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RECYCLING ELECTRIC VEHICLE BATTERIES:
ecological transformation and preserving resources

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The market for electric vehicles is currently experiencing unparalleled growth in many parts of the world. This expansion is supported by a range of policies designed to boost electric mobility. As a result, vehicle and battery manufacturers are significantly ramping up their production, which is now growing exponentially and incorporates materials that are often crucial and can pose risks to human health and the environment.

This in turn makes recycling electric vehicle batteries essential from both an ecological and strategic standpoint. Veolia offers solutions in this field that leverage its experience in hazardous waste processing, recycling expertise, and network of partners, specifically vehicle manufacturers and chemicals specialists. The aim is to protect the resources needed for ecological transformation.

Dismantling a battery - ©Veolia

Veolia develops innovative models for materials circularity on behalf of customers from a wide range of sectors, including agriculture, with soil fertilization and bioconversion to convert farm waste into animal feed, renewable energies, with recycling solutions for photovoltaic panels and wind turbine blades, and the textile industry. Recycling electric vehicle batteries is a major component of Veolia's innovation drive.

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INTRODUCTION

Electric vehicle batteries will become a major problem in the near future if they are not managed correctly. This is because they contain highly toxic chemicals that represent a threat to ecosystems as well as to the people who handle them. In addition to plastics, solvents and electronic components, the active parts of battery cells also contain strategic metals such as copper, nickel, lithium and cobalt. This means that recycling these components is an environmental and strategic imperative.

The market for recycling electric vehicle batteries is growing exponentially: from 200,000 metric tons of EV batteries eligible for recycling in 2021 to 7 million metric tons in 2035, representing metals with a value in excess of €15 billion. The market is particularly buoyant in China while it is expanding in Europe and should follow suit in the USA in a few years' time. The phenomenon is underpinned by rapidly changing regulations that increasingly require recycled metals to be used in the production of new batteries. Veolia plays an active part in this ecological transformation which boosts the mobility of tomorrow.

"Black mass" extracted from the grinding of battery cells, containing mainly a mixture of carbon, nickel, lithium and cobalt - ©Veolia

RECYCLING ELECTRIC VEHICLE BATTERIES: AT THE CROSSROADS OF ENVIRONMENTAL, HEALTH AND STRATEGIC CHALLENGES

ELECTRIC VEHICLES: A BOOMING MARKET

The market for electric cars is booming. In 2018, the global fleet accounted for over 5.1 million vehicles and is projected to exceed 130 million by 2030 according to Global EV Outlook 2019. This trend is rooted in the desire to reduce the numbers of cars that use internal combustion engines (ICE) in favor of electric vehicles, which are more environmentally friendly. China and Europe have set targets for electric vehicle rollouts paired with stringent emission regulations for ICE vehicles. For example, China now requires vehicle manufacturers operating on its domestic market to offer a complete range of electric vehicles. In November 2020, the United Kingdom announced a ban on the sale of new ICE vehicles on its market by 2030. A similar ban is likely to be in place across the European Union by 2035. These ambitious policies aim to:

- provide local answers to a pressing health problem caused by transport-related pollution, particularly in built-up areas. Tailpipe emissions from ICE vehicles contain particulates and gases from the nitrogen oxide (NOx) family that are particularly damaging to health;
- combat greenhouse gas emissions during the time vehicles are in use, and reduce dependency on fossil fuels. According to a lifecycle analysis by France's ADEME agency in 2016, full-life CO_2 emissions from an EV are three to four times lower than for a comparable ICE vehicle, and atmospheric pollution is very largely reduce.

EXAMPLES OF COUNTRIES THAT HAVE SET TARGETS FOR BANNING ICE VEHICLES

Country	Target date	Goal
USA	2030	50% of vehicles sold are electric or hybrid
California	*2025*	*Ban on ICE cars*
Canada	2040	Ban on ICE cars
Quebec	*2035*	
Norway	2025	All vehicles sold will be carbon neutral
UK	2030	Ban on sale of ICE cars
Singapore	2030	Ban on ICE cars
Israel	2030	Ban on ICE cars
Europe	2030	Ban on sale of ICE and hybrid cars
Sweden, Ireland, Netherland	*2035*	
	2050	Reach carbon neutrality
China	2025	20 % vehicles are electric or hybrid
	2035	>50 % vehicles are electric or hybrid
Japan	2035	Ban on sale of ICE cars
India	2035	30% of vehicles are electric

TAKING ACCOUNT OF THE ENVIRONMENTAL IMPACTS OF ELECTRIC VEHICLES

Electric vehicles are clearly not impact-free in terms of the environment: manufacturing, extracting materials to make batteries, and emissions generated by electricity production all need to be taken into account when assessing environmental footprints. This means that rising EV uptake must go hand in hand with greater production of electricity from renewable sources.
But it also requires limiting resource use with solutions such as eco-design and recycling. Any massive shift to EV also entails planning end-of-life management for these new vehicles. They contain different components to ICE vehicles and include pollutants, particularly in the batteries. Recycling ensures that these hazardous materials cause no major ecological damage owing to a lack of processing capabilities.

Recycling activities make it possible to reduce carbon emissions by one metric ton of CO_2 equivalent per metric ton of recycled batteries, and they avoid the extraction of virgin metals, with mining activities having critical impacts on biodiversity and water resources

The extended producer responsibility approach has already generated a considerable volume of regulation governing end-of-life vehicles of all types. EU directive 2000/53/EC, dated September 18, 2000, sets environmental performance targets for end-of-life vehicles, including a requirement to reuse and recycle at least 85% of the weight of end-of-life vehicles, and reuse or recover at least 95% of weight per vehicle, as required by the extended producer responsibility policy. Japan, South Korea and China have adopted similar regulations. It is worth noting that batteries represent 30% to 50% of vehicle weight and that, since 2006, European regulations have required that 50% of total battery weight is recycled (directive 2006/66/EC). The European Commission plans to increase this recycling requirement to 70% in 2030. A minimum of 90% of components classed as crucial owing to their toxic or strategic nature will have to be recovered.

Recycling activities deliver significant environmental advantages: they make it possible to reduce carbon emissions by one metric ton of CO_2 equivalent per metric ton of recycled batteries, and they avoid the extraction of virgin metals, with mining activities having critical impacts on biodiversity and water resources.

COMPOSITION OF BATTERIES: STRATEGIC RESOURCES

Another key issue to add to these environmental and regulatory considerations is the availability of raw materials. A battery is an assembly of ten or so modules, each made up of 10 to 15 cells. A new battery weighs an average 500 kg for a capacity of 50 kWh and costs around €7,500. Three distinct categories of materials are used in the composition of batteries, classified by value:

- low-value components (30%), plastic used to make the outer casing, electronics, volatile components and steel;
- intermediate-value components (40%), primarily aluminum used to make casings for modules;
- high-value components (30%), used in the composition of battery cells, such as lithium, cobalt, nickel and copper.

Prices for these metals on the open market can reach several thousand euros per ton and, for some of them, speculation constantly drives prices higher.

The supply of a number of these metals poses significant risks to importing countries. Since 2011, the European Union has regularly published a list of critical raw materials. Lithium was added to the list in 2020 and the European Commission says it is keeping a close watch on nickel, bearing in mind the growing demand for raw materials used to manufacture batteries, even though it is not yet judged "critical". Some metals are extracted in chronically unstable countries; for example, over 60% of cobalt is sourced from the Democratic Republic of the Congo. Recycling makes it possible to lock in a portion of the raw material supplies needed for electric vehicle batteries and countless other industrial applications. It is a real lever for achieving strategic independence.

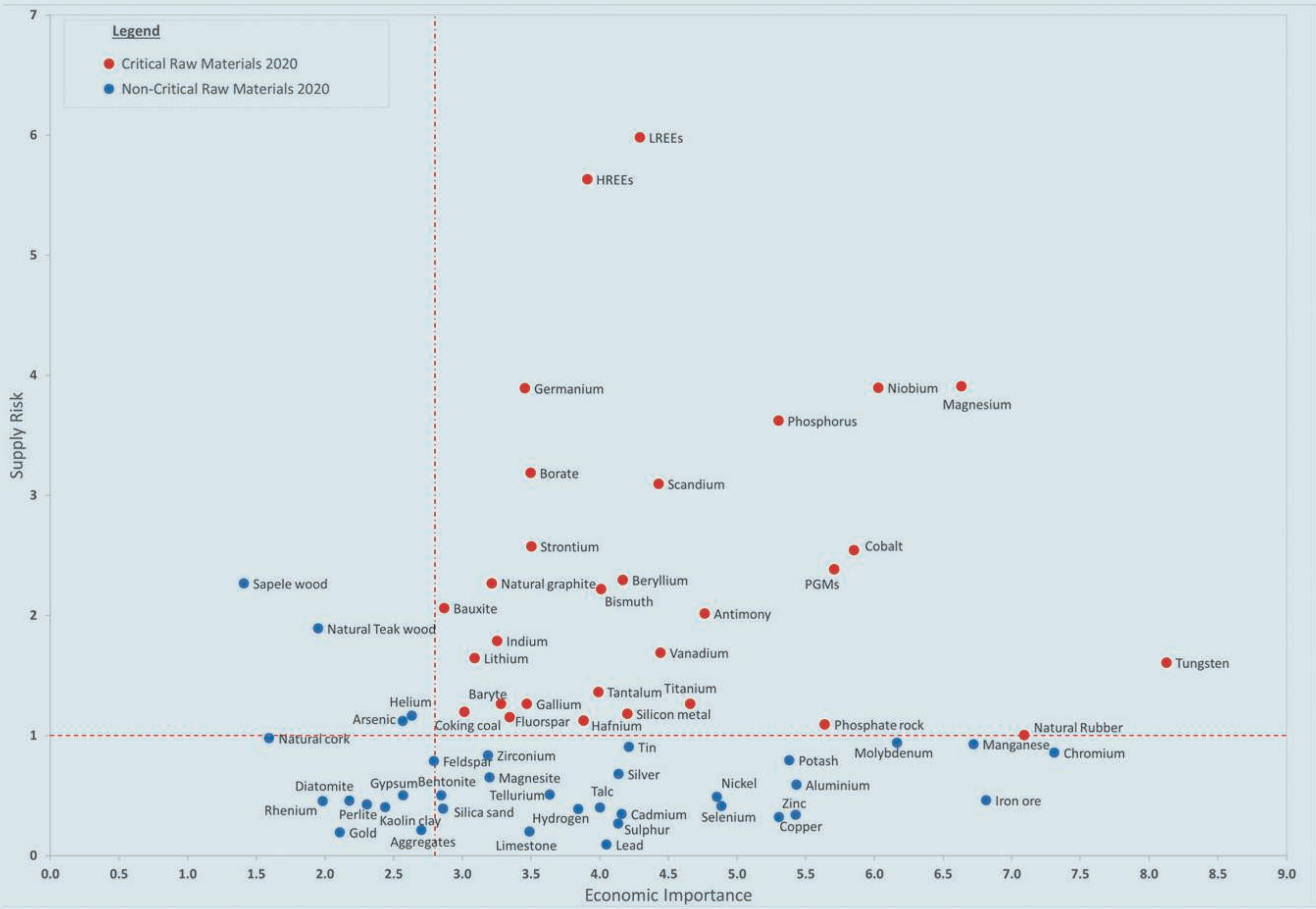
CLOSING THE LOOP: PRODUCING BATTERIES FROM RECYCLED MATERIALS

The medium-term aim is to arrive at a circular economy for batteries by developing closed loop recycling. The European Commission is currently working on drafting a regulation that will incrementally impose the use of recycled materials in the composition of electric vehicle batteries. Threshold levels for recycled materials will concern all batteries sold into the European market, irrespective of their place of manufacture. Starting in 2025, it will be mandatory to declare levels of recycled materials. In 2030, the levels demanded will be 12% for cobalt, 4% for lithium and 4% for nickel. These will rise to 20%, 10% and 12% respectively in 2035. Although these levels may at first glance appear fairly unambitious, in reality they will require a considerable increase in the amount of recycled material produced, and a major shift so that recycled by-products are re-routed back into new battery production processes. The overall efficiency of recycling rates will also be controlled via mandatory thresholds (2025: 90% for cobalt, copper and nickel, and 35% for lithium; rising to 95% and 70% respectively in 2030).

Veolia intends to play a major role in the emergence of this new sector of the circular economy.

List of critical raw materials established by the EU according to their economic importance and supply risk

2020 list of critical raw materials (in bold: newly added since 2017)		
Antimony	Hafnium	Phosphorus
Barite	Heavy rare earth elements	Scandium
Beryllium	Light rare earth elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural graphite	Vanadium
Coking coal	Natural rubber	**Bauxite**
Fluorspar	Niobium	**Lithium**
Gallium	Platinum group metals	**Titanium**
Germanium	Phosphate rock	**Strontium**



Source : European Commission, Study on the EU's list of Critical Raw Materials - Final Report (2020)

Figure 1

VEOLIA: SUPPORTING ECOLOGICAL TRANSFORMATION IN THE MOBILITY SECTOR

SOLUTIONS FOR RECYCLING THIS HAZARDOUS FORM OF WASTE

Recycling electric vehicle batteries is a major challenge that Veolia is ready to meet. In Europe, Veolia works via SARP Industries and its subsidiaries Euro Dieuze Industrie (EDI), specialists in the management, making safe, electric discharge and mechanical processing (grinding) of batteries and capacitors, and CEDILOR, a center for chemical processing (purifying) and recovery. In China, Veolia has recently started production at a new high-capacity plant (25,000 metric tons), a joint venture with local actors from the battery ecosystem. Work to develop additional projects is under way, including in the United States and Europe.

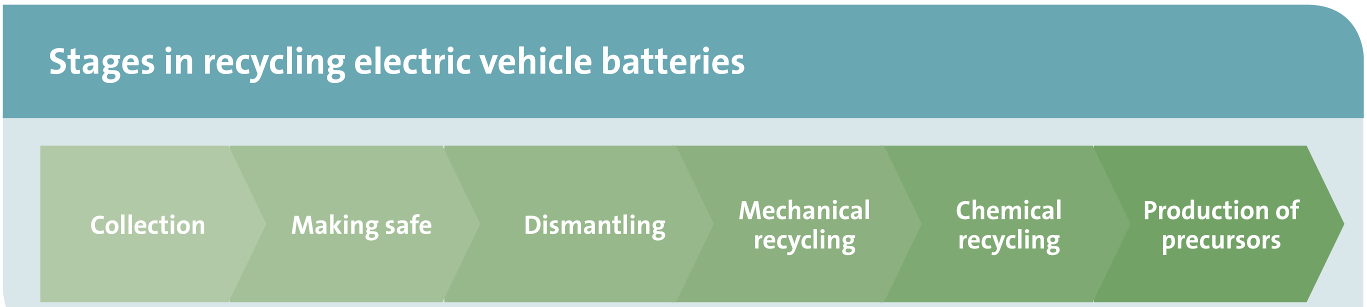


Figure 2

Composition of an electric vehicle battery - ©Veolia

Since 2013, Veolia has been leveraging its expertise in processing hazardous waste to develop recycling processes for EV batteries. The main stages are described below.

- **Collection and making safe.**

  Before any recycling can take place, batteries have to be removed from the vehicle where they were installed. They then have to be fully electrically discharged and made safe so that they can be handled securely at every step of the process. These stages are of great importance as it is possible to damage the batteries. They contain highly inflammable materials and chemicals that are harmful to humans and the environment.

- **Dismantling.**

  The protective plastic or aluminum casing, electronic components, wires, connectors and the cooling system are all removed to locate the separate modules that comprise the battery. This part of the process is accomplished manually by trained operators. Next, the aluminum protection around the modules is removed to uncover the battery cells.

- **Mechanical recycling.**

  The battery cells are then ground up to separate the elements with less value from those that are more valuable. Cell grinding takes place under high humidity to avoid all risk of fire or explosion. The ground materials are then mechanically separated to obtain three primary materials: paper and plastics; aluminum, copper and steel; and "black mass", a powder containing mostly a mixture of carbon, nickel, lithium and cobalt.

- **Chemical recycling.**

  The black mass is then processed chemically to separate and purify the materials it contains. Two main technologies are used to achieve purification: hydrometallurgy and pyrometallurgy. Although pyrometallurgy is simpler to use, it requires large amounts of energy and does not deliver high levels of purification. This means that it often needs to be followed by a hydrometallurgical process that allows materials to be extracted selectively. Veolia applies a hydrometallurgy process directly to purify lithium, nickel and cobalt and separate them from the black mass.

- **Production of precursors.**

  If the by-products produced by hydrometallurgy units are sufficiently pure, they can be used in the production of precursors and materials for anodes and cathodes. This closes the recycling loop as it means recycled lithium, nickel and cobalt can be used in the production of new batteries.

Dismantling a battery - ©Veolia

SARP INDUSTRIES: VEOLIA'S OPERATIONAL EXPERIENCE IN EUROPE

Euro Dieuze Industrie (EDI), a subsidiary of SARP Industries located near Metz in north-east France, processes over 6,000 metric tons of batteries annually, recycling up to 80% of them. Carbon can be used in the metallurgy industry for de-rusting metals. Recovered metals are sold for use in the manufacture of alloys and chemical salts. EDI carries out the initial stages of recycling, from collecting batteries to producing black mass. The plant currently processes 1,000 metric tons of EV batteries a year and will double its capacity to 2,000 metric tons in 2022 then to 5,000 metric tons in 2023.

Also located close to Metz, CEDILOR uses hydrometallurgy to chemically purify black mass from EDI into nickel and cobalt salts. The process is currently being upgraded to allow the use of recycled cobalt and nickel salts in the manufacture of new batteries. By 2023, the plant should be able to process 4,000 metric tons of black mass a year, equivalent to almost 15,000 metric tons of electric vehicle batteries.

VEOLIA CHINA: TWO BOOMING JOINT VENTURES

Veolia's battery recycling activities in China center on two joint ventures with Fang Yuan (a local producer of battery precursors), Pand (a specialist in reusing batteries), BTR (a leading global supplier of anode materials) and Dele (a local supplier of environmental services).

The first joint venture is operated by Veolia and carries out the initial stages of recycling, from collecting batteries to producing black mass. The plant has an annual capacity of up to 20,000 metric tons of batteries. It entered service during Q4 2021.

The second joint venture will purchase black mass produced by the first joint venture, as well as by other recyclers. The technology used will be developed and operated by Fang Yuan. The process will first use hydrometallurgy to purify the metals, then produce battery precursors that can be used for the production of new electric vehicle batteries. Work on building this second plant is not yet under way.

SUPPORTING AN EXPANDING NEW MARKET

The estimated volume of equivalent batteries available for recycling was 180,000 metric tons in 2020. This figure will rise to 7 million metric tons by 2035. These volumes will initially come from China, which is leading the way in electric vehicle adoption. More generally, the majority of battery (LG, Samsung) and EV manufacturers (BYD, Toyota) are historically also Asian. A second wave of material for recycling will come from Europe, which is currently significantly ramping up battery production. Lastly, the market in North America should develop along the same lines around 2030. All this means that the electric vehicle battery recycling industry needs to scale up as of today in order to keep pace with exponential growth in the market.

Battery waste requiring processing can be divided into two types

- **Production waste from battery manufacturing** currently accounts for over half the volume of material to recycle. Waste from the battery production process includes high value materials containing lithium, nickel and cobalt lost at various stages during the process (production of cells, assembling the modules, assembling the batteries, testing, etc.). The overall volume of waste generated by the battery production process is currently estimated to be equivalent to 5 to 10% of the total capacity of a standard factory. Despite the fact that the relative size of this waste stream will probably diminish as manufacturing processes are improved, the exponential increase in production means it will remain the primary source of material for recycling over the coming years.
- **End-of-life batteries** correspondent correspond to the overall volume of batteries available for recycling after a service life of 10 years (end of first life) and up to 15 years (for second-life batteries). This means there is a direct correlation between available volumes and the volume of batteries manufactured 10 years ago. This stream of waste batteries is therefore very limited at present since very few EVs were sold in 2010. It will progressively account for most of the material available for recycling in the years after 2030.

Veolia works non-exclusively with manufacturers of vehicles and batteries (gigafactories) alike. For example, Veolia has signed a deal with Renault that covers construction of a battery recycling plant in France, using streams of materials sourced from Renault vehicles. Discussions have also taken place with gigafactory operators with a view to establishing partnerships for recycling their production waste.

THE JOB-CREATION POTENTIAL OF BATTERY RECYCLING ACTIVITIES

Developing battery recycling activities is also about promoting new skills and encouraging an ecological shift that creates employment. There are several estimates of the job-creation potential of battery recycling. According to a recent study into how to achieve a well-balanced transition in the French automobile industry, conducted by the Fondation Nicolas Hulot (June 2021), battery recycling will create 9,000 jobs in 2030-2035. An earlier study by the Centre for European Policy Studies (Prospects for Electric Vehicle Batteries in a Circular Economy, Eleanor Drabik and Vasileios Rizos, July 2018) estimates that collecting, dismantling and recycling batteries creates 15 jobs for every 1,000 metric tons of lithium-ion battery waste. For example, the Euro Dieuze Industries site acquired by Veolia employed five people in 2000; 40 people work there today recycling batteries of all types, including from EVs. Veolia's teams closely monitor this aspect as part of the group's multi-faceted performance, which measures social impacts in the territories where it operates.

Recycling makes it possible to lock in a portion of the raw material supplies needed for electric vehicle batteries

LOOKING AHEAD: MOVING TO ENHANCED CIRCULARITY

Veolia is already working to deliver the constant improvements to processing procedures needed to obtain secondary raw materials of the highest possible purity. Significant advances in hydrometallurgical technologies will make it possible to meet the closed loop recycling requirements set out in forthcoming European regulations. The goal is to produce batteries from materials recycled from other batteries. In late 2020, Veolia unveiled a partnership with chemicals specialist Solvay for assessing alternatives to the processes for purifying metal salts currently used by Veolia.

Veolia is also examining ways to reuse electric vehicle batteries in other applications, such as energy storage for renewable energy, fast chargers for EVs and smart grid services, activities that offer synergies with Veolia's current operations. Projects are under study in the UK and France. This approach aims to offer solutions that leverage enhanced circularity to cut the carbon footprints of Veolia's customers.

CONCLUSION

Recycling electric vehicle batteries is a strategically important growth area for Veolia. It is a concrete response to the urgent need for ecological transformation among all actors in the electric vehicle value chain. Through its activities, Veolia contributes directly to exploiting urban mines and to increasing the mineral self-sufficiency and independence of its partner territories and businesses. Growth in recycling electric vehicle batteries also creates long-term employment opportunities for technicians: green jobs for the 21st century!