GreenSpace Tech
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Lithium-ion battery recycling

Momentum is building, enabled by new technology

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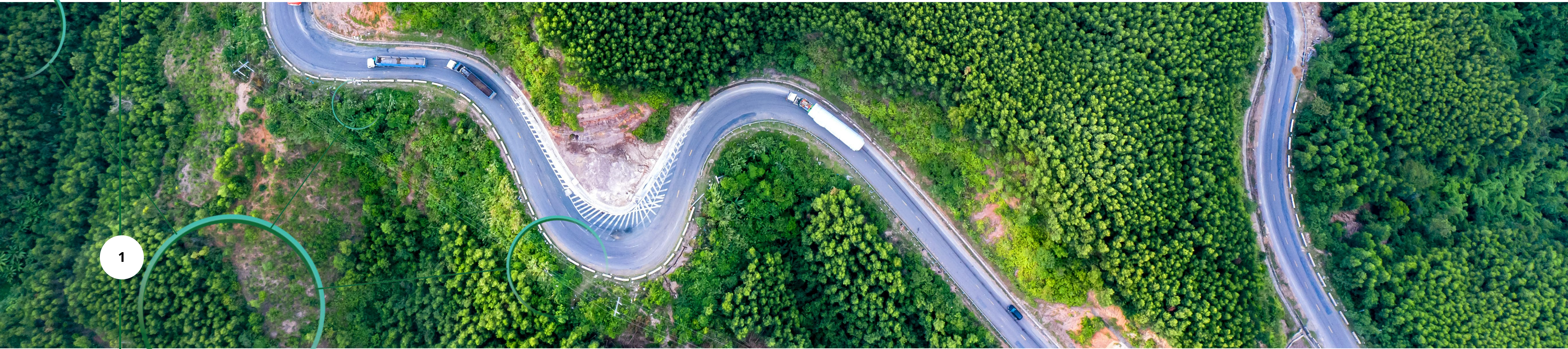
As the electric vehicle (EV) market grows, so does the demand for lithium-ion batteries (LIBs), the most common EV battery type. Improving and expanding the process of recycling LIBs will meet a critical need to bolster the supply of valuable minerals for batteries while reducing their environmental impact. Innovation is occurring across the battery recycling value chain, with digital technologies set to play a key role.

Securing supply, reducing climate impact

Minerals such as lithium and cobalt required to produce LIBs are geographically concentrated and projected to fall short of demand by 2025.[1] While mining currently provides most of these minerals, Goldman Sachs expects recycling to supply 39% to 57% of lithium, nickel, and cobalt by 2040.[2] Recycling can also significantly reduce the environmental impact of batteries. One study found that recycling can reduce global warming potential by 30% to 39%, depending on geography.[3]



Innovation along the recycling value chain

To reap these benefits, industry leaders and innovators are remaking the LIB recycling value chain, from tracking to transporting to processing.

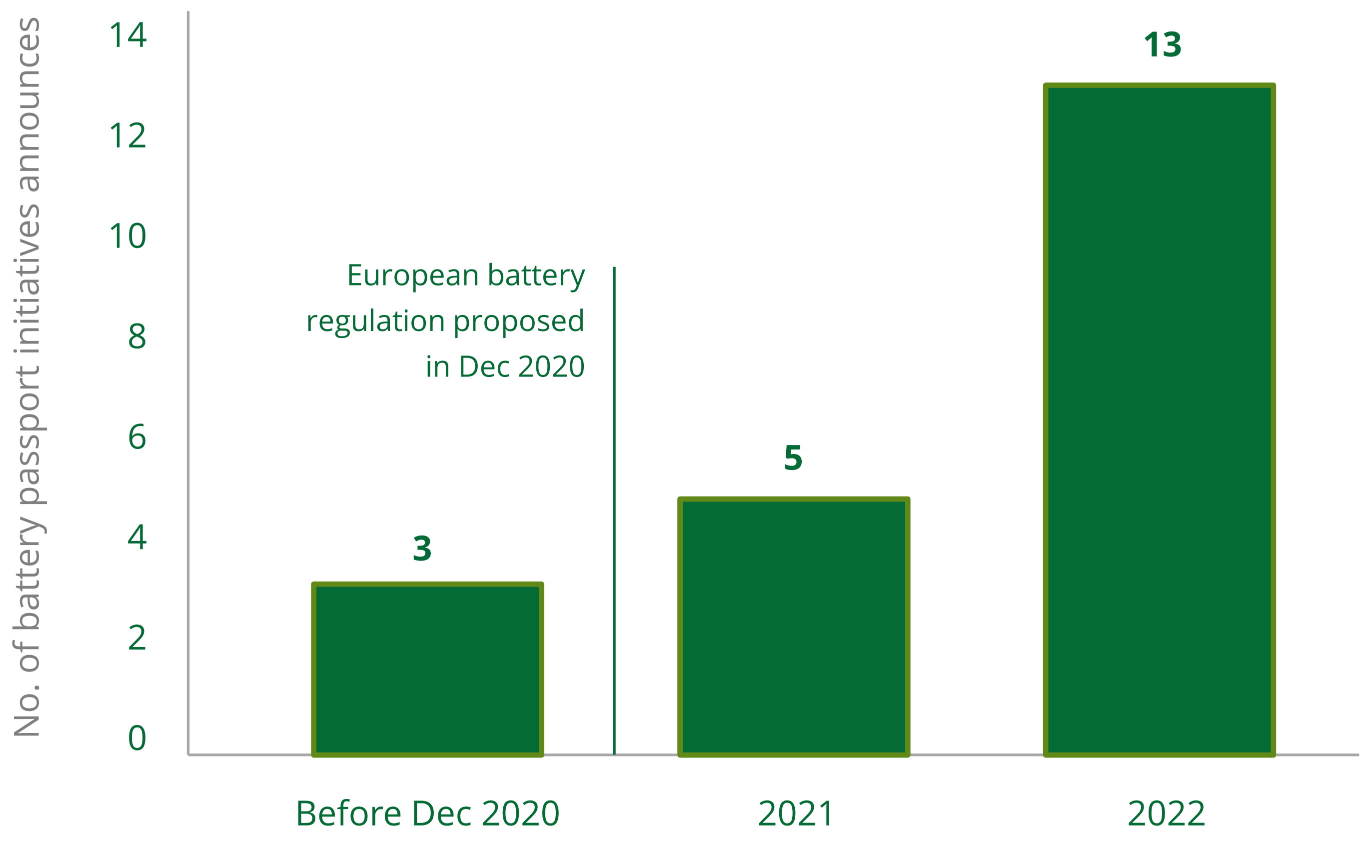
Tracking

Better information about the condition and location of batteries throughout their life cycle can help improve the efficiency of the recycling value chain. To this end, the Global Battery Alliance (GBA), an industry group, conceptualized a digital twin-based "Battery Passport." Passports store data on battery life cycles that help recyclers to predict and trace the end of life of batteries and determine their suitability for recycling.4

In December 2022, the European Commission affirmed its 2020 proposal to mandate battery passports for EV and industrial batteries in the EU by January 1, 2026.5 Since then, passport-related efforts have followed (see Figure 1).

Figure 1: Trend in battery passport-related efforts
(Sources: Press releases and company websites)

Increasing interest in digital-twin based battery passport (n=21)



Collection and transportation

Many national governments recognize low battery waste availability as an issue.[6] Currently, LIBs are collected and recycled at a rate of less than 10% in the United States and Australia, perhaps just 5% globally.[7] The U.S. Environmental Protection Agency plans on more collection sites, increased awareness, standard battery labeling, and financial incentives in the United States.[8] Efforts are also being made to make the transportation of batteries for recycling safer and cheaper. For example, fireproof cases to cart batteries safely and without the expense of specialized LIB handling training for personnel.[9]

Pre-recycling process

Robotic technologies could make the battery dismantling and sorting process more efficient and reduce risks from fire hazards. Oak Ridge National Laboratory researchers developed a robotic disassembly system that eliminates manual labor.[10] Swedish battery recycler Northvolt says it uses robots for dismantling.[11] Governments encourage battery makers to “design for recycling” for easy battery disassembly.[12]

Recycling processes (1/2)

The LIB recycling process is evolving, with innovators pursuing approaches to lower costs, improve yields, and reduce environmental impacts. Among the processes in use and being developed are pyrometallurgy, hydrometallurgy, direct recycling, and electricity-based recycling.

Table 1: Overview of technologies relevant for LIB recycling

TECHNOLOGY	DEFINITION	MATURITY	OTHER DETAILS
RECYCLING TECHNOLOGIES			
Pyrometallurgy	Uses high-temperature furnaces (>1000º C) to melt and separate the battery components	Mature (TRL = 11)	-
Hydrometallurgy	Uses aqueous solutions to dissolve the batter components. Includes acidic leaching, extraction, and precipitation. Since 2010, hydro recyclers have received VC funding of $1.2 billion.	Mature (TRL = 11)	Funding to be used for commercialization purposes including the construction of new facilities
Direct recycling	Cathode material can be recovered without the use of acids or smelting	Early prototype (TRL = 3-4)	Received $60 million in funds since 2019 including grants
Electricity-based recycling	Use of electric currents and voltage to separate the metals	Concept (TRL – 2-3*)	
DIGITAL TECHNOLOGIES			
Battery Passport	Digital twin technology using blockchain, AI, and battery analytics for battery traceability	Large prototype (TRL = 5*)	3 pilots announced: Funded EU research projects – Battery Pass ($8.7M), IDcycLIB ($7.3M), BATRAW project ($10.5M)
Robotics for dismantling	Use of robots to automate battery disassembly process and improve worker safety	Concept (TRL = 2-3)	Oak Ridge National Laboratory demonstrated a robotic disassembly system

Other nascent technologies such as bioleaching (use of microbes to extract minerals) & ultrasound-based recycling (ultrasonics for metal recovery) have not considered in this study.

TRL = Technology readiness level

*GreenSpace Research analysis

Sources: TRL has been taken from IEA (ETP Clean Energy Technology Guide); VC funding from CB Insights; Battery Passport pilot details from press releases

Recycling processes (2/2)

Pyrometallurgy ("Pyro")

The most mature LIB recycling process,[13] , is energy- and capital-intensive. And the high heat used in the process makes it challenging to recover many of the battery components, such as electrolyte, graphite, steel, aluminum, or lithium, as they are lost as slag or off-gas.[14]

Direct recycling

Direct recycling retains the original chemical structure of battery components.[20] One direct-recycling startup claims that its energy use and greenhouse gas emissions associated with its technology are 80% lower than hydro, and its cost is 29% lower.[21]

Hydrometallurgy (Hydro)

Which uses water-based acid solutions to extract battery minerals, can recover lithium along with other critical minerals and has better environmental performance (20% lower global warming potential[15]) and lower costs than pyro (approximately $8 to $14/kWh) versus (approximately $10 to $22/kWh).[16] Hydro is widely adopted.[17] Conventional hydro processes are complex and generate hazardous wastewater; however, so new methods are being explored.[18] Some startups are commercializing simplified processes with fewer steps or processes that reduce or eliminate wastewater.[19]

Electricity-based recycling

Electricity-based recycling uses renewable electricity instead of chemicals or furnaces to extract minerals from LIBs with potentially very low emissions depending on the electricity source.[22]

Responsibilities and opportunities

Over the next two decades, LIB recycling could supply up to half of the critical minerals used in manufacturing LIB batteries, while reducing their environmental impact.

This means opportunities—and sometimes regulatory requirements—for companies along the value chain. For example, chemical companies and battery makers can collaborate on battery design to support recyclability. Automakers and recyclers can partner to improve mechanisms to collect and recycle LIBs. And technology enterprises can offer digital solutions, from digital twins and passwords to enhanced robotic handling, to overcome challenges hindering LIB recycling.

References

1 https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales

2 https://www.goldmansachs.com/insights/pages/gs-research/batteries-the-greenflation-challenge/report.pdf

3 https://www.sciencedirect.com/science/article/pii/S0959652622032140

4 https://www.globalbattery.org/battery-passport/

5 Batteries: deal on new EU rules for design, production and waste treatment | News | European Parliament (europa.eu).

6 For the US region, see https://www.epa.gov/system/files/documents/2022-03/final_lithium-ion-battery-workshop-public-report_508web.pdf
For European region, see https://www.euwid-recycling.com/news/policy/eu-parliament-votes-for-higher-battery-collection-targets-230322/

7 For Australia's recycling rate, see https://www.csiro.au/en/research/technology-space/energy/energy-in-the-circular-economy/battery-recycling
For recycling rate in the US, see https://www.energy.gov/articles/energy-department-announces-battery-recycling-prize-and-battery-recycling-rd-center
Global estimate: https://www.cas.org/resources/cas-insights/sustainability/lithium-ion-battery-recycling

8 https://www.epa.gov/system/files/documents/2022-03/final_lithium-ion-battery-workshop-public-report_508web.pdf

9 https://www.canarymedia.com/articles/electric-vehicles/ev-battery-recycling-is-costly-these-five-startups-could-change-that

10 https://www.ornl.gov/news/automated-disassembly-line-aims-make-battery-recycling-safer-faster

11 https://northvolt.com/recycling/

12 https://www.energy.gov/sites/default/files/2019/06/f64/bat381_li_2019_o_5.14_3.30pm_jl.pdf

13 https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide?selectedSector=Battery+recycling

14 https://cicenergigune.com/en/blog/major-recycling-processes-battery-industry

15 https://www.sciencedirect.com/science/article/pii/S0959652622032140

16 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8283134/#mmc1 (Figure S6 in the pdf)

17 https://www.sciencedirect.com/science/article/abs/pii/S0925838821001821

18 https://technology.matthey.com/article/65/3/431-452/

19 See for example, https://ascendelements.com/innovation/ and https://investors.li-cycle.com/news/news-details/2022/Li-Cycle-Opens-Lithium-ion-Battery-Recycling-Facility-in-Alabama/default.aspx respectively.

20 https://www.anl.gov/event/processes-for-direct-recycling-of-lithiumion-batteries

21 https://pnecycle.com/company-overview/

22 See for example, https://www.recyclingtoday.com/news/aqua-metals-uses-electricity-to-recover-metals-from-lithium-ion-batteries/ and https://chargedevs.com/features/nth-cycle-says-its-electroextraction-tech-significantly-reduces-transportation-costs-for-li-ion-battery-recycling/

Together, we will connect climate technology innovation with industry to accelerate the solutions of the future.

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