Government
Office for Science

What are the technical and policy barriers to increasing EV battery recycling capacity in the UK?
Meeting note from roundtable chaired by Patrick Vallance, Government Chief Scientific Adviser
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Executive summary

- Expanding EV battery recycling capacity in the UK is an imperative, given the increase in EV volume, the fact that all batteries will reach end of life, and the fact that landfill is not a feasible option.
- Current recycling techniques are inefficient, labour intensive, and can be dangerous. Considering recycling in battery design would be beneficial. Research is needed to enable automation of dismantling.
- An optimal regulatory framework can encourage innovation by setting targets for recyclate yield without being prescriptive of method. The framework should also be adaptable to developments in battery technology.

1. Importance of the issue

1.1 The transition from ICE to EV cars will increase the number of batteries reaching end of life:

- Electrification will increase demand for battery production. This demand will come from the expansion of the EV market, as well as e-bikes, trains, forklift trucks, handhelds and battery storage systems.
- All batteries will reach end of life.
- Current pyrometallurgical recycling recovers less than 50% of the battery packs by mass. There will be a considerable waste problem to deal with if significant improvements are not made.
- There is a requirement for giga refining capability.

1.2 Landfill is not an option:

- Some constituents of batteries are highly toxic, particularly the electrolyte and binders (both of which are fluorinated and can react to form hydrogen fluoride). Cobalt and nickel compounds are also mutagens and respiratory sensitisers.
- Placing all this waste in landfill is not a feasible option. Landfill is a poor option for value recovery, chemical safety, fire prevention, carbon impact and resource security.

1.3 Supply is finite:

- The increased demand for batteries will strain supply chains of elements (though lithium, nickel and cobalt and not intrinsically rare, the scale of demand will still strain supply).
- Recycling materials back into feedstocks could mitigate this risk and provide an economic opportunity.
- Improving battery recycling could strengthen supply chain. Improving volume and yield will support cost, inventory management, CO2 footprint.

1.4 Future of grid:

- As electric-vehicle penetration grows, a market for second life batteries could emerge including stationary storage for the power sector (particularly in areas where weak grids require reinforcement and where high penetration of renewables requires supply to be balanced with demand).

- There is also the potential for direct vehicle-to-grid connection for demand side management.
- This would require battery passporting or other technique to identify and triage the batteries.
- Research is needed to develop a high-speed process to grade/sort battery modules from EVs.

1.5 If this issue is properly addressed, it can become an economic opportunity for the UK:

- Research by Green Alliance in 2019 found that the UK's fleet of electric cars and vans contained over 1,400 tonnes of lithium and 800 tonnes of cobalt, worth £26.3 million and £31.5 million respectively. If recycled, that volume of lithium and cobalt would be enough to make 220,000 electric car batteries.
- The Advanced Propulsion Centre (APC) calculates that manufacturing scrap from the scale up of UK gigafactories and from end-of-life vehicles could generate 28,000 tonnes of battery waste that could be reusable.
- The APC estimates that "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 approximately 50% of the total cell cost.

2. Technological issues

2.1 Current methods:

- Predominant method in Europe is currently pyrometallurgical. Batteries are shredded and heated to 1500 degrees to break the constituent parts down. A percentage of the value elements, mainly cobalt and nickel and copper, is retrieved at the end. The rest is lost, including the lithium.
- The other method is hydrometallurgical, in which China is the leader. New players are developing fast in South Korea, North America and, to a lesser extent, Europe. A major advantage of hydrometallurgical separation over pyrometallurgy is that lithium recovery is more feasible.

2.2 Safety concerns:

- Fluorinated material in electrolyte and binders can be converted to hydrogen fluoride.
- Risk of chemical fires in waste management chain and treatment facility.
- The recycling process can yield VOCs, dust/particulates, process effluents.
- Black mass contains nickel oxides which are hazardous/carcinogenic.

2.3 Principles for improvement:

- Consideration of recycling should begin at the beginning of the design process ('design for disassembly').
- Ideal (more valuable and safer) is to recover the constituents without breaking them down into their most basic components. The more spent on separation of materials, the less value there is in the chain.
- Research is needed to develop smart automation to deal with high throughput dismantling and processing (potentially leaking/unstable) batteries.
- This is a significant technical challenge, but larger and standardised cell sizes would help, as would excluding glue.
- Further research and innovation is required in a range of areas including water miscible binders, binderless electrodes, and methods of recycling current binder of choice (polyvinylidene difluoride).

2.4 Confounding issues:

- Those cars currently on the road in the UK will be so for another 8-20 years. Therefore, design now will improve waste recovery many years ahead, not today. Moreover, more than 70% of battery containing products placed on the market in UK (including cars) are made and designed outside UK.
- Current batteries in EVs in circulation are variable and therefore still require manual disassembly. A recent Institute of the Motor Industry survey found only 1,000 trained technicians in the UK capable of servicing electric vehicles, with another 1,000 in training. Given there are 170,000 motor technicians in the UK, this represents less than 2% of the workforce.
- Standardising cells for disassembly is a popular idea. But to make things economically attractive at industrial scale, volume is a key consideration; economics of cell disassembly are not currently compelling at high volume. Cells would need to look very different for this to work. Until then, shredding is the only viable option for scale.
- Many recycling companies take in a range of inputs (e.g. washing machines) at the same time as batteries.
- Recycling companies also have to manage variable feedstocks. Some countries shred and burn the whole battery, leaving remnants of plastic in the black mass. This is a challenge for refining and upcycling if and when material comes to UK.

3. Policy issues

3.1 Optimising regulations and design standards:

- An optimal regulatory framework should drive desired outcomes with incentives for recyclers to build infrastructure in the UK for black mass refining.
- Expected performance and durability criteria, as well as recyclate yields and targets, work best when agnostic to method. Prescribed technical solutions can hamper innovation.
- An optimal framework will protect against export to cheaper, lower efficiency and or less sustainable options overseas.
- Implementation of regulations should be timed to encourage sufficient scale to be competitive. A small scale may limit investment and adversely affect competitiveness.
- Cylinder cells are already made to standardised dimensions but (newer) pouch and prismatic designs are not. Moving to standardised sizes for pouch and prismatic cells could aid automated disassembly.
- New regulations could accelerate adoption of new manufacturing methods such as water-soluble binders for the negative electrodes (anodes). Options for the positive electrodes (cathodes) are less well advanced. Further research investment would be helpful in both cases.
- The regulatory framework could include passporting to prove provenance of materials including attestation of carbon footprint and labour standards.
- The highly differentiated nature of the supply of batteries for recycling may mean that new entrants need to be encouraged to focus on specific batteries in terms of either upgrading for re-use or recycling. Policies to encourage new entrants and policies to support existing firms are likely to be different and will need some additional consideration.
- For battery re-use, regulation should clarify responsibilities for producers vs those using refurbished batteries.
- EU regulations are changing with a view to accelerate recycling volumes across EU.

3.2 Waste policy:

- Consideration needs to be given to what will happen if battery recycling remains uneconomic.

- This could lead to the export of batteries for recycling, illegal dumping of waste etc.
- Waste regulations are needed for when batteries are not suitable for re-use or repair. This controls unscrupulous or dangerous operators.
- The UK could treat end of life batteries not as waste, but as a resource, to make it easier to trade and upcycle. (Note that to be traded, it would need to comply with international rules for exports).
- With sufficient resourcing, regulators can accelerate uptake of new methods.

3.3 Creating a competitive market and fostering innovation:

- Recovery and separation are scaling well in the UK. But black mass processing and refining is far behind.
- Battery recycling is, generally speaking, a low margin sector.
- The recovery of black mass and other battery materials into sustainable materials, and how recyclate can be made into batteries, are the biggest opportunities for the UK.
- However, consideration should be made for all the valuable waste associated with battery production, including cathode waste and anode waste.
- The percentage required for economic viability depends on the way the battery is originally made, the chemical composition, extent of damage, and form of presentation.
- Investment is difficult to secure at the early stage as processes are capital intensive. The risk and reward profiles match poorly with VC appetite. Companies at a later stage are often still seen as high risk as they are still proving revenue generation, forecasting material supply is difficult as useful lifespan of batteries remains unclear, and prospect of battery technology changes brings uncertainty. Moreover, raw materials are currently relatively low cost, though prices are rising due to increasing demand and supply disruption.
- Investors benefit from clarity on issues that inform investment decisions such as the lifespan of batteries, the scale of demand, and the impact of new battery technologies.
- The UK has strengths in innovation – including in the UKBIC – and, in a range of similar areas, has created the intellectual property that other countries employ.

3.4 International competition:

- Recycling needs to be considered part of a complete value chain of supply, including battery materials producers and battery manufacturers.
- In China there is close integration between what the regulator does and what industry is looking for. End-to-end planning, which recognises that materials will be needed again.
- The UK will never be able to compete on volume with China.

3.5 Next generation batteries:

- Next generation chemistries are being developed: solid state batteries, sodium batteries etc. The Advanced Propulsion Centre forecast around 25% penetration of Lithium Iron Phosphate (LFP) batteries in auto use in Europe by 2030.
- LFP will require new recycling and refining technologies that focus on recovering value from graphite, copper and aluminium foils, plastic and lithium, rather than nickel and cobalt.
- There won’t always be an economic case for next generation batteries – the materials won’t have the same value.
- The research on recycling next generation batteries has to be developed alongside the technology itself.

3.6 Ensuring a coherent net zero policy:

- Most synthetic graphite is imported from China, and produced using non green electricity. In the UK, energy prices are higher and where there is stricter regulation.

- HMT Green Book for analysis does not allow the valuation of reduced carbon footprint of UK produced materials vs imported.

3.7 Authorisation of new facilities:

- Current time to authorise new processing facility is typically 18 months

3.8 Demand effects:

- Measures which seek to encourage other forms of mobility (i.e. instead of motor vehicles) could reduce demand for batteries and, consequently, the need for battery recycling.
- However, attempts to reduce demand could reduce the size of the recycling market and associated economic viability.

Participants

Patrick Vallance (GCSA; Chair), Alan Colledge (Lithium Battery Recycling), Christian McBride (Genuine Solutions), Harriet Bulkeley (British Academy), Jacqui Murray (Faraday Institute), Jenny Edwards (Iconichem), Julian Hetherington (Advanced Propulsion Centre), Justus Loebler (BritishVolt), Madeleine Hall (Veolia), Mark Bedford (Johnson Matthey), Mike Short (CSA; DIT), Pam Thomas (Faraday Institute), Paul Knight (Envision), Paul Monks (CSA; BEIS), Peter Bruce (Royal Society), Peter Chesney (Environment Agency), Robin Brundle (Technology Minerals), Roger Morton (EMR), Sam Haig (RS Bruce), Sarah Sharples (CSA; DfT).

Annex: Government Activity as of July 2022

Landfill and waste:

- The Waste Batteries and Accumulators Regulations 2009 set collection/take-back and treatment requirements for all waste batteries, with producer responsibility obligations on battery manufacturers and importers to cover these costs.
- The same regulations set a landfill disposal ban on electric vehicle batteries, meaning all of batteries need to be recycled and recovered.

Supply chain:

- BEIS has launched the Critical Minerals Strategy to improve resilience and security. It contains two relevant workstreams:
    - Reviewing and updating regs with the future battery consultation coming out next year/WEEE consultation this year (Defra lead, DIT support).
    - Looking at current financial incentives and where they need to be tweaked to add black mass processing into scope (BEIS lead, DIT support). BEIS currently scoping this.

Second life of batteries:

- The Office for Product Safety and Standards (OPSS) is finalising a report called “Safety of Second-life Batteries in Battery Energy Storage Systems”.
- UK Innovation: In 2017-20, BEIS part-funded an innovation project led by Nissan (with partners: Warwick Manufacturing Group, Element Energy and Ametek) which successfully developed a high-speed process, based on Electro-Impedance Spectroscopy, to grade/sort battery modules from EVs within a few minutes (compared to hours taken for conventional approaches).
- An area to address to help encourage widespread uptake of second-life batteries is insurance and warranties. UK company Powervault is one of the few companies to offer a second-life home battery storage product but only about 5% of the units it sells use second-life batteries. A key reason given for this low level of second-life usage is the difficulty in

getting product insurance or warranties to guarantee a reasonable product life for second-life batteries.

Standards:

- BSI has recently produced a Standards Roadmap for battery manufacturing and technology in July 2021. This notes the importance of 'design for recycling' standards and sets out the next steps for developing relevant new standards in this area, subject to resources.
- BSI is also playing a leading role in development of battery standards. BSI is a key member of the European and international standards organisations (such as the IEC – International Electrochemical Commission), where relevant aspects of standardised battery design are also under development.
- The Environment Act 2021 could be used to set design requirements for electric vehicle batteries. Defra intend to explore the use of these powers and take forward measures such as the setting of minimum performance and durability criteria and minimum recycled content for materials such as cobalt, lithium and nickel in new batteries.
- Although not related to design, the Waste Batteries and Accumulators Regulations 2009 establish producer responsibility obligations covering all batteries, including those in electric vehicles. Defra consider that system can be improved in a number of ways and are reviewing the existing regime with a view to consulting later this year (subject to available resource). Changes in prospect include recasting the producer responsibility obligations so that they are clearer, linked directly to what a producer actually places on the market. Defra are also looking at introducing separate treatment material targets on cobalt, lithium and nickel to complement upstream minimum recycled content proposals for new batteries.

Research on new battery designs:

- Joint UK government-industry groups, such as the Sustainable Batteries Steering Group (SBSG), already exist and are working together on the challenges of battery waste reduction and recycling. SBSG is chaired by Faraday Battery Challenge (FBC) Deputy Director Jacqui Murray and meets quarterly to discuss the latest developments regarding the design and development of more sustainable batteries, including updates on projects which have been supported by funding from FBC. Membership of the group includes representatives from government, universities, research centres and industry.
- Government funding is also available – primarily through the Faraday Battery Challenge and the Advanced Propulsion Centre - to industry and the research base, to encourage research and innovation in vehicle battery use and recycling.