Roadmap and Implementation Plan for the Management of End-of-Life Electric Vehicles in Canada

Appendices - Research Technical Papers to Support Roadmap Development

Final

Prepared for

Automotive Recyclers of Canada

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Appendix A – Research Questions

A series of ten research questions (see list in Table 1) were explored in order to prepare the Automotive Recyclers of Canada (ARC) Roadmap.

Table 1: Research Questions Explored as Background to Roadmap Development

#	Research Question
1	What is the metal content difference between electric vehicles and internal combustion engine vehicles?
2	Which critical minerals are presently being used in EVs?
3	What different materials are used in EVs that may require new approaches for end-of-life?
4	Which EV parts can be re-used, re-purposed, rebuilt and recycled, and by whom?
5	How are automotive recyclers currently managing EV parts/components (including advanced batteries and rare earth magnets)?
6	What are the technical, safety, environmental, health and/or financial/commercial challenges and how can they be overcome?
7	Are there tools, information, processes and technologies to evaluate the state of health of a battery at end-of-life to determine what can be re-used and what needs to be recycled?
8	Will the automotive dismantling sector have sufficient infrastructure/capacity and work force expertise to manage EVs at EOL and, if not, what needs to be done?
9	Do the OEMs (original equipment - auto and battery - manufacturers) need to be involved in the management of EVs at EOL and if so, how?
10	Are there any regulatory barriers inhibiting the safe and cost-effective management of EVs at end of life?

The background research results are presented under a number of headings in this Appendix. While the Appendix provides more details than in the Roadmap itself, the reader is advised that there may be some duplication of text and numbers between the two parts of the report.

A.1 Canada's Emerging Electric Vehicle Supply Chain

ARC is a voluntary industry association representing seven provincial/regional associations across Canada. These associations in turn represent 375 professional automotive recyclers across Canada. Formed in 1997, ARC members have been at the forefront of the auto reuse and recycling industry, working with governments, insurers, manufacturers, repairers, vendors and allied industries to bring responsible environmental progress to the industry.

The "story" of auto recycling globally, and specifically in North America is very positive. At present in Canada, 1.6-1.8 million vehicles are retired from the road on an annual basis. The metal value associated with End-of-life vehicles (ELVs) results in a high percentage of vehicles (over 94%) being collected for recycling purposes. Of the 94%, approximately 83% of current ELVs by weight will be reused or recycled when properly dismantled. Today's ELVs are made primarily of metals; 74% to 77% of their weight is metal (88-91% ferrous and 9-12% non-ferrous).[1] Increasingly ELVs also contain precious and rare earth metals that might be recoverable through dismantling. Auto recycling expertise currently lies within the present-day automotive recycling sector of 1,500-2,000 SMEs across Canada.[2]

ARC Members process end-of-life vehicles (ELVs) for parts reuse and materials recycling, while managing the waste by-products from the collection of these resources in an environmentally responsible manner. Members are all audited to the Canadian Auto Recyclers Environmental Code (CAREC), developed for Environment Canada for the National Vehicle Scrappage Program.

ELVs processed by members come in two forms – older "scrap" vehicles, and newer total loss vehicles from the insurance industry. In both cases, an ELV is defined as a light-weight vehicle where the last owner determines the cost to repair and maintain the vehicle exceeds its value as parts and material. Dismantlers are the reuse experts in the end-of-life (EOL) industry; that is, after de-polluting each vehicle of hazardous/explosive materials, they harvest re-sellable parts for sale to auto repair shops and "do-it-your-selfers" (DIY players). Once these parts are removed, the hulk is sent off to shredders to be crushed and sold as "green steel" (that is selling at historically high prices as of July 2022). Some additional metals (and plastics in a few locations, mainly in Europe) are also removed from the auto shredding residue (ASR) that remains.

The Canadian Minerals and Metals Plan (CMMP) recognizes that Canada's recycling and reprocessing capacity and capabilities are of interest because they support sustainability and competitiveness in the minerals sector. Critical minerals are the building blocks for a clean, digitized economy. Canada is seeking to capitalize on the rising global demand for critical minerals driven largely by their role in the transition to a low carbon economy. Essential for renewable energy and clean technology applications (batteries, magnets, solar panels, wind turbines, etc.), a changing array of critical minerals are also required for advanced manufacturing supply chains, including the automotive sector.

Canada is the 11th largest automotive producer in the world[3] including internal combustion and electric passenger cars, trucks, buses, auto parts and systems, truck bodies and trailers as a well as tires and machine tool die molds. Automotive manufacturing is one of Canada's largest industrial sectors, and contributes over $16 billion to Canadian GDP.[4]

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[1] Steve Fletcher interview, December 2021
[2] Automotive Recyclers of Canada (ARC), Pre-Budget Submission, February 19 ,2021
[3] https://www.cvma.ca/industry/facts/
[4] https://www.cvma.ca/industry/facts/

Auto manufacturing accounts for 135,000 direct jobs in Canada, mostly located in Ontario. The auto industry is responsible for over 500,000 direct and indirect jobs across Canada. For every one auto assembly job, approximately ten other jobs are created in upstream and downstream activities.[5]

Motor vehicle and part sales were $74.2 billion in 2020, accounting for 12.1% of total sales ($611.2 billion). This part of the sector directly employs more than 117,000 people with an additional 371,400 in aftermarket services and dealership networks.[6]

Canada is currently the 3rd largest importer of electric vehicles and a leading exporter of electric buses. At the time of this report, only one automotive plant in Canada currently manufactures EV cars (Stellantis in Windsor with 9,000 units/year). However, Stellantis is investing $3.6 billion to retool and modernize its Windsor and Brampton assembly plants in Ontario to manufacture fully electric and hybrid electric vehicles.[7] Other recent Canadian EV investment announcements include $1.8 billion by Ford to retool its Oakville plant; Honda's announcement unveiling a $1.4 billion plan to develop next generation hybrids in Ontario; and GM's plans to produce electric vans in Ingersoll starting in 2021. There is also an opportunity for Canada to become a significant player in the global electric battery supply chain, from mining and refining through to battery and EV production. Three recent announcements in the Canadian battery production space include:

- BASF's securing land to build to build a cathode active materials and battery metals recycling plant in Quebec by 2025;
- GM and Posco's plan to build a $500-million Canadian cathode active material factory in Quebec to supply Ultium battery factories; and
- LG and Stellaris announced plan to build a $5 billion battery manufacturing plant in Windsor Ontario.

Canada's 2022 federal budget contains $85 billion in new spending, dedicating nearly 10% of that spending to the zero-emission sector, including a $3.8 billion commitment over the next 8 years towards implementing a critical materials strategy.[8] In addition, the government will provide up to an additional $1 billion to Innovation, Science and Economic Development Canada for the Strategic Innovation Fund. The Fund's goal is to "make Canada a more attractive destination for critical materials investment and to secure valuable agreements that would increase production of goods like electric vehicles and batteries."[9]

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[5] https://www.cvma.ca/industry/facts/
[6] https://www.cvma.ca/industry/facts/
[7] https://electricautonomy.ca/2022/05/03/stellantis-ontario-windsor-brampton-evs/
[8] htps://elctricautonomy.ca/2022/04/08budget- budget2022-canada-zero-emissions-vehicle/ pp. 2&3
[9]htps://elctricautonomy.ca/2022/04/08budget- budget2022-canada-zero-emissions-vehicle/
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A.2 Research Question #1: What is the metal content difference between EVs and ICEV?

A.2.1 Research Conclusions and Information Gaps

One of the most significant changes between ICEV and EVs will be the replacement of the metal castings and steel components used in ICE drivetrains and exhaust systems with the metals found in EV batteries, motors, battery housings and wiring.

- Since battery EVs (BEVs) have no ICEs or exhaust systems, the weight of cast aluminum and steel associated with these components is eliminated. However, the larger battery packs in BEVs means higher levels of battery metals and more copper wiring than in HEVs and PHEVs.
- The average BEV contains almost four times as much copper as conventional ICEVs. This is located primarily in the motor, where it is required for rotor and stator windings as well as for the copper wiring needed in the battery management system (BMS).[10]
- The continued push for light-weighting will also result in more aluminum, high strength steel and plastic composites replacing regular steel in vehicle bodies and parts.
- EVs have more copper than ICEV because of increased electrical wiring.
- EVS also have more aluminum than ICEV.
- Copper: According to the Center for Automotive Research (CAR), the use of all types of steel in cars may fall from 65% of total curb weight in 2020 vehicles to 46% by 2040.[11]
- Aluminum: PHEVs and BEVs contain on average over 200 kg of aluminium (mostly in the battery tray) compared to an average of 160 kg of aluminium contained in an ICEV. At the high end, the Tesla Model S, with aluminum battery trays and body panels, contains 661 kg of aluminium.[12]
- Knowledge gaps at this time are related to the range of metal and materials composition of EVs manufactured by different OEMs.

A.2.2 Background Material

Metals in ICEV

Although there has been some displacement of steel in light duty vehicles with lighter aluminum alloys and plastics over time, the growing preference among North American consumers for larger SUVs and pickup trucks has resulted in the total metal weight in the average vehicle remaining relatively steady or increasing.[13]

A 2020 report by the American Chemistry Council (ACC) estimated that the average light duty vehicle built in North America in 2018 weighed 1805 kg and contained 1331 kg of metal whereas an average light duty

[10] The Materials Really Driving the EV Industry, matmatch.com, September, 2018
[11] argusmedia.com, Steel in autos to drop sharply thru 2040: CAR, September, 2020
[12] https://aluminiuminsider.com/aluminium-vs-steel-in-electric-vehicles-the-battle-goes-on/
[13] https://www.forbes.com/wheels/news/light-trucks-now-outselling-cars/

vehicle built in 2009 weighed 1751 kg and contained 1254 kg of metal.[14] A complete comparison of metal content from the report is provided in Table 2.

Table 2: Comparison of Metal Content in North American Light Duty Vehicles: 2009 vs. 2018

Metal Type	2009 Weight (kg)	2018 Weight (kg)	Percentage Change
Regular Steel	663.1	551.1	-17%
High and Medium Strength Steel	231.3	350.2	+51%
Stainless Steels	30.4	32.2	+6%
Other Steels	13.6	13.6	0%
Total Steel	**938.4**	**947.1**	**+1%**
Iron Castings	91.2	112.9	+24%
Aluminum	144.7	193.7	+34%
Magnesium	5.0	4.5	-10%
Copper & Brass	31.8	31.3	-2%
Lead	18.6	15.4	-17%
Zinc Castings	4.1	4.1	0%
Powder Metal	18.1	20.0	+10%
Other Metals	2.3	2.3	0%
Total Metals	1,254.2	1,331.3	+6%
Total Vehicle Weight	1,750.9	1,804.8	+3%
Metals as a % of Vehicle Weight	71.6%	73.8%	

Source: American Chemistry Council, Plastics and Polymer Composites in Light Vehicles, August, 2019

What is particularly notable in Table 2 is:

- the 51% increase in high and medium strength steel displacing regular steel; and
- the 34% increase in light-weight aluminum to 193.7 kg per vehicle.

According to a February 2020 article in Modern Casting, the average 4,000 lb (1816 kg) ICEV has 600 lbs. (272 kg) of cast metals. An ICEV powertrain has about 2,000 parts, many of which are cast, whereas electric vehicle powertrains will have about 20 parts, few of which will be cast.[15]

Metals in EVs

Metal content in HEVs and PHEVs vs. full battery BEVs varies significantly. Both HEVs and PHEVs typically have cast aluminum ICEs, steel exhaust systems, catalytic converters, electric motors and electric batteries. Since BEVs have no ICEs or exhaust systems, the weight of cast aluminum and steel associated with these components is eliminated. However, the larger battery packs in BEVs means higher levels of battery metals and more copper wiring than in HEVs and PHEVs.

[14] American Chemistry Council, Plastics and Polymer Composites in Light Vehicles, August, 2019
[15] Rich Jefferson, What will the Rise of Electric Vehicles Mean for Metalcasters?, Modern Casting, February 2020

BEVs weigh more than similar gasoline-powered models because of the weight of the electric battery pack. The Ford F150 Lightning will weigh about 725 kg more than a similar gas-powered F-150 truck. Similarly, the electric Volvo XC40 Recharge weighs about 450 kg more than a gas-powered Volvo XC40.[16]

As a result, the transition to EVs is driving new light-weighting initiatives in the auto industry. Aluminum, carbon fiber composites, high-strength steel and other light-weight materials are all being used to offset the weight of electric batteries and increase range and load capacity. Major R&D initiatives are currently underway to identify new lightweight materials for BEVs.

Aluminum: The drive for light-weighting in BEVs is expected to boost demand for aluminum. On average, a BEV has a higher aluminium content than a traditional ICEV, with significantly more aluminium is used in a BEV platform.

PHEVs and BEVs contain on average over 200 kg of aluminium (mostly in the battery tray) compared to an average of 160 kg of aluminium contained in an ICEV of similar size. Some larger BEVs could contain as much as 363 kg of aluminium compared to approximately 160-193 kg on average for ICEVs. At the high end, the Tesla Model S, with aluminum battery trays and body panels, contains 661 kg of aluminium.[17]

In a "most likely" scenario, global demand for aluminium in EVs could grow from about 500,000 tonnes in 2020 to more than 17 million tonnes by 2030.[18]

Steel: Steel will continue to be used in three BEV components – the motor, the car body and the battery housing. Between 40 and 100 kg of "non-grain oriented electrical steel" is used in the construction of a BEV motor.[19]

High strength, lightweight steel competes with aluminum and carbon composites in BEV car bodies. BMW, for example, will be constructing its model i5 in steel and light alloys from 2021, rather than using carbon as it did in the i3. In addition, Tesla is reducing the share of aluminum and titanium in its model 3 in favor of steel.[20]

Lightweight steel also competes with aluminum, titanium, and carbon fibre or glass fiber plastic composites for use in electric battery housings. The large battery packs in BEVs need a correspondingly large housing which offers sufficient protection in the event of a crash, and prevents substances from leaking after an accident. Although heavier, steel has a superior ability to withstand distortion during accidents and is less expensive than the other options.[21]

Nonetheless, the amount of steel in automobiles is expected to fall sharply over the next two decades, replaced increasingly by aluminum and plastic, as automakers continue to strive for lighter weight vehicles and as sales of BEVs increase. According to the Center for Automotive Research (CAR), the use of all types of steel in cars may fall from 65% of total curb weight in 2020 vehicles to 46% by 2040.[22]

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[16] Peter Valdes-Dapena, Why EVs are heavier than gas-powered cars: batteries, CNN Business, June, 2021
[17] https://aluminiuminsider.com/aluminium-vs-steel-in-electric-vehicles-the-battle-goes-on/
[18] Electric vehicles to drive metals demand higher, think.ing.com, October, 2021
[19] Viktoria Steiniger, The Role of Steel in Electromobility, voestalpine.com, March 2019
[20] Viktoria Steiniger, The Role of Steel in Electromobility, voestalpine.com, March 2019
[21] Viktoria Steiniger, The Role of Steel in Electromobility, voestalpine.com, March 2019
[22] argusmedia.com, Steel in autos to drop sharply thru 2040: CAR, September, 2020

Copper: The average BEV contains almost four times as much copper as conventional ICEVs. It is located primarily in the motor, where it is required for rotor and stator windings as well as for the copper wiring needed in the battery management system (BMS).[23]

According to the Copper Development Association (CDA), the average copper content of an ICEV is around 23 kg, increasing to 60 kg for PHEVs and to 83 kg for BEVs. In a “most likely” scenario, demand for copper could grow from around 440,000 tonnes in 2020 to 3.2 million tonnes by 2030.[24]

Copper is also required in EV charging infrastructure. A home charger can use 2 kgs of copper whereas a public direct current fast charging (DCFC) could use up to 25 kg of copper per charger. Copper demand in charging infrastructure was approximately 10,000 tonnes in 2020 and is expected to expand to approximately 47,000 tonnes by 2030.[25]

Battery Metals: The majority of EVs use lithium-ion batteries (LIB), though battery chemistry mix and battery pack designs vary among manufacturers and are constantly evolving. The four main battery chemistries used in Lithium-ion batteries (LIBs) are presented in Table 3. Lithium cobalt battery (LCO) chemistry is not included in the table as it is not used extensively anymore because of its high cobalt content.

Table 3: Common LIB Chemistries Used in EVs in 2022

LIB Chemistry Term Commonly Used	Detailed Name of Battery Chemistry	Notes
NMC	lithium-manganese-cobalt oxide	Various formulations NMC 8:1:1, NMC 6:2:2. Numbers refer to the ratio of lithium to manganese to cobalt. Efforts are to reduce the cobalt concentration to reduce the cost of the batteries
NCA	lithium nickel cobalt aluminium oxides	
LMO	lithium manganese oxide (LMO	
LFP	lithium-ion-phosphate batteries	Used extensively in Chinese EVs to lower battery cost and because lithium, iron and phosphate are readily available materials. Of less interest to recyclers because no high value metals like nickel and cobalt

The raw materials that batteries use can differ depending on their chemical compositions. However, the four metals that are considered critical for LIBs are lithium, cobalt, manganese and nickel. Section A.2.3. provides more detail on these battery metals. The global demand for all four metals will grow substantially over the next decade.[26]

Platinum Group Metals: ICE, Hybrid and PHEV vehicles require catalytic converters, whereas they are not required in EVs which have no tail pipe emissions. A catalytic converter is part of the vehicle's exhaust system and helps to reduce emissions and reduce the noise the car produces. They contain rhodium, palladium and platinum. The catalytic converters in the Toyota Prius in particular are a target for theft because of their high metal value. Since the ICE in the Prius (and most other hybrids) doesn’t run all of the

[23] The Materials Really Driving the EV Industry, matmatch.com, September, 2018
[24] Electric vehicles to drive metals demand higher, think.ing.com, October, 2021
[25] Electric vehicles to drive metals demand higher, think.ing.com, October, 2021
[26] Electric vehicles to drive metals demand higher, think.ing.com, October, 2021

time, the catalytic converter doesn't have to work as hard. As a result, the converter is more likely to stay in better condition longer, thereby retaining more of its precious metals, and resulting in a high scrap value.[27]

Rare Earth Elements (REE): EVs contain more rare earth elements than ICEV, mostly located in some of the magnets. While ICEV contain small magnets to run many electrical switches (e.g., window wipers, windows, etc.), EVS contain more magnets related to the drivetrain. Locations which use magnets in both vehicles include a variety of motors located throughout the vehicle; electric seats; wiper blades; windows; some speakers; some fuel pumps and ignition coils; electric brakes; compressor; ERG valve; water pump; crank angle sensor; cooling fan; power fuel pump and other locations. All magnets are not made from REE; the amount varies by vehicle make and model, with higher end vehicles and luxury vehicles using more REE magnets.[28]

The following types of magnets (some are rare earth) are used in ICEVs and EVs:

- Neodymium (NDFEB, stands for neodymium, ferrous, boron), known as NEO – occasionally NEO magnets contain some praseodymium and dysprosium. The content of NEO magnets is about 25% ND; 65% ferrous; 1% boron from the literature[29]. Neo is largest part of market
- AlNiCo (pronounced Alnico) – much less common
- Samarian Cobalt - also not very common
- Ceramic/ferrite – much less common.

Both neodymium and samarian are used in different grades (strengths) and have different magnetic and physical properties. Neodymium magnets, the stronger of the two, are composed of alloys primarily of neodymium, iron, and boron. Magnets are found in both ICEV and EVs, related to the variety of motors throughout both vehicles. Generally, ICEV contain about 300-400 grams of NEO magnets, whereas EVs contain 2-5kg of NEO magnets.[30] They can replace the rare earth magnets with induction approach which uses more copper but is less efficient.

Tesla started in 2019 to combine engine types. Its S and X models have two motors: one with rare earth magnets, one without. The induction motor provides more power, while the one with permanent magnets is more efficient. Tesla has reported that including a rare earth motor boosted the models' driving range by 10%.

A.3 Research Question #2 - Which critical minerals are presently being used in EVs?

A.3.1 Research Conclusions and Information Gaps

[27] https://www.carparts.com/blog/what-cars-are-targeted-for-catalytic-converter-theft-the-most-often
[28] Personal communication Alex Forstner, Cycling Materials, Kingston Ontario 8th June, 2022
[29] Personal communication Alex Forstner, Cycling Materials, Kingston Ontario 8th June, 2022
[30] Personal communication Alex Forstner, Cycling Materials, Kingston Ontario 8th June, 2022

- The government of Canada has developed a list of 31 minerals considered critical for the sustainable economic success of Canada as set out in CMMP.
- Critical minerals currently being used in EVs include: aluminum, copper, cobalt; graphite, lithium, manganese, nickel, and rare earth elements (REE).
- Two information gaps currently exist related to critical minerals used in EVs, and when these minerals are likely to be available for recycling:
    - **EV sales and EOL vehicle estimates for Canada specifically** – while many international agencies have released projections, they are typically based on assumptions about metals availability, EV uptake and other unpredictable market forces, so their reliability is generally considered to be weak. Canada-specific projections would be interesting and possibly useful for ARC as it advances its Roadmap; and,
    - **Competing battery chemistries:** While many projections of future battery chemistries and changes to battery chemistries are available, these change constantly as new chemistries become viable. The long-term adoption of one battery chemistry is unlikely at this time, and lithium-based chemistries are expected to be used in the short to medium term. Adoption of any future battery chemistry will have a significant impact on supply estimates for critical minerals.

A.3.2 Background Information and Details

EVs commonly contain six “critical materials”, primarily with regard to battery production. These are:

- cobalt,
- graphite,
- lithium,
- manganese,
- nickel, and
- rare earth elements (REE)

Table 4 presents an estimate of the amount of critical minerals in a typical 60 kilowatt-hour (kWhr) LIB which contains 185 kg on average of various critical minerals.

Table 4: Critical Minerals in 60 kWhr Lithium Ion Battery in 2020[31]

Mineral	Cell Part	Amount in Average 60 kWhr EV Battery excluding electrolyte, binder, separator and battery pack casing (kg)
Graphite	Anode	52
Aluminum	Cathode, casing, current collectors	35
Nickel	Cathode	29
Copper	Current Collectors	20
Steel	Casing	20
Manganese	Cathode	10
Cobalt	Cathode	8
Lithium	Cathode	6 kg for cathode plus 45 kg for other components
Iron	Cathode	5
Total		185

A brief profile of each of these materials is presented below.

Cobalt: Cobalt is primarily used as a casement material for EV batteries. Because of high supply risks (a large amount of current cobalt supplies is found in locations such as DRC[32]), alternatives such as low cobalt and no cobalt battery chemistries (such as LFP) are being pursued. Canada produces cobalt, but not in a form suited for battery production at this time. Electra Materials in Timiskaming Shores is developing a cobalt production facility as part of its battery recycling business there.[33] BASF recently announced that it will produce cathode active materials (CAM) in Canada. Currently most cobalt supply is from DRC, with significant human rights concerns. Cobalt from DRC is processed into battery materials in China. Significant effort is underway to establish processing capacity in North America.

Graphite: Graphite is the main anode material for LIBs. Graphite for batteries accounts for only 5% of global demand; other uses include in steel making and numerous other applications. Both natural and synthetic graphite are used in LIB anodes. The blend depends on the battery maker and the relative cost of each. Generally, synthetic graphite is higher performing than natural graphite but 3 to 4 times more costly. Canada produces the bulk of graphite in North America. Nouveau Monde is developing a graphite mine in Quebec that will have the lowest carbon footprint of any graphite mine because of its use of electric mine vehicles and Quebec's zero carbon electrical infrastructure.

Lithium: Lithium is the most common EV cathode battery element. According to USGS, 74% of global production of lithium is used in manufacturing LIBs. An estimated 96% of the 2019 global output of lithium was produced by Australia, Chile, China and Argentina.[34] A number of lithium mines are in development or at the exploration stage in Canada. Production of lithium hydroxide or lithium carbonate needed for LIBs is not carried out in North America at this time.

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[31] https://elements.visualcapitalist.com/the-key-minerals-in-an-ev-battery/ "Visualizing the Key Minerals in an EV Battery "
[32] Democratic Republic of Congo
[33] See https://ca.proactiveinvestors.com/companies/news/979399/electra-battery-remains-on-schedule-to-commission-north-america-s-only-cobalt-sulfate-refinery-in-december-2022-979399.html
[34] USGS

Manganese: Manganese is used in various cathode chemistries (also for steel and dry cell batteries). No manganese mining operations are currently operating in Canada or the US, but manganese mining opportunities are being explored in Canada. As a result, North America is 100% import reliant for manganese supplies.

Nickel: Most LIB chemistries currently use include nickel, with some chemistries considered "high nickel". The current demand for nickel to make LIBs is small but growing as OEMs move away from battery chemistries that involve cobalt. Nickel demand forecasts suggest significant growth. Canada has nickel mines but does not produce the nickel hydroxide needed to make CAM. All current CAM production is in China. In 2021, 54% of battery capacity deployed globally in new EVs was powered by "high nickel" cathode chemistries (NMC 6-, 7-, 8-series, NCA, NMCA), 26% by "low nickel" cathodes (NMC 5-series and lower) and 20% by "no nickel" cathodes (primarily LFP). Tesla recently signed a multiyear nickel supply agreement with Vale. The agreement includes nickel from Vale's Canadian operations.[35]

REE: REE are used in permanent magnet motors, catalysts, glass polishing power and additives. Mostly Neodymium (NdFeB), but also can have dysprosium or terbium. Current forecasts are for greater than 500% long term demand increase in REE demand.

Battery production variations

The critical minerals contained in EV batteries vary depending on the battery chemistry. NMC and NCA are the most common li-ion chemistries used in EVs in North America. Currently, NMC cathodes account for nearly 28% of EV sales around the globe, and it has been predicted that market share will grow to 63% by 2027.[36] As the price of cobalt increases, it is estimated that the trend towards NMC and NCA batteries and away from other chemistries will continue.

In 2021, 54% of battery capacity deployed globally in new EVs was powered by "high nickel" cathode chemistries (NMC 6-, 7-, 8-series, NCA, NMCA), 26% by "low nickel" cathodes (NMC 5-series and lower) and 20% by "no nickel" cathodes (primarily LFP).[37]

LIB manufacturers have strived to reduce cobalt content in batteries because of the metal's high cost and due the fact that two-thirds of global supply is mined in the Democratic Republic of the Congo (DRC). Human-rights activists have raised concerns over mining conditions in the DRC, in particular over child labour and harm to workers' health. Also, like some other metals, the hazardous nature of cobalt requires safe use practices as well as assessment and management of associated handling risks.[38]

Manufacturers of NMC and NCA batteries have been able to reduce the level of cobalt in the cathode over time in order to reduce cost and supply risks as well as increase the battery's energy density. For example, the cathode in the original NMC 111 battery had an equal ratio of nickel, manganese and cobalt whereas

[35] Bloomberg, March 30, 2022, Vale Dodges Nickel Crises with Secret Deal to Get Supplies, https://www.bloomberg.com/news/articles/2022-03-30/tesla-dodges-nickel-crisis-with-secret-deal-locking-in-supplies?mc_cid=cbb37cb198&mc_eid=bab196c057

[36] https://www.mining.com/nmc-batteries-dominating-ev-sales-reach-63-global-market/

[37] https://www.adamasintel.com/nickelferous-battery-chemistries-led-the-pack-in-2021/

[38] https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/earth-sciences-resources/earth-sciences-federal-programs/minerals-and-metals-policy-government-canada/8690

the cathode in the newer NMC 811 (8-series) battery is made up of 80% nickel, 10% manganese, and 10% cobalt.

Lithium, cobalt, nickel and manganese each play an important role in giving batteries greater performance, high energy density and long service life. Current production of key LIB minerals and their known reserves are concentrated in limited countries. This is especially the case for lithium, cobalt and natural graphite, with the top three producing countries controlling well over 75% of the global output.

In some cases, one country is responsible for over 50% of global production. For instance, the DRC produces 70% of cobalt, while China is responsible for over 75% of mined natural graphite. Canada produces small quantities of most LIB raw materials, but exports most of these to China and other countries for processing.

The level of concentration of processing and refining capacity is even higher. China dominates the processing and refining landscape for battery minerals. China's share of global refining is about 65% for nickel, 82% for cobalt, 93% for manganese, and 100% for natural graphite.[39] The share of the top three producing countries in global production of key LIB minerals for 2021 is presented in Figure 1.

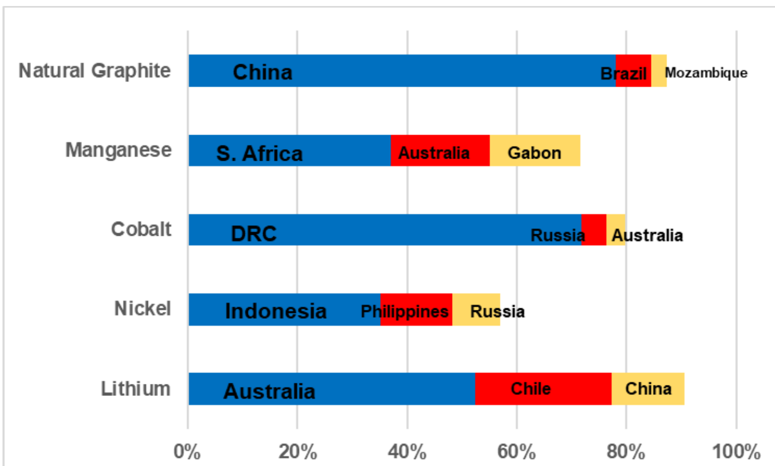

Figure 1: Share of Top Three Producing Countries in Global Production of Key LiB Minerals in 2021[40]

Data Gaps for Future Planning

Data needs which will impact on ARC membership are listed below:

EV sales forecasts – Canada has announced new electric vehicle sales goals targeting a 10% share for EVs by 2025, 40% by 2030 and 100% by 2040. This equates to about 3% of the vehicle fleet in 2025, 11% by 2030 and 60% by 2040. The International Energy Agency (IEA) projects 300 million EV sales by 2050 representing 60% of all new car sales.[41] About 3 million EVs were sold globally in 2020.[42] In Canada, 86,000 BEV and PHEV were sold in 2021, accounting for 5.2% of new registrations. That compares with

39 Benchmark Mineral Intelligence

40 Created using data from U.S. Geological Survey, 2022, Mineral commodity summaries 2022

41 International Energy Agency – Electric Vehicle Tracking report - November 2021

42 International Energy Agency – Electric Vehicle Tracking report - November 2021

54,000 in 2020, making up 3.5% of total vehicle registrations.[43] No publicly available projections of EVs being sold into the Canadian market annually over the next 10-20 years currently exist, although numerous projections have been developed both within government as well as through private companies. Reliable, publicly available EV sales projections are needed for Canada so that ARC members and others can model and predict when these EVs may arrive at auto recyclers under various scenarios.

Competing Battery Chemistries – 85% of current EV battery sales are comprised of four competing battery chemistries and technologies. As noted earlier, some of those choices relate to material costs, energy densities, perceived safety benefits and concerns about critical mineral supplies – e.g., shortages in the availability of cobalt and its high cost have led to the development of cobalt-free battery technologies. LFP in particular is gaining in popularity and is a dominant chemistry used in Chinese vehicles. Solid state batteries are expected to reach the market within five years, although they generally use similar materials to current LIB chemistries. Competing technologies in both batteries and other EV components and systems will continue to evolve.

A.4 Research Question #3: What Different Materials are Used in EVs that May Require Different Approaches at EOL?

A.4.1 Summary and Gaps

- Components that are different in EVs vs ICEVs include: LIBs, high-voltage cables more magnets and more printed circuit boards.
- Drivetrains and are completely different, but some Canadian auto recyclers have been successful in removing and reselling EV drivetrains
- Data gaps include the chemistry of the LIB in each different EV as well as the location and composition of magnets and circuit boards

A.4.2 Background

Vehicle Component Comparison[44]

The transition from ICEVs to BEVs will result in the reduction of many vehicle components since there are no fuel system or exhaust components required in a BEV. The ICEV components that are not required in a BEV include:

- All engine components: engine block, camshafts and valvetrain, piston and connecting rods, cylinder heads, crankshaft, exhaust manifolds, oil pan, spark plugs and alternator;
- Engine cooling system: radiator and radiator fans, coolant tank and coolant pump;
- Fuel system components: fuel pump, fuel tank and fuel filter;
- Transmission system including driveshafts and AWD (all wheel drive) units; and

[43] https://canada.autonews.com/electric-vehicles/canadian-ev-sales-grew-2021-are-not-track-federal-targets
[44] Extracted from https://canada.autonews.com/ice-vs-ev

- Muffler and exhaust components including catalytic converters and oxygen sensors.

In comparison, BEVs require over 40 new components, many of which are electrical or electronic:

- A battery pack consisting of interconnected LIB cells arranged into a series of modules that are contained in a protective enclosure (or tray), which is usually made of aluminum but can also be made of advanced high-strength steel or a glass fibre reinforced plastic composite.
- A BMS that
  - electronically manages the power delivery in the battery pack to optimize performance;
  - monitors temperature, voltage and current to ensure a safe operating environment; and
  - communicates with other electronic control units in the vehicle.[45]
- Anywhere from one to four electric motors consisting of a rotor inside a stator, reduction gears and cooling channels.
- An inverter and power control unit which converts direct current (DC) power to alternating current (AC) power that is delivered to the electric motor. The unit also regulates and controls the speed of the motor by changing the frequency of the AC.
- A DC-to-DC converter reduces DC power from the onboard high-voltage battery to lower voltages to run in-vehicle systems. The converter also charges the auxiliary battery.
- High voltage power cables.
- A charging port.

Most vehicle suspension and steering system components found in ICEVs are also found in EVs.

HEVs and PHEVs have all the components of both an ICEV and a BEV. However, a BEV might have a battery ten times larger than PHEV, which, in turn might have a battery times ten times larger than HEV.[46] Conversely, an HEV usually has a smaller gas engine than a comparable ICEV model and a PHEV has a smaller gas engine than a comparable HEV model.

Using lightweight materials in these vehicles can offset the weight of heavy LIBs and electric motors, improving efficiency and increasing driving range. Alternatively, the use of lightweight materials could allow for the use of a smaller and lower cost battery while keeping the driving range of EVs constant.[47]

In the short term, replacing heavy steel components with lighter weight materials such as advanced high-strength steel, aluminum alloys and glass fiber-reinforced polymer composites can decrease component weight by 10-60%.[48] In the long term, advanced materials such as magnesium alloys and carbon fiber reinforced composites could reduce the weight of some components by 50-75 percent.[49]

The full transition to BEVs will take decades during which time there will be many ICE vehicles still requiring dismantling at EOL. However, as the number of HEVs, PHEVs and BEVs reaching EOL begins to grow, dismantlers will need to adjust their operations and business models to manage an increasing number of BEVs with lithium-ion batteries, electric motors, high voltage cables and light-weight materials

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[45] https://evreporter.com/battery-management-system-for-electric-vehicles/
[46] https://www.caranddriver.com/news/a15345397/battery-taxonomy-the-differences-between-hybrid-and-ev-batteries/
[47] https://www.energy.gov/eere/vehicles/lightweight-and-propulsion-materials
[48] https://www.energy.gov/eere/vehicles/short-term-lightweight-materials-research-advanced-high-strength-steel-and-aluminum
[49] https://www.energy.gov/eere/vehicles/long-term-lightweight-materials-research-magnesium-and-carbon-fiber

replacing the cast iron and steel engines, drivetrains, fuel systems and exhaust systems (including valuable catalytic converters) found in ICE vehicles.

Materials in EV Magnets

EVs have heavier magnets than ICEVs for particular applications. While ICEVs use magnets in a number of applications (anything involving a switch, such as window wipers, car windows, etc.), the average HEV or EV uses between 2 and 5 kg of rare earth magnets, depending on the design. Rare earth magnets in EVs feature in:

- Heating, ventilation and air conditioning (HVAC) systems;
- Steering, transmission and brakes;
- HEV an PHEV electric motors;
- Permanent electric BEV motors;
- Sensors such as for security, seats, cameras, etc.;
- Door and windows;
- Entertainment system (speakers, radio, etc.); and
- Fuel and exhaust systems for HEVs.[50]

There are two types of rare earth magnet materials - Neodymium (Nd-Fe-B) and Samarium Cobalt (SmCo). Both materials come in different grades (strengths) and have different magnetic and physical properties. Neodymium magnets, the stronger of the two, are composed of alloys primarily of neodymium, iron, and boron. Some OEMs are experimenting with induction motors that would not require magnets.[51]

Managing LIBs at Auto Dismantler Facilities

Managing the LIB in an EV is a significant element of the future management of EVs by auto dismantlers, and is a new activity compared to ICEV management. For this reason, all of the text related to LIB management is moved into Section A.5

A.5 Management of LIB at Auto Dismantling Facilities

One of the significant differences between ICE vehicles and EVs is management of the EV LIB. Section A.5 covers off many of the issues raised in Research Question #3: "What Different Materials are Used in EVs that May Require Different Approaches at EOL?" as well as in Research Question #4 – "Which EV parts can be re-used, re-purposed, rebuilt and recycled, and by whom?".

Figure 2 shows the structure of LIBs used in EVs.

[50] https://www.bunting-berkhamsted.com/rare-earth-magnets-in-electric-vehicle-motors/
[51] https://www.bunting-berkhamsted.com/rare-earth-magnets-in-electric-vehicle-motors/

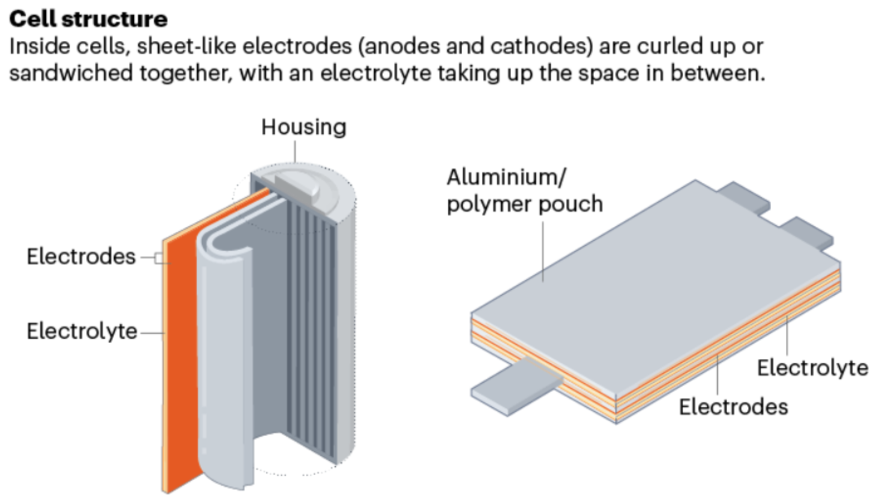

Figure 2: Lithium Ion Battery Cells[52]

LIB cells are one of three designs:

- Cylindrical (e.g., cells used in Tesla Model Y 4680 battery);
- Prismatic (cells used in Tesla Model 3 LFP battery)) or
- Pouch (e.g., cells used in GM Hummer Ultium battery).

Cells are combined into packs in various formats as shown in Figure 3.

[52] Source: "Electric cars and batteries: how will the world produce enough?", Nature, August 17, 2021

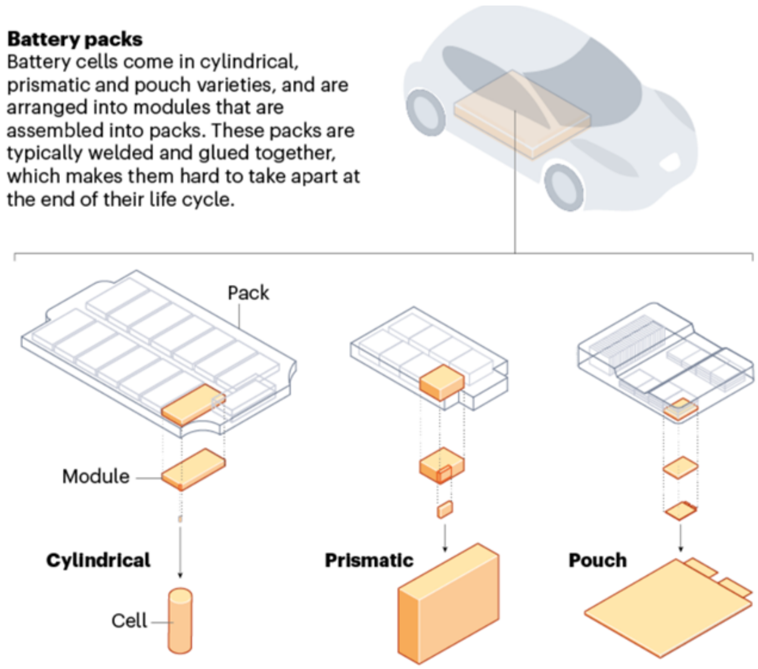

Figure 3: Cylindrical, Prismatic and Pouch Cells Are Combined into Battery Packs

Battery packs are placed in a housing of plastic or steel to form the complete EV battery which is rated by kilo-watt hours (kwhrs). A battery management system (BMS) is used to control battery operation. The BMS is made up of copper wiring for electrical connections, as well as various metals involved in electronic controls. Figures 4, 5 and 6 show the BMS for a Chevrolet Bolt, Jaguar iPace and Audi E-tron.

Figure 4 Chevrolet Bolt Battery Pack and Battery Management System (Shown in Orange)[53]

[53] Cobb, J. 11 January 2016. "Chevy Bolt EV's Battery Is As Big As A Tesla's."<https://www.hybridcars.com/chevy-bolt-evs-battery-is-as-big-as-a-teslas/>

Figure 5: Battery Pack and Battery Management System for Jaguar I Pace

Figure 6: Cut out View of Audi E-tron

Managing LIB packs in EOL EVs will create a significant challenge for auto dismantlers in terms of safe dismantling, storage and transportation practices. Due to electrical and fire hazards posed by LIBs, proper training of dismantling staff regarding different LIB chemistries and required health and safety protocols is critical. Batteries in new EVs are usually under warranty for at least eight years or 100,000 km. Any LIBs that require repairs or replacement during the warranty period are usually returned to the OEM dealer network.

With respect to EVs reaching auto dismantlers, there are **four main scenarios** for managing the LIBs. Each scenario requires a different set of actions by auto dismantlers.

- **Scenario 1**: The EV and LIB are damaged in an accident. In this scenario, the battery needs to be extracted and sent to a battery recycler where cathode metals such as cobalt, nickel, manganese and lithium can be recovered for use in new batteries and other products. Reuse/re-purposing companies are not yet at the point where they can deal with battery packs and cells from EVs that have been in an accident but believe that parts of these batteries can be recovered and re-purposed over time, rather than going direct to the recycler.[54]

- **Scenario 2**: The EV is damaged in an accident but the battery tray and LIB remain intact. In this scenario, the battery can be tested for state of health (SoH) and charge capacity (see Section A.8 regarding SoH testing) and, depending on its age and condition, could be sold for refurbishing and reuse in another EV or for repurposing in a stationary battery electric storage system (BESS) for use elsewhere (in solar farms, wind turbines, electrical grids or many other auxiliary or back-up power or energy storage applications).
- **Scenario 3**: The EV reaches EOL and the out of warranty LIB is undamaged. In this scenario, the remaining charging capacity would usually prevent reuse of the LIB in another EV unless it can be refurbished or sent to a remanufacturer. EV LIBs are replaced before they reach their physical EOL, typically when they reach 70–80% of their initial capacity due to limited driving range.[55] Under normal driving conditions, current EV LIBs can last about 10 years or longer before they need to be replaced,[56] although current data from Circular Energy Storage indicate that the LIBs can last 12 years or more.[57] However, the full life of a LIB is could be as much as 20 years. Depending on the cell chemistry and the cell design or cell assembly, these LIBs can still be used for less-demanding applications such as stationary BESSs.[58] They can also be repurposed for other energy needs such as an off-grid power source in remote areas, auxiliary power on recreational vehicles and boats or used in off road vehicles such as golf carts and wheelchairs, among other applications.[59]
- **Scenario 4**: EV reaches EOL and out of warranty LIB must be recycled. In this scenario, the poor SoH and/or low charging capacity make the LIB unsuitable for reuse or repurposing and it must be sent to a battery recycler to recover valuable metals. This would be the least likely scenario due to undamaged LIBs typically having a longer lifespan than an EV.

The risks and required practices associated with dismantling, storage and transportation of used LIBs are described below.

Dismantling:[60] LIBs used in EVs have a significantly higher voltage than the lead acid batteries used in ICEVs and as a result pose a threat of electrocution if mishandled. Auto dismantlers removing the battery from the vehicle must take certain safety precautions, particularly if the battery is physically damaged. This is an issue also for the health and safety of first responders arriving at the scene of a fire or accident involving an EV. For example, the battery must be drained and disconnected before performing any work on the vehicle or battery. Facilities should also be equipped with appropriate personal protective equipment (PPE), including rubber gloves and boots, high voltage-safe tools, matting, and a safety rescue hook.

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[54] Confidential interviews with representatives of the reuse repurposing industry

[55] Faessler B., Stationary, Second Use Battery Energy Storage Systems and Their Applications: A Research Review. *Energies*. 2021; 14(8):2335. https://doi.org/10.3390/en14082335

[56] https://www.truecar.com/blog/how-long-do-electric-car-batteries-last/

[57] https://autorecyclers.ca/2021/bring-on-the-batteries-arc-hosts-educational-ev-hybrid-webinar-provides-vast-overlook-of-end-of-life-batteries-and-recyclers-place-in-supply-chain/

[58] Faessler B., Stationary, Second Use Battery Energy Storage Systems and Their Applications: A Research Review. *Energies*. 2021; 14(8):2335. https://doi.org/10.3390/en14082335

[59] http://www.cvma.ca/wp-content/uploads/2021/12/ev-battery-journey.pdf

[60] Extracted from the California Lithium-ion Car Battery Recycling Advisory Group Draft Report, December 13, 2021

The other key safety issue is fire. Damaged LIBs can reach maximum temperatures between 600 and 1000 C due to a condition called thermal runaway. Dismantlers can mitigate fire damage by having proper fire suppression capacity onsite (e.g., strong water pressure, fire blankets) and ensuring that dismantling of EVs is done in isolation from combustible materials.

Storage:[61] Due to the safety hazards described above, dismantlers handling LIBs must follow specific storage protocols that are defined in the local fire codes including minimum space requirements and fire suppression capabilities. Storing batteries onsite may present a burden and liability, particularly for smaller facilities that do not have sufficient space to hold batteries for extended periods.

Transportation:[62] Transportation costs for LIBs depend on a variety of factors, including fuel cost, distance traveled, transportation corridor, and load size and the state of the LIB. To ensure LIBs are transported safely, the party handling the battery must comply with dangerous and hazardous materials shipping regulations under the federal *Transportation of Dangerous Good Act*, as well as designation as a hazardous waste by Environment and Climate Change Canada and separate and different hazardous waste regulation requirements by each province and territory in Canada, all of which have slightly different hazardous waste management regulations. Damaged batteries are subject to more stringent transport requirements. Specifically, they must be shipped in an UN-certified container, which are custom-ordered from dangerous goods packaging manufacturers.[63]

Auto Shredders

While automobile shredders are not members of ARC, they will also have to adjust their operations over time as the number of EVs reaching EOL begins to increase, containing less steel and more aluminum, copper and light weight composite materials compared to ICEVs.

A.5.2 Reuse, Repurposing and Recycling of LIBs

LIB Reuse and Re-Purposing: LIBs are the heaviest and largest component of a BEV and because of their long-life and modular structure can be re-purposed or recycled depending on the circumstances. As described in the response to Question #2, once a LIB no longer has sufficient charge capacity for use in an EV (less than 70-80% of initial capacity), it can be re-conditioned and put back into another vehicle or can be re-purposed into a battery energy storage system (BESS) or for other applications. While there is limited real world experience to draw on to date, industry members believe the LIBs can last an additional 5-10 years in stationary applications.[64] There are three potential applications for second use LIB energy storage systems:

- "In-front-of-the-meter" refers to power that must pass through an electric meter before reaching a customer;

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[61] Ibid
[62] Ibid
[63] https://tc.canada.ca/en/dangerous-goods/shipping-importing-devices-containing-lithium-batteries
[64] Kelleher Environmental in association with Millette Environmenal and Gracestone, Inc. Research Study of Reuse and Recycling of Batteries Employed in Electric Vehicles Report to API, September, 2019. Available at https://www.api.org/~/media/Files/Oil-and-Natural-Gas/Fuels/Kelleher%20Final%20EV%20Battery%20Reuse%20and%20Recycling%20Report%20to%20API%2018Sept2019%20edits%2018Dec2019.pdf

- "Behind-the meter" refers to power that can be used on-site without passing through a meter; and
- "Off-grid" refers to systems that are not connected to the main electrical grid and are mostly small applications.[65]

SoH testing is carried out to determine what application the used LIBs and cells can be applied to (See Section A.9).

Use of EV LIBs in BESSs is more advanced in Europe and Asia (i.e., China, South Korea and Japan) where there are larger supplies of used LIBs available to be re-purposed. Almost all storage systems of this type in Europe are using LIBs from BEVs. Most of these batteries are from Nissan, Renault, or Volkswagen BEVs that use mainly NMC (nickel-manganese cobalt) chemistry. Some storage systems combine old and new cells, but always with the same chemistry. Most of these BESS are developed for "behind-the-meter" applications, primarily to increase on-site consumption. The capacities and power inputs/outputs of these ESS are somewhat low compared to other industrial ESS.[66]

For example, a cooperative effort between Nissan, Eaton, BAM and The Mobility House led to the installation of a hybrid first-life/second-life LIB power system at the Johan Cruijff Arena, in Amsterdam, Netherlands. This system, comprised of 148 used Nissan Leaf NMC LIBs, has a 3 MW power capacity and a 2.8 MWh electricity storage capacity. The battery system helps to decrease energy costs and provides up to one hour of back-up power to the area. In 2016, a 13 MWh system was commissioned in Lunen, Germany based on 1,000 used BMW i3 NMC LIBs, approximately 90% of which are used LIBs.[67]

In Canada, some small off-grid systems have been implemented. For example, a small clean tech start-up company called Moment Energy, based in Vancouver, BC, has installed three systems in homes located in remote communities. One project in an off-the-grid home in Westlock County, Alberta, launched in June 2021, involved the repurposing of two used Nissan Leaf NMC battery packs into energy storage units to store power from solar panels, reducing the need to run on-site diesel generators on cloudy days.[68]

Another example is an auto dismantler in Clarington, ON who has sold LIBs from EOL EVs to a local paving contractor to power temporary signal lights at road construction project sites.[69]

Other companies entering the EV battery reuse/re-purposing space include: "EV 360" in Montreal; "Re-purposed Batteries"; and "All EV" (in Nova Scotia which re-conditions EV batteries for second hand EVs) among others.

LIB Recycling: Each LIB contains many critical minerals shown on Table 4 (Section A.2) which are of interest to recyclers because of their high value. A typical 60 KWhr LIB contains 185 kg of critical minerals on average. EOL LIBs can be recycled to recover valuable metals. Two Canadian companies currently (2022) have facilities that are capable of recycling EV LIBs – Li-Cycle in Kingston, ON and Retriev Technologies in Trail, BC. Two other companies – Lithion Recycling in Anjou, QC and Stelco in Hamilton, ON have

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[65] Faessler, B., Stationary, Second Use Battery Energy Storage Systems and Their Applications: A Research Review. Energies 2021, 14, 2335. https://doi.org/10.3390/ en14082335
[66] Ibid
[67] https://blog.ucsusa.org/hanjiro-ambrose/the-second-life-of-used-ev-batteries/
[68] https://clean50.com/projects/moment-energy-uses-retired-car-batteries-to-power-canadas-remote-regions/
[69] Interview, December 23, 2021

announced plans to build new facilities in 2023. Given the integrated nature of the Canada-US economies (including both the auto industry and the scrap metal recycling sector), LIB recycling business plans take a North American approach with spoke or hub facilities on both sides of the border, as discussed in this section.

Li-cycle's patented hub and spoke technology uses a combination of mechanical size reduction and hydrometallurgical resource recovery specifically designed for LIB recycling. At spoke facilities, such as the Kingston facility, all types of LIBs are transformed from a charged state to an inert product in a safe and efficient manner. At the hub facility in Rochester, NY, which is scheduled for commissioning in late 2023, cathode and anode materials are processed into battery grade lithium, nickel and cobalt for reuse in LIB production or other applications in the broader economy. The Kingston facility, one of three North American Li-cycle spoke facilities, has a processing capacity of 5,000 tonnes of LIB material per year.[70]

At **Retriev Technologies'** Trail facility, large LIBs from HEVs and BEVs first go through a manual disassembly process in which skilled technicians dismantle the pack, separating assembly pieces and circuitry from the actual battery cells. Separated cells and smaller packs (i.e., laptop, power tool, and cell phone LIBs) are then fed by conveyor to an automated crusher. The crusher, which operates under a hydrometallurgical liquid solution to prevent fugitive emissions and to reduce the reactivity of processed batteries, produces three types of materials: metal solids, metal-enriched liquid, and plastic fluff. The metal solids contain various amounts of copper, aluminum, and cobalt (depending on the type of LIB processed), which can all be used as raw materials in new products. The metal-enriched liquid is solidified (to produce a black mass) using filtering technology, which is sent off-site for further metal processing.[71]

Retriev also recycles NiMH batteries from HEVs such as the Toyota Prius and the Honda Insight using a pyrometallurgical process for component separation. Through this process, NiCad and NiMH batteries are heated to a temperature that enables the recovery of cadmium and the removal of battery separator materials. The resulting materials consist of cadmium ingots and a nickel-enriched iron material that can be reused as a raw material in many applications, including stainless steel production.[72]

Lithion Recycling's pilot facility in Anjou uses a patent-pending hydrometallurgy-based process to recycle all LIB chemistries. After a mechanical separation of plastic from metals, hydrometallurgical processes are used to refine the various metals contained in the cathode. These processes include a lixiviation step that dissolves metallic oxides in an aqueous solution, as well as several precipitation and separation steps to obtain high-purity components.[73]

On April 1, 2022, Lithion announced that they had received $22.5 million in funding from the Quebec government which, along with funds received earlier in 2022 from Quebec-based Fondaction, and from Korea's IMM Investment Global, will enable them to:

- build its first commercial battery "spoke" dismantling and reprocessing plant in Quebec in 2023;
- build a state-of-the-art Technology Development Center to continue to develop Lithion's technology for future battery chemistries and materials specifications; and

[70] https://li-cycle.com/
[71] https://www.retrievtech.com/lithiumion
[72] https://www.retrievtech.com/nicadnimh
[73] https://www.lithionrecycling.com/lithium-ion-battery-recycling-process/

- carry out detailed engineering studies for the construction of Lithion's own 'hub" hydrometallurgical plant in Quebec.[74]

In January 2022, **Stelco** announced that it is going to recycle EOL LIBs and vehicles at its facility in Nanticoke, ON, using proprietary technology from a joint venture of German and Australian metal companies. Stelco plans to recover up to 20,240 tonnes (18,400 net tons) of nickel, manganese and cobalt sulphates, lithium hydroxide and carbonate per year from LIBs, and up to 44,000 tonnes (40,000 net tons) of scrap steel from the vehicles. The company has a target of starting initial operations in 2023.[75]

Stelco has negotiated binding licencing and option agreements with Primobius GmbH, a joint venture of German steelmaking equipment manufacturer SMS Group, and Australian specialty metals company Neometals Ltd. Primobius currently uses its technology at a facility in Hilchenbach, Germany that can process 4,000 net tons of LIBs per year.[76]

American Manganese in Vancouver, BC is another Canadian company developing hydrometallurgical processes to produce chemical precursors to make cathode active materials from recycled batteries. A pilot plant is planned to demonstrate their technology which produced NMC811 cathode precursors in March, 2022.[77]

Electra Battery Materials Corporation (formerly First Cobalt) in November, 2021 announced a plan to recycle LIBs at their facility in Timiskaming Shores, Ontario.[78]

A.6 Research Question #4: Which EV parts can be re-used, re-purposed, rebuilt and recycled, and by whom?

Some answers to this question are found in the auto recycler survey discussed in Section A.7 as part of Research Question 5.

A.6.1 Summary and Gaps

- Several components found in EVs, such as bumpers, wheel covers, headlight/taillight assemblies, seating, steering systems, body panels, suspension systems and dashboards, are similar to components found ICEVs and as such offer the same opportunities for resale and, in some cases, recycling (e.g., TPO bumper covers).
- The components that are unique to EVs, such as LIBs, electric engines and high voltage power cables, also have potential opportunities for reuse, re-purposing and recycling.
- The business model to reuse EV components has not been fully developed as it is a young market where experience is limited at this time.

[74] https://www.lithionrecycling.com/lithion-recycling-receives-22-5-million-in-funding-from-the-quebec-government/
[75] https://driving.ca/auto-news/local-content/stelco-plans-to-recycle-electric-vehicle-batteries-at-its-ontario-plant
[76] Ibid
[77] https://americanmanganeseinc.com/news-publications-2/press-releases-2/
[78] https://www.northernontariobusiness.com/industry-news/manufacturing/electra-battery-materials-rakes-in-financing-for-temiskaming-refinery-5287684

A.6.2 Background

Several components found in EVs, such as bumpers, wheel covers, headlight/taillight assemblies, seating, steering systems, body panels, suspension systems and dashboards, are similar to components found ICE vehicles and as such offer the same opportunities for resale and, in some cases, recycling (e.g., TPO bumper covers). HEVs and PHEVs also retain the internal combustion engines, engine cooling systems, drivetrains, exhaust systems and fuel systems found in ICEVs which can continue to be resold and recycled. It should also be noted that conventional ICE vehicles, which will be sold in substantial numbers until at least 2030 will still be reaching end of life until the mid to late 2040s .

Depending on the definition of “component” (generally an assembly consisting of a number of separate parts), EVs have a large number of components. While the driveline is less involved than an ICEV, the supporting ecosystem still requires a large quantity of components and assemblies.

It is reported that 210 out of 850 ICEV parts are either slightly altered, fully eliminated, or have become optional with the shift to BEV manufacturing.[79]

However, there will be a number of common components such as mirrors, door panels, sun roofs, seats, etc. that will be sold into the reuse market through harvesting by auto recyclers.

The components that are unique to EVs, such as Lithium packs and trays, electric engines and high voltage power cables, also have potential opportunities for reuse, re-purposing and recycling.

The survey of Canadian auto recyclers (discussed under Research Question #5) reported that the four most common EV parts sold by respondents (in order) are: batteries; drivetrains; motors; and inverters. Only 10% are currently selling magnets.

Lithium-ion Batteries (LIB): LIBs can be reused, re-purposed, rebuilt and recycled by different players in the supply chain. In the ARC member survey:

- 60% of respondents reported that the EV battery is removed from the vehicle and is stored inside; 35% reported leaving the battery in the vehicle outside.
- 23% of respondents reported that the EV battery is resold as-is as their primary action;
- 21% reported holding batteries on-site;
- 21% reported that the EV battery was sent for recycling;
- 19% reported “other” or “don’t know”;
- 16% reported that EV batteries were resold for re-purposing.

A detailed description of these options is presented in Section A.5 along with other LIB related information.

[79] https://siteselection.com/issues/2022/mar/eight-means-great-for-findlay-ohio.cfm

Resale of EV Parts by Auto Recyclers

Table 5 presents a summary of the responses to a survey of Canadian auto recyclers (discussed in Section A.7) regarding which EV parts they sell and to where they are sold.

Table 5: EV Parts Sold by Auto Recyclers

EV Part	Removed and Sold		Where Was the Part Sold To?
	Yes	No	
Batteries	82%	18%	Mainly sold to repair shops and individuals
Drivetrain	78%	22%	Mainly sold to repair shops
Motor	69%	31%	Mainly sold to repair shops
Inverter	67%	33%	Mainly sold to repair shops and individuals
Other	47%	53%	Mainly sold to repair shops and individuals
Magnets	10%	90%	Sold to "others"

Electric Motors, High Voltage Power Cables and BMS: There will be multiple forms and designs of "traction" motors in EVs, most at this point are asynchronous induction style or synchronous permanent magnet motors.

EVs can have one to four electric motors. Front and rear wheel drive BEVs have one motor while all-wheel drive BEVs have two motors (one for each axle) or three motors (two on the back axle and one on the front axle). The Tesla Cybertruck and Rivian pickup truck have four motors – one for each wheel.[80] These are unlikely to be common sale components if they have failed or been damaged, but there is a market for motors used in the conversion of ICEVs into EVs. Otherwise, large quantities of copper and smaller amounts of rare earth materials from the drive system can be sent to the recycling stream for recovery.

The electric motors, BMSs and high voltage cables in EVs contain significant amounts of copper (see Section A.2). Given the increasing demand for copper in EVs and the (usually) high value for scrap copper, there should be a strong demand from metal recyclers for these components.[81]

The cabling needs of a true EV will likely fall in between those of an ICEV and an HEV. EVs will have less low-voltage cabling due to the decrease in number of sensors due to the simpler driveline. However, they will have substantial amounts of "High Current/High Voltage" wiring (also present in HEVs) for transferring power between the electric motors and the battery pack.

Battery Enclosures: Aluminum is the dominant material for EV battery enclosures (or trays) due to its light-weighting and corrosion resistance characteristics. All currently available long-range BEVs – those that can travel beyond 400 km – use aluminum as the main material for the battery enclosure for that reason.[82] Since aluminum is a valuable and highly recyclable metal, there will continue to be strong

[80] Types of Motors used in EV | Single, Dual, Three & Four Motor Configuration in EV (https://www.youtube.com/watch?v=6H5vtu5_SF4&ab_channel=TheEngineersPost)
[81] https://www.recyclingtoday.com/article/electric-vehicles-shock-recycling-infrastructure/ and see https://www.scrapmetalpricer.ca/ where copper scrap is listed at $4.94 per kg and aluminum scrap is $1.45 per kg (May 2022)
[82] https://www.sae.org/news/2021/02/constellium-aluminum-ev-battery-enclosures

demand for scrap aluminum parts from EVs, including battery enclosures. In all cases, if component reuse is possible, this will be the first choice for auto recyclers as it generates higher income than recycling.

Transmission: An ICEV requires a multiple gear transmission to ensure that the right amount of power goes to the wheels to drive at a given speed. By comparison, a BEV only requires a single gear transmission (or gearbox) because an inverter changes the frequency of the AC current going to the motor to control the power going to the wheels.[83]

Lubrication System: The engine oil and transmission fluid used for lubrication in an ICEV both require a filter, pump and pan. In a BEV, the gearbox is lubricated with a specialty oil which requires a small pump and filter (i.e., no oil pan).[84]

Radiator and Cooling System: ICEV engines are cooled by glycol antifreeze running through channels in the engine block. The heated glycol is then cooled in a fan/radiator assembly using air coming through the front grill. In contrast, BEVs typically have three internal heat exchangers (small radiators without fans) for cooling the glycol used to cool the battery, cooling the inverter/motor/gearbox assembly and to provide cooling for the HVAC system.[85]

Tires: BEVs can use traditional passenger tires - for example, the factory tires on many Tesla Model 3 cars are the Michelin Primacy MXM4, a conventional passenger tire. However, the heavier weight of a BEV due to the battery pack has led to the development of new high-load (HL) capacity tires that can carry a heavier load at the same tire pressure as traditional tires. HL capacity tires also have a lower rolling resistance and are quieter than traditional tires which is important because BEVs accelerate faster and are much quieter than ICE vehicles.[86]

A.7: Research Question #5: How are automotive recyclers currently managing EV parts/components (including advanced batteries and rare earth magnets)?

A.7.1 Summary and Gaps

- Most auto recyclers in Canada are receiving some EVs at this time.
- Management of the LIB ranges from storing on-site to re-purposing or re-selling, with a few auto recyclers sending LIBs for recycling.
- Other EV parts are also sold for reuse to repair shops and other outlets.
- Knowledge gaps were focussed on how to safely dismantle the LIB and how to address the potential for LIB fires.

[83] Tesla Model 3 Motor Tear Down - ALL EV (https://www.youtube.com/watch?v=oVge8I6kxPY&t=19s&ab_channel=AllEVCanada)

[84]Tesla Model 3 Motor Tear Down - ALL EV (https://www.youtube.com/watch?v=oVge8I6kxPY&t=19s&ab_channel=AllEVCanada)
[85] Tesla Model 3 - Cooling System Overview (https://www.youtube.com/watch?v=vgfXyLLaO7I&ab_channel=Ingineerix)
[86] https://www.consumerreports.org/tires/do-electric-vehicles-need-special-tires-a4689725362/

A.7.2 Background

Information on how EVs are currently being managed is based on two main sources of information:

- A detailed April, 2022 survey of ARC member companies on their current EV management activities and plans for the future; and,
- Information that came from follow up interviews with selected ARC organization executives and member companies who are leading the way on future EV management and dismantling plans in Canada.

Key findings from the ARC April, 2022 EV survey are presented below. The detailed responses are presented in Appendix C to this document.

The survey was administered electronically through Survey Monkey by ARC in April, 2022. It was translated into French and was distributed to the full ARC mailing list of 500 companies (350 member companies and 150 others on the ARC mailing list). One hundred and twenty-two (122) responses were received from across Canada, which is a very good sample size on which to base the description of current EV processing activities by auto recyclers. Most responses were from Ontario (45%), Alberta (16%) and BC (11%); however, some response was received from all provinces. The specific details in the responses are summarized in bullet form under headings below:

Number and Type of EV's Managed Annually

- 76% of ARC respondents currently handle EVs.
- Only 6% of respondents (4 companies) are storing more than 20 batteries; two of those have over 40 EV batteries stored at their sites.
- 64 respondents managed an average of 6 EVs each last year.
- From a total of 129 EVs reported to be managed last year by a selected number of companies who reported the type of EV specifically, almost half of those were "regular" hybrids (i.e., EV with no plug); 26% were plug-in hybrids and 25% were fully electric**.** This is a reasonable finding given that hybrids have been in the market the longer than other electric models.
- 77% of the EV's managed by respondents are more than 6 years old; the balance are 5 years old or less.
- 38% of EVs vehicles acquired were from insurance companies; 32% were from the public; 17% from dealers and 14% from "other sources".
- About two-thirds of respondents say they have seen a change in the number of EV vehicles *available* to purchase; less than 25% of respondents report that the number of EVs *purchased* have changed.
- 69% of respondents reported that they have not purchased new equipment to process EVs

How Canadian Auto Recyclers Currently Manage EV Batteries and Other EV Parts (Drivetrains, Inverters, Magnets, etc.)

- The four most common EV parts sold by respondents (in order) are: batteries; drivetrains; motors; and inverters. Only 10% are currently selling magnets.
- 60% of respondents reported that the EV battery is removed from the vehicle and is stored inside; 35% reported leaving the battery in the vehicle outside.
- 23% of respondents reported that the EV battery is resold as-is as their primary action; 21% reported holding batteries on-site; 21% reported that the EV battery was sent for recycling; 19% reported "other" or "don't know"; 16% reported that EV batteries were resold for re-purposing.

Training and Other Support Needs Expressed by Auto Recyclers

- Two-thirds of respondents are in active discussion, planning and testing to prepare for the shift to EVs.
- The top three respondent concerns regarding the transition to EVs are (in order):
  - (1) safety requirements;
  - (2) EV battery resale/reuse market options and
  - (3) recycling options.
- The financial differences between handling ICE and EVs ranked lowest, but with 30% of respondents still being concerned. This response will help inform the development of additional EV dismantling training materials
- 69% of respondents reported that they have not purchased new equipment to process EVs
- The interest from respondents in receiving additional information on the evolution and management of EVs is both very high and variable.
- Almost 80% of respondents want staff training on how to safely dismantle an EV. 75% prefer on-line training but almost 30% want in person training.
- 91% of respondents are interested in training or information on how to profitably dismantle EVs; 9% are not interested.

A.8 Research Question #6: What are the technical, safety, environmental, health and/or financial/commercial challenges and how can they be overcome?

A.8.1 Summary and Gaps

- Technical, safety, environmental, health and financial commercial challenges related to EVs are well documented.
- While some questions remain unanswered, significant efforts are underway by many parties to address these challenges.
- Safety and technical challenges are being addressed through training and awareness programs.
- Financial and commercial challenges are being addressed through government and private sector efforts.
- One of the technical infrastructure challenges is related to a lack of charging infrastructure in Canada. This shortfall is being addressed through various government and private sector efforts.
- Public education and awareness are an on-going need to increase adoption rates for EVs.

A.8.2 Background

Technical Challenges - Range, Charging Infrastructure; Battery: Technical challenges faced by ARC members are addressed in other sections of this document. These include a need for training on how to maximize profit from harvesting and selling EV components as well as understanding battery management options to maximize profit.

Consumers have a number of concerns about EVs. One technical challenge for EVs in Canada is their limited range (which is causing consumer "range anxiety"). This challenge can be overcome in several ways including better batteries and/or more charging infrastructure.

"Range anxiety" refers to the concern that drivers will run out of electrical charge and not be able to find a charging station. A number of trends are addressing this concern:

- EVs are being built with longer range, as the price of the bigger batteries (in terms of kWhrs of capacity) continues to decrease;
- Canada is building out a comprehensive EV charging station infrastructure;[87] and
- Fast charging technologies are available where a vehicle can be re-charged in 20 minutes.

As of December, 2021, Electric Autonomy Canada reports that Canada has 15,723 chargers at 6,723 public charging stations, according to data from Natural Resources Canada (NRCan). While most of these (more than 12,000) are Level 2 chargers, there are 1,237 stations across Canada that now offer DC fast chargers.[88]

Tesla has the most EV chargers of any company across Canada. The company started installing its proprietary charging network along the Highway 401 corridor between Montreal and Toronto in 2014. Today, it has thousands of chargers from Vancouver to Halifax, with superchargers in every province except for Newfoundland and Labrador and Canada's three territories. Early last year, Tesla updated its Supercharger map with plans to install 44 new chargers in Canada. For 2022, the company's map shows that 18 new charging stations are going to be installed, with 10 in Ontario, two each in British Columbia, Saskatchewan and Quebec and one in Manitoba and Alberta.

The **Zero Emission Vehicle Infrastructure Program (ZEVIP)[89]** is a $680 million initiative by the federal government ending in 2027 with the objective of addressing the lack of charging and refuelling stations in Canada by increasing the availability of localized charging and hydrogen refuelling opportunities across the country. This funding will be delivered through cost-sharing contribution agreements for eligible projects that will help meet the growing charging and refuelling demand.

ZEVIP targets multiple infrastructure streams through a competitive bid process which closes in August, 2022 to install EV charging stations at public spaces; on-street locations; workplaces; multi residential buildings (MURBs), and commercial and public fleets.

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87 https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876
88 https://www.tesla.com/en_ca/supercharger
89 https://electricautonomy.ca/2022/03/31/canadas-public-charging-networks-2021/

NRCan's contribution through this Program will be limited to fifty percent (50%) of Total Project Costs up to a maximum of five million dollars ($5,000,000) per project and up to a maximum of two million dollars ($2,000,000) per project for Delivery Organizations. Applications from Ultimate Recipient to Delivery Organizations will be limited to less than $100,000.

See Appendix E.2 for a short summary on ZEVIP including contact details.

Safety Challenges

Safety challenges are related to fires and also the injury and electric shock risks related to handling a charged LIB at an auto recycler, and the safety risk to first responders coming upon an accident involving and EV where there is a risk of the LIB catching fire, or a risk of injury dealing with the LIB. Various training programs are already in place for first responders addressing the risks of managing EV accidents and fires.

A fire in an EV is more significant than in an ICEV because of the thermal runaway of a LIB, and there are more concerns regarding first responder safety as well as the environmental impacts of putting out an EV fire, statistics show that fires per 100,000 vehicles are much higher for ICEVs vs EV's.[90] Data from Autoinsurance EZ, compiled in 2022 indicate that fires per 100,000 vehicle sales are highest for hybrids, followed by ICE vehicles, with the lowest for EVs.

Table 6: Car Fires by Vehicle Type[91]

Rank and Fuel Type	Fires (per 100k sales)	Total fires
HEV	3,474.5	16,051
ICE	1,529.9	199,533
EV	25.1	52

However, when an EV fire does occur, the technical and safety considerations are much more significant. First responders need to be and have been trained to manage EV fires involving a lithium battery, but significant concern remains throughout the industry that this training and awareness is not sufficiently in place at this time. Lithium battery fires require special managing – fire blankets; significant amounts of water etc. The runoff from lithium battery fires contains significant amounts of fluorine which in some cases has caused a threat of fish kills or actual fish kills.[92] Hydrofluoric acid can also be emitted in the white smoke seen at the late stage of a lithium battery fire.[93] This gas is toxic to humans.

Environmental Challenges: The environmental benefits of EV battery re-purposing and reuse relate to extending the lifespan of the battery and reducing the demand for virgin materials to manufacture new EV batteries. Reuse of EV batteries extends the lifespan of these batteries, thereby delaying the need for recycling. There is a perception that eVs have a significant negative environmental impact because of the mining of lithium and other metals and minerals needed to make the LIB. While it is true that manufacturing of the EV battery has more of an environmental impact than manufacture of an ICEV, a full lifecycle assessment shows that the environmental impact of an EV over its lifetime of 10-15 years is much lower than that of an ICEV because and EV runs on electricity, rather than gasoline.

[90] https://insideevs.com/news/561549/study-evs-smallest-fire-risk/
[91] https://insideevs.com/news/561549/study-evs-smallest-fire-risk/
[92] Colin McKean, Canadian Battery Association AGM presentation 13th April, 2022.
[93] ibid

Many provinces in Canada have low carbon electricity – particularly Quebec, BC and Manitoba where electricity is produced using hydro power. Ontario produces most of the electricity using nuclear and hydro facilities. Even in provinces that still use coal to produce electricity (Alberta and Nova Scotia), the net environmental impact of an EV versus an ICE over the lifetime of a vehicle is less.

A white paper published by the ICCT[94] (International Council for Clean Transportation) in July, 2021[95] reports that in the current US market, a medium-sized battery EV already has 60–68% lower lifetime carbon emissions than a comparable car with an internal combustion engine. The gap will widen as more renewable electricity or low carbon energy (such as nuclear, hydro power and renewables) are added to the grid.

The ICCT study compares the lifetime carbon emissions, both today and in 2030, of midsized vehicles in Europe, the US, China, and India, across a wide range of powertrain types, including gasoline, diesel, HEVs, PHEVs, BEVs, and fuel cell EVs (FCEVs).

The study takes into account the carbon emissions that result from the various fuels (fossil fuels, biofuels, electricity, hydrogen, and e-fuels), as well as the emissions that result from manufacturing and then recycling or disposing of vehicles and their various components. The study has also factored in real-world fuel or energy consumption—something that is especially important when it comes to PHEVs, according to the report. More electrification will reduce GHG emissions but will require much more copper and hence more mining; this was also taken into account in the analysis. Finally, the study accounts for the fact that energy production should become less carbon-intensive over time, based on stated government objectives.

According to the study, the life cycle emissions of a BEV driving around in Europe today are 66–69 % lower than a comparable gasoline-powered car. In the US, that range is 60–68% less over its lifetime.

From an air quality environmental impact, combustion of gasoline in ICEVs releases carbon monoxide nitrogen oxides volatile organic compounds sulphur oxides and particulate matter (PM) into the atmosphere. These emissions are eliminated in BEVs which results in an improvement in local air quality. A recent report makes the following projections for the Greater Toronto Hamilton Area (GTHA) based on improved air quality from adoption of electric vehicles:[96] Converting all cars and SUVs in the GTHA into electric vehicles would cause 313 fewer deaths per year resulting in an estimated social benefit of $2.4 billion; converting all transport trucks to more efficient models would cause 275 fewer deaths resulting in an estimated social benefit of $2.1 billion and converting all transit systems to electric buses would cause 143 fewer deaths per year resulting in an estimated social benefit of $1.1 billion[97]

Financial and Commercial Challenges: EVs currently have a higher up-front cost than their ICE equivalent at this time, although costs are coming down and with provincial and federal incentives EVs are becoming more affordable. However, the big financial benefit of EVs in the longer term is the lower cost of ownership because of lower maintenance costs and no need to buy gasoline.

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[94] The ICCT is the same organization that funded the research into VW Group's diesel emissions

[95] https://arstechnica.com/cars/2021/07/electric-cars-have-much-lower-life-cycle-emissions-new-study-confirms/

[96] Environmental Defence and Ontario Public Health Association, CLEARING THE AIR: How Electric Vehicles and Cleaner Trucks Can Reduce Pollution, Improve Health And Save Lives In The Greater Toronto And Hamilton Area, June 2020

[97] Based on value of $10 million per life typically used for economic studies.

Because electric cars use electricity instead of fossil fuels, they are much more affordable to drive. This is especially true if you charge over-night or on weekends when the cost of electricity is usually lower. Plug'n'Drive estimated that based on the average Canadian driver, travelling 20,000 km per year, EVs can save as much as $2,000 per year on fuel alone.[98] Higher gas prices will expand these savings further. In addition, electric motors are more sophisticated and durable than internal combustion engines. Electric motors have one moving part and do not require oil changes, coolant flushes, mufflers or exhaust systems, saving you hundreds of dollars per year on maintenance

Clean Energy Canada analyzed a number of popular electric car models, comparing their total ownership costs with that of gas equivalents. With just one exception, the electric version of every car analyzed was cheaper, usually significantly so. The analysis found that the electric Hyundai Kona, Canada's second best-selling EV in 2021 (after the Tesla Model 3), is $10,500 cheaper to own than the gas-powered Kona. If gas prices were $2 per litre, the electric Kona would be $17,800 cheaper to own than the gas-powered Kona.

The federal government iZEV (the "i" stands for incentive) offers buyers up to $5,000 in rebates when buying a zero-emission vehicle (ZEV). The program started in 2019 and has been extended until March 2025.Battery-electric, plug-in hybrid, and hydrogen fuel cell all qualify for the rebate. The program has two tiers: battery-electric, hydrogen fuel cell, and longer-range plug-in hybrid vehicles are eligible for an incentive of $5,000, while shorter-range plug-in hybrid electric vehicles are eligible for an incentive of $2,500. Combined provincial and federal incentives across Canada range from $5,000 to $12,000 depending on the province or territory.

British Columbia and Quebec were among the first provinces or territories to offer their own rebates in addition to the federal incentives, but others are starting to emerge across Canada including New Brunswick, Nova Scotia, PEI, Newfoundland & Labrador, and Yukon. Due to the combined federal/provincial rebates, Quebec and British Columbia lead Canada in terms of the highest adoption rates for BEVs with BC at 8.8% and Quebec at 5.4% in 2021. By comparison, Ontario has a BEV adoption rate of 2.4% in 2021.[99]

Plug'n'Drive ICE Scrappage and Used EV Incentive Program (Ontario only)

One incentive is a benefit to ARC membership as it encourages the early retirement of ICEVs, that are then processed by ARC members and other auto recyclers. The Scrappage Incentive Program[100] is operated by Plug'n Drive, in collaboration with Clean Air Partnership, with the support of the M. H. Brigham Foundation. The program provides an incentive of $1,000 to recycle an operating ICE vehicle which is insured in Ontario and replace them with a used EV.

The Scrappage Incentive combined with the existing Used EV Incentive program, qualifies all Ontario drivers for $1,000 off the purchase of a used fully electric vehicle. The two programs combined offer $2,000 in incentives to those who replace an ICE vehicle with a used EV.

Participants must attend a Used EV seminar, purchase a used EV and send a copy of the bill of sale, vehicle registration, proof of insurance and the Used EV seminar certificate to

[98] https://www.plugndrive.ca/electric-vehicle-benefits/
[99] https://electricautonomy.ca/2022/04/22/statscan-canada-zev-registrations-q4-2021/
[100] https://www.plugndrive.ca/used-electric-vehicles-scrappage/

usedevincentive@plugndrive.ca. The ICE vehicle that is scrapped must be insured in Ontario under the name of the participant for at least six months. There is a limit of one Scrappage Incentive per person.

A.9 Research Question 7: Are there tools, information, processes and technologies to evaluate the state of health of a battery at end-of-life to determine what can be re-used and what needs to be recycled?

A.9.1 Summary and Gaps

- There are a number of technologies and mechanisms available in Canada (and elsewhere) to assess battery state of health (SoH).
- All of these are proprietary to the technology developers who do not want to share IP which required significant investment.
- There is a gap in the market in that customers who buy repurposed batteries would like a standard to which they are re-purposed.
- UL1974 is an existing standard which industry members believe is out of date and needs updating.

A.9.2 Background

When an EV battery reaches EOL for the purposes of mobility—which is when it loses 15-20% of its initial capacity[101]— it can be directed to either reuse/repurposing or recycling. The reuse and repurposing processes include removal from a vehicle as well as any needed repair, refurbishment, or remanufacturing.[102] These steps are typically carried out by specialized battery re-purposers, although it might be possible for ARC members to be trained to carry out these steps over time

Reuse and repurposing are terms often used interchangeably. The California Lithium Ion Car Battery Recycling Advisory Group has defined these two terms to have particular meanings (which is used in this discussion paper also):

- **reuse** refers to the use of a used LIB in an EV; and
- **repurposing** refers to the use of a used LIB in another application (i.e., an application other than as a traction battery in an EV).[103]

State of health (SoH) refers to the condition of a battery (a cell or a battery pack), compared to ideal conditions (when it is first introduced to the market at effectively 100% capacity). Depending on the approach used, the units of SoH can be a percentage of full charge/discharge capacity or other measures.

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[101] Pagliaro, M. and Meneguzzo, F., "Review Article: Lithium battery reusing and recycling: A circular economy insight," *Heilyon* 5: e01866, 2019, https://doi.org/10.1016/j.heliyon.2019.e01866

[102] Kendal, Alissa et al. Lithium Ion Car Battery Recycling Advisory Group – AB2832. Prepared for CalEPA, https://calepa.ca.gov/lithium-ion-car-battery-recycling-advisory-group/

[103] https://calepa.ca.gov/wp-content/uploads/sites/6/2021/12/Final-Draft-Policy-Recommendations-Lithium-ion-Car-Battery-Recycling-Advisory-Group-AB-2832-As-of-12-13-21-for-public-comment.pdf

A battery management system (BMS) evaluates the SoH of the battery under current operating conditions. Then, the SoH is compared to a threshold to determine the suitability of the battery for a particular application. Based on the SoH assessment, the remaining useful life of the battery can be estimated. The following parameters are used to identify SoH by different battery companies:

- Internal resistance / impedance / conductance
- Capacity
- Voltage[2]
- Self-discharge
- Ability to accept a charge
- Number of charge–discharge cycles
- Age of the battery
- Temperature of battery during its previous uses
- Total energy charged and discharged.

SoH is often reported as percentage of original charge capacity remaining (e.g. 60%). As an example of how SoH measurement impacts on how an EV battery cell is repurposed/reused, a new Panasonic 18650 battery cell (used in Tesla vehicles) may have been 3,000 Mah (mili-amperes) when new but when degraded to a lower level, it still has appropriate uses, for instance[104]:

- At 2,600 MAh - it can be used in an e-Wheelchair;
- At 2,400 Mah - it can be used in a drone;
- At 2,200 Mah - it can be used in a solar powered video doorbell unit;
- At 1,500 Mah - it can be used in a very strong LED Torchlight.

At 1,100 Mah, the remaining capacity in the cell is no longer powerful enough to be reused so is recycled for commodity value.

Following SoH assessment, EOL EV batteries can be reused directly in EVs (as a reconditioned battery) or cascaded in alternative, lower-demand applications such as residential energy storage, grid-scale energy storage, EV charging remote energy storage or back up power for camping grounds, cottages, etc. or as battery cells in drones, wheelchairs and other lower duty applications.

There are many SoH testing protocols in existence today with each company stating that their approach is faster and more reliable than their competitors. Reuse companies have stated that they have invested significant time, effort and money in developing proprietary SoH techniques and protocols, and do not want SoH approaches embedded in a technical standard. A performance-based standard is considered acceptable.

Hans Eric Melin of Circular Energy Storage in the UK has stated that "EV battery reuse appears to be a viable business model with good profit margins if issues around liability and standards can be addressed. It is considered more likely that EV batteries will be directed to reuse (energy storage systems, back-up power, EVs and various other applications such as wheelchairs and drones, etc.) for the foreseeable future because of the favourable economics." Recent industry interviews are providing differing opinions on the future of the EV battery reuse and reconditioning business, with concerns being expressed

[104] Email correspondence with Eric Lundgren, former CEO of ITAP, January, 2018

about liability, standards and insurance company concerns about the safety of energy storage systems using reconditioned batteries.

Second-life opportunities for EV batteries include both stationary and mobile applications, and vary from applications that break the used battery down into its constituent parts (cells or battery packs) to applications that keep the unit intact, with low performing cells removed and replaced with new or reconditioned cells. Measuring the state of health (SoH) of the battery is the main step in determining appropriate second life uses and applications depending on the remaining capacity. Typically, the first step in reuse or refurbishing EV batteries starts with partial disassembly of the battery pack. The next step involves identifying cells that are no longer working, replacing them with cells capable of holding a sufficient charge, and reassembly of the battery pack, either in its original format or in a newer format suitable for the new application (such as energy storage, powering wheelchairs or other lower power requirement applications). This process involves diagnostic and screening tests to correctly identify the EV battery chemistries and designs, as well as the SoH of each battery cell, and for battery packs made up of a number of cells. Generally, each EV battery cell needs to be evaluated individually, because each one has been exposed to different charging and discharging conditions during its use in an EV.

Each reuse/repurposing company uses its own proprietary SoH testing equipment and protocols, and guard the IP for the SoH testing approach carefully. EV second life batteries have not been in use long enough to measure their actual lifespan in second life uses, and estimates of second life duration of 5-10 years typically used in the business are mostly theoretical.

There are a number of companies at the forefront of the EV battery repair, refurbishment, and reuse industry. Currently, Oklahoma City-based Spiers New Technologies (SNT) is the largest company involved in EV battery reuse in the US. Most of the battery packs the company receives come from dealers' warranty replacements as well as from test projects. In addition to reconditioning batteries for clients such as Nissan, General Motors and Ford, SNT also tests batteries and battery cells and incorporates them into energy storage systems (such as Watt Towers), that can be used in applications ranging from solar energy installations to general uninterruptible power supply (UPS).[105] Other companies involved in battery reuse include IT Asset Partners (ITAP) and BigBattery in the US.

In Canada, a number of companies have entered the EV battery reuse and repurposing space, but at a smaller scale. These include:

- Moment Energy, based in Langley, BC uses EOL EV batteries to provide energy storage pilot projects in Quadra Island and Seven Sisters Falls, BC as well as in Westlock County, Alberta;[106]
- "All EV" in Nova Scotia focuses on refurbishing EOL EV batteries for placement in other EVs; and,
- EV360 out of Montreal will come on line in 2022 to repurpose EV batteries supplied by OEMs.

As an example of how sophisticated some battery reuse/assessment companies are, SNT (Speirs New Technologies) has a proprietary database (called ALFRED) for managing EV battery information. ALFRED is a PHP / MySQL web application that collects, manages, and processes battery and battery related information. ALFRED receives input data from a wide variety of sources including SNT test equipment, SNT proprietary battery research equipment, production operators, OEM engineers and

[105] https://oklahoma.gov/ocast/about-ocast/news/snt-8-13-20.html
[106] https://www.momentenergy.ca/our-projects

stakeholders, dealerships, logistics companies, and major shipping entities. ALFRED is always studying and processing the information held in its databases. In a typical 24-hour time period, ALFRED manages the production of refurbished battery packs in five facilities divided across two continents, coordinates forward and reverse logistics to support thousands of dealerships, sends hundreds of emails, and provides on-demand data analysis and report generation to hundreds of users. ALFRED capabilities include:[107]

• OEM Adaptive Reports and Forecasting Models • Data Mining • Quality Records – Full Audit Trail • Automated Refurb Battery Capacity Matching	• 24 Hour Secure OEM Access (Supports Warranty, Engineering, Customer Care, Quality, etc.) • Capturing of usable data for root cause analysis of aged modules • Inventory Management • Ordering and Processing

SoH Within UL 1974 – Standard for Evaluation for Repurposing Batteries

UL is a global scientific standards development organization, which initiated a standard development process to address the safety and reliability of repurposing batteries. In October 2018, UL 1974 was published as a bi-national Standard of the United States and Canada.

By outlining how to sort and grade battery packs, modules and cells that were originally made for electric vehicles (EV) and other applications, UL 1974 helps identify a battery's SoH and introduces ratings to determine the viability for their continued use. Through this process, performance-validated "second-life" batteries can be utilized for energy storage systems to provide a safe, reliable, clean energy source.

In August, 2019, US announced that 4R Energy Corporation, a joint venture of Nissan Motors and Sumitomo Corporation focusing on the effective reuse of EV batteries for energy storage systems, was the first organization worldwide to be certified to UL 1974, the Standard for Evaluation for Repurposing Batteries.[108]

A.10 Research Question # 8– "Will the automotive dismantling sector have sufficient infrastructure/capacity and work force expertise to manage EVs at EOL and, if not, what needs to be done?"

A.10.1 Summary and Gaps

- EVs are different than ICEVs in that the energy potential built into their propulsion systems is dramatically different.

[107] SNT website

[108] https://www.ul.com/news/ul-issues-worlds-first-certification-repurposed-ev-batteries-4r-energy

- Auto recyclers have learned how to safely remove oils, fuel, gas tanks and lead acid batteries from ICEVs. The energy in EVs, the location, the chemistry, the discharge protocols, the handling protocols, the warnings, the equipment, and the training are all new for auto recyclers.
- A disruption like this has never hit auto recyclers before. EVs have fewer parts and more sophisticated electrical systems than ICEVs and are therefore disruptive to the current auto recycling sector.
- EVs have created a knowledge gap exists that needs to be addressed as soon as possible.
- Proper training documents, protocols and resources need to be developed and widely disseminated for any business interested in properly recycling EVs.
- It is recommended in the main Roadmap report that the Government of Canada fund the development of national guideline documents, training and resources for the safe and efficient recovery and dismantling of EVs, based on the great start that has begun in BC.
- By utilizing existing BC EV training materials and resources, which have been ground-tested by the auto recycling industry in BC, a national training program can be developed quickly, efficiently and in formats available to the widest possible audiences.

A.10.2 Background

Some key differences between EVs and ICEVs include:

- Displacement of metal castings and steel components used in ICE drive trains and exhaust systems with metals found in EV batteries, motors, battery housings and wiring.
- Increased push for light-weighting (to improve efficiency and compensate for new electric battery weights) is resulting in more aluminum and plastics composites replacing steel in vehicle parts and bodies (which may be offset with heavier metals to support large EV batteries).
- New management systems required for EV batteries are larger and more dangerous to handle than lead acid battery systems (that will be smaller but still exist in EVs).

As EV LIBs begin to make their way into the aftermarket, LIB removal and management require both infrastructure and skills attention (See Section A.5).

The key investments needed to properly manage EVBs are primarily local investment considerations – i.e., some upgrade in dismantler tools and, more importantly, comprehensive knowledge, safety and skill training.

Without much additional effort or investment, ARC estimates that dismantlers could process an additional 230,000 ELVs per year. On the shredder side of the equation, Cheminfo estimated that Canada has a current capacity to process up to 1.6 million ELVs per year; 60% of shredders' feedstock are ELVs.

With more EVs coming on to Canadian roads, more EVs will begin to hit auto recyclers – both as older EVs and total losses. The actual rate at which EVs are totaled will be greater than an ICEVs due to the complexity of repair, cost of parts and materials, limited number of collision repairers capable (or interested) in making these more complex repairs, and the difficulty of getting replacement parts within the 6-month window allowed by insurance companies before an EV is written off.[109]

Where required, EVs need to be removed from circulation responsibly and – especially for auto recyclers - safely. EVs provide two main risks to auto recyclers (and to first responders at accident sites) uncontrollable and spontaneous fires; and the risk of worker injury or in a worst-case scenario the risk of electrocution.

EVs are different than ICEVs in that the energy potential built in to their propulsion systems is dramatically different. Auto recyclers have learned how to safely remove oils, fuel, gas tanks and lead acid batteries from ICE vehicles. The energy in EVs, the location, the chemistry, the discharge protocols, the handling protocols, the warnings, the equipment, the training are all new for auto recyclers. A disrupter like this has never hit auto recyclers before.

Auto manufacturers create documents for first-responders and the handling information is similar for auto recyclers. But that information can be inaccessible to front-line dismantlers[110] and is spread across thousands of pages and platforms. The BC branch of ARC has been the Canadian leader (in partnership with the BC government and the Automotive Retailers Association) in the development and delivery of (in-person and) on-line training and certification. One of the top priority recommendations of the Roadmap and Implementation Plan for the Management of End-of-Lie Electric Vehicles in Canada is an immediate and national focus on updated, translated materials and expanded dismantler training for a safe EV future.

In 2008, ARC worked with Environment Canada (now Environment and Climate Change Canada) and the National Vehicle Scrappage Program to develop the "Code of Practice" for participating auto recyclers. In addition to the development of the Code, ARC delivered the training to the Code, both in-person and online, and oversaw the auditing of participating auto recyclers against the Code.

The Environment Canada strategy at that time was to retire older high-polluting vehicles to reduce emissions from the transportation sector. Also, at that time the processing of vehicles was a "hodgepodge" of old rules, regulations and enforcement specific to each Province. Environment Canada recognized that while they were solving an emissions problem, they did not want to create a waste problem by having the scrapped vehicles retired irresponsibly. Thus, the development of the Code of Practice, plus associated training and auditing.

The Code has been updated over time and ARC obtained the intellectual property of the Code and rebranded it as the Canadian Auto Recyclers Environmental Code (CAREC – www.carec.ca). All ARC Members are still audited to the CAREC standard every two to three years depending on their audit scores. It has been deemed by many, including ARC and its Members, that CAREC was one of the definitive long-term successes of the National Scrappage Program.

[109] Conversation with auto recycler, January, 2022

[110] Auto recyclers and auto dismantlers are used interchangeably. Both dismantle EOLVs to harvest and resell valuable parts before sending the hulk to auto shredders for metal recovery.

There are a number of parallels to the existing state of processing vs. the coming flood of EVs, as well as a significant opportunity to retool and “remake” the auto recycling sector in Canada over time to meet new EV challenges in particular.

The National Code of Practice for auto recyclers was developed originally in BC, and was in place on a voluntary basis at the Provincial level. The work that ARC undertook was to harness the BC approach, and then create national documents and protocols by updating them to national standards, nomenclature and regulations. The original technical work was already in hand – ARC simply had to nationalize, translate, etc. and a very effective program was developed quickly and efficiently.

We are at the same place with EVs today. The BC Auto Recycling Association - working with the Provincial government, Automotive Dealers, and a dedicated Technical Advisory Committee from the industry - have developed some comprehensive safety resources and protocols for handling ZEVs. And they have been involved in the development of training so that these guidelines can be delivered in-person and importantly for ARC – virtually. The BC project goals were:

- Increased OHS awareness for the hazards posed from handling EVs during transportation, dismantling and storage among employers, supervisors and workers; and
- Improved understanding of workplace safety risks, effective control measures, OHS program elements and compliance requirements.

In order to safely dismantle and prepare the resources in a EV for reuse or recycling, proper training documents, protocols and resources need to be developed and widely disseminated for any business interested in properly retiring these vehicles. Other sector’s reuse and recycling efforts, well underway in Canada, depend upon the dismantling sector to properly secure these batteries in the first place.

Therefore, as detailed in the Roadmap Report, it is recommended that the Government of Canada fund the development of national guideline documents, training and resources for the safe and efficient recovery and dismantling of ZEVs, based on the great start that has begun in BC. By utilizing the BC head start, resources, ground-tested by the auto recycling industry, a national training program can be developed quickly, efficiently and in formats available to the widest possible audiences.

A.11 Research Question # 9 “Do OEMs (original equipment - auto and battery) need to be involved in the management of EVs at EOL and if so, how?”

A.11.1 Summary and Gaps

- There is no need for battery and EV OEMS to be involved in EOL EV management, but there are benefits to their being involved.
- Both battery and EV OEMs are increasingly interested in EOL EV to capture the metal value from the EOL LIB, and ideally introduce the recovered metal back into the LIB supply chain.

- There is a significant data and knowledge gap related to the metal content of different EV designs. A database with information on EV parts, locations and metal content would be valuable to auto recyclers to maximize metal recovery from EVs before the metal shredder.
- Design for recycling (DfR) and design for environment (DfE) are increasingly essential for EVs in order to capture the value at EOL. OEMs have a role to play in this regard.

A.11.2 Background

There are a few reasons for automobile and battery OEMs to play an active role in the future EOL management of both EVs and LIBs.

1) Mineral exploration and mining companies, auto manufacturers, software developers, and battery manufacturers are actively involved in continuously moving the EV industry forward. New software, new battery chemistries and new car manufacturing technologies are changing rapidly. The auto industry of tomorrow will be very different from yesterday – the industry abounds with joint ventures and new partnerships. However, EOL considerations need to be better included and addressed in these new developments (because that is currently not business as usual).
2) There is increasing interest on the part of OEMs in recovering metals (especially critical minerals) from EOL LIBs in particular to feed back into the LIB supply chain. For OEMs based in the EU, this is driven by recycled content targets in the new Battery Regulation (described below).
3) Climate change and industry watchers are calling for unprecedented efforts to "green" the global electricity generation and distribution systems (i.e., to reduce GHG emissions across the value chain), while at the same innovate in the development of new, much needed energy storage systems. New LIBs in EVs commonly have a useful life for energy storage well beyond their use as the primary energy source for a vehicle. A highly integrated energy system requires the attention of all major players – again including both battery and EV OEMs but also power authorities/regulators, government agencies and the established and evolving end of life vehicle industry.
4) The complex challenge of integrating Design for Environment (DFE), and specifically Design for Recycling (DfR) into the evolution of the future auto industry would benefit from some OEM involvement at the EOL stage. To build into this change a set of fundamental Design for the Environment principles in the way future vehicles are built, dismantled, reused and recycled.
5) Battery and EV OEMS have a particular interest in maintaining a "line of sight" on LIBs after their warranty period has expired (generally 8 years). Auto recyclers can play a role in tracking LIB location after the auto recycler processing is complete.
6) The emergence of "battery as a service" (BaaS) may change how LIBs are tracked though their lifecycle by OEMs
7) There is a significant need to understand the composition of EVs as each EV by each OEM has a different metal composition. This is a significant data gap at this time (i.e., what EV parts contain what metals). OEMS could have a role in populating a database which provides this information to auto recyclers.

What might a National ZEV Alliance for the Automotive Aftermarket Sectors look like?

Presently, there is an active dialogue at the national level in Canada for getting faster adoption of Zero Emission Vehicles (ZEVs) through increased education, communication, inventories, incentives, charging infrastructure, etc., and a great deal of activity and effort is underway identifying the recycling and reuse options for the batteries at EOL in these vehicles.

The most significant gaps in information, communication, leadership, organization, etc. is in the post-dealer environment. Once someone is in a EV, the discussion on how to maintain, service, repair, re-use, dismantle, recover, re-purpose, and finally recycle the battery (and other parts) is lacking. Much of the post-sale activity happens at a local level, amongst small business, and often times siloed industries.

Consideration should be given to the formation of a National ZEV Alliance for the Automotive Aftermarket[111] to be created with the support and guidance of the Federal Government (NRCan, Environment and Climate Change Canada, Transport Canada and Innovation, Science and Economic Development Canada, because it has the ability to convene and facilitate discussion and cooperation among the various automotive aftermarket stakeholders.

From an automotive and battery OEM perspective, three EV dissemination information and EOL considerations are evolving:

- The need for enhanced consumer awareness of the safety and operating cost benefits of EVs along with assurances that key issues such an accessible, national charging infrastructure, energy storage demand requirements and greening the national energy grid are adequately addressed as the Canadian EV ecosystem evolves and expands.
- Automobile OEMs in particular are encouraging both federal and provincial governments to enhance buyer incentives to help reduce the up-front higher costs of electric vehicles.
- Automotive OEMs are also advocating for continued attention on a multi-year vehicle scrappage program targeting older, running vehicles and - as above - incentivizing the purchase of new or used EVs.

The Auto Recyclers of Canada (ARC) supports auto and battery OEMs regarding each of these key considerations and expects to be informed and consulted on these important EV issues and developments. A central outstanding issue for all of those concerned with EVs after markets and end-of-life is the ownership and responsibility of post-warrant EV batteries. As noted earlier, ARC is looking to build upon the successful record of the EOL management of ICEVs over the past 100 years, moving towards an even more successful future of properly managing the coming expansion of EOL EVs across Canada.

A.12 Research Question #10: Are there any regulatory barriers inhibiting the safe and cost-effective management of EVs at end of life?

A. 12.1 Summary and Gaps

- There are some specific regulatory barriers in Canada inhibiting the safe and cost-effective management of EV batteries at EOL, and some which relate to the entire EV.
- One regulatory barrier is related to transportation of used LIBs to recycling locations, after the LIBs are considered "used" and are therefore classified as hazardous waste.
- A second barrier is related to open access to proprietary software to ensure that auto repair shops and auto dismantlers have access to OEM EV software and training data to allow them to safely repair and dismantle EVs.

A.12.2 Background

"Right to Repair" and Access to OEM EV Software and Training Data: The auto repair sector relies on up to date, accurate information on vehicle components and software from OEMs to ensure that vehicles are repaired in a safe and cost-effective manner. This will become increasingly important as Canada transitions to electric vehicles.

In 2009, the Global Automakers of Canada (GAC) and the Canadian Vehicle Manufacturers Association (CVMA) signed a voluntary agreement with the National Automotive Trades Association (NATA) to have OEMs share key information with the auto repair sector. The Automotive Industries Association of Canada (AIA) also signed the agreement in 2011. ARC and eight provincial automobile associations are affiliate associations of NATA.[112]

Under the terms of the agreement, called the Canadian Automotive Service Information Standard (CASIS), the majority of OEMs agreed to post information related to vehicle emissions, diagnostic tools and training on OEMrepairinfo.ca. so that all independent mechanical and collision repair shops could access the information they require to properly repair vehicles.[113]

AIA Canada Pre-budget Submission to the Federal Government[114]: In a pre-budget submission to the Federal Government dated August 6, 2021, AIA Canada recommended that the government implement "right to repair" legislation to support consumers, protect jobs and improve environmental outcomes as part of Canada's economic recovery.

In the submission, AIA Canada stated that the overall objective of CASIS is to maintain an open, fair and competitive automotive industry by ensuring that the aftermarket has access to automakers information regarding emissions, diagnostic tools and training. However, there are a number of shortcomings with the current agreement.

Vehicle telematics systems installed by OEMs track and transmit significant amounts of user data from vehicles directly back to OEMs. Control of that data by OEMs may be used to ensure that only authorized dealerships have access to data needed to conduct repairs. This trend is already underway with some OEMs that are not part of the existing voluntary agreement. For consumers this results in: 1) less choice

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[112] https://www.autoserviceworld.com/is-casis-working/
[113] Ibid
[114] Extracted from AIA Canada, "Written Submission for the Pre-Budget Consultations in Advance of the Upcoming Federal Budget", August 6, 2021

in vehicle repairs 2) inconvenience, especially in rural communities and 3) less competition and increased costs for repairs and aftermarket replacement parts.

Wirelessly connected vehicles communicate only with the OEMs' backend servers, which helps drive business away from independent shops and the suppliers that serve the aftermarket. While CASIS gives the aftermarket access to vehicle service information, it does not give it access to a vehicle's wireless data or functions like onboard apps and the vehicle dashboard.

Legislation that mandates a "right to repair" would ensure that vehicle data is provided to independent shops or directly to consumers resulting in both Canadian consumers having more choice, and independent mechanical and collision shops being able to stay competitive.

There are currently two bills being debated in Parliament that address the right to repair issue: Bill C-244, An Act to Amend the *Copyright Act* (diagnosis, maintenance or repair) and Bill C-231, An Act to amend the *Competition Act* (vehicle repair).

Bill C-244, An Act to Amend the *Copyright Act* (diagnosis, maintenance or repair): Bill C-244, a private member's bill introduced by Liberal MP Wilson Miao on February 8, 2022, amends the *Copyright Act* in order to allow the circumvention of a technological protection measure in a computer program if the circumvention is solely for the purpose of the diagnosis, maintenance or repair of a product in which the program is embedded.[115] In the automotive sector, this will to enable the reverse-engineering of a product for the expressed purpose of vehicle repair and maintenance by auto repair shops.[116] The first reading of the bill was completed on February 8, 2022. The second reading has not yet been scheduled.

Bill C-231, An Act to amend the Competition Act (vehicle repair): Bill C-231, a private member's bill tabled by NDP MP Brian Masse on February 4, 2022, has three main priorities:

1. Amend the *Competition Act* to authorize the competition tribunal to issue an order requiring vehicle manufacturers to provide independent repair shops with access to diagnostic and repair information and service parts on the same terms and manner as a manufacturer makes that information and parts available to their own authorized repair providers.
2. Update the Canadian Automotive Service Information Standard (CASIS), the voluntary agreement put in place in 2009, to include the rights of digital software that will cover future innovations and technologies as we move to EVs.
3. Ensure that consumers have the right to choose where they get their vehicles repaired, improve the environment by making sure vehicle emissions are minimized, and improve public safety as vehicles on the road would be repaired and maintained in the best condition possible. [117]

The first reading of the bill was completed on February 4, 2022. A second reading has not yet been scheduled.

Other "Right to Repair" Legislative Developments: In Ontario, Bill 72 "An Act to amend the *Consumer Protection Act*, 2002 respecting the repair of electronic products", was defeated in 2019 on its second

[115] https://www.parl.ca/DocumentViewer/en/44-1/bill/C-244/first-reading
[116] https://autosphere.ca/mechanical/2022/03/15/right-to-repair-spreading-awareness/
[117] https://www.autoserviceworld.com/right-to-repair-bill-introduced-in-canada/

reading. Opponents to the bill stated that any form of right to repair would compromise U.S. companies' intellectual property rights, thereby affecting their ability and willingness to sell high-tech products in Ontario.[118]

Meanwhile, right to repair legislation is advancing in the US. In early July 2021, President Biden signed an executive order aimed at promoting competition across industries in the United States. The executive order encouraged the Federal Trade Commission ("FTC") to limit manufacturers' ability to bar consumers from repairing their own equipment or seeking repair services from third parties.[119]

On February 3 2022, U.S. Representative Bobby L. Rush (D-Ill.), a senior member of the House Committee on Energy and Commerce, introduced the Right to Equitable and Professional Auto Industry Repair (REPAIR) Act (H.R. 6570). This legislation would "preserve consumer access to high quality, affordable vehicle repair by ensuring that vehicle owners and independent repair shops have equal access to repair and maintenance tools and data as car companies and licensed dealerships."[120]

The REPAIR Act would prohibit OEMs from employing any technological or legal barrier that impairs the ability of a motor vehicle owner, or its designee, to access vehicle-generated data, which the Act defines as "any direct, real-time, in-vehicle data generated, or generated and retained, by the operation of a motor vehicle related to diagnostics, repair, service, wear, and calibration or recalibration of parts and systems required to return a vehicle to operational specifications in compliance with Federal motor vehicle safety and emissions laws, regulations, and standards."[121] The Act mirrors amendments to the Massachusetts right to repair law (originally enacted in 2012) that were passed by a ballot initiative in 2020, and which are currently being challenged by a coalition of OEMs in Massachusetts federal court.[122]

The various legislative initiatives described above demonstrate the need for regulations that will ensure a level playing field with respect to access to OEM EV software and training data.

Recyclability and Recycled Content in LIBs: Recyclability and recycled content are two new and emerging issues in the EV battery recycling front. First is the extent to which recycled metals and minerals from used EV batteries can contribute to the supply needed for new LIBs . Most other sources put this number at somewhere between 10% and 25%. For instance, Avicenne, a world leader in battery research, estimates that recycled batteries can provide about 12% of the supply by 2030. Other sources quote a range of values.[123]

[118] https://www.theglobeandmail.com/drive/mobility/article-right-to-repair-bill-reintroduced-which-would-benefit-all-consumers/
[119] https://www.bereskinparr.com/doc/one-person-s-trash-is-another-person-s-treasure-part-ii-the-right-to-repair-movement-in-the-united-states
[120] https://rush.house.gov/media-center/press-releases/rush-introduces-repair-act-ensure-equal-access-auto-repair-data
[121] https://www.jdsupra.com/legalnews/as-goes-massachusetts-so-goes-the-1905681/
[122] Ibid

[123] https://www.nanalyze.com/2021/10/li-cycle-stock-lithium-battery-recycling/ and https://www.woodmac.com/news/opinion/false-dawn-for-lithium-ion-battery-recycling/ and Lithium mining: How new production technologies could fuel the global EV revolution | McKinsey (see Ex.7 = 6% of total supply by 2030

On the European front, the European Commission published a proposal for new EU Batteries Regulation (to replace the EU Battery Directive) on December 10, 2020 with the aim of paving the way for sustainable batteries as part of a circular and climate neutral economy. The new batteries framework is the next step in delivering on the *European Strategic Action Plan on Batteries*. Under the proposed regulation industrial, EV and automotive batteries will have to:

- From 2030: meet the first minimum values of recycled content: Cobalt: 12%, Lead: 85%, Lithium: 4%, Nickel: 4%
- From 2035: meet higher minimum values of recycled content: Cobalt: 20%, Lead: 85%, Lithium: 10%, Nickel: 12%

The method to calculate the recycled content will be adopted by December 31, 2025. The targets are subject to a legal review, based on availability of waste materials.

Transportation of EV Batteries: In Canada at the present time, LIBs are classified as dangerous goods under the *Transportation of Dangerous Goods Act* and the Ministry of Transport has published a bulletin explaining LIB transport requirements. The bulletin addresses the required shipping document, dangerous goods safety marks, means of containment, training as well as special cases and provisions.[124]

However, there is no Federal legislation that addresses the management of LIBs in EOL EVs or EOL LIBs prior to or after transportation.

In addition to Federal legislation, each province classifies used LIBs has hazardous waste and they come under provincial hazardous waste requirements which are different in each province. This is reportedly a significant barrier to transporting LIBs across Canada. Transporters find it easier to ship the LIBs via the US as it is easier from a regulatory burden point of view and because their shipping standards are less stringent than in Canada.[125]

BC, Quebec, California, EU and New Zealand Legislation Targeting EV Batteries: At the provincial level, B.C. and Quebec are in the process of developing EPR legislation for LIBs. The Global Automakers of Canada (GAC) and the Canadian Vehicle Manufacturers Association (CVMA) are in discussion with these provinces because they believe that this regulatory work is premature given the unknown longevity and performance of LIBs. GAC and CVMA also believe that LIBs are not being disposed of because they are being reused or recycled and they are far too heavy for do-it-yourself EV owners. Presently there is a lack of data to shed light on this situation.

Several other jurisdictions are in the process of developing legislation and regulations to address accountability for managing LIBs safely and cost-effectively. These initiatives are summarized in Appendix D.

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[124] https://www.tc.gc.ca/eng/tdg/transporting-batteries.html
[125] Confidential discussion with LIB recycler, April, 2022

Appendix B: Key Informants Interviewed[126]

- Michael Adair, Chief, Perth County Paramedic Service at Perth County (confirm contact)
- Stuart Ady – Owner, Ernie's Used Auto Parts, Castlegar, BC
- Corey Earl – Operations Manager, Hotch's Auto Parts, Prince Edward County, ON
- Alex Forstner, Cycling Materials, Kingston Ontario
- David Giles – Co-founder and EV Technical Specialist, All EV Canada (Steele Auto Group), Halifax, NS
- Maureen Haun – President/CEO, Canadian Council on Rehabilitation and Work, Toronto, ON
- Ken Hendricks – Senior Project Manager, BC Automotive Retailers Association and EVfriendly Program Lead, Burnaby, BC
- Jay Illingworth – Director, Harmonization, Electronic Products Recycling Association (EPRA), Mississauga, ON

[126] Presented in alphabetical order

Appendix C: Detailed ARC April, 2022 Survey Responses

Questions and responses to the ARC April, 2022 EV Survey of membership and other contacts are organized into three main categories below:

- EV battery questions;
- electric vehicle questions and
- questions about processing future EVs.

C.1 EV Batteries

Q 1 Does your business currently handle EV? (hybrid, plug-in or fully electric)? - 121 respondents (almost 100% response rate)

- 76% said yes; 24% said no

Q2- How many EV batteries does the company currently have on site? - 56% response rate

- 65% reported 0-5
- 19% reported 6-10
- 10% reported 11-20
- 3% reported 21-30 (i.e. 2 respondents)
- 3% reported over 41

Only 6% of respondents (4 companies) are storing more than 20 batteries; two of those have over 40 EV batteries

Q3 – Where are the batteries stored on site – 56% response rate

- 60% reported battery removed from the vehicle and stored inside
- 35% reported left in the vehicle outside
- 15% reported removed from the vehicle and stored outside
- 12% said "other"

Q4 – What does your business do with these batteries - 54% response rate – rank ordered as a percentage of all responses

- 23% reported resold as-is
- 21% reported holding on-site
- 21% reported sent for recycling
- 19% reported "other/don't know "
- 16% reported resold for re-purposing (potentially as a power storage application)

Q5 - Please provide the name of the companies you have sold or provided batteries to for the following – 30 % response rate (some companies do both)

- 61% reported resold for repurposing
- 56% reported sent for recycling
- 36% reported "other"

None of the responses indicated the name of the company the auto recycler dealt with.

C.2 Electric Vehicles Received and Managed

Q6 – How many electric vehicles (including hybrids, plug-in hybrids and full electric vehicles) do you acquire per year? - 55 % response rate

- 65% reported 0-5 vehicles
- 17% reported 6-10 vehicles
- 11% reported 11- 20 vehicles
- 5% reported 21- 40 vehicles (3 respondents)
- 2 % reported 41-75 vehicles (1 respondent)
- 2% reported over 76 vehicles (1 respondent)

Q7 – Of the total vehicles you received in the last year, approximately what percentage of those vehicles are hybrids, plug-in hybrids or fully electric vehicles? - 48% response rate

Of the 64 respondents, an average of 6 EVs last year were received, and those responding accounted for a total of 357 EVs managed.

A survey completed by ARC in December, 2021 related to auto plastics contained a few questions related to EV's. Almost 80% (72 respondents) answered the survey questions about EV's. Almost 93% of respondents reported that EVs represent less than 5% of vehicles they receive

Q8 – For those EVs you received in the last year, approximately what percentage would be: hybrid, plug-in hybrid or fully electric vehicles? - 54% response rate

Of the vehicles for which numbers were reported, 63 were hybrids, 34 were plug-in hybrids and 32 were fully electric, which is to be expected given that hybrids have been in the market considerably longer than PHEV or BEV.

Q9 - What is the typical age range of the EVs you acquire? – 54% response rate

- 32% reported 6-8 years
- 25% reported 9-11 years
- 20% reported 12 years and older
- 14% reported 3-5 years
- 9% reported 1-2 years

77% of the EV's managed by respondents are more than 6 years old; the balance are 5 years old or less.

Q10 - What percentage would be acquired from insurance, dealers, the public or other? – 53% response rate. Of those responding:

- 38% of vehicles are acquired from insurance (total of 50 vehicles)
- 32% are from the public (42 vehicles)
- 17% are from dealers
- 14% are from "other sources"

Q11 – Have you seen a change in the number of EVs available to purchase? – 55% response rate

- 64% reported yes
- 36% said no

About two-thirds of respondents say they have seen a change in the number of EV vehicles available to purchase

Q12 – Have you seen a change in the number of EVs you have purchased? – 55% response rate

- 39% of respondents reported that the number is about the same
- 38% reported that the number has not changed
- 23% reported that the number has changed

C.3 Processing Current and Future EVs

Q13 – Have you had to purchase new equipment to process EVs ? – 55% response rate

- 69% of respondents reported that they have not yet purchased new equipment to process EVs
- 31% reported that they have

Q14 – Have you removed and sold the following parts from EVs? – 52% response rate

The responses to this question are presented in the table below which shows that the four most common EV parts sold by respondents (in order) are: batteries; drivetrains; motors; and inverters. Only 10% are currently selling magnets.

Table 7: EV Parts Sold By Auto Recyclers

EV Part	Removed and Sold		Where Was The Part Sold To?
	Yes	No	
Batteries	82%	18%	Mainly sold to repair shops and individuals
Drivetrain	78%	22%	Mainly sold to repair shops
Motor	69%	31%	Mainly sold to repair shops
Inverter	67%	33%	Mainly sold to repair shops and individuals
Other	47%	53%	Mainly sold to repair shops and individuals
Magnets	10%	90%	Sold to "others"

Q15 – What level of assessment has the company done in preparation for the shift to EVs? – 77% response rate

- Management team has discussed a number of times 48%
- No internal discussions as yet 33%
- We understand the impact and are making adjustments 21%
- We re testing different options 8%

Two-thirds of respondents are in active discussion, planning and testing to prepare for the shift to EVs.

Q16 – What business topic is the most important to address? – 69% response rate; most provided multiple answers

- Safety requirements 76%
- EV battery resale/reuse market options 57%
- Recycling options 54%
- Storage capabilities 46%
- EV battery collection/transport/logistics 35%
- EV/ICE financial differences 30%
- Other 7%

The top three respondent concerns regarding the transition to EVs are (in order): safety requirements; EV battery resale/reuse market options and recycling options. The financial differences between handling ICE and EV ranked lowest, but with 30% of respondents still being concerned.

Q17 – For which of these topics would your business like to receive additional information **–** 69% response rate; most provided multiple answers

- Options for disposition (recycling/repurposing/reselling) 76%
- Safe battery removal instructions 75%
- Storage requirements 60%
- Safety material/fire prevention/handling solutions 58%
- Transportation regulations and requirements 49%
- How to identify battery characteristics 37%
- Other 4%

The interest from respondents in receiving additional information on the evolution and management of EVs is both very high and variable.

Q18 – Do you have staff on-site trained to manage batteries from EVs? – 69% response rate. Of those that responded to this question:

- 60% of respondents do not have staff on site trained to manage batteries from EV
- 40% do have staff trained on site

Q19 – Would you be interested in training on how to safely dismantle an EV? – 69% response rate

Almost 80% of respondents want staff training on how to safely dismantle an EV. 75% prefer on-line training but almost 30% want in person training. Details of the responses are as follows:

- 79% of respondents said they would be interested in training on how to safely dismantle an EV
- 75% of respondents prefer virtual or on-line training
- 29% want in person training
- 15% expressed no interest in training on how to safely dismantle an EV

Q20 – Would you be interested in training or information on how to profitably dismantle EVs? – 67% response rate

- 91% of respondents are interested in training or information on how to profitably dismantle EVs; 9% are not interested

Q21 – Any final comments? - 10 respondents offered additional/final comments.

The comments are listed below and show a wide range of concerns, observations, interests and opinions:

- "We had a battery start to go on fire and would like to know how to make sure this doesn't happen again."
- …"we do not support EVs. We live deep in the north and have seen enough of them stranded in the winter already in our area. The fact they are trying to force this is the biggest joke I have seen."
- "We have 9 staff members trained up to now and will be training more".
- "We have been reluctant to get into this market because of safety and environmental uncertainty. We have learned battery handling procedures and high voltage procedures out of necessity".

- “In our area (Northern Ontario) there is no one to test the high voltage gloves.”
- “Scary - but that’s a first reaction to the unknown. Having just purchased an E-Bike, I'm starting to see good possibilities to the future for electric vehicles as a whole”.
- “I disagree with this shift as not only is the proper handling and "neutralizing" the electrical components in these vehicles not been addressed to prevent deaths of staff, but our electrical grid cannot handle its present demand, much less the addition of these vehicles. When employers have to have a proper "hook" to safely remove the electrocuted body from the vehicle should, our employees make a mistake in disabling the battery, then that issue should be corrected before this "project" moves forward. This danger has not been presented to the public in any form and that is wrong. Imagine making that call to a family.”
- “Thank you!!”
- “My involvement with electric vehicles has been very limited. I have only dismantled 2 hybrid vehicles. The batteries are still here (after years). My biggest concern is how to recycle them.”
- “Would be nice to find someone that would buy all the used ones to re-sell or dispose of properly.”

Appendix D: Legislative Initiatives in Quebec, BC, California, EU and New Zealand Targeting EV Batteries

Quebec: In October 2021, the Quebec Ministry of the Environment and the Fight Against Climate Change released a draft regulation proposing an EPR system for LIBs, making Quebec the first jurisdiction in North America to propose such a system for LIBs. Public consultation on the new draft regulation was scheduled to take place from October 13 to November 26, 2021.

The draft legislation deemed that EV batteries have a 10-year lifespan and obligated manufacturers to reclaim a large portion of their batteries — ultimately reaching 90 per cent — when they reach that age. This assumption did not take into account that EV batteries can last longer than 10 years in a vehicle, and once they no longer hold a sufficient charge for the original vehicle can be refurbished for use in another vehicle or can be repurposed for secondary energy storage applications. This can extend the lifespan of an EV battery to 18 or 20 years before it needs to be recycled.[127]

Dr. Jeff Dahn, a Professor in the Department of Physics & Atmospheric Science and the Department of Chemistry at Dalhousie University (and recognized as one of the pioneering developers of the lithium-ion battery) expressed concern that this policy would encourage manufacturers to install inferior batteries with a limited 10-year life span in order to meet the requirements of this proposed regulation. This would reward manufacturers of shorter lifespan batteries and penalize those companies manufacturing long-life batteries. He proposed that LIB producers should be responsible for the batteries they produce and they should have to collect their batteries, upon request, at end of life. Such a requirement would encourage automakers to focus on battery longevity.[128]

The draft legislation is currently being redrafted based on the feedback received in the public consultation process.

British Columbia: In September 2021, the B.C. government announced that EV batteries will become eligible for province-wide recycling under in the Recycling Regulation and the Extended Producer Responsibility (EPR) strategy, which is part of a five-year plan to advance recycling in the province. The EPR Five-Year Action Plan will give producers time to set up the necessary systems although the government has committed to accelerating proposed timelines where possible.[129]

Under B.C.'s EPR strategy, producers are responsible for implementing, funding and managing recycling programs, with the product's complexity informing the phase-in timeline, to ensure adequate time to establish comprehensive management systems, and to submit EPR program plans to the Ministry of Environment and Climate Change Strategy for approval. EV batteries are scheduled to be added to the regulation in late 2024, and EPR programs are scheduled to be operational in 2026.[130]

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[127] Dr. Jeff Dahn, "Quebec risks a critical circular economy misstep with proposed EV battery recycling plan", electricautonomy.ca, October 29, 2021

[128] Ibid

[129] C. Kim, N. Skuce, K. Tam Wu, Pembina Institute, "Closing the Loop B.C.'s role in recycling battery metals and minerals to power the electric vehicle revolution", December, 2021

[130] Ibid

California LIB Consultation Process and Legislation:[131] In 2018, California Assembly Bill 2832 (AB2832) required the convening of the Lithium-Ion Battery Recycling Advisory Group whose mandate includes submission of policy recommendations to the Legislature to ensure "…that as close to 100% as possible of lithium-ion batteries in the state are reused or recycled at end-of-life". In compliance with AB2832, an Advisory Group was convened and met quarterly between fall of 2019 and spring of 2022. A final report with recommendations for the California Legislature, dated March 16, 2022, was issued in May, 2022.

The Advisory Group's recommended policies in the final report focus on two main areas:

- clearly defining responsibility for the coordination and payment of recycling in cases where the cost presents a burden for the owner of the vehicle and the LIB is unwanted and,
- mitigating barriers that may currently inhibit the reuse, repurposing, and recycling of EV LIBs.

The recommendations allocate responsibility under three possible retirement pathways:

1. For EVs still in service, if a battery pack, module, or cell is replaced before the vehicle reaches EOL, a core exchange program detailed by the EV battery supplier shall be used for the replacement battery (or any module or cell). The entity removing the battery would become responsible for ensuring the used battery (or module or cell) is properly reused, repurposed, or recycled. The entity selling an EV battery would use a core exchange program to track that the used battery has been properly managed.
2. For EVs reaching EOL, a dismantler who takes ownership of an EOL vehicle would become responsible for ensuring the battery is properly reused, repurposed, refurbished, or recycled. If an EV battery is directly reused in another vehicle with no alterations, the process for EVs still in service shall apply. If the battery is refurbished or repurposed, the responsibility would transfer to the refurbisher or repurposer.
3. For EVs reaching EOL where an EOL EV with an OEM-certified battery is not acquired and removed by a licensed dismantler, the vehicle manufacturer would be responsible for ensuring that the vehicle is properly dismantled and the LIB is properly reused, refurbished, or recycled.

The majority of the Advisory Group also supported a producer take-back policy making the vehicle OEM or re-purposing company responsible for ensuring proper reuse, repurposing, or recycling at a licensed facility and at no cost to the consumer. The recommendations from the report were issued too late to meet the 2022 legislative deadline and may be introduced in the 2023 legislative session.

New Zealand's Proposed Large Format Battery EPR Legislation:[132] The New Zealand Ministry for the Environment is in the process of developing a producer responsibility scheme for large format batteries, which includes EV batteries, following a consultation process that ended in December, 2021.

[131] Extracted from Lithium-ion Battery Recycling Advisory Group Final Report, March 15, 2022
[132] Extracted from Consultation Document for Proposed Product Stewardship Regulations: Tyres and Large Batteries, NZ Ministry for the Environment, November 2021

The co-design for large battery scheme was led by stakeholders through the Waste Management Institute of New Zealand (WasteMINZ) and the Battery Industry Group (B.I.G.), and co-funded through the government's Waste Minimisation Fund.

The scheme will be run by a product stewardship organisation (PSO) which will oversee and administer the payment of incentives, manage data, and provide governance and operational functions. The PSO would be a not-for profit entity, governed by a board of trustees or directors, and supported by independent advisory or technical groups. The co-design working group is currently setting up a 'transition team' to establish the PSO and apply for scheme accreditation.

The co-design group has proposed the following process:

1. When a large battery is imported into New Zealand (either as a battery or in a vehicle or other machinery) or manufactured in New Zealand, information on the item is recorded by New Zealand Customs (Customs) and potentially other agencies, such as Waka Kotahi New Zealand Transport Agency (NZTA).

2. Parties obligated by regulation to participate in the scheme inform the PSO about the items they are importing or putting ion the market.

3. The PSO reviews and records the information, along with that from other obligated parties. The PSO calculates the financial obligations of each party (based on the total costs of operating the scheme for that period, divided by the proportion of batteries each party imports in that period), and bills them.

4. The PSO regularly informs the Ministry for the Environment about the imported batteries. The Ministry then checks this information against data from Customs or other agencies and audits each party's declarations.

5. The importers/obligated parties sell the products, which then move through the value chain (noting there may be multiple owners) as normal, until they reach end of use or end of life.

6. At end of use, 'second-life repurposers' accredited by the PSO record details about the battery and give this to the PSO. They may also claim for handling and upgrading the battery.

7. At end of use, a recycler accredited by the PSO will accept the battery at no cost to the owner. The recycler records details about the battery and gives these to the PSO. The PSO then makes payments to the recycler to cover the net costs of recycling.

Proposed EU Batteries Regulation:[133] The European Commission published a proposal for new EU batteries legislation on December 10, 2020 with the aim of paving the way for sustainable batteries as part of a circular and climate neutral economy. The new batteries framework is the next step in delivering on the *European Strategic Action Plan on Batteries*. Key changes are the shift from a Directive (2006/66/EC) to a Europe-wide Regulation as well as new requirements for social responsibility and environmental sustainability.

[133] Recharge: EU Batteries Regulation: New sustainability requirements, WRBRF, March 2021

The proposed regulation covers a wide range of requirements for EV batteries including:

- Reporting on battery carbon intensity and meeting mandatory CO2 thresholds
- Minimum levels of recycled cobalt, lead, lithium and nickel starting in 2030
- Eco design requirements related to performance & durability, removability & replaceability and repurposing & remanufacturing
- Information requirements including battery labels, QR codes and electronic passports

On February 22, 2022, after considering input from stakeholders, the EU Parliament instructed its President to forward the proposed amended regulation to the Council, Commission and EU national parliaments for review and approval.

Appendix E: Potential Funding Sources for ARC Roadmap Implementation

E.1 Background

In December 2021, the Government of Canada indicated that it is considering a mandate that all new light-duty vehicles sold be zero emission by 2035, with an interim sales target of at least 50 percent by 2030. About 1.85 million vehicles are sold in Canada each year with about 1.6 million reaching EOL. EVs currently represent 3-5 percent of total sales and they last for 10-15 years.

The Automotive Recyclers of Canada (ARC) play an important role in the supply chain for the processing of EOLVs , with processing steps including de-pollution, dismantling and separation of select components, recovery of reusable auto parts, and then transfer of remaining auto hulks to metal shredding facilities. This eco-system is well established, integrated across North America, and financially self-sufficient.

However, the EV represents a new challenge for ARC members because it contains different components made of different materials. In particular and compared to the lead acid battery (LAB), the LIB is larger and heavier, potentially explosive and flammable, and its metal content is more complex to recover at this time compared to a traditional LAB which auto recyclers are used to dealing with. Nevertheless, there are several compelling reasons why some attention towards this sector is required:

- **Critical minerals** – the projected demand for minerals and metals needed to build clean tech (including EVs and their batteries) far exceeds projected supply. In fact, it is highly likely that mandated sales targets for electric vehicles will not be reached because the required critical minerals will be unavailable. Governments across the globe are working diligently to build up the critical minerals supply chain for LIBs as quickly as possible to meet the future demand.
- **Competitiveness** – various Canadian companies have emerged with globally competitive technologies (some already funded by the government) and competitive business models to recover critical minerals from LIBs in EVs. An auto-dismantling sector that is unable to process EVs and their batteries in an effective and sustainable manner represents a bottleneck in this supply chain.
- **Circular economy** – the Government of Canada is considering the merits of a national CE strategy. A fundamental part of that is reuse and recycling, which is exactly what ARC members undertake with ELVs; that is, they seek to minimize waste and maximize material efficiencies.
- **Health & Safety** – the LIBs found in EVs must be handled with extreme care. The number one issue is the explosive potential of the LIBs, which can occur at the site of an accident or days later in the recycling yard.
- **Capacity building** – auto dismantlers need to be trained to process EVs using environmentally sound management principles and practices – including the safe recovery of components containing critical minerals. This will be challenging because the actual chemistry of the LIBs may vary according to each vehicle manufacturer.

- **Climate change** – in order to meet Canada's commitment under the Paris Accord, the prolonged use and reuse of auto parts, plus their eventual recycling optimizes resource and energy efficiencies, which subsequently helps avoid GHG emissions.

E.2 Potential Funding Sources

A range of federal funding options is available to support clean technology and carbon-reducing initiatives. However, none of them appears to link product reuse and/or material recycling with energy efficiency and reduced GHG emissions. Each of these is briefly described below and web links are provided for more information.

❖ Building Capacity with the Smart Renewables and Electrification Pathways (SREP) Program (NRCan)

Eligible projects:

All projects must support electricity/renewable energy in Canada. Capacity building activities eligible for funding under this stream can include, but are not limited to:

- Studies: feasibility, engineering, environmental, resource assessment and other studies that lead to tangible, transformative change.
- Knowledge building and sharing: training, workshops, engagement activities, networking, knowledge tools.
- Equity, diversity and inclusion projects: mentoring, apprenticeships, and training focused on underrepresented groups.

More Information and Contacts

https://www.nrcan.gc.ca/climate-change/green-infrastructure-programs/building-capacity-the-smart-renewables-and-electrification-pathways-program/23829

Contact: nrcan.sreps-erite.rncan@nrcan-rncan.gc.ca

SREP could potentially help auto dismantlers adapt to EVs which may require study, will involve transformational change, and will require training.

❖ Zero Emission Vehicle Infrastructure Program (ZEVIP, NRCan)

Details

5-year $280 million program ending in 2024 with an objective to address the lack of charging and refuelling stations in Canada (application closed as of Feb-2022).

Contact

https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/zero-emission-vehicle-infrastructure-program/21876

Contact: ZEV-infra-VEZ@nrcan-rncan.gc.ca

❖ Office of Energy Research and Development (OERD, NRCan)

Focus of Funding

Desired projects will focus on influencing the pace and direction of energy system transformation and targeting the most impactful technologies, in order to maximize environmental and economic outcomes. Four key "missions" to realize a clean energy future and a sustainable natural resources sector:

1. Improve Energy Efficiency and Processes to Reduce Emissions from Energy End-Use;
2. Accelerate Electrification and Maximize Benefits of Low-Emitting Heat and Power;
3. Develop Cleaner Hydrocarbon and Renewable Fuels Pathways;
4. Maintain Safe and Resilient Energy Systems to Protect Canadians in the Changing Energy Landscape.

The OERD carries a suite of funding initiatives: Energy innovation program, Clean growth program, Impact Canada, Green infrastructure (buildings, EV infrastructure, smart grids, and clean energy) with a focus on technology development.

Contact

https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/office-energy-research-development-oerd/5711

Contact: nrcan.energyinnovation-innovationenergetique.rncan@canada.ca

❖ Clean Growth Hub (c/o Innovation, Science and Economic Development Canada)

. The Clean Growth Hub is a whole-of-government focal point for clean technology focused on supporting companies and projects, coordinating programs and tracking results. The Hub's team of experts from across government helps clean technology developers and adopters identify the federal programs and services most relevant to their needs. Hub representatives can also help answer questions regarding policy, regulations, accessing federal laboratories, procurement and skills/training related to clean technology.

Clean technologies are defined as any process, good, or service that reduces environmental impacts through:

- Environmental protection activities that prevent, reduce, or eliminate pollution or any other degradation of the environment;

- Resource management activities that result in the more efficient use of natural resources, thus safeguarding against their depletion; or
- The use of goods that have been adapted to be significantly less energy or resource intensive than the industry standard.

Contact

https://www.ic.gc.ca/eic/site/099.nsf/eng/home

❖ Net Zero Accelerator (NZA) Initiative (under the Strategic Innovation Fund)

Description

Non-profit organizations can apply. Need to follow the Collaborations and Networks "process." ARC work on EV and LIB reuse/recycling would touch on many NZA points including GHG reduction, development of "Canadian battery ecosystem," Canadian focus, skills and/or employment generation, CDN supply chain benefits, and safety/human health improvements.

Stream 5 is called "national ecosystems." This initiative will support large-scale national ecosystems through high impact collaborations between small, medium and large corporations, academic and research institutions, and not-for-profit organization to support Canadian innovation ecosystems.

Eligible applicants include Networks and Consortia (e.g. for-profit corporations, and/or not-for-profit entities) that are incorporated in Canada and consist of multiple members located throughout Canada.

There may be a funding limit of 50% of total eligible costs (as noted in the Strategic Innovation Fund guide, https://www.ic.gc.ca/eic/site/125.nsf/eng/00007.html#c-5).

Contact:

sifinfo-infofsi@ised-isde.gc.ca

https://www.ic.gc.ca/eic/site/125.nsf/eng/00039.html

❖ The Low Carbon Economy Fund (ECCC)

Description

Two billion dollars to support projects that reduce GHG emissions. Need to be able to measure impact/benefit in terms of GHG emissions. Also appears that maximum contribution is 40% of project costs via the Low Carbon Economy Challenge.

Contact

https://www.canada.ca/en/environment-climate-change/services/climate-change/low-carbon-economy-fund.html

Contact: lcef-fefec@ec.gc.ca