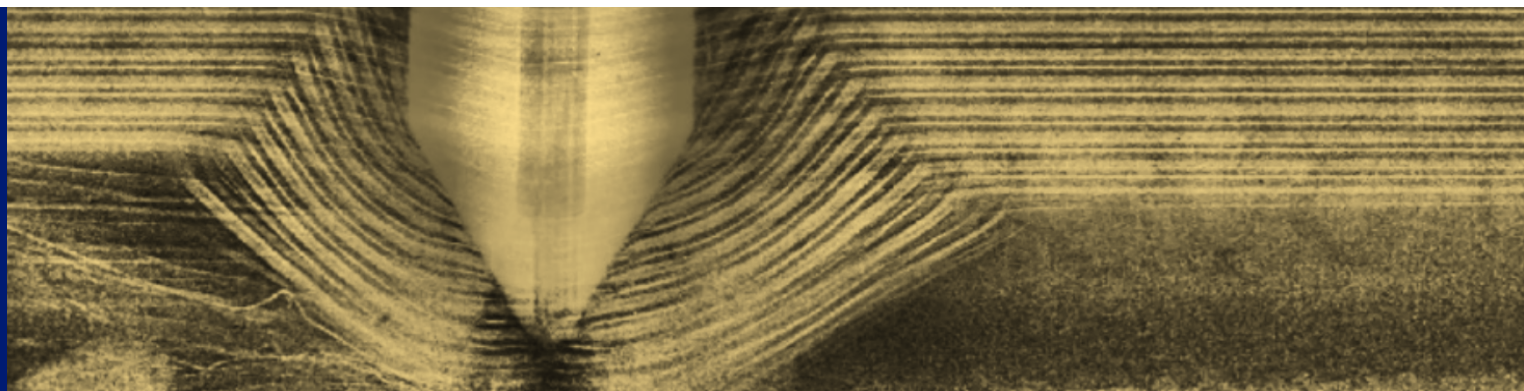


# Improving the Safety of Lithium-ion Battery Cells



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**Lithium-ion battery cells in electric vehicles are already safe and failure incidents are very rare. But with increasing use across automotive, stationary storage, aerospace and other sectors, there is a need to make them even safer. Whilst lithium-ion cell fires are extremely infrequent, they can occur under conditions of mechanical, thermal or electrical stress or abuse. Building safer and more reliable lithium-ion battery packs, as well as improving the design and optimisation of safety systems, will help to decrease the risks associated with rising lithium-ion battery usage.**

## Introduction

Even with billions of lithium-ion cells in circulation, there are very few safety incidents involving them, which is a testament to how safe they are. Rates of catastrophic cell failure and associated battery fires involving lithium-ion cells remain extremely low, with some estimates suggesting that only one in 40 million cells suffers such a failure.<sup>1</sup> But with an increasing range of use cases for lithium-ion batteries (LiBs), spanning electric vehicles (EVs), heavy goods vehicles, aerospace, micromobility and consumer electronics, as well as in second-life applications, the potential for problems is increasing. There is, therefore, a pressing need to improve LiB safety still further.

**As well as protecting end users, improving battery safety has economic benefits. Increasing the reliability of lithium-ion battery cells could allow EV automakers to reduce the complexity of their systems, saving space, weight, and system and warranty costs.**



This Insight looks at the routes to LiB failure, the different risks involved and the way fires in EVs differ to those in internal combustion engine (ICE) vehicles. It considers current mitigations in place and the additional mitigations that could

be implemented to further reduce these risks. It also sets out the work that the Faraday Institution SafeBatt project is undertaking to develop even safer LiBs.

## Routes to Cell Failure

When LiB fires do infrequently occur, the cause is generally due to the following forms of stress or abuse:

- **Mechanical** – An internal defect introduced during manufacture or damage caused to the cell by crushing or penetration (for example, from an EV collision or penetration by a sharp object) can lead to an internal short circuit. Shorting results in an excessive current flowing through the circuit, causing heating above safe limits, cell damage and, in some circumstances, may ignite a fire.
- **Thermal** – Overheating the cell (for example, if exposed to an external fire) causes the cell components, such as the cathode and electrolyte, to break down. These processes are heat generating (i.e. exothermic), resulting in a feedback loop where the cell temperature spirals upwards and eventually results in a fire. This is referred to as 'thermal runaway'. Overheating can also result in the softening or melting of the separator between the two electrodes (generally a polymer such as polypropylene), which can lead to an internal short circuit.

<sup>1</sup> D.H. Doughty and E.P. Roth, "A General Discussion of Li Ion Battery Safety", 2012 Electrochem. Soc. Interface 21 37.

- Electrical** – Shorting a LiB externally (for example, if a metal object is placed across the terminals or by cells in a battery shorting to one another) creates a low resistance pathway for a very high current to flow, which causes the temperature of the cell to rise above safe limits. Overcharging the cell by using, for example, an incorrect or incompatible charger, leads to internal heating and cathode breakdown, both of which contribute to thermal runaway. Poor pack design or poor battery management system (BMS) design can also result in some cells being overcharged. Overcharging is the most dangerous electrical abuse scenario, as it results in far more energy being pumped into the cell than the cell is designed to accommodate. If this leads to cell failure, the extra energy is released through a fire or explosion.

In summary, the operation of LiBs under the above abnormal or abuse conditions may lead to a significant temperature increase, as well as the venting of toxic and flammable gases, which then ignite and cause a fire or vapour cloud explosion. The mechanical, thermal and electrical abuse routes to LiB failure are schematically presented in Figure 1.

An EV battery has many cells, connected in series and parallel, to increase voltage and range. When a single cell enters thermal runaway, the heat can be propagated from cell to cell throughout the battery pack, escalating the hazard; eventually, all the cells in the battery pack may fail, venting the toxic and flammable gas mixture. When the gases vent from the cells they take with them small droplets of the organic solvents from the electrolyte, resulting in a white vapour cloud that may be mistaken for smoke or steam, and which could present an explosion risk.

The design of the whole system, namely the battery pack, inter-cell connections, surrounds (for example, insulation, packing material and casing), high voltage system and the thermal and electrical management systems, is critical to ensuring each cell is operated within its safe parameters,

thus mitigating cell failure and preventing cell-to-cell propagation of thermal runaway through the pack in the event that a cell does fail.

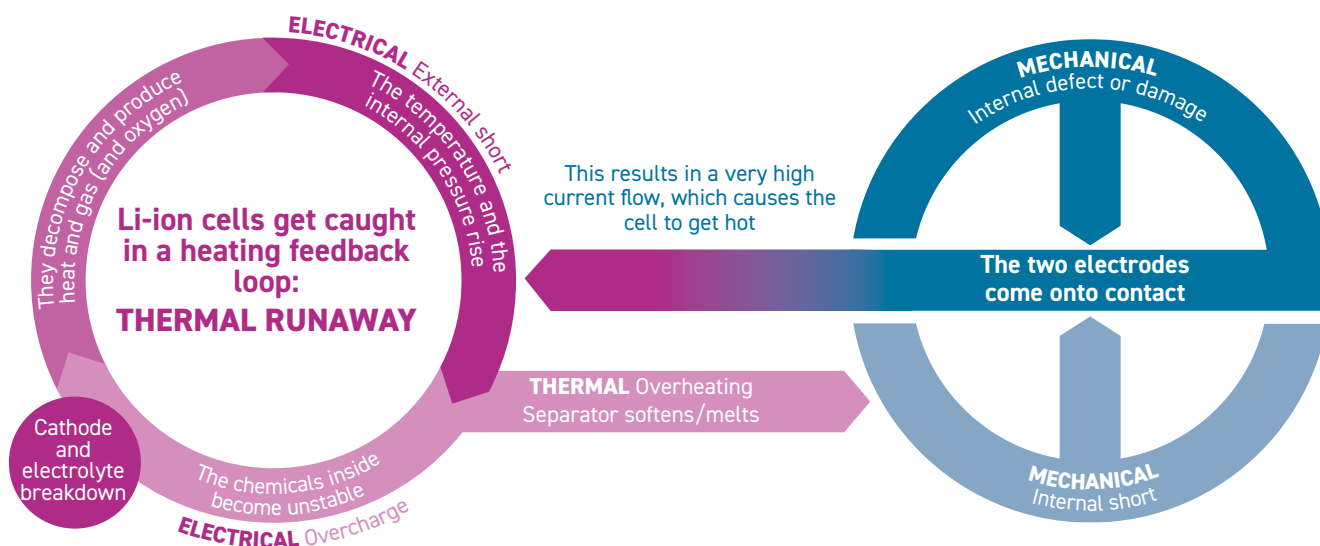
### Assessment of Risk

Vehicles containing LiBs present unique risks, which need to be understood and controlled. Of course, the perception of risk for a new, immature technology tends to be higher than the reality. Drivers of petrol cars are, in general, comfortable driving a vehicle containing a tank of flammable fuel because it is a familiar technology and risk. As EVs mature, the perception of risk will change. Factors that increase the risk of EVs catching fire compared with ICEs are summarised below.

**Table 1: Factors that increase the risk of fires in EVs and ICE vehicles**

Fire risk in electric vehicles	Fire risk in internal combustion engine vehicles
Additional risk for EVs during charging	Explosion risk when filling with petrol/diesel
Potential for a delayed fire in EVs, for instance, several days after a road traffic collision	Fire risk from the fuel in the vehicle
Risk that battery fires can re-ignite some time (hours, days or weeks) after being extinguished	Spillage risk, for example, if the fuel tank ruptures liquid can spill over the road and be a hazard to other drivers
Influence of ageing, as aged batteries may be more susceptible to catching fire/thermal runaway	Poor maintenance or ageing engines
Immaturity of the EV technology	

**Figure 1: Causes of lithium-ion cell failure**



### Incidents of fires in EVs and ICE vehicles

Rates of catastrophic LiB failure (fire or explosion) remain extremely low, ranging from 1 in 10 million to 1 in 40 million cells experiencing such a failure.<sup>1</sup> Emerging figures and comparisons of fire incidence rates for EVs and ICE vehicles<sup>2,3,4</sup> should be treated with caution as there is a lack of publicly available data from vehicle manufacturers and information varies. In 2022, the US insurance industry,<sup>3</sup> estimated 25 fires per 100,000 electric car sales (0.025%) and 3,475 fires per 100,000 hybrid vehicle sales (3.5%), compared to 1,530 fires per 100,000 (1.5%) petrol car sales. Data from the London Fire Brigade<sup>4</sup> indicated a fire incident rate in 2019 of around 0.1% per annum for plug-in vehicles relative to 0.04% per annum for petrol and diesel cars.

### Fire risks from DIY battery assembly

In EVs, the BMS, together with the battery pack electrical, thermal and mechanical design and the safety devices in the high voltage system (fuses, contactors, etc.) all help to manage and reduce risk and protect the vehicle occupants from hazards related to battery thermal runaway. A properly functioning vehicle should, therefore, not be able to operate the battery in an unsafe way, unless it is due to extreme events such as a collision. However, for smaller devices such as e-scooters and domestic battery energy storage systems (BESS), there is an increasing trend of 'do-it-yourself' battery assembly from sub-standard cells, posing a potential risk of house fires (see Box 2). Such systems may or may not include a BMS (or other safety devices) of sufficient quality to ensure that operation remains within safe parameters. Furthermore, many small LiBs in toys and radio control

#### Box 1: EV fires are different from petrol/diesel fires

The characteristics of fires in EVs differ from those in traditional ICE vehicles. EV battery fires release large amounts of heat, can be directional (involving projectiles), produce large volumes of toxic gases in a vapour cloud and produce micro- and nano-particles of nickel, cobalt and manganese metals and carbon fibres in fumes/smoke. EV fires also have the potential to reignite hours, days or even weeks after they have been extinguished, and may do so more than once.

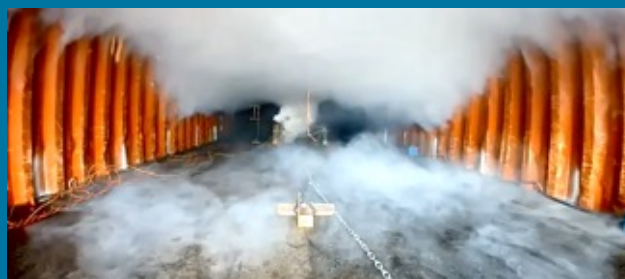
Battery fires involving lithium-ion cells take significantly longer to extinguish and require substantially larger volumes of water to do so. Any run-off water is toxic and should not be drained into the local environment. These differences could pose significant risks to human health if they are not managed or mitigated. Because of these unique risks, widespread reskilling of emergency service personnel, vehicle mechanics, auto dealers and the general public is required.<sup>5</sup>

In 2020, Professor Paul Christensen of Newcastle University (a co-investigator on the Faraday Institution's SafeBatt project) and his team were responsible for a major breakthrough, when they highlighted the previously unrecognised hazard of vapour cloud explosion from LiBs in thermal runaway. When overheated, crushed or overcharged, gases can be produced in lithium-ion cells, accompanied by a sudden increase in temperature under certain circumstances. This results in the venting of a vapour cloud (shown in Figure 2) that includes hydrogen, carbon monoxide, carbon dioxide and very small droplets of the organic solvents used in the electrolyte of the cells.

Emergency services had previously mistaken these clouds for steam or smoke, but their composition means they create the potential for a vapour cloud explosion,

which can be more damaging than the initial fire. Since its discovery, Professor Christensen has been delivering training and guidance to first responders around the world on how to deal with these vapour clouds safely. He has worked with over 40 different fire and rescue services across the globe, training hundreds of firefighters.<sup>6</sup> He was the recipient of the 2022 Motorola Foundations Knowledge Event Series award from the Australasian Fire and Emergency Service Authorities Council for educating fire and rescue services, police and government officials.

**Figure 2: Vapour cloud emitted from battery module undergoing nail penetration abuse test**



The risk of vapour cloud explosion is not confined to electric vehicles. The Norwegian Maritime Authority, for example, has recommended ship owners of vessels containing lithium-ion battery pack installations conduct new risk assessments that specifically cover the risk of explosion due to the accumulation of explosive gases in the event of LiB failure.<sup>7</sup> Because of the volume of vapour cloud released, even small LiBs (for example, for e-bikes and e-scooters) have caused vapour cloud explosions. There is a need for more scientific understanding of these complex failure processes, which is one of the goals of the SafeBatt programme.

<sup>2</sup> EV Fire Safe (December 2022). Passenger EV LiB Fire Incidents.

<sup>3</sup> Gas vs electric vehicle fires. AutoinsuranceEZ (2022), using data from the National Transportation Safety Board, Bureau of Transportation Statistics and US government recall data.

<sup>4</sup> Fleet News (November 2020). Vehicle fire data suggests higher incident rate for EVs, September 2020. The incident rate is based on 54 EV fires against 1,898 ICE fires in 2019 controlled for underlying vehicle registration numbers.

<sup>5</sup> Faraday Insight 4 (May 2021). Electric vehicle and battery safety skills for emergency services, vehicle repair, and auto retailers.

<sup>6</sup> Faraday Institution success story: Research breakthrough increases safety of lithium-ion batteries, June 2022.

<sup>7</sup> IMCA (October 2019). Battery fire with subsequent gas explosion: Warning about lithium-ion power following ferry fire.

hobby equipment just have single or multiple cells wired together and are charged with no BMS.

## Box 2: Safety in the micromobility<sup>8</sup> and BESS industries

With a 70% growth in e-bike sales in 2020 in the UK,<sup>9</sup> reports of thermal runaway events related to battery failures in micromobility applications resulting in fires and interior damage to flats/houses are increasing. Several fire services around the country have reported incidents linked to e-scooters and e-bikes, with the London Fire Brigade attending 28 e-scooter/e-bike fires in 2020 and 74 in 2021.<sup>10</sup> It is not clear whether these incidents were primarily due to battery design issues, the use of home-made replacement batteries (for example, in e-bikes) or incompatible/incorrectly specified chargers.

Dissemination of best practices to industry and consumers would be useful to mitigate these risks. It is essential that users are informed about the hazards of 'do-it-yourself' battery assembly, charging devices at home and bypassing safety features. The BMS and charging device must be designed to operate safely in conjunction with each other and the battery pack and charging device should be purchased simultaneously from a reputable supplier. A national education initiative, initially aimed at consumers and the wider public, is required to disseminate best practice and improve knowledge of risks.

The online trade in lithium-ion cells and batteries (including second life cells) also needs to be regulated and additional policy changes are required to ensure that the micromobility and BESS industries are subject to the same rigorous regulations as EVs. For example, a standard similar to UK Conformity Assessed (UKCA) marking, but specifically for the battery, could be introduced.

## Fire risks in the recycling space

Fires are a significant problem in recycling and waste facilities, with nearly one-third of incidents in these facilities (around 250 fires) in the UK between April 2019 and March 2020 attributed to LiBs,<sup>11</sup> with financial, environmental and societal costs amounting to £150 million in 2021 (Table 2). Currently, these fires typically involve small LiBs from consumer electronic products rather than from EVs. However, as the EV market grows, volumes of materials are set to increase substantially in recycling facilities over the next 5 to 10 years. Disposal of automotive and industrial batteries in landfill or by incineration is prohibited<sup>12</sup> and the development of appropriate recycling infrastructure to handle these volumes is critical. These facilities will need to put mitigative measures in place to ensure batteries can be safely recycled.

**Table 2: UK cost of waste fires caused by lithium-ion batteries**

Fire severity category	% of total fires	Estimated cost per fire (£ million)	Annual number of waste fires attributed to LiBs	Estimated annual cost (£ million)
1 (most severe)	1%	£3.8	1.7	£6.6
2	5%	£1.8	10.4	£19.0
3	73%	£0.9	147.5	£128.6
4 (least severe)	21%	£0.1	41.8	£3.8
<b>Total</b>			<b>201</b>	<b>£158.0</b>

**Source:** Eunomia (January 2021). [Cutting Lithium-ion Battery Fires in the Waste Industry.](#)

Tackling the risk and impact of fires in recycling and waste facilities requires a mix of regulation, policy and incentives, but the overall framework is similar, irrespective of whether the battery is from the consumer electronics market or an EV. Initiatives that can be implemented with immediate effect include public awareness campaigns, separate collection from households and businesses, increasing collection points, banning LiBs from residual/mixed recycling schemes, enhanced extended producer responsibilities and creating incentive schemes to encourage the return of LiBs for recycling. Longer-term initiatives are focused on research that aims to reduce the risk of fires when LiBs are damaged and the development and commercialisation of new battery chemistries that are intrinsically safer than those currently in use.

## Mitigations in Place

Although the rapid adoption of LIBs in EVs over the past few years has inevitably led to various media reports of fire incidents, LIB chemistries and cell designs have been under development for over 30 years and have been used extensively in consumer electronic applications for decades. Scientists and engineers continue to improve their understanding of these systems and innovative research and development is enabling the adoption of LIBs into new applications.

Novel technologies and cell components are under development to enable longer lifetime and driving range, coupled with improved safety. Sophisticated modelling techniques are increasing the understanding of the behaviour of LiBs under normal and extraordinary conditions, improving safety performance. Additionally, multiple mitigations are in use by cell manufacturers, pack designers and manufacturers

<sup>8</sup> For more details on micromobility, see: [Faraday Insight 16 \(February 2023\). The Micromobility Revolution Gathers Momentum.](#)

<sup>9</sup> [Mintel \(June 2021\). The great British bike boom: Brits bought over 3 million bikes in 2020.](#)

<sup>10</sup> [iNews \(May 2022\). Fears legalisation of e-scooters could lead to more house fires as batteries can 'explode'.](#)

<sup>11</sup> [Environmental Services Association \(October 2020\). Press Release.](#)

<sup>12</sup> [The Waste Batteries and Accumulators Regulations 2009.](#)



as well as the wider supply chain to minimise risks from the use of LiBs.

### Battery management systems

LiBs used in EVs have electronic circuitry that is monitored in the battery management system (BMS). This records cell voltage, temperature and charge, as well as ensuring cells are always balanced (i.e., the same voltage or state of charge). BMSs are generally always active (during charging, when parked and during use) and have safety features to prevent overcharging. The BMS is especially important when the battery is being charged, as it is in this situation that the battery is most likely to fail.

### EV safety systems

For many years automakers have focused on minimising risks around the use of LiBs in EVs. Multiple safety systems are now designed into EVs to protect passengers, emergency services, mechanics and other users from harm, including:

- Employing overcharge protection additives in the electrolyte in LiB cells.
- Incorporating features such as thermal and BMS, venting devices and fire-retardant materials into the battery pack and system.
- Integrating battery packs into the vehicle crash system design to minimise risk from impact.
- Developing flexible BMSs, which ensure that the EV operates well within application/design limits and can switch the vehicle to operate in different modes to protect the car and its occupants if safe operating limits are exceeded.
- Checking all high voltage circuits in an EV on start-up, before closing the battery circuit breakers.
- Employing suitable electrical, thermal and mechanical pack design rules to reduce risk.
- Incorporating an additional layer of protection (above that of the BMS) in the high voltage system, with fuses, contactors etc.
- Building in redundancy in certain safety systems, to ensure that if a critical component fails, a second one will take over control.
- Enhanced manufacturing quality and robust certification.

### Battery testing

Lithium-ion cells and batteries are required to undergo extensive testing at cell, module, pack and system level, and stringent quality control, before use in EVs. This includes assessment of cell and battery performance, as well as safety and abuse testing. Examples of different tests undertaken and testing regimes in place include:

- Extensive thermal, electrical and impact testing (for example, according to standards such as GB 38031-2020) under both normal operating conditions and abuse conditions, to comply with international legislation as well as the automakers' own safety standards.
- Ensuring that cells and batteries are tested to relevant standards, such as UN38.3, SAE, ISO, IEEE, IEC, BS EN and UL.<sup>13</sup>

### Benefits of improved cell safety

Increasing the safety of LiBs could allow automakers to reduce the complexity of the overall system (redundancy, packaging and BMS sophistication), saving space, weight and cost.

Safer LiBs may lead to a decrease in warranty costs. These costs can be substantial, potentially amounting to £10,000 or more, owing to the significant battery replacement costs.<sup>14</sup> The precise costs will depend on the warranty model, with the costs for out-of-warranty replacements subject to a service part mark-up set by automakers. Considering propagating effects, such as the spread of EV battery fires, the total cost from a single EV failure is likely to be higher than that of an ICE vehicle.

Improving the safety of LiBs is also critical to enable their adoption in non-automotive industries, such as aviation, aerospace, maritime, rail and stationary storage, leading to considerable economic benefits. There would be a particularly significant gain for the aviation industry as it evidently demands the highest safety standards commensurate with its unique operational conditions and the potential consequences of failure at high altitudes. To ensure the safe operation of battery-powered aircraft, yet more advanced temperature and safety features as well as new certification policies, are essential.

### Making Batteries Even Safer

In 2021, the Faraday Institution launched the LiB safety research programme, SafeBatt. This project takes a broad look at the science of LiB safety, building on the previous work of the Faraday Institution's Degradation and ReLiB projects. Led by Professor Paul Shearing at the University of Oxford, SafeBatt is a collaboration between eight academic<sup>15</sup> and numerous industry partners, across the following research areas:

- Studying sub-cell level events to understand the root causes of cell failure and the interplay between degradation and safety.
- Investigating how LiBs fail at the cell level and how cell failure propagates within a module/battery.
- Carrying out large-scale experiments on modules and

<sup>13</sup> UN38.3 (United Nations Standard to certify cells for transport); SAE (Society of Automotive Engineers); ISO (International Organisation for Standardization); IEEE (Institute of Electrical and Electronics Engineers); IEC (International Electrotechnical Commission), BS EN (British Standards Institution version of European Standard) and UL (Underwriters Laboratories). This list is not exhaustive as there are many different standards for different applications in use worldwide.

<sup>14</sup> Electrek (September 2021), [Tesla Battery Replacement](#).

<sup>15</sup> Academic partners are the University of Oxford (lead), University College London, King's College London, Imperial College London and the Universities of Cambridge, Newcastle, Sheffield and Warwick.

battery packs to observe how they behave under stress and understand the processes occurring during real-world failure, including the toxicity and environmental consequences of lithium-ion battery fires.

- Providing underpinning modelling and experimental tools to enhance understanding of the science of battery safety and deploying these to tackle key industry challenges.

The overall aim of SafeBatt is to understand the range of processes that could lead to LiB failure, which will help industry both to design and build more safety-reliable battery packs and to simplify safety systems. Further details are given in Box 3.

SafeBatt researchers are already using their skills and knowledge to advise fire services, local authorities and other government agencies on the risks posed by lithium-ion cells and batteries and how to respond to emergencies. SafeBatt research associates are also training and educating stakeholder groups in the UK and internationally.

A coordinated approach to LiB safety research and validation will greatly benefit the UK, particularly in the domain of standards development for emerging sectors such as electric aviation battery safety. By linking the Faraday Institution project with industry and government bodies, such as the Health and Safety Executive (HSE) and the National Physical Laboratory (NPL), the UK could position itself as a centre of excellence for battery safety.

### Legislation and Policy

There is a huge volume of legislation in place globally to minimise EV battery safety risks, but legislation and testing regimes for lithium-ion cells are highly dependent on geography and application. Furthermore, insufficient consideration has yet been given to repurposed and second-life lithium-ion cells and batteries. The adoption of global standardisation of testing and legislation in this area would not only increase safety but also save time and money.

The legislative and testing framework for battery safety in other sectors, such as aerospace and stationary storage (including repurposed and second-life lithium-ion cells and batteries) is in its infancy. There is a need for governments, industry bodies, standards institutes such as the British Standards Institution and measurement institutes such as the NPL, to work collaboratively to agree international legislation and testing protocols that are industry recognised, fit for purpose and coherent across boundaries. The HSE should also play a crucial role in providing guidance and enforcing safety regulations.

Measures that need to be taken to minimise further the unique safety risks of EVs include skills development for emergency service personnel, auto retailers and mechanics (with programmes led by appropriate government departments and coordinated through professional bodies and skills councils), and the adoption of a coherent, national framework and industry recognised guidelines for the safe handling and recycling of used and/or damaged EV LIBs.

#### Box 3: Objectives of the SafeBatt research programme

- Identify the safety signatures of LiBs and how they change over the cell lifetime and with degradation:
  - When does a degraded cell become an unsafe cell?
  - What are the specific safety signatures of degraded materials?
- Investigate the effect of fast charging and operation under extreme conditions on cell ageing and safety:
  - How do fast charging and cold charging affect the formation of dendrites and cell safety?
- Understand how cell failure modes translate to multi-cell modules:
  - Is there a minimum cell count that can be shown to be representative of a module, and how might cell-to-pack designs affect this?
- Develop an advanced model or models for thermal runaway and propagation:
  - What are the reaction pathways during cell failure?
  - What is the temperature distribution in a cell approaching thermal runaway?
  - What gases and other ejecta are released from a ruptured cell?
- What is the flame structure and behaviour?
- How does thermal runaway propagate from cell to cell?
- Develop a method to instrument cells to measure the internal temperature and pressure during failure.
- Investigate detection methods and mitigation strategies for thermal runaway.
- Improve the understanding of real-world battery failure:
  - What is the impact of failure in confined spaces, such as underground car parks?
  - How does ageing influence the stability and safety of LiBs in second life applications, for example, energy storage systems?
  - What factors affect the composition and toxicity of the vapour cloud and other gases and particulates emitted on venting?
  - What are the efficacy and environmental consequences of LiB fire extinguishing systems?
- Engage with standards bodies and provide expert advice to stakeholders such as the emergency services, cell/battery manufacturing facilities, recycling and storage facilities and government.

### Summary

Rates of catastrophic LiB failure remain extremely low, but with EV demand increasing and new applications and technologies emerging, there is a need to enhance LiB safety and the understanding of safety further. The economic case for building safer LiBs is compelling, the key benefits being lower warranty costs and a reduction in the financial cost of damage to EVs from a pack failing catastrophically. Warranty costs for EV automakers in the UK are expected to reach around £780 million per annum by 2030,<sup>16</sup> and in this context, even small safety improvements will have a significant positive economic benefit.

The SafeBatt initiative represents a pivotal step in enhancing LiB safety, which is vital for supporting the growing demand and expanding applications of LiBs. Alongside this ongoing research, the safety of batteries will also be an important cross-departmental government concern, that requires a coordinated approach involving activities such as:

- Educating end-users, the emergency services and other stakeholders on safety risks, mitigation measures and how to deal with any fires will be critical as the UK battery industry moves forward.
- The development of a coherent UK framework and industry-recognised guidelines for the safe handling, recycling and disposal of used and damaged EV LiBs to minimise safety risks.
- International collaboration to establish global standards of testing and legislation for LiBs across different applications and geographies, including repurposed and second-life batteries.

The need for an integrated understanding of the science of LiB safety will only increase with time. Next generation LiBs will contain even more energy as automakers seek to extend EV range. LiBs are also expanding into ever-increasing applications, such as e-scooters, aviation, marine, and domestic and industrial energy storage systems, as well as starting to permeate second-life applications and enter recycling facilities. Managing the risks associated with these new applications will require a combination of regulation, dissemination of best practices and ongoing scientific research to ensure safety across all sectors.

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<sup>16</sup> Faraday Insight 15 (December 2022). The Value of Modelling for Battery Development and UK.

### About the Faraday Institution and Faraday Insights

The Faraday Institution is the UK's independent institute for electrochemical energy storage research, skills development, market analysis, and early-stage commercialisation. 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 by this "Faraday Insight" or suggest a subject for a future Insight, please contact Stephen Gifford.

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