Study of **Extended Producer Responsibility** for Electric Vehicle Lithium-Ion Batteries in Quebec

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propulsion Québec

Cluster for Electric and Smart Transportation

This study by **Propulsion Québec**,
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Choisir l'avenir, transporter l'innovation

Lithion
Lithium-ion battery recycling

The study was led by **EY**

THE WORLD OF TRANSPORTATION IS ENTERING A NEW ERA ▸ The current pandemic is motivating us to revise our plans from top to bottom and take a fresh look at the world around us. This is an ideal time to collectively bring about a green revolution and create a more sustainable, just, and prosperous society. Government, economic, and environmental leaders over the world over are currently studying key issues that will transform our future, while concrete mobility solutions are already on the table, from electrified transportation and end-of-life battery management to public transit and integrated mobility.

It is estimated that by 2050, nearly 70% of North America's vehicle fleet will be electric, including light-, medium-, and heavy-duty vehicles. This major shift will have a big impact on the value chain in the electric transportation industry, especially battery management. According to a study commissioned by KPMG, the lithium-ion battery recycling capacity for the North American market will be 21,000 tons by 2025. Given that market requirements are estimated to rise to between 43,000 and 90,000 tons by 2025, this is an opportunity that Quebec would do well to cash in on.

Quebec has the necessary leadership to organize end-of-life battery collection and management, creating a rich alternative source of metals. We have the required resources to position ourselves as pioneers in this area in North America. Quebec has everything it takes to quickly meet its objectives in a number of promising transportation sectors.

This study will address numerous questions raised by the electric and smart transportation (EST) sector. What do we plan to do, and what should we do, with end-of-life lithium-ion batteries for electric vehicles? What would be the ideal regulatory mechanism for managing and collecting end-of-life batteries in Quebec? How would it be applied? Should it be linked to existing recycling systems?

Harmonized application of a mechanism for extended producer responsibility for lithium-ion batteries in electric vehicles in Quebec is not only a pressing environmental need but is also consistent with the emergence of a greener and more prosperous Quebec. To introduce a regulatory mechanism, Quebec will need to capitalize on its flexible research ecosystem and the innovative and collaborative spirit of EST sector players, develop a recycling industry based on robust hydrometallurgical and electrochemical processes, and adapt existing recycling facilities.

I would like to thank all the members of our industry who contributed to this study. Let us seize this unique opportunity to get the post-COVID economy back on track with an initiative that all Quebecers can get behind and support. The challenges will be big, but so are our goals.

Sarah Houde
CEO
Propulsion Québec,
the Cluster for Electric and Smart Transportation

Our Mission

Propulsion Québec rallies the entire sector around joint projects aimed at positioning Quebec as a global leader in developing and implementing smart and electric modes of ground transportation.

By 2026, the cluster's aim is for Quebec to :

- **Be recognized as a global leader in the business segments tied to electric and smart transportation;**
- **Have a solid core of worldclass businesses that span the entire electric and smart transportation value chain;**
- **Become a hub for electric and smart vehicle trials and use.**

About this report

EY was mandated by Propulsion Québec to examines the feasability of extended producer responsability measures of lithium-ion EV batteries in Quebec. it reviews the current situation around the world, identifies key issues, and suggests potential implementation scenarios.

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Objective

Sales of electric vehicles (EVs) in Quebec will grow substantially over the next decade and beyond. This growth will create environmental challenges and economic opportunities related to the management of end-of-life EV batteries.

More and more countries are using extended producer responsibility (EPR) to regulate and monitor end-of-life batteries. EPR measures are already in place in Quebec for household batteries and e-waste. This study examines the feasibility of such measures for lithium-ion EV batteries in Quebec. It reviews the current situation around the world, identifies key issues, and suggests potential implementation scenarios.

Key stakeholders and market players were interviewed individually and consulted as part of targeted presentations and discussions in order to accurately identify their concerns. EY consulting firm presented its findings to a steering committee over the course of the study.

Current Situation

For the purposes of this study, EPR is considered as an end-of-life management tool for EV batteries. EPR is already well-established in Quebec for other products. It helps clearly identify the responsibilities of those involved in collecting, sorting, packaging, and recycling. EV batteries are a fire hazard and contain materials that are toxic and harmful to the environment, so they must be handled, stored, and transported with care. Europe has already set up EPR for EV batteries (with the Directive on batteries and accumulators and the Directive on end-of-life vehicles) and Quebec has an opportunity to lead the way on EPR in North America.

Our analysis of the legal framework in North America for recycling end-of-life vehicles (ELVs) and batteries and transporting hazardous materials shows that there is no example for Quebec to follow in Canada or the U.S. This does not appear to be a major stumbling block for setting up EPR for EV batteries in Quebec. Our study also concluded that the possible slight increase in price caused by EPR for EVs should not affect sales or Quebec's ability to meet the objectives it set in the *Act to increase the number of zero-emission motor vehicles*.

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Issues

EPR rollout must be tailored to where it occurs. We have identified issues that correspond to various life cycle stages and grouped them into nine categories.

1. **Uncertainty about battery lifespan:** There is no standard definition of battery lifespan and the lengths of the first and second lives of batteries are uncertain.

2. **Second-life batteries:** Second-life use of batteries (e.g., for storage) raises questions about responsibility. Second-life batteries would also be in direct competition with new storage batteries, which could limit reuse rates.

3. **Hazardous materials:** Batteries are hazardous materials that must be handled safely, which requires special training. Because they are hazardous, batteries must be trackable and easy to identify.

4. **Legal framework:** A number of parameters for EPR programs, including scope and recovery targets, must be determined based on jurisdiction.

5. **Management and recycling costs:** EPR-related costs (supply, transport, slight impact on EV costs) are an issue for stakeholders.

6. **Battery composition:** There are multiple types of batteries with different chemical compositions.

7. **Orphan batteries:** Batteries already in use, imported from elsewhere, or whose producer has gone bankrupt will have to be managed.

8. **Recycling:** Recycling may be carried out locally or internationally. Profitability will vary depending on the batteries. Producers have concerns about the confidentiality of their technology in the event that they do not carry out the recycling.

9. **Environment:** Mismanagement of end-of-life batteries is a key issue.

The main issues regarding end-of-life battery management in Quebec are the following:

- **Definition of battery lifespan:** The market is still too young for a clear picture of battery lifespan to have emerged, both in terms of function (with or without a second life) and time period (different models vary). Since EPR is likely to include recovery targets based on battery lifespan, an average lifespan will have to be set, even if it is subsequently revised.

- **Economic value of end-of-life EV batteries and producer initiatives:** The economic value of end-of-life EV batteries should be sufficient to attract private investment. Some stakeholders, including EV producers, are concerned that EPR will undermine their ability to develop recycling chains.

- **EPR scope of application:** It will be very important to clearly identify which types of batteries are covered under EPR. Management needs differ from one type of battery to another (e.g., batteries for trucks and cars). The market is still in its infancy, so limited quantitative data is available. As a result, this study only provides estimates for the financial impact of EPR for passenger EV batteries. Batteries for medium-duty and heavy-duty vehicles are discussed qualitatively.

- **Battery tracing: EV producers** are wondering how they will recover their batteries if they cannot be tracked in the market. They are worried about a lack of visibility for EV batteries.

Key Factors for Successful EPR Implementation in Quebec

A SWOT analysis of EPR implementation in Quebec shows that introducing EPR could address many of the current and future challenges posed by end-of-life battery management. This study focuses specifically on EPR, but it is not necessarily the only approach capable of addressing the challenges posed by end-of-life battery management.

Strengths	Weaknesses
Clear responsibilities: Producers' financial and operational responsibilities are clearly defined and set out in legal terms. **Economies of scale:** An overarching management organization could centralize management tasks and coordinate stakeholders' efforts. **Sectoral risk prevention:** Consistent and coordinated communication campaigns could raise awareness about safety procedures, the use of standardized tool and the environmental risks of end-of-life battery mismanagement.	**Administrative monitoring:** The need to monitor processes and compliance will create an administrative burden for companies targeted by EPR. **Redundant reporting mechanisms:** Companies that operate in multiple jurisdictions with separate EPR measures may be required to comply with separate reporting regulations in each jurisdiction, which may involve redundancies if the reporting mechanisms are not harmonized.

Opportunities	Threats
Individual responsibility: EPR leaves room for producers to develop their own processes for recovering batteries. **Environmental performance targets:** EPR measures could include ambitious targets for recycling and reuse rates. **Growth and innovation in Quebec's recycling sector:** EPR could accelerate development of local expertise and investment in recycling.	**Perceived cost of EPR:** EPR costs assumed by producers can be integrated into the EV price. This amount would be equivalent to 1% or less of the price of a new EV. Increases in EV prices may have a slight impact on sales.

Key success factors for implementing EPR:

Setting the right parameters: EPR measures must set out parameters for when they apply (e.g., scope and definition of lifespan) and provide a balanced approach to funding.

Optimal launch time: The approach should be gradual and flexible. It must also take the unique situation in North America into account to ensure consistency between systems as the framework evolves.

Flexible EPR implementation: An overarching management organization could be created to centralize costs and administration, but the framework could leave room for private initiatives by EV producers that wish to develop their own recycling chains and recover the economic value of their own batteries.

Conservative recovery targets: It is important for recovery targets to be discussed with stakeholders and amended if necessary.

Battery identification system: An identification system could be set up to facilitate collection and recycling or reuse. A serial number could provide access to a battery's ID record.

Collaborative approach: End-of-life battery management involves the issues listed above. EPR requires the participation of multiple links in the recycling chain, so it is crucial for the system to take these issues into account and address them effectively.

R&D awareness and promotion: EPR should include education for all stakeholders and promote R&D.

Main Limits

As a result of the underdeveloped lithium-ion battery market, this study has some limitations. Data availability and uncertainty were the main issues. In some cases it was difficult to obtain robust and widely accepted data. Plus, developments in the vehicle electrification market will invariably influence future choices, including the second life of batteries. The quantitative and qualitative results should be viewed within the context of the information currently available and assumptions about market trends in late 2019 and early 2020.

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Definitions

Accumulator: Term used in Europe to refer to a set of cells. The term "battery" is more common in Quebec.

Battery: Device composed of multiple cells that stores electrical energy created by chemical reactions and redistributes it as current.

Cell: Device used independently that, like a battery, stores electrical energy from a chemical reaction and redistributes it as current.

EPR costs: EPR costs include the cost of collection, processing, transport, and packaging, along with other costs such as awareness and education campaigns, R&D, and administrative and operational tasks like reporting and human resources management.

Electric vehicle (EV): Vehicle powered in whole or in part by an electric motor and containing an EV battery. This includes electric cars, hybrids, plug-in hybrids, and any other mode of transport powered by electricity, such as light-duty vehicles (including light-duty motorized electric vehicles and electric bicycles) and medium-duty and heavy-duty vehicles (including electric trucks, electric buses, and so on). For the purposes of this study, "EV" refers exclusively to electric, hybrid, and plug-in hybrid cars. We are using the same definition of passenger EV as the 2019 Propulsion Québec study.

Electric vehicle battery (EV battery): A battery composed of lithium-ion cells (or cells with any other chemical composition) that is housed in an electric vehicle and powers its electric motor.

Freerider: According to RECYC-QUÉBEC, freeriders are actors that avoid paying end-of-life management fees on their products. This gives them a competitive advantage in the marketplace. These are companies targeted by the regulations that fail to set up a program or join the RMO.

Recognized management organization (RMO): Management organization accredited by the relevant authority (RECYC-QUÉBEC in Quebec) to operate a public system for recovering and recycling a given product.

UN number: 4-digit codes developed by the United Nations to identify hazardous materials.

Acronyms

4R-D	Reduce, reuse, recycle, recover (including energy recovery), and dispose
ARA	Automotive Recyclers Association
ARC	Automotive Recyclers of Canada
ARN	Auto Recycling Nederland
ARPAC	Association of Auto Parts Recyclers in Quebec
CFR	Code of Federal Regulations
CPPM	Containers, packaging, and printed matter
DOT	U.S. Department of Transportation
ELV	End-of-life vehicle
EOL	End-of-life
EPA	U.S. Environmental Protection Agency
EPR	Extended producer responsibility
EQA	Environment Quality Act
EV	Electric vehicle
MECP	Ontario's Department of Environment, Conservation and Parks
MELCC	Ministère de l'Environnement et de la Lutte contre les changements climatiques (Department of Environment and the Fight Against Climate Change)
MTQ	Ministère des Transports du Québec (Department of Transportation Quebec)
NSAC	National Stewardship Action Council
PSI	Product Stewardship Institute
R&D	Research and development
RMO	Recognized management organization
RRHM	Regulation respecting hazardous materials
TC	Transport Canada
TDG	Transportation of dangerous goods

1 Introduction and Background

1.1 Background

Transportation currently produces 43% of greenhouse gas emissions in Quebec. In order to meet its emission reduction targets by 2030, Quebec is moving towards electrification and investing in electric transportation. According to Propulsion Québec's study in 2019 on the lithium-ion battery industry, sales of EVs in Quebec will grow dramatically over the next decade.

This growth will create challenges and opportunities related to end-of-life EV battery management. An innovative approach is required as batteries contain a range of valuable materials that can offset recycling costs. Such costs are high because batteries must be dismantled before being chemically recycled. It is also good to remember that a big part of the environmental impact of EVs comes from the ecological and carbon footprint of extracting the metals needed in their batteries and the risk the batteries will be mismanaged at end of life, harming water resources and the environment in general.

All this points to the necessity of controlling and managing end-of-life batteries in order to harness their economic value and minimize environmental risk. More and more countries are using extended producer responsibility (EPR) to do so. EPR measures are effective tools for ensuring high recovery and recycling rates and are already in use in Quebec and Canada for similar materials such as household batteries and e-waste.

The 2019 Propulsion Québec study also shows that Quebec has industrial and technological expertise and strong prospects for its battery industry, but still lacks the infrastructure needed to collect and recycle EV batteries.

All this points to the necessity of controlling and managing end-of-life batteries in order to harness their economic value and minimize environmental risk.

1.2 Objectives and Methodology

Propulsion Québec tasked EY consulting firm with analyzing existing collection mechanisms and, more specifically, how EPR measures could be implemented in Quebec to manage end-of-life EV batteries. The objective was to identify the challenges and opportunities in the province, along with key factors for successful implementation of EPR measures in Quebec.

The study involved identifying the main tools and practices for collecting batteries; reviewing legal frameworks governing ELVs, EVs, and recovery and recycling in North America (Quebec, Ontario, Manitoba, British Columbia, P.E.I., Saskatchewan, and the U.S., with a special focus on California); examining existing EPR for EV batteries in other countries; and developing EPR implementation scenarios for North America and Quebec in particular.

This report is the result of research and consultation with key market players. EY conducted individual interviews and a stakeholder consultation workshop (full list in Appendix A) in order to gain a deeper understanding of the broader context for this study and the issues facing stakeholders. At the same time, Propulsion Québec struck a steering committee (full list in Appendix B), which met several times over the course of the study to review preliminary results, approve subsequent steps, and discuss the contents of this study.

1.3 Main Limits

This report should be interpreted in light of the fact that the quantitative and qualitative work it contains is based on public data. Data regarding the EV market in Quebec is based exclusively on a study by Propulsion Québec in 2019.

Given the fact that this market is still in its infancy, the data and facts presented in this study should be viewed cautiously—little information is available, especially for Quebec. It is also very difficult to predict how the situation will evolve and what decisions industry, government, and the public will make.

Various initiatives and measures implemented in other countries are presented in this report. These examples are not exhaustive and by no means represent all the systems currently in use. The focus is on those that made the most sense in the context of this study and given the amount of time available.

2 Collection Mechanisms for EV Batteries

2.1 Growth of Electric Vehicles and Batteries

In 2019, there were 139,000 EVs on Canadian roads. Sales of new EVs continue to grow and increased over 50% between 2018 and 2019.[1] The estimated number of EVs sold in in Quebec in 2019 was 17,000[2] and according to AVEQ there were over 67,000 EVs as of January 31, 2020.

Similar growth is evident elsewhere[3]—in the European Union, the number of battery EVs rose by 50% in 2018 to 300,000 and represented 2% of all new vehicles. Germany, France, and the Netherlands are leading the way, with almost a third of EVs in the EU between them. Outside the EU, Norway is the number one early adopter. Nearly half of new vehicles sold there in 2018 were battery or hybrid EVs. The number of battery EVs in Europe is expected to increase rapidly to 2.5 million by 2025.[4] Increased sales of new EVs means greater demand for lithium-ion battery materials and cells. Worldwide demand for some materials will rise between 500% and 1,200% over the next decade.[5]

It is estimated that between 43,000 and 90,000 metric tons of batteries will reach end of life in the U.S. Northeast by 2025. The figures for Quebec are between 3,000 and 7,000 tons. The anticipated recycling capacity for the U.S. Northeast is 21,000 tons in 2024 and 10,000 tons in Quebec.[6]

Now is a good time to consider the impact of this sustained growth and explore solutions to impending challenges, especially when it comes to managing end-of-life batteries.

1 Data from AVEQ and the EY report: https://assets.ey.com/content/dam/ey-sites/ey-com/en_ca/topics/oil-and-gas/canadian-electric-vehicle-transition-the-difference-between-revolution-or-evolution.pdf
2 Data from the Propulsion Québec study
3 https://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment-4
4 https://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment-4
5 Data from the Propulsion Québec study: https://propulsionquebec.com/ressources/documents-et-liens/
6 Data from the Propulsion Québec study: https://propulsionquebec.com/ressources/documents-et-liens/

2.2 Examples of Initiatives Around the World

Battery production and recycling technology is advancing rapidly. Pressure from competition has led producers and their suppliers to develop partnerships and invest in research projects to gain expertise. Here are some examples.

2.2.1 Battery Tracking in China

China launched the Energy-Saving and New Energy Vehicles Industry Development Plan in 2012 and has since become a trailblazer in EV adoption. EVs have been on the market for over a decade, so the first generation of batteries will reach end of life soon.

In 2018, the Ministry of Industry issued guidelines (provisional regulations[7]) requiring EV producers to organize and fund end-of-life battery management. Producers must provide collection points where batteries can be stored while awaiting transfer to specialized recyclers. Producers are also encouraged to standardize batteries and design them to be easily dismantled at end of life. The ministry also called for the implementation of a battery identification and tracing system. The aim is for storage sites and recyclers to easily identify the types of batteries collected in order to optimize recycling processes and accountability.

2.2.2 BMW, Northvolt, and Umicore

In October 2018, BMW, Northvolt, and Umicore formed a technology consortium with the aim of developing recyclable batteries with a view to creating a circular economy. With expertise in innovative use of materials, battery design and recycling, and EV development, the consortium has addressed key issues in the battery life cycle.

2.2.3 Volkswagen and Northvolt

In March 2019 VW and Northvolt formed a partnership to collaborate on EV battery research. Their main objective is to develop expertise on producing more sustainable, climate-friendly, and competitive battery cells.

7 Interim Measures for the Management of Recovery and Utilization of New Energy Vehicle Power Battery

2.2.4 Renault

Since 2000, Groupe Renault has been working to integrate the concept of circular economy into its operations, including end-of-life batteries. For example, when batteries are no longer usable, they are reconditioned to store renewable energy and to power buildings. As part of these initiatives, Renault has developed two business models for EVs:

Traditional model: Consumers buy vehicles and batteries. There is no monthly fee for batteries, but consumers are responsible for all maintenance. Batteries are covered under warranty for 8 years or 160,000 km, with a guaranteed performance of at least 66%.

Battery lease model: Consumers buy vehicles and pay a monthly fee to lease batteries. The leases allow consumers to replace their batteries free of charge when the charge capacity drops below 75% within 10 years or 60% thereafter, and provides free assistance for all breakdowns, including power failures.

The system offers consumers multiple advantages, including guaranteed battery performance, lower purchase price, a lease tailored to their needs, and easier resale because the new owner signs a lease with Renault for the battery. The solution also has a number of advantages from an environmental standpoint because Renault is involved throughout the battery life cycle and controls environmental impacts from manufacturing to recycling. The group funds and manages end-of-life battery recycling with companies such as Véolia that operate in accordance with environmental standards. Renault estimates that its battery recovery rates are around 100%.

2.2.5 Proterra

Proterra has a similar business model for electric buses. Its approach is based on the assumption that many companies cannot afford to invest in an electric fleet because the vehicles are too expensive. Since batteries are a major cost factor, the company offers a lease system to lower the purchase price to a level that is comparable to natural gas and diesel buses. Battery leases cover the 12-year lifespan of buses, and Proterra guarantees battery performance and provides a replacement battery after 6 years.

Proterra designs its batteries to have a second life. They are engineered to be easily dismantled for recycling. The company works with third parties that specialize in recycling, and more specifically in extraction and recycling of materials contained in EV lithium-ion batteries. According to Proterra, 99% of the constituent metals are recovered.

2.2.6 Nissan

In England, any company that brings EV batteries to market is required to recover, process, and recycle its batteries. In order to comply with these regulations, Nissan has implemented a system that allows consumers to return EV batteries to any Nissan dealer when buying or installing a new battery. If consumers are simply looking to dispose of batteries, they are encouraged to bring them to processing centers for recycling. But Nissan does not pay for them to be recycled. Nissan Motor (GB) is also committed to collecting Nissan industrial lithium batteries returned by consumers free of charge.

2.2.7 ReLieVe

ReLieVie's Recycling Li-Ion Batteries for Electric Vehicles project is headed up by Eramet in partnership with BASF and SUEZ and was awarded Can$7 million in funding by the European Union in September, 2019. The three industry partners have two goals:

- Develop an innovative technological process for recycling lithium-ion EV batteries.
- Establish an integrated recycling chain, including collection and dismantling of end-of-life batteries, recycling of constituent elements, and manufacturing of new electrode materials.

This partnership is especially promising because of each company's expertise in the value chain. SUEZ focuses on collecting and dismantling end-of-life batteries, Eramet specializes in developing recycling processes, and BASF concentrates on manufacturing active cathode materials.

2.2.8 Tesla

At present it appears that Tesla is not recovering significant numbers of end-of-life EV batteries. The few batteries that are returned come from the R&D, manufacturing, quality control, and operations departments, and Tesla handles recycling itself in conjunction with third parties. Tesla is nevertheless working on a large-scale recycling project at Gigafactory 1. The system will recycle defective batteries from the manufacturing phase and end-of-life batteries returned from the market. The recycling process will maximize recovery of critical minerals like lithium and cobalt and other metals used in cells, including copper, aluminum, and steel. Recovery of these metals will achieve volumes sufficient for use in the production of new batteries.

2.2.9 Toyota

In recent years, Toyota has developed a number of initiatives and partnerships to address the issue of end-of-life batteries.

In Europe, Toyota has implemented a plan to recover hybrid EV batteries through its dealer network. It has helped Toyota recover and safely and responsibly process over 90% of its batteries in Europe. The automaker's goal is to reach 100% recovery. Toyota has developed a partnership with Umicore and SNAM to recycle batteries when they cannot be reused either as replacement batteries in other vehicles or as standalone energy storage units.

Toyota has also developed a program to promote recycling of hybrid EV batteries in Australia. The automaker offers rewards at all points of sale to encourage consumers to return their batteries:

- Can$90 cashback for returning a hybrid EV battery
- Can$450 off replacement hybrid EV batteries when returning an old one

The metal casing and metal and plastic parts are recycled locally. The battery cells and printed circuit boards are exported for primary metal extraction.

In 2018, Toyota partnered with Chubu Electric Power in Japan to use second-life batteries to store energy. The batteries will be transformed into a renewable energy plant. Construction of the plant is slated to begin in 2020. The project is expected to take time as the batteries have to reach the end of their "first" lives. Chubu Electric Power will recycle them at the end of their second lives.

2.3 Survey of Existing Collection Mechanisms that Could Be Used for EV Batteries in Quebec

This section summarizes existing practices and mechanisms for waste collection and recycling that could be used for EV batteries.

In Quebec, waste management is currently governed by the Quebec Residual Materials Management Policy under the Environment Quality Act (EQA). The policy is based on the principles of 4R-D (Reduce, reuse, recycle, recover [including energy recovery], and dispose) and aims to minimize the amount of waste with recovery potential that ends up in landfills.

At the provincial level, Department of Environment and the Fight Against Climate Change (MELCC) (Ministère de l'Environnement et de la Lutte contre les Changements Climatiques) has policies and mechanisms to transfer responsibility for end-of-life waste management from municipalities to producers. Producers are often better equipped to handle end-of-life management, which reduces the financial burden on municipalities. Producers also have the option of improving product design to reduce processing costs. Products likely to be transferred to producers are generally those that are hazardous to dispose of or store, that are non-standard size or weight, or that have high potential for reuse.[8] Some examples of responsibility transfer mechanisms are presented below.

8 http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2035.1

2.3.1 Deposit System[9]

Consumers pay a refundable deposit upon purchase as an incentive to return containers.

Table 1 – Overview of the deposit system

Regulatory framework	***Act respecting the sale and distribution of beer and soft drinks in non-returnable containers***
Objectives	Sort materials at the source to improve recycling.
Applicable products	Non-refillable beer and soft drink containers Starting in 2022, the deposit will apply to all beverage containers ranging in size from 100 ml to 2 L and made of plastic, glass, metal, or cardboard.
Funding	Companies that market beverage containers.
Operation	
Other stakeholders	RECYC-QUÉBEC, Boissons Gazeuses Environnement (BGE), consumers and retailers.

Source: Deposit modernization FAQ (French only)[10]

In Quebec, the deposit system is only used for beverage containers. Discussions with the government indicate that a deposit mechanism is not likely to be adopted for EV batteries.

9 There is also a deposit system for refillable containers set up by private industry.
10 https://www.recyc-quebec.gouv.qc.ca/entreprises-organismes/mieux-gerer/consigne/foire-aux-questions

2.3.2 Compensation Plan for Separate Collection

Compensation plans require companies that sell specified products to pay fees to offset the costs for municipalities to collect them separately.

Table 2 – Overview of the compensation plan for separate collection

Regulatory framework	***Regulation respecting compensation for municipal services provided to recover and reclaim residual materials***
Objective	Transfer the cost of separate collection to specified companies.
Applicable products	Containers, packaging, printed matter (CPPM), and newspapers.
Funding	Companies it applies to.
Operation	Éco Entreprises Québec for CPPM and RecycleMédias for newspapers
Other stakeholders	RECYC-QUÉBEC and municipalities.

Source: RECYC-QUÉBEC[11]

End-of-life EV batteries will not be managed by municipalities, so this mechanism is not entirely relevant to this study. Also, in February 2020, MELCC announced a $30.5 million investment to modernize separate collection. The changes will transform the current plan into an extended producer responsibility mechanism.[12] In addition to their financial responsibilities under the compensation plan, businesses will also be tasked with operational end-of-life management for CPPM.

11 https://www.recyc-quebec.gouv.qc.ca/municipalites/collecte-selective-municipale/regime-de-compensation
12 https://www.newswire.ca/fr/news-releases/recuperer-plus-et-recycler-mieux-quebec-annonce-une-reforme-du-systeme-de-collecte-selective-et-injecte-30-5-m-pour-soutenir-cette-modernisation-805751764.html

2.3.3 Used Tire Management Program

Provincewide program to recover used tires and help out the Quebec recycling industry by making sure it has a ready supply of tires.

Table 3 – Overview of the used tire management program

Regulatory framework	***Quebec Integrated Used Tire Management Program***
Objectives	Use the self-funded system to recover used tires free of charge and help develop the recycling industry in Quebec.
Applicable products	Used tires
Funding	Consumers pay $3 plus federal and provincial taxes on the purchase of new tires to fund the program.[13]
Operation	RECYC-QUÉBEC
Other stakeholders	Facilities equipped to install and remove tires (e.g., garages, tire centers, dealerships, service stations)

Source: Quebec Integrated Used Tire Management Program 2015–2020[14]

The lithium-ion battery recycling industry in Quebec is still underdeveloped, so this mechanism is not suitable for EV batteries. Plus, tires are on the priority list of products to bring under EPR. The program is supposed to be integrated with EPR by the end of 2020, but it is still being operated by RECYC-QUÉBEC and no recent announcements have been made.

13 New tire fees (French only): http://www4.gouv.qc.ca/FR/Portail/Citoyens/Evenements/consommateur-renseignement-plainte/Pages/pneus-neufs-droits-payer.aspx
14 https://www.recyc-quebec.gouv.qc.ca/sites/default/files/documents/programme-pneus-2015-2020.pdf

2.3.4 Extended Producer Responsibility (EPR)

Companies that sell applicable products are responsible for managing them at end of life.

Table 4 – Overview of extended producer responsibility

Regulatory framework	***Regulation respecting the recovery and reclamation of products by enterprises (EPR regulatory mechanism)***
Objectives	Transfer responsibility for end-of-life management to companies while encouraging them to respect the principles of 4R-D and eco-design.
Companies it applies to	Producers, manufacturers, brand owners, and first suppliers of applicable products[15]
Funding	Companies it applies to
Operation	Companies ensure end-of-life management via an independent program or recognized management organization.
Other stakeholders	RECYC-QUÉBEC and consumers

Sources: MELCC[16] and RECYC-QUÉBEC[17]

Companies subject to the regulation must set up a program accesible for free for recovering and recycling their products via a collection system that includes dropoff points and ad hoc collection events across Quebec. The regulation also sets out obligations with respect to research and development, reporting, and running an awareness and education program. In order to meet their obligations, companies have the option of setting up their own recovery and recycling programs or joining a recognized management organization (RMO) that operates a system for its members.

The costs of setting up recovery and recycling systems are known as associated costs. They represent the costs incurred across all stages of end-of-life management, including collection, processing, transportation, packaging, and reporting. EPR costs can be included in a product's retail price.[18] When a company is a member of a management organization, the organization can request contributions based on the net costs of its operations.

15 https://www.recyc-quebec.gouv.qc.ca/entreprises-organismes/mieux-gerer/responsabilite-elargie-producteurs
16 http://www.environnement.gouv.qc.ca/matieres/reglement/recup-valor-entrepr/faq.htm
17 https://www.recyc-quebec.gouv.qc.ca/entreprises-organismes/mieux-gerer/responsabilite-elargie-producteurs
18 There is no regulatory requirement to pass the costs on to the consumer. But, like other marketing costs, it is a factor that affects the retail price.

EPR regulations currently apply to six categories of products. MELCC has the authority to add new product categories to the regulations, like the most recent category, household appliances and air conditioners. These appliances are composed of a cooling system and insulating foam and may contain harmful gases such as halocarbons, which have extremely high global warming potential (1,400 to 10,900 times higher than carbon dioxide.)[19] The Regulation amending the Regulation respecting the recovery and reclamation of products by enterprises was amended to this effect in November 2019 and sets out the following requirements, among other things:[20]

Applicable appliances and air conditioning units are grouped into four subcategories:

1. Refrigerators and freezers designed and intended for household use
2. Refrigerators and freezers designed and intended for commercial or institutional use
3. Air conditioners, heat pumps, and dehumidifiers
4. Ranges, built-in ovens, built-in cooking surfaces, dishwashers, washing machines, and dryers designed and intended for household use

   Exclusions: Appliances that weigh more than 300 kg, those that form an integral part of the operation of a building (e.g., arena refrigeration systems), small refrigerators and freezers with a usable volume under 2.5 sq. ft., and coolers.

- Companies that sell products in subcategories 1, 3, and 4 have until December 5, 2020, to set up recovery and recycling systems.
- Companies that sell products in subcategory 2 have until December 5, 2021.
- Companies must provide dropoff points and a collection service for their recovery and recycling systems.

All products subject to the regulation are listed in the table on the following page.

19 https://www.lapresse.ca/actualites/environnement/201911/04/01-5248255-les-fabricants-delectromenagers-devront-recuperer-leurs-produits.php
20 http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=1&file=71451.pdf

Table 5 – Products that fall under EPR in Quebec

	2020 recovery targets	Management organization	Recycling	Dropoff points
Mercury light bulbs	40% for fluorescent tubes 30% for fluorescent lightbulbs 40% for other types	Canadian Product Care Association (RecycFluo program)	Quebec and Ontario	Over 800
Household batteries	25% for rechargeable batteries 20% for non-rechargeable batteries	Call2Recycle, Inc.	British Columbia, Ontario, and the U.S.	Over 1,670
Oils, coolants, and antifreeze and any filters, containers, or other products used in conjunction with them	75% for oils, containers, and filters	Société de gestion des huiles usagées du Québec (SOGHU)	Quebec and Ontario	Over 1,750
Paint and paint containers	75% for products (stains, varnishes, primers, lacquers) 40% for containers, aerosols, and aerosol containers	Éco-Peinture	Quebec	Over 1,200
Electronics	40% for all products (25% for cellphones, corded phones, audio devices, and digital cameras)	ERPA-Quebec	Quebec	About 1,000
Household appliances and air conditioners	Starting 2024: 70% for household fridges and freezers 25% for air conditioners, heat pumps, and dehumidifiers	TBA	TBA	TBA

Sources: RECYC-QUÉBEC fact sheet and the Regulation amending the Regulation respecting the recovery and reclamation of products by enterprises

EPR's flexibility makes it a good candidate for effective EV battery collection and recycling. The advantages and features of EPR and the attendant challenges will be discussed in Section 4.

2.4 EPR Systems for EV Batteries in Europe

In Europe, EPR for EV batteries is governed by the Directive on batteries and accumulators (2006/66/CE) and the Directive on end-of-life vehicles (2000/53/CE).[21]

Member states can adjust their commitments to fit their own national requirements, so there is significant variation between systems across Europe. Measures in Norway, the Netherlands, and Belgium will be reviewed to identify best practices. These three countries already have functional systems for collecting and recycling end-of-life EV batteries.

2.4.1 Norway

Norway has been promoting the sale of EVs since the 1990s. A wide range of measures has been put in place since then, including tax incentives, subsidies, benefits such as reserved lanes, and a purchase ban on internal combustion vehicles set to come into effect in 2025. As a result, Norway has emerged as a world leader in EV market penetration. In 2018 half of all new vehicles were EVs.

Since 2014 battery collection and recycling has been managed by Batteriretur Hoyenergi AS, an organization funded by EV producers. The organization was created for a variety of reasons, including the collapse of Norwegian EV producer Think Global and the risks of a lack of funding in the end-of-life phase.

In 2018 Batteriretur collected 1,000 EV batteries, a significant portion of which were from vehicles damaged in collisions. 80% of the batteries collected were recycled, while 20% were reconditioned.[22]

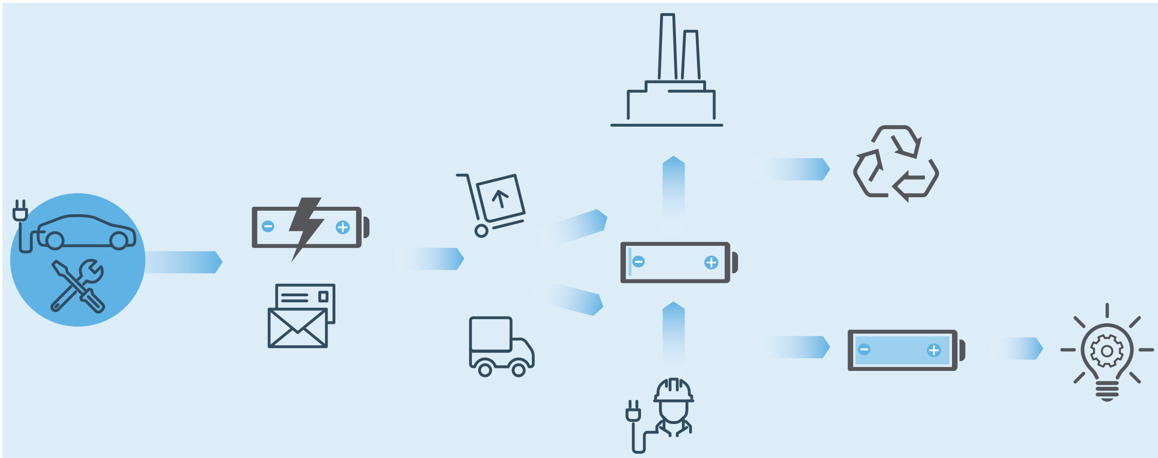
2.4.2 Netherlands

In the Netherlands, sales of EVs (hybrid and 100% electric) are on the rise as a result of tax incentives. Nearly 15% of new passenger vehicles sold in 2019 were EVs. Auto Recycling Nederland (ARN), the organization in charge of ELVs, set up a system in 2012 to collect EV batteries.

ARN collects batteries free of charge from garages and scrap yards that have removed them from vehicles and notified ARN via its website.[23] Mechanics describe the state of the batteries when notifying ARN. If a battery is damaged or defective, it is transported directly to a recycling center. If it appears to be in good shape, it is sent to a reconditioning center. The company doing the reconditioning measures the battery's capacity. If it is sufficient,[24] the battery is reconditioned for further use. If not, it goes to recycling, which currently involves a combination of hydrometallurgy and pyrometallurgy[25] and recovers cobalt, nickel, copper, and iron. Other metals such as lithium are not usually recovered.[26]

21 These directives are examined in greater detail in Sections 3.1 and 3.2.
22 Nordic Council of Ministers (2019), Mapping of lithium-ion batteries for vehicles: A study of their fate in the Nordic countries
23 https://arn.nl/batterijen/
24 A 70% capacity limit for battery reuse was stated in interviews.
25 Currently recycling takes place at existing facilities, such as Umicore in Belgium.
26 More information is available at https://circulareconomy.europa.eu/platform/sites/default/files/circular_economy_impacts_batteries_for_evs.pdf

Figure 1 – Illustration of the logistics of a battery after it has been removed from a vehicle in the Netherlands



EV producers fund the system and pay contributions based on battery weight. These are the rates for 2020:

Can$85 per battery > 25 kg and ≤ 100 kg

Can$170 per battery > 100 kg and ≤ 350 kg

Can$210 per battery > 350 kg and ≤ 600 kg

Can$250 per battery > 600 kg and ≤ 900 kg

Contributions cover end-of-life battery management for the current year, including transportation, sorting, processing, and administrative costs. Contributions in 2020 cover management costs for batteries that reach end of life in 2020. They also include a provision for future costs. It will take a number of years for EV batteries sold in 2020 to reach end of life. As a guarantee, ARN collects a provision that is equal to about 35% of estimated future management costs.

Limited volumes are currently being collected as a result of long battery lifespans. Less than 20 metric tons were collected in 2018. In order to develop a circular economy and minimize processing costs, ARN has set up a system for sorting and reusing batteries. In 2019 more than half of batteries were reconditioned for further use (energy storage). The companies that do the reconditioning take responsibility for second-life batteries. Details about logistics and operating costs are not public.

2.4.3 Belgium

In Belgium, EVs make up less than 2% of the passenger vehicle market, but sales are growing. Five percent of new vehicles are EVs and most of them are hybrids.

Two organizations offer end-of-life battery collection solutions.

Bebat

Bebat provides end-of-life management for all kinds of batteries, including household batteries and bike, motorcycle, and EV batteries. It has joined forces with other international players via the Reneos network to offer collection and processing services across Europe.

Febelauto

This organization collects and processes ELVs. Febelauto uses the existing network for dismantling and intervenes at key points for battery management. The online form used by garages and scrap yards to signal the need for end-of-life battery collection is included in Appendix C.

Vehicle owners generally bring end-of-life vehicles to a garage or scrapyard. Febelauto has partnerships with 124 approved recycling centers for end-of-life vehicles (not electric), as shown on the map below. In order to minimize safety risks, the organization recently launched training and certification for dismantling EVs.[27] Garages that are certified for dismantling batteries are represented by lightning bolts on the map below.

Figure 2 – Network of approved ELV recycling centers (not electric)

27 https://www.febelauto.be/fr/ce-que-nous-faisons/rentrer-un-vehicule-hors-dusage-en-tant-que-particulier

In the future, only garages and scrapyards that are approved for EVs will be allowed to use Febelauto's collection service. They will be required to meet strict standards issued by Febelauto with regard to:[28]

- Worker training
- Safety equipment
- Safety protocols
- Technical procedures for troubleshooting, disposing of, dismantling, and replacing high-voltage EV batteries

A mandatory external audit program ensures compliance with the standards.

For funding, Febelauto has framework agreements with importers so garages and scrapyards do not have to pay for battery collection and processing.

The volume of end-of-life batteries is still limited, but processing costs have already plummeted as a result of economies of scale and increased expertise. The cost of processing batteries containing cobalt is now approximately Can$1.50/kg. Collection and transportation costs can account for over half of the total costs of battery management. As a result, logistical efficiency is crucial.

Details about logistics and operating costs are not public. Volumes are still low, so the system still appears to be underdeveloped, and structural changes to pricing are expected.

28 The full list of standards is available at https://www.febelauto.be/public/Febelauto-norm-15.10.2019-FINAL-VERSION-_-FR.pdf (French only)

3 Legal Framework for EV Batteries

3.1 Legal Framework for End-of-life EV Batteries

Before discussing EPR for EV batteries, it is important to consider the legal framework. Since batteries are an integral component of electric vehicles and have to be removed by trained personnel, the legal framework for used vehicles should be taken into account. The European Union (EU) is a leader in legal frameworks for end-of-life recycling and recovery, which is why Sections 3.1 and 3.2 start with an overview of what is being done in the EU, before reviewing the legal context in North America.

European Union

Directive 2000/53/EC of the European Parliament on end-of-life (EOL) vehicles aims to lessen the environmental impact of EOL management by setting measures aimed at reducing the amount of disposable waste by means of recycling, reuse, and other forms of recovery. Nearly the entire value chain for ELVs is included in the Directive under the umbrella term "economic operators": the companies that produce,[29] collect, dismantle, and recycle vehicles, as well as vehicle insurance companies and others. Vehicle producers are encouraged when designing vehicles to limit the use of components that could become hazardous waste.[30] Producers thus play an active role in meeting the objectives for reuse, recycling, and recovery under the Directive. Member states are responsible for having producers cover the cost of the required collection systems. Since 2015, economic operators have been required to ensure that a minimum of 95% of the average weight per vehicle is reused and recovered each year and that a minimum of 85% of the average weight per vehicle is reused and recycled each year.

Canada

The rules and standards for recycling ELVs are under provincial jurisdiction and are aimed at the businesses that take ELVs apart and recycle them, instead of the entire value chain. Automotive Recyclers of Canada (ARC) is an association that represents some 400 ELV recyclers and dismantlers throughout Canada. Its mission is to promote best practices in recycling. ARC members are required to follow the Canadian Automotive Recyclers Environmental Code created by ARC.

Quebec

Automotive parts recycling has been a profitable industry for over 100 years. The Association of Auto Parts Recyclers in Quebec (ARPAC) has 75 members and manages to recycle 83.3% of the weight of vehicles (75% metals and 10% other recyclable materials). ARPAC is an ARC member, and its members are audited every three years to make sure they are meeting the requirements of ARC's Environmental Code. Although Quebec does not have its own regulations, the government published a first Guide to Best Practices for ELV Management in 2001 to improve the environmental performance of ELV recycling activities. Vehicles have materials and metals that can be harmful to the environment if they are not properly managed at the end of their lives, i.e., when they are dismantled, stored, compacted, and shredded. The main risks include soil and surface-water contamination. Lead batteries, for example, are classified as hazardous residuals in the Guide. In Quebec the ELV recycling industry must process its hazardous residuals in accordance with the Regulation respecting hazardous materials (RRHM).[31] The RRHM defines a hazardous material as:

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29 A producer is a company that builds or imports vehicles in a member state.
30 Directive 2000/53/EC (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32000L0053&from=EN)
31 For example, residual fluids such as motor oil, fuel, and antifreeze are considered contaminants and must be drained before a vehicle is dismantled.

"a material which, by reason of its properties, is a hazard to health or to the environment and which, within the meaning of a regulation under this Act, is explosive, gaseous, flammable, poisonous, radioactive, corrosive, oxidizing or leachable or is designated as a hazardous material, and any object classed by regulation as a hazardous material."[32]

According to this definition and an interview with the Direction des matières dangereuses et des pesticides under the MELCC's juridiction, EV batteries should also be regulated by the RRHM since they can leach and are explosive.[33] The RRHM sets out regulatory requirements governing the use, storage, and transport of hazardous residuals,[34] including a ban on dumping hazardous materials.

Ontario

The rules in Ontario (O. Reg. 85/16, the ELV Reg.) are aimed at ELV waste disposal sites. Under O. Reg. 85/16, ELV waste must be managed according to the provincial and federal regulations on hazardous waste.[35] The regulation sets out specific requirements for the disposal of batteries: they must be removed and stored in such a way as to avoid all contact with water and any possibility of short-circuiting. They cannot be stored for more than 24 months. However the definition of a battery is not provided in the regulation.[36]

Prince Edward Island

ELVs that are no longer being used for transportation fall under the regulations for ferrous metal waste. Disposal site operators must hold a permit and must ensure the proper management of parts that are classified as hazardous materials.[37] Automotive fluids and lead batteries, for example, must be removed before vehicles are dismantled. There are also requirements regarding the storage of lead batteries, which are further regulated by EPR.

British Columbia

ELV dismantling site operators must have an environmental management plan that sets out methods for storing, processing, recycling, and eliminating certain types of waste, including tires, fluids, and lead batteries.[38]

United States

The situation in the United States is similar to that in Canada in the sense that there is not a federal law on ELV recycling. National programs for the recovery of specific automotive parts are voluntary[39] and are often for parts that contain regulated contaminants. One such program is the National Vehicle Mercury Switch Recovery Program,[40] established in 2006 for mercury switches, which are classified as "universal waste" under the *Resource Conservation Recovery Act*.[41]

32 http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/Q-2
33 Based on the risks associated with transporting batteries. https://www.tc.gc.ca/eng/tdg/transporting-batteries.html
34 http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/Q-2
35 Environmental Law Insights (https://www.environmentlawinsights.com/2016/11/23/canadas-first-end-of-life-vehicle-recycling-law-in-force/)
36 O.Reg. 85/16 (https://www.ontario.ca/laws/regulation/160085)
37 https://www.princeedwardisland.ca/sites/default/files/legislation/e09-10-environmental_protection_act_materials_stewardship_and_recycling_regulations.pdf
38 http://www.bclaws.ca/Recon/document/ID/freeside/49_200_2007
39 https://archive.epa.gov/oswer/international/web/html/200811_elv_directive.html
40 The program has been run by "End of Life Vehicle Solutions" since 2018. http://elvsolutions.org/wp-content/uploads/2017/01/DC011477299-v1-ELVS_Agreement_Extension_One_Pager2.pdf
41 https://www.epa.gov/mercury/mercury-consumer-products#biz

In the absence of any federal recycling and recovery directives or objectives for ELVs, states are free to adopt whatever regulations they see fit. The ELV recycling market is already well established in the country—a full 95% of vehicles end up at recycling centers.[42] But since ELV processing is not governed by a legal framework, no one is responsible for developing recycling infrastructure, the costs have to be covered by the organizations doing the work, and recyclers can be tempted to junk materials that do not generate a profit. American states tend to look to environmental protection regulations such as the *Resource Conservation Recovery Act* to provide legal framework for ELV recycling. Given the situation, organizations such as the National Stewardship Action Council (NSAC) and the Automotive Recyclers Association (ARA) as well as some progressive states such as Maine and New York are working to create a more robust regulatory environment and move the industry toward more responsible and sustainable practices.

NSAC, a subsidiary of the California Product Stewardship Council, is a network of public and private sector organizations in favor of a circular economy. The organization is an advocate of EPR legislation for ELVs. To date, however, no such laws have been drafted—a situation that, according to NSAC, is due to lukewarm cooperation on the part of the automotive and recycling industries.[43] It is much more difficult for NSAC to come up with any EPR legislation without their support.

ARA continues to lobby members of Congress about the need for EPR legislation for ELVs but is dealing with an administration that takes a dim view of any calls for new environmental regulations and an automotive sector that fears such regulations would strike a devastating blow to the industry. ARA has created an online learning center aimed at building awareness, with courses on topics such as vehicle dismantling and end-of-life management.

In Maine extended producer responsibility for mercury switches has existed since 2001. Automotive producers have to pay US$4 in partial compensation for each traceable switch, i.e., for each switch that can be traced back to the producer using the vehicle identification number.[44] Models that contain mercury switches are all from 2002 or earlier, since Maine outlawed the use of mercury switches in new vehicles in 2003.[45]

Maine and New York have adopted regulations to ensure the proper management of hazardous waste and keep harmful contaminants from being dumped into the environment. Maine's Junkyards and Automobile Graveyards law requires mercury switches and headlamps, automotive fluids, coolants, batteries, and tires to be properly removed and handled.[46] New York introduced Article 27, Title 23: Vehicle Dismantling Facilities in 2006, which requires all parts that could potentially contain contaminants to be removed according to best practices before the vehicle is crushed or shredded. Automotive fluids, lead-acid batteries, mercury switches, coolants, and airbags are all specifically listed in the law.[47] Fluids must be drained on paved surfaces to avoid any groundwater contamination.

42 https://www.uscar.org/guest/article_view.php?articles_id=185
43 https://hal.archives-ouvertes.fr/hal-02190787/document
44 https://legislature.maine.gov/statutes/38/title38ch16-B.pdf
45 https://www.maine.gov/dep/mercury/documents/guidancemanual0608.pdf
46 https://www.maine.gov/dep/waste/motorvehiclerecycling/index.html
47 https://www.dec.ny.gov/chemical/28650.html

A review of the legal frameworks in North America shows that, unlike the European directive, there is no recycling target by weight for ELVs. Even in the absence of a legal framework, the percentage of each vehicle recycled in Quebec is respectable thanks to the value of the metals used in automotive parts.[48] But the results are still a far cry from those achieved by the EU's member states: 94% for vehicle recycling and reuse per weight, which climbs to 97% when energy recovery is factored in.[49]

When an ELV arrives at a dismantling site to be recycled, the EV battery's end-of-life scenario is largely determined by its resale value. In most cases, the ELV recycler will store the battery until it can be resold to a battery recycler at a good price. Knowing that the battery could explode and cause damage when the vehicle is being crushed or shredded, the scrap metal dealer will likely ask the ELV recycler to remove the battery before purchasing the body. If the storage period becomes untenable for the ELV recycler, the batteries may end up at a landfill unless that option is curtailed by a legal framework.

48 European Commission (2006) A study to examine the costs and benefits of the End-of-Life Vehicle Directive, Annex 2: Arising and treatment of end of life vehicles.
Sakai et al. (2014) "An international comparative study of end-of-life vehicle recycling systems," Journal of Material Cycles and Waste Management, 16,1–20.

49 https://www.febelauto.be/nl/kenniscentrum/cijfers

3.2 Legal Framework (EPR) for Rechargeable and Single-use Batteries

European Union

Europe's legal framework for batteries also goes further than those in North America. European Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators sets out rules regarding portable, automotive (lead starter), and industrial batteries. EV batteries, regardless of composition, are classified as industrial batteries and are therefore subject to specific requirements in how they are collected, processed, recycled, and disposed of[50] and cannot be sent to a landfill or incinerated.

In terms of collection, member states make sure industrial battery producers accept waste batteries from end users. The Directive divides batteries into three recycling categories: lead-acid, nickel-cadmium, and other. EV batteries fall under the "other" category, which means a minimum of 50% of their average weight has to be recycled once they become waste.

Canada

In Canada seven provinces have EPR for household batteries. Household batteries are disposable batteries (like alkaline batteries) or small rechargeable batteries (like cellphone batteries). Household lithium-ion batteries, which are found in cellphones, laptops, and other electronic devices, are subject to EPR in provinces where rechargeable batteries are included in the policy, namely Quebec, Manitoba, British Columbia, P.E.I., and Saskatchewan. Lead batteries are also covered by EPR legislation in a number of provinces, as shown in the table below.

50 Directive 2006/66/EC (https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32006L0066&from=EN#d1e949-1-1)

Table 6 – EPR for batteries in Canada

Province	Battery types included	Not included	Approved organization
Quebec	All rechargeable batteries Single-use coin and button batteries and all other single-use batteries	Lead-acid batteries Automotive batteries Batteries designed and produced exclusively for industrial use	Call2Recycle
Ontario	Disposable batteries Rechargeable batteries		No approved organization at this time
Manitoba	Lead-acid batteries for automotive vehicles		Canadian Battery Association
	Rechargeable batteries Other batteries		Call2Recycle
British Columbia	Lead-acid batteries		Canadian Battery Association
	Rechargeable and single-use batteries used in select electronic devices		Call2Recycle
P.E.I.	Lead-acid batteries		Canadian Battery Association
	Rechargeable and single-use batteries		Call2Recycle
Saskatchewan	Rechargeable batteries Other types of batteries	Lead batteries	No approved organization at this time

Source: Provincial regulations and Call2Recycle

Call2Recycle is the accredited organization in almost every province that has EPR for batteries and also runs a voluntary program in Ontario. The organization offers turnkey solutions for retailers and businesses that want to become collection partners. Call2Recycle accepts all rechargeable batteries weighing up to 5 kg, including small lithium-ion batteries, small sealed lead-acid batteries, single-use batteries, and cellphones. Dropoff sites are equipped with a collection kit, which includes a patented collection box preauthorized for shipping by Transport Canada and the U.S. Department of Transportation.[51] Call2Recycle also has over 16,000 dropoff sites in the United States. The program is the same in both countries.

51 https://www.call2recycle.ca/collection-program-overview/

In British Columbia, Manitoba, P.E.I., and New Brunswick, lead-acid vehicle battery recycling is managed by the Canadian Battery Association.[52] Quebec doesn't have EPR for lead-acid batteries. ARPAC's members, who recycle approximately 200,000 ELVs per year—50% of all ELVs—are able to resell 100% of the lead-acid batteries removed from vehicles at their dismantling site. Working batteries are sold to consumers, while scrap batteries are bought by recyclers for their valuable lead content. It is hard to know with any certainty what happens to lead-acid batteries that end up with ELV recyclers who aren't ARPAC members. Since lead-acid batteries have an excellent resale value, it seems safe to assume that they're recycled or resold. There are some voluntary systems, unregulated by government, whereby vehicle repair shops can return lead-acid batteries to producers and collect the deposit. Participating garages pay the producers a deposit on their batteries at the time of purchase. Once they've collected enough end-of-life batteries, they contact the producer, who picks up the lot and refunds the deposit. In stakeholder discussions, the feeling was that a voluntary system probably would not work for EV batteries, since the storage space required would be much greater than for lead-acid batteries.

United States

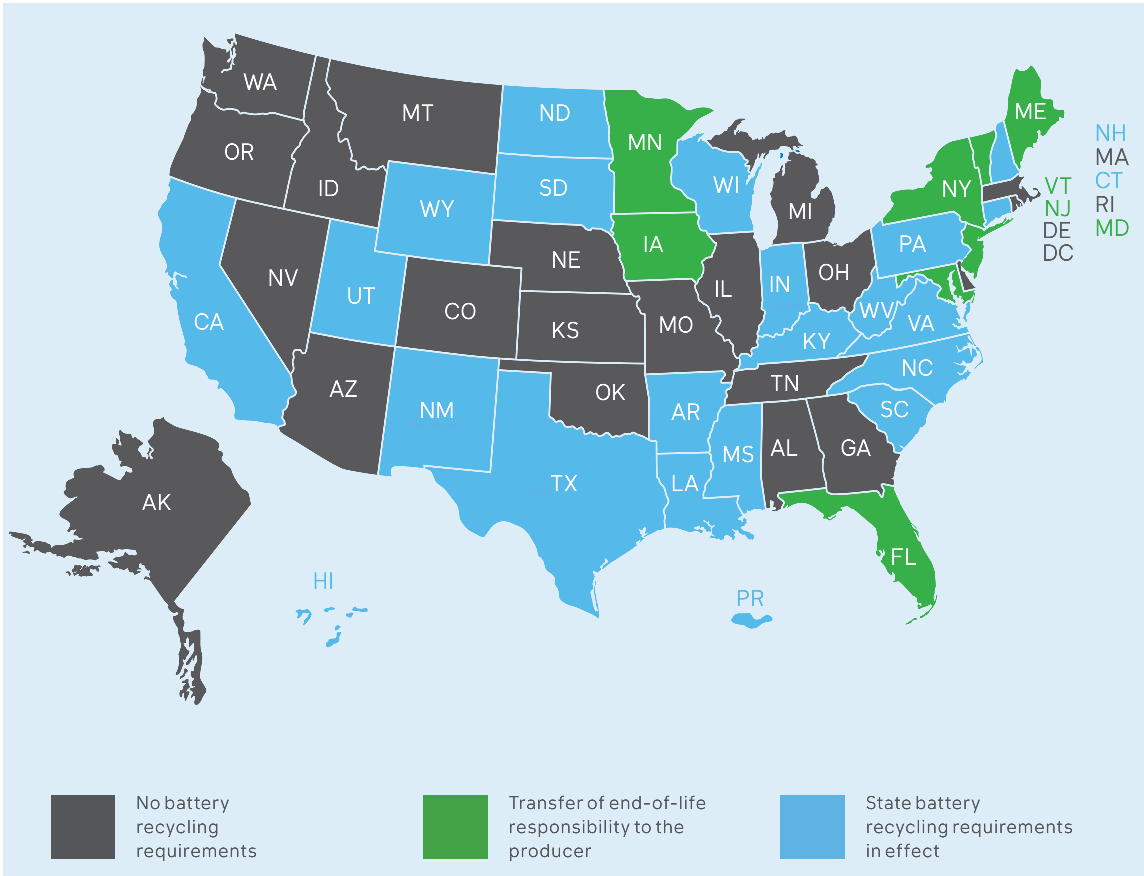
In the U.S., the *Battery and Critical Mineral Recycling Act* of 2020 was introduced in the senate on February 27, 2020. This law is a solution for supporting the growth of clean energy in the U.S. by securing a local source of rare metals and reducing the country's dependence on Chinese imports.[53] The law covers all electrochemical rechargeable batteries, including lithium-ion batteries.

The law sets out numerous requirements, including for the Environmental Protection Agency (EPA) to establish best practices for battery collection at the state level. The U.S. Secretary of Energy would be responsible for creating a working group tasked with developing an EPR structure for batteries with recycling targets, collection models, and means of transport for the types of batteries involved. The working group would have one year to submit a framework to the U.S. Secretary of Energy.[54] Given the current political situation in the United States, however, it is unclear when such a system could be rolled out.

The current federal requirements for battery recycling are established in the *Mercury-Containing and Rechargeable Battery Management Act*, which covers batteries that contain mercury, rechargeable nickel-cadmium batteries, and small sealed lead-acid batteries.[55] Under that act, lead-acid and nickel-cadmium batteries must be treated as "universal waste" as defined in the *Resource Conservation Recovery Act*. Dumping used lead-acid and nickel-cadmium batteries is illegal. By law, they must end up in recycling centers. The map below shows the states that have additional regulations on household batteries.

52 New Brunswick has a voluntary battery recycling program based on a government-industry partnership. Call2Recycle also offers recycling for small household batteries in the province.
53 https://www.king.senate.gov/newsroom/press-releases/with-energy-package-on-senate-floor-king-introduces-groundbreaking-battery-recycling-legislation
54 Bill to support the reuse and recycling of batteries and critical minerals, and other purposes.
55 https://www.call2recycle.org/wp-content/uploads/ImplementationoftheMercury-ContainingandRechargeableBatteryManagementAct.pdf

Figure 3 – States with regulations that apply to household batteries, United States



Source: Call2Recycle, Recycling Laws by State

All of the states in blue in the map above with the exception of Pennsylvania—which only follows federal laws—have end-of-life management regulations for lead batteries to keep them out of landfills.

California has its own laws on recovering and recycling other types of household batteries. AB-1125, the *Rechargeable Battery Recycling Act* (2005–2006), makes it illegal for four different types of rechargeable batteries, including lithium-ion batteries, to be sent to landfill.[56] Under the Act, battery retailers are required to accept used batteries and have a system in place to ensure they are reused, recycled, or properly disposed of. Retailers must offer the service free of charge for batteries that they sell or have sold in the past.[57] A number of California retailers joined Call2Recycle in order to comply with AB-1125.[58] The Act functions in much the same way as EPR in that it makes producers and manufacturers responsible for end-of-life battery management. The Department of Toxic Substances Control is required to conduct annual surveys of battery recycling facilities to see how many batteries are being recycled, as an indicator of the progress being made.

56 https://www.call2recycle.org/recycling-laws-by-state/#California
57 http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060AB1125
58 https://www.call2recycle.org/the-rechargeable-battery-recycling-corporation-reports-increase-in-collection-numbers/

In Minnesota, Iowa, Maine, Vermont, New York, Florida, Maryland, and New Jersey, EPR regulations have made the industry responsible for EOL management of household batteries. But the types of batteries covered varies from one state to the next.[59] Maine, for example, has EPR for small sealed lead batteries and nickel-cadmium batteries, whereas New York has EPR for batteries weighing less than 25 kg that are not found in automotive vehicles. Vermont introduced EPR for disposable batteries in 2014—a first in the United States.

The Product Stewardship Institute (PSI) is an organization dedicated to EPR research, advocacy, and implementation in the United States. Among other products, PSI helps governments better regulate household batteries, including small lithium-ion batteries. On its website, PSI recognizes the need for an integrated recycling system for EV batteries to keep them from becoming a public burden.[60] To date, however, no concrete efforts seem to have been made in that regard.

North American battery legislation does not account for EV batteries. The emphasis is on household batteries that can be returned to dropoff points. Any existing laws that govern automotive batteries only cover lead-acid batteries.

59 https://www.call2recycle.org/recycling-laws-by-state/#California
60 https://www.productstewardship.us/page/Batteries

3.2.1 The Legal Framework for Electric Vehicle Batteries

As of yet, there is no official legal framework for EV battery collection and recycling in North America.

Canada

As mentioned earlier, Canada's legal framework does not yet cover recycling for EV batteries or for the vehicles themselves.

Until recently in Ontario, Stewardship Ontario was the only organization responsible for managing all products covered by EPR, with the exception of oils, antifreeze, and their containers, which have been managed by Automotive Materials Stewardship since 2017.[61] Under the *Resource Recovery and Circular Economy Act* of 2016, individual regulations are established for each product covered by EPR. The companies that make the products will need to create their own EPR program or join one of the independent industry organizations (which are service providers, rather than ministry-approved organizations).[62] Tires were the first products to have an individual producer responsibility model. It came into being on January 1, 2019.

Further to the Act, battery regulations were drafted and released for public consultation in April 2019. The regulations divide batteries into three groups: small disposable batteries, small rechargeable batteries, and big batteries (over 5 kg).[63] This last category was meant to include lead batteries and other automotive batteries, including EV batteries.[64] A number of vehicle producers voiced their concerns over the proposed regulations, particularly the targets for collection and the number of dropoff points that would be needed, neither of which seemed to reflect the realities of electric vehicles. In the revised regulations released on February 27, 2020, batteries over 5 kg had been removed from the list. There is thus no EPR for EV batteries in Ontario.[65]

United States

As seen in the previous sections, a legal mechanism for EV and EV battery collection and recycling has yet to be proposed. We do see discussions being held with stakeholders.

NAATBatt, the national, multidisciplinary commercial organization that focuses specifically on advanced-technology batteries, holds talks and workshops for its members on emerging industry issues. To drive interest in end-of-life management for lithium-ion EV batteries, a workshop was held in Buffalo in July 2019 on collecting, sorting, transporting, and storing lithium-ion EV batteries and on recycling technologies.[66]

61 https://stewardshipontario.ca/stewards-orangedrop/am-i-a-steward-orange-drop/am-i-an-orange-drop-mhsw-steward/determine-whether-youre-an-orange-drop-mhsw-steward/
62 https://rpra.ca/wp-content/uploads/IPR-101-Presentation_Final_Dec-3-2019.pdf
63 https://prod-environmental-registry.s3.amazonaws.com/2019-04/Batteries%20Regulation%20-%20Consultation%20Version%20April%2026%202019.pdf
64 Conclusion based on a discussion with Ontario's Ministry of the Environment, Conservation and Parks.
65 https://www.ontario.ca/laws/regulation/r20030
66 https://naatbatt.org/lionworkshop/

California has begun addressing the end-of-life management of lithium-ion EV batteries. It is one of the most advanced states anywhere in terms of environmental legislation and initiatives and has set the ambitious target of 1.5 million zero-emission vehicles by 2025.[67] There are currently 400,000 electric vehicles in California—approximately 6 times more than in Quebec.[68] Following the adoption of a new law in 2018 (AB 2832 Recycling: lithium-ion vehicle batteries: advisory group), California's Environmental Protection Agency created a Lithium-ion Car Battery Recycling Advisory Group tasked with drawing up recommendations for EV lithium-ion battery recycling and recovery policies.[69] The group met in November 2019 and January 2020 to discuss the applicable mechanisms and EPR is one of the political tools being considered to ensure efficient EV battery collection.[70] However one of the members of the group, the Rechargeable Battery Association, formally expressed reticence with regard to EPR. The final report is set to be released in 2022.

To date, nothing in our research or discussions with stakeholders points to any regulatory initiatives in the United States or Canada that could serve as a model for Quebec's EPR program.

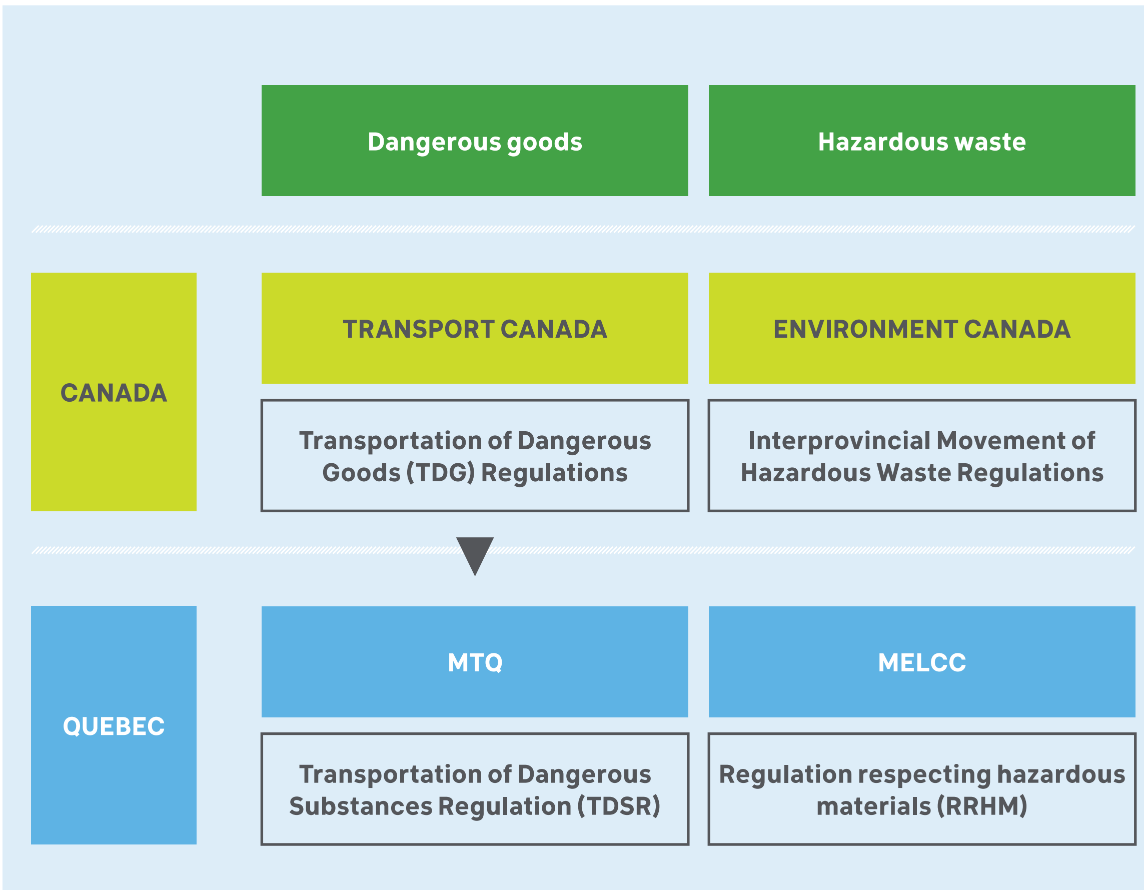
Some jurisdictions, such as Ontario and California, show a willingness to take end-of-life management for EV batteries into account, but there are not as yet any best regulatory practices in North America.

67 https://www.ase.org/blog/new-california-laws-set-example-making-electric-vehicles-more-accessible
68 There are approximately 61,000 EVs in Québec according to: https://www.aveq.ca/actualiteacutes/category/statistiques
69 http://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=200520060AB1125
70 https://calepa.ca.gov/wp-content/uploads/sites/6/2020/01/Lithium-ion-Car-Battery-Recycling-Advisory-Group-Minutes-11-18-2019.a.pdf

3.2.2 Legal Framework for the Transportation of Hazardous Materials in North America

Canada has federal and provincial regulations governing the transport of dangerous goods and hazardous materials. As shown in the figure below, the regulatory framework is different for each.

Figure 4 – Regulatory framework for the transport of dangerous goods and hazardous waste in Quebec and Canada



Dangerous goods are regulated by Transport Canada (TC) and Department of Transportation Quebec (MTQ), while hazardous waste is regulated by Environment Canada and Department of Environment and the Fight Against Climate Change (MELCC).

Goods regulated by federal and provincial transport authorities have to be shipped under the UN's Standard International Trade Classification system (UN classification). The provinces base their standards on Canadian law,[71] which harmonizes things across all provinces and territories. Transport Canada classifies lithium-ion batteries as dangerous goods since they can combust if overheated.[72] As such, they must be shipped in accordance with Canada's Transportation of Dangerous Goods Regulations (TDG regulations). Shippers in Canada must therefore ensure that any lithium-ion batteries shipped are properly labeled with the corresponding UN number. The UN numbers for lithium-ion batteries are:

UN3480 Lithium-ion batteries

UN3481 Lithium-ion batteries contained in equipment (including lithium-ion polymer batteries) or lithium-ion batteries packed with equipment (including lithium-ion polymer batteries)

Dangerous goods safety marks also need to be placed on the packaging and the truck carrying the dangerous goods. For the purpose of dangerous goods safety marks, lithium-ion batteries are classified as Class 9, Miscellaneous Products, Substances or Organisms. Shippers also have to follow TDG requirements regarding container types, employee training, safety standards, and mandatory paperwork.[73][74]

As a growing number of EV batteries in Quebec reach end of life, a majority of those being shipped will be recycled or reused. As mentioned in Section 2.3, end-of-life EV batteries fall under the category of hazardous residuals (hazardous waste) and are therefore subject to certain transportation requirements. Since residuals management falls under provincial jurisdiction, hazardous waste in Quebec is governed by the Regulation respecting hazardous materials. Under the regulation, shippers must be authorized to move hazardous residuals to a disposal site. The authorization is valid for a maximum of five years. To obtain it, the shipper must have a minimum of $1 million in liability insurance as well as a financial guarantee. There are also administrative fees for obtaining, renewing, and making changes to the authorization.[75] Little wonder then that transportation is often singled out as the most costly step in end-of-life management for EV batteries.[76]

Interprovincial hazardous waste shipments are regulated by Environment Canada. All shipments must be made by a certified shipper (who holds the proper provincial and federal authorizations) carrying a manifest that meets all TDG requirements. As explained by Ontario's Department of Environment, Conservation and Parks (MECP) in an interview, the purpose of these rules is to keep provinces from sending their hazardous waste elsewhere for disposal. The provincial authorities want to make sure that any waste being brought into the province is going to be recycled, not sent to landfill.

71 Provinces can have additional requirements (for grade crossings or going through tunnels, for example).
72 https://www.tc.gc.ca/eng/tdg/shipping-importing-devices-containing-lithium-batteries.html
73 https://www2.gouv.qc.ca/entreprises/portail/quebec/gerer?lang=fr&g=gerer&sg=&t=o&e=178392098:3385180488:1206147868
74 https://www.tc.gc.ca/eng/tdg/transporting-batteries.html
75 http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/Q-2
76 Olsson, L., Fallahi, S., Schnurr, M., Diener, D., & Van Loon, P. (2018) "Circular business models for extended EV battery life," Batteries, 4(4), 57.

Transborder shipments of hazardous waste and recyclable materials are governed by Canada's Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations. Shippers have access to an online system for obtaining the necessary permits and notifying Environment Canada of upcoming interprovincial shipments.[77] There is also a bilateral agreement between Canada and the United States for the shipping of hazardous waste and hazardous recyclable materials between the two countries that was signed in 1986. The agreement requires the two countries to establish regulations governing classification, import and export controls and tracking, and environmentally sound management practices for hazardous waste and hazardous recyclable materials.[78] It is based on the principles of the Basel Convention, which aims to reduce transboundary movements of hazardous waste, particularly from developed nations to developing nations.[79] Since Canada and the U.S. already have strict laws on hazardous waste management, the bilateral agreement mostly serves to establish the procedures for notification and consent between the two governments.[80]

In the U.S., new lithium-ion batteries are also classified as hazardous materials and fall under Title 49: Transportation of the U.S. Code of Federal Regulation (CFR). The CFR includes some UN classification requirements, including labeling standards. Regarding imports from the U.S. into Canada, hazardous materials can be shipped into Canada if they are authorized under the TDG regulations and if they meet the CFR 49 requirements for classification, marking, labeling, placarding, reporting, and record-keeping.

The federal rules on the transportation of hazardous residuals were established jointly by the Environmental Protection Agency (EPA) and the U.S. Department of Transportation (DOT).[81] In order to avoid redundant and duplicate requirements, EPA's *Resource Conservation and Recovery Act* has the same requirements as those established by DOT under CFR Title 40: Protection of the Environment.[82]

As shown, EV batteries are subject to strict transportation rules that can come with additional costs. However if the shipper has the necessary permits and meets the regulatory requirements there should not be any issues with interprovincial shipping or imports/exports with the United States. With recyclers in British Columbia and the U.S. for batteries collected in Quebec, Call2Recycle is a perfect example of the possibility of seamless transboundary transport within North America.

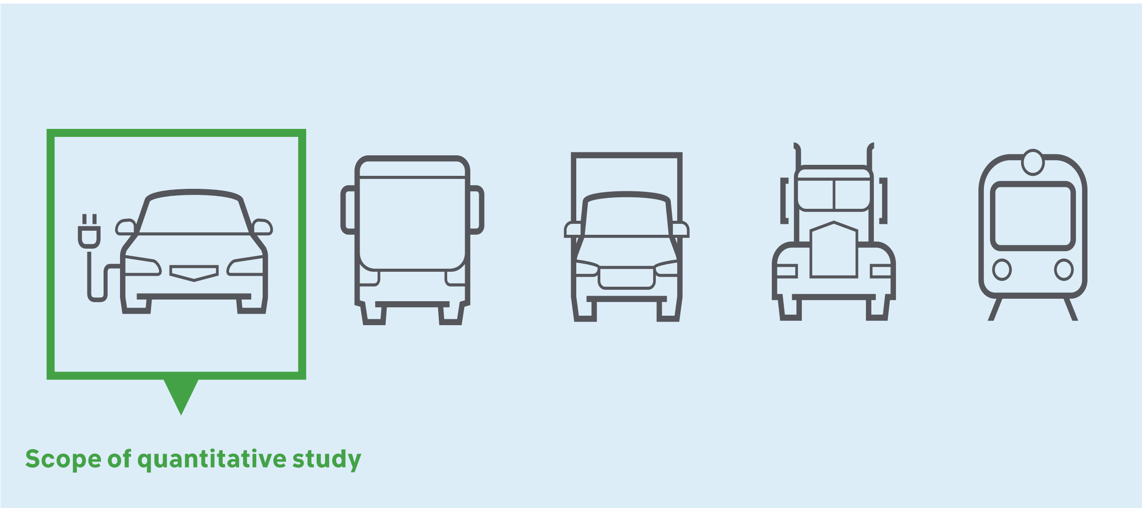
77 https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/permit-hazardous-wastes-recyclables/management.html
78 https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/north-america/canada-united-states-movement-hazardous-waste.html
79 https://www.canada.ca/en/environment-climate-change/services/managing-reducing-waste/international-commitments/basel-convention-control-transboundary-movements.html
80 https://nepis.epa.gov/Exe/ZyPDF.cgi/P10019VS.PDF?Dockey=P10019VS.PDF
81 https://www.epa.gov/hw/hazardous-waste-transportation
82 https://www.epa.gov/hw/hazardous-waste-transportation

4

EPR for Electric Vehicle Batteries in Quebec

4.1 Battery Type

The increasing use of batteries to power a growing range of vehicles has meant more industry players, differing management costs, and a wider variety of battery weights. In Quebec, EV batteries fall under different categories such as electric vehicles, medium-duty vehicules and heavy-duty vehicles. For the purposes of this report and given the available data, the quantitative study of EPR in Quebec focuses on passenger EVs; qualitative information is provided for the other category.



Medium-duty and heavy-duty vehicles

The North American market for electric buses and heavy trucks is expanding rapidly. Electric industrial vehicles and electric trains are also increasingly popular. These vehicles are usually part of commercial and public fleets (like school buses and municipal public transit organizations). For EPR purposes, interested producers can work with fleet managers to set up their own recovery systems. Joining a recognized management organization is another possibility, just as it is for personal EV producers.

4.2 EPR for EV Batteries: Advantages and Opportunities

There are many advantages to using EPR to optimize end-of-life product management, particularly for EV batteries. First of all, EPR regulations in Quebec can be adapted to account for the varying nature of the targeted products. Government recovery targets are designed to be realistic and take various factors into account such as the number of units on the market, product lifespan, and market growth.

Recovery targets can be set based on various indicators, such as the number of products recovered as a percentage of the estimated number of total products available for recovery and the gradual increase in the number of units recovered over time. Increased EV sales also suggest that end-of-life management for the thousands of batteries generated will grow to be an economic and environmental burden by 2030 unless something is done about it now. EPR would lead to the creation of a structured collection system that could be self-financing since the industry could internalize the cost. As discussed in Section 2.4, this mechanism has proven effective throughout the world, particularly in the European Union, where it is applied to EV batteries. EPR mechanisms also avoid any unfairness among industry players, since participation is mandatory. Voluntary programs that transfer responsibility never manage to get everyone onboard. And should Quebec gain recycling capabilities, EPR would help create a continuous supply of EV batteries in support of the industry. Local or national processing is encouraged because it helps create a circular economy and reduce GHG emissions.

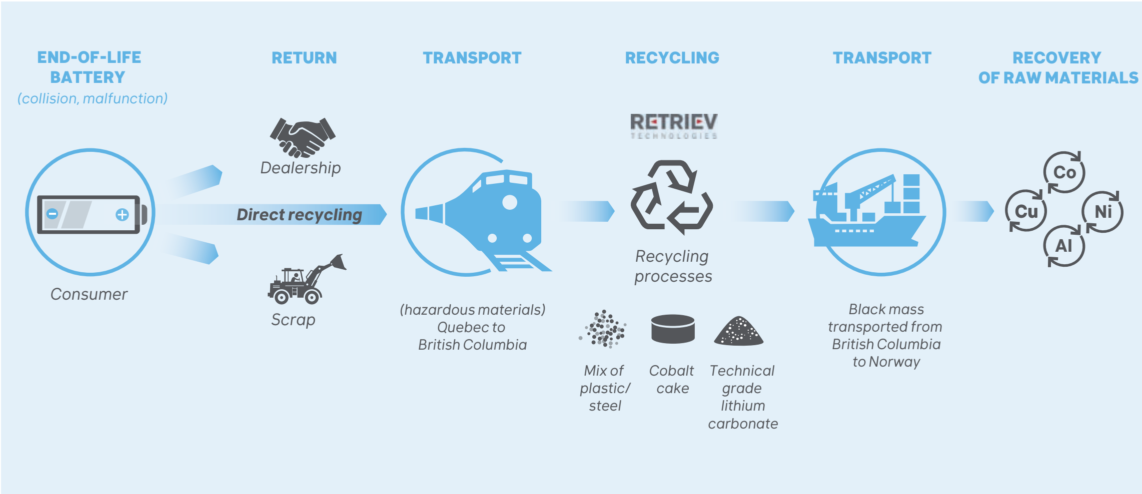
Experience with lead-acid batteries shows that if battery components have an attractive resale value, it acts as an incentive for the industry to handle end-of-life management and recycling. Consultations with stakeholders showed that EV producers would like to create their own collection systems in order to recover their batteries. Batteries are a highly valuable component of electric vehicles due to both the materials and the R&D investments involved. Unlike lead-acid batteries, however, the chemical composition of EV batteries varies widely from one to the next, which is reflected in their value at the recycling stage. With a voluntary approach, it is hard to predict what would happen to EV batteries made with low-value materials, since cost-effective recycling poses more of a challenge (such is the case with lithium-iron-phosphate batteries, for example).[83] What is more, without a regulatory mechanism that makes reporting and traceability mandatory in terms of the battery's final destination, there is no guarantee that the methods used to recover the materials will reflect environmental best practices.

For all these reasons, EPR is a logical choice for structuring end-of-life EV battery management.

End-of-life EV batteries are currently managed on a case-by-case basis and mostly come from wrecked vehicles.[84] The discussions held as part of the study have confirmed the conclusions drawn in Propulsion Québec's last report: most batteries are sent to automotive parts recyclers and scrap metal dealers rather than to recycling facilities with the necessary capabilities. Located in British Columbia, Retriev is currently the only facility that recycles EV batteries. It is expensive to ship batteries there from Quebec.

83 Melin, H. E. (2018) "The Lithium-Ion Battery End-of-Life Market—A Baseline Study," World Economic Forum, Cologny, Switzerland (pp. 1–11).
84 Propulsion Québec Study (2019)

Figure 5 – Current trajectory of end-of-life lithium-ion EV batteries in Quebec



Source: Propulsion Québec Study (2019)

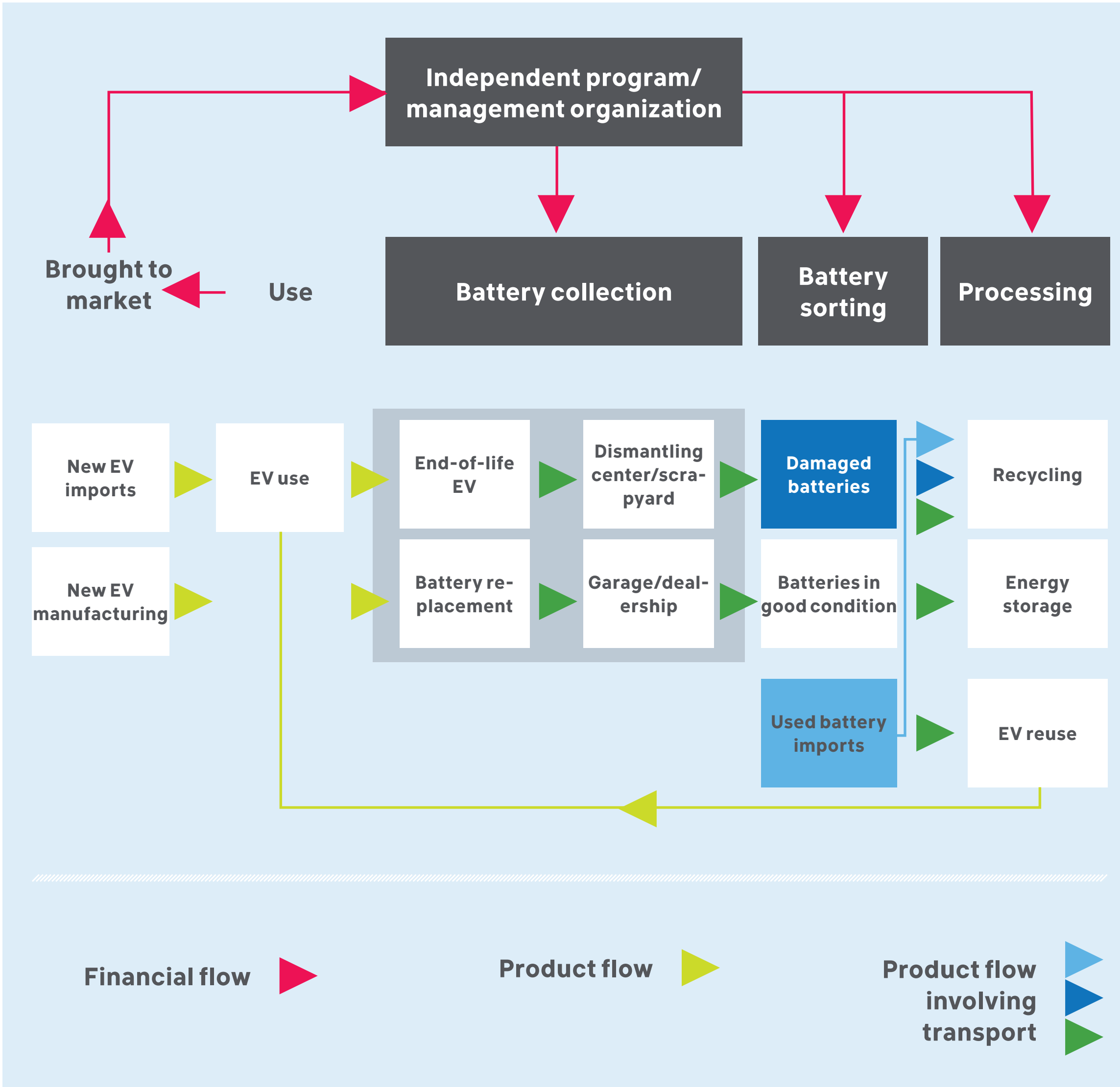
The figure below shows the EV battery lifecycle in an EPR system. The lifecycle starts when a battery is first sold and ends when it is processed for recycling or reuse (for energy storage or other). The EV battery lifecycle in an EPR program differs mainly from the one in the figure above in that:

- Batteries sent to automotive and scrapyards also end up being recycled.
- Collection, sorting, and processing are all the financial and operational responsibility of the businesses (in the form of an individual program) or the management organization involved. Those three steps make up the EPR recovery program.

Due to safety concerns, there are fewer processing options for damaged batteries than there are for intact batteries.[85] The latter category includes batteries that have been removed from EVs because they cannot hold enough of a charge to power the vehicle for a reasonable distance, but which may have other uses. Importing used batteries is only considered to the extent that a recycling facility is opened in Quebec, in which case they would only be imported for that facility's recycling activities. Imported used batteries would not be subject to the EPR program.

85 Data from the Propulsion Québec study: https://propulsionquebec.com/ressources/documents-et-liens/

Figure 6 – Battery lifecycle



Source: EY analysis

An EPR mechanism is a suitable approach that presents numerous advantages for end-of-life management of EV batteries:

- By establishing clear responsibilities between the various actors along the value chain, EPR makes it easier to anticipate the cost of a collection and recovery system.
- The current pool of batteries to be processed is small so there are not any major management issues as of yet. Creating an EPR mechanism now should be seen as a mean of preventing a future environmental crisis.
- The 4R-D targets central to EPR create an opportunity for the businesses involved to improve their battery design and make them easier to process.
- By creating demand for local processing, EPR could play a role in the growth and development of Quebec's EV battery recycling expertise.
- As a mandatory program, EPR creates a level playing field. Primary suppliers such as vehicle producers who already have plans to recover their own batteries would therefore still be encouraged to do so.

4.3 Unique Features of Quebec's EPR regulatory mechanism on EV Batteries

Quebec's EPR regulatory mechanism sets out general requirements for recovery, reporting, dropoff sites, and collection services that apply to all products and specifies penalties for failure to meet recovery targets. Individual products are then defined in separate sections that set out recovery objectives, implementation dates, and other specific requirements for that product type.

Should the MELCC decide to include EV batteries in its EPR regulatory mechanism (ELVs and their components are currently at the top of the list of products to be included[86]), there are two potential scenarios:

- Include electric vehicle batteries in the Batteries category
- Add a new product category for EV batteries

For the purposes of the report, the hypothesis is that in both cases, the general requirements would apply to EV batteries as well. Businesses subject to EPR would be the brand owners, the initial importers and/or suppliers of a targeted product or a product with a component that is a targeted product. For EV batteries, businesses it applies to would be: [87]

- Vehicle brand owners
- EV batteries brand owners and initial suppliers in Quebec (cars, buses, trucks, trains)
- Niche electric vehicle producers (excluding recreational EVs)
- Dealers that import electric vehicles of all kinds from brand owners who do not have places of business in Quebec

86 http://www.environnement.gouv.qc.ca/matieres/valorisation/Rapport_final_synthese.pdf
87 Note that when the term manufacturer or producer is used in the report, it also covers all the entities listed here.

It is important to clarify a few things about the general requirements set out in the regulation:

- **The regulation does not dictate how the recovery system has to be set up and operated. The targeted businesses (or associations) are responsible for creating a collection network that meets the requirements for the number of dropoff sites and establishing partnerships within the value chain.**
- **Businesses that do not have an extensive distribution network do not have to have dropoff points across the entire province. Accepting used batteries at the locations where they are sold is enough to meet the legal requirements (section 16, paragraph 1).[88] Businesses can also expand their collection networks by partnering with garages and automotive recyclers, as is the case currently for used oil.**
- **Although the EPR regulatory mechanism aims to promote local processing, the recycling facilities do not have to be in Quebec. Businesses can choose to send their end-of-life products outside the province or even outside the country.**
- **Businesses are not required to set up their own recovery systems. They can be exempted from most of their obligations if they join a recognized management organization. If a business does decide to create its own recovery system, however, it has to accept every type of EV battery, not just its own. As we will see further on, this is an issue for stakeholders.**
- **There is no definition of when a product has reached the end of its life. Nor does the regulation stipulate the expected product life, so if a battery remains on the market for longer than expected, it does not count as noncompliance for the business. MELCC simply estimates the product's service life in order to set recovery objectives and statistics.**
- **There is no risk of recycling objectives being set too high or low because the targets are negotiable and can be changed in the regulation to reflect market realities as time goes on.**

88 http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2035.1

4.4 Scenarios

This section presents potential scenarios for end-of-life battery management. For each EPR scenario, a preliminary quantitative analysis will be given, followed by key issues. There are three basic scenarios for EV battery management. Each will be assessed according to its strengths and weaknesses as well as the opportunities and threats involved (SWOT).

Note that due to the available data, quantitative aspects in the next sections only concern electric vehicles, whereas qualitative aspects concern electric vehicles, and medium- and heavy-duty vehicles.

SCENARIO 1	**Battery Management under the Current Legal Framework**
SCENARIO 2	**Battery Management Based on Voluntary Actions by producers**
SCENARIO 3	**EPR for End-of-life Batteries**

4.4.1 Scenario 1: Battery Management under the Current Legal Framework

Section 3 describes the current legal situation. Although there are legal obligations regarding the transportation and processing of hazardous materials, there is no specific legal framework for EV batteries.

Table 7 – SWOT matrix for Scenario 1

Strengths	Weaknesses
Status quo: No change, so no resistance and no investment of resources to put a new mechanism in place.	**Legal and financial uncertainty**: The cost of managing the batteries is covered by the recyclers, who would gain from having all or part of the necessary infrastructure investments shifted over to producers. **Risk of accident:** Without an EV battery management structure, prevention tools, and effective communication between the various parties, there is no way of limiting the risk of fire during storage and of electrocution during dismantling. **Environmental threats:** The cost of processing creates incentives for funneling batteries into parallel markets and employing solutions that do not meet the regulatory requirements. **Loss of opportunity:** Quebec could miss out on an opportunity to guarantee its access to critical materials and coordinate with the strategy currently being developed for lithium-ion batteries.

Opportunities	Threats
N/A	**Increase in battery liabilities**: Market volumes with no recycling mechanism will rise significantly over time. **Reactive approach**: This will make it harder and harder to implement solutions. **Negative reactions**: Businesses that fail to take responsibility for their products risk damaging their consumer reputations. **Lost revenue:** A major player in the North American recycling market could set up a recovery system that would capture Quebec's pool of EV batteries, depriving Quebec of the economic benefits.

4.4.2 Scenario 2: Battery Management Based on Voluntary Actions by Producers

This scenario depends on producers voluntarily creating an end-of-life battery management system.[89] Some producers have already taken such initiatives. But current initiatives are far from covering the whole market. For the purpose of our analysis, Scenarios 1 and 2 are considered separately, but one can suppose that there would be a natural progression from Scenario 1 to Scenario 2 in response to the rise in battery volumes.

Table 8 – SWOT matrix for Scenario 2

Strengths	Weaknesses
International approach: Producers are able to set up uniform, large-scale systems across provincial and national borders, thus maximizing economies of scale.	**Limited impact:** In the absence of structural change, voluntary approaches can result in the status quo being maintained for some players. **Freeriders:** The failure of some producers and importers to meet their end-of-life management responsibilities creates an unfair playing field. **Risk of accident:** Without an EV battery management structure, prevention tools, and effective communication between the various parties, there is no way of limiting the risk of fire during storage and of electrocution during dismantling. **Environmental threats:** The cost of processing creates incentives for funneling batteries into parallel markets and employing solutions that do not meet

Opportunities	Threats
Individual responsibility: Producers can differentiate themselves and develop individualized value chains for battery recovery. **Time to implement:** Since no legislative amendments are required, producers can start developing measures now.	**Lack of legal tools to address inaction:** System operation and performance depend on the goodwill of producers. This uncertainty discourages long-term investment in the recycling sector. **Risk of orphan batteries**: If an importer goes broke or a producer withdraws from the market, no other producer will want to pick up the tab for a former competitor's batteries. **Environmental impact:** In the absence of a legal obligation to collect and recycle, EV batteries could end up in storage or landfill and become a health and environmental hazard. **Accountability:** With a voluntary approach, it is hard to pin accidents on the actors responsible for the initiative.

89 For a generic discussion on the effects of voluntary approaches:
- Hickle, G.T. (2013) "Comparative analysis of extended producer responsibility policy in the United States and Canada," Journal of Industrial Ecology, 17, 2, 249-261.
- Nash, J., Bosso, C. (2013) "Extended producer responsibility in the United States," Journal of Industrial Ecology, 17, 2, 175.
- OECD (2003) Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Usage in Policy Mixes.

4.4.3 Scenario 3: EPR for End-of-life Batteries

Quebec already has EPR for a number of end-of-life product streams. Other countries already have laws and systems for end-of-life battery management based on EPR.

Table 9 – SWOT matrix for Scenario 3

Strengths	Weaknesses
Clear responsibilities: Producers' financial and operational responsibilities are clearly defined and set out in a legal framework. **Economies of scale:** A management organization could centralize and coordinate efforts. **Sectoral risk prevention:** Regular, coordinated communication campaigns could raise awareness about safety procedures, the use of standardized tool and the environmental risks of end-of-life battery mismanagement. **A reduction in asymmetrical information:** The cost of voluntary battery and recycling initiatives can be internalized in the price of electric vehicles. This impact on prices can bring the market price of an EV closer to its social price and would not have a negative impact on government EV sales targets. **Traceability:** In their annual accounting, companies with EPR or the RMO have to indicate where the recovered materials end up. **International approach:** Producers can develop uniform, large-scale systems across provinces and countries for end-of-life battery management (for collection, sorting, recycling, etc.).	**Administrative monitoring:** The need to manage operations and ensure compliance will create an administrative burden for companies with EPR. **Redundant reporting mechanisms:** Companies that operate in multiple jurisdictions with their own EPR measures may be required to comply with separate reporting regulations in each jurisdiction, which may create redundancies, especially if the reporting mechanisms are not harmonized.

Opportunities	Threats
Individual responsibility: Producers can differentiate themselves and set up their own value chains for recovering their batteries. **Advanced environmental performance:** EPR measures could include ambitious targets for recycling and reuse. **Reducing the risk of accident:** With an EV battery management structure, prevention tools, and effective communication between the parties, the risk of fire during storage and of electrocution during dismantling could be greatly reduced. **Growth and innovation in Quebec's recycling sector:** EPR could accelerate the development of local expertise and investment in recycling. **Source of materials:** REP provides recyclers with a secure supply of needed materials, which is good for the industry. Due to their composition, batteries are a solution to mineral resources being exhausted.	**Perceived cost of EPR:** EPR costs paid by producers could be integrated into the price of EVs. Increases in EV prices may have a slight impact on sales. There is often a perception that EPR creates the cost, when in fact EPR can offer transparency regarding end-of-life costs because they show up right from the start of the value chain (even if the battery is not recycled, there are costs to remove it from the EV).

4.4.4 Prioritizing the Scenarios

From a societal perspective, there are a number of criteria that need to be taken into account when deciding which scenario to prioritize. There are pros and cons to each. The multicriteria analysis below presents the key points identified in discussions with stakeholders and the steering committee when Scenarios 2 and 3 were compared with the basic scenario (Scenario 1 - status quo).

Figure 7 – Qualitative table of priority issues, comparison between scenario 2 and 3 using scenario 1 – Status quo as a reference

Selection criteria	SCENARIO 2 Voluntary approach	SCENARIO 3 EPR
Impact on EV industry growth	Minor	Minor
Quebec recycling industry growth	Positive	Positive
Environmental gains	Positive	Very positive
Security risks	Limited	Highly limited
Financial guarantee for future costs	No impact	Positive

With Scenarios 2 and 3, the cost of recycling can be internalized in the cost of a new vehicle and could therefore have an impact on sales. However, the quantitative effect of EPR in Section 4.5 shows that the financial impact is limited and would represent less than 1% of the cost of a new EV. So the expected impact on growth in EV sales is limited.

EPR could accelerate the development of battery recycling expertise in Quebec since it is an incentive for local processing, so one would expect to see local players looking to gain a foothold. That could green the industry and help businesses with circular-economy-based business models get established and thrive. A voluntary approach could have the same effect if Quebec had a bigger pool of EV batteries. In both cases, a business with EPR could decide to have its EV batteries recycled out-of-province, either for financial reasons or due to the intellectual property involved, in which case there would not be a positive impact on recycling in Quebec.

Ambitious objectives for communication, R&D, recycling rates, and rates of reuse can be included in an EPR program. Making these objectives mandatory results in environmental gains for the industry, whereas experience shows that voluntary, producer-led initiatives are often short on ambition.[90] Even if some individual EV producers have already launched initiatives, recycling industry growth is not an industry priority. What is more, freeriders can discourage competitors from meaningfully addressing the issue.

A sector-wide management organization is better positioned to set up a single communication system with standardized tools and regular monitoring to ensure the safe collection and processing of end-of-life batteries. Having a legal framework also makes it possible to have a battery identification and tracking system. If on the other hand each producer adopts its own procedures, any economies of scale will be lost.

90 More information on the pros and cons of voluntary approaches can be found in:
- Hickle, G.T. (2013) "Comparative analysis of extended producer responsibility policy in the United States and Canada," Journal of Industrial Ecology, 17, 2, 249-261.
- OECD (1999) Voluntary Approaches for Environmental Policy: An Assessment.
- OECD (2003) Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency and Usage in Policy Mixes.

Voluntary approaches fail to account for future recycling costs. They provide no financial guarantees if companies go bankrupt or refuse to participate. Since the volume of EV batteries is just starting to grow, the historic liability is still limited. But it is growing at a rapid pace, which is why a clear legal framework is urgently needed. EPR accounts for future costs, but there are different ways it can provide for them. This has an effect on EPR costs. Provision can cover part of the cost (one year of operation, for example) or the full cost (ten years of operation, to reflect the battery lifespan). It can cover part of the cost (one year of operation, for example) or the full cost (ten years of operation, to reflect the battery lifespan). The quantitative analysis section looks at the partial coverage option, since it is in line with what is being done abroad and with the EPR systems currently in place in Quebec.

To summarize, multicriteria analysis shows that EPR could have an impact on EV sales, but a limited one, and could provide a structural solution to the current and future challenges of end-of-life battery management. A legal framework for EPR would create the necessary incentives for organizing the market in a way that is safe and effective.

4.5 Quantitative Analysis of EPR

A preliminary analytical model has been developed to gain insight into the financial impact of implementing EPR in Quebec. The model estimates costs and simulates future developments. But the EV and battery recycling markets are underdeveloped, so there is considerable uncertainty about the parameters and assumptions. Limited data is available for Quebec, so many assumptions are based on the European market. Although costs would differ in Quebec as a result of the North American market, the sensitivity analysis provided in this section shows that these differences are marginal. The results should nevertheless be interpreted with caution.

The table below shows the basic data used.

Table 10 – Parameters for quantitative analysis of EPR

Parameter	Value	Source
Number of end-of-life batteries in 2025	11,750	Propulsion Québec study (2019)
Number of end-of-life batteries in 2030	73,000	Propulsion Québec study (2019)
Battery lifespan	10 years	Literature, interviews, workshops
Average battery weight	300 kg	Propulsion Québec study (2019)
Collection and transport costs	$1.50/kg	Interviews
Recycling costs	$1.50/kg	Interviews
Cost of reconditioning and transfer of liability	$0.50/kg	Interviews
Percentage of batteries suitable for reuse	30%	Conservative estimate based on reuse rates in Europe
Management costs (RMO communications, research, and operations)	15% of the operating budget (collection and processing)	Reference figures from other EPR systems
Financial reserve needed as a guarantee	Amount equivalent to the annual budget	Reference figures for EPR and EPR legislation in Quebec

Based on this data, the unit cost for collecting and recycling a battery is calculated as follows:

Unit cost for collection and recycling =	*Battery weight×(Collection and transport costs+Recycling costs)*

The unit cost for collecting and recycling an average-size battery would be approximately $900. This is the amount a battery's last owner would currently have to pay to send it to a scrapyard or dealership for recycling in the absence of any regulatory framework. The cost of recycling reflects the current cost of processing in Europe, which uses pyrometallurgy and hydrometallurgy to recover cobalt, nickel, copper, and iron and does not recover materials such as lithium. The cost is net and includes revenue from the resale of recovered materials.

If a battery is in good shape and is suitable for reuse, the unit cost of collection and reconditioning is calculated as follows:

Unit cost for collection and reconditioning =	*Battery weight×(Collection and transport costs+Cost of preparation for reuse)*

The unit cost for collection and reconditioning would be approximately $600.

The unit operating cost factors in that portion of the battery suitable for reuse.

Unit operating cost =	*Average battery weight×[Collection and transport costs+(1-Percentage of batteries suitable for reuse) x Recycling cost+Percentage of batteries suitable for reuse x Cost of reuse]*

The unit operating cost for these batteries would be approximately $810.

The unit management cost includes management costs:

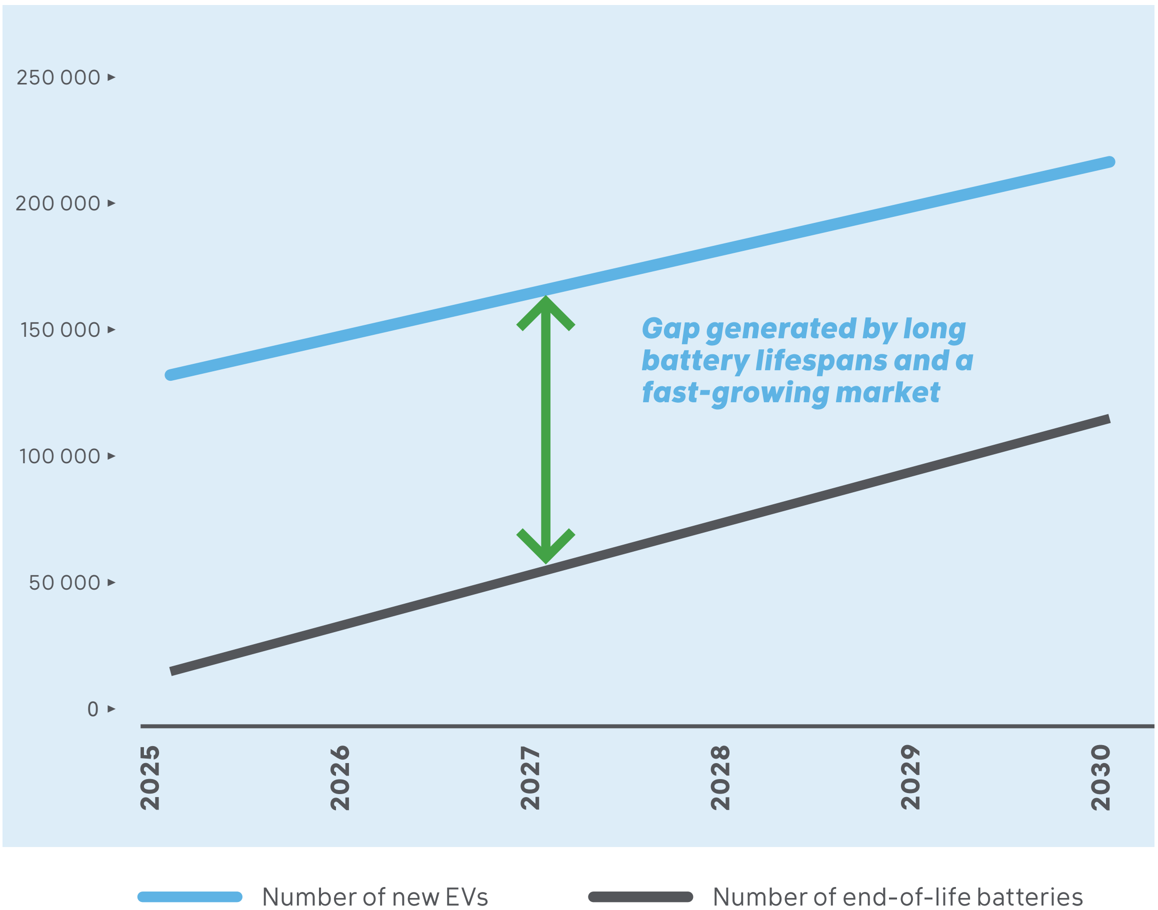
Unit management cost =	*Unit operating cost x (1+Management costs)*

The unit management cost per end-of-life battery would be about $932. This cost is an estimate and should be treated with caution. The recycling market is still underdeveloped, and the reference figures for Europe may not apply to Quebec. For example, distances are on average greater in Quebec. But fuel is usually cheaper as a result of lower taxes.

The graph below highlights two points that are important for understanding the quantitative analysis of EPR costs:

- EV sales are up sharply
- There is a lag in end-of-life battery volume due to long battery lifespans.

Figure 8 – Growth of new EVs and number of end-of-life batteries



EPR costs are based on the following formula:

$$\text{EPR costs} = \frac{(\text{Number of EOL batteries} \times \text{Unit management cost}) + \text{Financial reserve}}{\text{Number of EVs sold}}$$

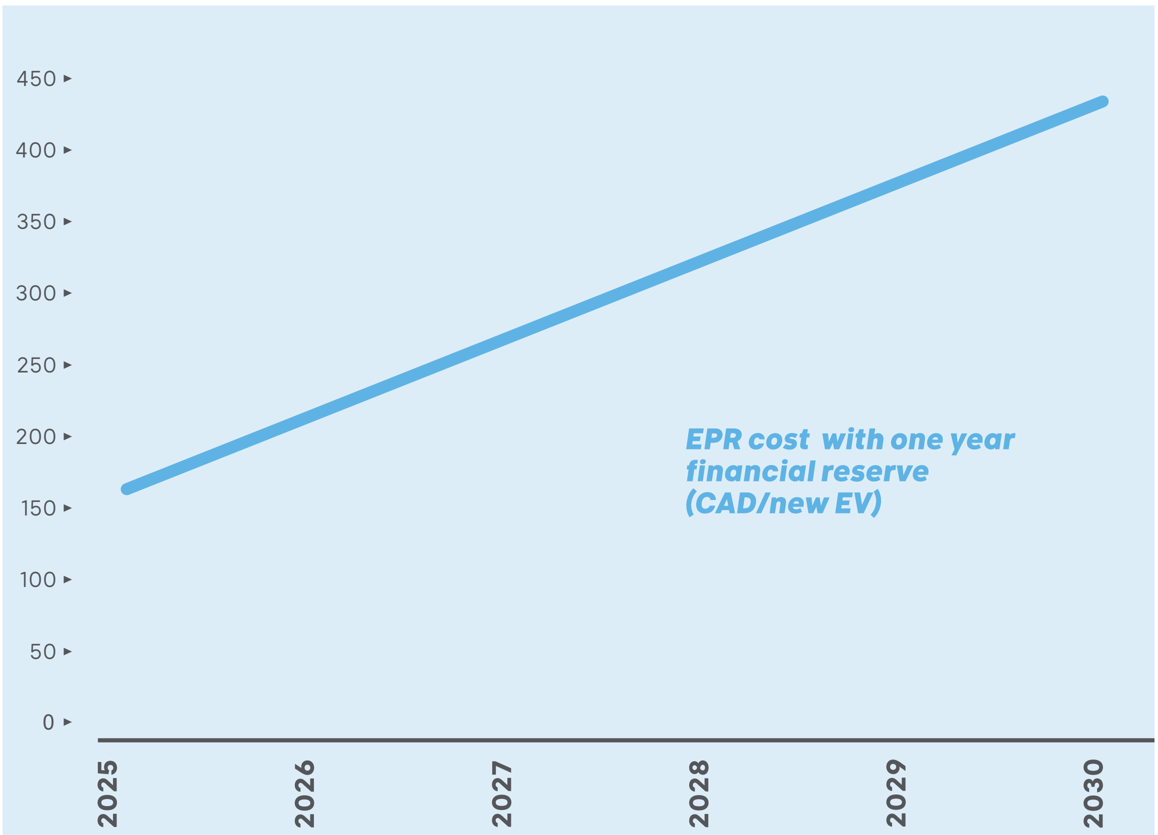
Initially, end-of-life battery volumes will be lower than the volumes of batteries on the market (in new EVs) due to the time lag between them. Recycling cost and EPR cost are respectively attributable to end-of-life battery volumes and battery volumes in new EVs. Considering the EPR cost per EV sold formula[91], the EPR cost per EV sold will initially be less than the recycling cost per battery (unit cost), e.g. the cost of EPR per new EV would be just over $400 in the next decade, or about 1% of the value of a new EV.[92] This is because the cost of EPR will be distributed across a large volume of new vehicles.

91 The EPR cost formula demonstrates that the number of new EVs sold is in the denominator and the number of end-of-life batteries is in the numerator.
92 Based on an average cost of $40,000.

However, the time lag does not reduce the cost of EPR, but defers it. The number of end-of-life batteries on the market will increase, which will reduce their recycling cost. The number of new EVs will continue to grow, but to a lesser extent than end-of-life batteries as EV sales reach a stable market share. Thus, the cost of EPR will gradually catch up with the unit cost of recycling (currently estimated at $900).

The recycling cost could decrease significantly as a result of economies of scale or new recycling technologies that more effectively recover high-value materials like cobalt and nickel. In this case, the point of intersection between the EPR cost and the recycling cost would occur sooner. Such developments were included in the sensitivity analysis below.

Figure 9 – EPR cost growth over time



EPR cost would be assumed by EV producers, who could include them in the prices of new vehicles. Significant price increases could negatively impact new EV sales. However, according to the above analysis EPR costs couldbe only 1% of the average price of a new EV. The resulting impact on new vehicle sales would be minimal.

It can be quantified using price elasticity of demand:

$$\varepsilon = \frac{\Delta P}{P}\frac{Q}{\Delta Q}$$

Elasticity determines the extent to which demand for a good reacts (in this case how much it decreases) as the price increases. The literature suggests that elasticity for EVs is around 1, which means a price increase of 1% would cause a 1% drop in sales.[93] There is an impact, but it is limited.

Other factors must be taken into account for EPR costs. Potential EV purchasers are deeply concerned about the environmental impacts of their choices. This could reduce the impact of EPR costs on sales relative to other price increases. Plus, current government incentives are sufficient to offset EPR costs . If revenues from the sale of recovered materials outmatch the total cost of end-of-life management, the EPR would not be reflected on the EV prices. In that case, there would be no increase in EV prices.

There is a lot of uncertainty in this preliminary estimate of EPR costs. Sensitivity analysis can provide insight into the potential impact of various parameters. The table below shows how variations in key parameters would impact EPR costs. Increasing and decreasing parameters significantly (by 50%) shows their potential impact on EPR costs. If the impact is significant (EPR costs increase or decrease considerably), erroneous assumptions will heavily skew the analysis. Conversely, if EPR costs do not change significantly, the assumptions have less impact. For example:

- If the volume of new EVs increases 50%, the EPR costs in 2030 decreases from $406 (value based on above calculations) to $271. In this scenario, the cost of managing end-of-life batteries is distributed across a larger volume of new EVs.
- If the volume of new EVs decreases 50%, the EPR costs in 2030 increases from $406 to $812. Here, the cost of managing end-of-life batteries is distributed across a smaller number of new EVs.

Sensitivity analysis shows that changes in the volume of new EVs have a significant impact on EPR costs.

93 Further information on the literature review regarding EV price elasticity is provided in the References section.

Table 11 – Sensitivity analysis of EPR parameters (base year: 2030)

Parameter	Impact on the 2030 EPR costs ($ per new EV) if a parameter changes by 50%			Impact
	(+)	(-)	Average	
Volume of new EVs sold in 2030	271	812	542	Significant
Volume of end-of-life batteries (metric tons)	914	102	508	Significant
Unit cost of collection and recycling	564	248	406	Moderate
Unit cost of collection and reuse	451	361	406	Limited
Portion of end-of-life batteries suitable for reuse	384	429	407	Limited

The above table shows that the volume of new EVs and the volume of end-of-life batteries (determined by past EV sales and battery lifespan) are the most important factors in the equation. Fluctuations in these two parameters have a significant impact on EPR costs. The unit cost of collection and recycling has a lower, but nevertheless considerable impact. Parameters related to reuse seem to have a relatively limited impact on EPR costs.

4.6 Key Issues for EPR in Quebec

The EPR framework must take a range of factors into consideration in order to properly address local issues and considerations. To gain further insight into the issues in North America and Quebec in particular, stakeholders were consulted and a workshop with key industry players was conducted. The objective was to ensure the issues presented below adequately reflect the concerns of stakeholders, including producers, manufacturers, government officials, and other industry players. The stakeholders consulted are listed in appendices A and B.

This section identifies issues involved in each stage of the EV battery life cycle. Some apply to several stages, so they have been grouped into broad categories as shown in the table below.

Table 12 – Battery life cycle issues

Lifespan uncertainty
- Definition of lifespan
- First and second lives

Second-life batteries
- Battery liability
- Competition with new storage batteries

Hazardous materials
- Safety and training across the value chain
- Tracking EVs and batteries in the market
- Battery identification
- Movement between provinces and the U.S. and Canada

Legal framework
- Scope
- Recovery targets
- Management of different batterie types
- North American market
- Economic value of end-of-life EV batteries and producer initiatives

Costs
- Price elasticity
- Funding
- Transportation costs

Battery composition
- Changes to chemical composition
- Changes to the EPR costs

Orphan batteries
- Managing batteries in the market
- Imported batteries
- Collapse of an industry player

Recycling
- Local vs. international processing
- Varying profitability by battery
- Confidentiality of technology

Environment
- Mismanagement of end-of-life batteries

4.6.1 Lifespan Uncertainty

Definition of Lifespan

A number of EPR parameters (e.g., recovery targets and financial impacts) are dependent on battery lifespan. It is difficult to make projections when the definition of "end of life" remains unclear. When has a battery reached end of life? When it is no longer usable in a certain type of EV? In any EV? After a second life? Such questions are compounded by the fact that there is no feedback on service life because the market is still underdeveloped. Service life also varies between EV models and the conditions of use and charging, which makes setting a specific figure even more challenging.

Lifespan uncertainty
- Definition of lifespan
- First and second lives

First and Second Lives

A battery's lifespan can be seen as having two phases. When it is no longer efficient enough to meet the needs of EV drivers, it can still be used for other applications. It can be converted for a new application—a storage battery, for example. It is currently difficult to estimate the first lifespan of a battery, determine whether it will have a second life, and estimate how long the second life might last. There are still a lot of question marks around battery lifespan.

4.6.2 Second-life Batteries

Battery Liability

Batteries are considered hazardous materials, and handling them involves risks. This creates liability issues at every stage of the battery life cycle. For example, when and to whom should liability be transferred when a battery is removed from a vehicle? Producers assume liability as long as batteries are used as intended in vehicles. But who is liable if someone decides to convert their used battery into a storage battery and a fire occurs? In Europe, liability is transferred to individuals as soon as they alter a battery to change its use. But under EPR regulations in Quebec, producers (first suppliers) are liable from marketing to end-of-life, even if batteries are reused. According to the regulations, there is no transfer of liability. Battery lifespan is still unknown, so producer liability could last a long time, which could pose management challenges. Such cases may be isolated, but they cannot be ignored. EPR would make it possible to better manage liability issues and provide better protection for all stakeholders in terms of both safety and insurance in the event of an accident. It is also possible that stakeholders may develop their own systems to address liability.

Second-life batteries

Battery liability

Competition with new storage batteries

Competition with New Storage Batteries

Having second lives for batteries (e.g., for energy storage) seems logical with EPR, but it presents certain challenges. Although used cells are less expensive than new ones, the costs involved in collecting, reconditioning, and putting them into storage batteries are high enough that new cells could be a cheaper solution. Plus, if the cost is equal or slightly higher, consumers are likely to prefer new batteries, which would benefit from technological advances. This issue reveals the importance of raising public awareness about environmental issues and encouraging reuse over the purchase of new products. Note that the EPR discussed in Section 4 is for batteries rather than cells. It is assumed that second-life batteries could be used as storage batteries and therefore would not necessarily be new.

4.6.3 Hazardous Materials

Safety and Training across the Value Chain

EV batteries differ significantly from the products that are currently under EPR regulations. The collection system should involve retailers (dealers), garages, ELV recyclers, and scrapyards. Due to their composition, batteries are considered hazardous materials when they are removed from vehicles and must be transported and managed according to applicable regulations, as discussed in Section 3.2.2. In order to limit the risks of explosion, fire, negative environmental impacts caused by end-of-life battery mismanagement, etc., it is crucial for workers across the entire collection system to receive advanced practical and theoretical training. A certification system could be established to verify that workers have completed all required training. In the absence of EPR, there is no obligation to fund and organize the training required to safely handle batteries, but private initiatives could still be implemented. It should be noted that in the case of car accidents, the situation is considered an emergency requiring emergency measures no matter which system is in place.

Hazardous materials

- Safety and training across the value chain
- Tracking EVs and batteries in the market
- Battery identification
- Movement between provinces and the U.S. and Canada

Tracking EVs and Batteries in the Market

One of the major issues raised by stakeholders was battery tracking. Notwithstanding battery leases (e.g., Renault's lease plan discussed in Section 2.2.4.), our stakeholder consultations indicated that EV producers are wondering how they will be able to collect their batteries if they cannot be tracked in the market. Between the sale of a product and its return at end of life, it remains essentially out of the company's line of vision. It is possible to use product lifespan and annual sales to estimate the quantities that will need to be recovered. In Quebec, SAAQ (Société de l'assurance automobile du Québec) is able to track EV batteries in the market through its registration system. This issue does not apply to EV batteries only. A number of products covered by current EPR regulations lack tracking systems because they are not mandatory under the regulations. Like gas vehicles, most end-of-life EVs will be sent to ELV recyclers in Quebec. It will be important to include ELV recyclers in independent recovery and recycling programs and RMO programs.

EV battery warranties could theoretically facilitate returns by consumers to original producers in the event of damage or reduced charge capacity. But according to CAA-Quebec, producer warranties are still vague and limited. EV producers do not commit to replacing batteries under warranty with new ones. Tesla appears to be an outlier in this regard. It guarantees equal or higher charge capacity for replacement batteries.

Battery Identification

Battery handling must take composition and other factors into account. Given that batteries vary depending on use, producer, and EV model, a battery identification system could be created. It could take the form of a serial number that would indicate the model and make it possible to determine the original EV dealer or producer. That would allow recyclers and scrapyards to use the appropriate technology and minimize risks. An identification system would also provide a solution to the tracking issue. Although EPR would facilitate the development of this type of system by making production of information documents mandatory, it could be implemented without EPR if all actors provide comprehensive data.

Movement between Provinces and the U.S. and Canada

Additional information on regulations for the transport of hazardous materials is provided in Section 3.2.2., which deals with the transportation of goods in Canada. Special training is required to handle hazardous materials, so carriers must hold the necessary permits for each province and state they pass through. At present we see no reason for significant movement of materials. It would be a different story, however, if a recycling plant were built in Quebec or the U.S northeast. If a plant were built in Quebec, we could expect to receive batteries from across Canada and the northern U.S.

4.6.4 Legal Framework

Scope

The scope of EPR measures is key to determining which types of EV batteries will be subject to the measures (for example, electric vehicle batteries are excluded from current EPR regulations for batteries). Given that EV battery management does not have the same demands as truck management, we can expect the Quebec market to be structured around two streams of batteries: electric car batteries, and medium-duty and heavy-duty vehicle batteries. The government will need to take the specific features of these battery streams into account when drafting regulations, especially in terms of recycling targets and nomenclature. Given the data currently available, the quantitative study examined passenger EV batteries and the qualitative study was extended to include medium-duty and heavy-duty vehicle batteries. That is why Section 4 deals exclusively with passenger EV batteries.

Legal framework
- Scope
- Recovery targets
- Management of different batterie types
- North American market
- Economic value of end-of-life EV batteries and producers initiatives

Recovery Targets

EPR comes with a legal framework for government to monitor system efficiency and meet specific objectives. Regulations set out recovery rates based on battery lifespan. Although the rates may be revised annually based on actual data, they are difficult to set because of uncertainty about battery lifespan, as explained above. Plus, each battery has specific features, so it could be advantageous to have different recovery targets for different types of batteries. Targets could be based on battery composition or weight or the volume collected, or they could be unrelated to the number of EVs sold. Recovery rates for batteries in the market and end-of-life batteries can be revised as needed. An adaptation period may be needed and targets may be altered based on feedback and data collected. It is difficult to determine the optimal launch time, but a gradual and flexible approach with targets that ramp up over one-, three-, and five-year periods would be preferable.

Management of Different Batteries Types

Producers subject to EPR that set up their own programs are obliged to recover the competition's batteries along with their own for free and regardless of battery technology or chemical composition. Some have raised issues about this constraint. Indeed, from a raw material restocking perspective, this can cause an operational issue. Producers' recycling technologies are not necessarily adapted to others types of batteries (further concerns in this regard are detailed in the sections on technology confidentiality and scope). But it is difficult to estimate the degree to which various batteries streams will cross into individual programs. To minimize the problem, companies subject to EPR can use their information, education, and awareness budget to encourage consumers to return their end-of-life EVs to the place of purchase or an authorized partner. Any recognized management organization would also be charged with directing consumers to appropriate dropoff points for each EV battery stream.

North American Market

Since EPR falls under provincial jurisdiction in North America, there is significant variation in product coverage and regulatory requirements between provinces and states. This lack of harmonization exacerbates the administrative burden of complying with regulations for companies subject to EPR that market their products in multiple jurisdictions. If multiple states or provinces decide to implement EPR for EV batteries, EV producers are likely to face an increased operational burden. For example, a multinational could be audited in every state or province with EPR regulations where it sells EVs. The current situation in the U.S. indicates that it is unlikely that a new regulatory mechanism for collecting and recycling EVs or EV batteries will be created within the next two years (when the Lithium-ion Car Battery Recycling Advisory is set to publish its recommendations).

If Quebec is the only jurisdiction to introduce EPR, there is a risk that some consumers may choose to purchase vehicles outside the province. But this is not a major issue and could easily be addressed by charging end-of-life vehicle management costs when vehicles are registered. Producers could also flaunt the rules in Quebec by transporting their end-of-life EVs to other provinces without EPR measures. Again, the risks are low. The North American market does not represent a stumbling block for EPR in Quebec, and research shows the province is ready to take on the challenge of being the first jurisdiction to adopt EPR.

Economic Value of End-of-life EV Batteries and Producer Initiatives

The economic value of end-of-life EV batteries should stimulate private initiatives. Some stakeholders, including EV producers, are concerned that EPR will undermine their ability to develop recycling chains.

4.6.5 Costs

Price Elasticity

In order to offset the cost of collecting and recycling batteries, vehicle prices will increase by up to $900, according to preliminary estimates. This number should be treated with caution because elasticity is based on parameters that are currently difficult to estimate. Although $900 seems high, the figure has been calculated based on current EV prices, which are relatively high. Regardless of EPR, EV prices are expected to drop over time, leading to increased sales that would offset the growing cost of end-of-life management, which EPR makes more visible.

Costs

- Price elasticity
- Funding
- Transportation costs

Funding

A centralized management organization could be responsible for managing financial costs for EPR, including setting aside funds for future expenses (independent programs could also do the same). The organization could collect funds to cover the management cost of end-of-life batteries and batteries expected to reach end of life during a given period. Depending on the system, funds could cover a few months, a number of years, or even the entire lifespan of a battery. The problem with this system is that it is difficult to predict future costs because the market is underdeveloped. This issue is examined in greater detail in Section 4.4.

Transportation Costs

As stated above, batteries require special handling, and carriers need permits, which increases transportation costs. There are also big challenges in terms of battery storage, including liability and the length of time an EV battery can be stored after it is removed from an EV. These issues are even more important for long distances, for example if a battery is transported to British Columbia. Producers could draw up implementation plans to better address these issues. All of these factors could create additional costs on top of the initial transportation cost.

4.6.6 Battery Composition

Changes to Chemical Composition

A number of R&D programs for EV batteries are currently underway. The chemical composition of batteries will almost certainly change over time. These constructive developments entail multiple challenges, including ensuring that collection and recycling systems adapt and providing the workforce with training geared toward rapidly changing technology. EPR could fund all or part of the cost of keeping up with these changes, but it is also possible that stakeholders will decide to underwrite the costs.

Battery composition

Changes to chemical composition

Changes to the EPR costs

Changes to the EPR costs

Some batteries are more expensive to process as a result of their chemical composition or design. A potential solution to this would be to adjust EV price depending on the type of battery to compensate for EPR costs.

4.6.7 Orphan Batteries

Managing Batteries in the Market

If an EPR mechanism were introduced, it would automatically apply to all new batteries that come to market starting on the date it is implemented. As shown in the previous Propulsion Québec study,[94] there are already significant numbers of batteries in the province and they are growing steadily. EPR measures should make it possible to include batteries that are already in the market to ensure they are managed properly at end of life.

Orphan batteries

- Managing batteries in the market
- Imported batteries
- Collapse of an industry player

Imported Batteries

The batteries in Quebec in the coming decades will not necessarily have been built by producers with operations in the province. Quebec EV owners could have their batteries changed elsewhere. And we can expect to see end-of-life batteries from other provinces and states. There will be a stream of new and used imported batteries.

Collapse of an Industry Player

Although producers and other industry players appear solid, it is possible that any of them could collapse in the coming years. If that happened, we do not know what would become of batteries they brought to market. EPR would help minimize the impact of any such collapse. But in the absence of EPR, it is not possible to predict how many producers would agree to recover orphan batteries for recycling or second-life uses. Although industry players appear proactive, we cannot tell how many batteries would get thrown away.

94 Data from the Propulsion Québec study: https://propulsionquebec.com/ressources/documents-et-liens/

4.6.8 Recycling

Recycling

Local vs. international processing

Varying profitability by battery

Confidentiality of technology

Local vs. International Processing

From a circular economy standpoint, there is consensus that EPR will facilitate development of local expertise in recycling the targeted product. EPR spurs local and regional processing but without imposing requirements. For example, Belgium has pioneered cross-border recycling with Umicore, which does not exclusively process Belgian batteries. But EPR regulations will not guarantee that EV batteries will be recycled in Quebec. Although EPR for batteries has been in place since 2011, hydrometallurgy and/or pyrometallurgy recycling processes are just beginning to appear in Quebec with the Lithion Recycling pilot plant for lithium-ion batteries. This is also due to the fact that the current supply of batteries is still low.

Producers that do not have facilities in Quebec will most likely want to ship their batteries to manufacturing plants (e.g., in the U.S. or Asia) in order to maintain their supply of raw materials.

According to RECYC-QUÉBEC: Quebec-based initiatives are underway to process batteries locally. From an environmental and economic point of view, it would be a good idea to carry out these operations in Quebec and cut out a significant amount of travel.[95]

Varying Profitability by Battery

Batteries are made of materials that fluctuate in value. For example, lithium iron phosphate batteries are less financially attractive because of the materials they contain. A parallel market (i.e., a recovery and recycling system) could form around batteries with appreciable economic value while others end up in landfill. EPR would minimize that risk, but would not eliminate it completely. It is a serious environmental problem and, in the absence of regulatory enforcement, it appears difficult to find a sufficiently strong incentive to encourage players to recycle all batteries, regardless of their composition and financial value. It is hard to tell what this would look like because battery technology is not yet at a stage where it is economically rewarding to recycle 100% of batteries.

Confidentiality of Technology

Producers and other industry players are currently working on advanced R&D programs to develop new, cutting-edge batteries that meet the needs of their target markets. There are also emerging questions about eco design. How can the challenges of battery recycling be addressed from manufacturing on? As mentioned earlier in the section on the management of different types of batteries, producers with an individual program must recover all types of batteries. Stakeholders are concerned that this feature of the EPR mechanism may limit producers's innovation, since their technology could easily fall into the hands of their competitors. All batteries covered by the program could end up at the same scrapyard or recycler, giving them access to all those technologies. This raises confidentiality issues. Stakeholders articulated this issue during our consultations. It is, however, difficult to ensure a company's technology will remain confidential and be prevented from falling into another company's hands, especially since nothing prevents companies from buying and dismantling competitors' EVs to learn about their technology. This approach is less likely to be employed for large vehicles. Furthermore, technology is protected as long as it is under patent.

95 " Certaines initiatives québécoises sont en développement en vue de traiter les piles localement. D'un point de vue environnemental et économique, il serait judicieux de pouvoir effectuer ces opérations au Québec et ainsi éviter des déplacements considérables. "

4.6.9 Environment

Mismanagement of end-of-life batteries

At this time it is not possible to ensure that batteries will not pile up in landfill or be tossed into nature. Battery components are extremely toxic to the environment, so the potential environmental issues raised by the lack of EPR are clear. If industry players were to take their responsibilities seriously and do what is needed to avoid such situations, EPR could prove less indispensable.
But if this is not the case, EPR is an important tool for mitigating end-of-life mismanagement.

Environment

Mismanagement of end-of-life batteries

Table 13 – Impact of EPR on identified issues

Lifespan uncertainty
- ● Definition of lifespan
- ● First and second lives

Second-life batteries
- ✓ Battery liability
- ● Competition with new storage batteries

Hazardous materials
- ✓ Safety and training across the value chain
- ✓ Tracking EVs and batteries in the market
- ✓ Battery identification
- ✓ Movement between provinces and the U.S. and Canada

Legal framework
- ✓ Scope
- ✓ Recovery targets
- ✗ Management of different batterie types
- ● North American market
- ● Economic value of end-of-life EV batteries and producer initiatives

Costs
- ✗ Price elasticity
- ✓ Funding
- ● Transportation costs

Battery composition
- ✓ Changes to chemical composition
- ✓ Changes to the EPR costs

Orphan batteries
- ✓ Managing batteries in the market
- ✗ Imported batteries
- ✓ Collapse of an industry player

Recycling
- ✓ Local vs. international processing
- ✓ Varying profitability by battery
- ✗ Confidentiality of technology

Environment
- ✓ Mismanagement of end-of-life batteries

✓ EPR would make it possible to better manage this issue
✗ EPR is not a solution to this issue
● EPR would have no impact on this issue

Taking into account the issues presented in this section is a key success factor for EPR implementation.

Conclusion

Growing EV sales in coming years will raise the challenge of how to manage and fund the recycling of end-of-life batteries. European nations like Norway, the Netherlands, and Belgium are using extended producer responsibility (EPR) to meet this challenge. EPR is a regulatory instrument that is already been implemented for other materials in Quebec without disrupting markets. This report has sought to study the suitability of this mechanism for lithium-ion EV batteries in Quebec. Other solutions may offer benefits comparable to EPR in the long term, but financial incentives are currently inadequate to ensure efficient end-of-life EV battery management. This study therefore focuses on EPR.

The following points have been identified:

EPR is an Existing Regulatory Framework that is Flexible Enough to be Applied to EV Batteries

The regulatory framework for EPR already exists in Quebec and is in use for other products. It can feasibly be applied to EV batteries. EPR provides a great deal of flexibility for industry. Producers have the choice of the means to implement the required program. Therefore, they can develop their own collection networks to recover their own batteries and technologies. Current EPR measures stipulate that they would also be required to recover any other batteries returned to them. This constraint is an issue for EV producers who fear EPR will limit opportunities for innovation and impede implementation of their own systems. Both independent programs and any recognized management organization will need to raise consumer awareness in order to direct batteries to the appropriate dropoff points.

The Current Regulatory Framework will not Hinder EPR Implementation

A survey of the current situation indicates that the legal framework in North America would not be an obstacle for EPR for EV batteries in Quebec. EPR would actually complement existing regulations, including on end-of-life vehicle and battery recycling and the transportation of hazardous materials.

EPR is a Solution to the Majority of Stakeholder Issues

EPR would address the challenges faced by key market players, especially how to ensure safe, environmentally friendly end-of-life battery management. Without EPR, the market could lack coordination and a shared framework, leading to increased risk of batteries going to landfill instead of being recycled. EPR regulations must define battery lifespan, set out a clear legal scope, and address traceability issues (see key success factors below).

EPR does not Pose a Threat to the EV Market

Preliminary financial estimates show that the cost of EPR would not be an impediment for the EV market. Contrary to popular belief, apart from administrative costs, EPR is not the main cause of recycling costs. Such costs are inherent in the end-of-life stage of the battery life cycle. EPR actually can make these costs more explicit from the outset. Quantitative analysis of EPR indicates that EPR contributions could be less than or equal to 1% of the cost of a new vehicle. The effect of EPR on EV growth would therefore be marginal, especially given that EVs are expected to fall dramatically in cost over the coming years. Quebec also has the Zero-Emission Vehicles Act, which aims to stimulate EV production and increase EV penetration in the Quebec market. Although introducing EPR in Quebec would not have significant economic impacts, the industry is concerned about the administrative burden it would create and its effects on emerging players in the EV market, especially in terms of growth.

EPR would Reinforce Quebec's Position in the EV Value Chain in North America

EPR would add to Quebec's expertise in the electrification of transportation and help carve out a place for the province in the North American battery recycling market.

Analysis of various jurisdictions shows that Quebec would be an early adopter. A number of provinces and states, including California and Ontario, are looking at EPR, but it has yet to be implemented in North America. Despite the administrative complexity involved, implementing one or a series of EPR measures provincially is viable, even in the absence of federal harmonization. The example of Europe (and EPR for other types of materials) shows that administrative complexity does not necessarily hinder success.

Key Success Factors for EPR

Analysis of regulations, issues raised by stakeholders, private and public practices implemented in other jurisdictions, and the scenario under consideration shows that EPR would meet current and future challenges. In order to ensure EPR's success in Quebec, special attention must be paid to the following issues:

1. **Setting the Right Parameters**

   EPR regulations must clearly set out applicability parameters to ensure stakeholders' issues are addressed and the regulations fit the situation in Quebec. Special attention must be paid to the legal scope of EPR and the definition of lifespan. In order to keep costs in equilibrium in the market, EPR should have a balanced source of funding.

2. **Optimal Launch Time**

   It's hard to say when's the best time to launch EPR. Too early and there will be an inadequate supply of batteries. Too late and some batteries may already have been mismanaged. Plus, the situation in other Canadian provinces and the U.S. must be taken into account to make sure Quebec is consistent with systems and legislation elsewhere in North America. The approach should be gradual and flexible. For example, stakeholders will need time to set up collection systems after the program is launched.

3. **Flexible EPR Implementation**

   A management organization could be created to centralize costs and administrative tasks, but the framework could leave room for independent initiatives by EV producers that wish to develop their own recycling chains and recover the economic value of their own batteries.

4. **Conservative Recovery Targets**

   The market is still too underdeveloped to provide feedback, so it is important for recovery targets to be discussed with stakeholders and amended in the regulations as necessary. It could be a good idea to start by setting one-year, three-year, and five-year targets, then reevaluating them at the end of each period.

5. **Battery Identification System**

   There is a wide range of battery types. They vary based on use and even within the same use. If EPR were to apply exclusively to EVs, there would still be significant variation in the batteries collected, including in their chemical composition. An identification system should be put in place to facilitate battery collection and recycling. A serial number could provide access to the battery's ID record.

6. **Collaborative Approach**

Stakeholders are aware of the environmental challenges posed by end-of-life battery management and the need to address it, but a number of industry-specific issues were identified during the interviews and the consultation workshop. The success of EPR is contingent on all stakeholders participating, so it iss crucial to consider these issues and address them to the best of our ability.

7. **R&D Awareness and Promotion**

Regulations in Quebec stipulate that EPR must include awareness and educational activities for the public and for industry stakeholders. It should also include an R&D component that deals with techniques for recovering and recycling the materials collected and developing markets for those products and materials.

A

Appendix

A – Stakeholders Consulted

Agence de l'environnement et de la maîtrise de l'énergie (ADEME)
Association des Véhicules Électriques du Québec (AVEQ)
Association du transport urbain du Québec (ATUQ)
Association of Auto Parts Recyclers in Quebec (ARPAC)
Automotive Recyclers of Canada (ARC)
Bebat
Bixi
Blue Solutions
Bombardier Transportation
Call2Recycle
Call2Recycle (U.S.)
Canadian Vehicule Manufacturer's Association (CVMA)
Concept GeeBee
Corporation des concessionnaires d'automobiles du Québec
E-Taxi
Febelauto
Global Automakers of Canada
Hydro-Québec
Ingeniarts
Johnson Matthey
Lion Electric Co.
Lithion Recycling
Mason Graphite
Ministère de l'Énergie et des Ressources naturelles (MERN)
Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC)
Ministère des Transports, de la Mobilité durable et de l'Électrification des transports
National Center in Environmental Technology and Electrochemistry (CNETE)
National Research Council Canada
Natural Resources Canada
Nemaska Lithium
Nouveau Monde Graphite
Ontario Ministry of the Environment, Conservation and Parks (MECP)
RECYC-QUÉBEC
Tesla
Transport Canada (Transportation of Dangerous Goods, Quebec Region)

B – Members of the Steering Committee

Simon Pillarella – Propulsion Québec

Julie Perreault-Henry – Propulsion Québec

Denis Geoffroy – Recyclage Lithion

Marie-Hélène Côté – Ministère de l'Énergie et des Ressources naturelles

Olga Kergaravat – Agence de l'environnement et de la maîtrise de l'énergie

Simon Matte – Association of Auto Parts Recyclers in Quebec

Sophie Cantin – RECYC-QUÉBEC

Patrick Bouchard – Ministère de l'Économie et de l'Innovation

C – Online End-of-Life Battery Collection Notification Form

Online End-of-Life Battery Collection Notification Form
(in French only)

https://www.febelauto.be/fr/remettre-une-batterie/formulaire

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