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Circular Economy Perspectives for the Management of Batteries Used in Electric Vehicles

Nikolas Hill

Associate Director and the Knowledge Leader – Ricardo Energy & Environment

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Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles (CEBEV)

Nikolas Hill

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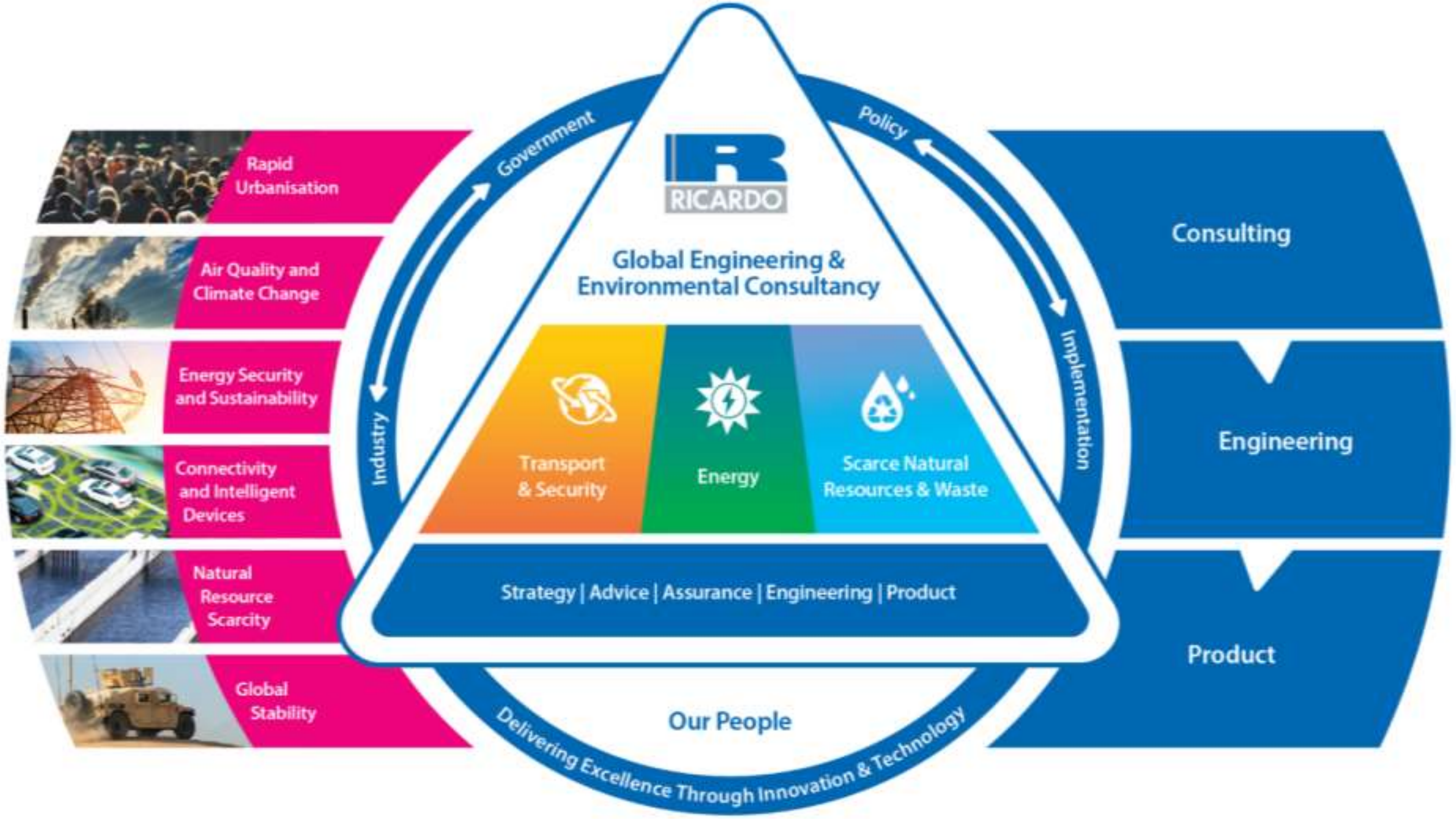


The EC DG JRC project *"Circular Economy Perspectives for the Management of Batteries used in Electric Vehicles"* (CEBEV) involved a literature review and a range of stakeholder consultation activities

Start Jan '18 — **End Apr '19**

Research Topics

Focus: **1. Technology aspects**

2. Battery lifecycle impacts

3. EV deploy-ment impacts

4. EU SWOT analysis

5. Circular Economy aspects

6. Policy options

Briefer summary: 2, 3, 6

Project scoping

Literature review

- Development of search criteria and rapid evidence assessment (REA) framework
- Identification, review and synthesis of evidence; identification of key gaps

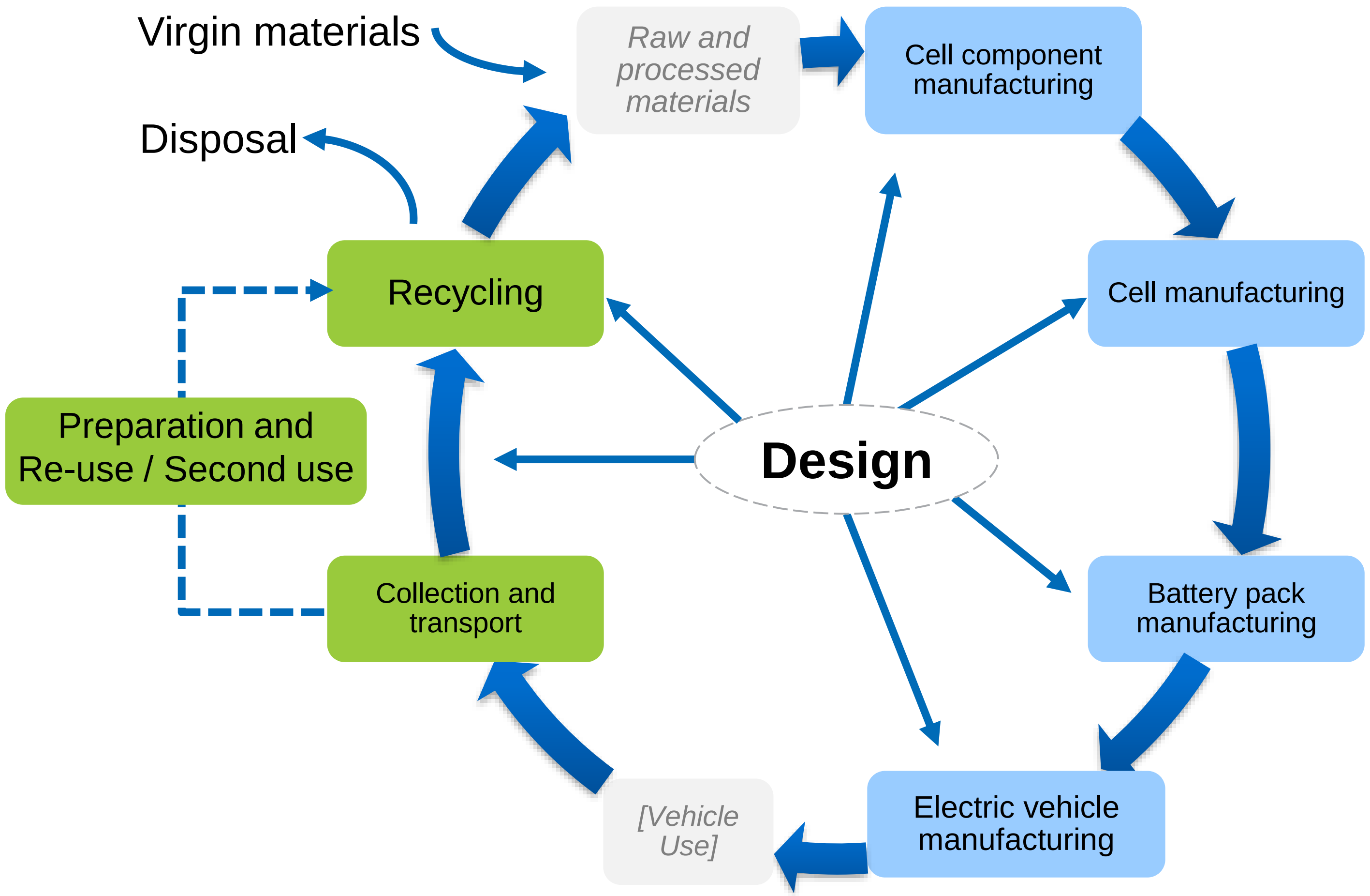
Stakeholder engagement

- Identification of stakeholders
- Targeted interviews
- Stakeholder workshop

Project reporting

The EC DG JRC project scope was to consider circular economy implications across EV battery value chain for Europe, to inform policy decisions

- Objective was to look across the value chain with the main focus / scope of the study being on:
  - Battery manufacturing and on the fate of the battery after it's first application in a vehicle
  - Li-ion traction batteries for xEV (BEV, PHEV / REEV, FCEV) and also HEV
  - Medium term (2020-2030) but consider longer term high-level implications (e.g. new battery chemistries)
  - Compare EU : ROW



- Publication of final version of the report by JRC still pending

Notes: The 'Raw and processed materials' and Vehicle use' stages are not directly addressed in this study. Re-use or Second use / repurposing are optional additional steps that may be applied where feasible; whenever batteries become waste (e.g. where further reuse or repurposing is not feasible) they should be recycled.

Whilst the front end of the Li-ion traction battery value chain is relatively well characterised/understood it is less so for the End-of-Life (EoL) fate

Cell materials (Value: 15%) → **Cell component production (Value: 15%)** → **Battery cell production (Value: 40%)** → **Battery pack production (Value: 30%)**

- Breakdown of the battery manufacturing value chain is relatively well understood (though relative values/impacts are shifting due to changes in battery technology and scale/deployment)
- Analysis of development battery chemistry/manufacturing improvements and lifecycle analysis show improvements linked to economic and performance drivers (e.g. energy density, lifetime, safety, etc.) should also reduce the largest environmental impacts from production in most cases

EoL EV / Battery dismantling (Value: -a%) → **Battery re-use (Value: b%)** → **Second-use / re-purposing (Value: c%)** → **Recycling (Value: ± d%)**

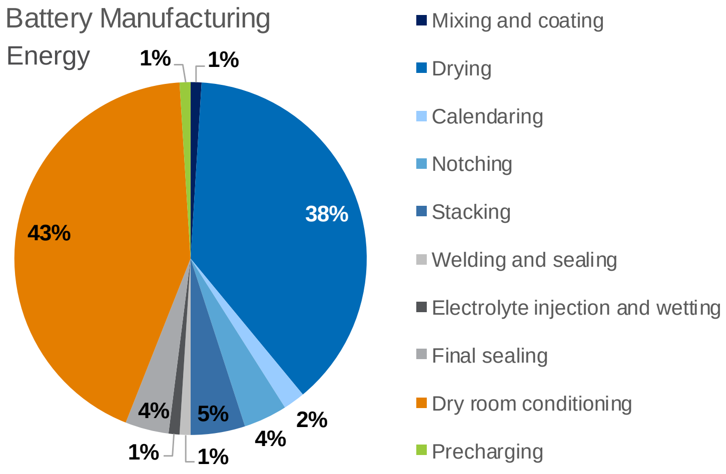
- In comparison, the value chain / economic case (and impacts) for the end of the first life of the battery in an electric vehicle is less well understood, with a range of uncertainties and data gaps
  - More research is still needed to better understand this in particular

Battery manufacturing is complex and highly energy intensive; future cost and performance improvements are likely to also reduce environmental impact

Cell production process		Battery pack process	
Electrode production	**Battery cell production**	**Battery module production**	**Battery pack production**
1.Slurry mixing dispersion 2.Coating and drying 3.Calendering*** (compressing) 4.Drying 5.Slitting and punching (cutting /notching)	1.Assembly (stacking/winding*, packaging, temporary sealing) 2.Electrolyte filling and permanent sealing 3.Formation/aging 4.Cell grading /testing 5.Packaging	i. Module assembly ii. Contacting iii. BMS** iv. Thermal management v. Functional test	i. Pack assembly ii. BMS** iii. Charging / flashing iv. Final assembly test

Source: (Siemens, 2018), (Electropaedia, 2018), (ANL, 2018), (Gert Berckmans, 2017)

- Most of the battery cost reductions in last 10 years due to process efficiency improvements
- Energy consumption is >20% of total cost - a key driver to reduce overall costs
  - Also responsible for a large share of environmental impact



- The greatest future cost reductions are projected to be in cell and pack manufacturing
- Improvements likely to reduce cost/impacts the most are also likely to have an impact on particularly energy intensive materials / manufacturing stages – i.e. cathode materials and drying processes
- One of the big challenges is also solvent (i.e. NMP, N-Acetyl-P) recycling and reuse during the manufacturing process, hence there is significant interest in exploring alternatives

Source: Ricardo research and feedback from stakeholder interviews

Processes for handling xEV batteries for repair or from end-of-life vehicles are still evolving; will need to scale rapidly with volumes

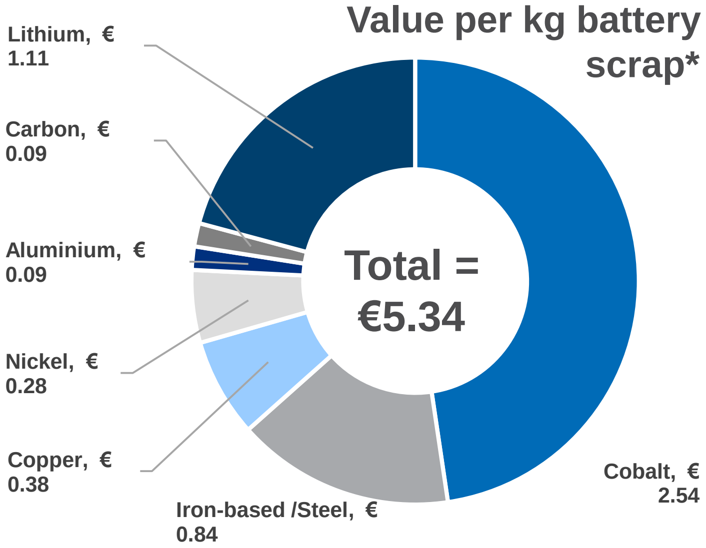
EoL vehicle | **Battery reuse or repurposing [optional]** | **Recycling process**

EoL EV, battery assessment
- Vehicle /battery collection
- Battery safety assessment and classification
- Storage
- [Potential removal from vehicle]

Battery re-use / **Second use/ re-purposing**
- Collection
- Measuring and grading (including cell analysis)
- Storage
- Repair /refurbish /recondition / remanufacture
- Inspection and delivery

Recycling & disposal
- Collection & assessment
- Battery pack and module disassembly
- Recycling process
- Refining of materials
- Disposal of non-recyclable waste

- Stages for end-of-life processes generally common for different chemistries / forms

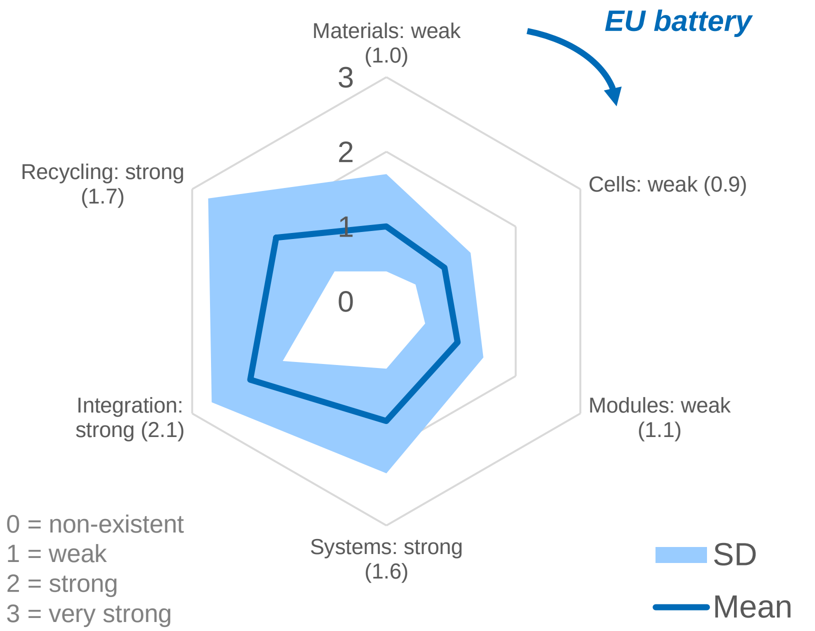


- Flow through processes depends currently primarily on economics:
  - Economics of recycling (and other stages) dependent on technology development and economy-of-scale improvements
  - Repurposing / second life options are under investigation, dependent on a range of factors – more/better information on status/use, greater standardisation and automation for disassembly will facilitate these (and could also improve safety)
  - Innovations in the power electronics, e.g. cell-by-cell control, needed to aid reuse/repurposing

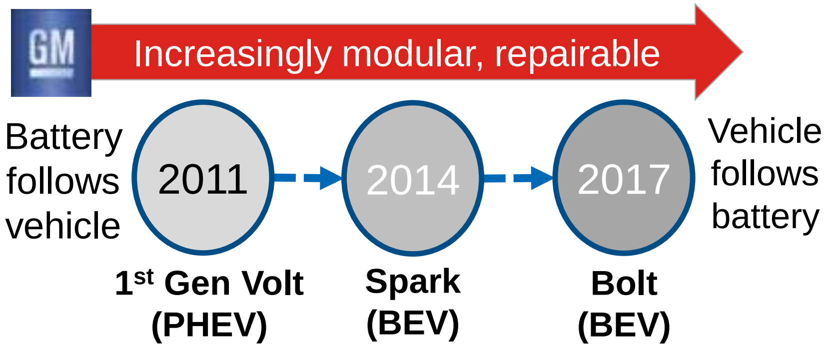
Source: (RECHARGE, 2014), (Tytgat & Tomboy, 2017), (Gattiglio, 2017); * From: B. Friedrich L. P. (2017) – IME, RWTH AACHEN University.

A wide range of manufacturing, reuse/second use and recycling improvements were identified, but there is little information available on advanced battery implications

- A wide range of manufacturing improvements were identified covering process optimisation, changes to materials/components, improved design and enhanced control/monitoring
  - Most are driven cost or performance (including safety), but likely to produce environmental benefits also
  - Improvements to binders and solvents have a particularly high potential for GHG impact reduction (i.e. on drying processes)
- Common processes for reuse/repurposing depend strongly on battery pack construction. Repurposing economics are uncertain
- Current industrial LIB recycling focus on hybrid pyromet./hydromet. processes; novel processes potentially offer enhanced recovery
- Improvements in xEV battery design, coupled with general scale-up and process optimisation will facilitate recycling improvements
- New chemistry agnostic hydrometallurgical processes are being developed, however there is currently no clear roadmap for scale up
- There are already examples of improvements being made to and improve battery lifecycle and facilitate reuse/repurposing/recycling

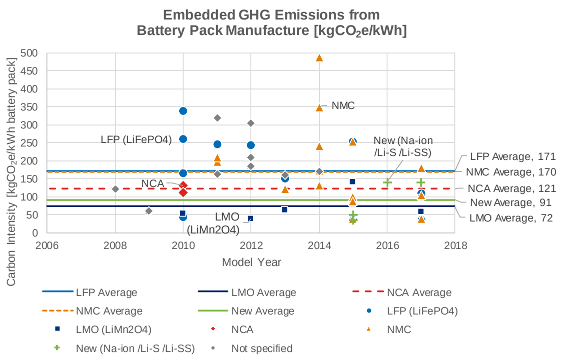


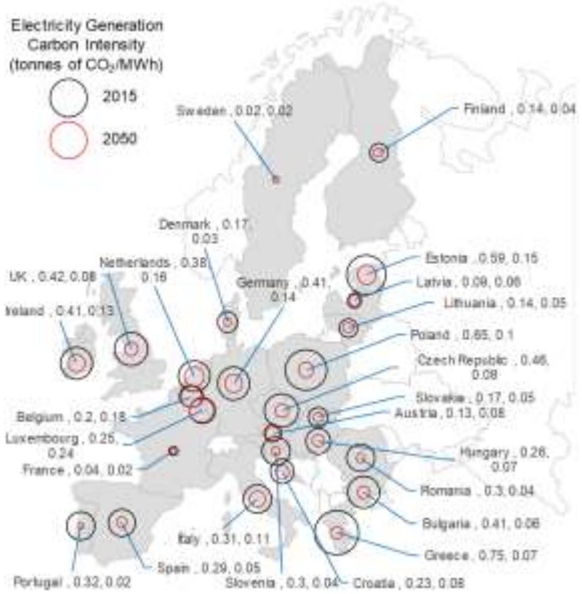
Source: Reproduced from JRC (2017b), Ecofys (2017)



A review of the current evidence on life cycle assessment (LCA) of impacts from xEV batteries was used to help inform the importance of CE management

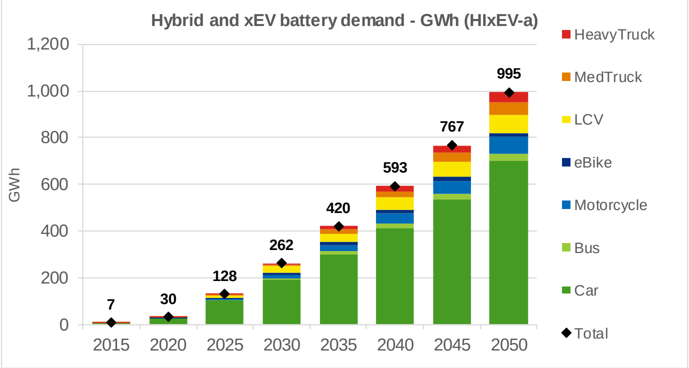
- xEV battery manufacturing is relatively well characterised in LCA, but results are highly variable, most based on older batteries and end-of-life processes are less analysed. There is significant variability mainly due to:
  - Electricity mix for manufacturing
  - Battery energy density, and
  - Treatment of end-of-life/recycling
- Impacts of battery recycling depend on different LCA method approaches, future benefits also uncertain but likely to increase
- Recent analysis suggests significant lifecycle benefits from second life used with renewables, however LCA treatment is still developing
- Impacts from xEV battery production are significant in comparison to other powertrains, but small versus operational energy benefits
- Global and European decarbonization objectives are likely to significantly reduce impacts of battery materials and manufacturing
- Improvements in battery energy density and the introduction of advanced battery chemistries are expected to reduce impacts/kWh
- A range of outstanding questions, gaps and uncertainties require further research

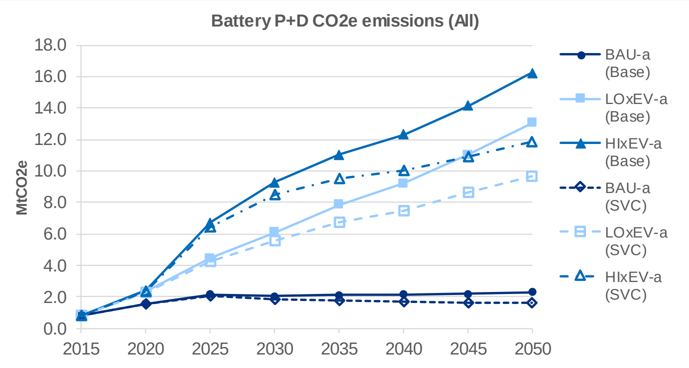


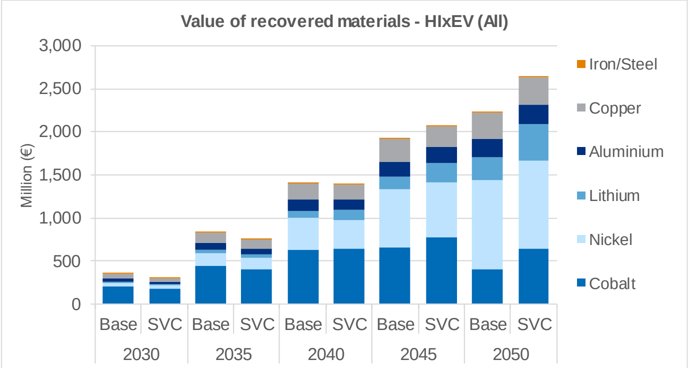


xEV fleet impact scenario analysis using Ricardo's SULTAN model highlighted benefits and also challenges that can be mitigated with a sustainable value chain

- The potential benefits of a Sustainable Value Chain (SVC) for EV batteries was explored for alternative xEV uptake in the EU road vehicle fleet
- The demand for xEV batteries is projected to increase dramatically to 2030 and beyond: GWh battery demand is dominated by cars, numbers of batteries by eBikes
- xEV use phase impacts dominate over battery lifecycle components, though significant reductions in impacts of the battery are possible for sustainable value chain
- All xEV scenarios lead to significant net reductions in air quality pollutants versus the baseline scenario; a further 43% reduction in battery-related emissions for SVC vs base
- xEV uptake is likely to significantly increase critical material demand – particularly for Li, with 2050 demand >3x current global production. SVC case could cut this by 1/3
- Recycling and repurposing leads to significant reduction in primary material demand, and significant value from recovered materials – a sustainable value chain will increase this significantly in the medium-long term







A portfolio of policy alternatives was developed to address the key challenges identified for developing a sustainable value chain for xEV batteries in Europe

- A portfolio of policy alternatives was assessed and discussed with expert stakeholders
  - Outcome set out priorities for current and near-future policy needs which include the following four areas:

1. **Addressing legal uncertainties in existing standards and definitions:**
   - The current regulatory landscape may either not be sufficient to cover a well-functioning market, or on the other hand may present overlaps or inconsistencies. Clarifying uncertainties (e.g. on product responsibility, waste definitions, etc.) is expected to facilitate the development of a robust market
2. **Improving transparency across the different value chain components through extended regulation:**
   - This could facilitate access to information throughout the supply chain to allow market actors to make more informed choice, e.g. on material sourcing or product performance
3. **Establishing new and updating existing targets:**
   - With respect to existing recycling targets and the option to establish new reuse and repurposing, where appropriate. This is expected to foster a more resource-efficient use of materials
4. **Establishing a monitoring and reporting framework to facilitate evidence gathering:**
   - This could help set a level playing field to better understand environmental impacts throughout the lifecycle of batteries

Thank you

Nikolas Hill
Ricardo Energy & Environment
The Gemini Building
Fermi Avenue
Harwell, Didcot
OX11 0QR
United Kingdom

T: +44 (0)1235 75 3522
E: nikolas.hill@ricardo.com
E: VehicleLCA@ricardo.com