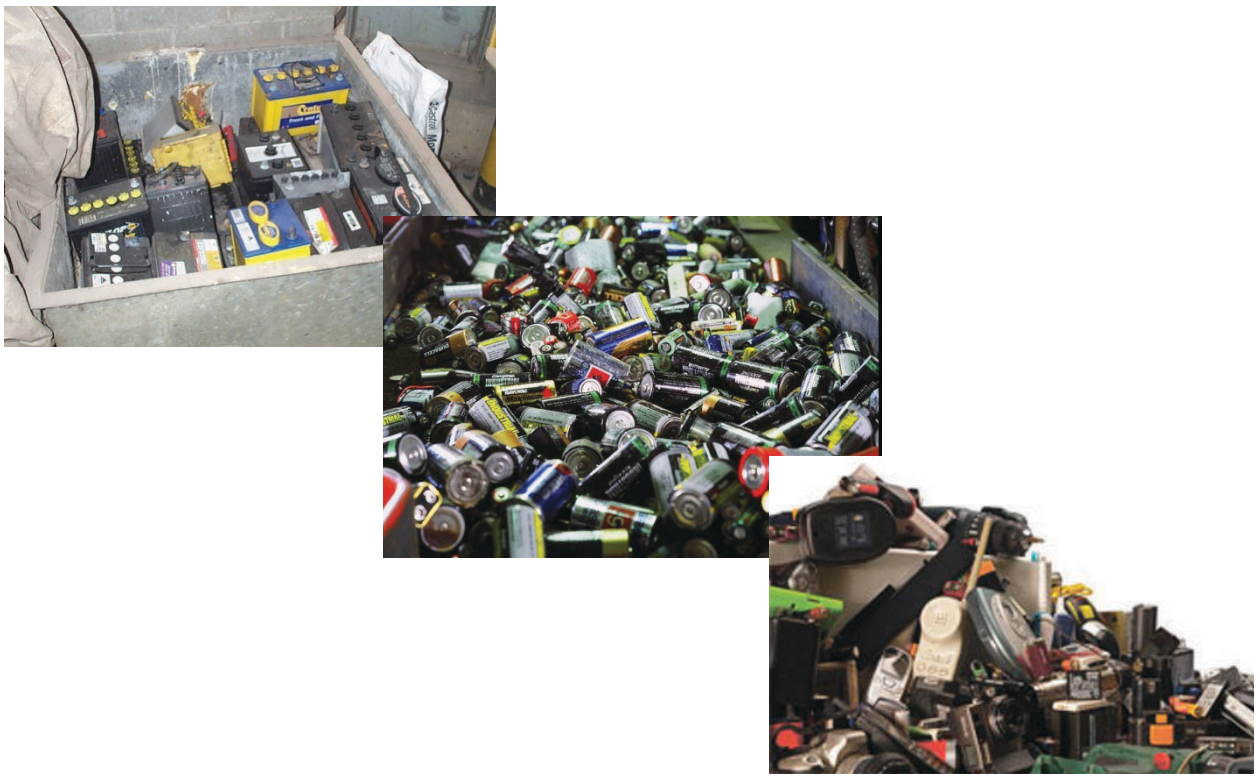
Analysis of Battery Consumption, Recycling and Disposal in Australia



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ANALYSIS OF BATTERY CONSUMPTION, RECYCLING AND DISPOSAL IN AUSTRALIA

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FOR

AUSTRALIAN BATTERY RECYCLING INITIATIVE
(ABRI)

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Front cover photos (top to bottom):

Photo 1 – Used Lead Acid Batteries (ULABs) separated at waste transfer station.

Photo 2 – mixed Handheld batteries for processing overseas - www.stewardship.gatech.edu/batteries.php

Photo 3 – many batteries are embedded in products like mobile phones, cordless power tools and other digital devices - http://www.resourcesmart.vic.gov.au/for_households/dropoff_points_3797.html

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EXECUTIVE SUMMARY

Batteries are integral to the functioning of our economy and support many aspects of modern lifestyles. They provide the portable power solution for mobile telecommunications, computers, construction tools, emerging electric vehicles and standby back up power in addition to many other solutions. However, we do not understand the magnitude of battery use from a mass flow perspective. For example, how many tonnes of batteries are there in active service within the economy? How quickly do they reach their end-of-life? What happens at their point of discard? What challenges do different chemistry types present? These questions need to be answered in ordered to understand the potential impacts of battery consumption and to develop solutions for resource recovery.

The Australian Battery Recycling Initiative (ABRI) is a not-for profit incorporated association of members who seek to maximise resource recovery from batteries. ABRI members also seek to achieve the highest resource order or value stemming from recovered materials. ABRI aims to stop batteries going to landfill, and is motivated by the economic value arising from the recovery and recycling of valuable and finite materials. As part of delivering ABRI's vision and mission, ABRI has commissioned this comprehensive and detailed assessment of the Australian battery market as an important step in developing a robust plan for battery stewardship implementation.

Battery Classification

Developing a classification system for batteries is important from a stewardship perspective. Systems are needed to channel certain types of batteries to their appropriate recycling option. The following hierarchy is suggested for a battery classification system in Australia:

- household and commercial, or large and industrial. There is a difference in battery chemistry and size between batteries that are used in household and office applications, and those used in heavy industrial applications for standby power and motive power. Collection systems will also need to be tailored to domestic and commercial sources, and industrial sources, with the former favouring drop off or small container delivery systems and the latter favouring individual site pick up
- technology/chemistry type. Materials of manufacture are critical determinants of recycling opportunities and also requirements. For example, Nickel Cadmium (NiCd) batteries are processed differently to Zinc Carbon battery types
- typical uses, for example embedded or stand alone. If a battery is embedded in another product, such as a television or video or mobile phone, then the recovery channel will need to deal with the bulk of the product mass before the battery is 'liberated' for recovery
- handheld (<1kg) or heavy (>1kg). This will be the primary determinant of the resource recovery channel in that heavy batteries are most likely to be found in industrial or automotive applications and are likely to require pick up
- single use or rechargeable. This factor is a primary determinant of the length of time a battery remains operational within the economy. Rechargeable batteries will go through many charge cycles and as such will outlast single use batteries in a given application. Thus the replacement rate (and hence the waste arising rate) is likely to be higher for single use batteries
- Customs and ABS codes. It is important to calibrate with existing systems of battery classification in Australia. For example Australian Customs Tariff Nomenclature and Statistical

Classification, and the Australian Bureau of Statistics (ABS) system for battery classification under the Australian and New Zealand Standard Commodity Classification (ANZSCC)

- hazardous. The hazardous nature of batteries needs to be clearly defined and articulated. For example, a NiCd mobile phone battery at its end-of-life is likely to be classified as hazardous, however this does not make the mobile phone or even the battery hazardous in its working life.

National Material Stocks and Flows of Batteries

Estimating the materials stocks and flows for all batteries in Australia is a complex task, given the differences in battery types, applications and channels to market. The methodology used in this study draws on information from a number of sources including Australian Bureau of Statistics, scientific literature, public reports, government (state, federal and international), battery manufacturers, ABRI Working Group, industry participants, and resource recovery companies.

Battery **inputs** are the consumption of batteries; **stocks** are those batteries in service within the economy; and **arisings** are batteries that have reached the end of their service life (or are unwanted for any other purpose) and require a resource recovery or waste management solution. In each table data is presented for a single year based on the most recently available data (the methodology is explained in detail in Chapter 2 and the Appendices). A breakdown of the estimated inputs, stocks and arisings of batteries in Australia by count is presented in the table below.

Table – Estimated Australian battery materials stocks and arisings by count*

Type	*Inputs*	*Stocks*	*Arisings*
Handheld	345,270,000	465,300,000	264,297,000
Automotive Starting Lighting and Ignition (SLI)	5,840,800	15,440,000	5,410,000
Large and Industrial	1,748,000	6,641,000	1,473,000
Total Units	**352,858,800**	**487,381,000**	**271,180,000**

* Information in the tables may not total due to rounding

A similar breakdown of the estimated inputs, stocks and flows (waste arisings) of batteries for Australia by weight is presented in the table below.

Table – Estimated Australian battery materials stocks and arisings by weight (kilograms)

Type	*Inputs*	*Stocks*	*Arisings*
Handheld	16,140,000	26,240,000	11,904,000
Automotive SLI	85,670,000	224,170,000	80,260,000
Large and Industrial	51,680,000	198,500,000	42,785,000
Total Weight (kilograms)	**153,490,000**	**448,910,000**	**134,949,000**

From this analysis it is estimated that approximately 350 million batteries are consumed annually in Australia, either as stand alone batteries or embedded in products such as mobile phones and automobiles. The majority of these batteries on a count basis (98 per cent) were 'Handheld' batteries, in other words, batteries less than 1 kg in weight. However, the weight of all battery inputs into Australia was more than 150 million kilograms (150,000 tonnes) and Handheld batteries were only approximately 10 per cent of this total.

The bulk by weight (nearly 90 per cent) is composed of Automotive Starting, Lighting and Ignition (SLI) batteries and Large and Industrial batteries, even though on a count basis they are only 2 per cent of inputs. This difference in proportion between weight and count is the primary reason that data is presented on both count and weight. Without information on both aspects of battery inputs, stocks and arisings, important challenges facing battery stewardship can be overlooked.

Handheld Battery Inputs

The nearly 350 million Handheld battery inputs comprise approximately 300 million batteries in 'stand alone' sales and 45 million batteries in embedded products. All Handheld batteries are imported as there is no local production of the original battery. Six main channels to the Handheld market for 'stand alone' sales were identified as part of this study. These include:

- grocery, for example Woolworths, Coles and independent supermarkets. This is the largest channel with an estimated 60 per cent of market share
- mass merchant, for example K-Mart, Big W, and Target with an estimated 10 per cent of the market
- hardware, for example Bunnings, Mitre 10, and Home Timber and Hardware with an estimated 10 per cent of the market
- electrical retail, for example, Harvey Norman, Dick Smith Power House and Tandy with an estimated 7.5 per cent of the market
- office supplies, for example Office Works, with an estimated 7.5 per cent of the market
- speciality stores and online sources with an estimated 5 per cent of the market.

Batteries embedded in products such as mobile phones account for a further 45 million batteries. A breakdown of Handheld battery inputs by size, count and weight is presented in the table below.

Table – Estimated Australian Handheld battery inputs by size, count and weight

Size	*Number of Batteries*	*Proportion Count*	*Average Weight (grams)*	*Total Weight (kg)*	*Proportion Weight*
AAA	98,505,000	29%	12.0	1,180,000	7%
AA	147,730,000	43%	24.0	3,545,000	22%
9v	24,629,000	7%	42.1	1,037,000	6%
C	16,423,000	5%	65.0	1,068,000	7%
D	16,423,000	5%	135.1	2,218,000	14%
Other Size	19,701,000	6%	6.1	120,000	1%
Lantern	4,939,000	1.4%	742.5	3,667,000	23%
Mobile	7,860,000	2.3%	21.2	167,000	1%
Digital Device	4,030,000	1.2%	21.3	86,000	0.5%
Laptop	1,460,000	0.4%	563.7	823,000	5%
Cordless Power Tools	1,750,000	0.5%	546.3	955,000	6%
Sealed Lead Acid	1,820,000	0.5%	700.0	1,274,000	8%
Totals	**345,270,000**	**100%**		**16,140,000**	**100%**

The battery sizes AA and AAA account for the greatest number of Handheld inputs with an estimated 147.7 million and 98.5 million batteries respectively sold for a combined share of 72 per cent of Handheld battery inputs by count.

However, on a weight basis it is the batteries that weigh on average over 500 grams per battery that make the disproportionate contribution. Lantern, laptop, cordless power tools and Sealed Lead Acid Batteries (SLAB) account for only 3 per cent of Handheld battery inputs on a count basis, yet make up approximately 42 per cent of inputs on a weight basis. This compares to AA and AAA batteries, which together make up for approximately 29 per cent of Handheld inputs on a weight basis.

Handheld Battery Inputs by Chemistry Type

Alkaline chemistry is the dominant form of Handheld battery inputs both on a count basis and on a weight basis. Alkaline accounted for 57 per cent of Handheld battery inputs (198 million) on a count basis and 57 per cent (9,248 tonnes) on a weight basis. The break down of Handheld battery chemistry types is shown in the table below.

Table – Estimated Australian Handheld battery inputs by chemistry type, count and weight (kilograms)

Chemistry	*Number of Batteries*	*Proportion Count*	*Total Weight (kg)*	*Proportion Weight*
Alkaline	198,000,000	57%	9,248,000	57%
Carbon Zinc	65,992,000	19%	1,973,000	12%
Lithium	33,796,000	10%	1,963,000	12%
Nickel Metal Hydride	20,664,000	6%	899,000	6%
Nickel Cadmium	10,150,000	3%	656,000	4%
Lead Acid (SLAB)	1,820,000	0.5%	1,275,000	8%
Other (ZA, SO, ZC)	14,850,000	4%	126,000	1%
Total	**345,270,000**	**100%**	**16,140,000**	**100%**

Automotive Starting, Lighting and Ignition (SLI) Batteries

Automotive Starting, Lighting and Ignition (SLI) batteries are such a dominant sub-category within the total stocks and flows of batteries in Australia that they warrant specific discussion. It is estimated that nearly six million Automotive SLI batteries entered into the Australian economy. Approximately one third of these batteries are locally manufactured. There are four main channels for Automotive SLIs to enter the market:

- 'do-it-yourself 'where the battery is bought direct from a retailer such as SuperCheap, Autobarn or Repco. This is the largest channel with approximately one third (35 per cent) of Automotive SLI batteries being sold through DIY stores
- 'do-it-for-me' change over at a service centre, for example vehicle repairs or tyre outlets. It is estimated that this channel accounts for a similar proportion to the direct battery replacement channel at 25 per cent of Automotive SLI battery inputs
- embedded in a new car sale, either locally produced or imported. Based on estimates of new vehicle sales in Australia, approximately 20 per cent of Automotive SLI battery inputs are in new vehicles, with the majority of these (approximately 85 per cent) imported

- direct battery replacement, for example through roadside replacement programs, with approximately 20 per cent of the inputs through the direct replacement channel.

The largest inputs of Automotive SLI batteries by count were passenger vehicles with approximately 75 per cent of the total by count and also by weight. Next largest was Light Commercial with approximately 15 per cent by count and also by weight. A further breakdown of Automotive SLI battery inputs by vehicle type is presented below.

Table – Estimated Australian Automotive SLI battery inputs by vehicle type, count and weight (tonnes)

Vehicle Type	*Number of Batteries*	*Proportion Count*	*Average Weight (kg)*	*Total Weight (tonnes)*	*Proportion Weight*
Motorcycle	260,000	4%	3.0	780	1%
Passenger Vehicle	4,413,000	76%	14.3	63,110	74%
Light Commercial	863,000	15%	15.7	13,550	16%
Rigid Trucks	172,000	3%	23.0	3,960	5%
Articulated Trucks	61,000	1%	31.5	1,920	2%
Non-Freight Carrying Trucks	9,000	0%	31.8	290	0%
Buses	65,000	1%	31.6	2,070	2%
Total Automotive SLI	**5,840,000**	**100%**		**85,670**	**100%**

All of the Automotive SLI battery inputs are lead acid batteries. The weight of the Passenger Vehicle and Light Commercial batteries accounts for 90 per cent of Automotive SLI battery inputs (85,670 tonnes) and over 55 per cent of all battery inputs (153,490 tonnes).

Large and Industrial Batteries

Large and Industrial batteries is the category of batteries that picks up non-automotive lead acid batteries such as those used in marine and mining applications, for traction and motive power and large stationary standby power storage applications. It also includes other chemistry types that provide motive power for electric vehicles and hybrid electric vehicles in addition to standby power for photovoltaic systems and emergency back up. The categories within Large and Industrial batteries include:

- marine engine applications
- forestry, farming, construction and mining applications where engines are used on items such as excavators, front-end loaders, dozers, graders, tractors, harvesters, trucks, feller-bunchers, compressors and gensets
- traction and motive power applications, for example golf carts, mobility scooters, small fork lifts, large materials handling units, hybrid vehicles and electric vehicles
- large stationary standby applications, including emergency power and renewable energy storage systems.

This category of battery use is the least well known with little data available. As such it relies on calculations built within the model. It is estimated that approximately 1.75 million Large and Industrial batteries enter into the Australian economy each year. These inputs are fairly evenly split across the four categories of use on both a count and weight basis.

The total weight of 51,680 tonnes for Large and Industrial battery inputs represents one third of the weight of total Australian battery inputs, even though on a count basis these batteries are less than one per cent of the number of battery inputs. A breakdown of Large and Industrial battery inputs by application is presented below.

Table – Estimated Australian Large and Industrial battery inputs by application, count and weight (tonnes)

Application	*Number of Batteries*	*Proportion Count*	*Average Weight (kg)*	*Total Weight (tonnes)*	*Proportion Weight*
Marine	289,000	17%	21.8	6,310	12%
Forestry/Farm/Constr/Mine	600,000	34%	34.4	20,660	40%
Traction and Motive	430,000	25%	22.6	9,710	19%
Large Stationary Standby	429,000	25%	35.0	15,000	29%
Total Large and Industrial	**1,748,000**	**100%**		**51,680**	**100%**

Large and Industrial Battery Inputs by Chemistry Type

Lead based chemistry dominates Large and Industrial battery inputs into Australia with approximately 90 per cent by count and also by weight. (Note that this includes lead acid batteries, sealed lead acid batteries, and lead based gels). The remaining battery chemistry types have been allocated on the same proportion as arisings between nickel metal hydride, nickel cadmium and lithium based (including lithium ion and lithium polymer). This breakdown is presented in the table below.

Table – Estimated Australian Large and Industrial battery inputs by chemistry type, count and weight (kilograms)

Chemistry	*Number of Batteries*	*Proportion Count*	*Total Weight (tonnes)*	*Proportion Weight*
Lead based	1,574,000	90%	46,670	90%
Nickel Cadmium	105,000	6%	3,020	6%
Nickel Metal Hydride	17,000	1%	490	1%
Lithium based	52,000	3%	1,500	3%
Total	**1,748,000**	**100%**	**51,680**	**100%**

Battery Arisings

Battery arisings from the Australian economy are defined as batteries that have finished their active service life and now require an end-of-life management solution, such as resource recovery. These estimates of arisings were built on a predictive model based on the amount of battery inputs and replacement rates as a function of battery stocks.

The chemistry, total tonnages and also unit count is important to understand with regard to battery arisings in Australia. Batteries with a high weight and low number of units present an ideal opportunity for resource recovery as they are readily identified and can be aggregated into large numbers for reprocessing.

However, in terms of sheer number and ubiquity throughout the economy, a stewardship solution is also required for low weight Handheld batteries. A breakdown of battery arisings by chemistry, count and weight is presented in the table below.

Table – Estimated Australian battery arisings by chemistry type, count and weight (tonnes)

Chemistry	*Number of Batteries*	*Proportion Count*	*Total Weight (tonnes)*	*Proportion Weight*
Alkaline	157,636,000	58%	7,180	5%
Carbon Zinc	52,513,000	19%	1,530	1%
Lithium	17,423,600	6%	1,440	1%
Nickel Metal Hydride	11,089,100	4%	623	0%
Nickel Cadmium	13,374,500	5%	1,772	1%
Lead Acid	7,829,800	3%	122,218	91%
Other (ZA, SO, ZC)	11,314,000	4%	186	0%
Total	**271,180,000**	**100%**	**134,949**	**100%**

This analysis shows that lead acid batteries account for over 90 per cent of all battery arisings in Australia on a weight basis, which is approximately 122,000 tonnes out of 135,000 tonnes of total battery arisings. However, given the large average weight of a lead acid battery, they account for only 3 per cent on a count basis, which is 7.8 million batteries out of a total arisings of 271.2 million batteries.

Fate of Battery Arisings

The fate of battery arisings was calculated according to the following end-of-life outcomes:

- reprocessed in Australia
- legal export for reprocessing overseas
- landfill
- stockpiled formal, in warehouses and at industrial facilities according to relevant legislation for battery storage in bulk
- stockpiled informal, for example left embedded in products such as mobile phones or left to accumulate in the house, garage, office, barn or mine site
- rebirthing, which is the inappropriate re-branding of an end-of-life battery for resale
- illegal export, which although is likely to be for reprocessing, nevertheless carries all of the risks of potentially hazardous materials being processed at unlicensed facilities.

A breakdown of the fate of battery arisings is presented in the table below. This shows that for total battery arisings in Australia, three quarters of batteries by weight are estimated to be reprocessed in Australia.

Table – Estimated fate of Australian battery arisings by category and tonnes

Fate of Arisings	*Handheld*	*Automotive SLI*	*Large and Industrial*	*Total*	*Total Proportion*
Reprocessed in Australia	350	66,050	34,350	100,750	75%
Legal Export	150	-	150	300	0%
Landfill	8,024	2,000	1,350	11,374	8%
Stockpiled Formal	250	3,960	2,290	6,500	5%
Stockpiled Informal	3,070	1,650	1,100	5,820	4%
Rebirth	10	1,320	725	2,055	2%
Illegal Export	50	5,280	2,820	8,150	6%
Totals	**11,904**	**80,260**	**42,785**	**134,949**	**100%**

The resource recovery of battery arisings is dominated by lead acid batteries which make up virtually the entirety of Australian battery reprocessing. The estimated 100,250 tonnes of lead battery reprocessing is approximately 75 per cent of all battery arisings and 82 per cent of all lead acid battery arisings. (Note that the legal export of lead acid batteries ceased after October 2009 when an application for an export permit was not granted. No reason for refusing the application was given on the official notice of decision, however the excess in processing capacity for lead acid batteries (143,000 tonnes of capacity and an estimated 122,218 tonnes of lead based battery arisings) would have been a significant factor.)

The fate of arisings on a count basis is also presented in the table below (estimated using average weights). This shows that reprocessing of batteries, legal export and formal stockpiling only accounts for 6 per cent of all battery arisings on a count basis.

Table – Estimated fate of Australian battery arisings by category and count (average weight basis)

Fate of Arisings	*Handheld*	*Automotive SLI*	*Large and Industrial*	*Total*	*Total Proportion*
Reprocessed in Australia	2,109,000	4,452,000	1,183,000	7,744,000	3%
Legal Export	3,330,000	-	5,000	3,335,000	1%
Landfill	183,389,000	135,000	46,000	183,570,000	68%
Stockpiled Formal	5,551,000	267,000	79,000	5,897,000	2%
Stockpiled Informal	68,546,000	111,000	38,000	68,695,000	25%
Rebirth	229,000	89,000	25,000	343,000	0%
Illegal Export	1,143,000	356,000	97,000	1,596,000	1%
Totals	**264,297,000**	**5,410,000**	**1,473,000**	**271,180,000**	**100%**

'Leakage' in battery arisings comes from informal stockpiling, within households and offices for handheld batteries and in remote and rural locations for Automotive SLI and Large and Industrial batteries. Informal stockpiling accounts for 4 per cent of battery arisings on a weight basis, which is 5,820 tonnes, including approximately 2,560 tonnes of lead acid batteries and over 3,000 tonnes of Handheld batteries. On a

count basis the Handheld batteries increase the proportion of batteries informally stockpiled to 25 per cent of all battery arisings.

Similarly, the landfill of batteries is estimated to be approximately 8 per cent of battery arisings including 8,000 tonnes of Handheld batteries and also 3,000 tonnes of lead acid batteries when assessed on a weight basis. However, on a count basis landfill of batteries accounts for nearly 70 per cent of all batteries.

If landfill is considered an undesirable management option for batteries, and is grouped with illegal export, rebirthing and informal stockpiling (all arguably undesirable from a stewardship perspective), then approximately 20 per cent of all batteries in Australia by weight are not being managed in an optimal way. This is 27,400 tonnes of batteries, comprising 15,940 tonnes of lead acid batteries and over 11,000 tonnes of Handheld batteries. On a count basis, the proportion increases to 94 per cent of all batteries ending up in sub-optimal management options, which is 254.2 million batteries per annum.

The table below presents a breakdown of the fate of Australian battery arisings by category and tonnes, but excludes lead acid based chemistry. This suggests that nearly two-thirds of non-lead acid battery arisings are ending up in landfill, and nearly one quarter of arisings being stockpiled informally (in other words, temporarily 'landfilled' in household and office cupboards and drawers). On a count basis, this equates to approximately 250 million batteries.

Table – Estimated fate of Australian battery arisings by category and tonnes – excluding lead acid batteries

Fate of Arisings	*Handheld*	*Automotive SLI*	*Large and Industrial*	*Total*	*Total Proportion*
Reprocessed in Australia	100	-	400	500	4%
Legal Export	150	-	150	300	2%
Landfill	7,820	-	310	8,130	64%
Stockpiled Formal	240	-	250	490	4%
Stockpiled Informal	2,860	-	250	3,110	24%
Rebirth	10	-	50	60	0%
Illegal Export	50	-	100	150	1%
Totals	**11,230**	**-**	**1,510**	**12,740**	**100%**

Challenges for Battery Resource Recovery

There is a high resource recovery rate when all batteries in Australia are considered as a whole (75 per cent as measured by weight as a percentage of arisings). However, there are very few Handheld batteries recovered for recycling, with only 750 tonnes across all chemistry types collected for local processing and legal export. This represents a recovery rate of 6 per cent of Handheld batteries by weight or 4 per cent by count. The main barriers for increased recovery of Handheld batteries are the establishment of collection systems and reprocessing capacity.

Automotive SLI batteries have a recovery rate of 87 per cent (when including formal stockpiling and reprocessing as a percentage of arisings), owing to their size and also to the value of lead as a commodity. Large and Industrial batteries are also dominated by lead acid battery chemistry and have a high recovery rate.

However, even with the established industry of lead acid battery reprocessing in Australia, the emerging picture is that a significant tonnage of material is being managed through 'undesirable' options such as landfill, informal stockpiling and illegal export. Thus there is room for improved stewardship of lead acid batteries including taking action on the eradication of illegal export, improved recovery from remote and regional sites and prevention of batteries entering the urban waste stream and being landfilled.

Recommendations

This analysis of the Australian battery market has demonstrated that there are significant numbers of batteries being consumed each year, and as a result, there will be increasing numbers of batteries arising in the foreseeable future. Handheld batteries of all chemistry types are most likely to end up in landfill, unless systems for collection and reprocessing can be established. While there are existing resource recovery solutions for lead acid batteries, there is also room to improve their performance.

It is recommended that ABRI take a lead role in delivering the following outcomes:

- improved collections of Handheld batteries to capture a critical mass for reprocessing of these batteries within Australia
- a sustainable funding model to support the collection of Handheld batteries
- eradication of illegal export of batteries by working with relevant authorities
- improved recovery of Automotive SLI and Large and Industrial batteries from remote and regional sites
- prevention of batteries entering the mixed urban waste stream
- design of a product stewardship model with the capacity to deliver the above desired outcomes.