SE

The electric vehicle investment opportunity

Why battery recycling could become inadmissible

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November 23

White Paper

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Green energy markets are expected to grow significantly into the 2030s with some clear opportunities for investment in high growth potential technologies



High Growth Potential Technologies



Investment required for European battery recycling over the next ten years could be in the region of €4.1 billion as battery recycling bridges the expected raw material supply gap

Battery recycling presents a potential investment opportunity of €4.1 billion in Europe, with key players already leading the way with large scale investment

Battery Recycling Opportunity

Potential investment required over 10 years

Example large scale investments

€4.1 billion

€190 million

(Glencore investment in Li-Cycle Holdings)

- Battery recycling is required to bridge the expected raw material supply gap as demand for batteries grows
- SE forecasts that a 60% recycling rate in Europe is required to bridge the raw material supply gap
- Glencore will supply Li-Cycle with all end-of-life lithium-ion batteries
- This is a prime example of vertical integration within the battery supply chain
- Technology maturity: Low High



Potential battery production overcapacity, raw material cost increases and more stringent EOL legislation could lead to a strong investment opportunity in battery recycling

Background and Current State



- Battery cell and pack manufacturing has seen significant global investment
- Battery production capacity could soon outstrip demand, with an increasing number of EV start-ups failing

Situation

• Over-supply may lead to downward pricing pressure squeezing manufacturers margins and investor ROI



- Uncertainty in virgin raw material supply is driving up production costs and increasing market volatility
- EU legislation for recycled battery mass content is becoming increasingly stringent for automakers
- Battery recycling capacity is not well developed and processes are not yet mature



- What capacity of recycling is required to meet EU "Green Deal" legislative targets and market demand?
- How much opportunity is there for increased recycling capacity within the European market?
- Is battery recycling a viable area for investment?

Source: SE | EOL: End-of-life; EV: Electric vehicle; ROI: Return on investment

Fechnology rough of disillusionment trigger

Profit margins for battery and cell manufacturing are decreasing following a strong investment cycle, making it increasingly challenging to realise returns

Automotive Technology Lifecycle

Price expectations vs time



- Peak rate of returns from upstream battery and cell manufacture may have been reached
 - **1** Battery and cell manufacturing has seen strong investment over the last few years
 - 2 It is anticipated that planned global capacity will exceed demand until at least 2030
- **3** OEMs expect battery pack cost decreases, whilst raw material prices increase
- Profit margins in the battery supply chain upstream of OEMs are likely to come under pressure

Backed by major OEM and supplier investment, global battery cell and pack supply could exceed demand in the long term



Battery Cell Production and Investment



Battery cell capacity vs demand (GWh/yr)

• Global battery cell capacity appears to be outstripping demand, with key players dominating the market



Investment value (EUR billion): 2022 snapshot

• OEMs and suppliers have announced aggressive and longterm investment plans to support capacity increase

Over-supply and downward pricing pressure may become pervasive in the battery supply chain

Source: SE, Goldman Sachs | 1) Announced in USD at 1€:1.14\$; 2) Announced in JPY at 1€:130,84 JPY; 3) Announced in CNY at 1€:7.18CNY; 4) Announced in KRW at 1€:1338 KRW; 4) If no plan for 2025 or 2030 was communicated

Battery and cell manufacturer's margins may be squeezed, as the expectation of decreasing pack costs come up against increasing raw material prices

Comparison of Battery Pack Costs and Raw Material Prices^{1,2}

Cost (USD/KWh)



Source: SE, BloombergNEF, Goldman Sachs, US Department of Energy, Automotive Council UK, IEA, S&P Global | 1) Calculated using NMC battery cell chemistry; 2) Cathode active material prices are approximated using Lithium, Nickel, Cobalt and Manganese data

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INDICATIVE

Source: SE, Baker McKenzie, European Commission, Stena Recycling | 1) Automakers take on liability from battery manufacturers with assembly into production vehicle | EOL: End of life; ELV: End-of-life vehicle; EC: European Commission

European Green Deal: Impacts to Vehicle Manufacturers for EOL Battery Disposal



Legislative pressure will increasingly push OEMs¹ to ensure waste battery mass is collected and recycled

Vehicle manufacturers¹ will have to ensure 65% waste battery mass is collected and recycled in 2025 and 70% by 2030; updated ELV legislation may come into force late 2022

come into force late 2022 SE

Production battery scrap will dominate the recycling demand until close to 2030, beyond which EOL vehicles could become the major driving factor

Battery Recycling Demand including EOL, Production Scrap and Warranty Recall¹

20m Equivalent number of batteries requiring recycling _ Battery recycling demand, GWh End-of-life battery: Vehicle batteries requiring disposal from automotive usage Battery recycling Production battery: Scrappage due to issues during manufacture of battery cells 15m Warranty recall: Vehicle batteries requiring replacement during warranty period 10m demand, units 5m om

In the near future, production battery scrap will be the main driver of recycling demand

SE forecasts that lithium ion battery recycling capacity in Europe will be ~37 GWh by 2025 and with current investment, is likely to continue expanding at ~16% CAGR

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Battery Recycling Capacity in Europe





- Today major recycling facilities in Europe include
 - Hydrovolt, Norway
 - Umicore, Belgium
 - REDEX, Germany
 - Valdi, France
 - Sungeel Hitech, Hungary
- It is assumed publicly announced investments and development time of new facilities means that the recycling capacity in Europe will grow at ~16% CAGR over the next decade

Source: SE, WMG, Public domain | CAGR: Compound annual growth rate

Recycling supply surplus will diminish until an inflection point is reached in the late 2020s, leading to under-capacity that could require significant investment to close

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Supply Gap and Required Investment

Battery recycling supply vs demand, GWh

Forecast recycling supply/capacityForecast demand for recycling



- Our battery recycling capacity forecasts suggest that recycling supply will exceed demand in 2023 and could continue to do so over the short term
- Recycling demand grows strongly as electrified powertrains increase their share of vehicle production – decreasing battery scrappage rates do not slow demand
- This is exacerbated as more EOL batteries require disposal, initially a minimal share of the total but potentially becoming the key driver early in the 2030s
- The inflexion point where demand for recycling exceeds supply could be reached in 2028 on the current trajectory, increasing aggressively from 2030 onwards
 - 2030: Deficit of 29GWh
 - 2033: Deficit of 142GWh

Over the next ten years, ~331GWh additional recycling capacity may be needed requiring ~€4.1b investment



Investment in a large scale battery recycling facility could breakeven within 5years, assuming current material prices and operating costs

Battery Recycling Return on Investment Potential for a 50,000t Recycling Facility

Input	Value
Initial investment (€)	45,000,000
Recycling capacity per year (GWh)	8.5
Operating cost (€/kWh)	6.60
Sale price of recycled material (€/kWh)	10.5
Recycling process efficiency	80%

Gross Cashflow



• An investment of €45 million is likely to be required to construct a battery recycling facility capable of processing 8.5 GWh of material per year

EXAMPL

- Assuming a gross profit of €3.90 per kWh, the return on investment period is 3-4 years
- Growing demand for battery recycling in Europe and European Green Deal legislation will require continued expansion of European battery recycling capacity
- Global logistical pressures may also create a trend towards localising battery recycling in Europe
- In conclusion, battery recycling will require future investment in order to meet future demand due to the growth of EOL batteries over the next decade

Entry to the battery recycling ecosystem requires careful consideration but may provide healthy long-term return on investment



? Where, when, how to play in the ecosystem? Location of battery supply, customer, competitive landscape

- ? Market for second life by application, impacting the opportunity for reuse of pack, module and cell
- ? Battery standardisation and the link to the reuse and second life market opportunities
- ? Level of vertical integration: reduced transaction costs, guaranteed supply and/or offtake
- ? Scale and scalability of the operation: matching to future supply and demand
- ? Embedded CO2 of the process, including logistics and energy required
- ? Finance: The age of cheap capital is over, public sector funding and support, industry partnerships/investment
- ? Robustness against Black Swan events, e.g. conflict that significantly increases the cost of EV ownership

SE assists investors in the battery recycling value chain, providing expert technical and market insights to support due diligence activities, identify new growth opportunities and reduce transaction risk

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Giving substance to a new reality

Mobility-focused management consulting

Strategy Engineers is an international management consulting company specialised in mobility

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We share one common purpose: To unlock our clients' potential to navigate uncertainty towards sustainable mobility

Our vision is to make mobility sustainable. Our team follows a clear mission to get there:



Combine commercial and technical perspectives to help our clients make robust strategic decisions towards the transformation to sustainable mobility

Understand our clients' unique situation, as trusted advisors, and deliver innovative, customised, and implementable solutions



Create an environment which allows us to attract, grow, and retain exceptional people, passionate to work with our clients

We are member of the AVL group – together, we create a unique consulting offering to our automotive clients



Leading technology know-how

• World's largest independent engineering service provider for automotive powertrain systems, founded in 1948

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- More than 7,500 engineers at 45 engineering centres world wide
- 1st hand knowledge from global OEM R&D and SOP projects

Our end-to-end capabilities

Turnaround

Screening

Acquisition

Divestment

Growth

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- SE supports investors through all phases of the value creation cycle from screening through to divestment
- Areas of expertise
 - Screening: Finding the right targets in the market place
 - Acquisition: Completing due diligence to support evaluation
 - Turnaround: Managing organisational transformation
 - Growth: Driving growth of the business
 - Divestment: Planning and prioritising exit strategies
- Our experience with the investment community allows us to provide actionable insights to drive successful decision in complex and evolving markets

We offer end-to-end investor support for all investment and acquisition requirements

Are you ready for the next step?



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