

October 2022

**BATTERY RECYCLING -
CIRCULAR ECONOMY
ON THE EXAMPLE OF E-MOBILITY**

BATTERY RECYCLING IS MOVING INTO THE SPOTLIGHT

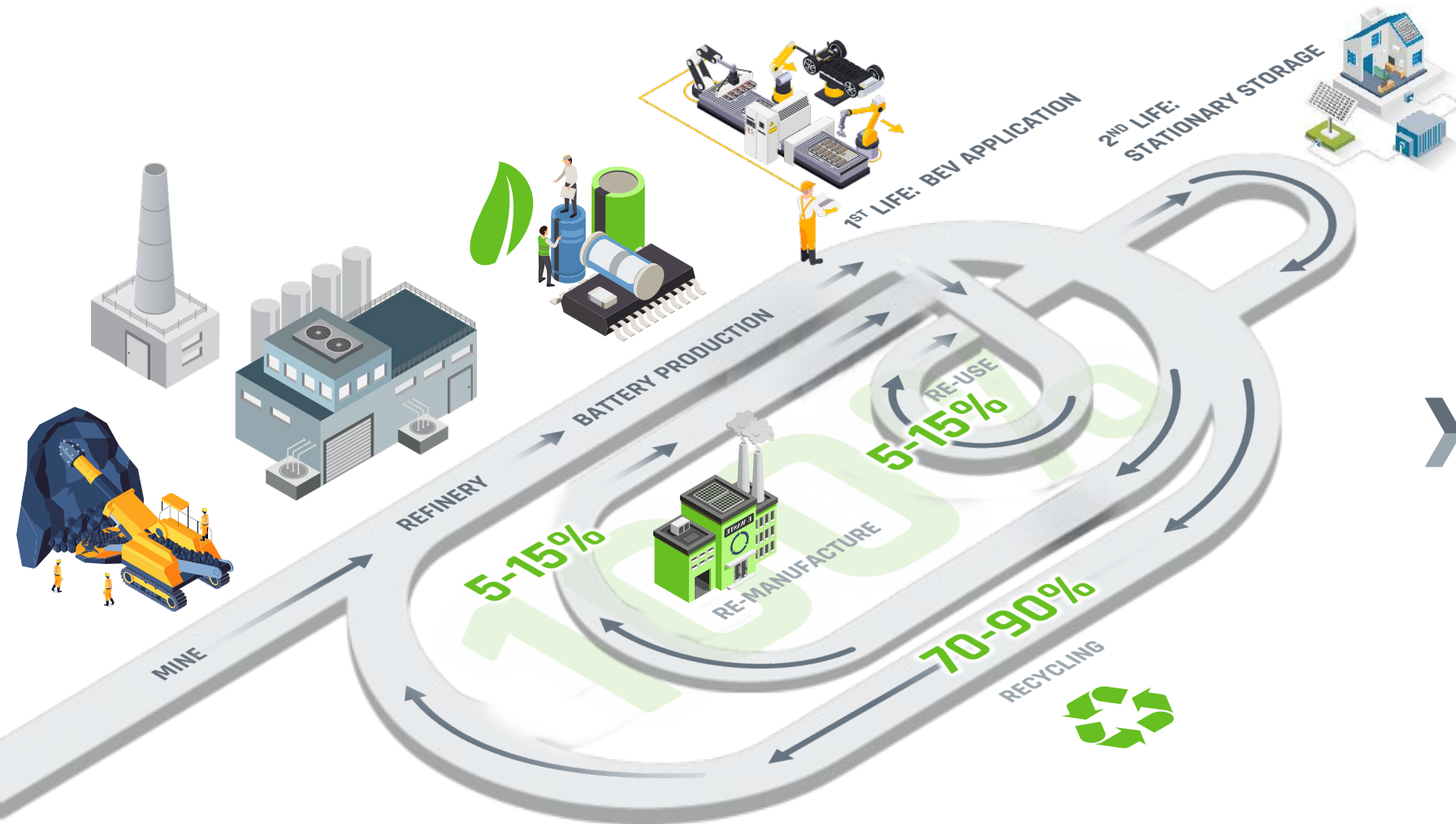
Battery recycling will gain enormous relevance by 2040 – successful management of bottlenecks in material supply, building regional capacities, and establishing technical standards will be crucial

KEY MESSAGES

- 1 The amount of recycling is growing rapidly.** Between 2030 and 2040, a nearly 15-fold increase in recycling worldwide is to be expected
- 2 There is a long-term need for investments.** By 2040, >€35 billion will have to be invested in plants and machinery to meet Europe's recycling needs. By 2030, however, the announced recycling capacities exceed the demand
- 3 Bottlenecks are to be expected.** While a global bottleneck will be averted by building up capacity, regional/local bottlenecks are to be expected due to technological diversity. A footprint strategy is necessary

THE RE-X CYCLE OF BATTERY CELLS

The battery cycle will be significantly driven by recycling – only a fraction of 5-15% will find its way into 2nd life applications after the use inside a BEV



CORE STATEMENTS

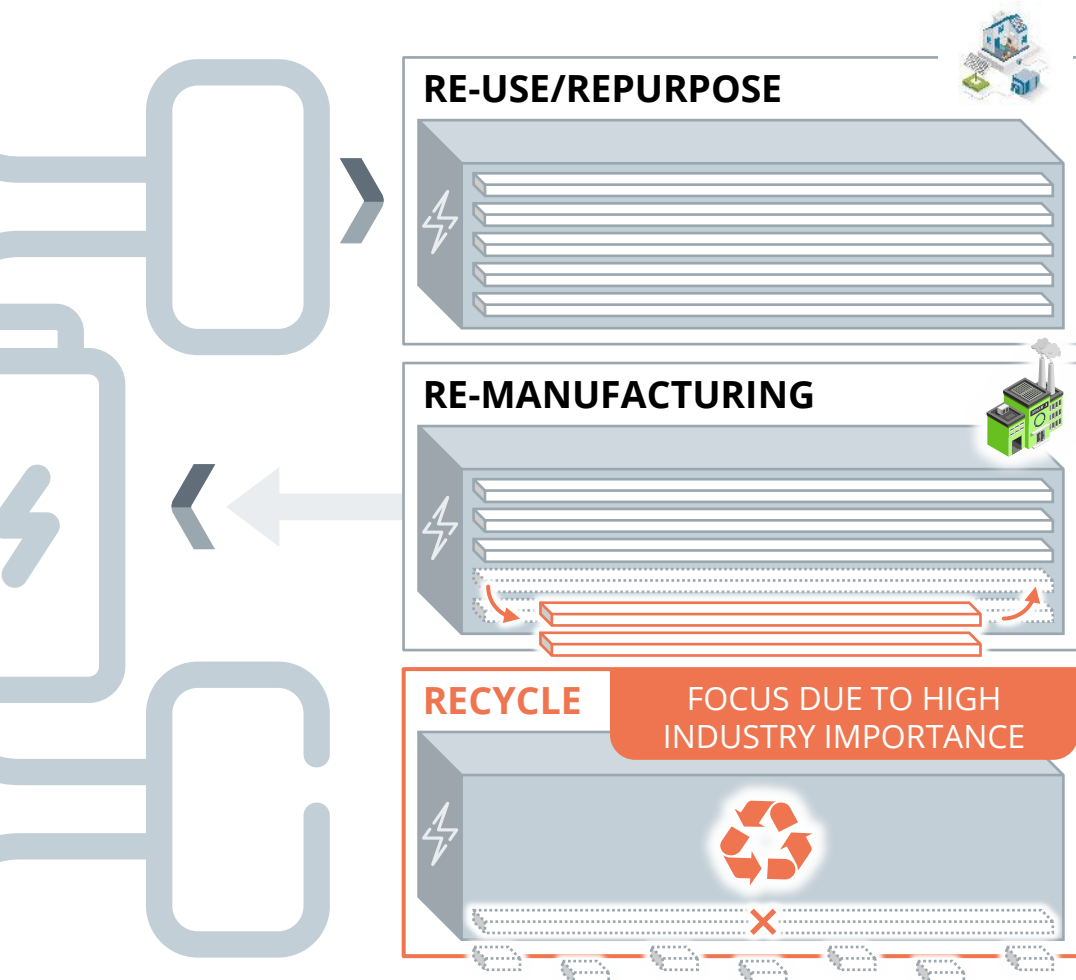
- » Only a fraction of **5-15%** will find its way into **2nd life applications** after the use inside a BEV
- » Further **5-15%** of the cells are expected to be re-manufactured for **reuse in battery vehicles** (e.g. after-market)
- » The majority of **70-90%** will be **recycled** and the raw materials are returned to the material cycle via battery cell manufacturers and other industry players
- » The 2nd life application is usually always followed by recycling

Source: Berylls Strategy Advisors, PEM Motion BEV: Battery electric vehicle



EXAMPLES OF RE-X APPLICATIONS

The different use cases for Re-X applications are depending on durability and battery condition after the 1st life – various existing and new fields of application are being developed



APPLICATION AFTER 1ST LIFE („State of Health“)



- » Disassembly down to module level
- » Exchange against as-new BMS

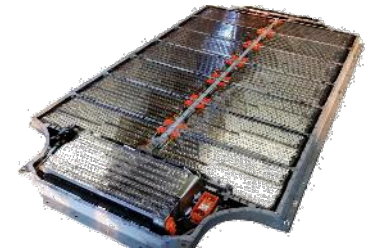
EXAMPLES

BMW i3 storage facility Leipzig plant



- » Disassembly down to cell level
- » Replacement of defective cells
- » Reassembly

Re-manufactured service battery pack Tesla



RECYCLE **FOCUS DUE TO HIGH INDUSTRY IMPORTANCE**



- » Complete dismantling, separation to AL, CU, PP/PE & cell
- » Separations by Hydro & Pyro processes

Recycling joint venture between Northvolt & Hydrovolt



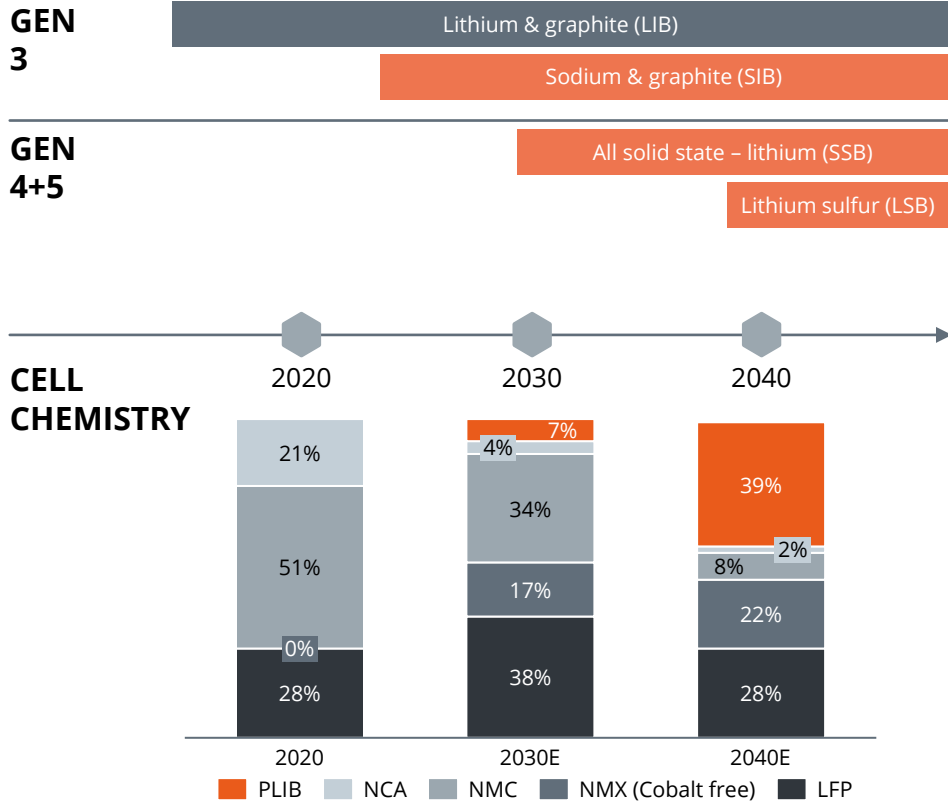
Source: Berylls Strategy Advisors



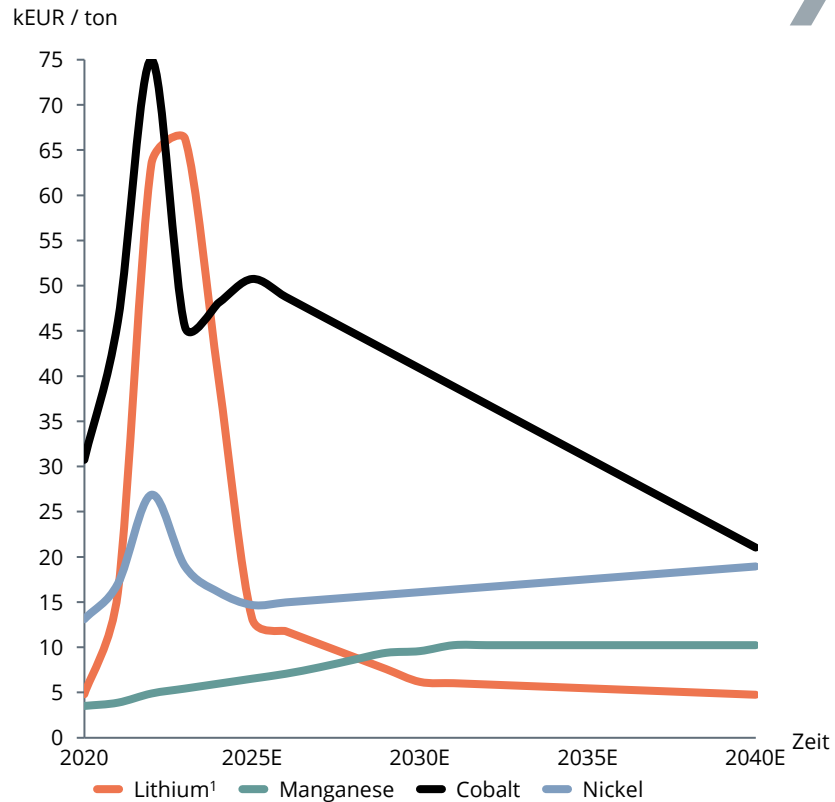
RAW MATERIAL PRICE DEVELOPMENT AND IMPACT

The shift of cell chemistry determines the demand for relevant raw materials – both the demand and external factors determine price developments of material costs

NEW BATTERY TECHNOLOGIES AND THE UNDERLYING CELL CHEMISTRIES



FORECAST OF SELECTED RAW MATERIAL PRICES



CORE MESSAGES

- » New battery technologies and the development of new cell chemistries determine the **battery roadmap**
- » At the same time, the **development of new cell chemistries** also determines the **demand for relevant raw materials**
- » The development of raw material prices is subject to **many factors**, which are in many cases **unpredictable**
- » This leads to a **high volatility** of raw material prices, which can be seen in the cases of lithium and cobalt

PLIB: Post-Lithium-ion battery, NCA: Lithium Nickel Cobalt Aluminum Oxide, NMC: Lithium Nickel Manganese Cobalt Oxide, NMX: Nickel-Manganese-X Oxide, LFP: Lithium Iron Phosphate
Source: Berylls Strategy Advisors; capital.com; German Lithium Participation; DIW Wochenbericht; Tetra Tech Canada Inc.; globenewswire.com; Bloomberg; Trading Economics

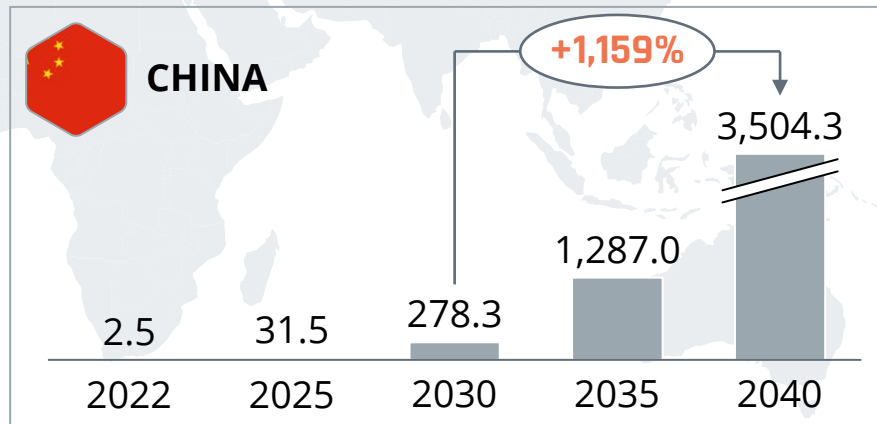
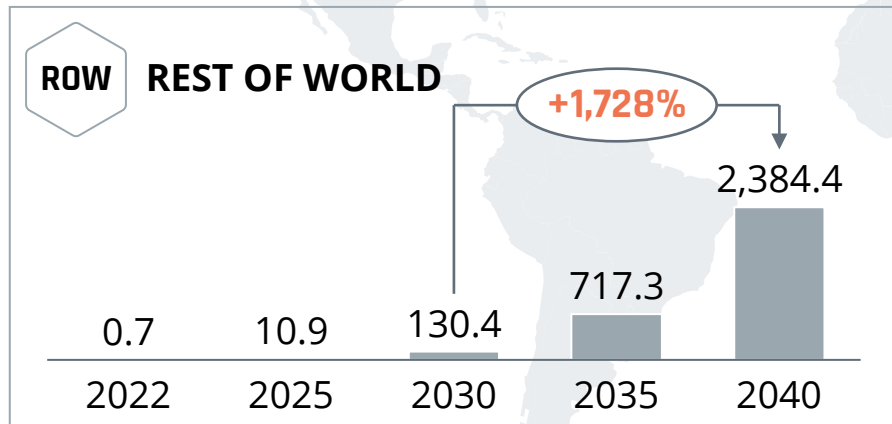
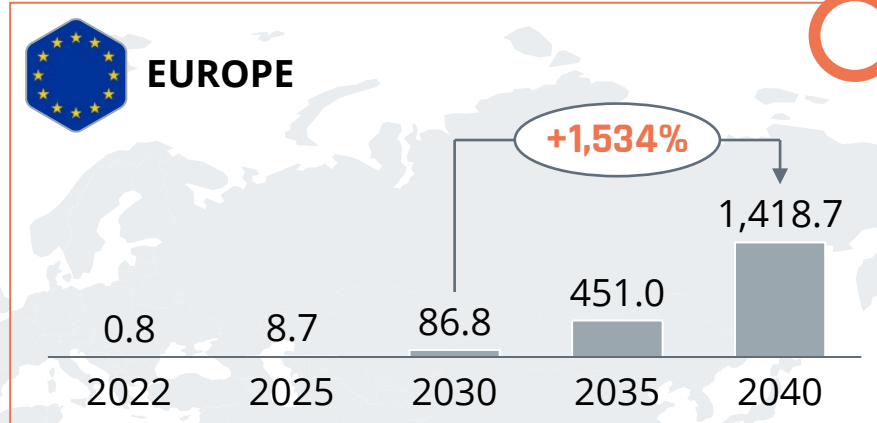
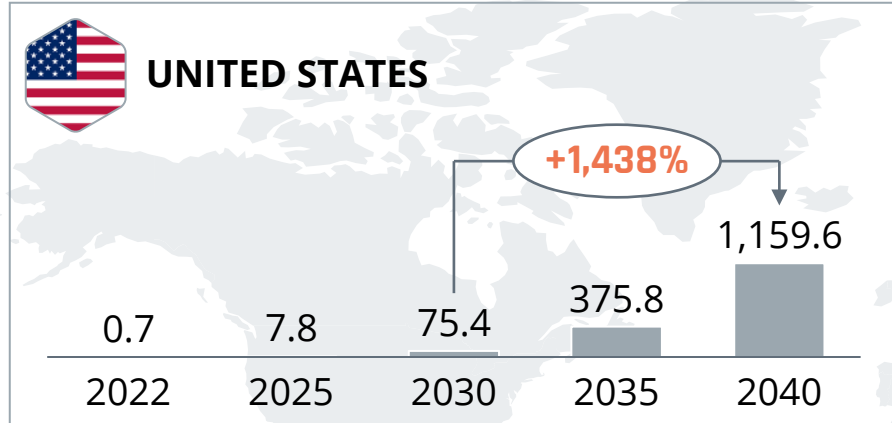
¹ Price Lithium Carbonate



BATTERY RECYCLING VOLUMES

All regions will record significant volume growth – the largest quantities of materials for recycling will be accumulated in China

OVERVIEW BATTERY RECYCLING QUANTITY PER REGION (IN K TON)



CORE MESSAGES

- » Between 2030 and 2040, global **recycling volumes** are expected to **increase almost 15-fold**
- » While the **largest volume is found in China**, significant increases are seen in Europe and the rest of the world
- » Due to the regional dispersion, **logistics costs** are a major issue

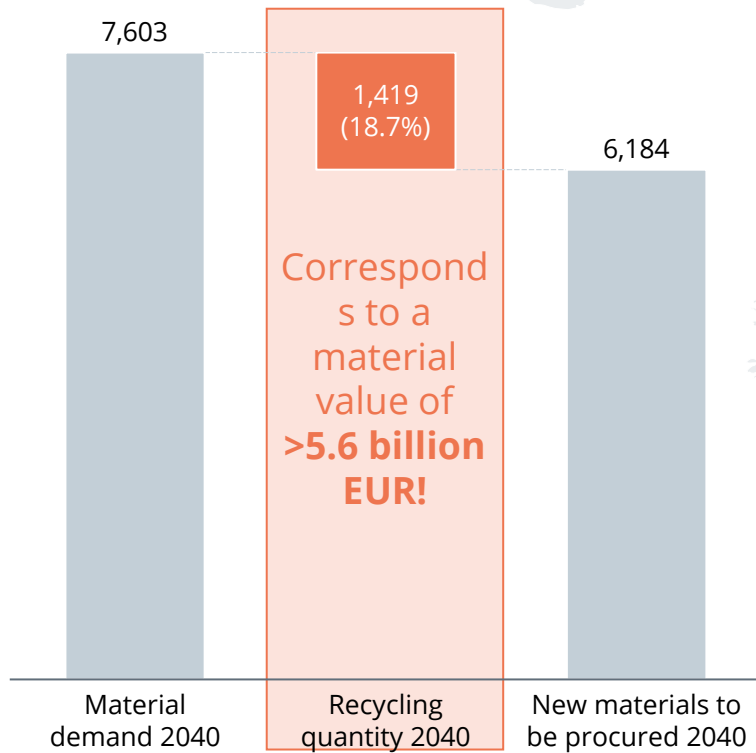
Source: Berylls Strategy Advisors



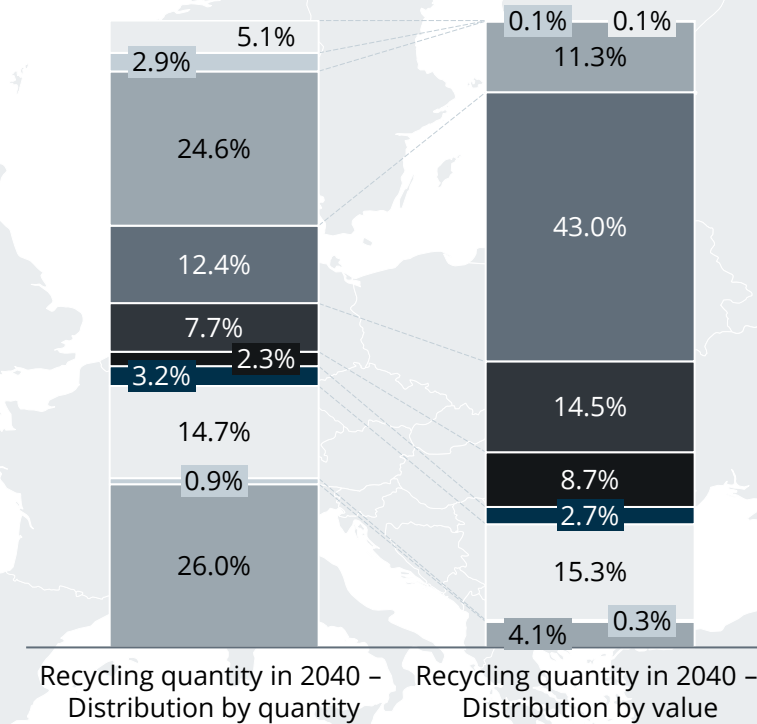
VALUE OF RECYCLING MATERIALS

In 2040, recycling materials worth >€5.6 billion will be generated – aluminum and graphite are the two largest material groups by volume, but the total value of recycled material is dominated by nickel

MATERIAL DEMAND IN 2040 VS. RECYCLING QUANTITY IN 2040 [IN KT]



DISTRIBUTION OF MATERIAL IN QUANTITY VS. DISTRIBUTION OF MATERIAL IN VALUE¹⁾



CORE MESSAGES

- » In 2040, approx. **18.7% of battery material** requirements can be covered by recycled materials
- » In particular, the demand for **phosphate, copper and graphite** can be fully covered by recycled materials
- » The value of recycled materials is **>€5.6 billion**, with **nickel** accounting for over EUR 2 billion.

Iron Phosphate Aluminum Nickel Manganese Kobalt Lithium Copper PE Graphite

1) Limited to materials specified in the legend

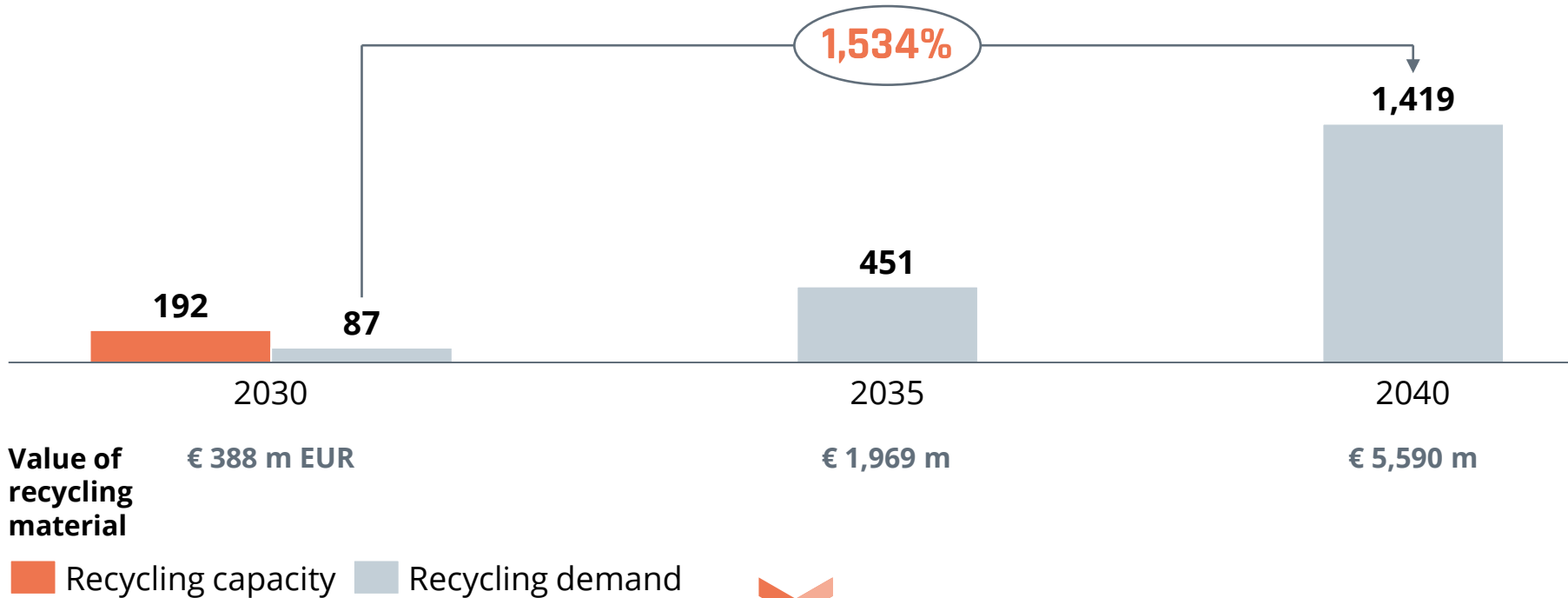
Source: Berylls Strategy Advisors



RECYCLING CAPACITIES

Recycling capacities must also cover future needs – in Europe, recycling demand will increase 16-fold from 2030 to 2040, requiring investments of >€35 billion

OVERVIEW OF RECYCLING CAPACITIES VS. RECYCLING DEMAND (IN KT)



CAPITAL EXPENDITURES AND COSTS OF TOTAL >€35 BN, JUST IN EUROPE!

CORE MESSAGES

- » **Recycling capacity** installed by 2030 is **not sufficient** to meet demand in 2040 – an increase of 1,534% needed by 2040
- » While there have been numerous **announcements** about capacity building, these **have not yet materialized**
- » Logistics costs correspond to approx. 30% of OpEx and thus strengthen **local recycling business models**

Source: Berylls Strategy Advisors



berylls

DR. ALEXANDER TIMMER

Focus: Supplier & E-Mobility

Partner

alexander.timmer@berylls.com

Phone: +49 173 2802870



PETER TRÖGEL

Focus: Sustainability

Associate Partner

peter.troegel@berylls.com

Phone: +43 664 5152915



WILLY LU WANG

Focus: E-mobility & China

Associate Partner

willy.wang@berylls.com

Phone: +49 175 1400361

