EV battery recycling

UK’s biggest opportunity from battery waste is to feed its cathode manufacturing industry

Insights by Technology Trends, APC UK
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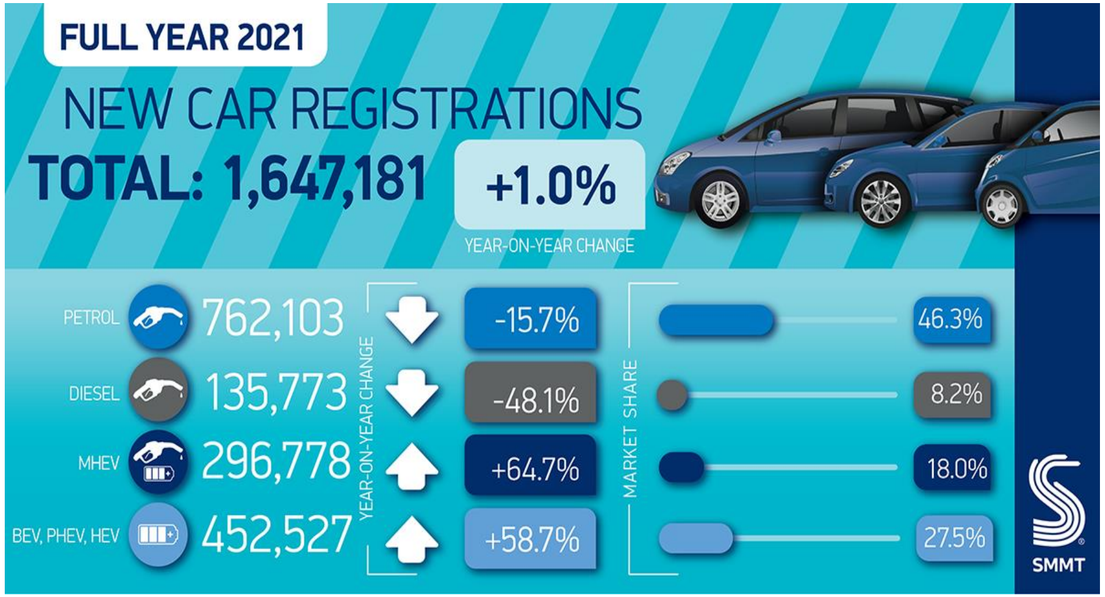
ADVANCED PROPULSION CENTRE UK | Accelerating Progress

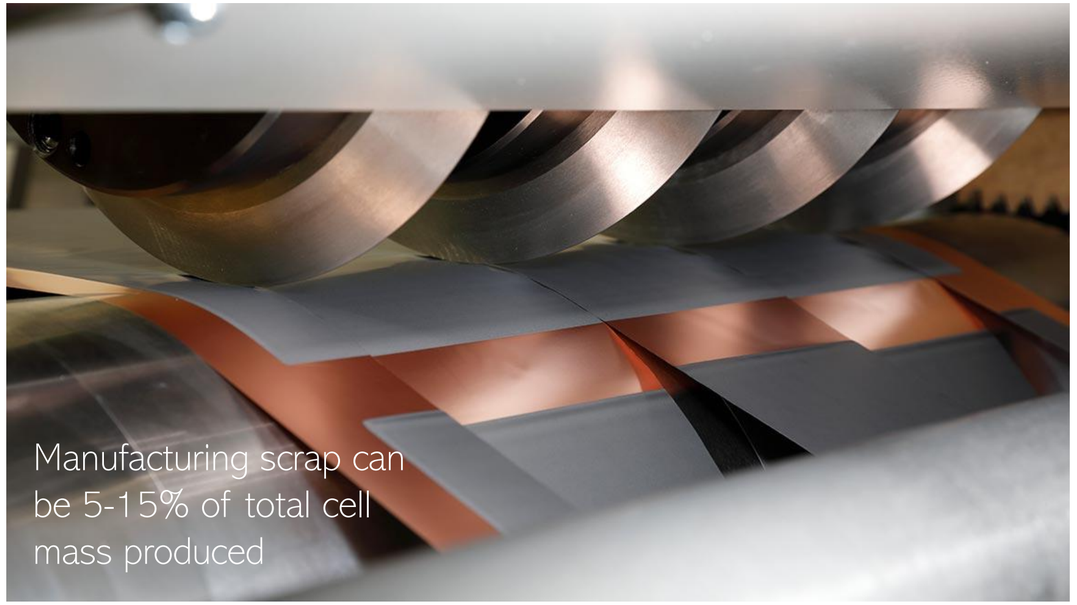
Setting the scene for EV battery waste in the UK

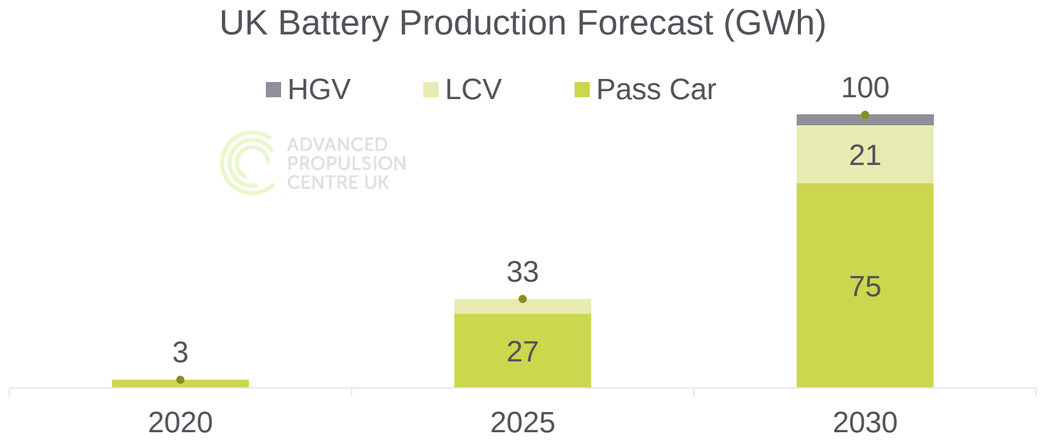
Growing electric vehicle sales = future end-of-life batteries



190,727 BEVs were sold in the UK during 2021. That's a 12% market share with sales forecast to double in 2022 and reaching 80% by 2030.

Battery production → generates manufacturing scrap





Policy is moving in the right direction:

Summary of proposed EU EV battery regulation introduction timeline

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Regulation approval planned for early 2022

1 July 2024, EV batteries will require a **carbon footprint declaration**

31st Dec 2025, **65% recycling efficiency, recovering** 90% Co, 90% Ni, 35% Li and 90% Cu

1 Jan 2026, carbon footprint **performance class requirements**

1 July 2027, **maximum life cycle carbon footprint** thresholds

31st Dec 2030, **70% recycling efficiency, recovering** 95% Co, 95% Ni, 70% Li and 95% Cu

2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2035

1 Jan 2023, start of **QR labelling,** "separate collection" symbol

1 Jan 2026, online electronically readable **"battery passport"** with SoH, life, performance & durability information

1 Jan 2027, **full labelling** of chemistry, recycled content, life, safety, collection …

1 Jan 2027, EV batteries required to **declare content** of recycled Co, Li and Ni

1 Jan 2030, **minimum levels** of recycled content (12% cobalt, 4% lithium and 4% nickel).

1 Jan 2035, **minimum levels** of recycled content (20% cobalt, 10% lithium and 12% nickel).

Colour code:

- **Recovery efficiency**
- **Carbon footprint**
- **Labelling & digital**
- **Recycled content**

EU Battery Directive Proposal 2020

End of life vehicle (ELV) directive and EU battery regulation proposal brings a new economic stream of activities for second life and battery recycling

Current ELV Directive

	As of 1 January 2006	As of 1 January 2015
Reuse & Recycling	80%	85%
Reuse & Recovery	85%	95%

Vehicle collection → Dismantling and airbag deployment → Fluid removal → Cables and circuit board removal → Triage and value assessment → Streaming materials / segregation → Shredding / metals recovery

- Steel
- Aluminium
- Copper

EU Battery Regulation (NEW)

EV batteries

Battery removal → Safe discharging → Electronics, cables & cooling → Module separation & shredding → Electrolyte evaporation / drying → Fine shredding → Material separation

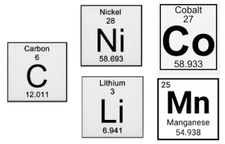
- Metal foils (Cu, Al)
- Plastics
- Black mass

2nd life / repurposed

Materials Supply

Recycled recovered metals have a 10-25% lower carbon footprint than virgin materials. Expected be the first line of supply chain into CAM and p-CAM production and deliver OEM ESG / carbon goals.

CAM supply chain



Material recovery ← Hydrometallurgy / Leaching

Artifact created by the APC Technology Trends team

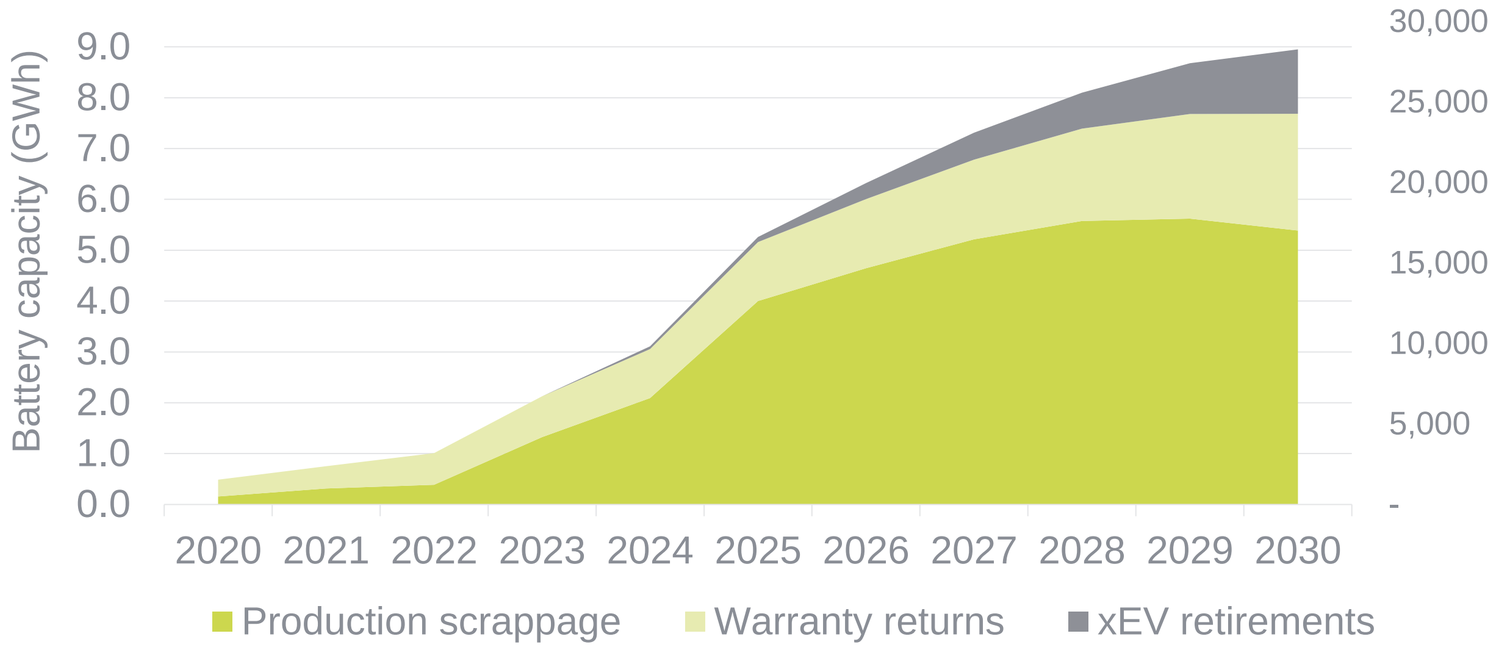
The UK will be generating 28,000 tonnes of reusable battery cell waste by 2030

Cell production scrap | **Warranty recalls** | **EV retirements**

Recycling & material recovery

Second life & repurposing

UK battery capacity available for recycling and reuse



EV retirements (BEV and PHEV based on UK sales)

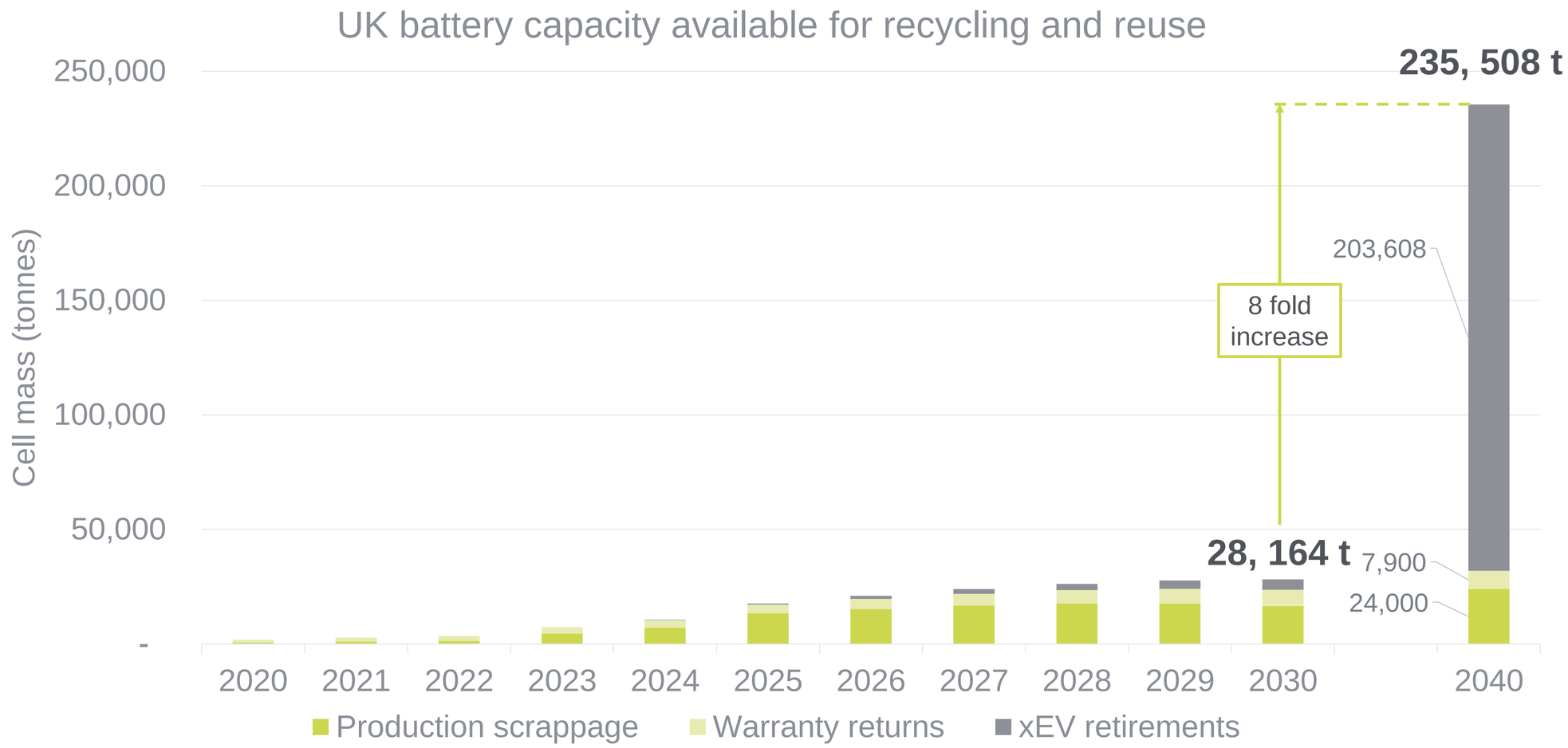
Warranty returns (based on recalls in 2020)

Production scrap (based on industry average of 4-11%)

Sufficient for 2-3 recycling plants from 2025

Notes: Analysis based on BEV and PHEV sales in the UK from 2012, warranty recalls based on 2020 BNEF data and cell production forecasts published by the APC

By 2040, the dominant feedstock for battery materials will be from EoL vehicle retirements. A total of 235,000 tonnes will be available for recycling and reuse by 2040, almost 8 times that in 2030.



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EV batteries end-of-life pathways will be determined by its state-of-health and economic value

Vehicle retirement → Battery triage

Battery triage:
- >80% SoH → Second life
  - Stationary storage
  - New e-mobility products
  - Low power e-mobility
- <80% SoH → Recycle

Raw material recovery (Li, Co, Ni, Mn & C) [Depends on cell chemistry]

End of life

Residual waste material

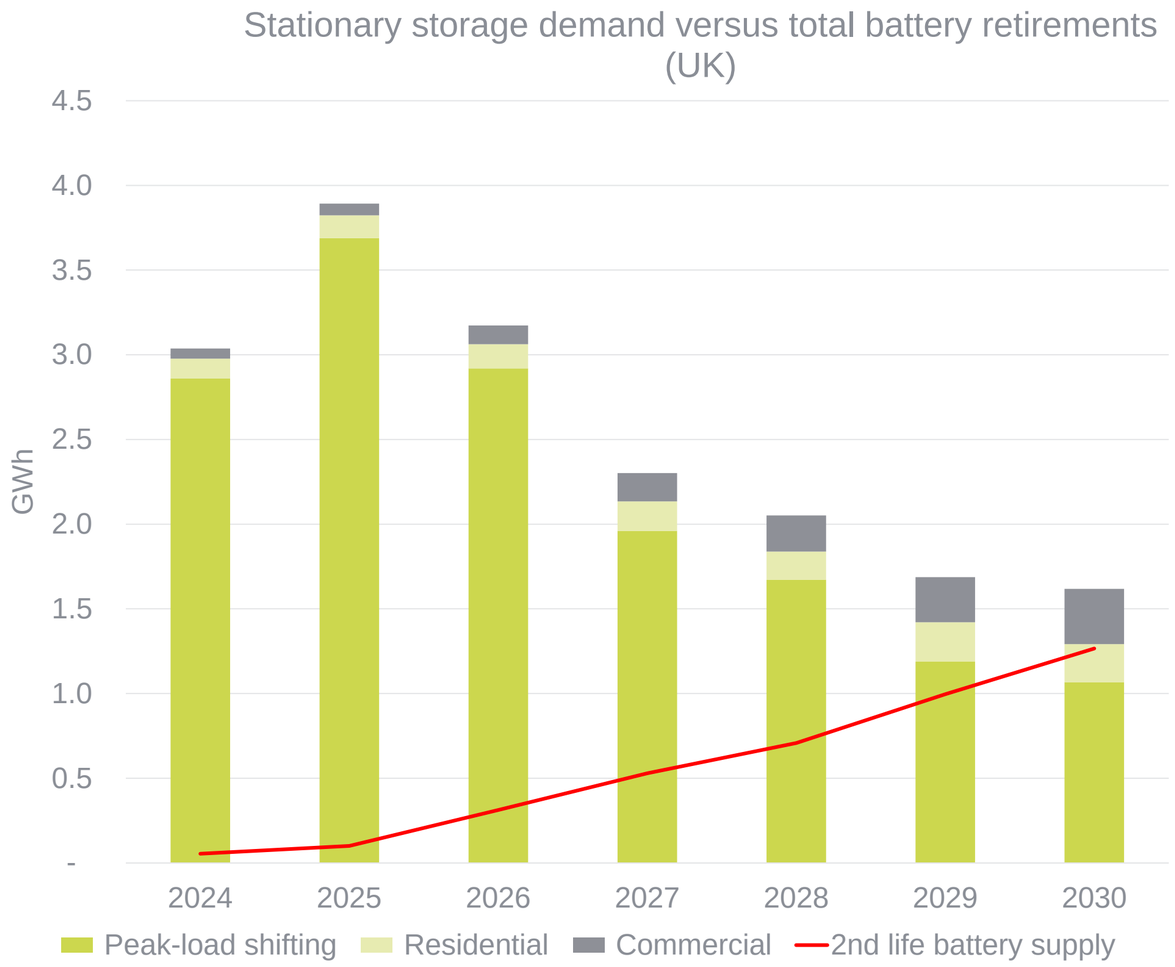
Battery EU Directive:
70% recycling rates by 2035 with the rest needing disposal

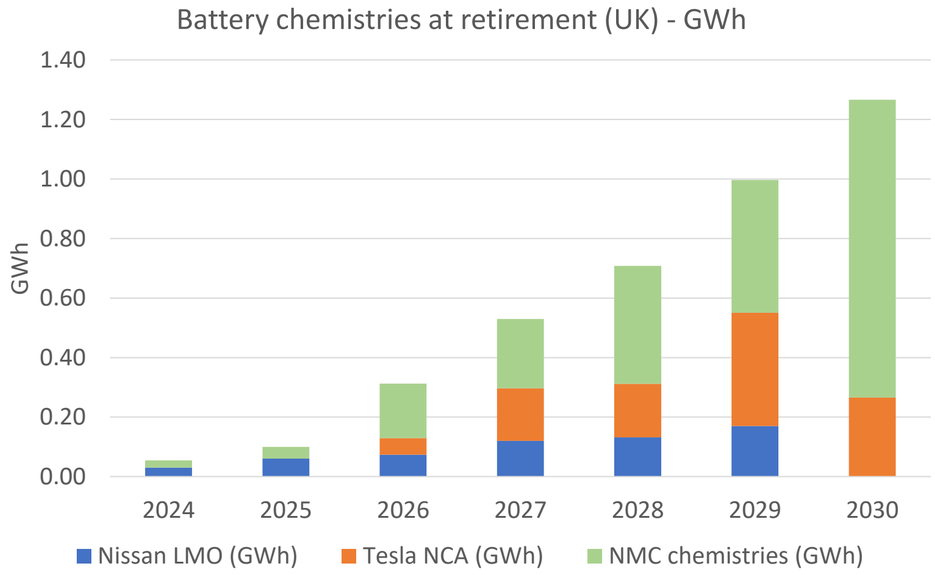
Factors determining route forward
- State-of-health (SoH)
- Residual economic value (cell chemistry)
- Raw material market supply & pricing
- Min recycled content in EU Regulation

Artifact created by the APC Technology Trends team

Second life use will be limited as the stationary storage market is moving forward quicker than EoL supplies

Demand for battery storage applications is far greater than the supply from EV retirements. Not all batteries will be suitable for re-purposing.





Retired batteries cannot meet the demands of stationary storage due to limited supply & poor residual warranties. Likely to be a niche market for 2nd life, with specific chemistries more attractive.

Analysis completed by the APC Technology Trends team. Data based on battery retirements in the UK from BEV and PHEV sales and energy storage capacity forecasts from BNEF.

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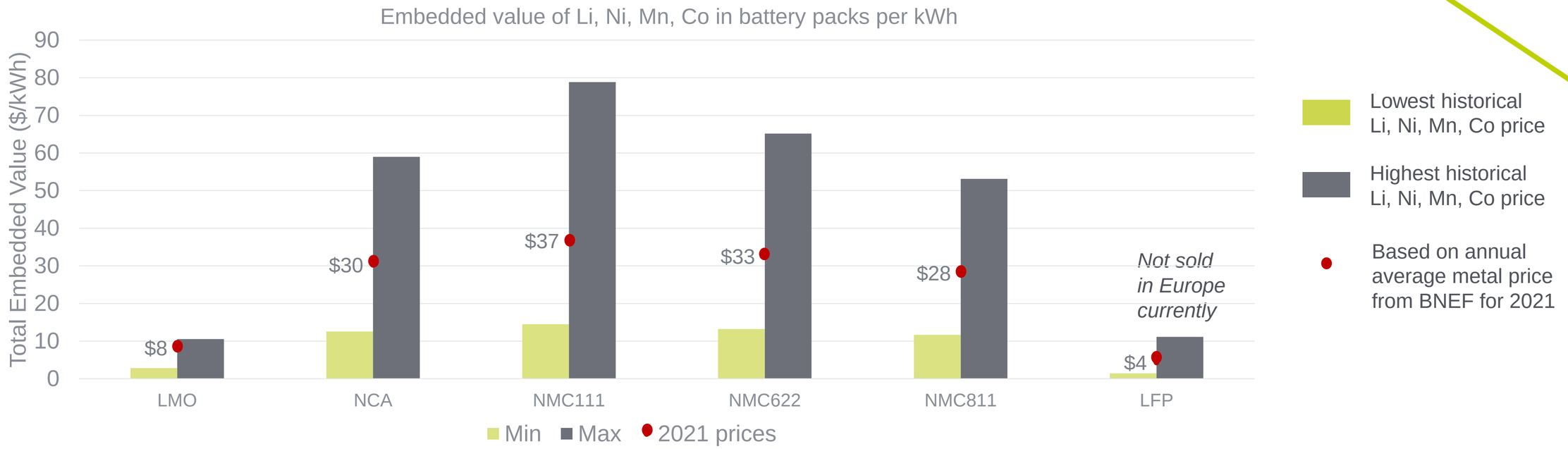
Embedded raw material value in batteries will dominate the future decisions on retirements

Battery pack embedded value. The value of Li, Ni, Mn and Co in batteries varies by chemistry, with NMC111 containing the highest at $79/kWh and LMO lowest at $10/kWh



Example of vehicle models:

Nissan Leaf

Tesla Model 3

BMW i3

Chevy Bolt

E.g.: New Nissan Leaf BMW i3

New models

E.g.: New Tesla 3

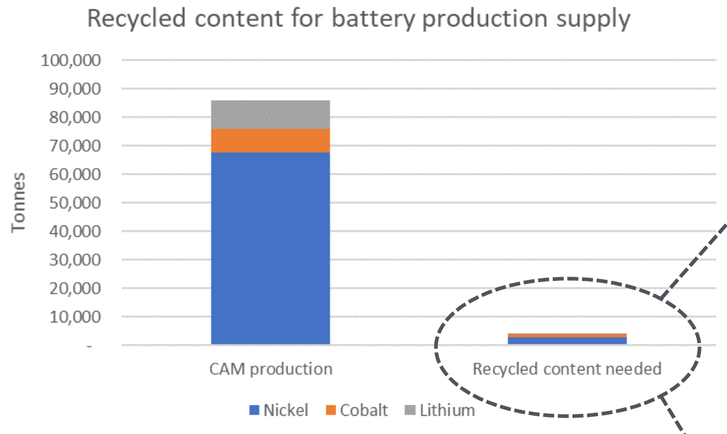
From 2022

Battery Chemistry	LMO	NCA	NMC111	NMC622	NMC811	LFP
Pack Size (kWh)	24 / 30 / 40	54 / 62 / 75 / 82	22 / 33 / 42	60	60	60

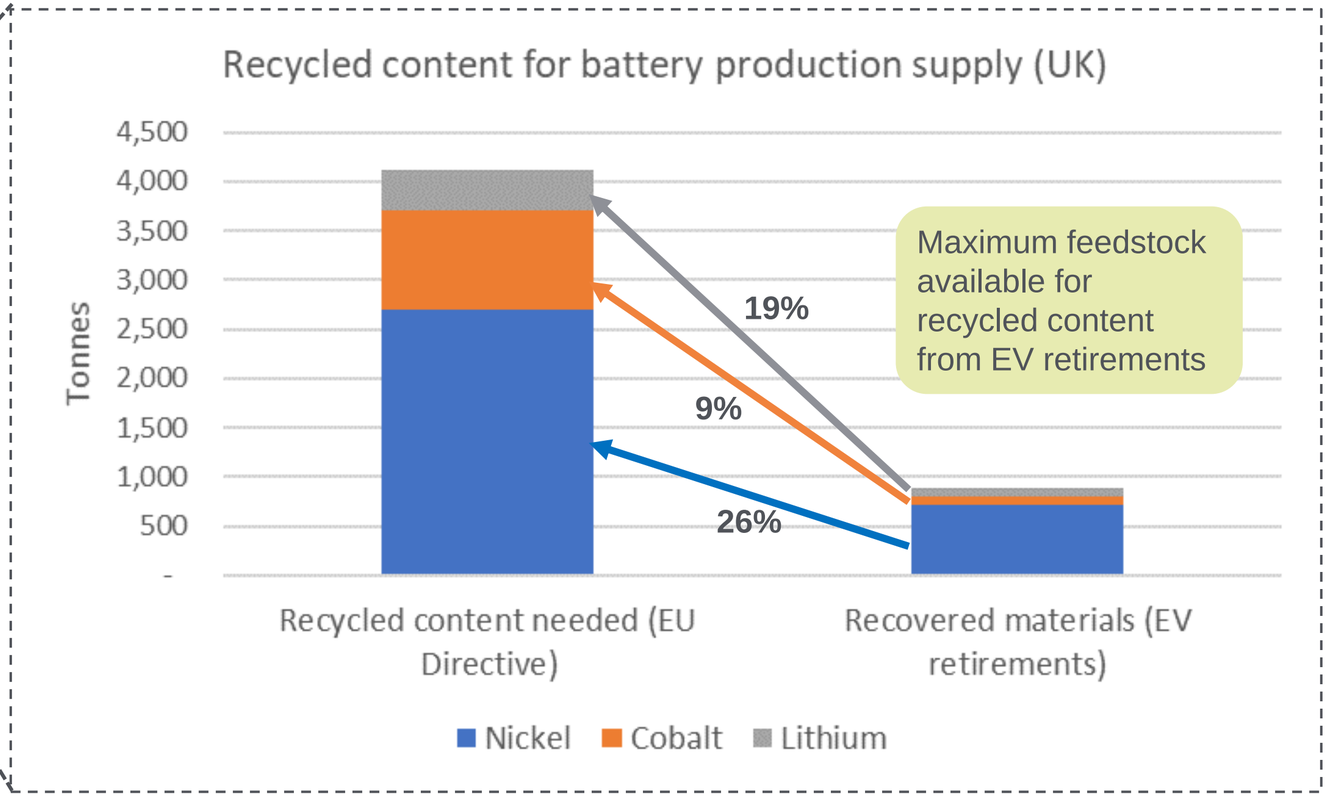
Estimates based on most common battery chemistries sold in the UK
The maximum and minimum material prices for Li, Ni, Co and Mn are taken from BNEF historical data and annualised average over 12 months for 2021
This analysis has been completed by the APC Technology Trends team

The recycled content required for new cell production cannot be met by EV battery retirements in the UK. A phase shift between production and old batteries retiring will create a shortage in supply for 2030.

The UK will not have a sufficient supply of retired EVs to supply the minimum recycled content targets in 2030

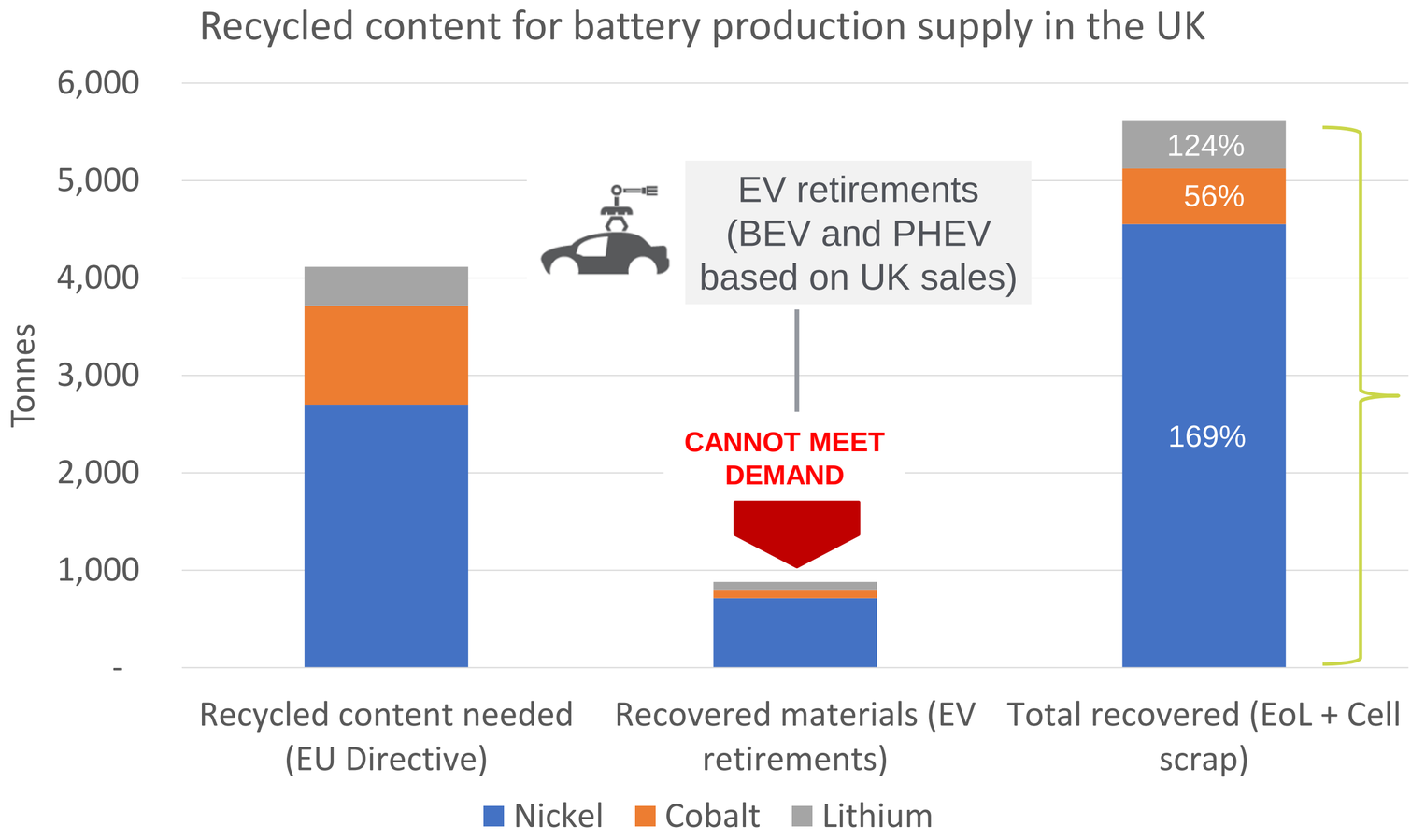


A maximum of 26% Nickel, 9% Cobalt and 19% Lithium can been extracted from used batteries against the total content required by the EU Battery Regulation for new cell production in 2030.



NOTES:
Based on battery recovery rates and minimum recycled content in batteries stated in the EU Battery Directive and UK cell production forecasts published by the APC (90GWh in 2030).
2030 recycled content: 4% Ni, 12% Co, 4% Li @ recovery rates of 95% Ni, 95% Co, 70% Li

Extending the recovery of critical materials to include cell production scrap, has the opportunity to meet Nickel and Lithium demand but not Cobalt in 2030



Adding production scrap can fulfil the cell production demand for Ni and Li.

Cobalt may be supplied from recycled phones.

EV retirements (BEV and PHEV based on UK sales)

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Production scrap (based on industry average of 4-11%)

1 tonne of Cobalt is approximately 90,000 iPhones (3227 mAh. 3.84V) ~11-16 g / iPhone

500 tonnes Co → 45 million iPhones

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Key takeaways

Recovering battery materials is critical to making new batteries with a **lower carbon footprint** than mined materials. Battery producers can build **viable circular eco-systems,** harness the manufacturing scrap and build new cells. The EU Battery Regulation is an important framework for this.

Batteries of the future **need large quantities of Nickel and Lithium** to supply the growing electric vehicle (EV) market.

What does this all mean for the UK?

- Re-processing scrap from the scale up of UK gigafactories could generate up to 20,000 tonnes of cathode active materials by 2030 that can be reused, capable of making **7GWh of new batteries**, equivalent to **100,000 cars**.
- **By 2040** recycled battery waste from end-of-life vehicles and manufacturing waste could supply enough cathode materials to produce **60GWh** of new batteries.
- **Cathode active materials make up ~50% of the total cell cost**, containing critical metals that can be harvested from production scrap and retired batteries. Secure your materials supply chain!
- Cathode active material suppliers are well placed to **deliver battery quality materials from waste** by working closely with recyclers and harnessing material recovery technologies like hydrometallurgy and direct recycling.
- High-nickel chemistry have **enough embedded recoverable material value** to make this a viable business model.

The UK has rich opportunities to build a sustainable battery materials supply chain

- Circular raw material supply chains
- Virtuous management of battery waste
- New economic opportunities for green technology

Thanks for listening and we look forward to working with you!

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