FARADAY INSIGHTS - ISSUE 9: SEPTEMBER 2020

THE FARADAY INSTITUTION

The importance of coherent regulatory and policy strategies for the recycling of EV batteries

The move to electric vehicles (EVs) has the potential to reduce carbon emissions and air pollution. However, the transition also brings associated environmental challenges with the need for efficient recycling systems to tackle the large numbers of EV lithium-ion batteries reaching end-of-life. Unless this waste flow is managed, some of the gains of the transition to EVs will be lost. Effective waste management infrastructure and a supportive regulatory framework will be necessary to realise the full benefits of a decarbonised transport sector.

Introduction

The number of electric vehicle (EV) batteries reaching the end-of-life is currently small, but this will soon exceed several thousand per year as the market grows. The Faraday Institution's ReLiB project estimates that around 16,500 tonnes of battery packs will need to be processed by 2028 and the volumes will continue to rise thereafter.[1]

There is a danger that many of the environmental gains from the transition to EVs will be lost if the UK fails to manage the increasing volumes of EV lithium-ion batteries at the end of their useful life. A revised policy and regulatory framework is needed to address recycling issues across the entire EV battery lifecycle – raw material supply, design and manufacture, safety, storage, transportation and end-of-life.

This Faraday Insight considers the supporting regulatory provisions for end-of-life recycling to review present provision and recommends a high level regulatory and policy framework that will help manage lithium-ion batteries at the end of their life. The framework is comprised of the following elements:

1. A coherent waste hierarchy strategy for lithium-ion batteries, which addresses end-of-life management and covers recycling, re-use and repurposing of the batteries in the UK rather than abroad.
2. Clear regulation and policy on re-use and re-purposing, including the influencing of contractual and ownership models (e.g. battery leasing schemes) for EV batteries to facilitate recycling and second-use.
3. Internalised social and environmental costs of mineral extraction in the market price, which encourages recycling, minimises supply chain vulnerabilities and supports self-sufficiency in critical material supplies.
4. Extended producer responsibility (EPR) regulations that support a move to a circular economy model, ensuring safe and effective re-use of EV batteries, with increasingly robust recycling targets.
5. Eco-design criteria for recycling and remanufacturing, including restrictions on the use of hazardous substances and promotion of designs that allow easy separation of parts.

Because the current volumes of end-of-life EV batteries are low and because of the many uncertainties, government intervention is necessary to help establish the first EV recycling facility in the UK. It will take time to negotiate the planning and permitting processes, making early start-up support imperative.

[1] Estimates from the Faraday Institution ReLiB project.

6. The updating and clarification of existing waste management law as it relates to EV lithium-ion batteries to ensure a high standard of protection for human health and the environment, together with the use of smart regulation techniques to facilitate the transportation of waste to support recycling while ensuring that safety is prioritised in any policy for EV battery management.
7. The introduction, as part of the review of the Waste Battery and Accumulator Regulations in 2021, of mandatory chemistry labelling requirements for lithium-ion batteries to enable end-of-life lithium batteries to be easily and safely sorted and separated for recycling in specific groups.
8. A strategy to create the conditions for a new lithium-ion battery recycling industry in the UK to flourish.

1. A Waste Hierarchy Strategy for Lithium-ion Batteries

Although lithium-ion batteries are durable, they have a finite lifespan.[2] In terms of final disposal, end-of-life EV lithium-ion batteries that are not returned to the producer for research or remanufacture are almost entirely transhipped to elsewhere in the EU for recycling. This is a problem now for lithium-ion batteries from consumer sources and could become problematic for EVs after 2025 when volumes rise substantially due to increased numbers of vehicles in use, as well as issues around processing capacity, transport, safety and waste shipment regulations.

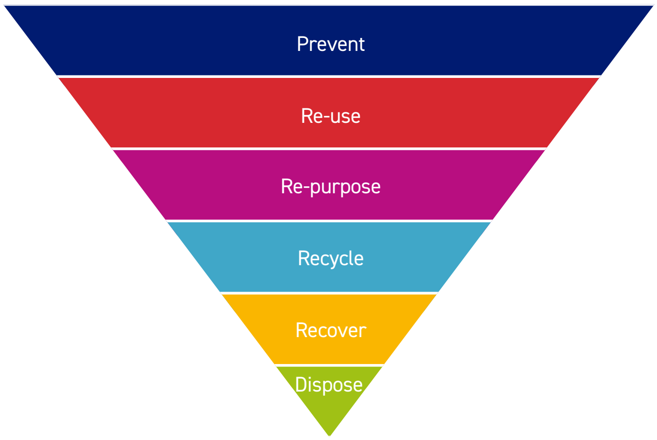
The handling and transportation of end-of-life lithium-ion batteries requires a good degree of care, leading to high transportation costs. Environmental considerations prevent the disposal of lithium-ion batteries in landfills and EU regulations are expected to restrict the exportation of end-of-life lithium-ion batteries in the future.[3] The EU is rightly committed to the proximity principle in relation to waste treatment, meaning that under EU law waste should go for treatment or disposal within reasonable proximity of the point of generation. If capacity is restricted in a European recycling market, this means that EV battery waste from within the EU is likely to be favoured above that from a third country such as the UK. Exporting end-of-life EV batteries from the UK for recycling is therefore neither a sustainable nor cost-effective solution for the medium to long-term.

We welcome a new approach to the UK regulatory framework that promotes re-use and recycling of lithium-ion batteries in the UK, planning for the EV transition while paying regard to the need to protect human health and the environment. The UK strategy will need to cover the following main options for dealing with end-of-life lithium-ion batteries:

- Re-use: Using the battery again for the same purpose it was originally designed for (i.e. EVs) after remanufacturing, refurbishment or repair.
- Repurposing (second-use): Re-using the battery for a different purpose from that which it was originally designed for, such as less demanding energy storage applications.
- Recycling: Separating out the important components and particularly the raw materials from the lithium-ion battery to make these available for future production.

Re-use is preferable to repurposing as it should be less energy and resource-intensive to make the battery fit again for the same purpose, compared with the effort and time required to remanufacture it for an alternative purpose.[4] Re-use and re-purposing are also preferable to recycling according to waste hierarchy principles (Figure 1).[5] Historically, there has been little regulation to promote repair and remanufacture to remain within the higher levels of the waste hierarchy, but a more favourable tax treatment of re-used products would be one mechanism to encourage consumers to purchase, and OEMs to provide, remanufactured lithium-ion batteries. However, even if some cells can be re-used and/or repurposed, all cells will eventually reach the end of their useful life and will need to be recycled or disposed of, probably by incineration.

Figure 1: Waste management hierarchy



While re-use and repurposing have many potential environmental and economic benefits, they also have many associated challenges. These include potential health and safety risks (such as the risk of explosion, high voltage and toxic gaseous emissions in the event of a fire),[6] technical barriers and lack of clear regulations regarding re-used batteries.

2. Clear Regulation and Policy on Re-use and Re-purposing

Policy and regulation should be designed to influence business models in favour of those that promote re-use,

[2] Trafigura Research Report, 'Meeting the EV challenge: responsible sourcing in the electric vehicle battery supply chain' (Trafigura 2018).
[3] As from 1 January 2021, the UK will be treated as a third country for the purposes of Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.
[4] For a detailed discussion of these, see Sections 2.5 and 2.6 in: European Commission, Ricardo Energy & Environment (2019) 'Circular Economy Perspectives for the Management of Batteries Used in Electric Vehicles'.
[5] See for example, Council Directive 75/442/EEC of 15 July 1975 on Waste OJ L 194/39.
[6] See for example, Commission for Environmental Cooperation, 'Environmentally Sound Management of End-of-Life Batteries from Electric-Drive Vehicles in North America' (CEC Project Report 2015).

and safe and effective end-of-life management. This will require a mix of carrot and stick within an extended producer responsibility model. That is to say that targets could be set for recycling and other second life use, perhaps with allowances for OEMs exceeding the target to trade with those lagging behind (the carrot) alongside strict waste controls on disposal (the stick). Such an EPR scheme might drive business and consumer thinking to reconfigure traditional models of vehicle use and ownership.

In traditional models of ownership, where a purchaser owns the car and all its components, the battery state of health (SOH) is not something that the manufacturer can influence or even fully understand before the used battery is returned to them. There is, therefore, a risk that the owner continues to use the battery well below 70-80% capacity, which is the optimal time for batteries to be re-used or repurposed.[7]

The strategy should include both re-use and repurposing.

Re-use

As the SOH has a considerable impact on reusability, a proper assessment that considers capacity and damage is not just essential to ensure effective performance of a repurposed battery, but also necessary for safety reasons. EPR regulations will be needed to ensure that battery recycling drives a supply loop in which critical materials are returned to production.

This might be most easily achieved in battery leasing schemes, which have already been employed in the marketing of early EVs, where customers purchase the vehicle but lease the battery, with the lease price per month linked to annual mileage.[8] This treats battery maintenance as part of the running cost of the vehicle, thus reducing the upfront cost of the EV and making it more competitive with petrol and diesel vehicles. The manufacturer retains ownership of the battery throughout and therefore can make the decisions about whether to repair or replace as well as when to re-use, re-purpose or recycle the battery. If the battery is leased and will be replaced at around 80% SOH, it could much more easily be re-purposed.

It is thought unlikely that the government would wish to mandate the business form for the supply of batteries in EVs. However, well-devised EPR regulations, with stringent targets for the collection of EV batteries whenever they leave the vehicle may help drive servitisation models such as leasing. These in turn might help secure much higher rates of recovery and help prolong battery life through better battery management.

Repurposing

The high-power demand required to provide EV traction means that batteries with significant residual capacity may no longer be efficient for use in EVs. In a circular economy, to promote sustainable development and reduce wastage, it is possible to harness the remaining capacity of used EV batteries for other second-uses (e.g. grid or home stationary storage or smart grid power buffering strategies).[9] However, because one would wish to recover valuable components through recycling when the cells can provide no further useful benefits, there is a case for regulating any second use. This would help both in order to ensure safe use, as well as to maintain a loop back into remanufacture. This would be helpful, also, because there is substantial uncertainty around the legal definition and regulation of repurposing for second use. Regulation of export for second use will bring clarity and control to safety and liability structures, which will also assist the producers' engagement in developing such applications.[10]

Definitions of what amounts to 're-use', 'recycling' and 'repurposing' need to be clearly specified to direct the fate of first life batteries (as outlined in section 1). Additionally, if the battery pack is classified as 'waste' at the end of the first life, then this has implications on its handling and treatment and will inhibit re-use. The UK should look to depart from definitions of waste in the Waste Framework Directive to develop clear parameters of when EV batteries will or will not constitute waste.

Any repurposing should be carefully monitored if only for reasons of safety. This includes regulation of the re-sale of repurposed lithium-ion battery cells, modules and packs and available information on their location. For example, energy storage in living space within the home is wholly unsuitable as a second use. In addition, the location of such storage systems of any size using new or repurposed lithium-ion batteries should be required to be notified to first responders, especially fire and rescue services. Widespread repurposing will also delay access to secondary materials and hinder the operation of take-back schemes under EPR models, so clear policy decisions must be taken as to the circumstances in which repurposing would be encouraged.

3. Internalised Social & Environmental Costs of Mineral Extraction

The social and environmental costs of extracting raw materials should be internalised in market pricing in order to level the playing field between virgin raw material and recycled material. UK Government intervention in the form of incentives to recycle or conversely to tax the use of certain raw materials should be examined.

A recycling market will struggle to develop in the UK and EU if the price of virgin materials is competitive with or even cheaper than the price of secondary materials. This will remain the case if the social and environmental costs of extracting raw materials are not internalised in market pricing. In any case, the supply of some critical materials is fragile,[11] so that building in some security over access to such critical minerals through recycling is a sensible step to take; and one that is followed in the EU and other jurisdictions.

It will be necessary to assess the extent to which targets for recycling or recyclate content will drive effective secondary

[7] J Tytgat & W Tomboy, 'New insights into residual value: RECHARGE perspective' 5th E-mobility Stakeholder Forum (2017).
[8] Renault continued to employ this model announcing its closure at the end of 2019.
[9] As happens at the Johan Cruijff Stadium, Amsterdam – see the World Economic Forum coverage. See also: European Commission, 'Sustainability assessment of second-life applications of automotive batteries (SASLAB)' (JRC Final technical report 2018).
[10] European Commission (2019) 'Circular Economy Perspectives for the Management of Batteries Used in Electric Vehicles' Ricardo.
[11] Lithium, cobalt and nickel; the gold rush of the 21st century, Faraday Insight Issue 6, April 2020.

material use. An important feature of any regulatory design will be the extent to which recycling targets should be accompanied by tradable instruments similar to producer responsibility notes (PRNs) available to those exceeding the set targets.

4. EPR Regulations Linked to Recycling Targets

Increasing the recycling and recovery of materials within EV batteries will result in reduced demand for primary raw materials and the transportation of those materials from other parts of the world. EPR regulations, which require battery manufactures to take back their products for recycling, should be developed to incentivise battery manufacturers to meet specific recycling rates.

The production of raw material components of lithium-ion batteries accounts for approximately half of the greenhouse gas emissions from battery production. The rapid increase in demand for raw materials has led to sharp rises in mining activities to feed this demand. These large-scale mining activities have given rise to concerns about both the environmental and social costs, due to the lack of adequate regulation of mining operations in many developing countries.

In a circular economy, materials that are recovered through recycling processes can be sold back on the market as secondary raw materials. This reduces the need for the extraction of virgin materials, thus allowing the value to be retained within the UK market. Recycling also mitigates carbon emissions when compared to extracting those materials from virgin sources. Based on a hydrometallurgical recycling process, lithium-ion batteries mitigate about a net 1 kg of CO_2 equivalent for every for 1 kg of battery recycled.[12]

The primary objective of the EU Batteries Directive (2006/66/EC)[13] is to minimise the negative environmental impacts of waste batteries, thus protecting, preserving and improving environmental quality.[14] The Directive also sets collection and recycling efficiency rates for certain types of batteries. In the UK, the Directive is transposed into domestic law through the Waste Batteries and Accumulators Regulations 2009. These regulations ban the disposal of industrial and automotive batteries to landfill, require producer responsibility systems and set targets. The Regulations (like the EU Batteries Directive) are considered widely to be out of date due to the pace of technological advancements in this sector. For example, automotive batteries are defined as lead-acid starter batteries and lithium-ion batteries are classed as portable (e.g. consumer batteries for cordless or mobile phones) or industrial – such as lithium-ion propulsion batteries for EVs.

As things presently stand, a vast number of batteries classed as industrial will actually be owned, operated and discarded by consumers and it is widely agreed that revision to the regulation is needed. Regulation of end-of-life vehicles[15] should ensure that a vehicle coming off the road is recycled at an approved treatment facility with a certificate of destruction accrediting this. The battery should be removed as part of the depollution of the vehicle. However, up to 4.5 million vehicles are deregistered each year from the European market without a certificate of destruction and it is assumed that these 'missing' vehicles are not subject to an approved treatment.[16] Moreover, there is regulatory uncertainty as to the responsibility of the producer of an EV's battery once that battery is repurposed for use outside of the vehicle.

In 2018, Defra published a Resources and Waste Strategy for England[17] which committed to consult on amendments to the Waste Batteries Regime, to consider higher recycling rates, consider new mandatory labelling requirements and to take into account new classifications of battery types to reflect those being developed. Linkages between end-of-life vehicles regulation and batteries regulation can be addressed in light of the move towards electric mobility. Defra has committed to continue to work with the Faraday Battery Challenge and across Government to update this legislation, so the UK Government can ensure British companies are well placed to respond to these changes. The EU, too, is considering the revision of the Directive and it is likely that EPR responsibilities will be imposed alongside the setting of new collection and recycling targets. The UK will doubtless monitor these developments but will be free to determine its own mechanisms and targets.

5. Eco-Design for Recycling and Remanufacturing

The best place to optimise arrangements for end-of-life management is at the product design stage through an eco-design[18] for recycling and remanufacturing. Dismantling and component separation must be foreseen at this stage so that any component that makes a battery harder to dismantle should be replaced while waste arising out of production is minimised. The chemical make-up of the cells is continuing to evolve, which will bring ongoing challenges for their recycling.

Examples that ease separation of parts and make recycling economically viable include a separable cooling system, reversible joining (nuts and bolts instead of welds), and avoidance of potting or adhesive compounds to hold cells in place.[19] Vehicle manufacturers use a range of different configurations for the installation of the battery pack. Standardisation of pack assembly would also make it easier to use robotic disassembly for lithium-ion batteries, and thus enhance safe and efficient recycling.[19]

Removing and disassembling lithium-ion batteries is much more costly and time-consuming than for lead-acid batteries and the associated safety hazards are different. Lithium-ion

[12] M Romare & L Dahllöf, 'The life-cycle energy consumption and greenhouse gas emissions from lithium-ion batteries' (IVL Swedish Environmental Research Institute Report Number C 243, May 2017).
[13] EU Batteries Directive 2006.
[14] The Directive prohibits placing batteries and accumulators with a certain mercury or cadmium content on the market and establishes rules for the collection, recycling, treatment and disposal of waste batteries.
[15] Directive 2000/53/EC of 18 September 2000 on end-of-life vehicles
[16] Argus, Implementation of Directive 2000/53/EU on end-of-life vehicles (the ELV Directive) with emphasis on the end-of-life vehicles with unknown whereabouts (2016), see page 47.
[17] Our Waste, Our Resources: A Strategy for England, Defra (2018).
[18] Eco-design is the consideration of the whole-life environmental impacts of the product, i.e. it considers the ecological footprint of the product on the planet
[19] L Gaines, 'The future of automotive battery recycling: charting a sustainable course' (2014) 1-2 Sustainable Materials and Technologies.

packs are larger, more complex and vary in shape as well as the location in the vehicle. These batteries also contain many more individual cells connected together into modules which are in turn assembled into a pack. They also have a higher voltage and capacity and need to be handled by a qualified high-voltage technician.

The variability of lithium-ion battery pack design also means that this process does not easily lend itself to automated disassembly. Some of the complexities are illustrated in Figure 2. Again, the ideal way of achieving greater uniformity of design is by standardisation of core elements of the battery packs (such as their assembly) and government might wish to work either at the national level with BSI or at the international level through the OECD to promote the development and uptake of standards for EV lithium-ion batteries.

Regulatory provision of this type is already included for other waste electrical equipment under the EU WEEE Directive (2012).[20] The main relevant provision in Article 11 demands that Member States should ensure the easy removal of waste batteries and accumulators, i.e. their removal without delay or difficulty and at a reasonable cost. This facilitates recycling as well as extending the lifetime of the appliances in which the batteries are used.

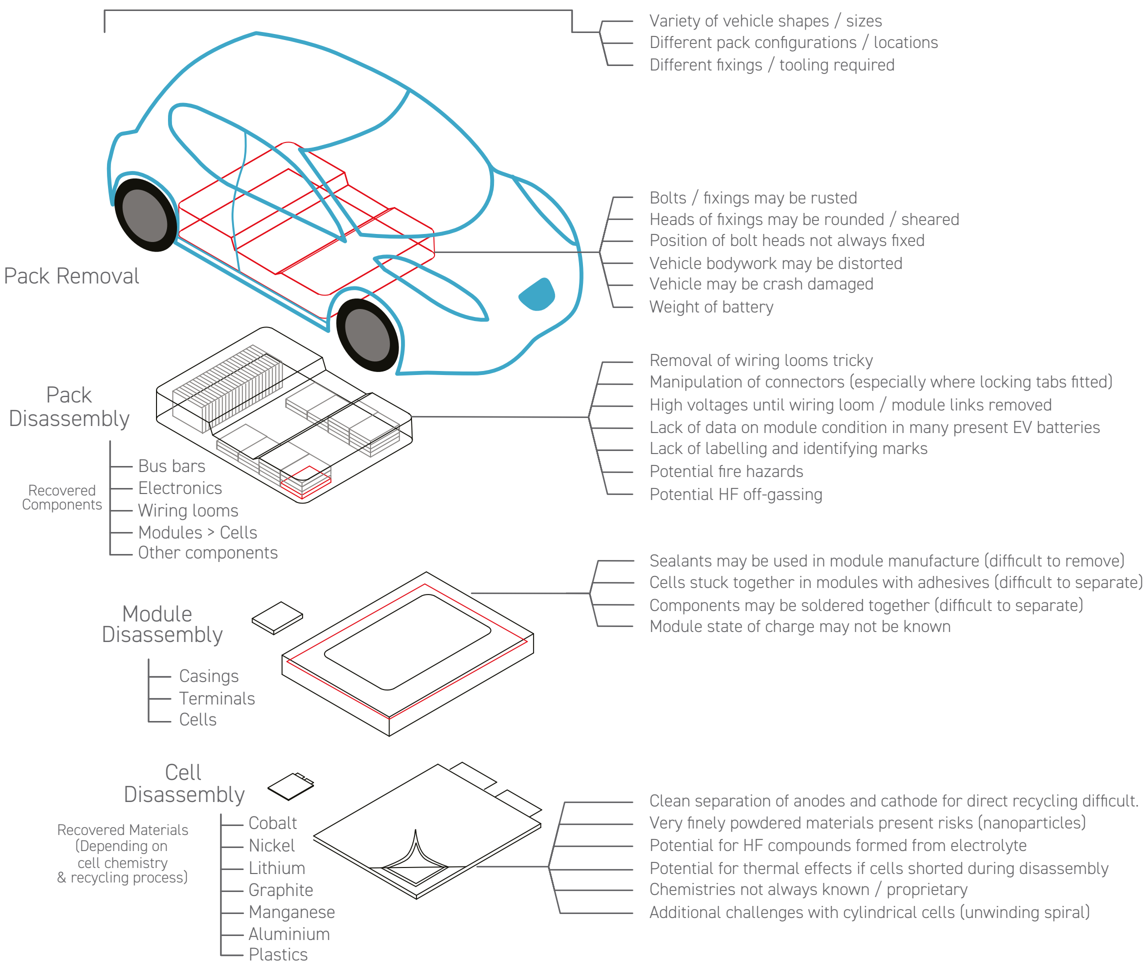
Defra also stated in the 2019 Resources from Waste Strategy that they will consider whether closer alignment between the batteries and WEEE regimes or indeed a single approach for both batteries and WEEE, is possible as part of their regulatory review. In 2019, the EU completed a study on Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries[21] as a precursor to reviewing whether Ecodesign Regulations could be expanded to include EVs and energy storage.

6. Protection of the Environment and Human Health

Lithium-ion batteries have the potential to harm the environment and human health. Waste law and the classification of EV lithium-ion batteries must be carefully considered and defined. Smart regulation techniques will be necessary to facilitate the transportation of waste to support recycling.

From the point at which an EV battery is removed from the vehicle, it poses an increased hazard to human health and the environment and needs careful handling. Even when fully discharged, this constitutes bulky waste, which will be coming through in high volumes in the future. Whatever

Figure 2: Challenges of disassembly at different levels of scale



[20] Directive 2012/19/EU on waste electrical and electronic equipment (WEEE).
[21] Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage, European Commission (August 2019).

solutions are devised for it, it will be necessary to take account of the potential for environmental harm.

Waste law needs to be carefully considered, including definitions of what constitutes a waste EV lithium-ion battery given its potential for immediate re-use with little adaptation. This might be taken to mean that no waste controls would be triggered since the battery is not discarded. However, there are good reasons for safety and materials' security to track the battery pack through its active use (for whatever purpose) to the point that it becomes waste.

Another consideration is the waste classification of EV lithium-ion batteries, which are not (yet) classed as hazardous waste. Fire risk alone, which could result from a single battery failure, suggests that we should consider the conditions that attach to their storage and treatment once in the waste chain; and waste management law may need appropriate adaptation.

Regulations controlling waste batteries do exist, but these are poorly positioned to regulate the large future volumes of lithium-ion waste flows. For example, there is a particular difficulty in transporting EV lithium-ion batteries, as while not labelled hazardous waste under the carriage regime, they are classed as dangerous in transit.[22] So even where regulation exists, some streamlining will be necessary to facilitate waste flows to support the recycling of end-of-life lithium-ion batteries.

7. Requirements for Chemistry Labelling

Better labelling of lithium-ion battery cathode chemistries will aid efficient sorting and routing of batteries. Currently, there is no requirement for the label on a battery pack to mention the specific type of cathode chemistry employed in a given battery, which makes recycling extremely complicated.

At present, the information needed on a lithium-ion battery label is minimal and simply needs to identify that it is a lithium-ion battery. However, lithium-ion is not one single technology, but the common descriptor for several different chemistries that all use a similar principle but a wide variety of materials. While the anode is fairly uniform for most cell types and is made historically of graphite, there are several different kinds of cathodes. The major cathode chemistries for automotive batteries include lithium-nickel-cobalt-aluminium, lithium-nickel-manganese-cobalt, lithium-manganese-spinel, lithium cobaltite and lithium-iron phosphate.

Many of the active materials are in the form of powders supported on metal foils and are formed into multiple layers, which make them difficult to separate. Within the cells, the chemical compositions of the active materials vary with manufacturer and battery function, are still evolving and may never standardise to the same extent as lead-acid batteries.

These factors contribute to making lithium-ion battery recycling much more complicated than lead-acid batteries. Better labelling would allow certain types of batteries to be recycled together and easily sorted or separated from those that need to be recycled in a different way.[19] Labelling is more important for consumer portable batteries than for EV lithium-ion batteries, but given that routes to recycling are uncertain, labelling is an obvious safeguard at this stage.

8. A UK Battery Recycling Industry

Although large amounts of lithium-ion battery packs will be available for recycling from around 2028, there are no substantial recycling facilities currently or planned for the UK. Many UK manufacturers currently export used lithium-ion batteries to European facilities (such as the Umicore facility in Belgium) for recycling. Batteries at the end-of-life are collected and exported for processing. This is expensive, logistically challenging, and only viable in the short term while the numbers of EV batteries reaching their end-of-life is relatively small. Moreover, it will not be safe to allow stockpiles of end-of-life batteries to accumulate in the UK. Existing EU facilities are insufficient to cater to the level of UK need in the coming decade.

In the light of these constraints and the aim to develop a more circular economy, it is essential to develop a functioning UK battery recycling industry alongside systems that enable the recovery of important components and avoid the export of end-of-life batteries. The difficulties of transfrontier shipment of waste lithium-ion batteries and the hazards posed by this waste stream mean that a UK recycling base is essential. Without the early development of UK waste recycling facilities, a serious waste problem will be created as waste volumes build up. The elements or requirements for a fully functioning UK recycling industry are illustrated in Figure 3.

Because the current volumes of end-of-life EV batteries generated are low and because of the many uncertainties that exist, government intervention will be necessary to help establish the first facility in the UK. It will also take time to negotiate the planning processes and necessary permits for a battery processing factory, making early start-up support imperative. Potential support mechanisms include recycling pilots and start-ups, alongside a national strategy for critical materials and their supply chains.

One issue that arises here is the extent to which the UK Government can intervene to positively support the development of a battery recycling industry. Such forms of assistance can constitute 'state aid' under EU law. This is ordinarily prohibited but exemptions can be allowed in cases such as support for policies of environmental protection. During the current implementation period, state aid rules apply. Whether or not they apply thereafter depends on what is negotiated in any future UK-EU trade agreement, and the scope that this leaves for the UK government to reform existing state aid provisions.

The EU is likely to argue for state aid provisions in any agreement but, in the event that a departure from EU law is agreed in this area, the WTO Agreement on Subsidies and Countervailing Measures will apply. This does leave more scope for industrial support because subsidy is not banned outright although other states might feel that it harms their interests. At a point in time, when these provisions are more clearly settled, the UK Government will need to consider the scope for supporting the development of EV battery recycling facilities.

[22] ADR (2019) 'European Agreements Concerning the International Carriage of Dangerous Goods by Road.'

Regulatory Issues across the Whole Battery Value Chain

Although this Insight has focussed only on the specific question of regulation for the end-of-life management of lithium-ion batteries, this is not the only area of the EV lifecycle where clearer regulations are needed. Other regulatory activity in relation to issues such as materials supply and sourcing, safety, storage/transport, manufacture etc. will also be needed.

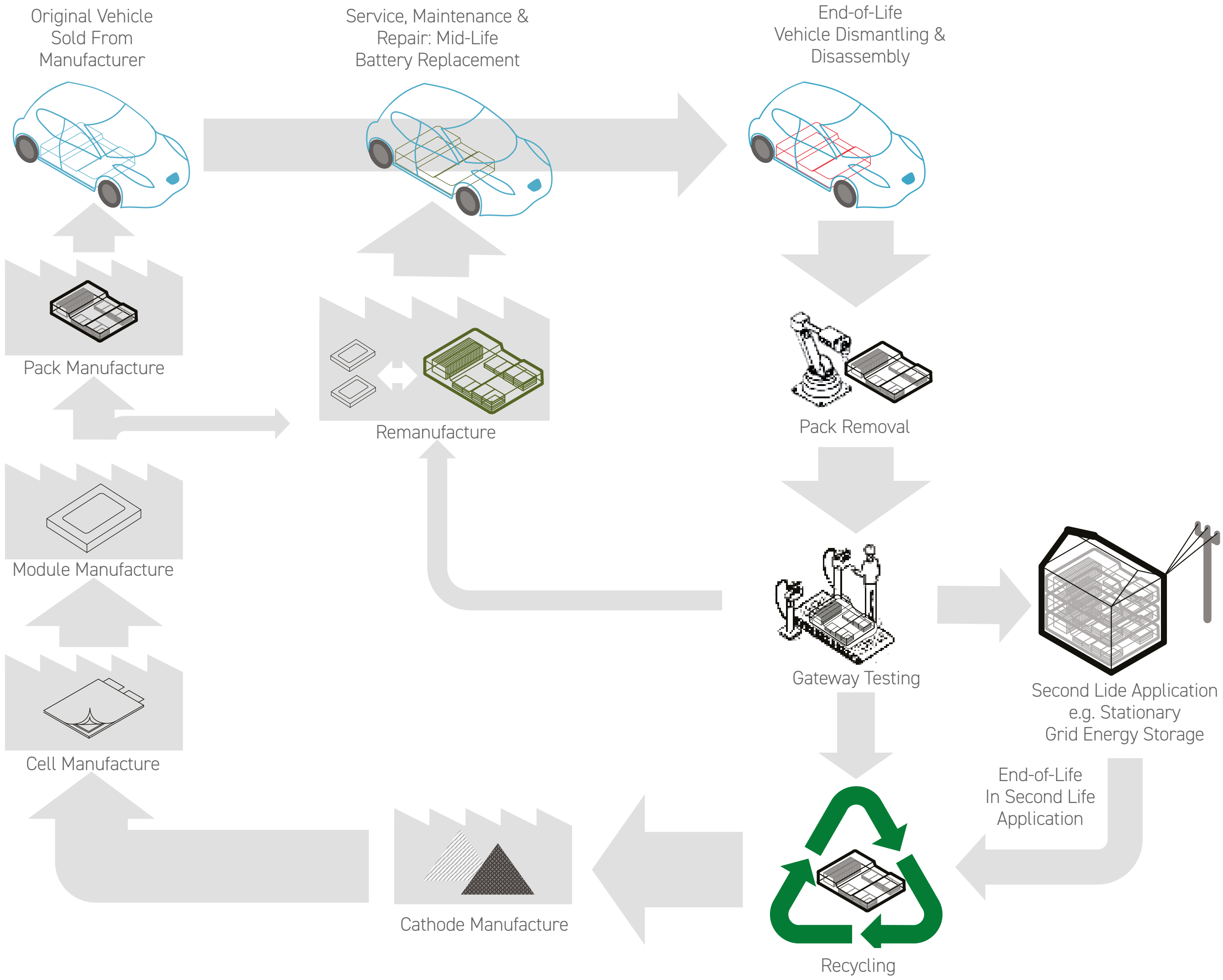
Measures such as progressive decarbonisation of the global power grid, better tracking of supply chains and materials and clarifying standards for safe transport and storage are also essential to achieve social and environmental goals.[23] Moves to standardisation in relation to battery packs would unquestionably help. Technological advances in lithium-ion battery recycling and re-use, as well as the development of more recycling facilities in the UK, will also prove essential.

Summary

This Insight has outlined the scale of the anticipated challenge to recycling and re-use of lithium-ion batteries and the high-level regulatory and policy framework required to help manage the issues. It makes the case for regulatory policy that supports lithium-ion battery recycling efficiencies and safe development of second-life applications. Policy and regulation need to keep pace with emerging technologies in the transition to EV mobility.

The current cost and complexities of lithium-ion battery recycling mean that early development of the regulatory and policy framework is crucial to driving innovation and industrial engagement to build an efficient circular economy in the UK. Regulatory changes will help facilitate the sustainable management of spent EV batteries, and thus help to achieve the circular economy goals of UK industrial policy. Appropriate regulations are a necessary step that will also help utilise the component parts of lithium-ion batteries in an efficient and profitable manner as part of a move towards a green, circular economy that will deliver benefit to the UK.

Figure 3: Elements of a functioning battery recycling industry



[23] T.R. Hawkins, B. Singh, G. Majeau-Bettez, A.H. Strømman. Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles (2013) 17 Journal of Industrial Ecology: 53.

About the Faraday Institution and Faraday Insights

The Faraday Institution is the UK's independent research institute for electrochemical energy storage research and skills development. We bring together academics and industry partners in a way that is fundamentally changing how basic research is carried out at scale to address industry-defined goals.

Our 'Faraday Insights' provide an evidence-based assessment of the market, economics, technology and capabilities for energy storage technologies and the transition to a fully electric UK. The insights are concise briefings that aim to help bridge knowledge gaps across industry, academia and government. If you would like to discuss any issues raised in this 'Faraday Insight', or our wider battery research programme, please contact Stephen Gifford.

Sign up today to be added to the distribution list for future Faraday Insights www.faraday.ac.uk/subscribe

CONTACT
Stephen Gifford
Chief Economist
stephen.gifford@faraday.ac.uk
www.faraday.ac.uk
01235 425125
07741 853068

Robert Lee
Co-Investigator
Faraday Institution ReLiB Project
University of Birmingham
r.g.lee@bham.ac.uk

THE FARADAY INSTITUTION

INDUSTRIAL STRATEGY

UK Research and Innovation