Guide to recycling options for large and industrial batteries

Australian Battery Recycling Initiative

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Purpose

This document provides a guide to the recyclability of batteries that are being used, or are under development, for energy storage. Companies involved in the manufacture, distribution, use or recovery of batteries need to work together ensure that all batteries are recycled at the end of their life.

The guide was developed by the Australian Battery Recycling Initiative (ABRI) with assistance from CSIRO and other members of the Clean Energy Council's PV Storage Working Group.

ABRI invites further feedback on the draft: Contact Helen Lewis, secretariat@batteryrecycling.org.au.

Overview

- Lead acid batteries are the most established and the most recyclable of all large battery chemistries.
- Lithium ion (Li-ion) batteries are the major competitor to lead acid. There are many variations of electrode chemistry that are currently in use or emerging.
- Most of the value in a used Li-ion battery is from the cobalt, nickel and copper components. Cobalt is being reduced or removed in newer Li-ion batteries, and this reduces their value to recyclers.
- Recycling technologies for Li-ion are still being developed. A high recovery rate of materials is difficult due to varieties of chemical components and system complexity[1]. Pyrometallurgy is considered to be the best recycling technology at present because it can recover a wide range of electrode chemistries. Hydrometallurgy can recover more materials, including lithium and aluminium, but is still under development for commercial use[2].

[1] http://www.acea.be/uploads/publications/Rev_of_Battery_technology_-_full_report.pdf

[2] http://iopscience.iop.org/1748-9326/10/1/014011

Battery type	Stage of development / applications	UN Number	Components	Manufacturers	Local recycling companies	Overseas recycling companies	Companies with export permits	Collectors	Recycling value and constraints	Transport requirements
Lead acid battery	Mature technology. Mainly used in automotive and industrial applications – energy storage is emerging	Batteries, wet, filled with acid: 2794 Batteries, wet, non-spillable: 2800 (sealed)	Lead, lead oxide, sulphuric acid, plastics (PP)	There are two local manufacturers: Century Yuasa Batteries and Pacific Marine. The remainder are imported e.g. Ecoult (ex-CSIRO)	Lex Enviro Services Enirgi Metal Group (ARA and RMT) Hydromet V Resource	Kookjea Metallic Co (+ many others)	Dodd & Dodd Group (to Kookjea Metallic Co)	BAT REC Battery Recycling Dodd & Dodd Group Lex Enviro Services Siel Recycling Watt Batteries Orbitas Metal recyclers Local councils	Lead has a high commercial value. Plastics and electrolyte (H_2SO_4) are also recovered. Collection from remote areas is less commercially viable.	Australian Dangerous Goods (ADG) Code and associated legislation. Hazardous waste transport regulations. ABRI packaging standards
Lithium Ion										
Lithium cobalt oxide ($LiCoO_2$), also known as Li-cobalt	Mature technology. Commonly used in mobile phones & laptops.	Lithium ion batteries (including lithium ion polymer batteries): 3480	Lithium, iron, aluminium, copper, cobalt. Cobalt is up to 24% of battery weight.		None	TES-AMM/Recupyl (Singapore) Umicore (Belgium) INMETCO (US) Retriev Technologies (US) (formerly Toxco)	MRI (to Kobar) Powercell (to Nippon Recycle Center Corp) Sims E-Recycling (to Umicore) Application by Beverich	MRI Sims E-Recycling TES-AMM Powercell	Cobalt, copper, aluminium and carbon can be recovered. No local recycling (all currently exported) Safety risks have to be	Australian Dangerous Goods (ADG) Code and associated legislation.

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						Toxco (US & Canada) Accurec (Germany) Recupyl (France) SNAM (France) Kinsbursky Brothers (US) Kobar (Korea) Nippon Recycle Center Corp (Japan)	Holdings (to Kobar)		managed e.g. by fully discharging prior to recycling	
Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$), also known NMC	New technology. Used in power tools, e-bikes, electric vehicles, medical applications.	As above	Lithium, nickel, manganese, cobalt. Cobalt makes up to 8% of the battery weight.		None	As above	As above	As above	Cobalt, nickel, copper, aluminium and carbon can be recovered. The batteries have lower value to recyclers than $LiCoO_2$ due to reduced cobalt.	As above

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Lithium iron phosphate ($LiFePO_4$), also known as Li-phosphate or Li-ferrous	New technology. Applications as above.	As above	Lithium, iron, phosphate, aluminium, copper, organic electrolyte, graphite	Exide Technologies Heter Electronics Group Alevo	None	As above	As above	As above	Iron, copper and aluminium can be recovered. No cobalt means they have a lower commercial value to recyclers than other Li-ion types.	As above
Lithium manganese oxide ($Li-Mn_2O_4$), also known as Li-manganese, LMO or spinel	New technology. Applications as above.	As above	Lithium, manganese, graphite	Century Yuasa	None	As above	As above	As above	Manganese, copper and aluminium can be recovered. No cobalt means they have a lower commercial value to recyclers than other Li-ion types.	As above
Lithium manganese dioxide (primary battery)	New technology. Military applications.	As above	Lithium, manganese		None	As above	As above	As above	As above	As above

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Lithium titanate ($Li_4Ti_5O_{12}$), also known as Li-titanate	New technology (improved safety). Applications include grid storage, electric powertrains, electric vehicles (Mitsubushi & Honda).	As above	As for Li-manganese but with Lithium titanate anode	Toshiba, Altairnano, Leclanche, Seiko, YABO	None	As above	As above	As above	Manganese, copper and aluminium can be recovered; possibly the titanium.	As above
Lithium nickel cobalt aluminium oxide ($LiNiCoAlO_2$), also known as NCA	New technology. Applications similar to above.	As above	Lithium, nickel, manganese, cobalt, graphite		None	As above	As above	As above	Cobalt, nickel and manganese can be recovered.	As above
Lithium sulphur (Li-S)	Emerging technology (5-10 years)	As above	Lithium, sulphur, carbon	GS Yuasa	None	None	None	None	Unknown	As above
Lithium polymer, also known as	These are not considered to be a distinct chemistry type as they can be built on most of the other lithium chemistries including Li-cobalt, NMC, Li-phosphate and Li-manganese The anode and cathode materials are the same, but there are differences in the electrolyte (solid or gell).[3]									

1. http://batteryuniversity.com/learn/article/the_li_polymer_battery_substance_or_hype

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Lithium ion polymer										
Flow batteries										
Zinc bromine ($Zn\text{-}Br_2$)	Emerging technology. Grid storage.		Hydrochloric acid, Zinc bromine organic additives, plastics, carbons	RedFlow (Australia)	None		NA	Redflow is investigating recovery options	Recycling not currently available but should be relatively simple (similar to ULAB) – could recover the zinc bromine, plastics & acid.	
Zinc iron redox flow	As above		Zinc, iron, electrolyte	ViZn			NA		Potentially recyclable	
Vanadium flow	As above.		Vanadium, sulphuric acid, plastics, carbons	Prudent Energy Imergy Power Systems	None		NA		As above – could recover vanadium, acid, plastics[4]	
Other										
Nickel cadmium (NiCd)	Mature technology		Nickel, cadmium, steel, plastic		MRI (Aust) Pty Ltd	INMETCO (US) Kobar (Korea)	MRI (to Kobar)	MRI Powercell Dodd & Dodd Group	Nickel, cadmium, steel & plastics are recovered	Australian Dangerous Goods (ADG) Code and

[4] http://www.triplepundit.com/2015/02/dark-horse-may-outdo-lithium-ion-battery-storage/?utm_source=WEEKLY+TriplePundit+Mailing+List&utm_campaign=0e75f4e390-Weekly_May_29_20145_23_2014&utm_medium=email&utm_term=0_1d50d22c4a-0e75f4e390-220398313

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					(vented wet cell NiCd only)	Kinsbursky Brothers (US) Nippon Recycle Center Corp (Japan)	Dodd & Dodd Group (to Kobar) Powercell (to Nippon Recycle Center Corp) Application by Beverich Holdings (to Kobar)			associated legislation. Hazardous waste regulations. ABRI packaging standards
Nickel metal hydride (NiMH)	Mature technology Automotive (Toyota Prius)	Batteries, nickel-metal hydride: 3496	Nickel, rare earth elements, steel, aluminium, manganese, zinc, cobalt			Umicore Belgium) INMETCO (US) Kinsbursky Brothers (US) Nippon Recycle Center Corp (Japan)	MRI (to Kobar) Powercell (to Nippon Recycle Center Corp) Application by Beverich Holdings (to Kobar)	MRI Powercell	High nickel content and a significant amounts of cobalt make these attractive to recyclers. Nickel, rare earth elements, steel, manganese, zinc, cobalt are recovered	?
Sodium nickel chloride ($NaNiCl_2$)	Mature technology Heavy duty	Batteries containing	Nickel, sodium, chloride	GE	Potentially recyclable within	INMETCO (US)	None	None	Fully recyclable within existing	?

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(ZEBRA)	hybrid and electric vehicles e.g. buses, trucks Back-up, energy storage	sodium: 3292	(common salt), sodium, aluminium, iron, copper, plastics		existing industries for the production of stainless steel and road paving[5]	Xstrata Nickel (Canada) (?)			industries for the production of stainless steel and road paving[6]	

[5] http://www.eurobat.org/battery-technologies; http://corrente.gse.it/Lists/GSE%20Contenuti/Attachments/654/It_FIAMM.pdf

[6] http://www.eurobat.org/battery-technologies; http://corrente.gse.it/Lists/GSE%20Contenuti/Attachments/654/It_FIAMM.pdf, http://www.acea.be/uploads/publications/Rev_of_Battery_technology_-_full_report.pdf