Lithium-ion battery consultation report

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CONTENTS

EXECUTIVE SUMMARY

The roll-out of large lithium-ion (Li-ion) batteries for automotive and energy storage applications is still at a very early stage in Australia. As a result, the majority of these batteries are not expected to reach the end of their life for another 10-15 years.

Because of the long lag between installation and disposal, most of the companies consulted for this study do not yet have formal recycling policies or take-back systems for used batteries in Australia. However, many provided feedback that they expect to do so when the need arises.

Automotive companies appear to be most advanced in having policies, take-back systems and research trials underway in other markets to ensure that their batteries are reused or recycled. Further industry engagement will be needed to ensure that these policies and take-back systems are also introduced in Australia as electric and hybrid vehicles are released onto the market.

The most immediate issue for energy storage batteries from a product stewardship perspective is to ensure that they meet relevant design and installation standards and are safely managed during their extended use period. At the same time all of the relevant stakeholders – manufacturers, distributors, installers, energy retailers and industry associations – must be engaged to ensure that systems are in place to recover used batteries at end of life.

While it will be some time before large capacity lithium-ion batteries enter the waste stream in large numbers, the ground work needs to be done now to ensure that the environmental and safety risks are managed effectively. This ground work should include:

- Ensuring that all stakeholders in the distribution chain, as well as consumers, have information on recycling options and regulatory requirements (e.g. transport)
- Preparing Australian Standards for design, installation and recycling
- Exploring the feasibility of a tracking system for used batteries
- Monitoring individual product stewardship programs for electric and hybrid electric vehicle batteries to ensure that these are operating effectively
- Developing an industry-wide stewardship program for energy storage batteries
- Introducing mandatory labelling of batteries to include the international Li-in symbol as well as the chemistry.

1 PURPOSE

The purpose of the study was to gather information on corporate policies and practices in relation to the recovery of used Lithium-ion (LI-ion) batteries at end of life. The focus was on the high capacity batteries used in energy storage, power back-up and automotive applications. Information was gathered through a short survey that was answered by email or phone.

Issues that were canvased with companies included the types of batteries currently in use, expected sales, how any safety risks will be managed, policies for recovery at end-of-life, and any regulatory or infrastructure gaps.

2 ORGANISATIONS CONSULTED

The consultation focused on the distribution and use of large LI-ion batteries in Australia. The applications that are expected to grow significantly over the next 10-20 years are:

- Electric vehicles (section 4)
- Stationary energy storage (section 5).

For completeness, the use of smaller Li-ion batteries in consumer electronics is also briefly discussed in this report (section 6), but manufacturers were not surveyed because most are already involved in recycling trials.

The organisations that were contacted included associations, battery brand owners, distributors, automotive companies and energy retailers. Those that provided feedback by phone or returned the survey by email are listed in **Attachment 1** and survey questions in **Attachment 2**.

3 TYPES OF LITHIUM ION BATTERY CHEMISTRIES

There are many Li-ion battery chemistries in use or under development (**Table 1).** This makes recycling more complex compared to established technologies such as the lead acid battery.

Most of the intrinsic value to recyclers is from recovery of nickel, cobalt and copper. The trend is increasingly to less (or no) nickel and cobalt, which will make recycling less profitable.

Table 1: Types of lithium-ion batteries

Full name and common abbreviations	Status and common applications
Lithium nickel cobalt aluminium oxide ($LiNiCoAlO_2$), also known as Lithium cobalt aluminium (NCA)	Gaining importance in electric vehicles (EV) and grid storage
Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$), also known NMC	Power tools, e-bikes, EV, medical applications.
Lithium cobalt oxide ($LiCoO_2$), also known as Li-cobalt or LCA	Smart phones, laptops, tablets cameras
Lithium iron phosphate ($LiFePO_4$), also known as Lithium Ferrous or Lithium Ferro Phosphate (LFP)	Energy storage, power tools, e-bikes, EV, medical applications
Lithium manganese oxide ($Li\text{-}Mn_2O_4$), also known as Li-manganese, LMO or spinel	Power tools, e-bikes, EV, medical devices, hobbies
Lithium titanate ($Li_4Ti_5O_{12}$), also known as Li-titanate or LTO	Grid storage, EV, buses and ferries
Lithium sulphur (Li-S)	Emerging technology
Lithium ion polymer – Term previously referred to batteries with a polymer electrolyte (still under development). More commonly refers to a Li-ion battery in a soft pouch instead of a rigid metal case	Various including consumer electronics, EV
Lithium manganese dioxide (primary battery)	Defence applications

4 ELECTRIC AND HYBRID ELECTRIC VEHICLES

4.1 ELECTRIC VEHICLES AND BATTERIES IN AUSTRALIA

While most vehicle manufacturers have released at least one battery electric vehicle (BEV) or plug in hybrid electric vehicle (PHEV), only a small percentage of these are available to view or purchase in Australia **(Table 2**). Audi and Tesla appear to be the most active in promoting their electric range. Others may be taking a similar position to Renault, who responded that 'we are still evaluating the business case for electric vehicles in Australia'.

The Federal Chamber of Automotive Industries (FCAI) advised that there has been very low uptake of BEV and PEHV vehicles in Australia, with approximately 1100 BEV, PHEV and petrol electric hybrid vehicles (PHV) sold in 2015 out of a market of around 1.1 million. One manufacturer suggested that sales are 'difficult to estimate based on current uptake of electric vehicles in Australia'.

Common feedback from surveyed associations and vehicle brands was that demand in Australia is very low due to the high purchase cost and consumer concerns about battery range. They claim that at present the market is limited to 'early adopters', and will only take off when governments introduce supporting policies. In the US for example, the market is driven by low emission standards.

One respondent commented that most companies are waiting for demand to pick up in Australia before they become actively involved in marketing BEV and PHEV here. One of the challenges for manufacturers is to the high cost of setting up a servicing centre (over $1M), when the number of vehicles in use is so small. Dealers may also be less interested in promoting electric cars because they are not as profitable to service as petrol cars (Tucker 2016).

Various battery chemistries are being used in electric and hybrid electric vehicles **(Table 2**). Toyota continue to use nickel metal hydride (NiMH) but other brands use Li-ion. The industry is shifting to lower cost Li-ion batteries with less cobalt (e.g. Lithium iron phosphate), which means that they also have lower value to recyclers (Arsenault 2013).

Table 2: Electric and hybrid vehicles and batteries in Australia 2016

Company	Vehicles on the market	Market status in Australia	Battery type (where identified)*
Toyota	Toyota Prius (PH), Toyota Prius C (PH), Toyota Prius B (PH), Camry hybrid (PH)	78,000 sold[1]	Nickel metal hydride (NiMH) (The new PHEV – not yet in Australia - uses LI-ion batteries)
Lexus	Lexus CT200h (PH)	Available in Australia	NiMH
Honda	Accord Hybrid	Available in Australia (3 more models coming)	Lithium nickel manganese cobalt oxide (NMC)
BMW	i3 (BEV), i8 (PHEV), ActiveHybrid 3 (PHEV), X5 (PHEV), 330e (PHEV), 225e	These models currently available in Australia. Sales ~ 100/year. Entire range expected to be available as an electric model by 2017.	Lithium manganese cobalt in the i3
Tesla	Model S (BEV), Model X SUV (BEV)	Available in Australia. Model 3 (BEV) on order for late 2017	Lithium cobalt aluminium (NCA) – 7,104 cylindrical cells in each

[1] http://www.toyota.com.au/hybrid-battery-recycling

Nissan	Leaf (BEV)	Available in Australia	Lithium nickel manganese cobalt oxide (NMC)
Mitsubishi	i-Miev (BEV), Outlander (PHEV)	Available in Australia	Lithium manganese oxide (Spinel)
Audi	A3 e-tron (PHEV with petrol engine)	Available in Australia	Li-ion (not specified)
Porsche	Panamera (PHEV), Cayenne (PHEV)	Available in Australia	
GM Holden	Volt (PHEV)	No longer available in Australia – very few sold	
Mercedes	350e (PHEV)	Available in Australia	
Volvo	XC90 T8	Expected to be available in Australia soon	
Renault	Kangoo (BEV)	Not available in Australia	
BYD	BYD E6	Will be available in Australia in 2016	Lithium iron phosphate (LiFePO4)`

Key: BEV (battery electric vehicle), PHEV (plug-in hybrid electric vehicle), PH (petrol hybrid)

* Information on the specific chemistry used in automotive applications was in some cases difficult to find or varied between different sources.

4.2 Expected battery life

Respondents advised that the batteries are designed for the life of the vehicle, and are therefore not considered to be a 'service item'. The Audi respondent estimated their vehicle life to be around 12-15 years.

In a conference presentation several years ago, Ford Motor Company estimated that the electric and hybrid batteries would reach the end of their first life after an average of 10 years, and that significant numbers were expected to enter the waste stream around 2020 (Arsenault 2013).

Another estimate is that around 50% of batteries installed in electric cars are recycled after 5 to 7 years, when they still have about 80% of their original capacity (Zaripova 2016). They can then potentially be used for many more years in energy storage (solar and battery) before needing to be recycled.

4.3 Battery take-back and recycling policies

FCAI advised that all of their member brands have systems in place to take back used batteries at the end of their service life, normally as part of a global corporate approach. This is supported by some of their publicly available information. Renault, for example, has a global electric vehicle and recycling policy for its ZE (zero emissions) range (Renault 2013, p. 17):

1. In any market where Z.E. vehicles are sold, Renault ensures that the industrial battery at the end of use is taken back and processed in accordance with human health, safety and environmental protection, while being compliant to all local regulations.
2. Within the EU, compliance with the End-of-Life Vehicle Directive, the Batteries Directive, and all other related regulations, is guaranteed.
3. Even for markets outside of the EU, Renault will ensure that they will align in these countries also to the European legislative requirements.

Because the market for BEV and PHEV is so small in Australia and the batteries have a relatively long life, very few Li-ion batteries have been returned for recycling.

As an example of how these batteries could be managed at end of life, Toyota has introduced a consumer incentive for the return of the Prius NiMH batteries. They offer a $100 cash rebate or $500 discount on the purchase price of a new battery[2]. Batteries are taken back by the dealer, who pays the customer and claims it back from Toyota. The batteries are currently exported for recycling.

Audi has a policy to recycle all end of life batteries through MRI, but their cars are yet to need a battery replacement. GM Holden no longer imports the Volt, but advised that their global recycling policies apply in Australia and any recycler engaged by the local company would have to meet strict standards and be audited.

In their conference presentation Ford Motor Company highlighted the complexity of the value chain for automotive batteries, and the fact that there were multiple sources of waste batteries including from the Original Equipment Manufacturer (OEM), dealers, and salvage at end of life (Arsenault 2013). In Australia most of the batteries that have required an end of life solution so far have been damaged or defective batteries returned through the dealer network. Ford is working with salvage companies, dismantlers, recyclers and other stakeholders in the US to develop the end of life infrastructure for NiMH and Li-ion batteries in the US. This provides a model for industry stewardship in Australia.

4.4 WHAT HAPPENS TO RETURNED BATTERIES

Two of the respondents advised that their company had engaged MRI as their recycling partner. MRI has a permit to export NiMH and Li-ion batteries for recycling under the Hazardous Waste Act.

Mitsubishi advised that at a global level the company is working with its battery partners to undertake research into re-use, repurposing and recycling. Any batteries removed from Mitsubishi vehicles to date have been returned to the OEM. They also advised they that 'had had some discussions with appropriately accredited and licensed e-waste disposal companies in Australia with a view to local disposal as and when the need arises.'

FCAI reports that many of their member brands are researching opportunities for reuse. Internationally a number of automotive companies including BMW, Nissan, General Motors and Renault are trialling the reuse of electric vehicle batteries for energy storage.

4.5 REMOVAL OF USED BATTERIES FROM THE VEHICLE

According to FCAI, the batteries can be removed by trained service personnel with the necessary, specialist tools.

This was supported by comments from two survey respondents. Audi advised that specialised equipment is used for safe removal of the battery from the car by Audi-trained technicians. Mitsubishi 'recommends removal only by service personnel who are trained for electric vehicle service operations due to the risk arising from high level of high voltage electrical energy stored in EV traction batteries.' Mitsubishi has published detailed instructions on how to disconnect, discharge and remove batteries from the i-Miev[3].

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[2] http://www.toyota.com.au/hybrid-battery-recycling

[3] http://elvsolutions.org/wp-content/uploads/2013/06/2012_I_Dismantling_guide.pdf

4.6 MANAGING ENVIRONMENTAL AND SAFETY RISKS

According to FCAI, international vehicle safety and environmental regulatory standards and UN regulations have been developed to address any safety risks of traction batteries in-use. They also noted that the Department of Infrastructure and Regional Development is responsible for regulating vehicle safety through the Australian Design Rules, and in their view will be able to adopt the relevant UN regulations if either a safety or environmental case is demonstrated.

In relation to risks at end of life, Audi advised that: 'Audi dealerships and Audi Approved Panel repairers have a robust process with dealing with damaged or end of life batteries, this is also supported by Audi Australia. All used batteries will be recycled by MRI …'

4.7 BATTERY LABELLING

Mitsubishi provided a photo of the label on the outside of their traction battery (**Photo 1**). This includes a warning symbol for high voltage, the European Union's 'do not dispose' symbol (crossed-out wheelie bin), and a web link for more information about 'battery recycling and disposal'. The URL is for their *2012 i-MiEV dismantling guide*.

Another brand simply advised that they 'comply with EU regulations' on labelling.

Photo 1: Label on the Mitsubishi Li-ion battery

5 ENERGY STORAGE

5.1 LITHIUM-ION ENERGY STORAGE BATTERIES IN AUSTRALIA

The traditional technology for energy storage and grid back-up has been the lead acid battery, and this is still widely used. Work is underway to improve their efficiency and lifespan, for example the CSIRO-developed Ultra Battery (Ecoult brand).

Li-ion batteries are becoming the technology of choice for a number of reasons, including (Turner 2016):

- their greater energy density, which means that they are smaller and lighter
- they are expected to have longer life spans
- they are able to undergo deeper discharges, reducing the capacity required.

Storage batteries currently available in Australia are shown in **Table 3.** Information on the specific chemistry being used for batteries is sometimes difficult to find, as it is often not mentioned in product literature or on websites. Labelling is generally limited (if at all) to the generic Li-ion symbol.

The dominant Li-ion technology for energy storage at present appears to be Lithium Iron Phosphate (also known as Lithium Ferrous) because of its longevity, robustness and resistance to battery fires (Turner 2016). Batteries are generally sold as part of a system, with a number of batteries encapsulated in a cabinet or shipping container with a battery management system. Panasonic's Residential Storage Battery System, for example, contains three battery units weighing 27g each. Ergon Energy's larger 'GUSS' system contains many more batteries (56).

Sales of energy storage batteries are expected to grow exponentially over the next 10-20 years as prices fall. Chief Executive of the Australian Energy Storage Council, John Grimes, predicts that the number of domestic energy storage systems will go from around 200 per month to 1000 a month or more over the next 12 months (Grimes 2016). The total market is estimated to be 2.4 million households, if half of all households install batteries to store output from their solar panels (Parkinson 2015). One supplier, Enphase, has received orders for 60,000 units over the next 12 months only two weeks after inviting orders (Macdonald-Smith 2016).

Like other energy retailers, AGL has started to offer its customers a solar and battery storage system. AGL is mainly focused on the residential market but with some commercial and industrial users. In their response to this survey AGL claimed that it was too difficult to forecast quantities because the market is still relatively immature. In their view some forecasts may be too optimistic: 'we know we're going to get there but we don't know how long it's going to take'.

Selected retailer initiatives are shown in **Table 4.**

Table 3: Lithium-ion Energy storage batteries available in Australia

Company	**Product**	**Battery type**	**Warranty period**
360Storage	AiO	Lithium iron phosphate	5 years
Bosch	BPT-S 5 Hybrid battery solar inverter system	Lithium nickel cobalt aluminium oxide	5 years with 5 year extension
Alpha-ESS	Storion S5	Lithium iron phosphate	5 years
BYD	DESS	Lithium iron phosphate	10 years
Enphase	Enphase AC battery	Lithium iron phosphate	10 years
Fronius	Solar Battery	Lithium iron phosphate	5 years
Kokam	Various	Lithium titanate, Lithium nickel manganese cobalt oxide, Lithium iron phosphate, or hybrid ('Nano')	
Leclanche	Apollion Cube	Lithium nickel manganese cobalt oxide	7 years
Leclanche	TI-Box	Lithium titanate oxide	10 years
Lishen	Lishen M4860-SI	Lithium iron phosphate	
LG Chem	RESU U6.4EX	Lithium nickel manganese cobalt oxide	10 years
Magellan Power	HESS	Lithium manganese cobalt oxide	10 years
Panasonic	Residential Storage Battery System LJ-SK84A	Lithium nickel manganese cobalt oxide	
Positronics	Positronics ESS	Lithium iron phosphate	
Pylontech	Extra2000 LFP	Lithium iron phosphate	5 years
Samsung	Samsung AIO	Lithium manganese oxide	5 years
Selectronic	myGrid Lithium	Lithium iron phosphate	
Simpliphi	Simpliphi OES2 and OES3	Lithium iron phosphate	10 years
Sonnenschein	Sonnenschein Lithium	Lithium iron phosphate	
Sunverge	Solar Integration System (SIS)	Kokam brand - Lithium nickel manganese cobalt oxide	10 years
Tesla	Powerwall	Lithium manganese cobalt	10 years
Toshiba	Smart Battery SCiB (Super Charged ion Battery)	Lithium titanate oxide	
Zen Energy	Urban and Freedom PowerBanks	Lithium iron phosphate	

Table 4: Energy retailers and other distributors

Company	Batteries being installed	Details
ActewAGL	Panasonic residential	These three systems will be installed in Canberra as part of ACT Government. pilot http://citynews.com.au/2016/discount-home-power-batteries-thanks-to-the-act-government/
ITP Renewables	LG Chem	
Solar Hub	Tesla Powerwall and LG Chem	
AGL	AUO PowerLegato Sunverge SIS 11.6 and 19.4	Available for solar systems 3-5 kW https://aglsolar.com.au/energy-storage/?SEM=1&gclid=CJOhssTs-MwCFRSVvQodBCEBYw&gclsrc=aw.ds
Origin Energy	Tesla Powerwall	https://www.energyaustralia.com.au/residential/home-services/batterystorage?cid=sol%7csem%7cgg%7csolbat%7c%7cnsw&gclid=CPmuiNzs-MwCFYTZvAod-WQENA&gclsrc=ds
Energex	Tesla Powerwall	Trial in SE Queensland over the next 2 years
Ergon Energy	Sunverge Solar Integration System (SIS)	12 month trial in regional Queensland with 33 homes http://statements.qld.gov.au/Statement/2015/8/6/us-firm-sunverge-doing-solar-battery-trial-in-queensland
	Toshiba Lithium Titanate Oxide	200 KWh installed in May 2016
	Grid Utility Support System (GUSS) – battery units, inverter and switchboard	Designed by Ergon. Piloted in 2013 and now 20 systems are being installed in their network. https://www.ergon.com.au/about-us/news-hub/talking-energy/technology/battery-storage-systems-arrive-soon
	Others being trialled for residential use	Zen, Sunverg, BYD, Panasonic, Legato, NeeoQube, Tesla, Sonnenschien, LG Chem

5.2 Expected battery life

Many brands offer a 10 year warranty (**Table 3**), although respondents commented that they generally expect the batteries to last longer. Sunverge suggested between 15-20 years, Panasonic between 10 -14 years from installation date (depending on usage), and Toshiba 20 years.

AGL advised that they provide a 10 year warranty, at which stage the batteries are expected to have 80% of their original capacity. How long they live beyond that depends on how they're treated and whether the consumer is monitoring their performance.

5.3 Battery take-back and recycling policies

All of the surveyed brand owners reported that it was too early to have a take-back policy or arrangement in place because none of their batteries had reached end of life:

- While Sunverge doesn't currently have a recycling program in place, they believe that it is important to ensure that all batteries installed in Australia are properly recycled. However, they are unsure whether there are 'quality recycling plants' in Australia.
- LG Chem said that at present they would take any waste batteries back to Korea, but they were looking for a recycling company in Australia. Like the other respondents, they noted that none of their batteries have yet reached end of life.
- Panasonic commented that they have not yet had a battery failure, but should a battery fail, it would be replaced and the faulty battery shipped back to their factory for investigation as to why it failed. The results of their investigation would be used to inform future product development and product improvement.

- GNB Industrial Batteries (a division of Exide Technologies) distribute the Sonnenschein batteries in Australia. They do have plans for recycling but don't anticipate this being required for the next 10 years.
- Another distributor had no arrangement in place for recycling and no future plans for reuse, repurposing or recycling.

The energy retailers that were surveyed are starting to install Li-ion energy storage batteries for larger customers and residential projects and are aware that recycling will need to be considered in the future. Ergon, for example, advised that they were writing into their tenders a requirement for suppliers to take back the batteries at end of product life, and this was done for their GUSS project.

ActewAGL said that recyclability was considered for their current residential storage pilot in the ACT. They said that they are 'committed to meeting the standards and requirements set by the Government and/or Clean Energy Council to reduce the safety and environmental impact of the high capacity Li-ion battery when they reach their end of life.'

AGL advised that it was 'early days' but they intend to develop a recycling policy. They know that recycling is an important issue, which is why they recently joined the Australian Battery Recycling Initiative (ABRI). Recyclers will be like any other supplier, i.e. they would have to meet certain standards.

5.4 WHAT HAPPENS TO RETURNED BATTERIES?

Most respondents did not think this question was relevant at present as very few (if any) Li-ion storage batteries have been recovered. Toshiba commented that the batteries will be recycled in the same manner as traditional Li-ion batteries used for laptops and other rechargeable devices. While this is a reasonable assumption for reprocessing, infrastructures will need to be established to recover, remove and discharge large capacity batteries prior to recycling (see section 7).

5.5 REMOVAL OF USED BATTERIES FROM CABINETS

Respondents gave mixed feedback on whether or not the batteries are easy to remove. Panasonic reported that access to the cabinet requires a security torx screw driver, after which it can be removed and disassembled with commonly available tools. Other feedback included:

- 'Very time consuming to remove' (Sunverge)
- 'Can be easily removed without specialist tools' (Toshiba)
- 'Just need a screw driver' (LG Chem).

AGL advised that their batteries would require a technician to open, and that opening by a consumer would void the warranty.

5.6 MANAGING ENVIRONMENTAL AND SAFETY RISKS

Manufacturers and distributors have tended to focus on design and labelling initiatives to ensure safe operation, with the risks generally well understood. Less attention is being paid to any risks at end of life. This is understandable given that most are not expecting their batteries to be replaced for at least 10 years.

Respondents provided feedback on a variety of safety features:

- Panasonic claimed that the common environmental and safety risks of Li-Ion batteries are well understood by Panasonic:

> To mitigate risk the battery modules are housed in a metal enclosure that in turn are installed in a metal cabinet (LJ-SK84A). The installed product is labelled with content type, shutdown procedure and notices in customer's main switchboard about the presence of a battery storage system with a dedicated circuit breaker to turn off the batteries.

- Sunverge advised that their systems are designed to add to and maximise the safety of the batteries, with multiple features such as BMS protections and strengthened enclosures. They do not anticipate any risks at the end of life.
- Toshiba reported that the SCiB batteries are fully enclosed inside 'cells' which are additionally enclosed within a module. The risk of chemical leakage is therefore extremely low. In addition they are housed in racks that prevent movement and risks of breakage. The potential for thermal runaway was being managed through the choice of a safer chemistry:

> A significant concern in transport is that lithium batteries will exhibit 'thermal runway' which may cause it to explode ... Our SCiB lithium titanate batteries are inherently much safer than traditional batteries and do not exhibit thermal runway. As a result, the risk of explosion and fire on any form of transport is significantly reduced.

- LG Chem commented that their batteries did not contain materials that were hazardous to the environment, and if used according to operating guidelines, safety was not likely to be an issue.

5.7 BATTERY LABELLING

Most companies advised that their batteries included environmental and safety information but did not provide details:

- Toshiba has labelling on the battery that 'highlights the safety risks and managements of the batteries'.
- LG Chem also mentioned a safety label on the 'top cover'.
- AGL reported that the batteries they sell contain their own safety labels, and then AGL add their own during installation.
- Sunverge said that safety and environmental information is included in the product MSDS rather than on the battery.

Examples of external labels (on the outer cabinets) are provided below (**Photos 2 and 3**). **The** batteries inside the cabinets are likely to include the international symbol for Li-ion, which is not mandatory in most countries (**Photo 4**). The problem with this label is that it doesn't identify the specific chemistry (e.g. Lithium Iron Phosphate). This information is necessary at end of life so that recyclers know the material composition of the battery.

Photo 2: Safety labels on the Kokam cabinet

Photo 3: Label on the Simpliphi cabinet

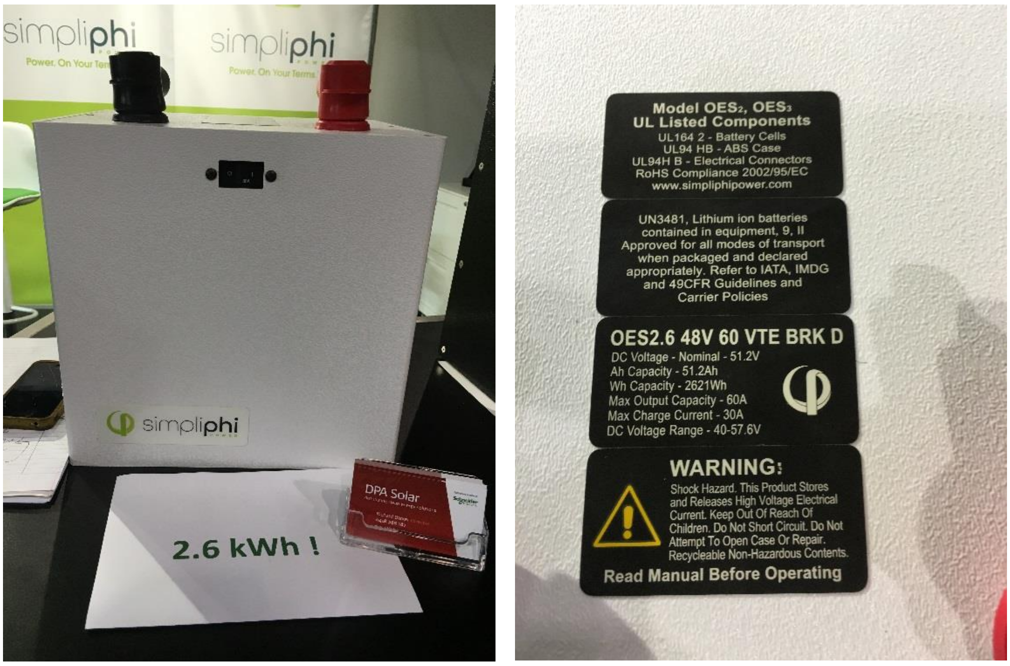

Photo 4: Lithium ion identification symbol

6 CONSUMER ELECTRONICS

The quantity of Li-ion handheld batteries reaching end of life is expected to double between 2014-15 and 2019-2020, from 2,770 to 5,600 tonnes per year **(Table 5).**

Table 5: Handheld batteries reaching end-of-life by chemistry, 2009-10 – 2019-20 (tonnes)

Battery chemistry	2009–10	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20
Alkaline	5,610	5,600	5,390	5,130	5,100	5,350	5,460	5,550	5,630	5,740	5,880
Zinc carbon	3,910	3,910	3,760	3,580	3,560	3,740	3,810	3,870	3,930	4,010	4,110
Lithium primary	150	160	160	150	140	180	190	200	210	220	230
Lithium ion	860	1,060	1,350	1,750	2,240	2,770	3,340	3,910	4,490	5,080	5,680
Nickel metal hydride	620	650	690	720	740	750	740	710	660	600	540
Nickel cadmium	680	680	680	670	670	660	640	620	590	550	510
Lead acid	2,380	2,440	2,540	2,700	2,920	3,180	3,440	3,660	3,810	3,920	4,060
Other chemistry	80	80	70	40	40	50	60	60	60	70	70
Total	**14,290**	**14,580**	**14,640**	**14,740**	**15,410**	**16,680**	**17,680**	**18,580**	**19,380**	**20,190**	**21,080**

Source: SRU and Perchards (2014)

Manufacturers and distributors of Li-ion batteries used in consumer electronics were not included in this survey, although some respondents do manufacture these in addition to larger batteries (e.g. Panasonic, Toshiba).

Many Li-ion brand owners are involved in the Battery Industry Working Group (IWG), which is working to establish a national, voluntary stewardship scheme for handheld rechargeable batteries (<5kg). Members of IWG include Panasonic, Energizer, Bosch, Metcash, Officeworks and Battery World. IWG will provide a report to Environment Ministers at the end of 2016, with the aim of starting the scheme in 2017.

Li-ion batteries are rapidly replacing nickel cadmium (NiCd) batteries in two key markets: power tools and emergency lighting. There are currently two pilot recycling projects underway to investigate the best way to recycle batteries from these products, with support from manufacturers and retailers:

- A power tool battery recycling pilot in Brisbane in Bunnings, Masters and Trade Tools stores. The project is managed by ABRI with support from Robert Bosch (Aust) Pty Ltd.

Other brand owners and retailers, including Techtronics Industries, Hitachi, Ozito and Total Tools, are being consulted. The project will finish in July 2016.
- An emergency lighting battery pilot in Queensland is being managed by the Lighting Council of Australia, whose members almost all of the main suppliers. This is based on the Fluorocycle model, i.e. recycling will be funded by the waste generator rather than the manufacturer.

7 EXISTING RECYCLING INFRASTRUCTURE

The only current option to recycle Li-ion batteries in Australia is through PF Metals[4], who established a small-scale recycling facility for batteries in Melbourne in early 2016. The batteries are sorted by chemistry and alkaline, lithium, nickel and lead based batteries are all treated separately. Li-ion batteries are discharged before processing. They are then crushed and separated into three streams:

- Aluminium and coper are recovered and supplied to customers for further separation and better copper recovery, or as an additive for the production of various grades of aluminium
- Cobalt, nickel and lithium is recovered in the form of dust. This is further refined to go back into the production of new batteries
- Plastics are separated from the aluminium and copper fraction, granulated and sold as clean granules to various users.

Li-ion batteries are also being exported for recycling by a number of companies including MRI (Aust) Pty Ltd, Powercell, Sims E-Recycling and TES-AMM. This requires a permit from the Department of Environment in accordance with the Hazardous Waste Act.

There is some interesting research underway at CSIRO on new methods to recycle Li-ion batteries, for example through biohydrometallurgy[5].

8 INDUSTRY PERCEPTIONS ON RECYCLING INFRASTRUCTURE GAPS

Perceptions about the availability and adequacy of recycling infrastructure vary between the automotive and energy storage sectors, reflecting their different levels of development.

The electric vehicle sector is moving ahead rapidly, with most brands having battery driven or plug in electric vehicles available (although not all in Australia). In countries where these vehicles are becoming more common—particularly in Europe and the US—manufacturers have had to establish policies and programs to deal with end of life batteries. Over time, as the market grows and the need arises, these policies and programs will be rolled out in Australia.

This is reflected in feedback from the FCAI, who do not see any gaps in the infrastructure for collection and recycling of automotive batteries. Their comment was that 'All FCAI member brands have processes in place for collection and recycling of traction batteries.' Similar feedback was provided in separate responses from Tesla, Mitsubishi and Audi.

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[4] http://www.pfmetals.com.au/
[5] http://www.batteryrecycling.org.au/csiro-invests-in-battery-recycling-research

Recovery of automotive batteries will generally only be required at the end of the vehicle's life and will be relatively straightforward. At present companies are relying on their network of dealers to recover any used batteries, and to supply them to an approved recycler.

The situation is different for companies in the energy storage sector, which has a more complex distribution chain and is at an earlier stage of development. Many stakeholders involved in distribution, including battery manufacturers, suppliers of storage 'systems', solar installers and energy retailers, may have had limited involved in battery recycling in the past. Li-ion battery recycling is also a relatively new activity, and small to medium sized business do not necessarily have the resources to undertake the required research (unlike global automotive companies).

Despite the fact that Li-ion batteries are already being collected for recycling and either exported or processed locally (a small scale plant opened in early 2016), this is not widely known:

- Sunverge, for example, said that 'We are aware of facilities that recycle lithium ion batteries in North America but have not confirmed whether there are quality lithium-ion battery recycling plants in Australia.'
- Panasonic said that 'currently there is no infrastructure for large scale collection & re-cycling of Li-ion batteries / modules / banks etc.'
- LG Chem believe there are 'not many recycling companies'
- GNB Industrial Batteries claim that there is no existing infrastructure.

ActewAGL is aware of the recycling infrastructure for handheld batteries but state that there is a gap for high capacity storage batteries:

> Currently a Li-ion battery recycling scheme does not exist in Australia for high capacity Li-ion batteries such as those used in Panasonic Energy Storage Systems. High capacity Li-ion batteries are constructed using small capacity Li-ion cells (similar in size to AA type size batteries) wired in a series/parallel combination. At present, small individual cells, laptop batteries etc. are collected and sent overseas for recycling and the extraction & separation of metals/plastic etc. Feedback from Panasonic is that this may be the short term stop-gap measure until a recycling scheme is established for high capacity Li-ion batteries.

Ergon Energy is concerned that transport costs will be a barrier to recycling: 'You have to factor in transport costs, since we're in regional Queensland they have to be sent to capital cities or southern ones.'

AGL is aware of export markets for used batteries but would prefer to see proper on-shore recycling capacity.

9 INDUSTRY PERCEPTIONS ON REGULATORY GAPS AT END OF LIFE

Some regulatory gaps and uncertainties were identified in installation standards, transport regulations and recycling.

Toshiba believe that there is a lack of standards that govern the safe design and installation of Li-ion batteries. They advised that the last relevant standards (AS3011) were written in 1990 and are based on lead-acid batteries. In their view they are 'severely out-dated and impractical to use'. This gap is being addressed by Standards Australia through their 'Roadmap for energy storage batteries' (Vorrath 2016).

According to AGL ‘the whole area is ill defined and has gaps’. While installation standards have recently been published by the Clean Energy Council and the Australian Energy Storage Council, AGL believes that further work is required. GNB Industrial Batteries also provided feedback that there are ‘no standard guidelines’.

Several respondents mentioned the lack of regulation for recycling, or uncertainty about whether or not there are regulations. For example this from Audi:

> Audi AG and Audi Australia are very mindful of battery recycling and we would not market a vehicle without a recycling policy in place. However when doing our research over a year ago, it was not so easy or clear on what local responsibilities or regulations were necessary or required without engaging a company like MRI.

There was also some feedback on transport regulations:

- Solar 360 noted that the transport industry is confused about road travel and the Dangerous Goods status of lithium batteries.
- Ergon Energy commented that ‘Lithium is not trackable waste from our understanding, so if there isn’t a recycling plant built for a while, how do recyclers know how long they have to store them before being recycled? If they’re not tracked they could be sent anywhere by companies with a different moral compass.’

10 CONCLUSIONS

Lithium-ion batteries are already widely used in Australia for consumer electronics, and the numbers are expected to continue growing. New applications that are expected to contribute to exponential growth in Li-ion battery waste in future are energy storage and electric vehicles. Companies in both of these sectors were consulted for this research.

Automotive companies advised that they have policies and take-back programs at a global level and that these will be extended to Australia when the need arises. Some already have arrangements in place with a local recycler, but the number that have reached end of life is very low. When the batteries do need to be replaced, they will be collected for recycling via their dealer network.

Most manufacturers and distributors of energy storage batteries said that they did not have a formal recycling policy or take-back program in place because this would not be required for at least 10-15 years. The distribution chain for these batteries involves a much larger number of companies, and in contrast to the electric vehicle sector, reverse logistics will not necessarily be straightforward. It is therefore more likely that an organised (and possibly regulated) product stewardship program will be required.

In both sectors there is a need for better information on:

- Available options for recycling in Australia (local processing or export)
- Transport regulations including the Dangerous Goods Code.

The three regulatory gaps that were identified (only by 1-2 respondents in each case) were installation standards, waste tracking and recycling regulations.

While it will be some time before these batteries enter the waste stream in large numbers, the ground work needs to be done ahead of time to ensure that all environmental and safety risks are managed effectively. This could include:

- Ensuring that all stakeholders in the distribution chain, as well as consumers, have information on recycling options and regulatory requirements (e.g. transport)
- Preparing Australian Standards for design, installation and recycling
- Exploring the feasibility of a tracking system for used batteries
- Monitoring individual product stewardship programs for electric and hybrid electric vehicle batteries to ensure that these are operating effectively
- Developing an industry-wide stewardship program for energy storage batteries
- Introducing mandatory labelling of batteries to include the international Li-in symbol as well as the chemistry.

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Attachment 1: Organisations that provided feedback

Associations

- Clean Energy Council's Storage Advisory Group
- Electric Vehicle Council
- Federal Chamber of Automotive Industries

Companies - automotive

- AlphaBet Fleet (BMW)
- Audi
- GM Holden
- Honda
- Lexus
- Lexus
- Mitsubishi
- Renault
- Tesla
- Toyota

Energy retailers and solar installers

- ACTewAGL
- AGL
- Ergon

Battery brand owners and distributors

- DPA Solar
- Solar360
- LG Chem
- GNB Industrial Power (Exide Technologies)
- Panasonic
- Sunverge
- Toshiba

ATTACHMENT 2: TYPICAL SURVEY QUESTIONS

(The questions were adapted depending on the company's role in the supply chain.)

1. Please provide details of Lithium-ion batteries being distributed in Australia (e.g. product name, type of Li-ion chemistry).
2. Can you estimate current and/or future sales in number of units?
3. What is the expected battery or product life?
4. Are the batteries 'embedded' (difficult to remove from the product without special tools)?
5. Have you identified any environmental or safety risks during use or at end-of-life, and how will these be managed?
6. Is there any labelling on the product or battery about safety risks and their management?
7. Do you or the manufacturer currently have an arrangement in place to take back used Li-ion batteries at end of life?
8. Do you have any future plans for reuse, repurposing or recycling?
9. What happens to batteries that are currently collected for recycling?
10. Have you identified any gaps in the infrastructure for collection and recycling?
11. Have you identified any gaps in government regulations relating to batteries at end of life, e.g. hazardous waste regulations, dangerous goods, transport, standards?