Written evidence submitted by the Royal Society of Chemistry

1. With about 50,000 members in over 100 countries and a knowledge business that spans the globe, the Royal Society of Chemistry is the UK's professional body for chemical scientists, supporting and representing our members in large multinational companies and small and medium enterprises, universities, schools, government and regulatory agencies. We also draw on chemistry using professionals' expertise to provide advice to Government to help it achieve its ambitions, whether regulating chemicals appropriately[1] and responsibly, identifying priorities, opportunities and challenges in chemical science[2], or supporting the development of a UK circular economy[3].

2. The UK chemical science community has much to offer in the development of batteries and electric vehicles and addressing their environmental impact, not least the substantial work of the Faraday Institution. In March 2021 the RSC convened a workshop of over 30 chemical science experts to discuss the role of Critical Raw Materials (CRMs) in the technologies that will help us reach net-zero emissions. Drawing on the insights of this event, we have focussed this submission on CRM materials recycling and recovery though other topics are briefly discussed.

Question 2) How well is Government policy aligned with high-level commitment for growth of battery electric vehicles to support its net zero ambition?

3. While the UK government's phase out of the sale of new petrol and diesel cars by 2030 is crucial for the reduction of GHG emissions, it will also lead to a significantly greater number of batteries in production, operation, and end-of-life processing. This change carries a potentially significant environmental impact.

4. UK government should consider at this early stage who is responsible for recycling batteries at end of life as battery ownership and recycling responsibility can vary. In China, the battery manufacturer is responsible and thus design for recycling is incentivized. The US has developed guidelines of this nature, and proposed updates to EU battery legislation recommend a similar approach by bringing requirements for EV batteries into alignment with other portable batteries.[4] Regulatory proposals should incentivise the use of secondary raw materials across the entire battery manufacture value chain and it should be clear to consumers how to return products for reprocessing.

5. The alignment of legislation and material markets is critical for the success of new end of life processes. For example, the aforementioned update to the EU Batteries Directive legislation considers both battery recovery and resource efficiency. Elimination of hazardous materials, such as mercury and cadmium, would reduce the cost of waste handling. Economic incentives, such as Deposit Return Schemes (DRS), are needed to encourage the return of 'waste' technology to appropriate stakeholders, or other mechanisms, as in the case of WEEE return where secure data wiping, and curb-side collection have been employed. Legislative actors such as the Environment Agency, who license recyclers, have the scope to promote circularity and identify best practice/centres of excellence.

6. Economies of scale are a major barrier to the establishment of new recycling infrastructure. The viability of new recycling business models relies on the scaling up of processes, such as that experienced by the established recycling routes of the aluminium and steel industries. Where industries are not yet established, legislative incentives should encourage markets for secondary raw materials and support industries that are managing this transition, e.g. support for new jobs and training, sector-enabling funding, forward-looking research and innovation in this area, or strategic collaborations.

---

[1] https://www.rsc.org/new-perspectives/sustainability/sustainable-chemicals-strategy/
[2] https://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/science-horizons/science-horizons-report.pdf
[3] https://www.rsc.org/new-perspectives/sustainability/progressive-plastics/
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0798

7. As we highlighted in evidence to the EAC's 2020 inquiry into electronic waste, the circular economy is enabled at the design stage.[5] This should be recognised in the EV manufacturing sector through comprehensive right to repair legislation, extended producer responsibility, and end of life design standards that aid material recovery.

Question 3) Are the UK supply chain opportunities around supply of batteries and power electronics, machines and drive supply chain clear?

8. Under a linear production system, technologies at their end of life are not sufficiently utilised, creating waste and representing a loss of materials to the UK's manufacturing industry. More accurate and accountable metrics should be developed to track technologies and their component materials throughout their lifetimes. The standardisation of protocols and consistent labelling of components in these technologies is important in their circular use, for instance in the chemistries and contents of batteries. Policy in this area should aid the development of circular supply chains.

Question 4) What natural advantages in terms of access to raw materials, renewable energy supply, technological readiness, IP or other competitive advantage does the UK have to encourage development of battery manufacture in the UK?

9. The chemistry research community is a great strength of the UK, and within industry, academia and partnerships they are developing and applying advancements in battery technologies and manufacture, as well as CRM recovery. Our research community is also considering the importance of product design and construction in the use and recovery of CRMs in technologies. Collaborations exist within the battery manufacturing sector, and recyclers are increasingly being involved, but this alone will not drive sector transformation.

Question 7) What action is needed to support growth of associated power electronics, machines and drive supply chain, including securing supply of raw materials and material processing?

10. The transition to an electric vehicle fleet will see a substantial increase in global demand for critical raw materials including cobalt, lithium, nickel and graphite in the production of battery technologies, and dysprosium, neodymium, and praseodymium in the magnets of electric drives and generators. Material substitution offers promise in this latter area. The Offshore Renewable Energy (ORE) Catapult is working with start-up Greenspur Renewables to develop permanent magnet generators that use ferrite instead of neodymium to alleviate raw material concerns.[6] However, while funding and collaboration incentives are in place for battery recycling, they are less established for magnet recycling and driven by EU partnerships. UK researchers face challenges in participation since the departure of the UK from the EU, and magnet feasibility studies are challenging to conduct if manufacturers are not based in the UK.

Question 9) The £1 billion Net Zero Innovation Portfolio will focus on research into low carbon technologies. What proportion of this funding should be directed towards battery electric vehicle research? What areas should ARIA target in distributing funding for high-risk, high-reward research into battery electric vehicles?

11. In January 2021 our workshop of 26 members of the chemical sciences community explored the challenges and opportunities in creating a new UK funding agency based on the US ARPA/DARPA model. Whilst we did not discuss the balance between topics there were a number of conclusions that should be borne in mind. ARIA will necessarily have limited resources and will need to focus on

[5] https://committees.parliament.uk/publications/3675/documents/35777/default/
[6] https://ore.catapult.org.uk/stories/greenspur-renewables/

a small set of research areas which should be determined in close consultation with the scientific community.

12. ARIA will need to build an advisory structure which reflects its strategic context, its desired agility and the long-term focus of its funding. Once established, the agency should be as flexible as private R&D funding which includes the provision of seed corn funding in addition to the proposed longer-term grants to support diversity of ideas and participants. Further detail on these points is available in our summary of the workshop.[7]

13. Separately, our Science Horizons report identified that collaboration is a key enabler for much of the materials chemistry field which is relevant to advances in batteries and electric vehicles.[8] Materials chemistry is a particularly interdisciplinary area within the chemical sciences, having the most frequently identified relationships with other sub-fields. If battery materials are identified as a priority for ARIA then this feature should be borne in mind when structuring funding for projects. Government should also consider how ARIA's high risk high reward objectives can best complement the more goal focused approach of the Faraday Battery Challenge. Consultation with the research community on proposals will be essential when acting on these aspects.

Questions 11 and 13 are linked and so we have answered them together. Q11) What measures should the Government take to ensure that minerals for battery electric vehicles are sourced in a responsible way? Q13) What steps should be taken to ensure that EV batteries are recycled at the end of their lives and not simply sent to landfill?

14. With a typical lifetime of 8-10 years and mass of 300 kg to 600 kg per electric vehicle, batteries have the potential to become a significant waste stream. While these batteries can be used for storage capacity in static applications for up to 20 years post-vehicle use, the valuable materials contained within them can be recovered avoiding the need for new mineral extraction. At present, a large number of waste electronics that contain valuable CRMs are not sufficiency utilised due to a lack of recycling infrastructure in the UK. Waste electronics are exported to other countries instead of being fed back into the UK's manufacturing base, with most end-of-life products containing metals and minerals in higher concentrations than primary resources. This represents a missed opportunity.

15. **Designing batteries and cells with circularity in mind would substantially ease the process of recovery at end of life rather than store up difficulties for the future.** Innovative chemical solutions to the construction of batteries could allow for easier, safer disassembly and the reuse of their valuable components increasing their useful life. **Interdisciplinary approaches are required, such that chemists work with engineers and product designers to understand where chemical solutions can be impactful,** for instance, in the development of debondable polymers or reversible adhesives to ease the physical separation of components in packs.

16. The safe disassembly of batteries is challenging both in terms of human and environment harm and carries a number of technical challenges. Battery disassembly is complex and one of the largest barriers to recycling. Hazardous compounds produced through battery aging and the propensity for lithium-ion batteries to catch fire represents a significant challenge to the waste industry. Safer battery formulations would be impactful, though the technological difficulties faced in designing these mean that risk management strategies should also be introduced.

17. More considered design such as separable battery components can make it easier to reclaim high value materials. Physical and chemical separation of materials are often used in combination, with physical processing similar to those practiced by the mining industry. It is important to consider the trade-off between physical and chemical separation as the ability to separate chemically in part relies on the extent that physical separation is employed. Use of a limited number of connectives,

[7] https://www.rsc.org/globalassets/04-campaigning-outreach/policy/uk-research-funding-policies/rsc_new-uk-funding-agency-uk-arpa_feb21.pdf
[8] https://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/science-horizons/science-horizons-report.pdf

adhesives and corrosion protection coatings across the industry would also help to mitigate this challenge. Further, the contents of cells are often unknown due to commercial sensitivities. Cells need to be labelled consistently to identify their contents and chemistries (the update to EU Battery legislation proposes this), so that substances of concern can be monitored and CRMs recovered more readily.

18. To better understand material criticality for the UK, Government or a relevant authority should establish regular assessment of the criticality of materials at a national level with a view to sectoral demand and industrial strategy.[9] It is essential that this is done in close collaboration with industry to allow for appropriate information sharing. Cobalt and lithium were included in the 2020 EU list of CRMs, while nickel is being closely monitored in view of developments relating to growth in demand for battery raw materials. Inclusion in the EU CRM list indicates that these materials are of high importance to the EU economy and of high risk associated with their supply. A CRM assessment similar to the one performed by the EU does not currently exist for the UK economy.

19. Alongside efforts by governments and manufacturers to manage supply risks and by global producers to scale-up considerably, recovering a large proportion of the CRMs in batteries will be required to meet demand. Downcycling of materials is often incentivised at present, by markets or policies, over the production of superior quality secondary raw materials or products. Investment can be encouraged and justified by pooling end of life materials/technologies from a range of low carbon sectors. **To better understand material availability for reuse and recovery, we recommend combining the national waste tracking system with the National Materials Datahub, creating a powerful tool to identify the fates of CRMs in the UK and viable secondary resources for their extraction.** It is essential that we have a better view of material needs, along with supply chain and recycling rates. Not knowing where critical materials are in the supply chain and waste streams (not only battery supply chains but also supply chains of other products that use cobalt, lithium and nickel) limits the ability to extract CRMs from products and wastes, and ensure they are not lost from our economy. The benefits could be substantial with one tonne of lithium requiring the processing of 250 tonnes of ore or 750 tonnes of brine, in comparison to just 28 tonnes of end of life batteries.[10] Researchers at the Birmingham Centre for Strategic Elements & Critical Materials have particular expertise in this area.

20. Considering the means of CRM recovery from waste, more tailored and integrated solutions should be sought to achieve sustainable, safe, and economical recovery. Current approaches typically rely on energy intensive and environmentally hazardous techniques in pyrometallurgy and hydrometallurgy. Where non-aqueous solvents are used they are typically fossil-fuel based, toxic, not environmentally benign and the source of large volumes of waste from these processes. Advances in process intensification, including advances in electrocatalysis without ongoing consumption of reagents, subcritical and supercritical CO2 for electrolyte recovery, diffusion dialysis systems, and counter current leaching, will promote commercial-scale recovery of CRMs from batteries. Our March workshop, however, identified that further development and novel solutions from the chemical sciences are often required.

21. We must also be aware that developments to minimise the use of CRMs may act as an economic disincentive for recycling of battery packs as a whole. For instance, lithium iron phosphate ($LiFePO_4$ or LFP) batteries, which were originally deprioritised for EVs due to their relatively low energy density, are now attracting significant interest as they do not require cobalt and nickel. Low availability of cobalt in China has prompted their use in the domestic bus market, with current generation requiring only incremental refinement of their original chemistry to achieve acceptable performance. However, there is a risk that such cells will be less attractive for commercial end of life recovery due to the lesser economic value of their constituents. As such, **structures to promote**

---

[9] Our written evidence to the HoC Environmental Audit Committee inquiry into electronic was discusses this further: http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/environmental-audit-committee/electronic-waste-and-the-circular-economy/written/104579.html

[10] Harper et al 2019 Recycling lithium-ion batteries from electric vehicles | Nature

the sustainable recovery of lower value resources may require more explicit policy intervention.

Question 12) What action can Government take to support growth of secondary markets to extend lifetime use of EV batteries?

22. Recycling sits in the middle tier of the waste hierarchy with re-use and remanufacturing offering opportunities for greater resource efficiency. There is undoubtedly potential for second life, such as stationary uses of electric vehicle battery packs. For example, UK businesses Connected Energy and Kiwi Power are working with the Belgian recycling and resources company Umicore on megawatt scale projects. This system is expected to provide seven more years of usage from batteries with depleted capacity following service in electric vehicles. Such life extensions substantially reduce the life cycle environmental impact of battery systems and are facilitated by design for reuse and circular flows of resources at the outset. This is a topic currently under investigation by the High Value Manufacturing Catapult.

23. Whatever way end of life management of EVs is established, there is the risk that it is not supported by consumer actions. An Ipsos MORI survey of over 2000 people investigated knowledge and behaviours around WEEE as part of our Elements in Danger campaign, and highlighted that the majority are unaware of the valuable materials contained within their electronic devices which contributed to a propensity to store devices indefinitely or neglect recycling.[11] Consumers should be provided with support and information to encourage disposal options that maximise reuse of battery packs.

24. The need for direct innovation in underpinning chemical processes and alternative technologies is clear, as is the integration of chemistry insights at the design stage to aid the transition to a circular economy. We hope this submission will support you in your inquiry and we would be happy to discuss further any of the issues raised.

Tanya Sheridan
Policy and Evidence Manager

May 2021

[11] https://www.rsc.org/new-perspectives/sustainability/elements-in-danger/