Canadian Vehicle Manufacturers' Association
Association canadienne des constructeurs de véhicules

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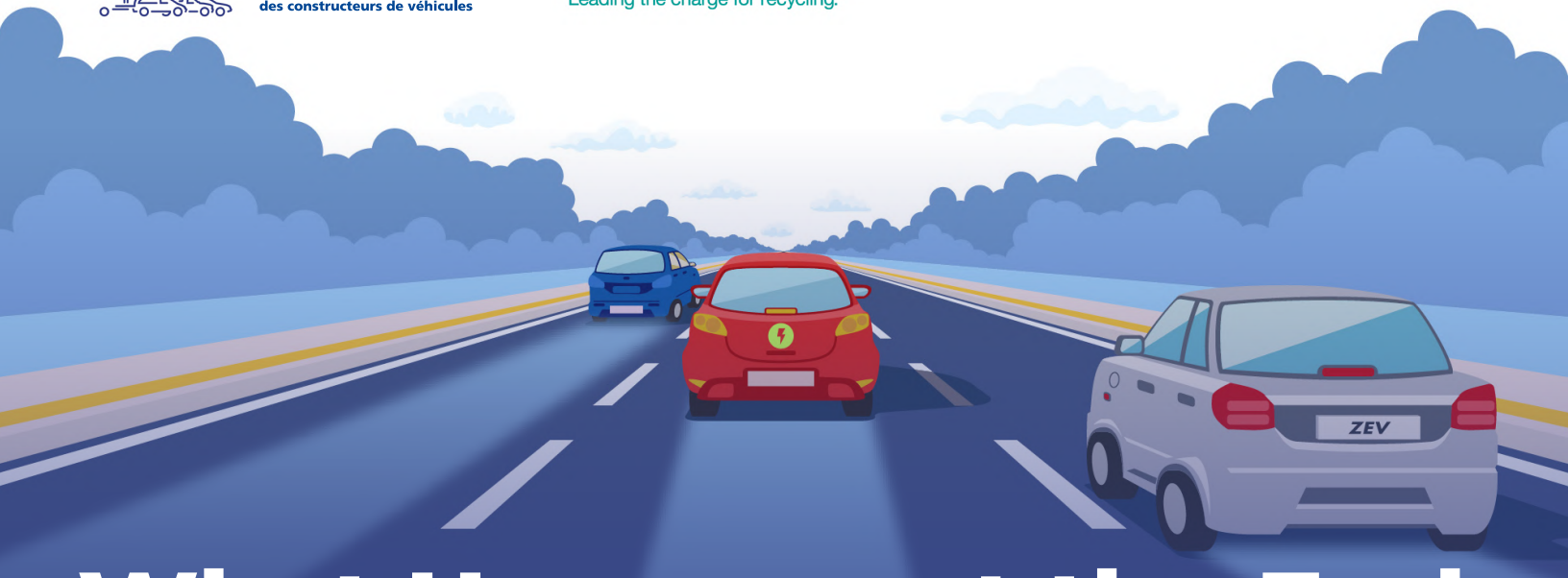


What Happens at the End of the Electric Vehicle Battery's Journey?

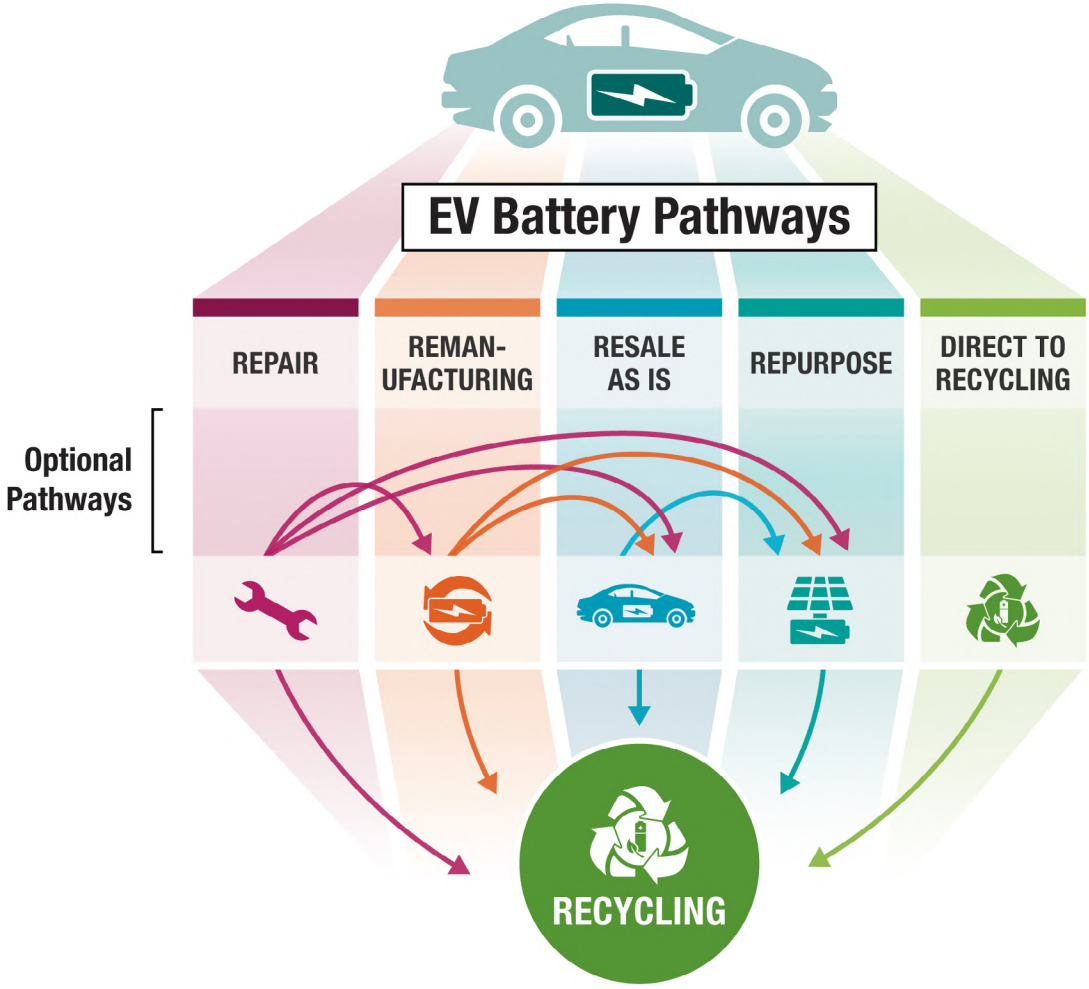
Now that we have reviewed electric vehicle batteries (EVBs), their growth and where these batteries will be removed from the vehicle in the two previously published fact sheets [1][2], it's time to explore what happens to these EV batteries after they are removed from an electric vehicle. A common misperception is that EV batteries will end up in a landfill or be indiscriminately discarded, and all the valuable materials contained within the batteries will be wasted. This is not the case. The great news is that there are multiple pathways available to address EV batteries at the end of their vehicle life journey that do not include landfilling. In fact most provincial waste regulations would prevent an EVB from even entering a landfill. More importantly, the combination of an EVBs size and weight, along with the specialized tools and training required to remove them are important factors that help to ensure these batteries are not inadvertently ending up in a landfill or otherwise abandoned.

So, what does happen to EVBs when they are removed from a vehicle?

REDUCE, REUSE, RECYCLE: HOW DOES THIS APPLY TO EVBS?

In the automotive world of EV batteries, the **typical environmental management hierarchy of 'reduce, reuse, recycle' becomes a little more complex.**

As depicted in the graphic below, an EVB may be directed to any or all of the possible pathways depending on the EVB owners business model, processes, and overall health of the battery. The overarching goals are typically to prioritize extending the life of the EVB through either repair, remanufacturing, repurposing, or reselling as is, and then recycling the battery when its working life is complete.



All paths lead to recycling.

Source: Call2Recycle®

It is important to understand recycling is the ultimate destination for all EVBs and this has environmental benefits. Recycled battery metals – lithium, nickel, cobalt, manganese, graphite, copper, and aluminium – are used in the manufacture of new products, and in the near future will be used to make new batteries (reducing demand for newly mined metals).

Plastic is either removed from the battery packs before processing and then recycled, or the entire battery is shredded followed by recovering plastics in a float-sink process, with the plastics being recovered, and then recycled.

UNDERSTANDING THE *5Rs*:

Repair – Doing minor repairs to an EVB to allow for ongoing use in an EV.

Remanufacturing – The ability to extend a battery's life by assessing a damaged, defective, or poorly performing battery pack and subsequently replacing only faulty cells/ modules/components. The battery is remanufactured (or rebuilt) to a like new condition suitable for redeploying in a vehicle, thus extending its life.

Resale as is – Resale can refer to any owner of the battery reselling it as is. Buyers are sourcing the battery as a used part for their EV.

Repurposing – Commonly referred to as preparing a battery for a "secondary life". An EV battery that no longer meets performance requirements for use in a vehicle is repurposed by identifying useful components, assessing their suitability for an alternative use, and if appropriate the battery is reconfigured for use in alternative non-vehicle applications such as energy storage or backup power for residential/commercial/industrial uses.

Recycling – The process of returning a battery to either its original metals to be sold into the market for use in new non-battery products or using advanced processes to extract materials at a quality sufficient to be re-incorporated back into new EVB components.

This fact sheet now looks at Remanufacturing, Repurposing, and Recycling in more detail.

REMANUFACTURING

Remanufacturing automotive components is not a new concept. In fact, the remanufacturing of engines, catalytic converters, transmissions, and other valuable automotive components has been a common practice for decades. Therefore, it is not surprising that many OEMs have incorporated remanufacturing of EV batteries into their current business practice such that when they are removed at a dealer or automotive service centre they are automatically sent to a remanufacturer. Remanufactured EVBs are batteries that meet the same high standards as the original EVB and can be used as service and replacement batteries. Any EV battery cells/modules that are removed and cannot be remanufactured are either repurposed in a second life application or sent for recycling.

Remanufacturing is highly valuable as it keeps useable cells and modules in service, supports a circular economy and reduces the need for new battery production, minimizing the need for mining new virgin materials. The process requires customized software, specialized equipment, and skilled labour.

Today there are only a few companies currently offering EVB remanufacturing services to automotive manufacturers in North America (Map 1). Remanufacturing requires a reliable and steady supply of EVBs in order to be efficient and effective. As the number of EVBs in the market is still low, remanufacturing sites consolidate batteries from a large geography.

REPURPOSING

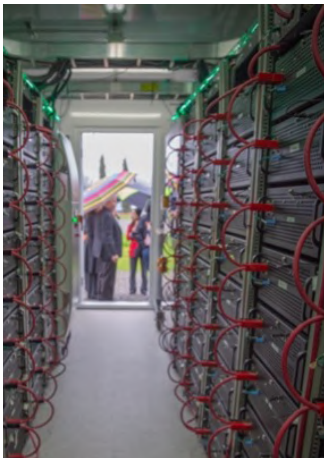
It is suggested EV batteries will have more than half of their useful capacity left when removed from a vehicle. Batteries may be removed due to reduced charging capacity, collision, software issues, battery pack upgrades, and other causes. Often times, it may be more appropriate to repurpose these batteries in a non vehicle “second life” setting rather than sending them for remanufacturing or recycling.

Used Chevrolet Volt batteries are helping keep the lights on at the new General Motors Enterprise Data Center at its Milford Proving Ground in Milford, Michigan. Five Volt batteries work with an adjacent solar array and two wind turbines to help supply power to the data center’s administrative offices.

Photo by John F. Martin for General Motors

Commercial-scale second-life battery system at the Robert Mondavi Institute For Wine and Food Science, a combined winery, brewery, and food processing complex located in Davis, California. This 300 kW energy storage system is paired with 200 kW of solar PV for peak demand reduction of 20% and at times more. Batteries sourced from retired electric vehicles.

Photos courtesy of RePurpose Energy



View from inside energy storage unit

The energy storage unit is built into the shipping container

A battery pack or module is repurposed when it is disassembled, components are assessed and those meeting a certain performance standard are assembled with new software and/or controls into a new finished product, not intended for vehicle use. In certain instances entire battery packs are repurposed without disassembly. If the repurposed batteries are redirected for a new energy storage product then it is paired and calibrated to an energy source such as solar panels, wind generator, or an electrical grid.

Several larger repurposers have been identified in North America at the time of publishing this fact sheet (Map 1). The total number of repurposers is difficult to determine as many companies and entrepreneurs are still evaluating the potential for larger commercial enterprises.

New products produced using repurposed cells, modules, or packs are being targeted for use in the residential, commercial, and municipal sectors for:

- Alternative energy source to provide power (commercial applications)
- Emergency back up power (all sectors)
- Off-grid power source (remote areas)
- Managing peak power demand (all sectors)
- Auxiliary power (within recreational vehicles or maritime vessels)
- Off-road vehicles (golf carts being one example)

RECYCLING

Recycling of EV batteries has been undergoing significant innovation and financial investment over the last 10 years. Until recently there were only a handful of recyclers in North America that accepted and processed EVBs. Many of these initial recyclers use traditional recycling processes (see pyrometallurgical recycling below) to recover the valuable metals in the batteries. In North America, there are several new recycling facilities that use more advanced hydrometallurgical processes, and there are at least another half dozen sites that have been announced or are currently under construction.

Pyrometallurgical Recycling[1]

Traditional recycling technology is sometimes referred to as pyrometallurgical recycling which uses high temperatures to essentially melt and separate base metals such as cobalt, manganese, and nickel. This method can be used to recycle both lithium-ion batteries as well as nickel-metal hydride batteries (NiMH). Recovery rates are up to 85% for the base metal battery components which can be sold as raw materials for the production of new products, but are not suitable to be directly reused in EV battery manufacturing without additional processing[2].

Source:
[1] For more detailed information on these processes please visit Nature via www.nature.com/articles/s41586-019-1682-5
[2] Call2Recycle

Hydrometallurgical Recycling[3]

Hydrometallurgical treatments involve the use of aqueous solutions to leach the desired materials contained in the battery with a stated recovery rate of 95% and higher for battery components. Some of these facilities have developed, or are in process of developing, proprietary technology to recover the base metals of nickel, cobalt, manganese, and lithium that are the metals used in cathodes, which in turn is used in the manufacturing of new battery cells. Hydrometallurgical processes have also been refined to recover additional materials such as copper, aluminum, and other battery materials which increases the overall battery recycling efficiency.

At the time of writing, up to four of the hydrometallurgical processors in North America are at various stages of developing the capability to manufacturer the cathode precursors which in turn will be used to directly produce new EVB components. Many of the other recyclers have indicated their intent to build new facilities or modify their processes to follow suit over the coming years.

Table 1: Current Recycling Facilities Across North America

Presented in alphabetical order

Canada	Plant	Chemistry	Process
American Manganese	Pilot stage complete; building demonstration plant	Lithium	Hydrometallurgical
Li-Cycle	Commercial Scale	Lithium	Hydrometallurgical
Lithion	Demonstration Plant	Lithium	Hydrometallurgical
Retriev Technologies	Commercial Scale	Lithium	Hydrometallurgical
United States	**Plant**	**Chemistry**	**Process**
Battery Resourcers	Demonstration Plant	Lithium	Hydrometallurgical
Inmetco	Commercial Scale	NiMH	Pyrometallurgical
Interco	Commercial Scale	NiMH, Lithium	Pyrometallurgical
Li-Cycle	Commercial Scale	Lithium	Hydrometallurgical
Recycling Coordinators	Commercial Scale	NiMH, Lithium	Pyrometallurgical
Redwood	Commercial Scale	NiMH, Lithium	Hydrometallurgical
Retriev Technologies	Commercial Scale	NiMH, Lithium	Hydrometallurgical

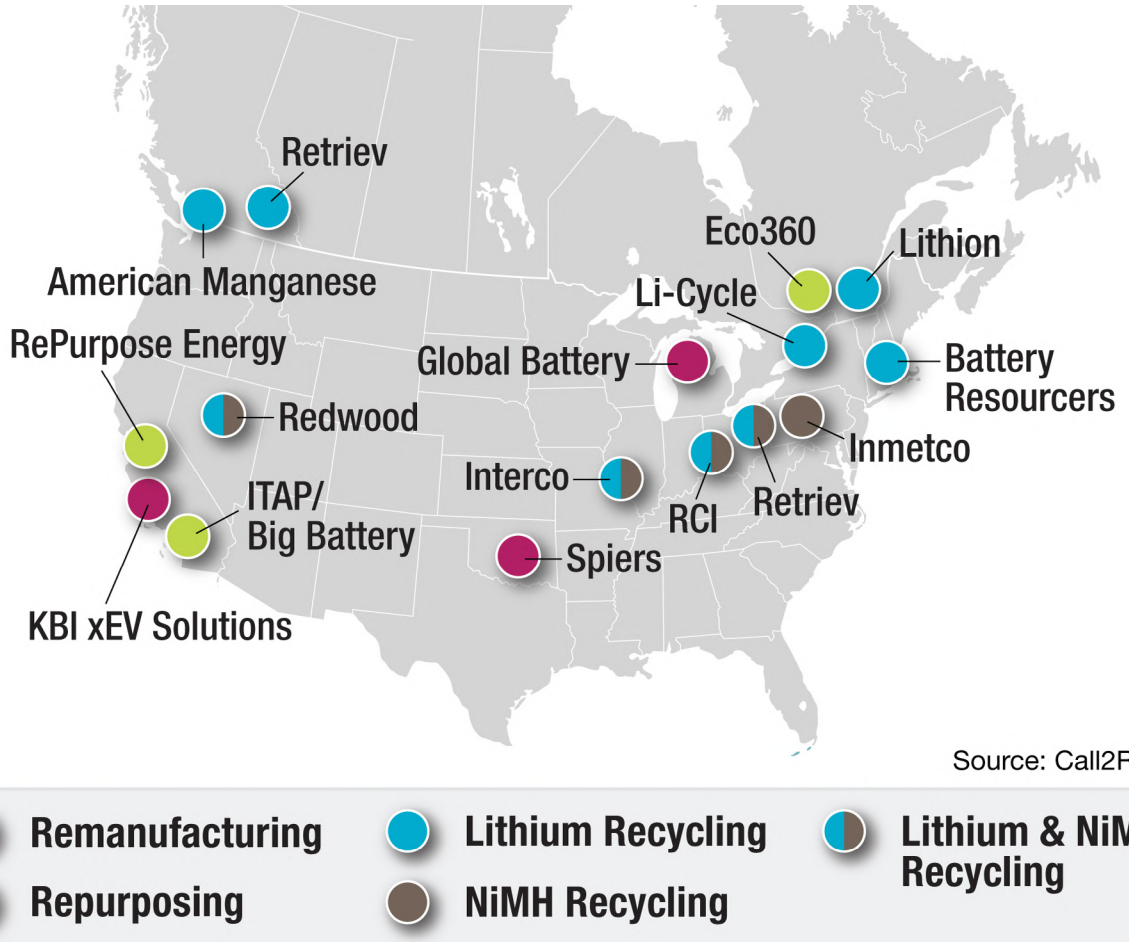
Source:
[3] For more detailed information on these processes please visit Nature via www.nature.com/articles/s41586-019-1682-5

Lithion Recycling Demonstration Plant (hydro)
Source: Lithion

Retriev Technologies Lancaster Commercial Scale Plant (hydro)
Source: Retriev

Li-Cycle Commercial Scale Plant (hydro)
Source: Li-Cycle

Map 1: North American EVB Management Sites



Source Call2Recycle
Facility list compiled by Call2Recycle based on publicly available information November 15, 2021.

TO REMANUFACTURE, REPURPOSE, OR RECYCLE?

Choosing between remanufacturing, repurposing or recycling for each EV battery requires the owner of the EVB to consider a number of criteria. Owners will consider the overall capacity/health of their battery, access or proximity to the nearest processing facility, the market price for batteries versus base metals, as well as the overall costs/value proposition. **There is no single pathway that is superior and therefore should be prioritized.** All paths have environmental and financial considerations, and as the EV battery ecosystem develops and innovates, market forces may pull or push batteries towards any of these options or completely different options as they become available.

NEXT STEPS

This is the last of the series of facts sheets on the journey of electric vehicles batteries. As part of our education series, we intend to publish a more comprehensive white paper that will further explore additional topics related to electric vehicle battery management.

If you wish to be added to our distribution list or receive information on this project, please direct any inquiries to **ProjectEVbattery@cvma.ca.**