programmed to round up to the nearest 10, so it does not catch the 3 tonnes of silver oxide batteries sold in 2021.

Figure 21. Total battery sales by chemistry group (2021)



3.4.3 Battery sales by chemistry group and application area in 2021

The next section presents battery sales by chemistry group and application area, this includes batteries from a range of market segments. Sales have been provided by chemistry group for Handheld batteries, BESS batteries, vehicle batteries (ICE, EV, commercial, and other).

Figure 22 provides a breakdown of battery sales by chemistry group, collected by application for those batteries under 5kg. Consumer electronics contain batteries from a broad range of chemistry groups, reflecting the diverse nature of products this category. Power tools, toys, personal mobility, SES and vehicles[28] are predominantly powered by Lithium-ion batteries. Consumption of Alkaline batteries is predominantly driven by consumer electronics, torches, and toys. Lead Acid battery consumption is predominantly driven by smaller internal combustion engine vehicles such as motorcycles.

[28] Note: The vehicles category in Figure 28 only includes vehicles with batteries smaller than 5kg (e.g. motorcycles).

Figure 22. Handheld under 5kg battery sales by chemistry group and application area (2021)

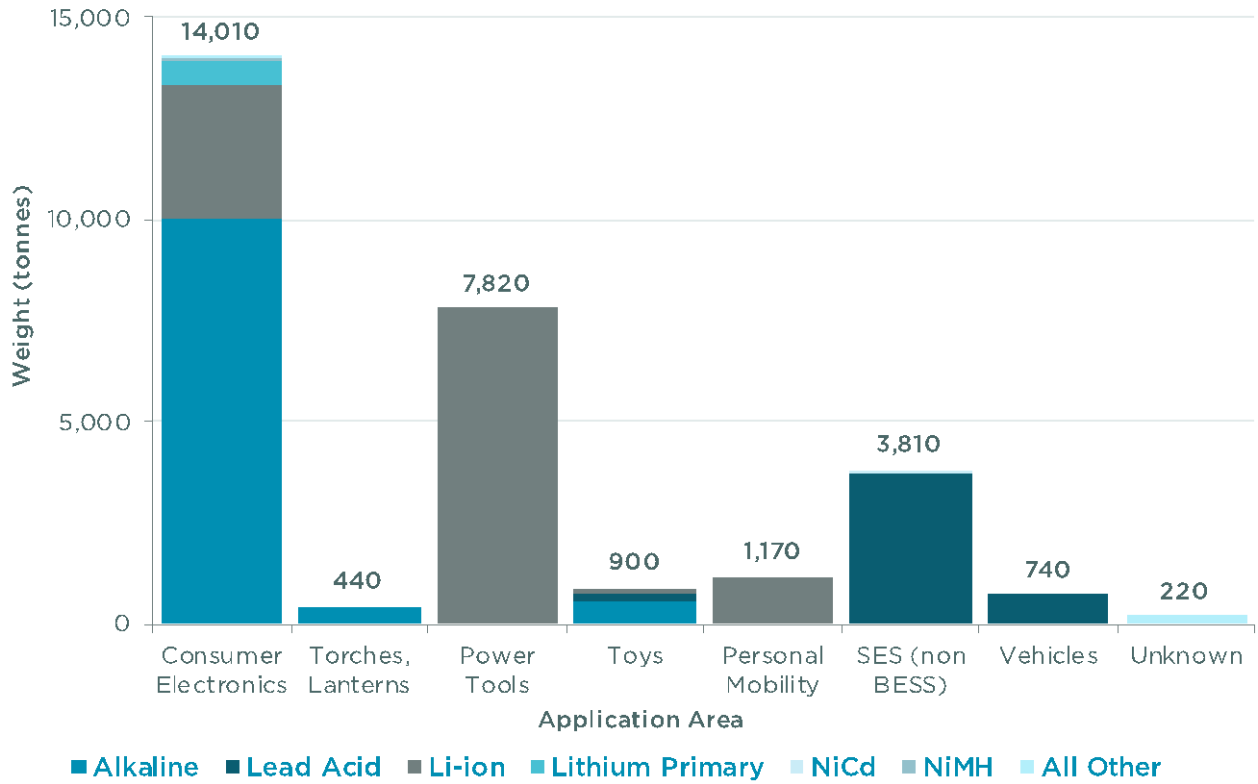
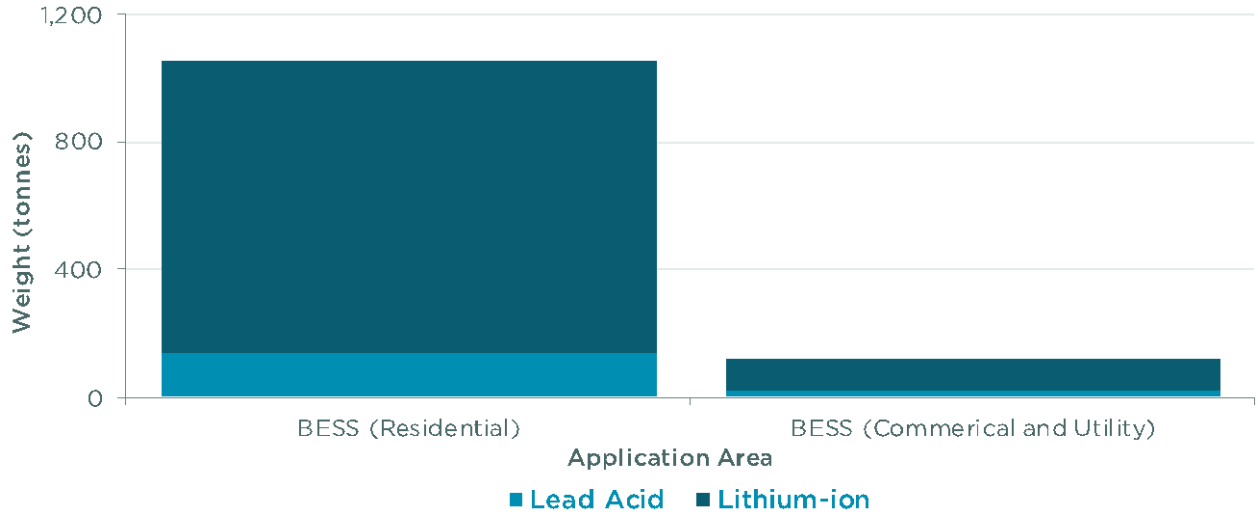


Figure 23 provides an overview of battery chemistries for BESS applications. Lithium-ion batteries are the predominant chemistry for these applications, with smaller share of Lead Acid batteries for these larger scale storage systems. Utility-scale BESS systems have not been included in this estimate.

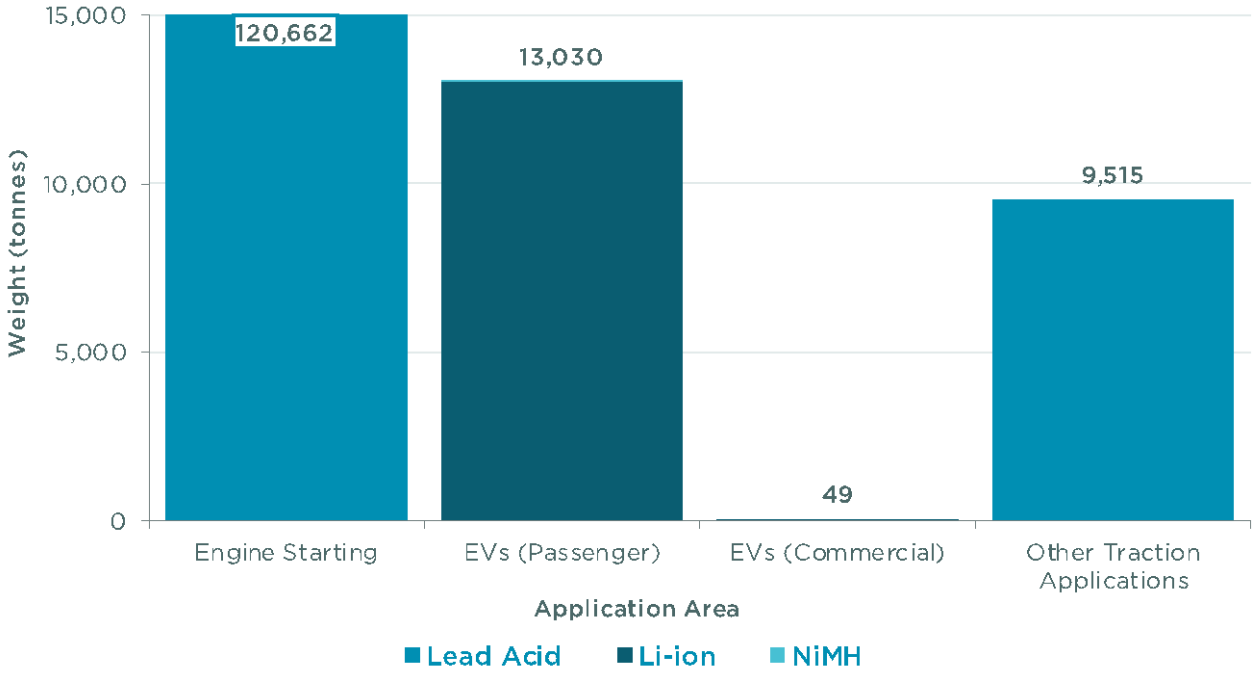
Figure 23. Total of BESS battery sales by chemistry group and application area (2021)



Total tonnes of vehicle battery sales are shown in Table 24 below. Most battery sales by weight for this application area are SLI Lead Acid batteries at just over 120,000 tonnes of batteries, with a smaller share of Lead Acid batteries used for other traction applications such as forklifts and other warehouse vehicles. The next largest share is Lithium-ion batteries for passenger EVs, at around 13,000 tonnes.

A very small share of Nickel Metal Hydride batteries are also used for hybrid EV applications. A much smaller share of Lithium-ion batteries can be seen for commercial EVs however given these sales are predominantly driven by import data, this does not represent the share of vehicles that may be manufactured in Australia such as new electric buses.

Figure 24. Total of vehicles battery sales by chemistry group and application area (2021)



3.4.4 Battery sales by weight range in 2021

A representation of batteries by size and weight provides further information for those battery sizes in high demand. Battery types such as button cells, AA and AAA, are in high demand across numerous consumer electronic products and so represent the highest number of battery sales due to their wide market demand. Table 13 and Figure 25 show the largest share of battery sales by weight is the 10kg–50kg range, at 154,980 tonnes, driven predominantly by SLI automotive batteries.

Table 13. Total battery sales by weight range (2021)

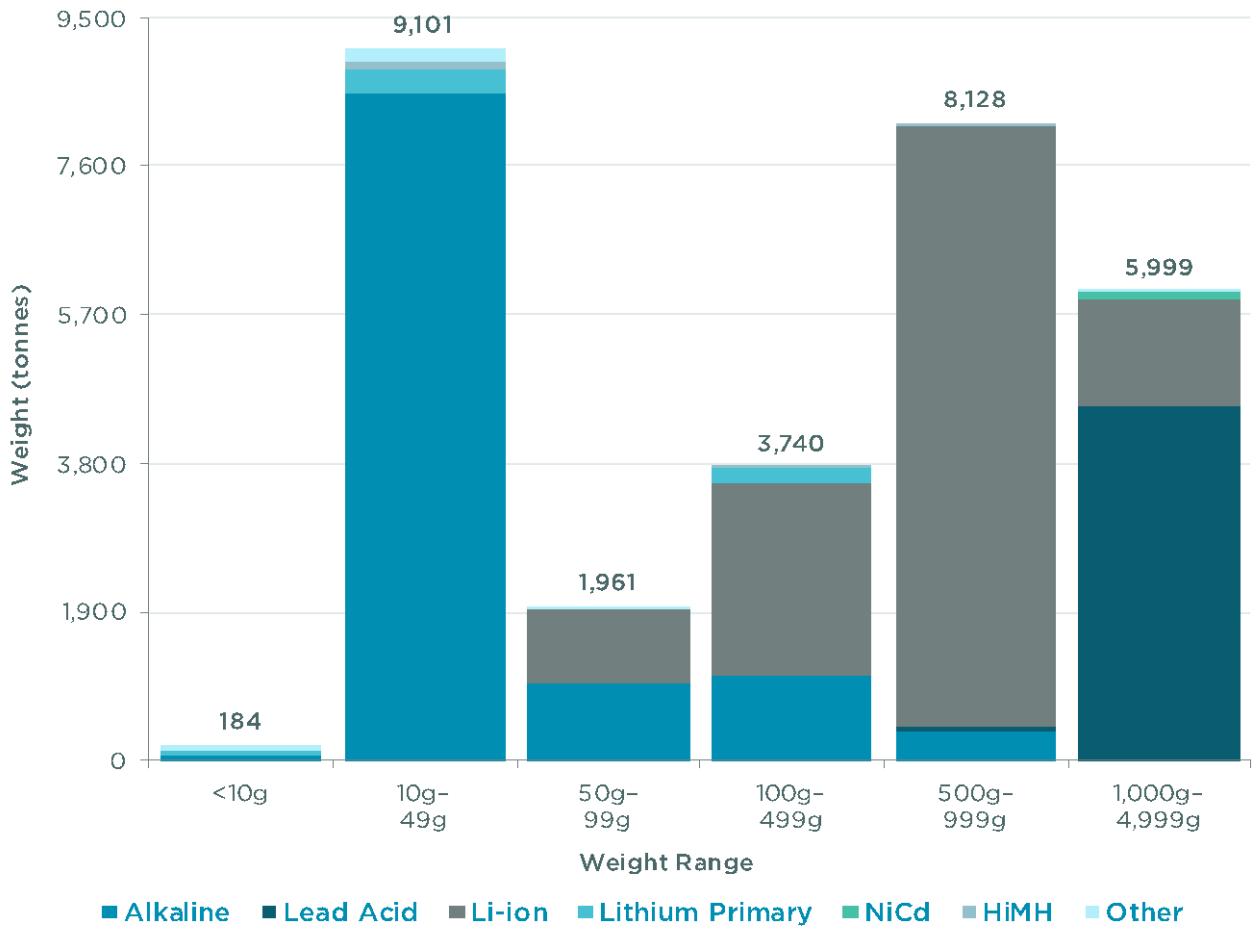
Size or Weight Range	Typical Battery Types	Sales	
		Weight (tonnes)	Number ('000)
<10g	Buttons cell	180	107,220
10g–49g	AA cell, AAA cell	9,100	550,090
50g–99g	C cell, 9-volt battery, mobile phone battery	1,960	37,580
100g–499g	D cell, laptop battery, tablet battery	3,740	19,060
500g–999g	6-volt lantern battery, power tool battery	8,130	12,380
1,000g–4,999g	General purpose SSLAB, e-bicycle Lithium-ion battery	6,000	2,170
5kg–10kg	General purpose SSLAB, e-bicycle Lithium-ion battery	6,170	770
>10kg–50kg	SLI automotive battery	154,980	8,170
>50kg–100kg	Industrial Lead Acid battery, residential and commercial BESS battery	6,800	100
>100kg	Industrial Lead Acid battery, EV battery system	11,260	30
Total		208,320	737,570

Figure 25. Total battery sales by weight range (2021)[29]

[29] SSLAB = Small, Sealed Lead Acid Batteries; SLI = Starting, Lighting and Ignition; BESS = Battery Energy Storage System.

Figure 26 shows battery sales by weight range shared by common battery chemistries. The Alkaline chemistry represents more the 90% of all 10g–49g batteries at 8,500 tonnes. Lithium-ion chemistry represents 95% of all 500g–999g batteries at 7,690 tonnes.

Figure 26. Handheld under 5kg battery sales by chemistry group, and by weight range (2021)



3.4.5 Battery sales by single use or rechargeable in 2021

A total of 11,830 tonnes of batteries were sold for single use applications, shown in Table 14. The applications demanding the largest share of single use battery chemistries (e.g. Alkaline, Lithium Primary) are consumer electronics, toys, and torches. Compare this to rechargeable applications and the tonnages are much higher at 196,510 tonnes in total.

Demand for Rechargeable batteries (refer to Table 15) is driven predominantly by vehicle applications requiring SLI batteries at 130,180 tonnes. SES and power tools also drive demand for Rechargeable batteries in both Lead Acid and Lithium-ion chemistries at 34,850 tonnes and 7,820 tonnes respectively. Rechargeable batteries make up 95% of all battery sales in 2021 by weight, with single use battery sales at 5% of battery sales by weight.

Table 14. Single use battery sales by chemistry group and application area (2021)

Application Area	Single Use (tonnes)					
	Alkaline	Lithium Primary	Silver Oxide	Zinc Air	Other	Total
Consumer Electronics	10,010	580	3	18	0	10,611
Torches, Lanterns	440	0	0	0	0	440
Power Tools	0	0	0	0	0	0
Toys	560	0	0	0	0	560
Personal Mobility	0	0	0	0	0	0
BESS	0	0	0	0	0	0
Emergency and Standby	0	0	0	0	0	0
Vehicles (EV)	0	0	0	0	0	0
Vehicles (SLI)	0	0	0	0	0	0
Other	0	0	0	0	0	0
Unknown	0	0	0	0	220	220
Total	11,010	580	3	18	220	11,831

Table 15. Rechargeable battery sales by chemistry group and application area (2021)

Application Area	Single Use (tonnes)				
	Lead Acid	Lithium-ion	Nickel Cadmium	Nickel Metal Hydride	Total
Consumer Electronics	0	3,300	0	100	3,400
Torches, Lanterns	0	0	0	0	0
Power Tools	0	7,810	0	0	7,810
Toys	160	180	0	0	340
Personal Mobility	680	1,170	0	0	1,850
BESS	160	1,010	0	0	1,170
Emergency and Standby	34,660	70	120	0	34,850
Vehicles (EV)	30	13,040	0	10	13,080
Vehicles (SLI)	130,180	0	0	0	130,180
Other	3,820	0	0	0	3,820
Unknown	0	0	0	0	0
Total	169,690	26,590	120	110	196,510

1.1.2. Handheld under 5kg battery sales by level of integration in 2021

This section estimates sales of batteries that current fall within the scope of the B-cycle Scheme. The current scope of B-cycle includes batteries that are under 5kg, loose or stand-alone, or easily removed by the consumer. B-cycle does not include Lead Acid batteries or batteries already covered by other stewardship schemes, such as laptop or mobile phone batteries, even if they fit under the under 5kg category.

Batteries that can be removed from battery powered devices by consumers were taken to one of 1,000 battery collection points around Australia in 2021 (BSC, 2022). Batteries within the scope of B-cycle have been estimated by creating a breakdown of batteries under 5kg by 'level of embeddedness' or 'removability'[30] represented in Table 16 on the following page. B-cycle in-scope batteries feature are highlighted with a bright green border.

For those batteries we consider within the scope of B-cycle, the following can be observed.

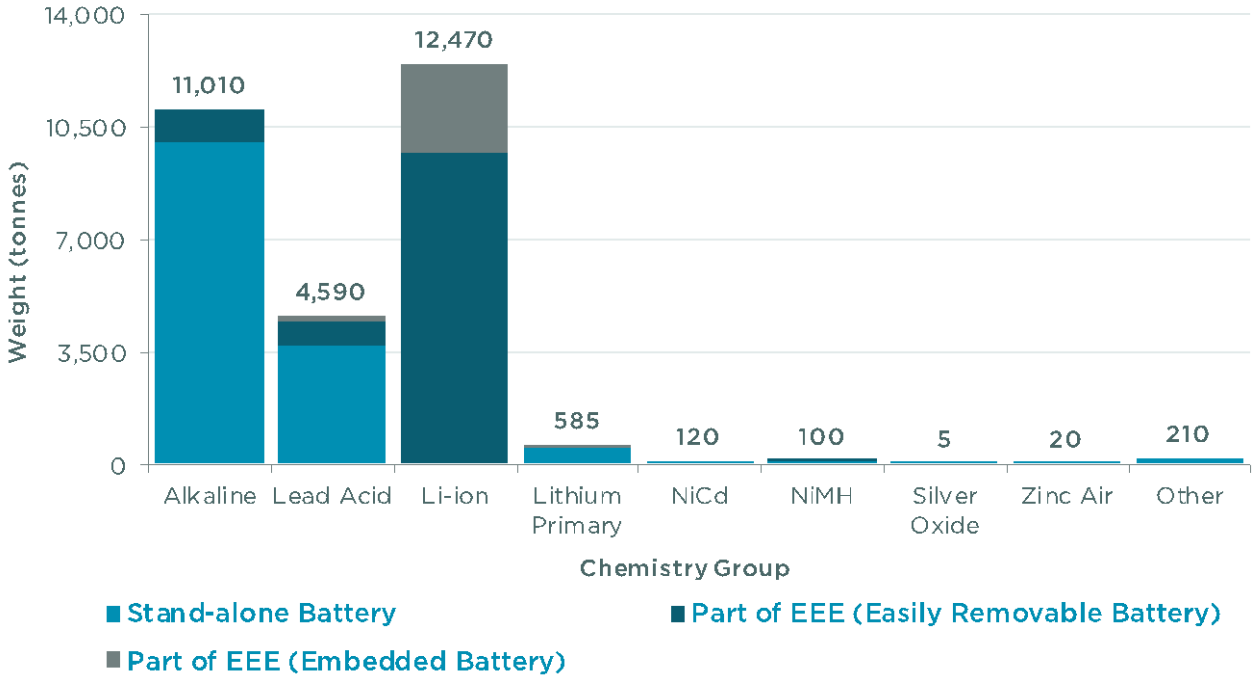
- A total of 21,785 tonnes of batteries under 5kg are within the current scope of the B-cycle Scheme. This represents 75% of all batteries under 5kg.
- Alkaline batteries represent the largest share of battery sales at 11,010 tonnes (50% of sales).
- Lithium-ion batteries represent the second largest share of batteries within this scope at 9,750 tonnes (45% of sales).

[30] Embeddedness describes the degree to which a battery can be easily removed from an electronic device. 'Embedded batteries' are not easily removed by the consumer and require specialist care or skills to remove the battery. 'Easily removable batteries' can be removed by the consumer either by hand or with a simple tool such as a screwdriver.

Table 16. Handheld under 5kg battery sales by level of integration and chemistry group (2021)[31]

Chemistry Group	Battery Sales (Handheld <5kg)			Total
	Stand-alone	Part of EEE (easily removeable battery)	Part of EEE (embedded battery)	
Alkaline	10,010	1,000	0	11,010
Lithium-ion	0	9,750	2,720	12,470
Lithium Primary	560	10	15	585
Nickel Cadmium	120	0	0	120
Nickel Metal Hybrid	90	10	0	100
Silver Oxide	5	0	0	5
Zinc Air	20	0	0	20
Other	210	0	0	210
Lead Acid	3690	740	160	4 590
Total (All Batteries <5kg)	**14,705**	**11,510**	**2,895**	**29,110**
Total (B-cycle Scope)	**11,015**	**10,770**	**0**	**21,785**

Figure 27. Handheld under 5kg battery sales by level of integration and chemistry group (2021)



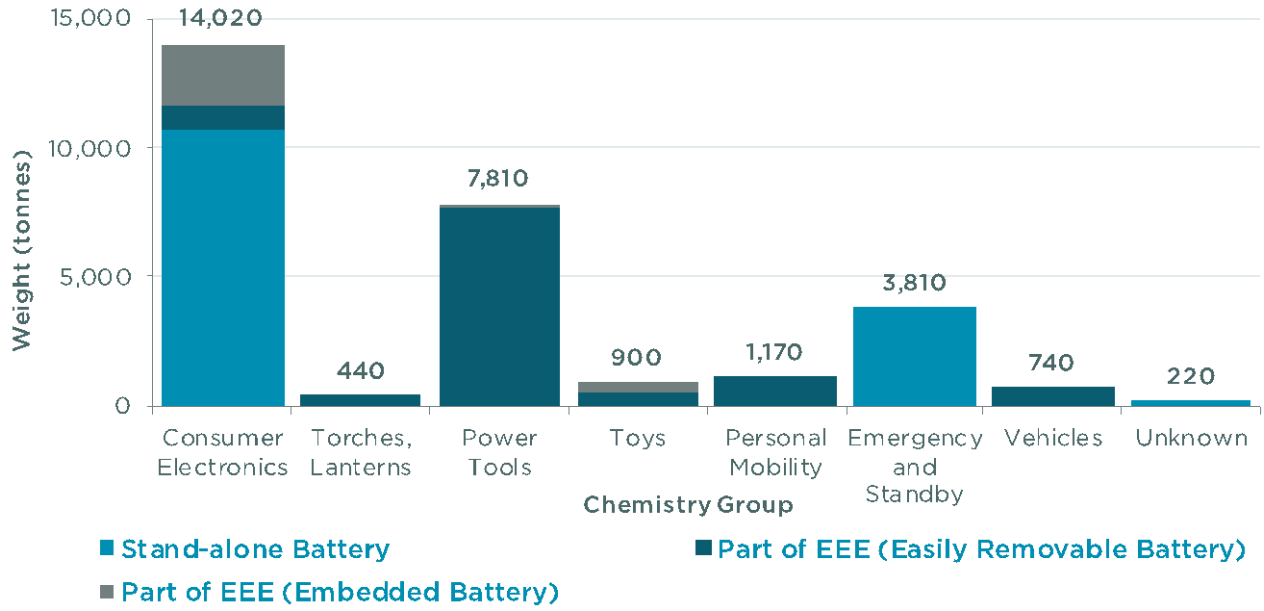
[31] Batteries considered to be within the B-cycle scope are highlighted with a bright green border.

By application area, most Stand-alone batteries (Table 17 and Figure 28), and easily removeable batteries under 5kg were consumer electronics batteries with 11,595 tonnes of total batteries sold. Power tools and gardening equipment also contributed a significant share with 7,680 tonnes of batteries sold in 2021. As shown in Figure 28, there are some Stand-alone Handheld batteries used for SES, most of these are Lead Acid.

Table 17. Handheld under 5kg battery sales by level of integration and application area (2021)

Application Area	Battery Sales (Handheld <5kg)			Total (tonnes)
	Stand-alone Battery (tonnes)	Part Of EEE (Easily Removable Battery) (tonnes)	Part Of EEE (Embedded Battery) (tonnes)	
Consumer Electronics	10,675	920	2,425	14,020
Torches, Lanterns	0	440	0	440
Power Tools	0	7,680	130	7,810
Toys	0	560	340	900
Personal Mobility	0	1,170	0	1,170
Emergency and Standby	3,810	0	0	3,810
Vehicles	0	740	0	740
Unknown	220	0	0	220
Total	14,705	11,510	2,895	29,110

Figure 28. Handheld under 5kg battery sales by level of integration and application area (2021)



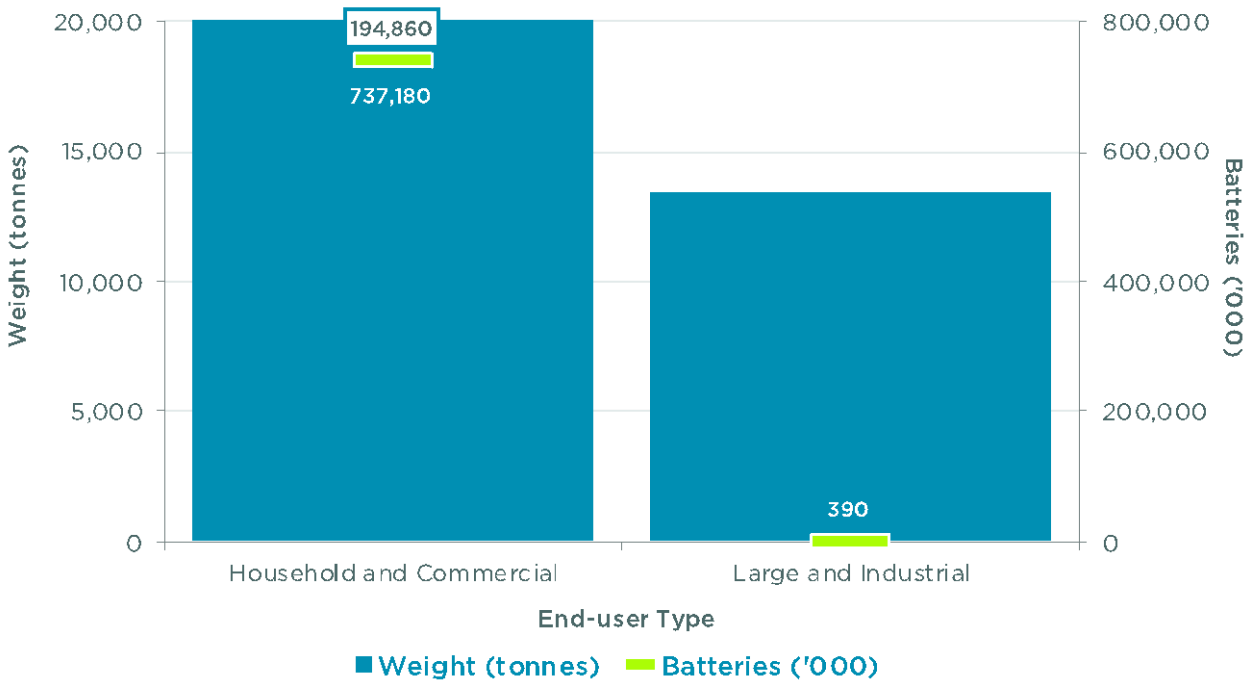
3.4.6 Battery sales by end-user type in 2021

Household and commercial batteries[32] represent 93% of all sales in weight and 99% in number of batteries sold, as shown in Table 18 and 0 below. Large and industrial batteries[33] represent a smaller number of battery sales at around 390,000 batteries, and just under 7% of batteries sold by weight.

Table 18. Total battery sales by end-user type (2021)

End-user Type	Sales	
	Weight (tonnes)	Number ('000)
Household and Commercial	194,860	737,180
Large and Industrial	13,460	390
Total	**208,320**	**737,570**

Figure 29. Total battery sales by end-user type (2021)



[32] The household and commercial category covers a range of product categories including consumer electronics, EVs and BESS for residential and commercial settings.

[33] Large and industrial batteries are those batteries used for industrial purposes, mostly for traction applications in warehouses and other industrial settings.

3.4.7 Battery sales by jurisdiction in 2021

The share of battery sales by state and territory is shown in Table 19 and Figure 30 below. The highest number of battery sales occurred in New South Wales at 31% of all sales and a total of 63,920 tonnes of batteries by weight. The next highest share of sales occurred in Victoria at 25%, closely followed by Queensland at 22% of all battery sales in 2021.

Table 19. Total battery sales by jurisdiction (2021)

Jurisdiction	Single Use		Rechargeable		Total	
	Weight (tonnes)	Number ('000)	Weight (tonnes)	Number ('000)	Weight (tonnes)	Number ('000)
Australian Capital Territory	210	12,080	3,370	970	**3,580**	**13,050**
New South Wales	3,750	216,820	60,170	17,350	**63,920**	**234,170**
Northern Territory	110	6,380	1,960	510	**2,070**	**6,890**
Queensland	2,400	138,390	44,460	11,400	**46,860**	**149,790**
South Australia	830	47,820	13,210	3,820	**14,040**	**51,640**
Tasmania	260	14,890	4,060	1,190	**4,320**	**16,080**
Victoria	3,030	174,810	48,510	13,930	**51,540**	**188,740**
Western Australia	1,240	71,450	20,750	5,760	**21,990**	**77,210**
Total	**11,830**	**682,640**	**196,490**	**54,930**	**208,320**	**737,570**

Figure 30. Total battery sales by jurisdiction (2021)

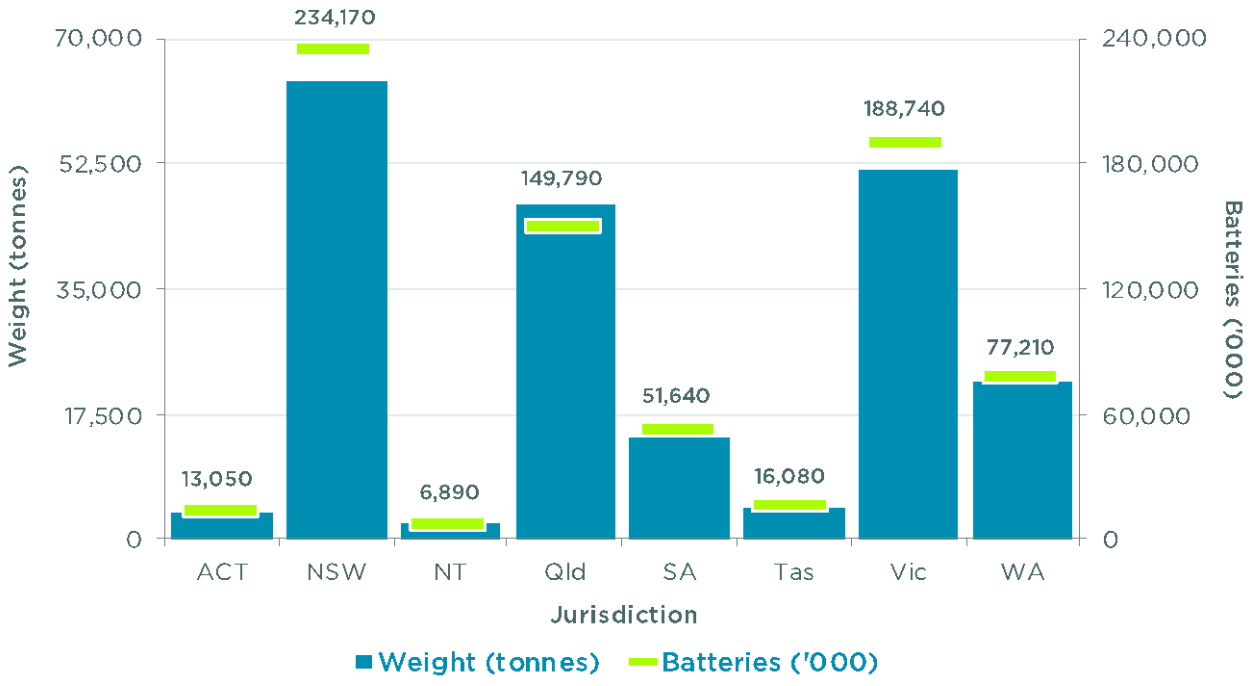
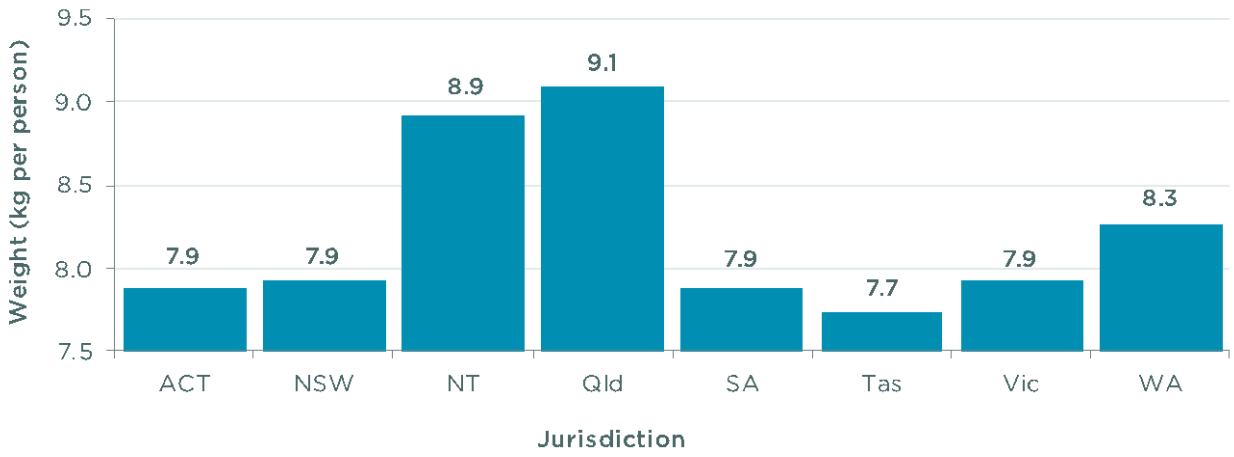


Figure 31 shows battery consumption per capita. Queensland has the highest battery sales per capita at just over 9kg per capita, followed by the Northern Territory. New South Wales, South Australia, and Victoria feature a very similar consumption rate at around 8kg per capita.

Figure 31. Total battery sales per capita (2021)



3.4.8 Major brand owners and distributors in 2020

The following information provides a breakdown of major brand owners in each application area, by single use and Rechargeable battery product specifications. Table 20 has been adapted from (Envisage Works, 2020) and includes further market participant information on e-bicycle, drone, e-scooter, BESS and EV product markets. It is estimated that the following brands represent 95% of the market share for each product category for the year 2021.

Table 20. Current major brand owners and distributors by product category (Envisage Works, 2020)

Application Area	Single Use Batteries	Rechargeable Batteries
Consumer Electronics	+ Energizer (Energizer / Eveready / Varta) + Duracell Company (Berkshire Hathaway Group) + IKEA + Panasonic (Panasonic) + Woolworths (Essentials) + Coles (Coles) + ALDI (Ultracell / Activ Energy) + Fuji (Fuji) Battery World (Battery World) + Others: Sony, Maxell, Rocket, Toshiba, Philips, GP and Kodak	+ Acer + Apple + Asus + Canon + Dell + Dyson + Hewlett Packard + Kogan + Lenovo + LG Electronics + Motorola + Nokia + Panasonic + Samsung + Sony + Toshiba + Others: Google, HTC, Fujitsu, Huawei Technologies, Mitsubishi, NEC, Nikon, Olympus, Uniden

Application Area	Single Use Batteries	Rechargeable Batteries
Torches, Lanterns	+ Arlec + Black Diamond + Cat Eye + Coleman + Duracell + Energizer (Energizer / Eveready / Dolphin) + LED Lenser + Maglite + Panasonic + Primus + Spinifex + Tactical + Tioga + Varta + Wild Country + Other: BBB, Blackburn, Blackfire, Coast, Cryo-Lite, Dune, Knog, Lezyne, Meteor, Moon, Planet Bike, and many other torch and lantern brand names	+ Arlec + Cat Eye + Coleman + LED Lenser + Primus + Spinifex + Varta + Wild Country + Other: Cryo-Lite, Knog, Lezyne, Moon, Planet Bike, and many other torch and lantern brand names
Power Tools and Gardening Equipment	+ N/A	+ Black & Decker + Bosch + DeWALT + Hitachi + Makita + Ozito + Panasonic + Positec (Rockwell / Worx) + Techtronic Industries / TTI (Milwaukee / AEG / Ryobi / Homelite) + Tooltechnic Systems (Australia) Pty Ltd (Festool / Fein) + Others: Wesco, Stihl, Husqvarna Group (Gardena), Briggs and Stratton (Victa), Ramset
Toys (Misc.)	+ Insufficient information (many brand owners and distributors)	
Toys (e-Scooters, Hoverboards, etc.)	+ N/A	+ Bluetran, e-Glide, Inmotion, Kaabo, Segway, VIVID (scooters and hoverboards) + Livall, Segway, Thousand, Unagi, Evolve (e-skateboard) + Mearth + Pedl + iScoot + Micro Scooters Australia + Razor Scooters

Application Area	Single Use Batteries	Rechargeable Batteries
Toys (Drones)	+ N/A	+ Aerodex + Autel robotics + DJI + Gladius + Kaiser Baas + Parrot + Pgytech + Ryze + Tello + Zero-X + Blade + Yuneec
Personal Mobility (General)	+ N/A	+ Century Yuasa Batteries (Century / Yuasa) + Federal Batteries (Federal) + Marshall Batteries (Exide) + MPower (Sonnenschein / Powerblock) + Premier Batteries (Premier) + Ramcar (Supercharge and Motolite Batteries)
Personal Mobility (e-Bicycles)	+ N/A	**Motor Brands** + Bafang + Bosch + Shimano + Specialized + Yamaha **Bicycle Brands** + Ezee + Focus + Gazelle + Giant + Lekker + Merida + Norco + Riese & Muller + Specialized + Tern + Trek + XDS

Application Area	Single Use Batteries	Rechargeable Batteries
Storage Emergency and Standby (including BESS)	+ N/A	+ Allgrid + Alpha + Ampetus + Aquion Battery Specialties Australia (Sonnenschein / Power-Sonic / CYB / SAFT / Eaton UPS) + BYD + CALB + Century Yuasa Batteries (Century / Yuasa) + Clevertronics (Clevertronics) + EcoUlt Enersys (PowerSafe / Genesis / Cyclon / Datasafe) + Enphase Federal Batteries (Federal) + GNB Sonnenschein + Kokam + LG Chem + Marshall Batteries (Exide) + MPower (Sonnenschein / Powerblock) + NeeoQube + Premier Batteries (Premier) + Panasonic + R&J Batteries (Fullriver) + Ramcar (Supercharge and Motolite Batteries) + Redback + Redflow + Samsung + SDI + SimpliPhi + Sonnen + Sony + Tesla + YHI Power (CSB / Vision / C&D / Neuton Power) + ZEN Energy

Application Area	Single Use Batteries	Rechargeable Batteries
Vehicles (EV and ICE)	+ N/A	+ Audi + Battery Specialties Australia (Sonnenschein / Power + Sonic / CYB / SAFT / Eaton UPS) + Century Yuasa Batteries (Century / Yuasa) + BMW + Federal Batteries (Federal) + Fonzarelli + Hyundai + Jaguar + Kai + Marshall Batteries (Exide) + Mercedes + Mitsubishi + MG + MPower (Sonnenschein / Powerblock) + Nissan + Polestar + Porsche + Premier Batteries (Premier) + R&J Batteries (Fullriver) + Ramcar (Supercharge) + Tesla + YHI Power (CSB / Vision / C&D / Neuton Power) + Toyota + Volvo

3.5 Australian battery market sales projections

The following section estimates projections of battery sales to 2050 based on historic data and literature outlining market trends for key product categories.

3.5.1 Battery sales projections between 2021 and 2050

MFA modelling integrates historic data on total sales per year between 2013 and 2021 and then projects sales to 2050 based on available projections for individual product markets[34]. The result is a projection of sales by market segment, application area, and chemistry group, as shown in Figure 32, Figure 33, and Figure 34.

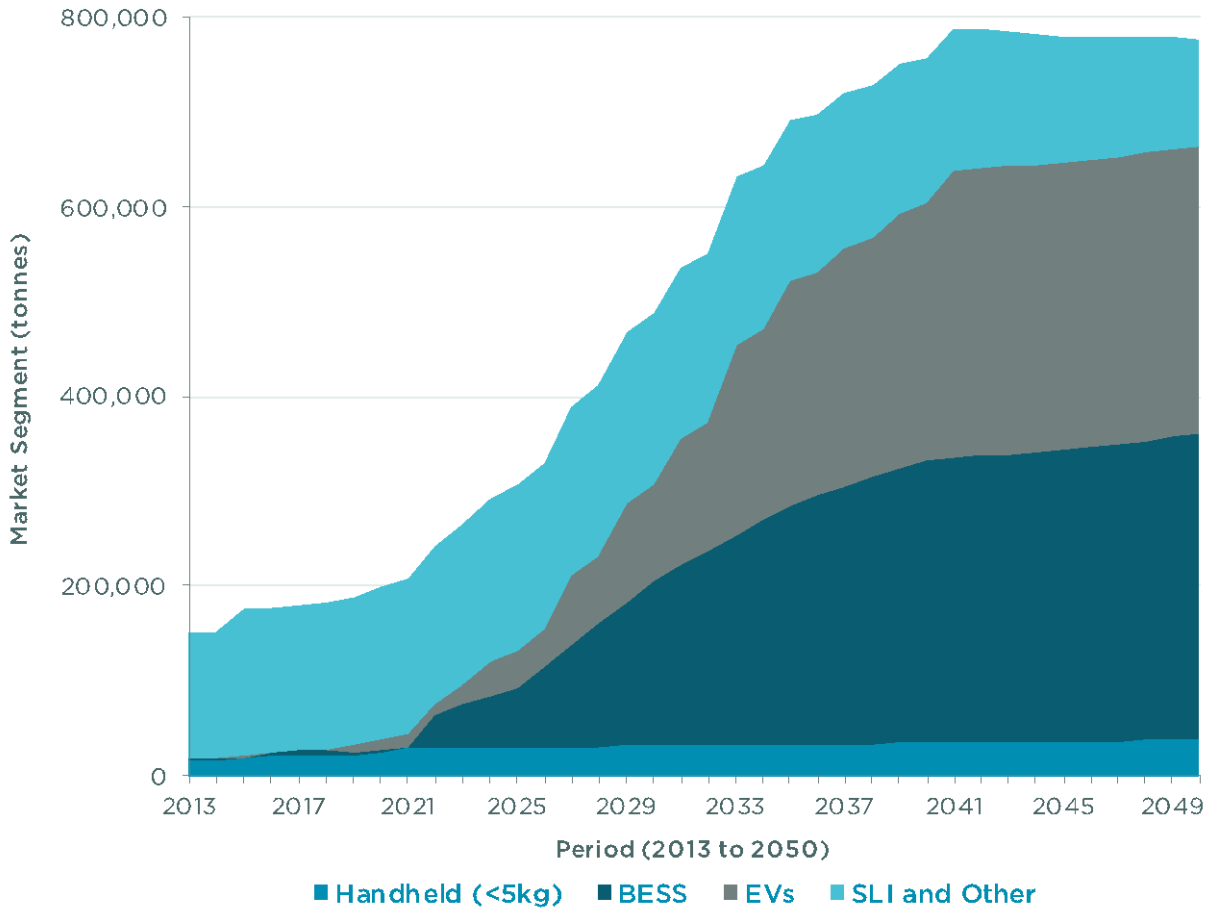
According to these results the following from MFA projections are observed.

+ The tonnage of Handheld batteries sold onto the Australian market has increased by around 33% between 2018 and 2021, with a much smaller year on year growth rate of 1%–2% projected until 2050.

[34] Sales projections for BESS and EV are estimated based projections in (Energeia, 2019), all other projections are based on population growth rate prorated to applications by market share growth.

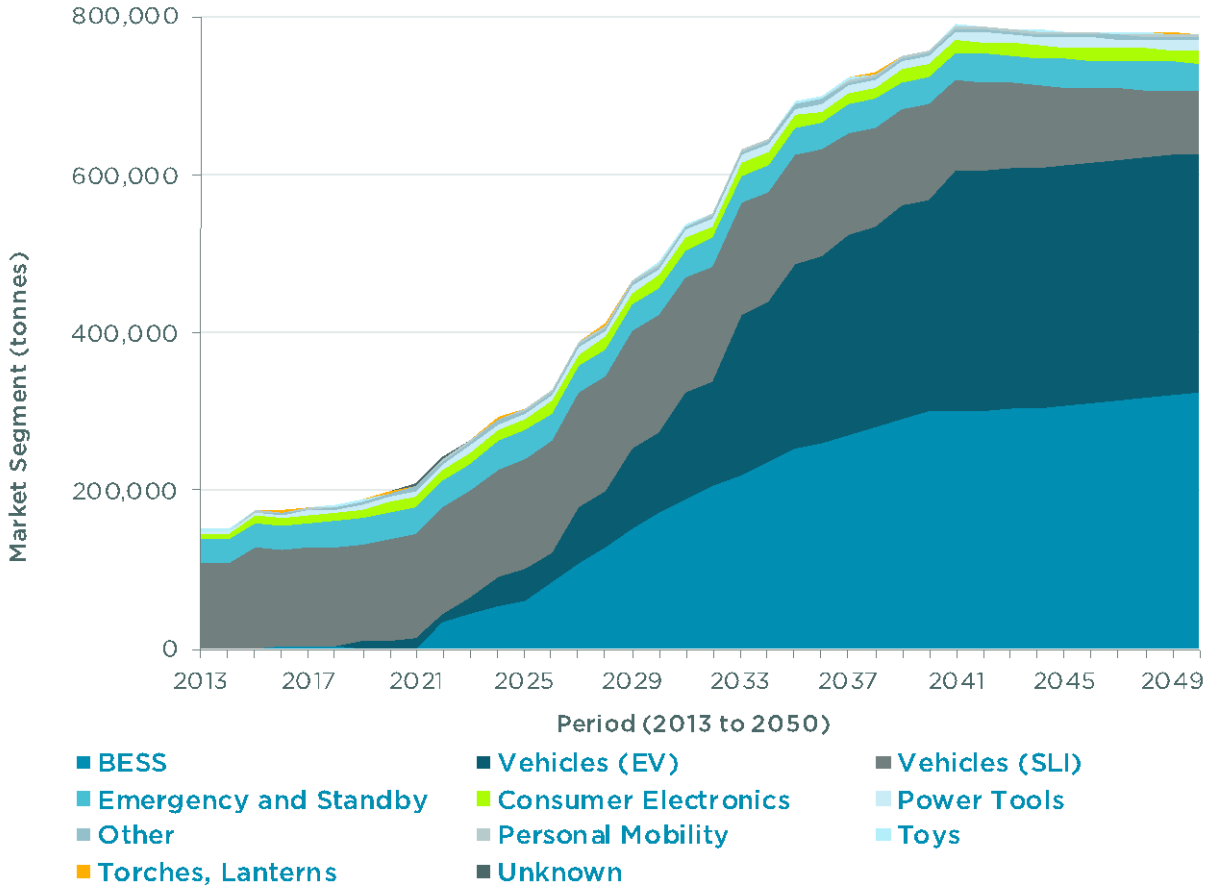
- The total tonnage of BESS and EV batteries sold is projected to grow between 10% and 40% year on year until 2030. A greater increase in BESS systems is expected between now and 2030 which reflects the considerable uptake of battery storage to support a growing portion of solar and wind in the Australian electricity mix.
- SLI battery sales only increase 1% year on year, peaking in 2030 and then start to decline in line with increased EV market share.
- Total battery sales are projected to reach 778,293 tonnes by 2050, as presented in Figure 32, Figure 33, and Figure 34. Projections have increased by around 25,000 tonnes from 2018 estimates due to a larger than expected increase in battery sales between 2018 and 2021.
- Demand for Lithium-ion batteries is projected to increase steeply between now and 2040, driven by large demand for this fast-charging chemistry with a long lifetime.

Figure 32. Battery sales projections from 2021 to 2050 by market segment (2013–2050)[35]



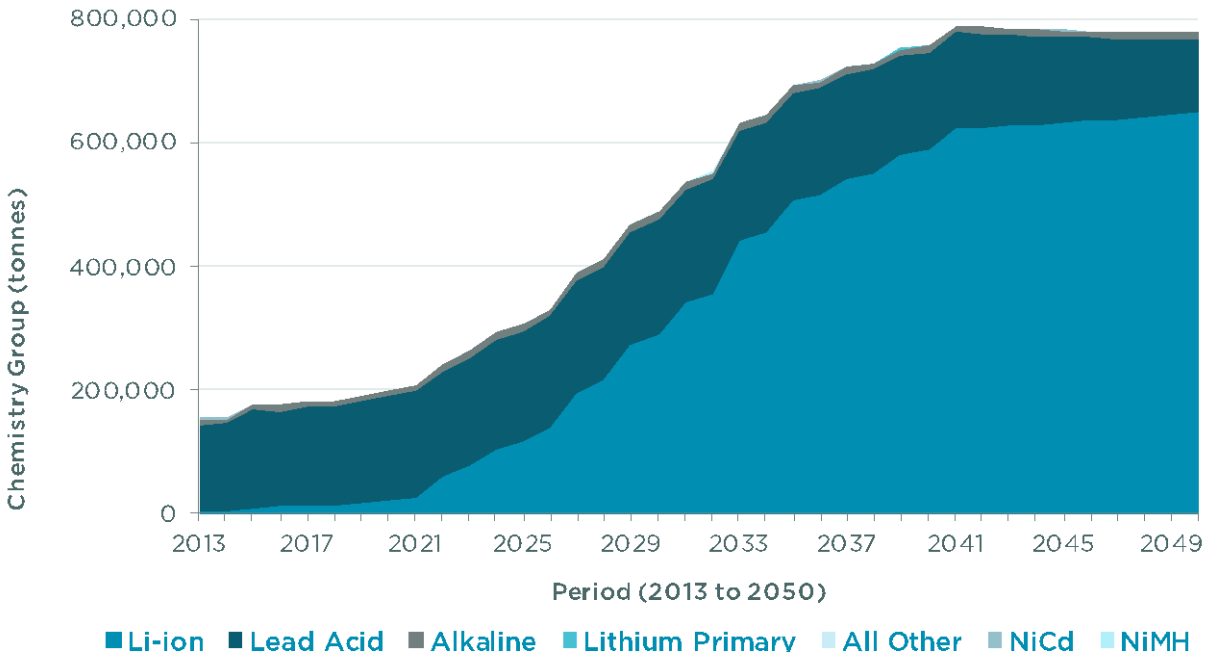
[35] Figure adapted from Envisage (2020).

Figure 33. Battery sales projections from 2021 to 2050 by application area (2013–2050)[36]



[36] Figure adapted from Envisage (2020).

Figure 34. Battery sales projections from 2021 to 2050 by chemistry group (2013–2050)[36]



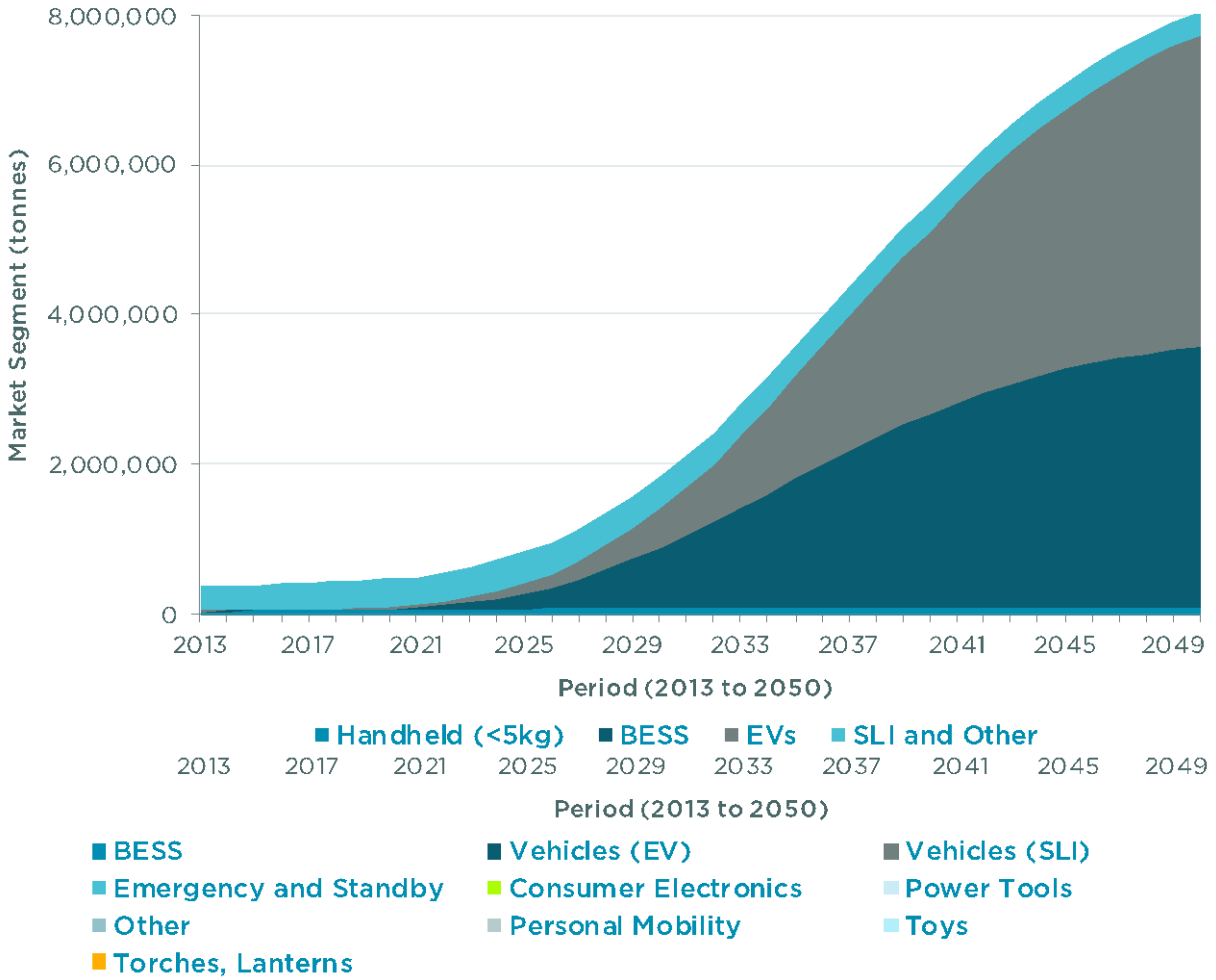
3.6 Australian battery usage analysis

3.6.1 Battery stocks projections between 2021 and 2050

Batteries held in stocks are those batteries in use in any given year between 2013 and 2050. Stocks are calculated based on battery sales and estimated cumulatively using technical information on battery lifetimes. The MFA calculates projections of batteries in use each year by market segment, application area and chemistry group, to 2050, and the results are presented in Figure 35, Figure 36, and Figure 37. Based on these projections, the following is estimated.

- Total battery stocks are projected to reach around 8 million tonnes of batteries by 2050.
- Stocks of EV batteries are projected to reach just over 600,000 tonnes in 2030 and just over 4 million tonnes by 2050.
- Stocks of BESS batteries are projected to reach around 800,000 tonnes in 2030, 3.4 million tonnes by 2050.
- Stocks of Handheld batteries are projected to reach just over 195,000 tonnes by 2030 and just over 260,000 tonnes by 2050.
- SLI batteries will stay relatively constant to 2030 reaching around 430,000 tonnes and then decline to just over 300,000 tonnes by 2050.

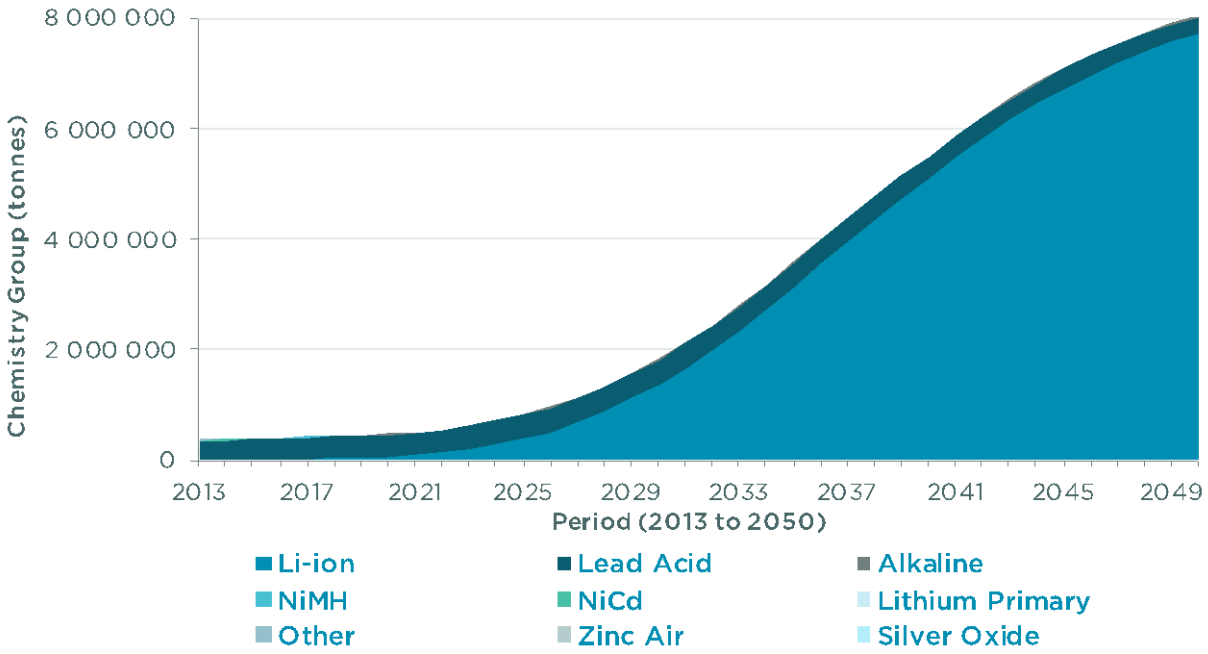
Figure 35. Battery stocks projections from 2021 to 2050 by market segment (2013–2050)[37]



[37] Figure adapted from Envisage (2020).

[38] Figure adapted from Envisage (2020).

Figure 37. Battery stocks projections from 2021 to 2050 by chemistry group (2013–2050)[38]



3.7 Australian battery sector EoL analysis

EoL arisings are estimated based on a combination of historic data on battery sales and technical information on battery lifetimes. This section presents EoL arisings in 2021, and projects EoL arisings by chemistry group, market segment, application area to 2050.

3.7.1 Total battery EoL arisings by chemistry group in 2021

Based on MFA modelling results the following is estimated for batteries reaching EoL in 2021 (refer to Table 21).

+ A total of 184,600 tonnes of batteries reached the EoL in 2021.
+ A total of 87% of batteries that reached EoL were Lead Acid batteries.
+ 6.7% of batteries EoL were Lithium-ion chemistries.
+ 5.5% of batteries reaching EoL were Alkaline chemistries.

Table 21. Total battery EoL arisings by chemistry group (2021)

Chemistry Group	EoL Arising (tonnes)
Alkaline	10,090
Lead Acid	160,510
Lithium-ion	8,250
Nickel Cadmium	450

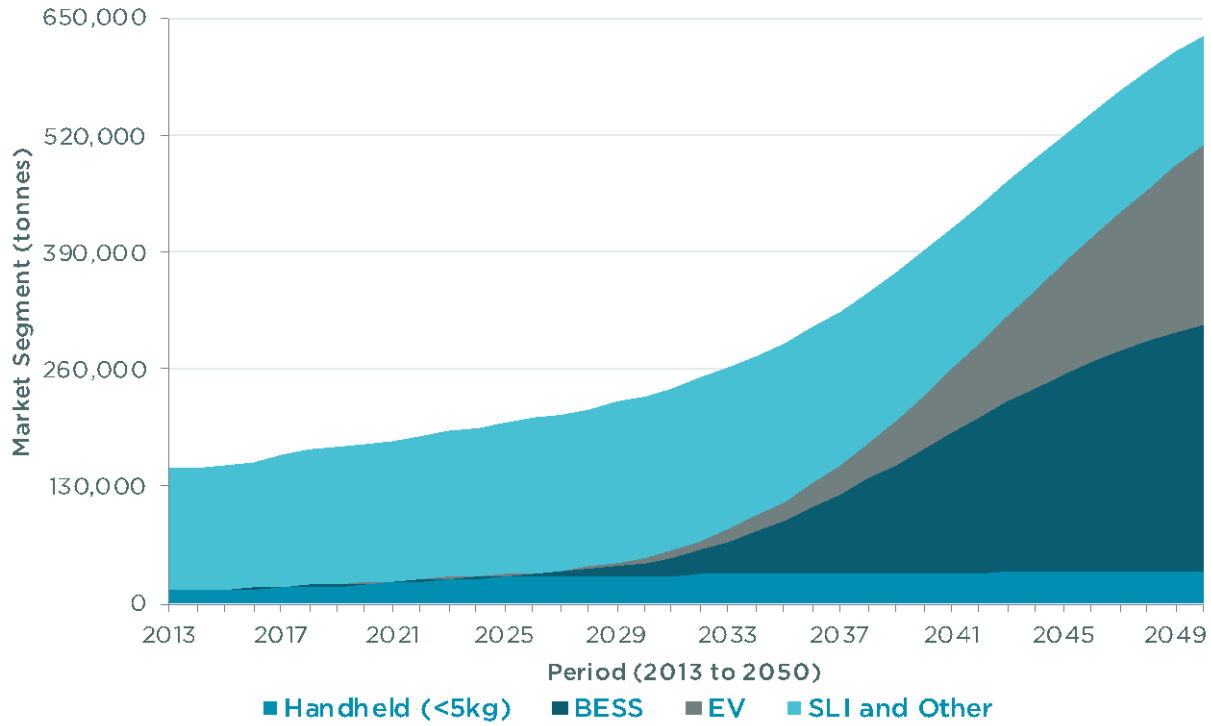
Nickel Metal Hydride	420
Other	590
Total	180,310

3.7.2 Projections of battery EoL arisings by market segment between 2021 and 2050

Figure 38 and Table 22 provide projections of EoL arisings to 2050 by market segment. Based on MFA results the following trends are observed:

- The dominance of Lithium-ion batteries in future sales projections results in this chemistry group contributing up to 80% of EoL arisings by 2050.
- Currently, Lead Acid batteries hold the market share for EoL arisings at just over 160,000 tonnes in 2021. However, as product markets such as BESS and EV start to increase their share of battery demand over the next decade, Lithium-ion EoL arisings will increase as these batteries reach EoL in 15 to 20 years.
- Handheld batteries experience an increase in batteries reaching EoL between 2021 and 2028 due to the increase in sales for this product category over the last three years.

Figure 38. Projections of battery EoL arising from 2021 to 2050 by market segment (2013–2050)[39]



[39] Figure adapted from Envisage (2020).

Table 22. Projections of battery EoL arising from 2021 to 2050 by market segment (2014–2050)

Year (5-year Periods)	Market Segment (tonnes)				Total
	Handheld (<5kg)	BESS	EV	SLI and Other	
2014–2015	14,820	990	130	136,000	151,940
2019–2020	21,120	1,180	390	153,490	176,180
2024–2025	28,670	2,110	1,250	168,720	200,750
2029–2030	30 ,880	14,820	5,500	179,380	230,580
2034–2035	32,280	59,980	20,780	176,280	289,320
2039–2040	33,550	138,390	58,310	160,920	391,170
2044–2045	34,920	218,660	123,070	142,110	518,760
2049–2050	36,250	273,580	198,990	121,900	630,720

3.7.3 Projections of total battery EoL arisings by application area between 2021 and 2050

Figure 39 and Table 23 show historic and projected EoL arisings by application area from 2013 to 2050. SLI batteries for ICE vehicles are projected to hold the market share until the early 2030s, when EVs start to contribute a larger share.

Figure 39. Projections of battery EoL arisings from 2021 to 2050 by application area (2013–2050)[40]

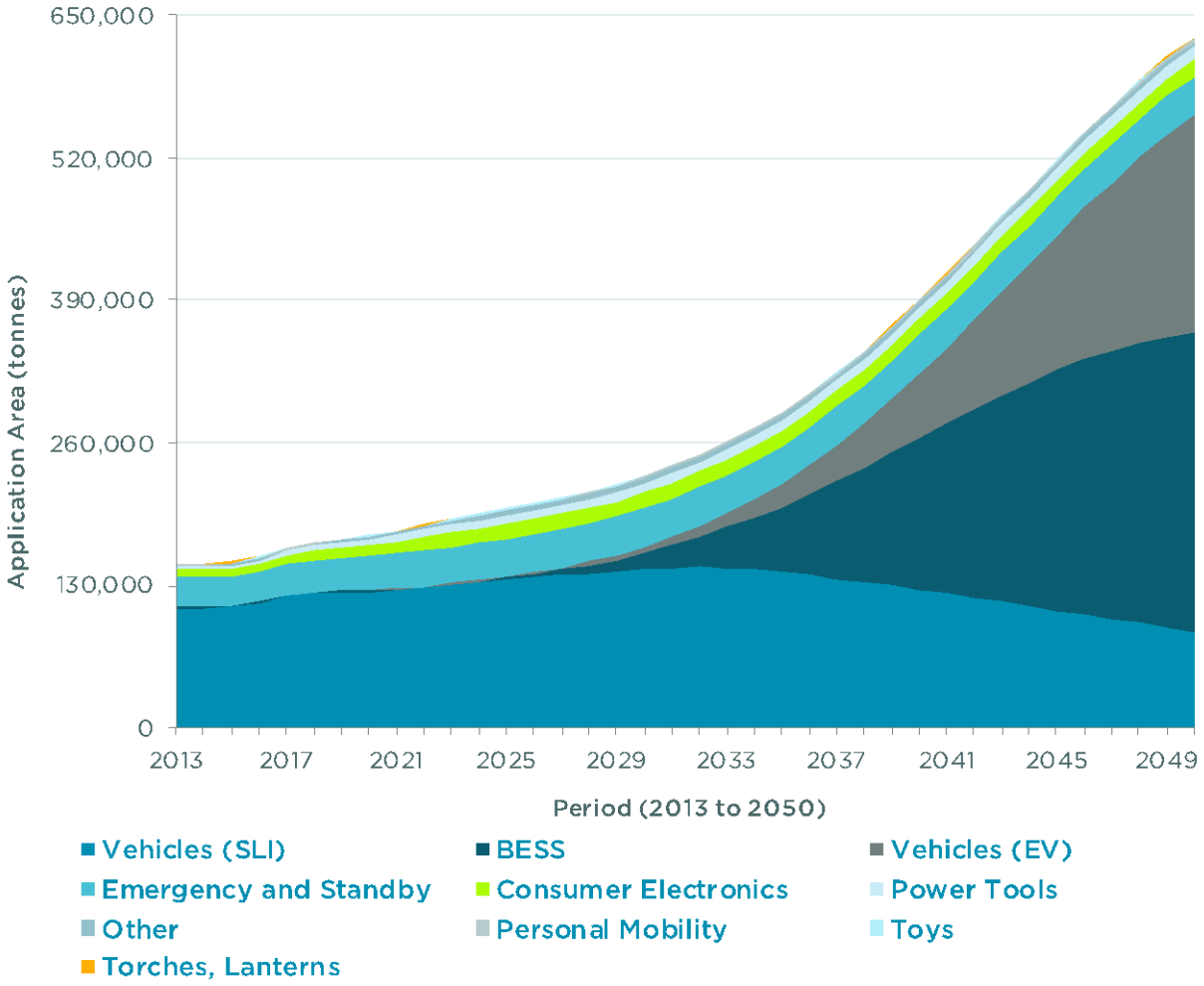


Table 23. Projections of total battery EoL arising from 2021 to 2050 by application area (2014–2050)

Year (5-year Periods)	Application Area (tonnes)										Total
	Consumer Electronics	Torches, Lanterns	Power Tools	Toys	Personal Mobility	BESS	SES	Vehicles (EV)	Vehicles (SLI)	Other / Unknown	
2014–15	7,060	450	1,940	730	630	990	27,690	130	109,840	1,670	151,130
2019–20	9,630	370	5,490	780	810	1,180	31,050	390	124,240	1,960	175,900
2024–25	13,420	440	8,010	880	1,570	2,110	34,500	1,250	134,700	3,650	200,530
2029–30	14,320	440	8,820	910	2,120	14,820	34,910	5,500	144,740	3,820	230,400
2034–35	14,690	440	9,630	920	2,460	59,980	34,820	20,780	141,630	3,820	289,170
2039–40	15,080	440	10,460	940	2,650	138,390	34,780	58,310	126,170	3,820	391,040
2044–45	15,510	440	11,350	960	2,820	218,660	34,780	123,070	107,250	3,820	518,660
2049–50	15,890	440	12,270	970	2,990	273,580	34,670	198,990	87,020	3,800	630,620

[40] Figure adapted from Envisage (2020).

1.1.3. Projections of total battery EoL arisings by chemistry group between 2021 and 2050

Figure 40 and Table 24 show historic and projected EoL arisings by battery chemistry group from 2013 to 2050. Lead Acid batteries dominate batteries reaching EoL until the late 2030s. Lithium-ion batteries increase their share of batteries reaching EoL dramatically between 2021 and 2050, this is due to their increasing market share across product groups using Rechargeable batteries.

Figure 40. Projections of total battery EoL arising from 2021 to 2050 by chemistry group (2013–2050)[41]

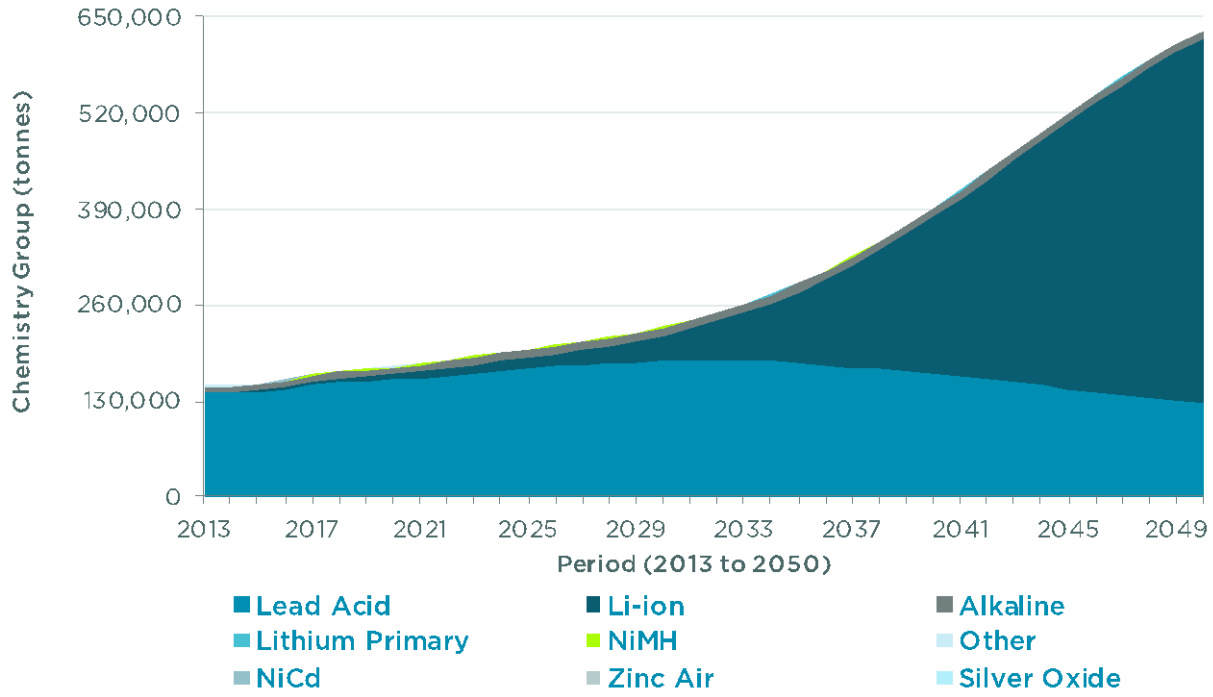


Table 24. Projections of total battery EoL arising from 2021 to 2050 by chemistry group (2014–2050)

Year (5-year Periods)	Battery Chemistry (tonnes)							Total
	Alkaline	Lead Acid	Lithium-ion	Lithium Primary	Nickel Cadmium	Nickel Metal Hydride	All Other	
2014–15	7,430	140,730	2,430	120	230	170	820	151,930
2019–20	8,820	158,700	7,390	160	440	370	300	176,180
2024–25	11,010	173,460	14,580	620	410	440	220	200,740
2029–30	11,010	184,080	33,990	670	250	380	200	230,580
2034–35	11,010	180,950	96,050	730	160	250	180	289,330
2039–40	11,010	165,490	213,430	790	130	150	160	391,160
2044–45	11,010	146,570	359,930	850	120	130	150	518,760
2049–50	10,930	126,220	492,270	920	120	130	140	630,730

[41] Figure adapted from Envisage (2020).

3.8 Australian battery collections and recycling sector

3.8.1 Total battery collection rate by chemistry group in 2021

The following breakdown of battery recycling provides an overview of all batteries recycled in Australia, this includes an estimated collection rate for Lead Acid batteries (which includes a large portion of Lead Acid batteries >5kg) and other batteries not currently within the scope of the B-cycle Scheme.

The following estimates have been provided based on a combination of information collected from B-cycle participants and information from the previous analysis by Envisage. Based on this information we have estimated the total battery recycling rate in Australia is estimated to be 87%. However, if Lead Acid batteries, which already have an established recycling market, are excluded from the analysis, the collection rate is much lower, sitting somewhere between 3% and 29% for those chemistries identified individually. Total battery collection rates are presented in Table 25, based on these results the following is observed.

- Nickel Metal Hydride batteries feature the highest collection rate at 29%.
- Alkaline batteries follow closely at 13%.
- Nickel Cadmium battery recycling rate is 9%.
- Lithium-ion features by far the lowest recycling rate at 3% of EoL arisings.
- Lead Acid batteries (which includes batteries >5kg and smaller batteries embedded in products) have a recycling rate of 96% due to the mature nature of the recycling market for this chemistry in Australia.

The last column presents data for collection of batteries that today falls in the scope of B-cycle Scheme. In exclusion of Lead Acid batteries, the collection of in-scope batteries in 2021 represented 58% of all collected batteries (1,258 out of 2,160 tonnes) and 5% of all batteries reaching their EoL (1,258 out of 24,090).

Table 25. Battery collection rates by chemistry group (2021)

Chemistry Group	EoL Arising (tonnes)	Collection Processing (tonnes)	Collection Rate (%)	In-scope Collection (tonnes)
Alkaline	10,090	1,300	13%	757
Lithium-ion	8,250	280	3%	163
Nickel Cadmium	450	40	9%	23
Nickel Metal Hydride	420	120	29%	70
Other[42]	590	420	71%	245
Lead Acid	160,510	153,850	96%	0
Total	**180,310**	**156,010**	**87%**	**1,258**

Figure 41. Battery collection rates by chemistry group excluding Lead Acid (2021)

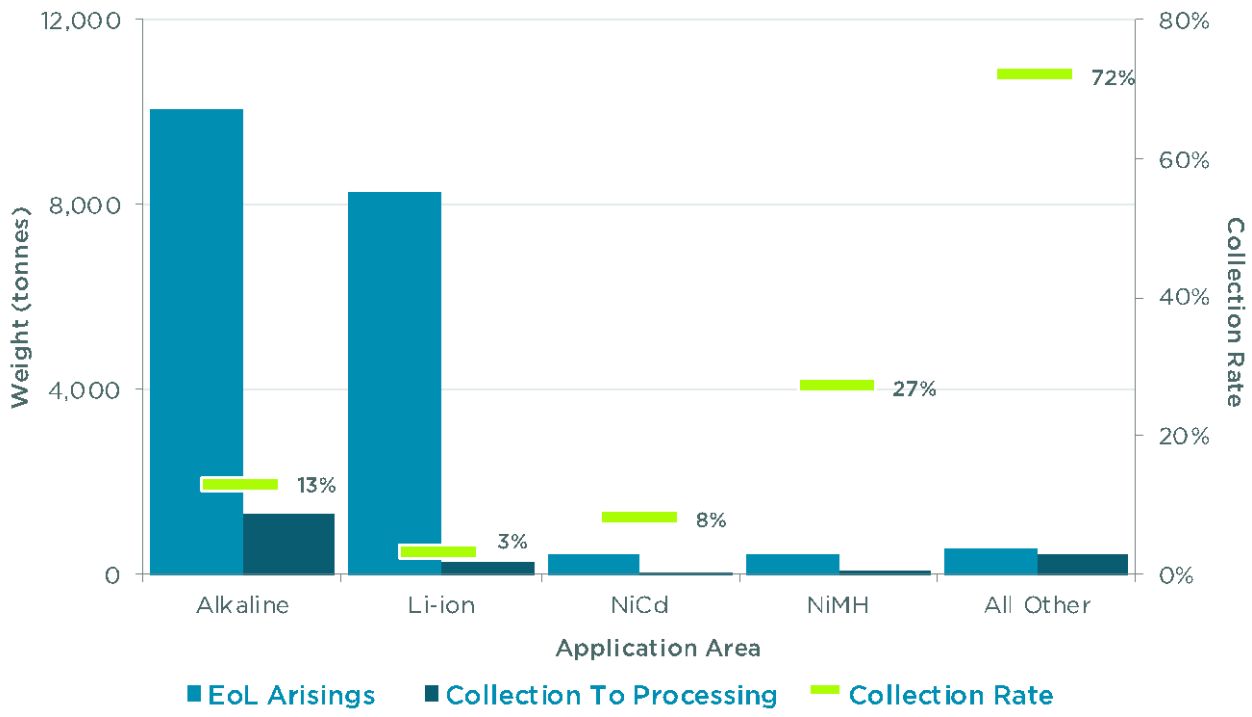


Table 26 and Figure 42 describe total battery collections by chemistry group and estimates of the remaining batteries are inferred to go to landfill. These batteries could also be stockpiled in homes and businesses around the country, however for this analysis it is assumed that batteries reaching EoL and not collected for recovery go to landfill.

[42] Other chemistries include a mixture of battery chemistries not able to be disaggregated for the purpose of this analysis.

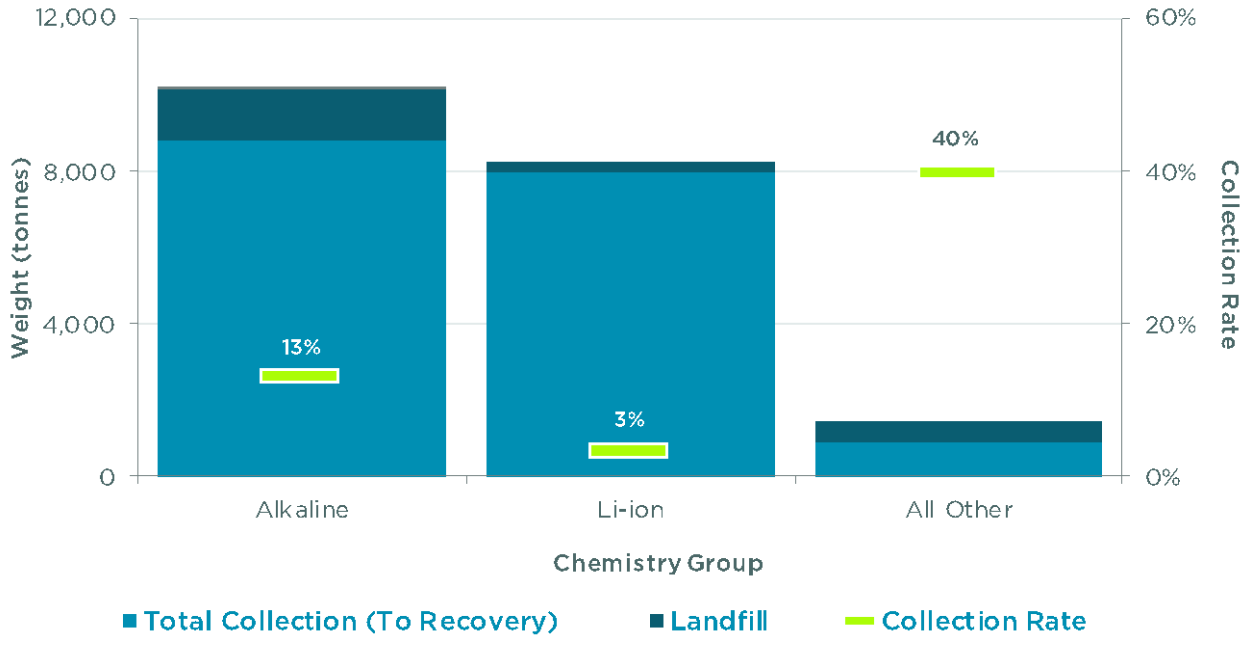
Based on MFA modelling, it is estimated that the largest share of batteries going to landfill are Alkaline batteries with a total of 8,790 tonnes, the next largest share is Lithium-ion batteries with a total of 7,970 batteries estimated to go to landfill. Lead Acid batteries have a high recycling rate but still have around 4% of batteries assumed to go to landfill.

The results presented in Table 26 below are also described in Figure 42 for all chemistries except Lead Acid.

Table 26. Total battery collection rate by chemistry group (2021)

(tonnes)	Total Collection (Recovery)	Landfill	Total	Collection Rate (%)
Alkaline	1,300	8,790	10,090	13%
Lead Acid	153,850	6,660	160,510	96%
Lithium-ion	280	7,970	8,250	3%
Other[42]	580	880	1,460	40%
Total	**156,010**	**24,300**	**180,310**	**87%**

Figure 42. Battery collection by chemistry group (2021)

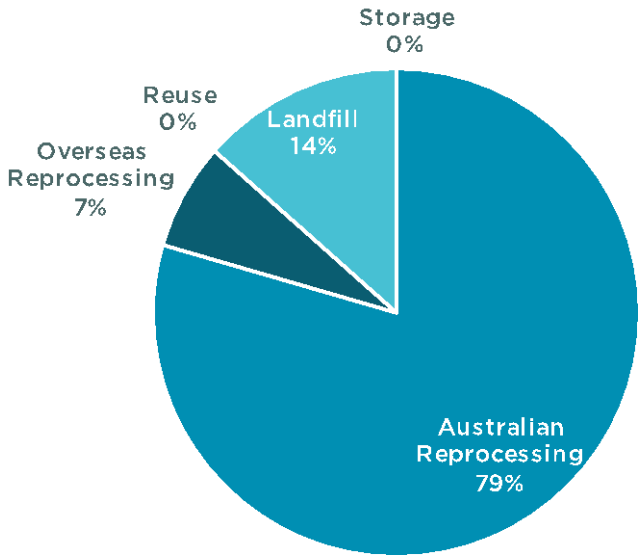


Based on the information provided by Australian battery recyclers a broad overview of battery fates in 2021 is provided in Figure 43.

+ A total of 79% of whole used batteries collected were directed to Australian materials markets and secondary processors.
+ As little as 7% of whole used batteries collected were exported to overseas materials markets.

+ It is inferred that the 14% of whole batteries reaching EoL and not recycled in 2021 went to landfill, this includes Lead Acid batteries.

Figure 43. Whole battery fates (2021)



3.8.2 Battery collection rate for batteries under 5kg in 2021

The following analysis gives a breakdown of batteries that have been collected and processed in Australia for the calendar year 2021. Lead Acid batteries larger than 5kg have been excluded from this analysis as they are assumed to be collected and recycled via mature and established Lead Acid recycling markets.

Surveys and interviews with Australian collectors and recyclers provided an overview of collection and recycling processes and these insights have been used to present recycling flows in Figure 45 below.

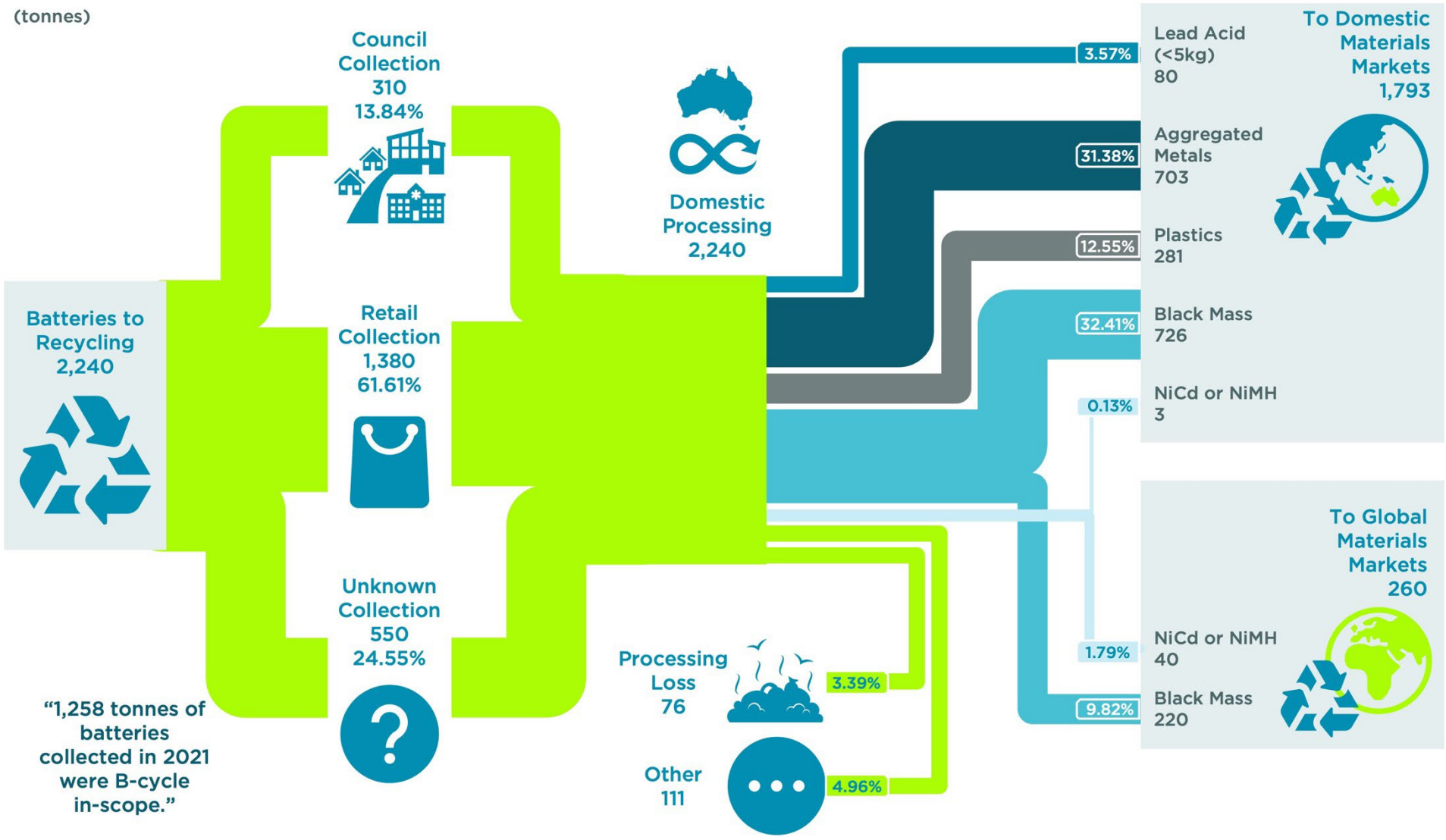
Batteries were collected from 1,000 collection points in states and territories around the country. Batteries were then sorted, shredded, and separated into key material groups including metals, plastics, and black mass for further downstream processing. Most of this material was sent to the domestic materials market, except for lithium black mass and some Nickel Metal Hydride and Nickel Cadmium batteries which were exported. Lead Acid batteries that do end up in this collection channel were sorted and then sent directly to domestic Lead Acid recyclers in Australia.

Key observations are made based on Australian battery recycling sector flows in 2021, identified in Figure 45.

+ A total of 1,258 tonnes of batteries that today is in the B-cycle Scheme scope were collected in Australia in 2021.

- A total of 60% of the batteries collected were dropped off at retail collection points. A total of 14% of batteries collected were dropped at a council collection point. A data gap exists on the remaining batteries collected as this detailed information was not provided by some collectors.
- 76% of batteries collected in Australia were mechanically shredded and the battery materials were supplied to domestic materials markets such as plastics recyclers, metal recyclers, and downstream material processers.
- A smaller amount, 11% of material recovered, was exported to global materials markets which includes black mass from Lithium-ion batteries and some Nickel Cadmium and Nickel Metal Hydride batteries.
- A total of 76 tonnes or around 3.5% of material recovered is lost during the recovery process and assumed to end up in landfill (domestic landfills).
- A total of 111 tonnes of material, almost 5% of processed material, was reported as other or out of scope material and is assumed to be made up of mixed battery chemistries and electronics waste. The fate of this material is not known.

Figure 44. Handheld under 5kg battery (excluding Lead Acid batteries) recycling fates (2021)[43]



[43] It is noted that these figures do not include collection figures for a significant portion of Lead Acid battery collection. However, a small portion of Lead Acid batteries find their way into this collection stream but predominantly, Lead Acid battery collections and recycling markets fall outside the focus of this analysis.

3.8.3 In-scope battery collection by chemistry group, and by collection route in 2021

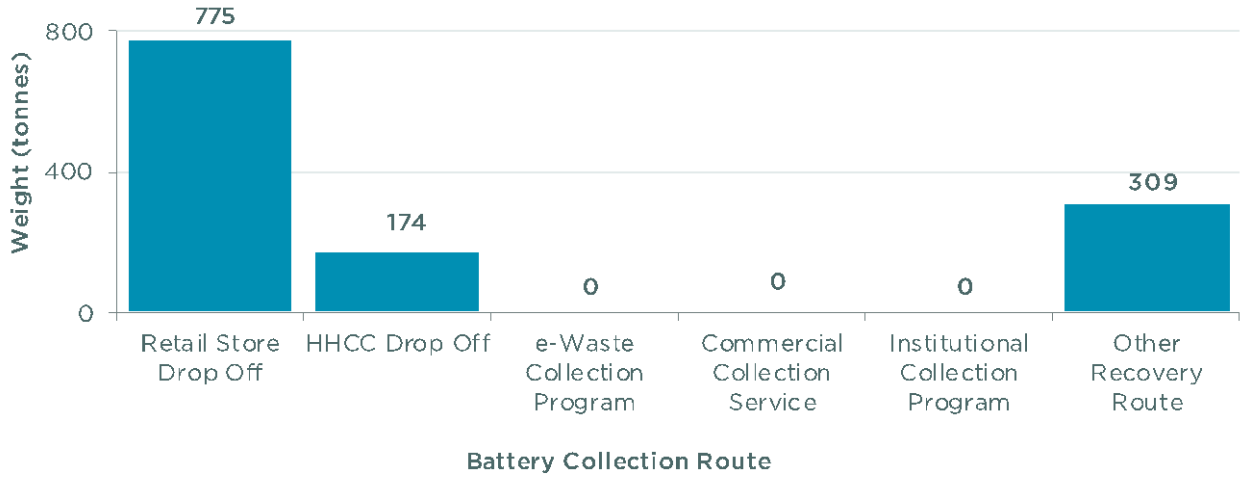
A percentage of collections are categorised as other recovery route as data was unavailable from some survey and interview participants on collections by collection point. Results on collections by collection route are presented in Table 27 and Figure 45.

A total of 309 tonnes of batteries have been categorised under 'Other Recovery Routes', however these battery collections are likely shared across the other collection routes. A total of 60% of batteries collected were from retail Drop Off points and a total of 14% of batteries collected were from council or state government managed Hazardous Household Chemical Collection (HHCC) program. It is noted that these figures do not include collections figures for a significant portion of Lead Acid battery collection, a small portion of Lead Acid batteries find their way into this collection stream but collections however, Lead Acid collections and recycling markets fall outside the focus of this analysis.

Table 27. Battery collection by collection route (2021)[44]

Collection Route	Total (tonnes)
Retail Store Drop Off	775
HHCC Drop Off	174
e-Waste Collection Program	Unknown
Commercial Collection Service	Unknown
Institutional Collection Program	Unknown
Other Recovery Route	309
Total	**1,258**

Figure 45. Battery collection by collection route (2021)



[44] HHCC = Hazardous household chemical collection, through a state or council government program. HHCC and e-Waste collections frequently occur at council or state government Drop Off points.

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Appendix A – Additional table data

Table 28. Battery sales by chemistry group and application area (2021)

Application Area (tonnes)	Battery Chemistry							Total
	Alkaline	Lead Acid	Lithium-ion	Lithium Primary	Nickel Cadmium	Nickel Metal Hydride	All Other	
Handheld (<5kg)								
Consumer Electronics	10,010	0	3,310	580	0	100	20	14,020
Torches, Lanterns	440	0	0	0	0	0	0	440
Power Tools	0	0	7,810	0	0	0	0	7,810
Toys	560	160	180	0	0	0	0	900
Personal Mobility	0	0	1,170	0	0	0	0	1,170
SES	0	3,690	0	0	120	0	0	3,810
Vehicles	0	740	0	0	0	0	0	740
Other	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	220	220
Total Handheld	**11,010**	**4,590**	**12,470**	**580**	**120**	**100**	**240**	**29,110**
BESS & EV								
Consumer Electronics	0	0	0	0	0	0	0	0
Torches, Lanterns	0	0	0	0	0	0	0	0
Power Tools	0	0	0	0	0	0	0	0
Toys	0	0	0	0	0	0	0	0
Personal Mobility	0	0	0	0	0	0	0	0
SES	0	160	1,010	0	0	0	0	1,170
Vehicles	0	40	13,030	0	0	10	0	13,080
Other	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0	0
Total BESS & EV	**0**	**200**	**14,040**	**0**	**0**	**10**	**0**	**14,250**
Lead acid (≥5kg)								
Consumer Electronics	0	0	0	0	0	0	0	0
Torches, Lanterns	0	0	0	0	0	0	0	0
Power Tools	0	0	0	0	0	0	0	0
Toys	0	0	0	0	0	0	0	0
Personal Mobility	0	680	0	0	0	0	0	680
SES	0	30,950	70	0	0	0	0	31,020
Vehicles	0	129,440	0	0	0	0	0	129,440
Other	0	3,820	0	0	0	0	0	3,820
Unknown	0	0	0	0	0	0	0	0
Total Lead Acid	**0**	**164,890**	**70**	**0**	**0**	**0**	**0**	**164,960**
Total	**11,010**	**169,680**	**26,580**	**580**	**120**	**110**	**240**	**208,320**

Table 29. Battery sales by application area, excluding Lead Acid – EBUs basis (2014–2050)

Year (5-year Periods)	Application Area (million EBUs)								Total
	Consumer Electronics	Torches, Lanterns	Power Tools and Gardening Equipment	Toys	Personal Mobility	Storage, Emergency and Standby	Vehicles	Other / Unknown	
2014–15	353	20	153	28	5	10	17	0	585
2019–20	506	17	270	27	40	41	452	0	1,353
2024–25	595	19	350	31	59	2,630	1,616	0	5,300
2029–30	610	19	385	32	75	7,225	4,214	0	12,559
2034–35	627	19	417	32	82	10,506	9,831	0	21,515
2039–40	645	19	453	33	89	12,475	11,236	0	24,950
2044–45	665	19	492	34	96	12,803	12,640	0	26,749
2049–50	686	19	534	35	105	13,460	12,640	0	27,478

Table 30. Battery sales projections by market segment (2014–2050)

Year (5-year Periods)	Market Segment (tonnes)			Total
	Handheld (<5kg)	BESS and EV	Lead Acid (>5kg)	
2014–15	18,660	1,550	156,480	176,690
2019–20	25,520	11,840	160,980	198,340
2024–25	30,260	101,820	173,690	305,770
2029–30	31,880	274,400	182,520	488,800
2034–35	33,140	487,990	170,660	691,790
2039–40	34,500	568,950	153,970	757,420
2044–45	35,960	610,530	134,210	780,700
2049–50	37,560	626,280	114,450	778,290

Table 31. Battery sales projections by application area (2014–2050)

Year (5-year Periods)	Application Area (tonnes)								Total
	Consumer Electronics	Torches, Lanterns	Power Tools and Gardening Equipment	Toys	Personal Mobility	Storage, Emergency and Standby	Vehicles	Other / Unknown	
2014–15	8,470	470	3,660	880	810	33,140	126,640	2,630	176,700
2019–20	12,140	400	6,490	800	1,630	34,970	137,930	3,980	198,340
2024–25	14,280	440	8,400	900	2,100	97,800	177,820	4,010	305,750
2029–30	14,650	440	9,230	920	2,490	208,050	249,030	3,980	488,790
2034–35	15,050	440	10,020	940	2,650	286,810	371,930	3,960	691,800
2039–40	15,480	440	10,870	960	2,810	334,070	388,840	3,930	757,400
2044–45	15,950	440	11,800	980	2,990	341,940	402,660	3,920	780,680
2049–50	16,470	440	12,810	1,000	3,190	357,700	382,780	3,900	778,290

Table 32. Battery sales projections by chemistry group (2014–2050)

Year (5-year Periods)	Battery Chemistry (tonnes)							Total
	Alkaline	Lead Acid	Lithium-ion	Lithium Primary	Nickel Cadmium	Nickel Metal Hydride	All Other	
2014–15	8,470	470	3,660	880	810	33,140	126,640	176,700
2019–20	12,140	400	6,490	800	1,630	34,970	137,930	198,340
2024–25	14,280	440	8,400	900	2,100	97,800	177,820	305,750
2029–30	14,650	440	9,230	920	2,490	208,050	249,030	488,790
2034–35	15,050	440	10,020	940	2,650	286,810	371,930	691,800
2039–40	15,480	440	10,870	960	2,810	334,070	388,840	757,400
2044–45	15,950	440	11,800	980	2,990	341,940	402,660	780,680
2049–50	16,470	440	12,810	1,000	3,190	357,700	382,780	778,290

Table 33. Battery stocks projections by market segment (2014–2050)

Year (5-year Periods)	Market Segment (tonnes)			Total
	Handheld (<5kg)	BESS and EV	Lead Acid (>5kg)	
2014–15	39,220	9,850	344,330	393,400
2019–20	57,630	38,810	378,780	475,220
2024–25	74,230	344,880	415,350	834,460
2029–30	79,600	1,321,030	434,290	1,834,920
2034–35	84,070	3,073,610	417,260	3,574,940
2039–40	88,620	5,024,080	384,720	5,497,420
2044–45	93,630	6,645,650	345,870	7,085,150
2049–50	99,300	7,629,820	306,820	8,035,940

Table 34. Battery stocks projections by application area (2014–2050)

Year (5-year Periods)	Application Area (tonnes)								Total
	Consumer Electronics	Torches, Lanterns	Power Tools and Gardening Equipment	Toys	Personal Mobility	Storage, Emergency and Standby	Vehicles	Other / Unknown	
2014–15	10,530	360	6,930	1,510	2,810	123,510	240,280	7,470	393,400
2019–20	19,250	300	14,130	1,840	4,810	146,120	277,590	11,190	475,230
2024–25	26,760	340	19,820	1,930	8,640	343,530	418,100	15,360	834,480
2029–30	29,070	340	21,750	2,020	10,530	948,580	807,220	15,410	1,834,920
2034–35	30,750	340	23,670	2,100	11,780	1,857,460	1,633,460	15,390	3,574,950
2039–40	32,680	340	25,690	2,180	12,590	2,732,490	2,676,080	15,370	5,497,420
2044–45	34,820	340	27,890	2,280	13,430	3,313,470	3,677,560	15,360	7,085,150
2049–50	37,250	340	30,330	2,390	14,350	3,625,710	4,310,210	15,360	8,035,940

Table 35. Battery stocks by chemistry group (2014–2050)

Year (5-year Periods)	Battery Chemistry (tonnes)							Total
	Alkaline	Lead Acid	Lithium-ion	Lithium Primary	Nickel Cadmium	Nickel Metal Hydride	All Other	
2014–15	5,970	362,670	13,120	80	5,470	5,520	560	393,390
2019–20	7,390	397,280	59,830	150	4,580	5,770	220	475,220
2024–25	8,390	432,590	385,700	470	2,980	4,160	180	834,470
2029–30	8,390	451,440	1,369,770	510	2,000	2,650	160	1,834,920
2034–35	8,390	434,290	3,128,170	550	1,660	1,730	140	3,574,930
2039–40	8,390	401,550	5,083,720	600	1,590	1,450	130	5,497,430
2044–45	8,390	362,460	6,710,490	650	1,580	1,460	120	7,085,150
2049–50	8,480	323,180	7,700,310	720	1,580	1,560	120	8,035,950

Appendix B – Battery chemistries, sizes and applications

Table 36. Battery chemistry group (Envisage Works, 2020)

Chemistry		Chemistry Group	Comments
Zinc Manganese Dioxide	Alkaline	Alkaline	+ Zinc metal anode, manganese dioxide and carbon cathode, and electrolyte of potassium hydroxide.
	Zinc Carbon	Alkaline	+ Zinc metal anode, manganese dioxide and carbon cathode, and electrolyte of zinc chloride and ammonium chloride. + Zinc.
	Zinc Chloride	Alkaline	+ Zinc metal anode, manganese dioxide and carbon cathode, and electrolyte of zinc chloride.
Lead Acid	Flooded	Lead Acid	+ Unsealed Lead Acid battery types.
	Sealed	Lead Acid	+ Sealed Lead Acid battery types include gel batteries and absorbed glass mat (AGM) batteries.
Lithium-ion	Unknown Specific Chemistry	Lithium-ion	+ Listing for Lithium-ion batteries where the specific chemistry is unknown.
Lithium Cobalt Oxide	$LiCoO_2$	Lithium-ion	+ Also known as Li- cobalt or LCA. + Applications include mobile phones, laptops, tablets cameras.
Lithium Iron Phosphate	$LiFePO_4$	Lithium-ion	+ Also known as lithium ferrous or lithium ferro phosphate (LFP). + Applications include BESSs (e.g. BYD, CALB and Sony), power tools, e-bicycles, EVs, medical applications.
Lithium Manganese Oxide	$LiMn2O_4$	Lithium-ion	+ Also known as Li-manganese, LMO or lithium manganese-spinel. + Applications include power tools, e e-bicycles,, EVs, medical devices, hobbies.
Lithium Nickel Cobalt Aluminium Oxide	$LiNCAO_2$	Lithium-ion	+ Also known as (lithium) nickel cobalt aluminium (NCA). + Applications include electric vehicles (EVs) and grid storage.

Chemistry		Chemistry Group	Comments
Lithium Nickel Manganese Cobalt Oxide	$LiNMCO_2$	Lithium-ion	+ Also known as (lithium) nickel manganese cobalt (NMC). + Applications include BESSs (e.g. LG Chem, Samsung and Tesla), power tools, e-bicycles, EVs (e.g. Tesla), medical applications.
Lithium-ion Polymer	LiPo	Lithium-ion	+ Lithium-ion battery chemistries with a polymer electrolyte. + Various applications including consumer electronics, EVs.
Lithium Titanate	$Li_4Ti_5O_{12}$	Lithium-ion	+ Also known as Li- titanate or LTO. + Applications include grid storage, EV, buses and ferries.
Lithium Iron Disulphide	$LiFeS_2$	Lithium Primary	+ Primary cell or battery. + Applications include AA and AAA cells for consumer products.
Lithium Manganese Dioxide	$LiMnO_2$	Lithium Primary	+ Primary cell or battery. + Applications include button cells for consumer products, defence applications.
Lithium Sulphur	Li-S	Lithium Primary	+ Emerging technology with rechargeable lithium metal anode.
Nickel Cadmium	Nickel Cadmium	Nickel Cadmium	
Nickel Metal Hydride	Nickel Metal Hybrid	Nickel Metal Hydride	
Silver Oxide	Ag_2O	Silver Oxide	
Zinc Air		Zinc Air	+ Zinc metal anode, oxygen cathode, and electrolyte of zinc chloride and ammonium chloride.

Table 37. Battery size categories and weight ranges (Envisage Works, 2020)

Size or Weight Range
AA
AAA
Button Cell
C
D
Lantern (6V)
9V
Laptop
Mobile Phone
Tablet
Power Tool
<10g
10g–49g
50g–99g
100g–499g
500g–999g
1,000g–4,999g
5kg–10kg
>10kg–50kg
>50kg–100kg
>100kg

Table 38. Battery applications by application area (Envisage Works, 2020)

Application Area	Primary Market Segment
Consumer Electronics	
Standard Single Use Applications	Handheld <5kg
Cameras	Handheld <5kg
Cordless Phones and Answering Machines	Handheld <5kg
Health, Hygiene and Wearable Devices	Handheld <5kg
Laptops	Handheld <5kg
Mobile Phones	Handheld <5kg
Remote Controls	Handheld <5kg
Tablets	Handheld <5kg
Watches and Calculators	Handheld <5kg
Other Consumer Electronic Devices	Handheld <5kg
Torches, Lanterns	
Torches, Lanterns	Handheld <5kg
Power Tools and Gardening Equipment	
Blowers, Vacuums, Trimmers, Garden Edgers and Similar	Handheld <5kg
Drills, Circular Saws, Sanders, Routers and Similar	Handheld <5kg
Lawn Mowers (Electric)	Handheld <5kg
Other Handheld Tools	Handheld <5kg
Toys	
Toys	Handheld <5kg
Video Game Consoles and Related	Handheld <5kg
Other Toys	Handheld <5kg
Personal Mobility	
e-Bicycles	Handheld <5kg
Power Wheelchairs	≥5 kg
Other Personal Mobility (e.g. Golf Buggies, Boating)	≥5 kg
Storage, Emergency and Standby	
BESSS (Residential)	BESS & EV
BESSS (Commercial and Utility)	BESS & EV
Emergency Lighting	Handheld <5kg
Fire and Burglar Alarms	Handheld <5kg
Street and Garden Lights	Handheld <5kg

Application Area	Primary Market Segment
Uninterruptible Power Supply (UPS)	≥5kg
Other Storage, Emergency and Standby	Lead Acid ≥5kg
Vehicles	
Engine Starting	Lead Acid ≥5kg
Electric Vehicles (Passenger)	BESS & EV
Electric Vehicles (Commercial)	BESS & EV
Other Traction Applications	Lead Acid ≥5kg
Other Application Area	
Outdoor Public Works	Lead Acid ≥5kg
Farming Applications	Lead Acid ≥5kg
Industrial Applications	Lead Acid ≥5kg
Mining Applications	Lead Acid ≥5kg
All Other Applications	Handheld <5kg

Table 39. Average battery weights by chemistry group (Envisage Works, 2020)

Battery Sizes or Weight Ranges	Average Battery Weights (g per battery)								
	Alkaline	Lead Acid	Lithium-ion	Lithium Primary	Nickel Cadmium	Nickel Metal Hydride	Silver Oxide	Zinc Air	Other
AA	20.5	0.0	15.0	15.0	16.7	25.8	0.0	0.0	18.6
AAA	10.6	0.0	0.0	7.5	9.5	10.0	0.0	0.0	9.4
Button Cell	2.1	0.0	0.0	2.7	2.7	0.0	0.9	0.5	1.8
C	59.1	0.0	0.0	42.0	71.0	66.0	0.0	0.0	59.5
D	125.7	0.0	0.0	83.9	101.0	73.0	0.0	0.0	95.9
Lantern (6V)	683.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	683.0
9V	44.8	0.0	0.0	35.4	0.0	31.0	0.0	0.0	37.1
Laptop	0.0	0.0	299.4	0.0	0.0	0.0	0.0	0.0	299.4
Mobile Phone	0.0	0.0	49.5	0.0	110.0	92.0	0.0	0.0	83.8
Tablet	0.0	0.0	125.0	0.0	0.0	0.0	0.0	0.0	125.0
Power Tool	0.0	0.0	604.6	0.0	577.0	150.0	0.0	0.0	443.9
<10g	6.4	0.0	5.0	0.0	0.0	0.0	0.0	0.0	5.7
10g–49g	30.0	0.0	43.3	13.8	29.5	29.5	0.0	0.0	29.2
50g–99g	0.0	0.0	62.0	0.0	75.0	74.5	0.0	0.0	70.5
100g–499g	201.0	325.0	167.9	0.0	300.0	263.0	0.0	0.0	251.4
500g–999g	0.0	712.0	531.6	0.0	577.0	577.0	0.0	0.0	599.4
1,000g–4,999g	0.0	2,710.6	3,000.0	2,999.5	2,560.7	0.0	0.0	0.0	2,817.7
5kg–10kg	0.0	8,055.0	7,500.0	0.0	7,522.2	0.0	0.0	0.0	7,692.4
>10kg–50kg	0.0	20,006.8	0.0	0.0	29,463.3	50,000.0	0.0	0.0	33,156.7
>50kg–100kg	0.0	63,125.0	90,912.9	0.0	63,875.0	75,000.0	0.0	0.0	73,228.2
>100kg	0.0	350,584.8	350,584.8	0.0	0.0	0.0	0.0	0.0	350,584.8

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BatteryStewardshipCouncil

B-cycle Battery Recycling

Battery Market Analysis

The latest market data for the battery industry in Australia

This technical report presents the findings from a benchmarking project commissioned by the Battery Stewardship Council (BSC), undertaken by the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS).

The new research considers the projected growth of the Australian battery market over the first half of the century outlining the entire lifecycle, from sales through to end of life. It confirms the rapid growth of the Australian battery market across all battery formats, particularly the dominance of lithium-ion batteries.

Although Australia's current share of battery recycling is small compared to the global scale, there is great potential to increase capacity to contribute to a circular battery supply chain and balance the demand on constrained regions.

Australian Government Accredited Product Stewardship Scheme

This Scheme is authorised by the Australian Competition & Consumer Commission (ACCC), accredited by the Australian Government, and has received financial support from the Australian Government and industry.