Impact of BEV Adoption on the Repair and Insurance Sectors

Final Report

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Contents

Acronyms

ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
BEV	Battery Electric Vehicles
CCC	Climate Change Commission
CRM	Critical Raw Material
Euro NCAP	European New Car Assessment Programme
FNOL	First Notification of Loss
HV	High Voltage
ICE	Internal Combustion Engine
LCA	Life-Cycle Analysis
LiB	Lithium Ion Battery
Li-Ion	Lithium Ion
OEM	Original Equipment Manufacturer
RTA	Road Traffic Accident
SMMT	Society of Motor Manufacturers and Traders
SoC	State of Charge
SoH	State of Health
SRS	Supplemental Restraint System
VDA	Vehicle Damage Assessor
VM	Vehicle Manufacturer

1. Executive Summary

Thatcham Research has been working to understand the potential impacts of adoption of Battery Electric Vehicles (BEVs) along with other new vehicle powertrain options such as Hydrogen Fuel Cell Electric Vehicles and various forms of hybrid powertrains for over 5 years.

This report looks specifically at the end-to-end differences to the Insurance Claims Process that arise because of the technical and practical differences between BEVs and Internal Combustion Engine (ICE) vehicles. It explores the potential technical and practical implications for Motor Insurers and their supply chains as well as highlighting impacts on consumers.

Furthermore, the report attempts to project some of the consequences of identified challenges using historical claims data, early views of performance of BEVs in the market and modelling of future state.

The findings of the report can be summarised as:

- There is no part of the Motor Insurance Claims process which is unaffected by BEVs. The workflow impacts are profound and will, over time, force a wholescale adaption of the industry.
- Much of the Motor Insurance industry is yet to start to adapt to the challenges ahead and the implications remain unquantified on repair capacity, training and skills, cost, and the lifetime sustainability of BEVs. Despite this, the Motor Insurance industry is already seeing BEVs performing differently in the market. BEV claims are already ~25.5% more expensive than their ICE equivalents and are taking ~14% longer to repair. It is impossible to quantify whether total-loss rates are higher for the current generation of vehicles as there are too many confounding factors.
- Varying lack of engagement and awareness across all parties in the market presents barriers to quantification of the impact of increased BEV uptake on motor insurer costs, claims workflow, and repair. It is highly likely that early data on BEV performance paints an incomplete picture of the challenge.
- For many of the future challenges that will arise as adoption of BEVs in the UK Car Parc (all registered cars within the UK) grows there are possible solutions to mitigate or enable adaption of the market, however this requires further research, facilitation, and market support. Consultation with several of Thatcham Research's member organisations and their supply chains in preparation of this report indicates that there is a significant lack of awareness of those challenges and a reluctance to engage with wholescale change until there is a significantly higher percentage of BEVs in the UK Car Parc.
- The most significant challenges to the claims flow originate from high voltage (HV) batteries. BEV batteries are a significant percentage of the original vehicle value, rapidly presenting significant negative impact to the economic model of vehicle repair. Despite the relatively small number of BEVs in the market there is already a lack of affordable or available repair solutions, inadequate post-accident diagnostics, and limited availability of recycling and reusability options. Without meaningful change, there is a strong likelihood that claims costs will continue to rise disproportionally. Modelling shows that in 2022, 9400 vehicles were potentially involved in an accident which could result in battery inclusion in a post-accident repair. This is estimated to reach up to 260,000 vehicles annually by 2035.

  - Although several vehicle manufacturers are considering repair schemes, battery recycling and repurposing schemes and indeed battery remanufacturing, little or none of this is yet planned in the UK market. Feedback from the vehicle recycling industry in the UK is that no value is being recovered from UK based BEV batteries and in fact it costs money to dispose of batteries. Those costs include export of materials to Europe and re-import of waste.

Although technical solutions exist for most if not all challenges highlighted in this report, the predicted rate of adoption of BEVs may be impacted by the increase in cost and complexity of the supply chain issues. Insurance premiums are anticipated to rise as risks and costs are increasingly quantified by insurers.

With the forecasted adoption curves and current market readiness, it is imperative that action be taken imminently. This action should take the form of credible cross-industry plans to address the challenges of battery cost, diagnostics, and creation of a sustainable ecosystem for battery repair, refurbishment, paths to second life applications and cost-effective recycling, otherwise mass-market adoption of BEVs will suffer practical and economic challenges which will impact business and consumers alike.

2. Introduction

The full transition to battery electric vehicles (BEVs) is seen as one of the most important actions to achieve the UK's Net Zero target. By 2035, government legislation requires all new light-duty vehicles sold in the UK to emit zero tail-pipe emissions. To reach the current Net Zero target, all vehicles need to be 'fossil fuel free' by 2050.

The move to Zero Emissions Vehicles for road transport is occurring in response to two substantial challenges: Climate change and air quality.

- Emissions of CO_2 are a huge contribution to climate change and have a global impact. It is the total level of greenhouse gases in the atmosphere that influences the global climate.
- Tailpipe emissions of other pollutants such as Nitrogen Oxides (NOx) and particulates affect air quality and can directly cause serious respiratory problems and premature deaths in people that are exposed to elevated levels. These emissions have a localised effect and will be high near busy roads and much lower further away from them.
- Cars and taxis alone accounted for 56% of the UK's domestic transport emissions in 2019 [1].

With conventional Internal Combustion Engine (ICE) vehicles, these two objectives have been in partial conflict because measures to improve air quality through the legislation known as the Euro standards (e.g., Euro IV, V, VI etc) has tended to make it harder to reduce CO_2 [2]. NOx emissions are mitigated through reducing combustion temperature within an engine, particularly in diesel engines. This limits fuel efficiency and results in the vehicle creating more CO_2 emissions [3].

Alignment to the UK Government's Road to Zero strategy and enablement of its success is a primary driver for the UK Insurance Industries priorities. The journey however is not without its challenges.

2.1 Thatcham Research Provenance

Thatcham Research has been working to understand the potential impacts of adoption of Battery Electric Vehicles (BEVs) along with other new vehicle powertrain options such as Hydrogen Fuel Cell Electric Vehicles and various forms of hybrid powertrains for over 5 years. This work has included:

- Understanding and providing industry solutions to enable the repair industry to understand the dangers of working with BEVs.
- Providing cross-industry training approaches, recognizing that BEVs are not just a technical challenge for training body-shop technicians.
- Analysing BEVs from an engineering perspective and quantifying their insurance risk differential against conventional ICE vehicles.
- Understanding the impact of new technologies and systems on every part of an insurer's workflow.

2.2 Purpose

This document seeks to provide an awareness of, and to forecast the impact of the potential issues arising from an increase of BEV adoption in the UK Car Parc. Using current data sets already available to Thatcham Research and supported by additional data from LV= and Synetiq, Thatcham Research can show the impact that the rising numbers of BEVs will have on the repair and salvage process, and crucially the whole motor insurance sector. This impact is likely in turn, to impact consumers with both their experiences of ownership and the associated potential cost increases.

Focusing on the downstream process following a claim, this document highlights key areas of current issues, along with anticipated issues which are yet to be realised issues due to the current volume in the Car Parc.

Although data on BEV underwriting performance in the market is limited, the report uses examples based on long established knowledge and models of internal combustion engine (ICE) vehicle insurance underwriting and claims, along with current examples of BEV data to support both current and projected impacts to the motor insurance market.

This report identifies challenges and recommendations associated with the increased uptake of BEVs in the UK Car Parc, however, it does not propose solutions as further investigation would be required.

This study and subsequent analysis does not consider the crossover between ICE and BEV vehicles of Hybrid or Plug-in Hybrid Electric Vehicles (HEVs and PHEV).

3. The Insurance Process

As of Quarter 3, 2022, the UK vehicle Car Parc is made up of only 1.65% BEVs [4], however, that is going to radically change in the coming years, with sales of new BEVs already rising to record levels. December 2022 saw BEVs claim their largest ever new vehicle monthly market share, of 32.9%, while for the whole of 2022, they comprised 16.6% of new registrations [5]. LCVs and commercial vehicles are also going to see a radical shift but perhaps at a slower pace and with the options for achieving zero emissions such as Hydrogen based Fuel Cell Electric vehicles (FCEV) looking like a potentially major growth technology.

This matters to motor insurers, who traditionally base their underwriting and pricing practices, along with their claims handling on historical vehicle experience in the market which is limited for BEVs. Although technology advances within vehicles have been aggressively changing vehicle risk for some years, nothing has caused such a fundamental shift in vehicle design and implementation as the electrification of the power train.

A sustainable motor insurance market which can offer insurance to both private and fleet / commercial customers at a competitive premium, whilst providing the required level of cover, is essential to any migration of the UK Car Parc in line with zero emissions targets.

Although zero emissions vehicles have many features and factors in common with conventional vehicles, there are several factors which add complexity and cost into insurance and associated post incident vehicle handling and repair. These factors are discussed at length throughout this paper.

3.1 Underwriting challenges – managing risk

Electrification of automotive vehicle powertrains and technologies is forecast to continue to proliferate in the UK Carparc over the next 10-15 years. Therefore, we should accept and expect that the volume of vehicles with an electrified powertrain being involved in Road Traffic Accidents (RTAs) and requiring recovery and repair will also increase significantly. Longer term we can expect this type of powertrain to make up the majority of vehicles in the insurance accident repair parc.

Whilst regulations for electric vehicles have not changed significantly, UK Government and European emissions targets are focusing vehicle manufacturers strategies to bring down the carbon footprint of their vehicle fleets. This will only continue to increase the number of electrified vehicles on UK roads and while vehicles such as mild hybrids and plug-in hybrids continue to increase in numbers, they are only steppingstones in the switch to fully electric vehicles.

The timescale for the end of new purely-ICE powered vehicles has already been brought forward effectively to 2030 for the UK. This date may be brought further forwards in the same vein as countries such as Norway (2025). No new hybrid or plug-in hybrid vehicles will be sold from, at the latest, 2035.

Over the next 10-15 years, we expect to see the rise in electric vehicle sales as the new norm, which will eclipse diesel powered vehicles first followed closely by petrol.

The future of HV batteries, commonly defined as batteries with outputs over 400 volts, is of high interest. Universities, Industrial companies, and vehicle manufacturers are searching for the ideal chemistry to bring long range, long cycle life, low degradation and above all safety to vehicle batteries.

There are numerous new risk-affecting factors which change the way insurers build their financial and pricing models. Many, but not all, relate to the differences in handling vehicles post-accident in the claims flow:

- BEV weight is approx. 300 - 500 kgs heavier than ICE equivalents. This will no doubt have a cost implication in RTAs with the increase in vehicle mass due to increased severity.
- Most high voltage components are expensive and costly to replace.
- Key-to-key times are crucial (time from FNoL (See 3.2.1) to the keys being returned to the customer), and a total repair being carried out at a receiving repairer has obvious benefits. There are many new factors which make the repair more complex and therefore likely to increase the time taken to process a claim to completion.
- High voltage component availability and cost needs to be monitored at an early stage, with numbers of electric vehicles rising, component availability and cost control are crucial to avoid total loss.
- High voltage component location and vulnerability must be considered at an early stage, i.e., will a low-speed accident impact heavily on cost if high voltage components are involved.

3.2 The Claims Process

At a very high level, Figure 1 below represents a high-level flow of a motor insurance accident claim.

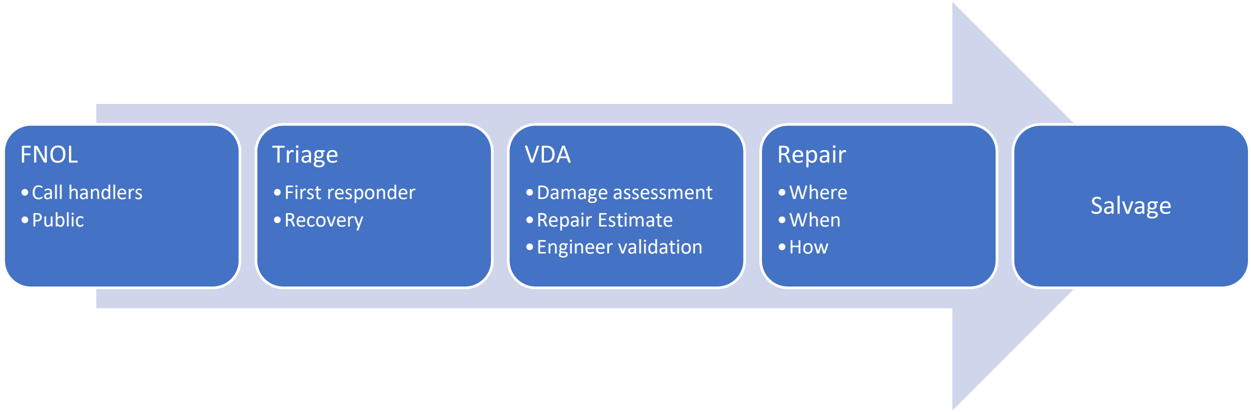

Figure 1: High level flow of motor insurance accident claim

Noting in figure 1 that the salvage section appears at the end of the flow, however, this section can take place any time after FNOL if deemed the correct decision.

Post-accident claims form a significant part of an insurer's work, with spend on repairs and total losses one of the most controllable elements of spend. Making the right decision at the right time and optimising the workflow is critical to the provision of cost-effective insurance and traditionally forms one of the more financially controllable aspects of a motor insurer's work.

Claim performance has a financial impact on the insurer but also has a significant effect on customer satisfaction. UK insurers try to target claims handling time to 7-14 days. Every day a claim is open costs money as well as impacting customer satisfaction.

There is a wide variation in the way that individual insurers handle the claims process. As such, the following sections have genericised the process as far as possible.

3.2.1 FNOL – First Notification of Loss

FNOL refers to the moment at which a policy holder notifies an insurer of an accident or incident (a loss). Typically supported by a telephone claims handler but increasingly through automated, AI supported tools.

The main purpose of FNOL is to make quick and accurate decisions about handling of the customer's loss. Questions are asked of the policy holder and data gather at the point of FNOL which supports decision making.

3.2.2 Triage

Basic triaging is performed immediately post FNOL using the information gathered at the point of loss.

- Immediate high-level assessment of accident circumstances and severity.
- Initial assessment of vehicle damage levels.
- Determine if emergency services or first responders are required at the scene of any accident.
- Modelling and early decision making about the viability of any repair, including rapid assessment of whether a vehicle should be marked for total-loss.
- Routing decisions for optimization of repair time / quality.
- Transportation and recovery decisions for the damaged vehicle.

3.2.3 Vehicle Damage Assessment

Typically performed in a bodyshop, but sometimes in other locations, highly trained Vehicle Damage Assessors (VDAs) perform detailed analysis of the damage condition of a vehicle.

VDAs have a process of assessing and costing repair of a vehicle and use industry standard electronic estimating software to document their findings. To be successful VDAs will have knowledge of all types of vehicles including petrol, diesel, electric and hybrid and typically stay abreast of ever-changing vehicle technology.

During this process they will:

- Methodically and accurately inspect and assess all elements of a motor vehicle that has sustained damage and requires repair.
- Identify and record damage on a vehicle and determine (using prescribed information from manufacturers) which parts of the vehicle should be repaired or replaced.
- Produce accurate & detailed repair specifications to be used to carry out the required repair process.
- Use commercial knowledge of their respective workplace and know how to apply this to determine a monetary cost and timescale for each repair job.

It is possible that during this assessment process, a vehicle previously identified for repair, may be assessed as either economically or structurally unable to be repaired resulting in a decision to send the vehicle for salvage.

Repair estimates may be validated by an insurance engineer during the assessment phase. It is important to note that any assessment includes any requirements to move the vehicle to other specialist premises or indeed to estimate requirements for third party support to the repair outside of the designated bodyshop.

3.2.4 Repair

The repair phase of the claim is performed based on the VDAs validated assessment of the repair needs.

Factors that affect the effectiveness of the repair process include:

- Parts availability and lead times.
- Service condition of any panels or items.
- Vehicle diagnostic checks.
- Feature and technology fitment.
- Labour and skills availability.
- Specific VM mandated processes or special tooling.
- Third party or VM specialist services
- Calibration and testing
- Quarantine and storage
- Powering up / down of HV battery

During the repair process, loan cars are usually offered by the repairing body in line with agreements, contracts, and policies.

3.2.5 Salvage

Differing financial models apply to how vehicles are handled when determined to be a total loss. The ABI Code of Practice for the Categorisation of Motor Vehicle Salvage provides a framework against which UK Insurers apply salvage codes to vehicles. Decisions to categorise a vehicle can be based on the severity of the damage or on the basic economics of the balance between repair costs and the value of the vehicle in the market.

Each insurer has a different approach to determining whether a vehicle is economically viable to repair.

3.3 ICE Claims Process

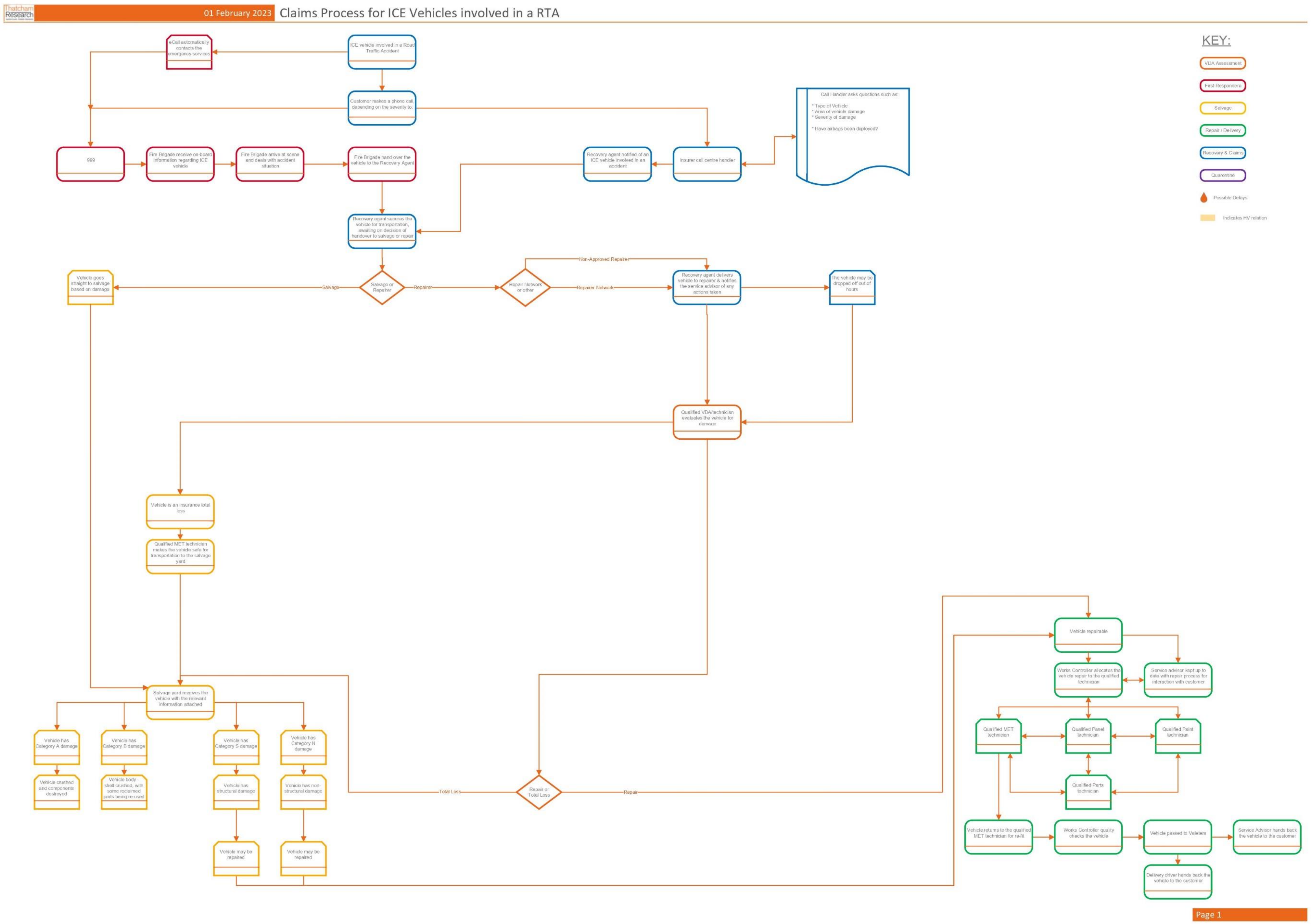

Figure - ICE Claims Process map

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3.4 BEV Claims Process

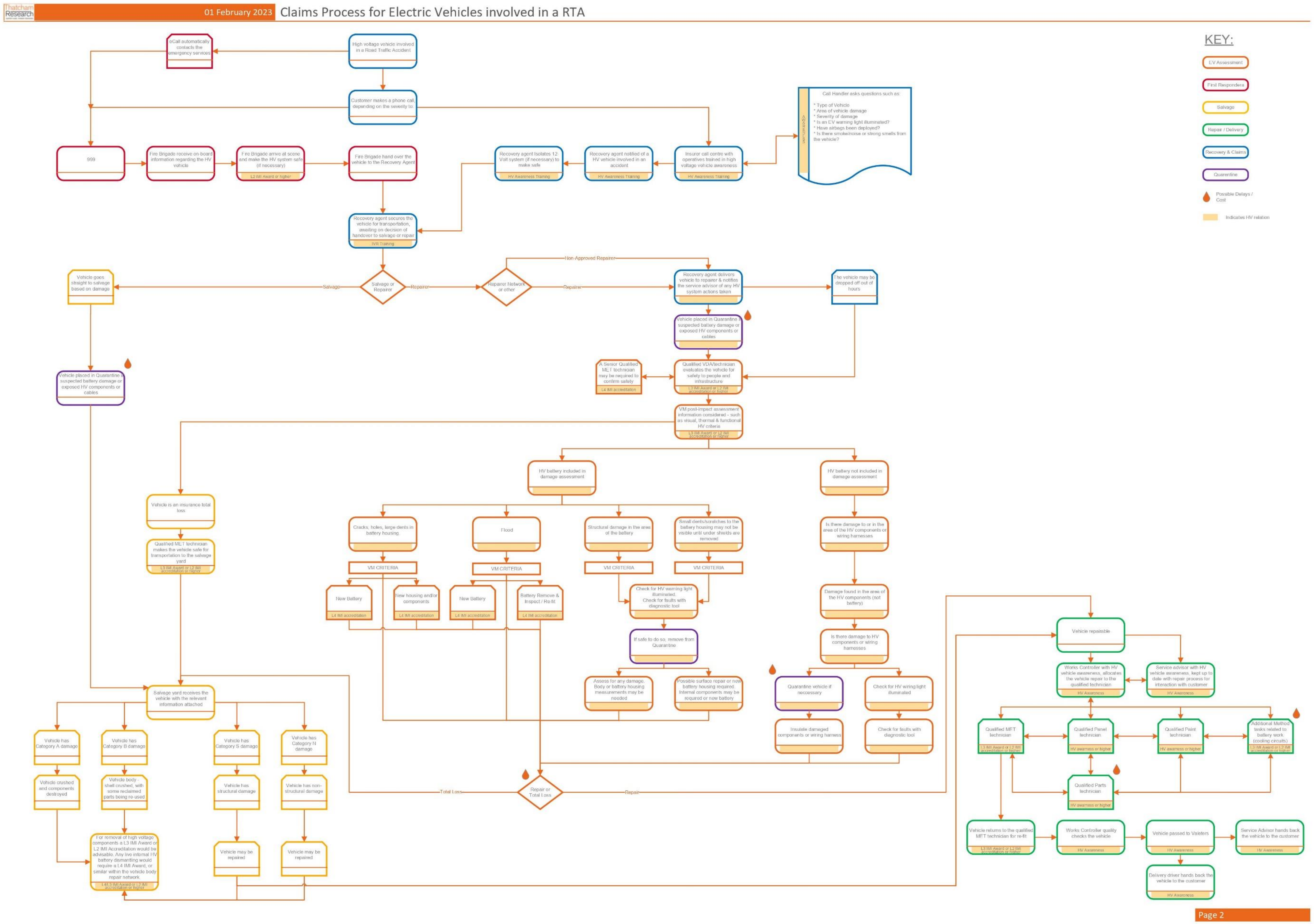

Figure 2 - BEV Claims Process map

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3.5 Difference in Claims Processes

3.5.1 Introduction

The mapping process validates the assumption that there is a significant difference in the insurance claims process for a BEV in comparison to an ICE vehicle. With support from key stakeholders including LV= and Synetiq, the end-to-end insurance claims process for both ICE vehicles and BEVs has been mapped out by means of a detailed workflow flow. See Figure 1: ICE Claims Process map and Figure 2: BEV Claims Process map.

As a result of this work, the variations to the insurance claims process caused specifically by BEVs have been identified and researched.

The process for BEVs is significantly more complicated than for the traditional ICE vehicle.

There are several common themes which determine the differences:

- The nature of the accident itself and the likelihood of involvement of the HV battery in the claim
- The ability to diagnose the battery status at various stages of the process.
- Skills required to enable the process

3.5.2 State of the Nation

When highlighting the differences between the two claims models, it becomes clear that there are several common factors which cause the additional complication to the process:

- The challenges caused by accidents themselves
- Battery involvement
- Rescue and transportation post-accident
- Storage considerations
- Repair
- The battery design itself
- Technology supporting repair
- Sustainability of the current model and its impact on salvage and total-loss
- The viability of the secondhand market

3.6 Immaturity in BEV Claims Handling

During this research, several interviews were held with insurers and their supply chains to ascertain whether the mapping performed in section 3.4 was correct.

The above process flow diagrams are considered current best practice as determined by Thatcham Research and their partners. However, the processes are not being followed consistently by relevant parties.

It has become very clear that the small penetration of BEVs in the market reflected in the maturity of processing BEV claims. Very few processes and systems have changed. Indeed, in many cases, no changes have been made to FNOL question sets, to vehicle triaging processes or to damage assessment and repair processes.

In a similar way, many of the underlying software systems which are used to process claims through to completion have had little or no change to reflect new requirements when handling BEVs.

It should be noted that this lack of maturity limits the effectiveness of any future modelling. Some examples which should be taken into consideration:

- Vehicle Manufacturer information is inconsistent and, in many cases, completely lacking when providing critical guidance on post-accident triage and assessment
- Training only partially addresses the impact of BEVs. Affected groups found to have only partial information to change their practices and approach;
  - FNOL call handlers
  - First Responders
  - Recovery agents
  - Bodyshop managers and schedulers
  - Vehicle Damage Assessors
  - Repair agents
- Industry common data sets have not been updated to include critical new categories. As an example, many underlying systems only have Petrol / Diesel as powertrain options.
- Claims handling systems rely heavily on text fields to specify custom BEV related repair considerations and can easily be missed.

3.7 Data Sources

The pattern of vehicle accidents in the UK varies over time and for a variety of reasons. There is no single source of data which makes it easy to predict accident damage location or severity. There are, however, multiple data sources which provide some potential to show primary and secondary damage locations, and to infer the severity of the accident.

For example, commercial software which is used for a significant number of repair estimates for authorised and non- authorised repairs in the UK market. Data tends to be highly variable in its quality;

- the individuals creating estimates have a variety of skills and training.
- insurers have differing relationships with repairers and can build in their own assessment requirements, rules, and discounting structures within the core system.
- many insurers and bodyshops / Vehicle Damage Assessors have not yet aligned their processes with newer technologies and do not include all required information.
- there are many factors affecting damage, price and repair information which do not have data entry fields natively within the systems resulting in incomplete estimates.
- some repairs do not route through conventional insurer-controlled processes and therefore are missing from the analysis.

Insurer claims data might appear to be a good choice to define definitive accident and claims data details but unfortunately, no insurers use the same system for gathering and storing data and claims are complicated by nature. Furthermore, most of the larger insurers are founded from multiple acquisitions, mergers, and divestments and therefore several different, and sometimes legacy systems.

For the purposes of this project, LV= have shared significant data on their own claims which has been invaluable in extrapolating many aspects of the data analysis for this project.

4. Accidents

4.1 Introduction

The number of BEVs provides challenges to an accurate analysis of accidents. Annual repair rates are typically about 6.55% of UK vehicles covered by valid insurance policies in the UK. With a couple of notable exceptions, a significant percentage of the BEVs are less than three years old and therefore in good roadworthy condition and fitted with the latest generation of Advanced Driver Assistance Systems (ADAS) which might lead to lower frequency and severity accidents. This makes the number of BEV related accidents small and parallels difficult to draw. Other factors which will have influence on crash rates in the future include change in policy, improvements to road safety, autonomous driving, and changes car ownership models. The following sections outline the approach that has been taken to identify the accident scenarios which could cause battery involvement and expands on considerations which allow modelling to be carried out in section 0.

4.2 Summary of potential issues relating to BEVs involved in an accident

Damage patterns – Research carried out by Thatcham Research has shown that the damage patterns on both ICE vehicles and BEVs are comparable, and this has allowed the use of ICE claims data to assist in the predictions of likelihood of HV battery damage in the given accident scenarios detailed in Section 4.3.

Battery vulnerabilities – Despite the vast amount of repair data available, there are significant limitations in some areas. Some vehicles are deemed a total loss at FNOL and as a result that will not be assessed for repair, meaning battery damage data is not recorded by the damage assessor. Additionally, vehicle damage assessors may not specifically look for HV battery damage as part of the damage assessment. For these reasons, a calculation of probability of battery damage has been included. There are a wide variety of both external and internal designs for batteries and their casings. Estimations of battery damage scenarios have been based on accidents likely to cause twisting, distortion, or deformation of the battery casing as defined by Thatcham Research’s own Repair and Safety subject matter experts who have both specific training and extensive experience in inspection and repair of crashed vehicles, crash structures, and structural load paths.

Rescue – A European New Car Assessment Programme (EURO NCAP) rescue app is available for free download and is used by some first responders. However, the procedures in the rescue sheets may lead to isolating some vehicles by severing the responder loop as opposed to disconnecting, leading to additional repair costs.

Storage of damaged BEVs – Quarantine guidelines are not currently consistently recognised or followed in the repair sector, and as such there is significant risk associated with this. As and when the repair sector starts to see an increase in the BEVs in the repair chain, the risk of significant damage to other vehicles or infrastructure increases.

4.3 Impact scenario assumptions

All impact scenarios have been considered with a focus on those which expose the battery to either superficial damage, or extreme force circumstances, have been identified and used within this report. The scenarios and probability have been calculated based on knowledge gathered from our subject matter expert in vehicle repair and Thatcham Research’s vehicle safety subject matter expert, along with analysing a wealth of claims and estimate data.

The impact scenarios used to gather data for this report are defined as follows:

- Side impact
- Corner impact
- Any crash resulting in SRS deployment.

A prediction of the numbers of damaged HV batteries can be made using the BEV Car Parc forecast, BEV repair rate, percentage of detected damaged HV batteries and an assumed current detection rate.

Notes:

- For the purposes of this report, forecasts are based on BEV passenger vehicles only, and does not include LCVs.
- Supplemental Restraint System (SRS) refers to passive safety systems such as airbags and seatbelt pretensioners.

4.4 Damage

4.4.1 Damage assumptions

From analysis of claims data, the following assumptions have been made relating to damage:

- Only a certain percentage of claims will carry enough severity to cause structural damage.
- Multiple damage zones are likely to be higher severity than single damage zones.
- Mechanical damage increases likelihood of battery damage by 10%.
- Underbody damage is 85% likely to result in battery damage.

Note: The rationale of these assumptions is found throughout section 4.4.

Research previously undertaken by Thatcham Research for its members has shown that vehicles with ADAS technology generally have fewer claims with front end damage as Autonomous Emergency Braking (AEB) prevents / reduces this damage. That research is built upon data held, but with the understanding that neither the data, nor the output, can be shared outside of the membership.

As AEB becomes more prevalent in the Car Parc, it would be expected that claims with rear end damage for all vehicles will also decrease. Early indications in LV= claims data shows there is potential evidence to support this hypothesis. However, as the risk of battery damage is still relatively low for rear end impacts, it is anticipated that this will not significantly affect the number of damaged batteries seen in the future. See section 4.4.4: Damage patterns are associated with HV battery damage for more detail.

4.4.2 Comparing damage patterns BEVs vs new ICE vs all ICE

The damage patterns shown in Figure 3 - BEV vs ICE damage patterns below, show the similarities between ICE and BEV damage, and as such it is appropriate to project the scale of likely battery damage based on ICE repair volumes.

Figure 3 - BEV vs ICE damage patterns

Further information relating to damage patterns can be found in section 4.4.4.

4.4.3 Accident types likely to result in battery involvement

As detailed in section 4.3: Impact scenario assumptions, the accidents that are most likely to involve battery damage are accidents which cause SRS deployment, side impacts, or corner impacts.

It is also likely that actions such as dropping hard off a curb, driving at speed over a speed bump, and hitting large potholes are putting the undercarriage at risk and are likely to cause damage to the battery. As these are unlikely to result in a claim on an ICE vehicle, it is difficult to quantify the number of claims that may be seen in the future caused by undercarriage damage. Until such time as a consistent diagnosis and repair methodology is established, the repair will require battery replacement.

A previous project carried out by Thatcham Research investigated an issue relating to an established manufacturer’s vehicles. The VM has a safety-based approach to HV battery isolation within their HEV/BEV fleet which is different than other vehicle manufacturers.

For these vehicles, in the event of an incident which is serious enough to cause SRS activation, the battery is deliberately isolated using a pyro fuse to sever the connection. This is due to the VMs view, which is that the integrity of the battery structure cannot be determined. As a result of this, even if the vehicle is deemed repairable post-accident, the battery would still require diagnosis. Some dealers are allowing reinstatement of the battery post successful prognosis but request the owner voids their battery warranty. This is not a recommended by the VM.

In a comprehensive case study of UK BEV repairs, Thatcham Research have carried out deep dives into repair elements and identified where high voltage batteries and associated components were recorded as damaged (for electrified power trains) over the last 5 years. This can be found in Figure 4 - BEV & HV battery repairs as a proportion of total repairs

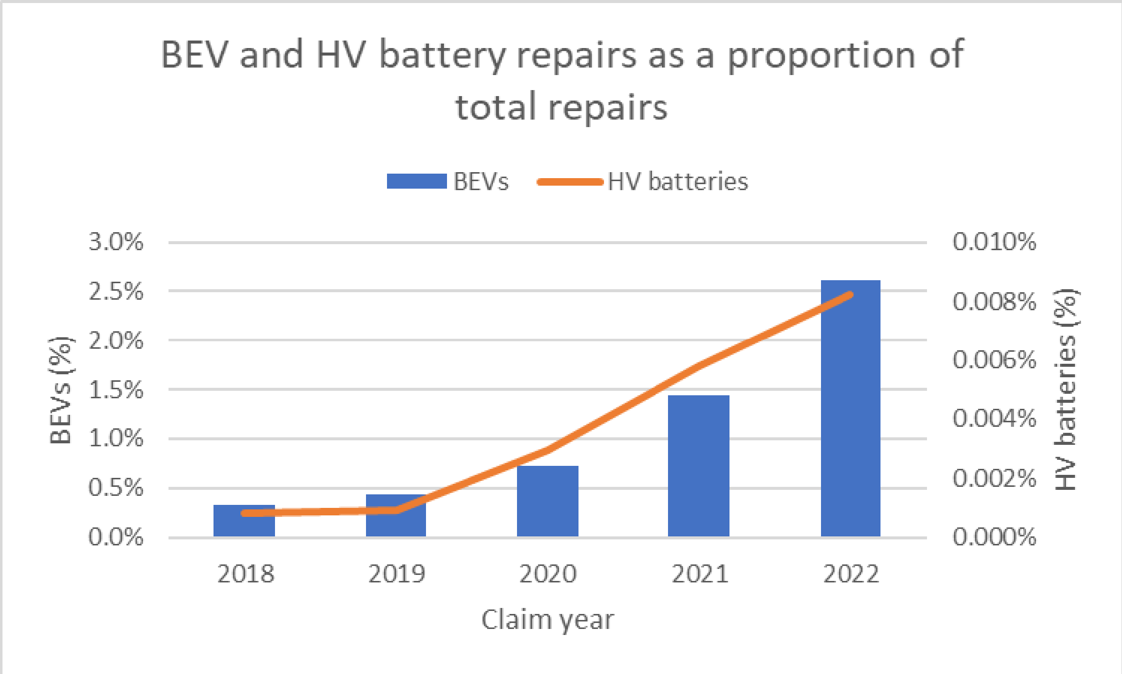


Figure 4 - BEV & HV battery repairs as a proportion of total repairs

It can be approximated that 0.33% of BEV repair estimates include damaged batteries. This is based on current capture rates; however, research indicates that there is likely to be a degree of under-reporting. The reasons for under-reporting have been outlined in Section 3.6.

Claim and repair information captures the damage areas on a vehicle, and up to three damage zones can be listed for each assessment. The possible damage zones are shown in the Figure 5: Damage areas below.

For the analysis done as part of this project, assessments have been excluded where zero or unknown damage is recorded. Glass damage claims have also been excluded.

The combination of impact areas can be grouped into 'damage patterns'. The damage patterns where damage to the HV batteries can be compared to the damage patterns for all BEVs which have been captured within the repair data. These have subsequently been used to calculate the risk of battery damage for each specific damage pattern.

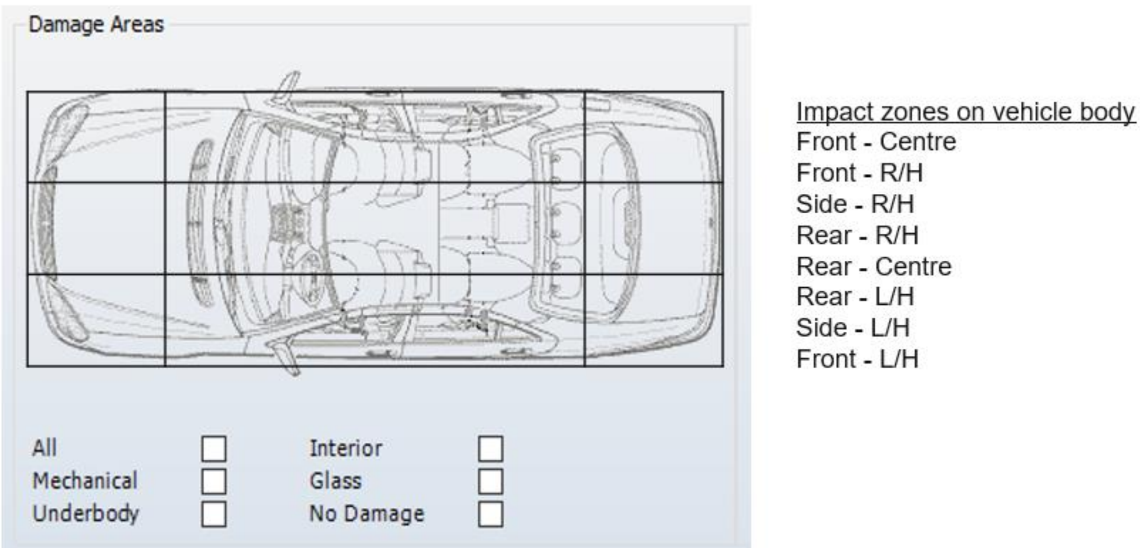


Figure 5: Damage areas schematic

4.4.4 Damage patterns are associated with HV battery damage

The damage patterns can be sub divided into three main groups; Adjacent body zones, non-adjacent body zones and where there is at least one non-body zone. The common damage patterns for BEVs can be visualised by the concentric circle in the graphics in Figure 6 - BEV damage patterns and probability of HV battery damage. The deeper colours indicate a higher number of damage assessments with that damage pattern. The inner circle represents a single zone damage area, the middle circle represents two adjacent zones (offset), and the outer circle three adjacent zones (distributed damage). This infers that front to rear impacts are one of the most common accident types. Single corner impacts are also very common and are likely to be low speed manoeuvring accidents.

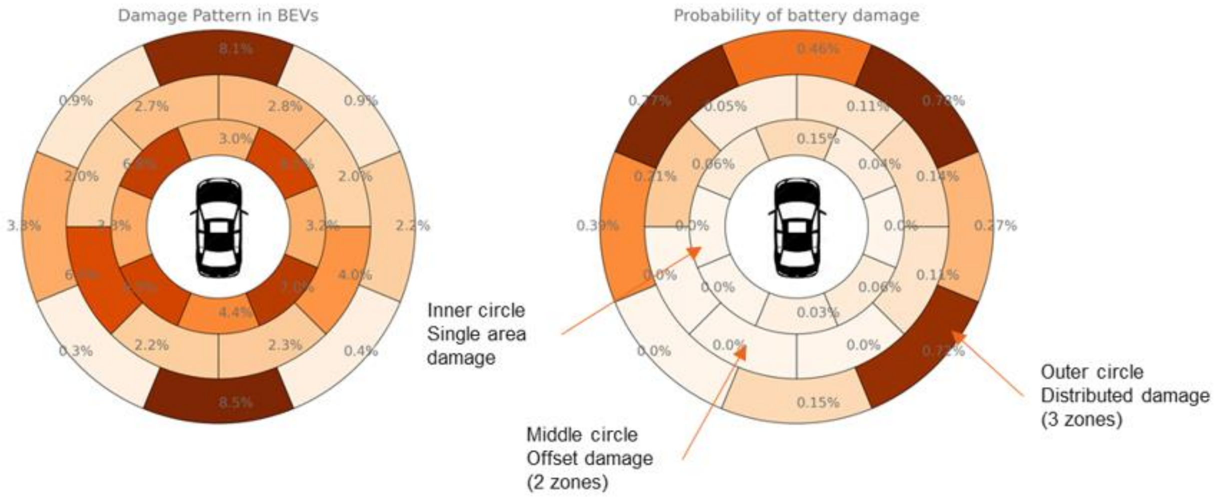


Figure 6 - BEV damage patterns and probability of HV battery damage

By dividing the number of damaged batteries by the number of BEV assessments, it is possible to calculate a battery damage frequency for a particular damage pattern. This is graphically displayed in Figure 6 - BEV damage patterns and probability of HV battery damage. The probability of battery damage is highest where there are 3 zones of damage, indicating accidents with a more severe impact. This is the highest when there are cases of severe corner damage.

4.4.4.1 Adjacent body zones

89% of BEV repair assessments noted adjacent damage areas on the car body so these damage patterns are the most significant in terms of vehicle repair estimates. Of these, the common damage patterns on BEVs (and in vehicles in general) are front distributed, rear distributed, individual corners and LH side corner offset.

4.4.4.2 Non-adjacent body zones

It is difficult to classify all the different combinations of non-adjacent areas, so for the purposes of this report, the damage patterns have been grouped by the number of damaged zones. However, the number of damage assessments in this category are much smaller than for adjacent impact areas (5.6%). Battery damage is much more likely to occur if there are 3 impact areas as shown in Figure 7 - HV battery damage risk with damage on non-adjacent body areas.

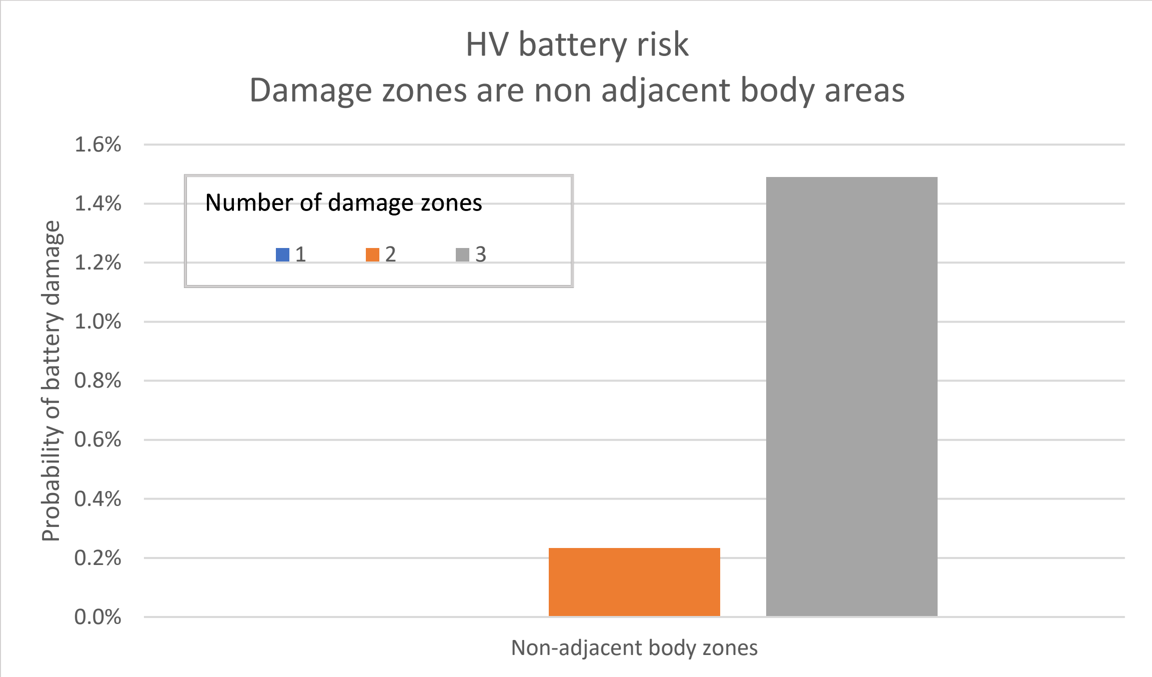


Figure 7 - HV battery damage risk with damage on non-adjacent body areas

4.4.4.3 Non-body zones

Damage assessments where there is at least one non-body damage area, account for a small proportion of assessments (5.5%). However, battery damage appears much more likely for these scenarios when compared to assessments which have body damage alone. This risk is highest when underbody damage is present as shown in Figure 8 - HV battery risk with damage zone including a non-body zone.

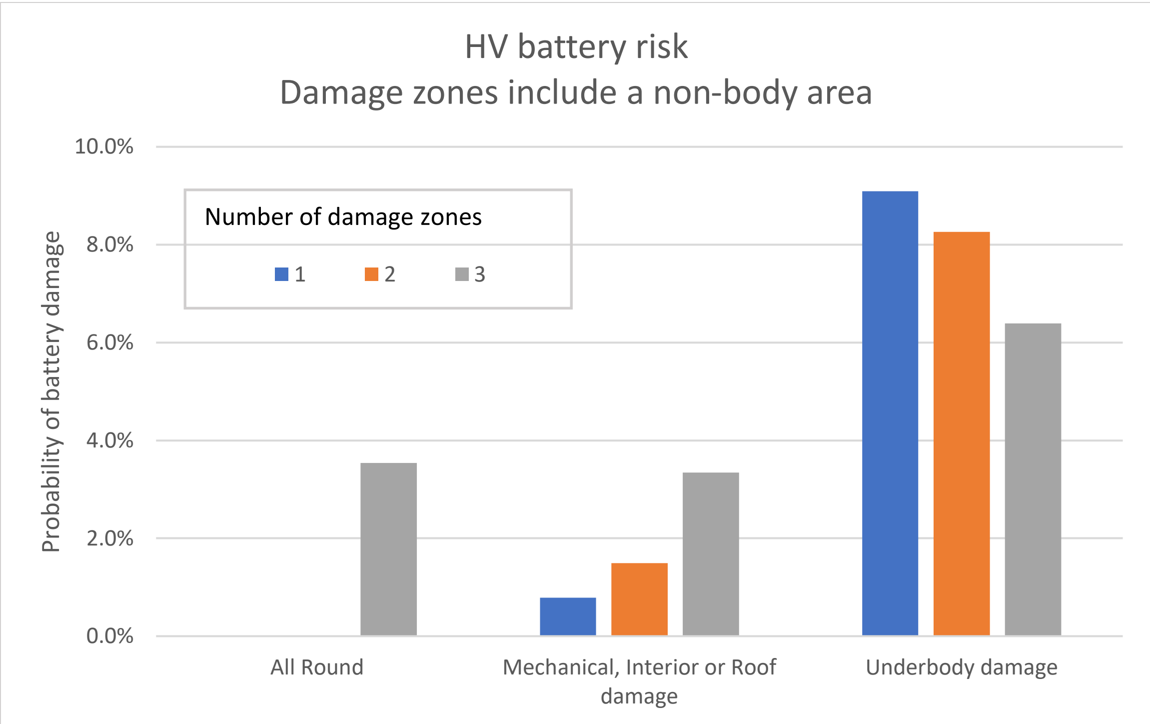


Figure 8 - HV battery risk with damage zone including a non-body zone

4.4.5 Vulnerability of batteries

The design of current high voltage battery packs, often located under the vehicle with mounting points under the side sills, can make them vulnerable to damage in crashes.

An investigation of crash damage sustained by BEVs was undertaken using repair data to determine how many HV batteries were identified as having sustained damage by vehicle damage assessors. This was broken down by damage location.

However, there are significant limitations in repair data, including that vehicles with HV battery damage may have already been declared a total loss at FNOL and would therefore not even be assessed for repair. Additionally, vehicle damage assessors may not specifically look for HV battery damage as part of the damage assessment, especially if the damage is relatively minor or not obvious without close inspection. This suggests that probability of damage based on repair data alone is likely to be a gross underestimation of the vulnerability of HV batteries to damage.

A reassessment of the probability of damage to HV batteries in different impact types was undertaken based on expert knowledge and understanding of vehicle impacts and repair. An assessment of the likelihood of HV battery damage occurring in crashes was made. This attributed a low/medium/high likelihood to each of the damage zones established in Section 4.4.4, and incorporated the assumptions made in Section 4.4.1. This indicated that BEVs with single zone damage could have a battery damage probability of between 1.5% and 7.5%, while BEVs sustaining damage to multiple zones could have a battery damage probability of between 25% to 35%. Damage to the underside of the vehicle was considered to represent an 85% probability of HV battery damage.

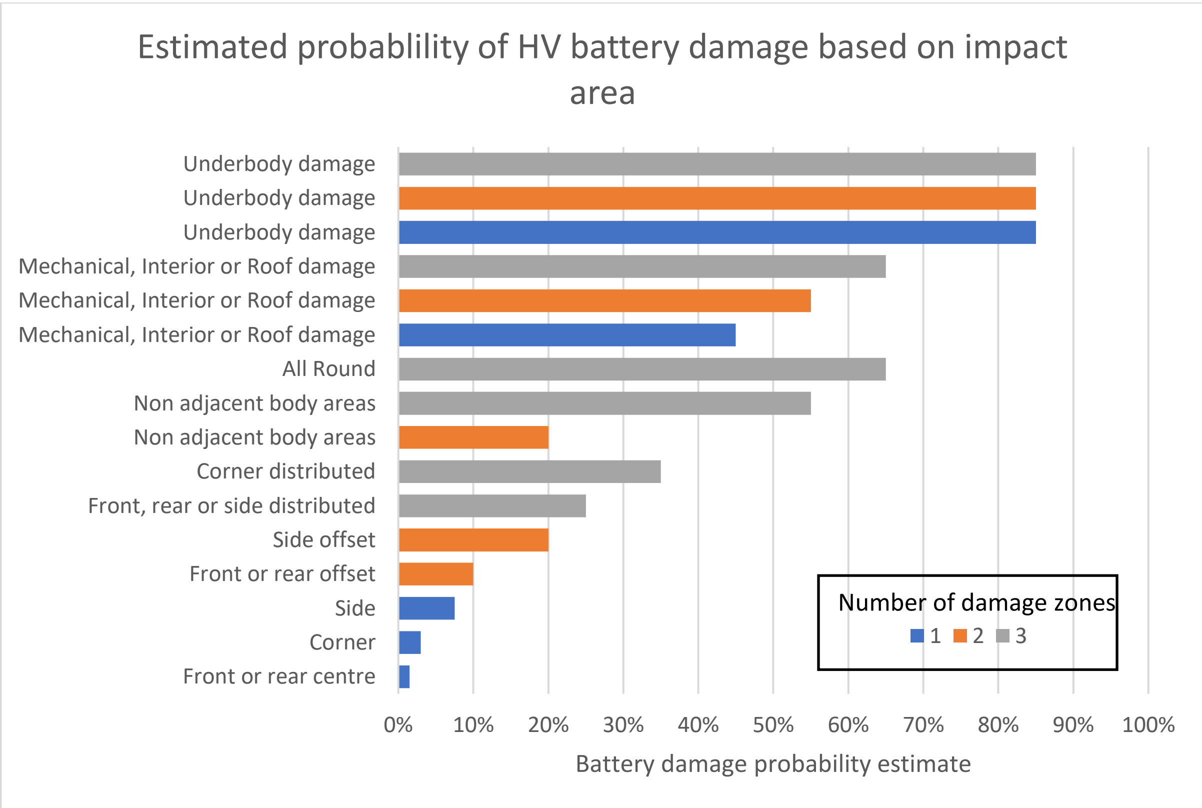


Figure 9 - probability of HV battery damage based on impact area.

Table 1 - HV Battery damage risk

Number of damage zones	Impact areas	Impact zone	Battery count	BEV count	Probability of battery damage (%)	Reassessed battery damage probability %	Estimated battery count
1	Front - Centre	Front - Centre			0.15%	1.5	31
1	Rear - Centre	Rear - Centre			0.03%	1.5	46
1	Front - R/H	Front - R/H			0.04%	3	135
1	Rear - R/H	Rear - R/H			0.06%	3	146
1	Rear - L/H	Rear - L/H			0.00%	3	135
1	Front - L/H	Front - L/H			0.06%	3	142
1	Side - R/H	Side - R/H			0.00%	7.5	164
1	Side - L/H	Side - L/H			0.00%	7.5	171
2	Front - Centre, Front - R/H	Front RH offset			0.10%	10	191
2	Rear - R/H, Rear - Centre	Rear RH offset			0.00%	10	157
2	Rear - Centre, Rear - L/H	Rear LH offset			0.00%	10	153
2	Front - Centre, Front - L/H	Front LH offset			0.05%	10	186
2	Front - R/H, Side - R/H	Side RH front offset			0.14%	20	280
2	Side - R/H, Rear - R/H	Side RH rear offset			0.07%	20	556
2	Rear - L/H, Side - L/H	Side LH rear offset			0.00%	20	864
2	Side - L/H, Front - L/H	Side LH front offset			0.21%	20	285
2	Non-adjacent body zones	Non-adjacent body zones			0.23%	20	430
3	Front - Centre, Front - R/H, Front - L/H	Front distributed			0.41%	25	1403
3	Front - R/H, Side - R/H, Rear - R/H	RH side distributed			0.27%	25	376
3	Rear - R/H, Rear - Centre, Rear - L/H	LH side distributed			0.39%	25	570
3	Rear - L/H, Side - L/H, Front - L/H	Rear distributed			0.14%	25	1469
3	Front - Centre, Front - R/H, Side - R/H	Front RH corner distributed			0.78%	35	224
3	Side - R/H, Rear - R/H, Rear - Centre	Rear RH corner distributed			0.72%	35	97
3	Rear - Centre, Rear - L/H, Side - L/H	Rear LH corner distributed			0.00%	35	81
3	Front - Centre, Side - L/H, Front - L/H	Front LH corner distributed			0.77%	35	226
1	Includes non-body area	Mechanical, Interioror Roof damage			0.78%	45	230
2	Includes non-body area	Mechanical, Interioror Roof damage			1.49%	55	479
3	Non-adjacent body zones	Non-adjacent body zones			1.49%	55	961
3	All Round	All Round			3.54%	65	404
3	Includes non-body area	Mechanical, Interioror Roof damage			3.34%	65	758
1	Includes non-body area	Underbody damage			9.09%	85	65
2	Includes non-body area	Underbody damage			8.26%	85	103
3	Includes non-body area	Underbody damage			6.39%	85	186

Recent crash testing undertaken by Thatcham Research on a BEV demonstrated that HV battery casing damage could be sustained in a side pole crash at lower severities than Euro NCAP or regulatory test requirements. Whilst the damage may appear relatively superficial, the lack of repair methods for renewing the battery casing would likely result in the entire battery requiring replacement.

Figure 10 – Thatcham Research low severity crash test (Left) with resulting damage to battery casing (Right) .

This specific HV battery case design, with relatively narrow mounting brackets at the side in combination with the design of the vehicle load paths through the sill and floorpan, suggest that this casing design may be less vulnerable to damage than the HV battery cases on some other BEVs where wider mounting structures are used.

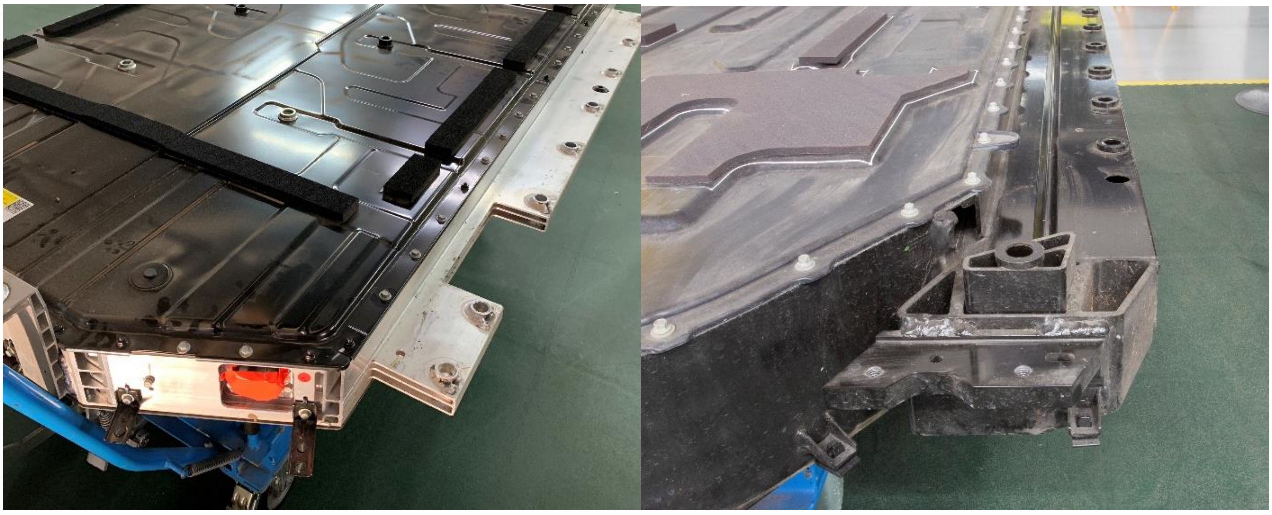


Figure 11 – Examples of different HV battery casing design with wider side structures.

4.5 Rescue

4.5.1 Rescue risk assessment

The UK government have produced guidelines on recovery of damaged BEVs along with a risk assessment table as shown in Table 2 - Recovery risk assessment.

Figure 15 - Recovery and Repair Process shows the process flow for recovering a damaged BEV and the repair process in more detail.

Table 2 - Recovery risk assessment [6].

Observation	Low Risk (GREEN)	Medium Risk (AMBER)	High Risk (RED)
Airbags	Not deployed	Deployed	Deployed and another RED condition observed (But not electrical b isolation)
Vehicle structural damage	Minor or no damage	Major damage but not intruding into HV locations	Severe damage into HV locations, especially battery area
Chemical smell	No smell	Slight smell or smell like that expected from petrol or diesel vehicles	Strong pungent or acrid smell that may also cause irritation to the eyes or nose/throat
Sound	No sound	Intermittent electrical sparking or gas release hiss heard	Continuous electrical sparking, frequent gas release hiss or popping heard
Battery temperature	Battery at ambient temperature with no temperature rise observed or temperature reducing	Battery temperature not significantly hotter than ambient (max 50°C) and no temperature rise observed	Hot battery (greater than 50°C) or increasing temperature observed
Fire	No fire	No fire	On fire or has been on fire
Smoke and gas	No smoke	Light smoke or vapour	Thick dark smoke or white/grey acrid smoke
Electrical isolation	Low voltage disconnected and MSD removed or HV systems undamaged	Possible damage to HV systems and only low voltage disconnected	No isolation possible and another RED condition observed (but not airbags)
Dashboard fault codes	No fault codes	Fault code displayed	Fault code displayed and severe damage to HV locations
Recommended recovery procedure	Normal recovery with basic EV awareness training	Normal recovery with basic EV awareness training but the situation should be monitored. Specialist recovery with advanced training may be required if conditions change	Emergency Service attendance required and specialist recovery with advanced training

4.5.2 Submersion in water

If a battery electric vehicle is submerged in water, current industry guidelines on vehicle recovery from water should be followed. If the submerged vehicle is still attached to a charger, then the charger should be made safe, and the charge lead removed before any recovery operation. In general, the HV systems are isolated from the chassis and are designed for protection against water ingress and being in the water next to the vehicle does not pose any additional risk of electric shock [6].

4.5.3 Rescue protocols

Throughout the research done for this project, it has become apparent that there is a lack of standardisation in almost every area. One key area that requires standardisation is of protocols relating to rescue and recovery. Euro NCAP has, together with The International Association of Fire & Rescue Services (the CTIF), centralised the manufacturers' rescue sheets in a new app, 'Euro Rescue'. It can be used both online and offline, allowing rescuers to access the information even when there is little or no network coverage at the scene of the crash. Most importantly, research has shown that first responders are not necessarily aware that this app exists and should be mandated as part of training.

As part of the app, the user can download a Rescue Sheet, an example of which can be found in section 4.5.1. The rescue sheet is a standardised summary page containing all the crucial information rescuers need to carry out occupant extrication quickly and safely. Along with including information on the location of components (e.g., airbags and pre-tensioners), it is significantly important for the rescue/recover of a BEV as it details locations of high-voltage electrical cables and batteries, all of which could present a hazard to trapped occupants and to the rescuers themselves. Manufacturer emergency response guides contain more detailed instructions to educate and assist first responders during training and are particularly important for alternative fuel vehicles.

As part of newly released vehicle data onto the app, Euro NCAP verifies the content and shares ISO-compliant rescue sheets and emergency response guides for new energy vehicles, via the new app. Currently the app contains rescue sheets for all cars assessed from 2020 onwards.

It is worth noting that whilst the availability of these sheets is very beneficial to first responders, some rescue sheets with different advice for first responders on isolating the HV system. Some VMs say that the first step is to cut the responder loop, whereas others suggest disconnecting the 12V battery or pulling a service plug. Cutting the responder loop could cause a significant impact on the repair cost in addition to removing the ability to diagnose the battery.

4.5.3.1 Example rescue sheets: ID.3

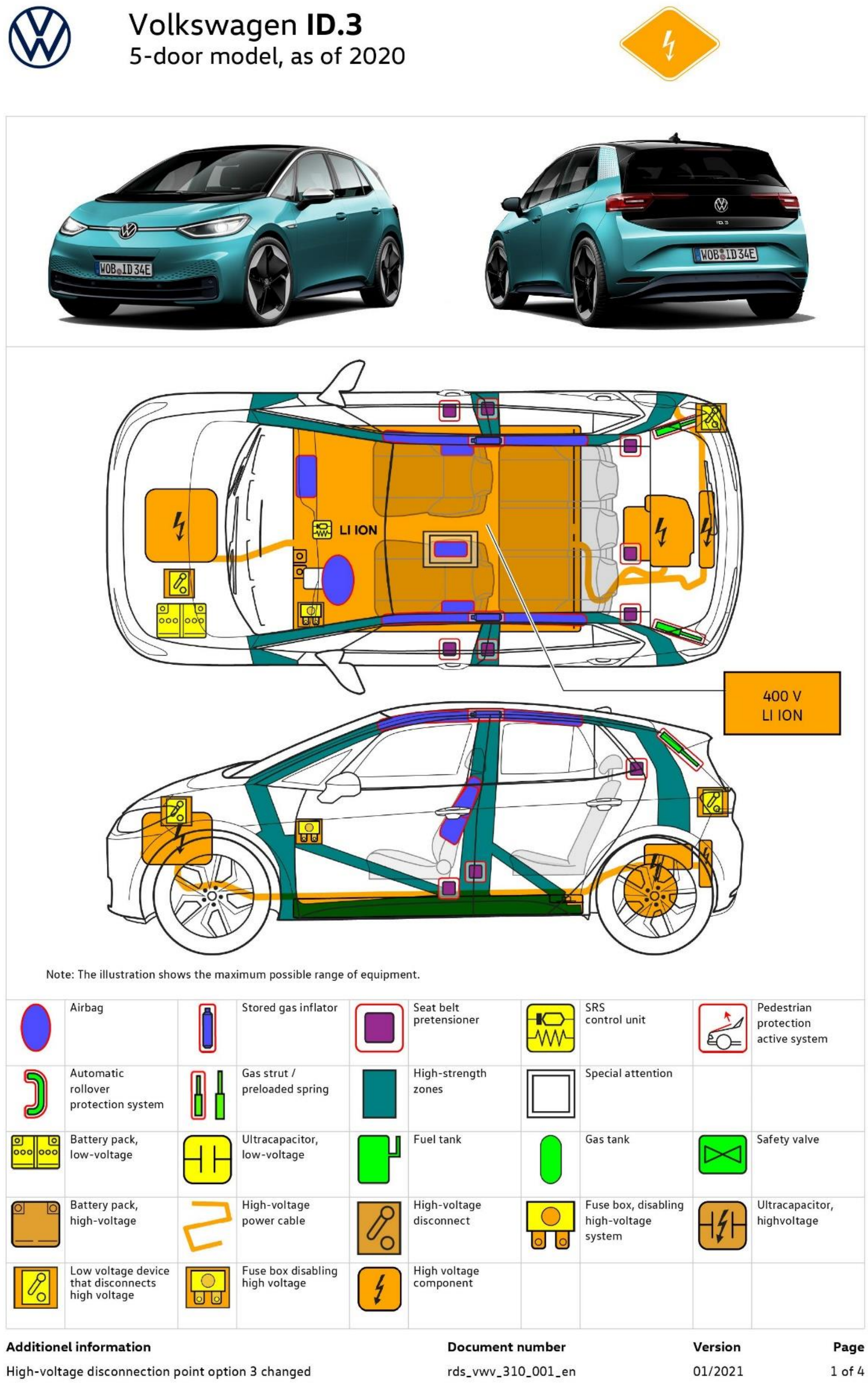


Figure 12.1

Volkswagen **ID.3**
5-door model, as of 2020

1. Identification / recognition

The electric motor is silent. The indicator on the left of the instrument cluster (power meter) indicates whether the electric drive is switched "OFF" or "READY" for operation.

Lettering

Charging connection

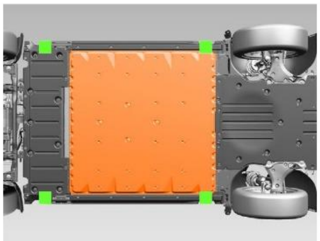
Engine compartment

2. Immobilisation / stabilisation / lifting

Immobilize the vehicle

Apply the parking brake.

Lifting points



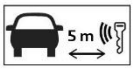
suitable lifting points

High-voltage battery

3. Disable direct hazards / safety regulations

Turn off the ignition (Powermeter "OFF")

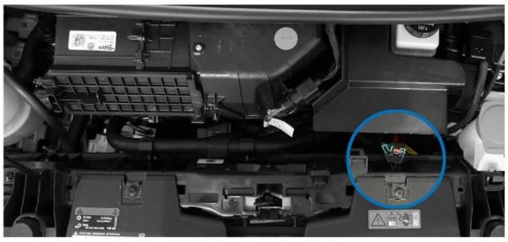
Press the START-STOP button without depressing the brake pedal.



Instead of a radio key, it is also possible to use a key card or smartphone app.

Deactivate the high-voltage system

Option 1: From the engine compartment



Disconnect the 12-volt battery

Disconnect the negative pole from the body contact point.

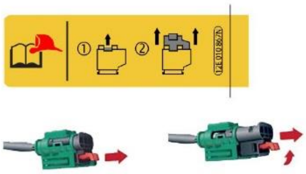


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Figure 12.2

Volkswagen **ID.3**
5-door model, as of 2020

Option 2: from the passenger compartment

left hand drive:

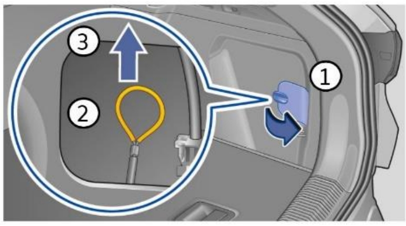
right hand drive:

Option 3: from the rear of the vehicle

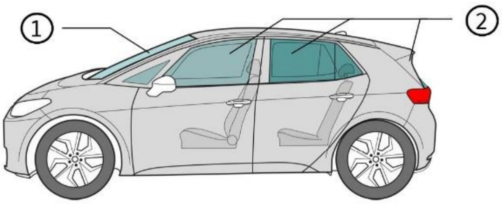
Do not touch, cut or open high-voltage components and high-voltage batteries!
Wear appropriate protective equipment!

In the event of an accident in which the airbags are deployed, the high-voltage system will be automatically deactivated. The high-voltage system is de-energised approx. 20 seconds after deactivation.

Disconnect from the charging station (emergency release)



4. Access to the occupants



Glas types:

1. Laminated safety glass
2. Toughened safety glass

5. Stored energy / liquids / gases / solids

400 V

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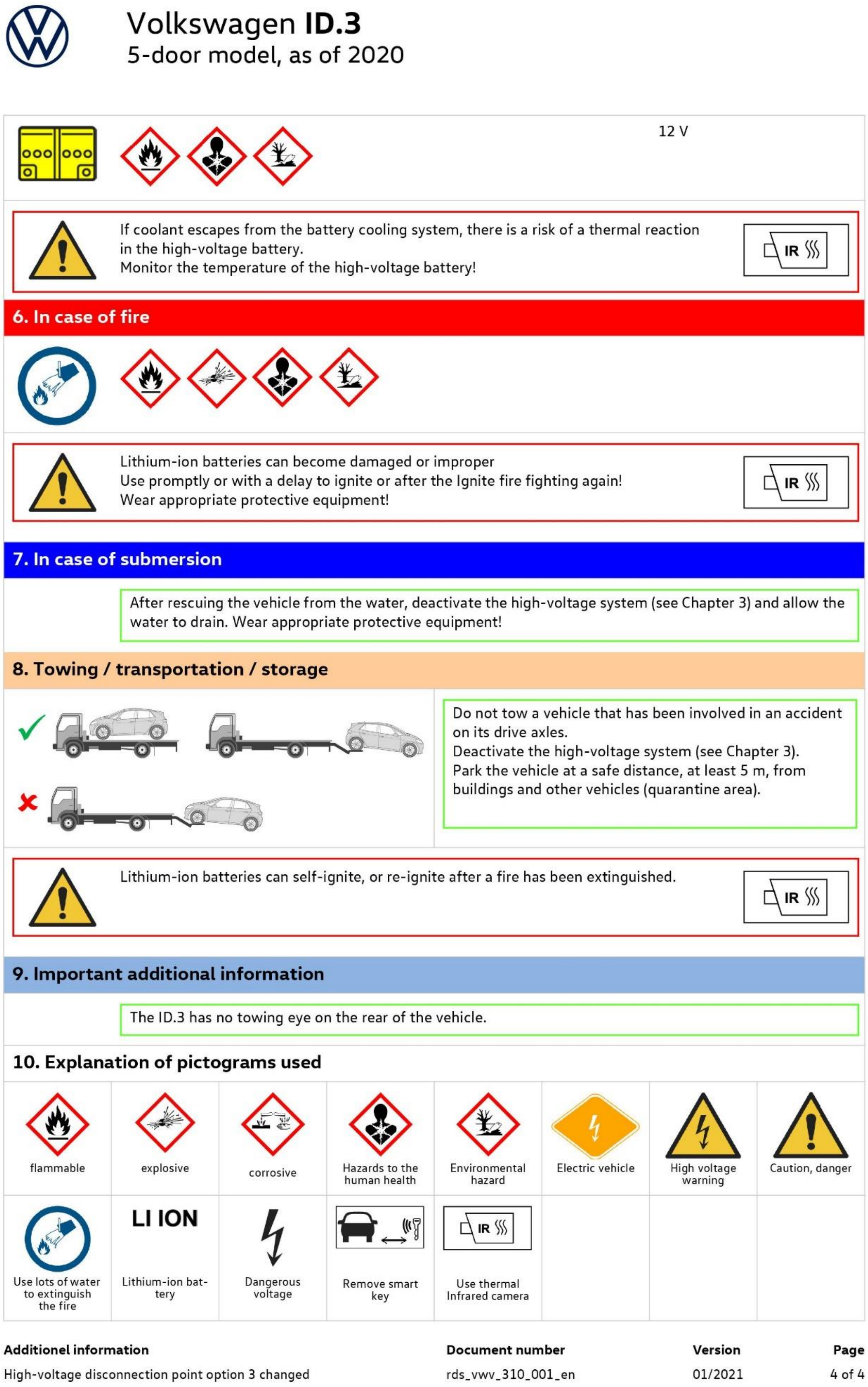
Figure 12.3



Volkswagen **ID.3**
5-door model, as of 2020

12 V

If coolant escapes from the battery cooling system, there is a risk of a thermal reaction in the high-voltage battery.
Monitor the temperature of the high-voltage battery!

IR

6. In case of fire

Lithium-ion batteries can become damaged or improper
Use promptly or with a delay to ignite or after the Ignite fire fighting again!
Wear appropriate protective equipment!

IR

7. In case of submersion

After rescuing the vehicle from the water, deactivate the high-voltage system (see Chapter 3) and allow the water to drain. Wear appropriate protective equipment!

8. Towing / transportation / storage

Do not tow a vehicle that has been involved in an accident on its drive axles.
Deactivate the high-voltage system (see Chapter 3).
Park the vehicle at a safe distance, at least 5 m, from buildings and other vehicles (quarantine area).

Lithium-ion batteries can self-ignite, or re-ignite after a fire has been extinguished.

IR

9. Important additional information

The ID.3 has no towing eye on the rear of the vehicle.

10. Explanation of pictograms used

flammable	explosive	corrosive	Hazards to the human health	Environmental hazard	Electric vehicle	High voltage warning	Caution, danger
Use lots of water to extinguish the fire	LI ION Lithium-ion bat-tery	Dangerous voltage	Remove smart key	IR Use thermal Infrared camera			

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Figure 12.4

Figure 12.1-12.4: Example of ID.3 data sheets within Rescue App [7].

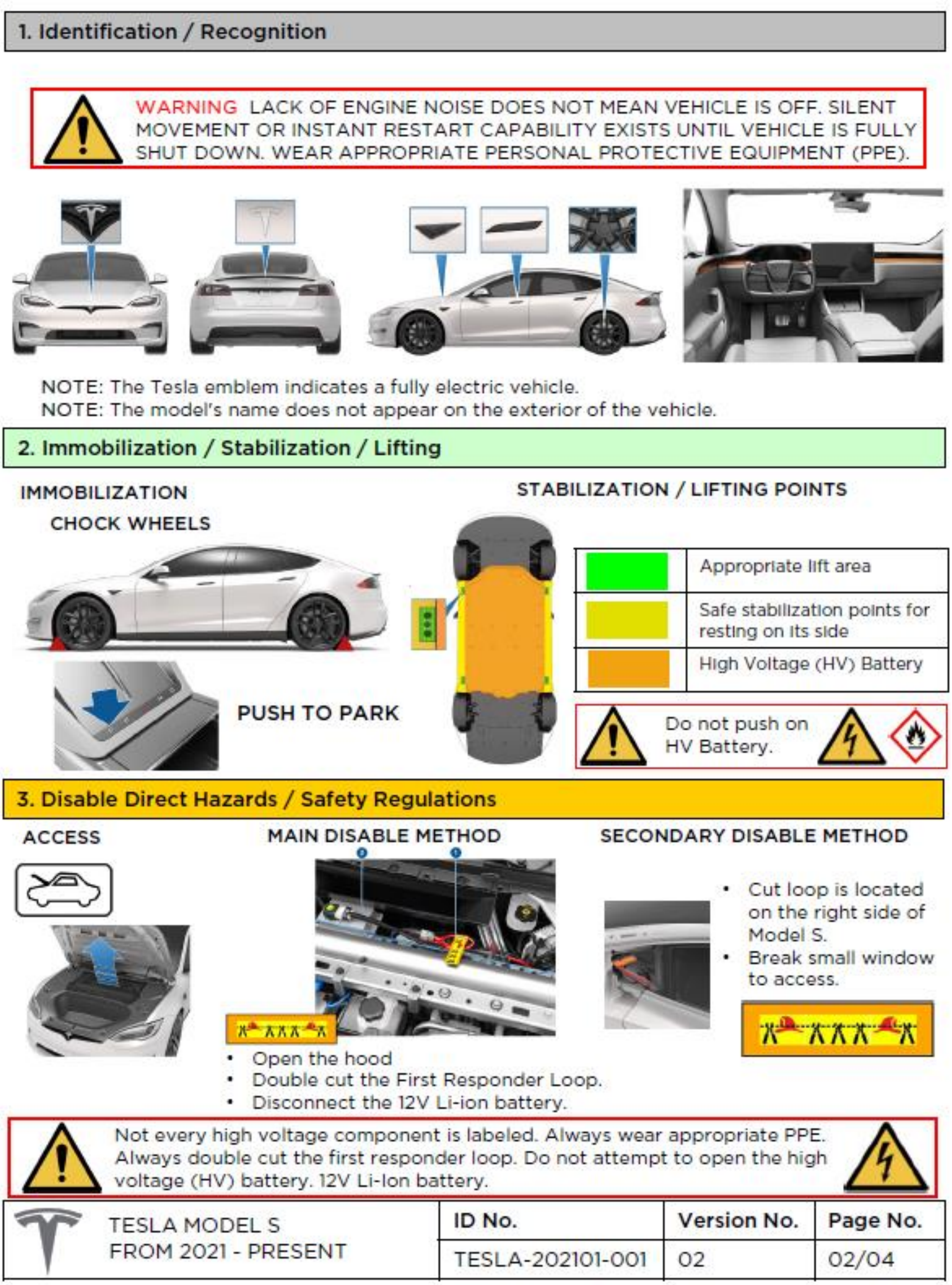

Figure 13 - Tesla Model S Data sheet exert [8].

4.5.4 Battery Flooding protocol

One VM has taken a unique approach on their post-accident protocols. This VM has worked with firefighters to create the design of what they term an "extremely effective Firefighting Access feature". The feature enables first responders to entirely extinguish a fire in the battery caused by external heat sources. All examples of electric vehicles are equipped with two heat-sensitive parts positioned opposite each other, one on the chassis side and the other on the battery side. Should a fire start, they melt and leave a hole, giving the firefighters clear access to the battery. By soaking the battery, they can put the fire out in under a minute [9].

The VM have also produced emergency rescue sheets for all vehicles, whether electric or not, so first responders can quickly assess the model's characteristics and take account of them as part of their immediate response. Emergency workers can access the information directly on the site of the accident, using either the dedicated Rescue Code app that the VM, the French fire and emergency services were involved in developing, or via the Euro Rescue app.

4.6 Transportation

When moving a vehicle any shock loads or body movement should be minimised. These may exacerbate any internal damage to the HV battery system that may not have been apparent from the initial visual inspection.

It is not recommended to tow damaged BEVs on their driven wheels because this can cause regenerative electrical power to be produced, which can cause damage to the HV systems and safety mechanisms. Many manufacturers recommend that the vehicle should only be transported on a flat-bed truck or on a trailer, with all 4 wheels off the ground, but some may allow towing if the driven wheels are off the ground.

There have been some rare instances of vehicles igniting during the loading operation, see section 4.6.1: Fire Risk

4.6.1 Fire Risk

RC59 legislation provides guidance surrounding the safe charging of both private and commercial electric vehicles. This document provides information regarding the location and situation in which charging points and the connected vehicles should be safely exposed to. These include spatial suitability of a charging points, distances from hazardous areas (ATEX zones 1 & 2), and mitigation against fires using sprinkler systems [10].

It is important however, to consider whether there is any evidence that BEVs pose more fire risk than ICE vehicles. A report based on a meta-analysis of available global reports was published internally to Thatcham Research's membership in January 2022. Although its analysis cannot be shared it drew the following conclusions:

- The total number of EV fires found in the sample of MIAFTR data are very small [11]. This would be expected, given the relatively small numbers of EVs in the UK Car Parc.
- The risk of fire increases with vehicle age for all fuel types in the UK, but the analysis shows that EV fires are less common than petrol and diesel car fires even when taking vehicle age into account. There is less certainty in the data for EVs older than five years old because of the small number of fires and small number of EVs in the Car Parc.
- Evidence from the fire statistics collated by the Home Office indicate that thermal runaway fires are rare and about 5 times less likely to occur than other accidental car fires.

- Whilst in theory there is a risk of thermal runaway in EVs, vehicle manufacturers have gone to great lengths to mitigate this. Battery management systems (BMS) continually monitor battery performance, aiming to mitigate identified risks and faults developing into fires.
- Most EV fires reported in the media can be traced back to battery manufacturing faults. Some VMs had expensive recalls to replace batteries, the cost being shared between the VMs and battery manufacturers. There is a huge financial incentive to both parties to not repeat this.
- Over half of fires recorded to a specific BEV in the media were due to high-speed crashes but some occurred during charging and when parked. The VM has provided OTA updates over the years to improve the BMS.
- Some vehicle manufacturers are actively looking to use LFP Li-ion batteries instead of NMC Li-ion batteries. These are cheaper and have a lower fire risk at the expense of range and performance.
- Reports by NHSTA and AGCS also conclude that EVs do not pose a greater fire risk compared to ICE vehicles [12] [13].
- Euro NCAP EV crash tests up to end of 2021 have also not resulted in any vehicle fires.

As the Car Parc grows and modern BEVs age within it, fire risk data needs to be monitored. It is hoped that the trend outlined above continues as this will likely result in less requirement for such stringent protections and quarantining requirements.

4.6.2 Fire or thermal runaway

Emergency services are required to attend if a vehicle is on fire, has been on fire or there is a possibility that a fire could start. 'Thermal runaway' occurs when the battery becomes unstable and an uncontrolled chemical reaction causes it to overheat, often leading to a battery fire. See Figure 14 - Conditions leading to potential thermal runaway. A fire to the main HV battery is a very severe incident and should only be tackled by fire service personnel with self-contained breathing apparatus and specialist training.

In the event of a main battery fire, all people around the vehicle should be evacuated to a safe place well away from the fire and any smoke or fumes. A battery fire or thermal event will release toxic chemicals which can pose a risk to health. If a fire is starting from the low voltage supply (12/24 V battery) then a suitable extinguisher can be used to suppress the fire and stop it from spreading. During a thermal event, the HV batteries should not explode in a dangerous manner due to the safety systems built into them. If some cells have been damaged, these may be heard to "pop". In some circumstances these cells could be ejected from the vehicle if the battery has been exposed by crash damage.

Current industry guidance is that a vehicle is deemed to be in a safe location if it is at least 15 metres away from anything else, but further guidance should be sought from the vehicle manufacturer's guidelines.

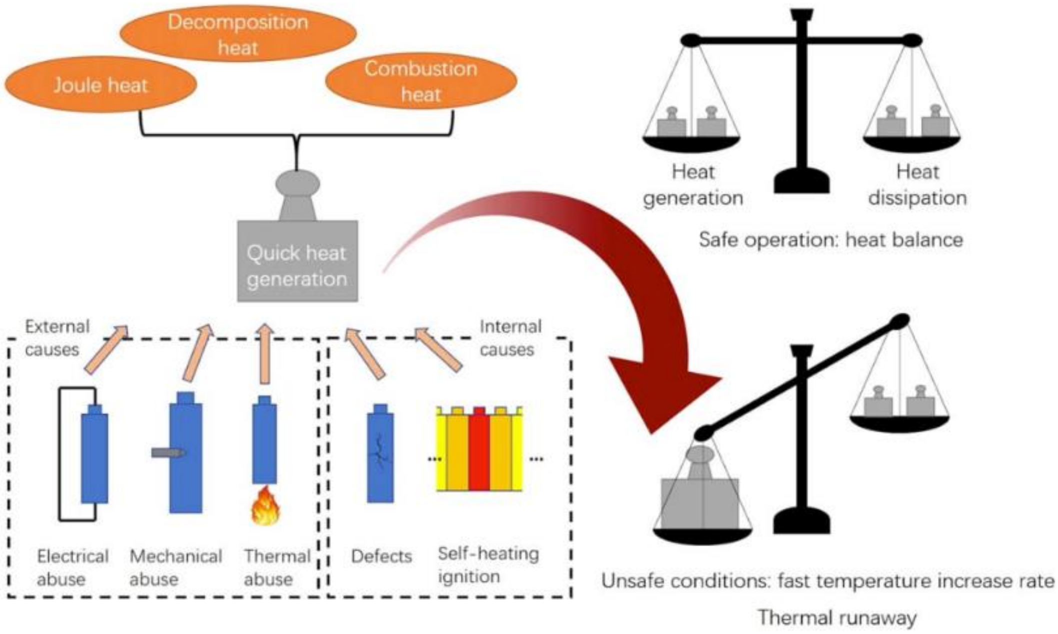

Figure 14 - Conditions leading to potential thermal runaway [14].

Recovery and Repair Process

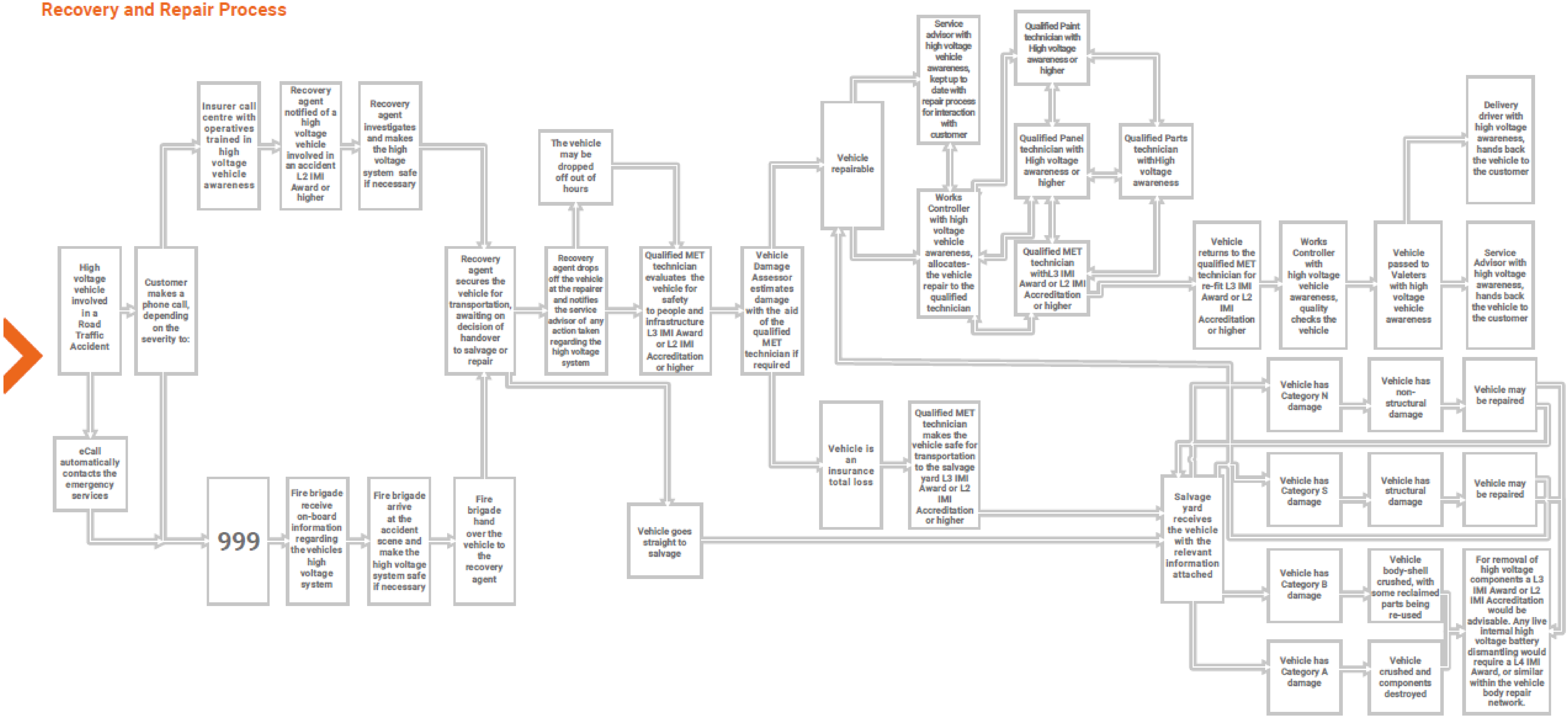

Figure 15 - Recovery and Repair Process.

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4.7 Storage of damaged BEVs

Before a damaged BEV is allowed into storage, there are several checks that must be carried out to ensure it is safe to store the damaged BEV. Britannia Rescue, the breakdown service provider used by LV=, have provided their handover protocol as an example of the checks required. A copy of this can be found in Table 3 - Handover protocols.

There are Government guidelines regarding safe storage of battery electric vehicles following a road traffic collision (RTC). This is often referred to as quarantining the vehicle and involves storing a vehicle for period at a set distance from any other vehicles and infrastructure [6]. This is to safely ascertain whether the battery is safe to be investigated and potentially removed from the body of the vehicle. This procedure allows for any unobservable damage to the battery to present itself, such as thermal runaway which is described in 4.6.2: Fire or thermal runaway.

Just like any conventional damaged ICE vehicle, damaged BEVs have the potential to reignite hours or even days after an incident, although the likelihood of this happening may be higher with a BEV. Damaged BEVs should be stored in an outside quarantine area, at a safe distance away from any other nearby objects. Government guidelines state that 15 metres is considered an adequate safe distance, however the vehicle manufacturer's methods should always be deferred to as many manufacturers have different requirements.

See section 4.7.1: Quarantine Limitation Calculations for further detail on quarantine scenarios and calculations of average distances used in this document. This distance may be reduced if a suitable fire-resistant barrier is employed or if the vehicle is parked in dedicated fire protected parking areas.

Further work is required to understand the implications for bodyshops and other parts of the transport, repair and salvage industry. It is clear from the following calculations that financial, time and logistical challenges will exist because of quarantine requirements.

Table 3 - Handover protocols

<table>
<tr><th colspan="3">VEHICLE STORAGE – Handover Protocol</th></tr>
<tr><th>No thermal event present</th><th>Potential thermal event occurring</th><th>Thermal event is occurring</th></tr>
<tr><td>Follow IVR thermal checks</td><td>Follow IVR thermal checks</td><td>Follow IVR protocol</td></tr>
<tr><td>If no spike in temperature</td><td>If there is a spike in temperature</td><td>If there is smoke, flame, noise, gases, smell</td></tr>
<tr><td>1. Vehicle can go into general storage (allied to company operating policy/procedures).
2. Continue to monitor.</td><td>1. Call 999 and ask for Fire Service.
2. Must emphasise to the call handler:
a) That it is an electric or hybrid vehicle with potential of thermal event.
b) To request attendance with thermal imaging equipment.
c) A potential deployment of a vehicle fire blanket by VRO.
3. Before Fire Service is on scene and if VRO feels that it is safe to do so, a vehicle fire blanket* could be deployed over the vehicle (in line with manufacturer's instructions).
4. Ensure good access for Fire Service.
5. Dynamically risk assess if it is safe to move other vehicles from around the vehicle.
6. Stand well back and upwind of vehicle (smoke and gases are toxic and possibly life threatening).</td><td>1. Stand well back and upwind of vehicle (smoke and gases are toxic and possibly life threatening).
2. Call 999 and ask for Fire Service.
3. Must emphasise to the call handler:
a) That it is an electric or hybrid vehicle with thermal event.
b) To request attendance with thermal imaging equipment.
4. Ensure good access for Fire Service.
5. Dynamically risk assess if it is safe to move other vehicles from around the vehicle.</td></tr>
<tr><td colspan="3">* Vehicle fire blankets should only be deployed
• Following a dynamic risk assessment and should you deem it necessary and safe to do so
• By persons trained in vehicle fire blanket deployment and in line with manufacturer's instructions
• Where specific operational arrangements at your premises have been agreed, with your local Fire Service
NEVER deploy a vehicle fire blanket on a vehicle that is already on fire
(e.g. where there is smoke, flame, noise, gases, smell).

NEVER attempt to remove a vehicle fire blanket after deployment, this can only be done by the fire service.</td></tr>
</table>

4.7.1 Quarantine Limitation Calculations

Assumptions and considerations:

- Storage areas are rectangular (W x L).
- Average Quarantine time and distance calculated using the mean of stated values from OEM methods.
- In the absence of OEM specific quarantine periods and distance, it assumed technicians would use the government recommended distance (15m), however for the purposes of this report, the average distance is used.
- Average UK car dimensions have been used (4.4m x 1.8m) to calculate the true quarantine area [15].
- Repair bay dimensions and spatial arrangement has been assumed using standard procedure for dealing with damaged BEVs.

As such, assuming an outside storage space with capacity for 100 cars using the standard car space (2.8 x 5 m [16]) with surrounding infrastructure, and with the current average quarantine radius of 11.67 metres from the extremities of the car, this would allow the safe quarantine of 2 battery electric vehicles, a 98% reduction in capacity. As shown by Figure 16 - Quarantine Arrangement of a storage area of which the boundaries have surrounding infrastructure (orange zones represent quarantine radius) below, the quarantine areas can intersect given that the BEVs remain the sated distance apart.

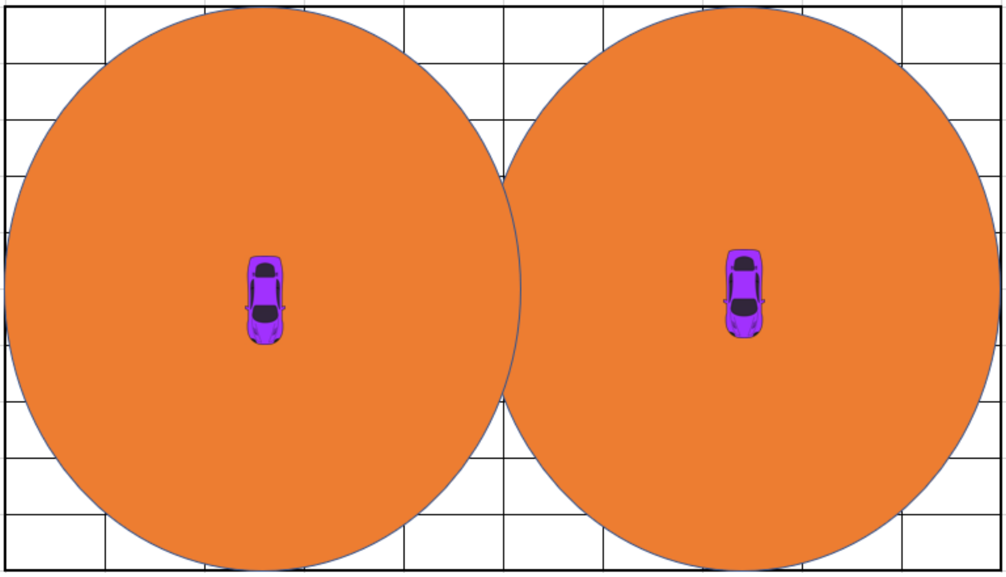

Figure 16 - Quarantine Arrangement of a storage area of which the boundaries have surrounding infrastructure (orange zones represent quarantine radius).

For a similar size storage area where the boundary is not surrounded by infrastructure, in an open green space for example. As shown below in Figure 17 - Quarantine Arrangement of a storage area of which the boundaries have no surrounding infrastructure (orange zones represent quarantine radius), the quarantined cars can be arranged in such mitigate the restrictions to an extent through careful arrangement, ensuring that all cars are distanced appropriately from one another. This arrangement displays a 92% reduction in storage capacity. -

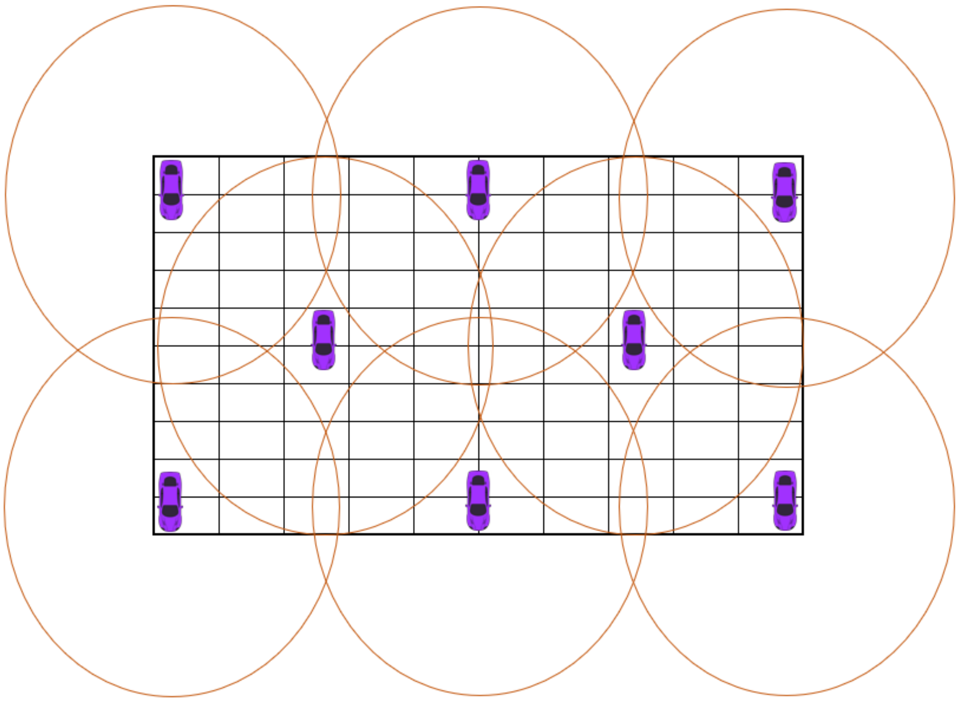

Figure 17 - Quarantine Arrangement of a storage area of which the boundaries have no surrounding infrastructure (orange zones represent quarantine radius).

For quarantine periods, which using government guidelines should be for 48 hours. 100 storage bays at a cost of £25 per day (as informed by market experts) would accumulate £5000. With the two scenarios of no surrounding infrastructure and surrounding infrastructure, the new incurred storage costs per car would be £2500 and £625 respectively,

For repair network entities that do not possess outside storage space they may be required to quarantine with in the workshop which will most definitely be surrounded internally by infrastructure. The dimensions of a repair shop with bays equipped to deal with BEVs are (7.62 m x 3.96 m) with an additional 1 metre by 1 metre for the high voltage (HV) safety cordon. With the current average quarantine radius of 11.67 metres and some adjustment so the cordoned area does not cover the walkways, this space would allow the safe storage of one battery electric vehicle, a 91.7% reduction in capacity as show in figure 16.

This issue can be further exacerbated by the design characteristics for some EVs. For example, the chassis on some vehicles cannot be moved if the battery has been removed as it is rendered structurally unsound. This severely limits the capacity if one of these models requires repairing. See section 5.1: Repair for further information on this.

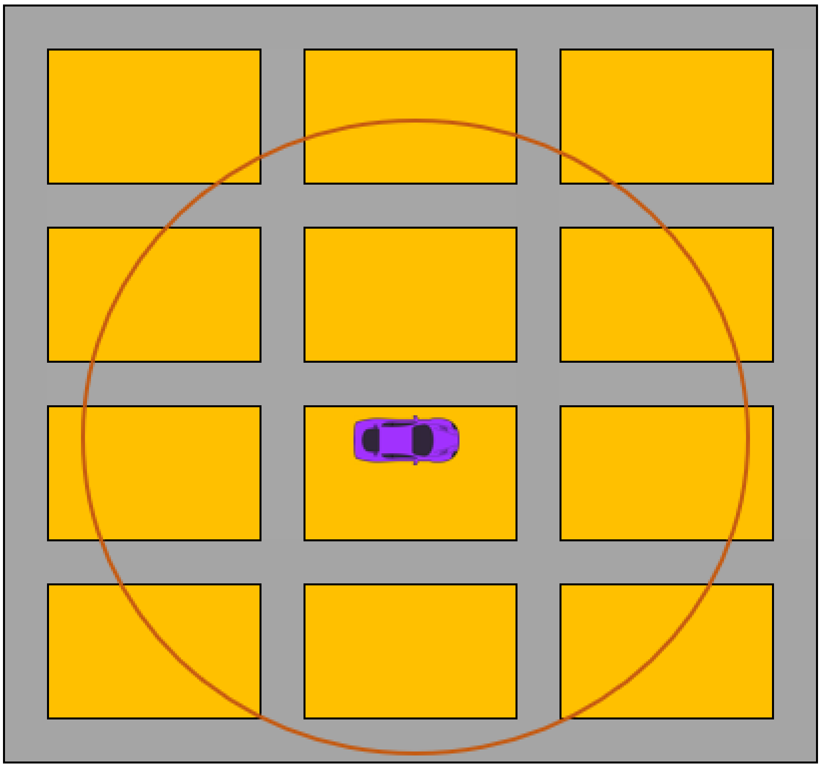

Figure 18 - Quarantined Vehicle within a repair shop (orange areas represent repair bay with included High Voltage safety cordon, grey areas represent walkways and workspace, and the red radius represents quarantine zone).

An important note is that the distance and durations applied to these scenarios are averages calculated from values included in OEM methods and governing body guidelines. This could result in specific situations requiring increased values and incurring heightened limitations.

Claims data shows that the cost of a hire vehicle as part of a claim is ~£30 per day (estimate as of 2023). The incurred cost through following recommended quarantine protocols of 48hrs will add a minimum of £60 to every claim for the battery discharge time. If the vehicle cannot be safely stored at the repair centre there will be further costs associated with transportation to and from an alternative location, storage at the alternative location, along with a longer duration of hire vehicle. All these factors could result in a measurable rise in the associated claim cost, duration and likely impact on customer satisfaction.

4.7.2 Current capacity of storage

Research has shown that currently only a few repair networks are following the industry or specific VM quarantine requirements, and therefore there are no obvious concerns over storage capacity to date. However, this leads to the current claim costs data being not reflective of the realistic totals. Projections show that repair costs will increase significantly when the entire repair network follows the quarantine time requirements and associated floor space, as this will lead to a lack of capacity and throughput.

5. Handling of Damaged Battery Electric Vehicles

Thatcham Research has carried out a review of the capability and capacity to adequately, and cost effectively, handle damaged BEVs within UK's vehicle repair sector, including both franchised and independent repairers.

Synetiq, a market leader in the salvage and handling of damaged vehicles has provided insight into both the claims processes and the technical handling of damaged BEVs and their batteries.

Of the surveyed vehicles and manufacturers:

- **48%** had repair methods and parts to support repairable high voltage batteries.
- **28%** had some repair methods and parts to support partially repairable batteries.
- **24%** had non-repairable batteries.

Currently, Thatcham Research is aware of only two Vehicle Manufacturers offer a battery exchange programme.

Due to the lack of training and available VM methods for battery repair, it is likely that battery repair will only be performed within a specific Vehicle Manufacturer's dealer network. This will remain the case until training addresses EV awareness and competency.

5.1 Repair

5.1.1 Prior to repair

As previously indicated, little update has been made to the assessment of repair itself. New methods of damage assessment on the vehicle should be carried out, considering the time, equipment and facilities required for battery discharge, removal, and or replacement in the majority of repair scenarios, as this will influence whether the vehicle is deemed repairable or a total loss.

Quarantine time for the vehicle should be included in the estimate when necessary. This should include its additional storage costs.

Additional consideration should be taken of transportation to and from specialist locations for battery diagnosis or repair.

5.1.2 Ease and likelihood of repair

Repairs of all vehicles, regardless of type, tend to fall into two categories, non-structural and structural repairs.

Non-structural repairs typically fall into the following categories:

- Paint repairs: scratches
- Cosmetic exterior body panel repair: dents
- Bolted panel replacement: doors, wings, bonnet, tailgate
- Exterior plastic component repair: bumpers, trim
- ADAS component replacement and system calibration
- Bolted crash structure replacement
- Cooling system component replacement - radiator

The only factors which are likely to differ between a BEV and a conventional ICE vehicle are:

- Isolating and reinstating HV power for the relevant repair. It’s important to note that not all of the repairs listed above will require this and that the approach taken across different VM’s can lack in terms of the repair information being available and standardisation in the repair process.
- Draining and refilling coolant system: in some cases, specific diagnostic equipment and expensive coolant is required. While this procedure also applies to an ICE vehicle, the coolant system on a BEV is there to cool the H.V battery and other HV components such as the drive motors. The potential risk of damage to high-cost H.V components if processes are not followed or not identified correctly are far greater than that of an ICE vehicle. This is due to the complexities in diagnosing faults.
- Different requirements for lifting the vehicle: weight, ramp/tooling
- Space requirements for safety barriers and signage around the vehicles
- Paint booth temperature: subjecting the HV battery to high temperatures can cause damage to the component. The stated safe temperatures vary across different BEV’s and sometimes the information is not provided by VM’s

As such, non-structural type repairs on a BEV vehicle will largely be similar to that of an ICE vehicle. But there are repair scenarios that have specific requirements that will have an impact to repair cost and safety.

All possible repairs to a vehicle fall into the category of structural repairs. This encompasses the non-structural repair attributes and also the more complexed repairs that result from higher severity scenarios of damage. Repairs that are specific to structural repair include:

- Chassis panel replacement and chassis alignment
- Permanently fixed exterior body panel replacement
- HV component replacement and repair
- Mechanical component replacement and repair

The following factors have been identified as affecting the cost, time, quality, and safety of BEV structural repairs:

- Ability to diagnose HV battery status
- VM repair information to identify HV battery distortion and clarity for assessment of repair
- New and specific limitations and restrictions on standard repair related diagnostic procedures, such as coolant draining and refilling
- VM information and unstandardised approach to isolate and reinstate power to the HV system
- Special tooling requirements
- Restrictions in moving the vehicle once the HV battery is removed – due to the HV battery being an integral part of the vehicles structure
- Lack of clarity in VM repair information for when a HV battery needs to be removed as part of a repair

Examples are provided below where vehicle led research carried out at Thatcham Research has identified that specific vehicles present repair industry with some challenging repair concerns.

- Example 1

  Special adapters that provide the clearance are required to remove the HV battery when on a two-post ramp.

  VM repair methods make a specific note that severely damaged vehicles should not be stored inside a structure or within 15 m of a structure or another vehicle.

- Example 2

  The battery forms an integral part of the vehicle's structure and the vehicle manufacturer method states that if the HV battery has been removed: the vehicle cannot be moved due to risk of damage to underbody and persons cannot enter the vehicle due to risk of damage to the underbody. This means that the vehicle requires quarantine in the position of repair required, and therefore has significant implications on the throughput of other vehicles due to its quarantine limitations.

5.1.3 Skills Gap/ Development

With the growing adoption of BEVs, supporting repair infrastructure must grow proportionately in line to maintain market requirements and sustainability. The Institute of the Motor Industry (IMI) has stated that in January 2023, roughly 16% of technicians in the U.K. had the relevant qualifications to work on electrified vehicles and have produced some analysis concerning the impending skill gap between EV trained automotive technicians and the increasing demand. This gap between the minimum required number of Level 3 and 4 HV qualified technicians and the forecasted actual workforce, is the point at which the skills gap materialises. They have predicted this will become a significant concern around 2026 and that by 2030, this skills gap will have grown to a shortfall of ~35,700 technicians [5].

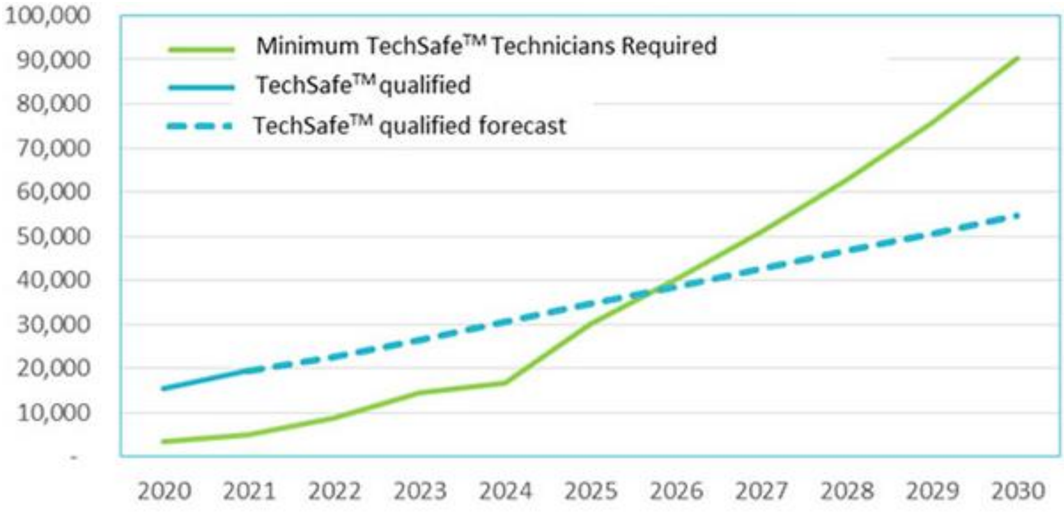

Figure 19 - Forecast Gap Between Predicted Electric Vehicles on UK Roads and TechSafe™ Technicians [17]

However, research has shown that there is a current emphasis on training from the industry's awarding organisations, and specifically TechSafe™, which is aimed at technicians who operate within the sectors of repair and maintenance. The bias of the focus to date has been for them to meet a minimum standard of Level 3 HV repair and maintenance competence. While this is appropriate for many, this level is not, and will not, be required by a significant portion of technicians. As part of this project, discussions with LV= have indicated that while many of their repair technicians have had level 4 training, the training is not currently being used as there are no appropriate repair methods available to allow them to carry out repairs.

Research has highlighted the need for specialised training in the absence of methods for the repair of BEVs. Another emerging training course in this area is the ELEC303 – Repairs, Rework, and High Voltage Component Replacement on Automotive Electric Vehicles. This programme is focused on educating attendees in fault identification and overhaul using the appropriate tools and standard operating processes (SOPs) [18].

6. Batteries

6.1 Introduction

Whilst battery chemistry itself is less important to an insurer's workflow, there are significant reasons to explore the technology implementation to understand where insurer concerns do arise.

Furthermore, the detail in section 4 of this document outlines accident scenarios where battery involvement may occur. Much of the research and development of batteries and the use of newer battery architectures such as the structural use of Lithium Iron Phosphate (LFP) batteries in the latest generation of one VM are designed around structural rigidity, ease of production and reduction of vehicle weight. Whilst this may be good for cost, performance and range, those features are likely to make battery and vehicle repair more challenging and lead to more total loss decisions. This is only applicable for one emerging cathode chemistry, of which there are others also gaining prevalence.

As a good example to illustrate the challenge, below is a picture of a vehicle which was declared uneconomic to repair due to an underbody scrape. The HV battery was deemed unrepairable despite significant metal plating to protect it.

Figure 20 – Volkswagen ID4 battery underside with an abrasion 5mm in depth.

A similar class of vehicles is planned for released to market which has pouch based LFP batteries with only a plastic underbody, justified by the increased stability of the LFP technology. Whilst understandable from many design and efficiency viewpoints, such designs expose batteries to more damage in accidents. When balancing design factors, vehicle manufacturers rarely consider repairability of accident damage.

6.2 Battery technology

This section explores the current technologies and situations that exist in the battery industry. These factors have a serious effect on the life and cost analysis of a battery' market pathway, sustainability, and environmental favourability. The most impactful of these factors being the diverse array of cathode chemistries and battery designs that exist making standardisation of repair and diagnosis extremely problematic.

6.2.1 Introduction to batteries

A Battery Electric Vehicle (BEV) is a vehicle in which 100% of the driving force is created through electrochemical reaction. There are an array of mechanisms through which a battery can create the electrical energy required by a motor to force a vehicle in a motion with continuous development occurring. The most populous in the automotive industry being the creation of electron flow between a graphite anode and Lithium based cathode.

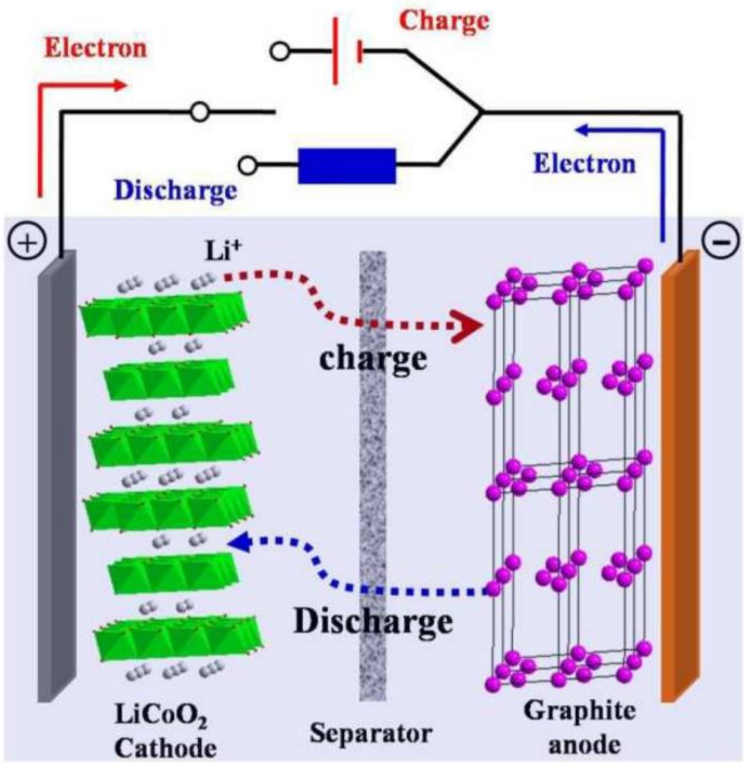

Figure 21 - Mechanism schematic depicting the electrochemical process of a lithium-ion battery [19].

6.2.2 Cathode Chemistry

One of the many complexities that exist when attempting to optimise the lifecycle of EV batteries is the array of cathode chemistries that exist in the market. The following are the most common with Lithium being the most prominent constituent.

Lithium Cobalt Oxide (LCO).

With diminishing popularity in today's EVs because of their high cobalt fraction (~60%). This was the favoured choice owing to the high energy density, extended lifespan, and manufacturing simplicity [20].

Lithium Nickel Manganese Cobalt (NMC)

With high reliability the NMC cathodes boast high energy densities. However, as the market tends towards higher nickel fraction combinations, thermal stability decreases. There are multiple variants adjusting the ratio of active materials which produce varying outputs and cost [20].

Lithium Iron Phosphate (LFP)

LFP cathodes are unique when compared to other lithium-based counterparts due to their robust nature. LFPs can maintain electrochemical performance at an increased temperature range resulting in reduced chances of thermal runaway while remaining cost effective. This is due to higher stability and results in increased cycle life [21].

Lithium Manganese Oxide (LMO)

Manganese based chemistries produce increased cell voltage and thermal stability at a lower cost relative to the cobalt alternatives. However, these benefits come at the cost of reduced durability and subsequently lower lifespans [20].

Lithium Nickel Cobalt Aluminium (NCA)

NCA batteries whilst incurring higher costs, boast impressive performance limits with increased energy density, resulting in a higher power to weight ratio. This allows OEMs to install smaller, lighter batteries to achieve the same range as other chemistries. In addition, NCA based systems have increased performance in cooler climates, a pitfall for the standard EV performance [22].

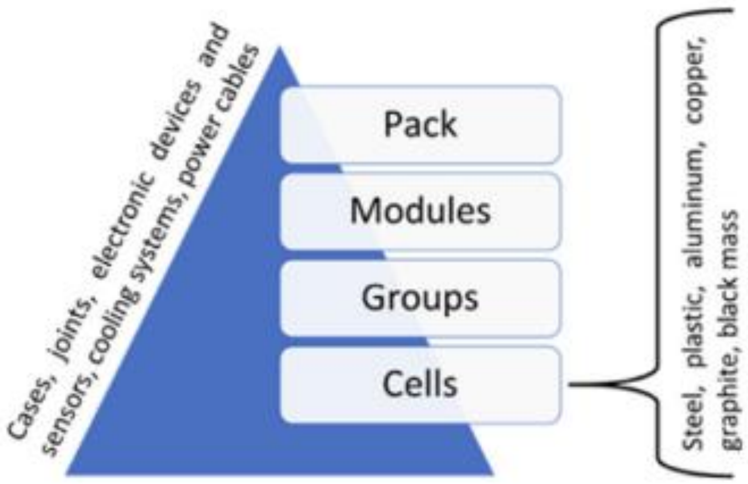

Figure 22 - Hierarchical Structure of a Battery Pack [23]

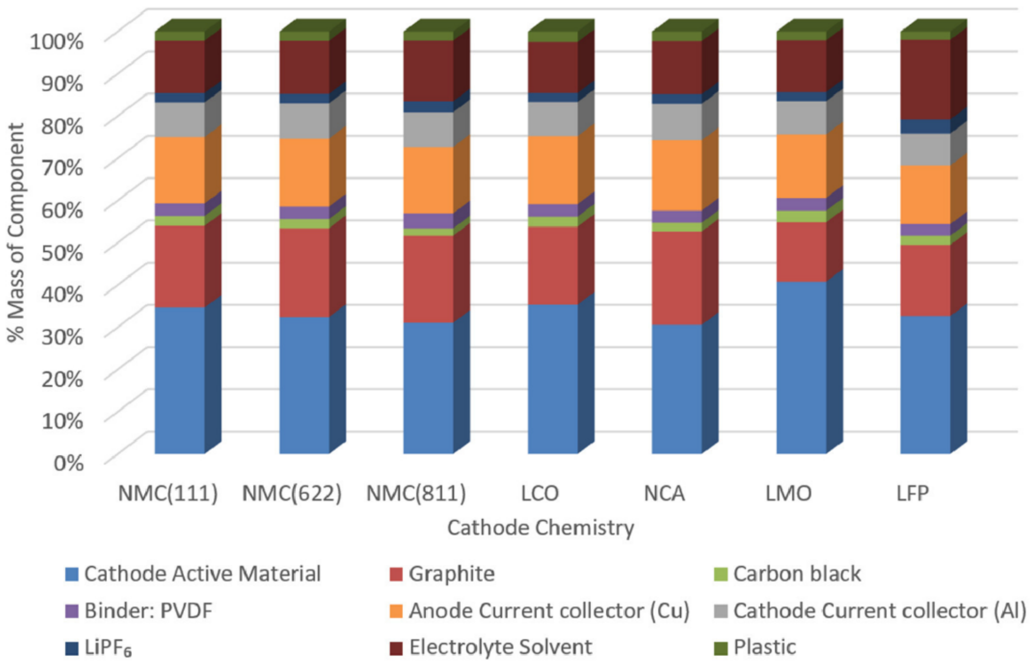

Figure 23 - Relative mass fractions of different cathode variants in electric vehicles (EV) [24].

6.2.3 What is Battery State of Health (SoH)?

The state of health (SoH) is a parameter that reflects the general condition of the battery and its ability to deliver the specified performance compared with a fresh battery (displayed as a %). Factors that are considered include charge acceptance, self-discharge, internal resistance, and voltage. The State of Health is a measure of the long-term current capacity of the battery and gives an estimation of how much of the available life of the battery has been consumed, and how much is left.

There is no absolute definition of the SoH. It is a subjective measure as it is derived it from a variety of different measurable battery performance parameters which are interpreted according to their own set of rules. It is an estimation rather than a measurement and is evaluated by the designer of the battery management system.

Within the Electric Vehicle environment, a measurement of battery life is the total amount of energy (in watthours) which can be put in and taken out of a battery over all the cycles in its lifetime and before its capacity reduces. For example, a 60-kWh battery that has 90% SoH would effectively act like a 54-kWh battery.

6.2.4 What is Battery State of Charge (SoC)?

The state of charge (SoC) of a battery or cell is a ratio of the current capacity at any given time compared to the total available capacity. The value of this ratio can range between 0 and 100 percent and a cell with 100% SoC would be deemed fully charged.

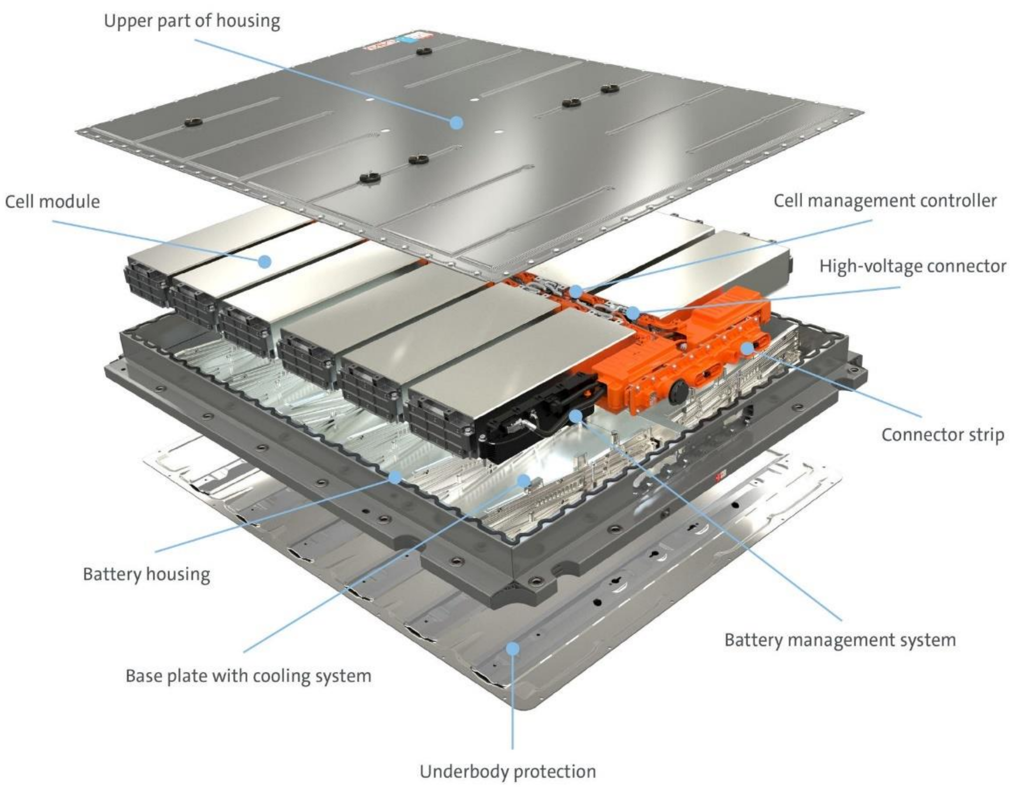

Figure 24 - Internal Architecture of Volkswagen's Modular Electric Drive Matrix (MEB) Battery [25].

6.2.5 Battery Degradation

During a battery's lifetime aging will occur, meaning the vehicle won't have as much range compared to its initial performance. The measure of loss in battery capacity is called capacity fade as a result of battery degradation, which can be caused by multiple factors.

The major factors that affect battery health and influence degradation are:

- Driver patterns (e.g. aggression)
- Climate (e.g. high temperatures)
- Overcharging (continued charging on a fully charged cell)
- Deep discharging (occurs when the battery's capacity has been exhausted)
- Charging with a high charge rate
- Corrosion
- Storing with full state of charge

A notable situation is that batteries are increasingly degraded by the cycling effects in respect to gradual degradation over time. Cycling effects refer to implications on resistance and capacity because of charging and discharging the battery [26]. Calendar effects relate to the effects experienced on the same parameters in the absence of current flow. The Society of Automotive Engineers (SAE) conducted a study using their Battery Lifetime Analysis and Simulation Tool for Vehicles (BLAST-V) and discovered that the climate in which the battery exists (i.e. temperature) and the driving patterns of the driver, have the biggest influence on battery degradation [26].

6.2.6 Future technology

There are promising improvements in battery technology on the horizon propagated by changes in architecture, chemistry, and the mechanisms by which power is generated. Developments are focused around improving characteristics including but not limited to total range, cell efficiency, production cost, total mass, charge rate, predictability, and thermal operating range.

One new architecture consists of an array of wafer-thin cells, which increase space utilisation by up to 50% compared to conventional EV battery packs [27]. Another developing modification to battery structures involves integrating the battery modules into the structure of the car chassis, reducing battery mass, and increasing range [28].

Altering cathode and anode chemistries is a continuous area of development which is influenced by demand for range and reliability in addition to the availability of rare metals. One advancement involves the replacement of graphite as the primary anode material with silicon, which has 10 times the capacity and can be produced sustainably from by-products of agricultural processes [29].

Another focus of development is the chemical mechanism by which the battery stores energy. A carbon nanotube electrode ultracapacitor is 100 – 1000 times more conductive which creates a system capable of higher frequency charging and discharging for up to 1 million cycles. These properties when applied to the automotive industry results in faster vehicle charging, increased range, and thermal resilience [30].

6.3 Effectiveness of Battery Diagnosis

Battery diagnosis poses significant challenges to be effectively applied in the field. Throughout this section the current limitations will be explored with the most prominent examples being the limited data recorded by the battery and subsequent polarisation from the end user. This severely limits the health diagnosis of batteries involved in an RTA and greatly increases the chance of unnecessary total loss. This section focuses on the limitations faced by parties in the repair and salvage industries. Vehicle manufacturers are able to mitigate many of these due to access to methods and technology.

6.3.1 Current Landscape

EV batteries are controlled and measured using a battery management system (BMS). These systems are responsible for the optimal charging and discharging of the battery to maximise life. The BMS achieves this through ensuring the efficient use of the residual energy by avoiding deep discharge and over voltage [31].

Battery Diagnosis is a vital appendage to various parts of the claims process. This procedure if actionable, is crucial in understanding the current health of a battery however the current limitations are multi-facetted:

- The information that is recorded by the BMS is only accessible when the battery is still connected to the car and displayed through the cars infotainment system.
- The data recorded by the BMS is further censored by the OEM from both the driver and any technician accessing the car.
- The extent of data recorded both pre and post censorship is not sufficient to accurately diagnose the overall state of the battery.

- Individual cell damage is not necessarily revealed by conventional BMS health monitoring and may yet not be revealed until some time post impact.

As a result of the non-linear behaviour of Lithium-ion batteries, the prediction and modelling of the State of Charge (SoC) or State of Health (SoH) remains a challenge. Accurate forecasting of this characteristic by the Battery Management System (BMS) is essential for the effective operation of these batteries [32]. Research is on-going to develop increasingly accurate infrastructures with the most promising results being produced using physical experimental methods in partnership with machine learning models. One of these partnerships involves using Electrochemical Impedance Spectroscopy (EIS) to measure physical characteristics upon which models are trained. A study by the Warwick Manufacturing Group in this structure discovered their model could accurately predict the SoH of a Li-Ion battery with a 1.1% error [33]. These EIS measurements can be effectively embedded into the BMS of an electric vehicle to guarantee the effective operation and management of its battery [32]. However, is it worth noting this method has only been achieved at a modular level within batteries.

6.3.2 Future Developments

As of April 2022, MAHLE have integrated new triage software into their popular TechPRO® diagnosis tool. This new platform is the first to permit independent repair workshops to diagnose electric vehicle faults from the thousands of relevant error codes within an average time of 30 seconds, whilst possessing local data storage and subsequent analysis, reducing the need for the device to re-connected to the vehicle, thus optimising the triage process of electric vehicles [34].

An interesting development influenced by the growing existence of connected cars is surrounding cloud based BMS modelling. This idea involves uploading live data to cloud-based processing models. The machine learning algorithms, by their very nature, continuously evolve in response to real time data to accurately calculate an extensive repertoire of battery characteristics. This process creates a feedback loop through which onboard settings can be adjusted by the model to optimise various performance qualities [35].

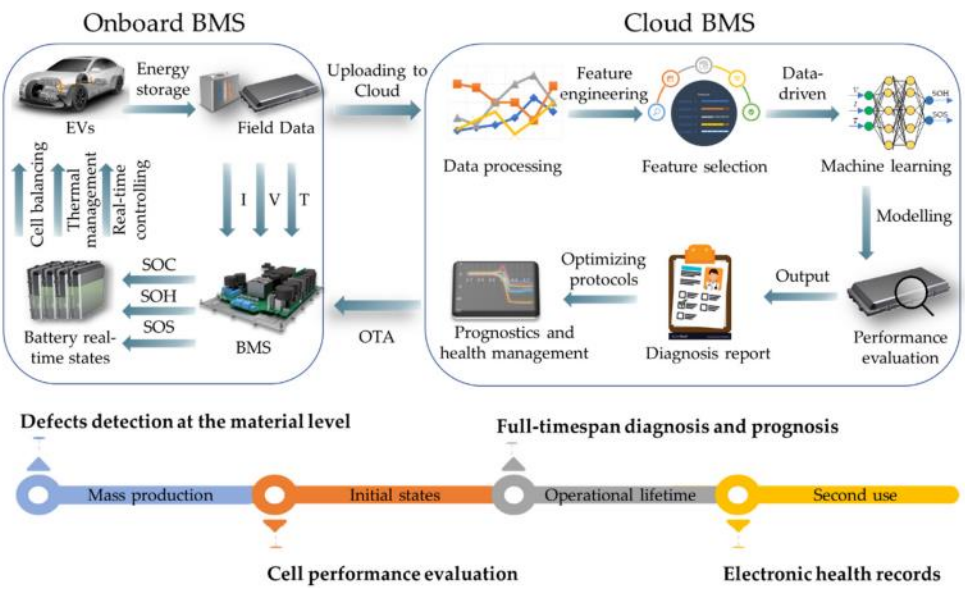

Figure 25 - Cloud-based Battery Data Analysis System Concept Schematic [35].

6.4 Environmental Sustainability

6.4.1 Recycling

Whilst repair is the most sustainably favourable option, it is not always technically viable and therefore the recycling market has an increasing responsibility. With growing demand and decreasing raw supply of precious metals essential in the production of EV batteries, enhancing the recycling and recovery of these compounds from End-of-Life (EOL) batteries is the logical evolution for the industry. Current populous methods for the recovery of critical raw materials (CRM) involve the processing of shredded battery packs creating a homogenous mixture known as 'Black mass'. This mixture may contain Lithium, manganese, cobalt, graphite, steel, and nickel.

Pyrometallurgy

Pyrometallurgy, as the name suggests is a high temperature smelting process in which the black mass mixture is further broken down and organic material such as the anode material, most commonly graphite, are oxidized and further fuel the process. Using aluminium as a reductant catalyst, the newly formed alloys undergo carbon reduction before being further separated into pure compounds. This process has high recovery rates for precious metals - copper (Cu), nickel (Ni) and Cobalt (Co). Lithium is confined to the slag fraction which requires further processing to efficiently recover [36].

These processes have developed successful business models due to the cobalt content being a popular by product for use in portable electronics. However, as the cobalt content of EV batteries tends to zero, these models are becoming less lucrative [24]. The main attractions of pyrometallurgy are its simplicity and maturity within the space and that both LiB and NiMH batteries can be processed to output large blocks of each element. Disadvantages include the elements being efficiently recovered only accounting for 30% wt. of the battery the high energy requirements and high CO_2 creation [36]. Progression in this area through altering temperatures, pressure and slag composition has resulted in some promising recovery efficiencies of high purity lithium from rich slag of 97.45%.

Hydrometallurgy

Hydrometallurgy applies aqueous chemical reactions to achieve material separation. This involves the black mass blend being saturated in either an acid or base solution causing the corresponding constituent ions to 'leach' into the solute. Under the various techniques, including electrolysis and precipitation, these ions are separated. Benefits of this method involve the production of high purity elements, the most constituents of Li-ion batteries can be recovered, requires significantly lower temperature conditions and lower carbon emissions. The limitations include difficult separation of compounds in solution due to their chemical similarities and high wastewater treatments costs.

Leaching and more specifically alkali leaching has grown in popularity because of its ability to selectively separate ions, reducing the need for further separation and processing. Acid leaching is still prevalent due to its high recovery rates. Due to the affinity of lower valence metals to dissolve more readily, the efficiency of leaching can be further improved using reducing agents. This technology has been further developed to utilize biological acid produced through the metabolism cycle of micro-organisms, offering an environmentally stable option, with results of culturing *Aspergillus Niger,* a fungus, recovering 100% of Copper and Lithium from spent batteries [36]. These organic techniques have intrinsic limitations with high contamination susceptibility and extended time periods required to culture the species.

Solvent Extraction applies the different solubilities of metallic ions in aqueous solution against a solvent. This technology hosts rapid reaction periods (~30 Minutes) whilst achieving high purity recovery [36]. However, this method poses economical restrictions due to the expensive solvents and apparatus required for the complex mechanism.

Chemical precipitation, in a similar fashion to solvent extraction, applies chemical reaction mechanisms to extract metallic ions and impurities and can remove specific ions from complex mixture through the modification of the pH environment. Using leaching solutions phosphoric acid (H_3PO_4) and Hydrogen Peroxide (H_2O_2) in partnership with Oxalic acid and Sodium hydroxide (NaOH), Pinna et al were able to achieve 88% and 99% recovery of Cobalt and Lithium respectively [36].

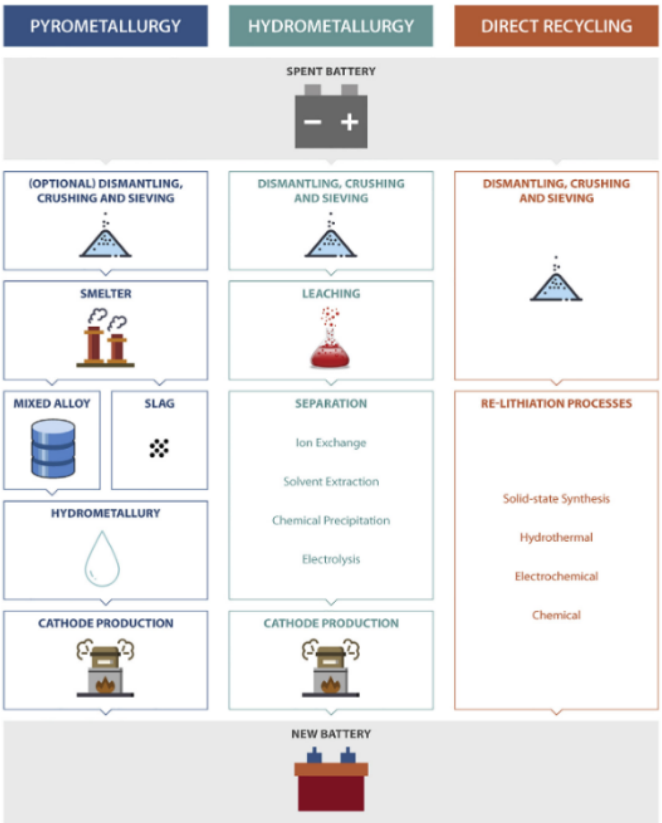

Figure 26 - Recycling Methods Pathway Diagram [36].

Direct Recycling Methods

Direct Recycling refers to a branch of methods which involve the direct harvesting and recovery of active compounds without altering the chemical structure of the materials. These methods whilst subject battery constituents to rudimentary separation techniques such as magnetic or density separation. The use of thermal treatment is used moderately to mitigate chemical breakdown of the target materials further whilst further reducing the energy requirement compared to standard pyrometallurgical techniques. Subsequent to the initial processing, both bulk and surface defects are restored using appropriate mechanisms, in lithium’s case through re-lithiation [36].

Whilst posing a comparatively lower technology readiness level to the other method classes, benefits include the simplicity of the process, almost immediate readiness of extracted materials for repurposing and considerably reduced emissions relative to its *pyro* and *hydro* metallurgical counterparts. A host of limitations of direct recycling are propagated when considering complex chemically structured cathodes, where multiple target compounds may exist. This situation is conducive with economic and technical difficulties due to the requirement of matching the sorting and processing to the exact cathode makeup. This need for adjustment creates significant uncertainty pertaining to the guaranteed recovery rates and structure of recovered material [36].

A development of these methods has emerged in the form of solid-state sintering, in which material is compacted under pressure or heat without reaching the liquefaction stage. This, in the presence of a lithium source, repairs deficiencies which influence battery degradation, such as unwanted phase changes [36].

Figure 27 - Location of established Lithium-Ion battery recycling facilities designated by recycling technique (as of 2019) [37].

Future Developments

In the battery recycling space, there are consistent advancements in the efficiency of the methods used to separate and refine materials to be repurposed or remanufactured. With the EV LiB market forecasted to reach £11 Billion by 2027 [38], these developments will continue to be developed and scaled to match demand.

There are also crucial advancements in this field which are of a non-technical nature. These developments include the establishment of stable business models for LiBs akin to those used for lead-acid batteries. Local recycling of batteries and widespread adoption of all techniques, currently facilities only exist in approximately 10 countries [37]. Finally, the adaptation of EV battery design to integrate the use of remanufactured materials more easily.

In the US, there are developing examples of the creation of circular economies regarding the processing, refining, and remanufacturing of critical raw materials (CRM) within domestic markets. Redwood Materials are a prime model aiming to retain anode and cathode materials within the United States and reduce fossil fuel consumption through creating a supply chain loop [39]. This retainment is created through the development of component fabrication, recycling, and distribution facilities to reduce the reliance on exporting these materials to foreign markets.

In the United Kingdom, while there are promising pilot installations developing, there are currently no operational facilities capable of refining the black mass material created by shredding batteries, resulting in this material being shipped to Europe. Current EU legislation demands that certain limits of materials must be conserved (by mass, displayed in tables 5.1,5.2,5.3) must be met when concerned with the lifecycle of certain elements leaving and re-entering the market.

Tables 5.1,5.2 and 5.3 - Current to Proposed EU Recycled Material Benchmarks (percentages by mass) [40].

Year	Average LIB Recycling Target
2021 (current)	50%
2025	65%
2030	70%

Year	Specific Target per Metal			
	Li	Ni	Co	Cu
2021	N/A	N/A	N/A	N/A
2026	35%	90%	90%	90%
2030	70%	95%	95%	95%

Year	% Recycled Metal in New Cells			
	Li	Ni	Co	Cu
2021	N/A	N/A	N/A	N/A
2030	4%	4%	12%	N/A
2035	10%	12%	20%	N/A

6.4.2 Remanufacturing and Re-use

The remanufacturing of EV batteries and deploying them back into the primary market requires the batteries to have adequate SoH and meet the OEM specifications. The United States Advanced Battery Consortium (USABC) states that EV batteries are not appropriate for redeployment when any denomination of a battery pack's delivered capacity is 80% or lower than its rated output [36]. Upon further inspection it may be discovered that a single module or group of cells are unable to hold the desired capacity and that retiring the entire battery presents a loss outcome.

Repurposing End-of-Life (EOL) batteries presents an alternative to the recycling of these batteries. however, this avenue presents numerous hurdles to effectively achieve. In its instance, a candidate battery for repurposing must be accurately graded whilst considering the array of designs, cell chemistry and performance characteristics. This will then require the replacement of identified degraded cells. For alternate purposes to automation, battery management systems will need to be configured and integrated. The next challenge concerns the contractual risk of liability and the adoption of that risk. The final obstacle albeit the most important one is executing the repair and configuration for a competitive cost over a new battery [38].

Inspection/Test Categories	Type of Inspections/Tests	Influence on Safety	Risk Impact [1]
Visual	Swelling of modules or cells	Medium	Medium/Low
	Corrosion of connectors	Medium/Low	Low
	Intrusion of water and dust	High	Medium
	Loose cables and connections	Medium	Medium/Low
	Production date is available	Low	Not Applicable (N/A)
Electrical and Mechanical	Internal resistance	Low	High/Medium
	Measured discharge capacity	Low	High
	Insulation resistance	High	Medium
	Potential equalisation	Medium	Medium/Low
	State of Charge (SOC) range as per datasheet	High	High
Battery Management System (BMS)	Remaining useful capacity	Low	High
	Direct Current (DC) resistance	Low	High/Medium
	On board State of Health (SOH)	Low	High

[1] Evaluation factor for battery reuse (High to Low = impact on battery reuse).

Table 24 - Generic Checks for Battery Reuse Suitability [41].

6.5 Viability of the Second-hand Vehicle and Battery Market

A contributing factor to the viability of the second-hand battery market is the considerable number of cathode chemistries as elucidated in section 5.1.2 and growing development in anode technology. This range propagates logistical difficulties when using second hand batteries that possess varying energy densities, lifecycle durations and optimal operating conditions. Cell balancing is utilised by a battery's BMS to extend a battery pack's capacity. Through an active approach, the BMS system will move charge between cells to maintain consistent output from each cell while in series. The passive approach requires the BMS to ensure each cell only applies the same capacity across the whole pack. This technique is required as batteries are extremely susceptible to damage because of overcharging or over discharging [42]. This management of battery behaviour is required to mitigate both safety and performance characteristics such as thermal runaway and cell degradation. If a situation arose without cell balancing in which one cell is performing at over capacity, it would begin to generate heat. Due to their fragile temperature stability, other cells would be subject to a knock-on effect causing the reaction to become perpetual, further fuelling the thermal runaway. This need for cell balancing is a product of the systems being in series, which will be present when considering the grouping of second-hand batteries for secondary markets and poses the main challenge to achieving efficient repurposing.

There is currently a lack of guidance concerning the safe storage of batteries involved in an RTA and after removal from the vehicle. This void in recommendations creates scenarios through which parties are more likely to adequate batteries through to recyclers instead of into repurposing opportunities. Synetiq, a market leader in vehicle recycling and repurposing has developed custom battery storage apparatus including retrofitted safety features such as temperature sensors and a quench system. However, it is costly and, despite the small number of salvage classified BEVs, is already full.

Another limitation is heterogeneity of battery design in regard to connection port architecture. This will require the influenced parts of the industry chain, such as the repair network to acquire all possible variations to guarantee their ability to work on all EV batteries that they may be subject to.

6.5.1 Cost Analysis

Cost analysis provides a metric by which market routes can be assessed for viability against the value of producing new batteries. This comparison whilst seemingly entirely economical provides a distinct environmental benefit. In 2010, an EV lithium-ion battery cost around 600€/kWh reducing by over 50% to approximately 270€/kWh in 2015. This decrease is continuing to follow trend with prices estimate to reach under 100€/kWh as a product of the increased battery sales and advancement in manufacturing techniques [41]. However, regardless of current market price per Kilowatt hour, the total accumulated value of second-hand batteries must not be higher than the forecasted cost of production to maintain the economic attractiveness of repurposing.

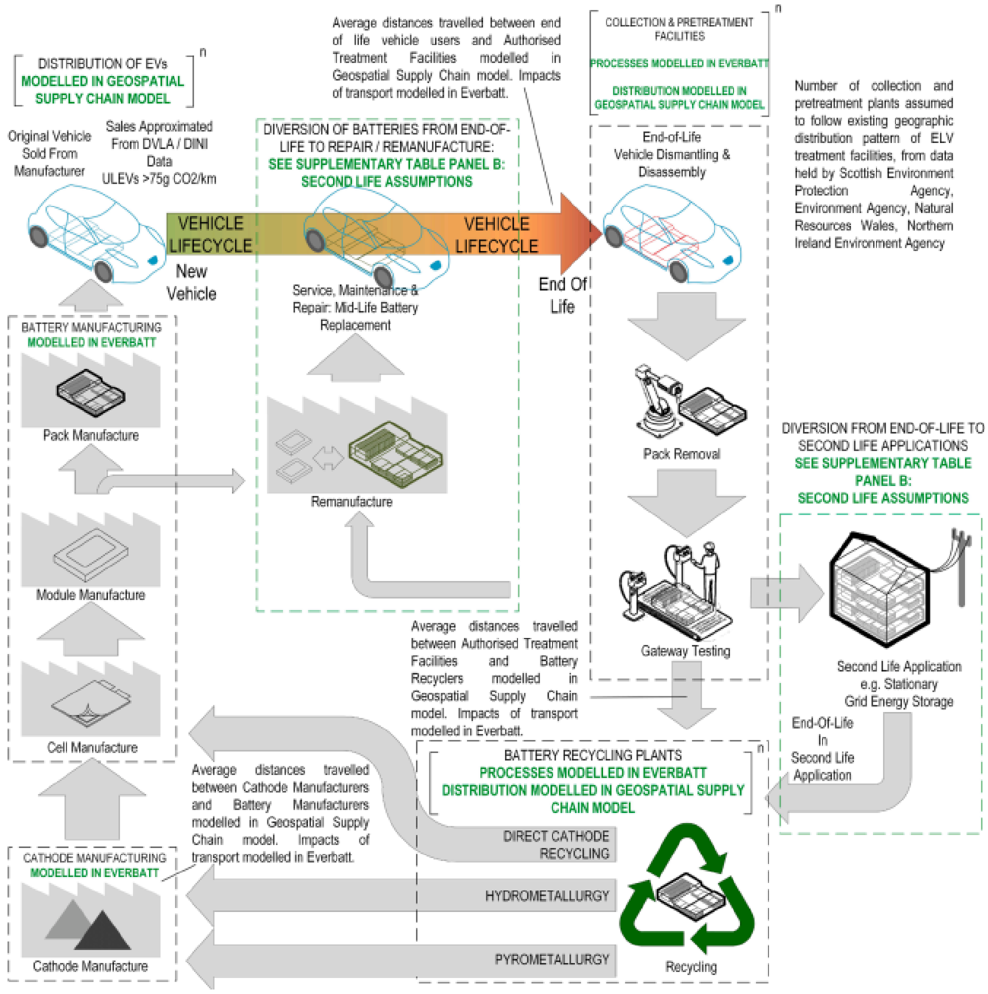

Figure 28 - Circular Economy Model for Li-Ion EV Batteries [43].

6.5.2 Life-Cycle analysis (LCA)

Life-Cycle Analysis is an ecologically based method to compare the relatively viability of technologies by computing the environmental impact, in this case BEVs against traditional ICEVs. The evaluation is distributed across 4 stages. The first phase of analysis is considering the extraction of the raw material required to complete manufacturing, the second is the fabrication of the systems themselves, the third concerns the impact when being operated, and the final stage evaluates the recovery of materials [41].

Two major boundary conditions exist when considering the 'use' phase of BEVs; the provenance of the power that charges the battery, and the range that battery has over its lifetime. Whilst the power source can be encapsulated with the extraction phase, it leaves total mileage as the last determining factor. This characteristic has many influences such as battery design and dimensions. A larger, more robust battery will require more raw materials and possess a longer lifespan and therefore be able to complete more miles and inherently have more environmental impact [41].

6.5.3 Legislation

To aid the adoption of BEVs into the supply chain, legislation may need to be implemented to ensure governance and accountability.

A developed infrastructure known as the Global Battery Alliance Battery passport is a global framework for the management of regulations surrounding the measuring and the subsequent auditing and reporting of environmental, social and Governance (ESG) parameters across the battery supply chain [44]. This is achieved using the following basis:

- Digital 'Passport' identification for batteries encompassing history, provenance, and ESG data.
- These parameters will aid in improving lifespan extension and recycling.
- Integrating systems to effectively record data into the battery passport.
- A platform to allow the collation and analysis of data between designated stakeholders to develop a value chain for electric vehicles based on sustainability.

Researchers believe this platform will provide the foundations for other parties to utilise, much like a software package, to build systems upon which can add further value. These systems could include models to monitor and calculate the SoH and residual value of a battery, understanding when the optimum state is to replace the battery and direct it into secondary use.

Unfortunately, like so many other aspects of battery design and conversation, the focus of this governance is around usage and lifetime and not about condition post-accident. There is however scope within the framework to make the case for expansion of the passport for other purposes.

Below is a timeline created using the European Commission's Regulation No. 2019/1020 [45], which concerns batteries and waste batteries. This graphic was devised by WMG using the option exert which can be found in the Annex section [40].

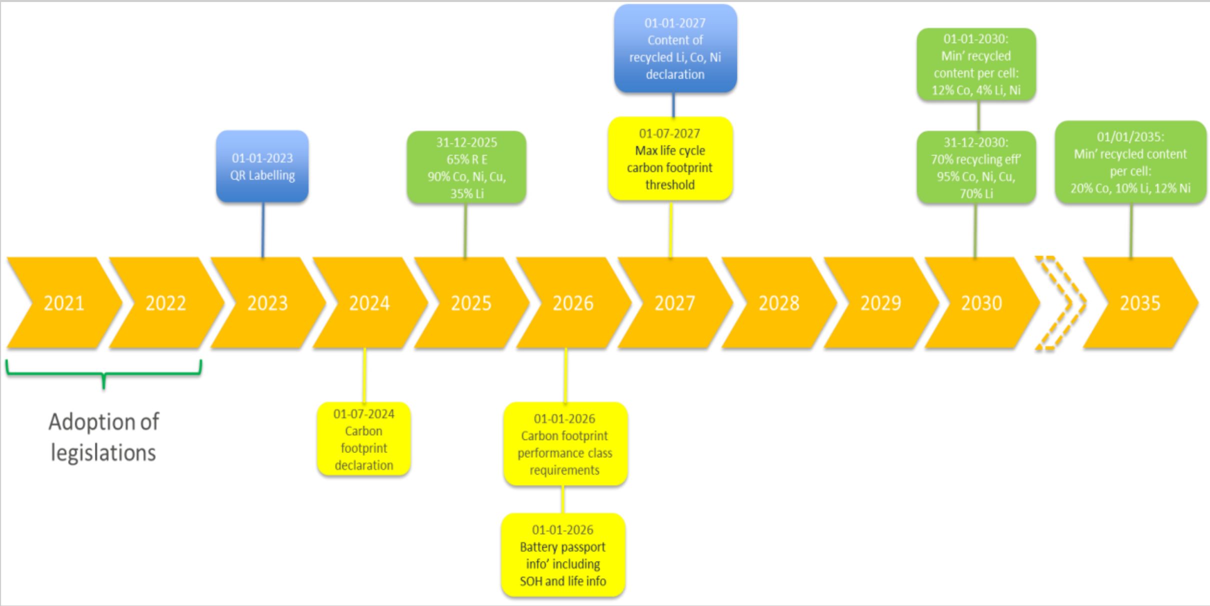

Figure 29 - Proposed Legislation Timeline [40].

7. Cost

7.1 Summary of financial concerns for BEVs

As outlined in section 3.5: Difference in Claims Processes, many insurers have not yet made any significant changes to their procedures to account for handling BEVs. This includes procedures from FNOL such as identification that the vehicle is a BEV, through to returning the vehicle to the owner.

Repairers are not currently increasing their base costs to reflect the increase in processing costs related to BEVs for quarantine times and storage costs.

The cost of replacement batteries is significant, and the lack of diagnosis, repair methods, or recycling / salvage options currently account for a large proportion of the total loss rate / claims costs.

Data gathered as part of this project has shown that the average cost of a claim is already ~25.5% greater than a standard ICE claim. This section details the costs that are currently not being factored into these claim totals, which will only increase this percentage difference.

Some used BEVs are currently retailing at a lower price than a replacement battery within a year of life, which only adds to the likelihood of total loss at FNOL. See Figure 32 - Depreciation curve of battery cost vs average used value.

Claims data shows that the average Key to Key time is already ~14% longer for a BEV repair compared to an ICE vehicle.

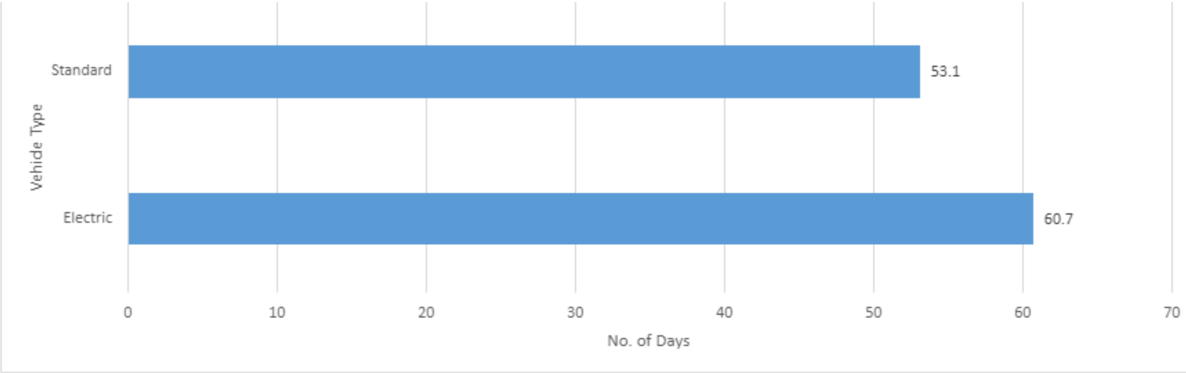

Figure 30 - Average Key to Key time.

7.2 Factors affecting claims value

Many factors can change the cost of a claim from type of damage to availability of parts. Data supplied from LV= in Table 5 - LV= Claims costs 2022 shows the wide variation in cost depending on drivetrain and model age.

Table 5 - LV= Claims costs 2022

Vehicle age	ICE Cost	BEV Cost	BEV No. claims	Difference
Up to 2 years	£2,209	£2,569	2515	£360
3-5 years	£2,155	£3,012	595	£857
Average	**£2,187.5**	**£2,789**		

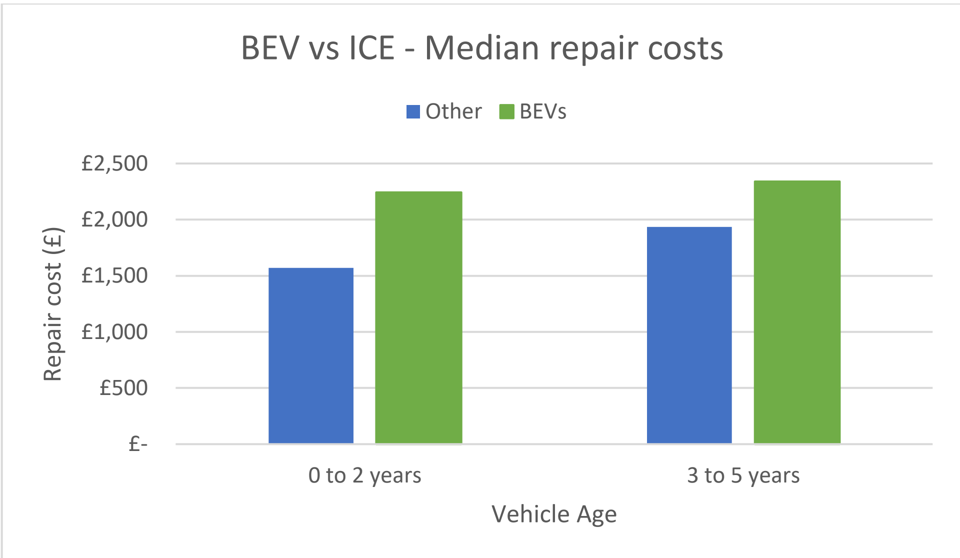

Figure 31 - Vehicle repair costs for BEV vs ICE.

7.2.1 Factors Determining Repair or Loss Outcome Route

Post-accident vehicles, whether ICE or BEV, undergo an assessment at FNOL and will either be deemed a total loss at that point, or if regarded financially viable for repair, then have a full repair assessment carried out by a qualified Vehicle Damage Assessor.

A VDA will use the following vehicle damage assessment criteria list to make an estimate in cost associated with the repair of the BEV:

- Damage levels
- Replacement parts required
- Paint time
- Labour
- Parts lead time and availability
- Key-to-key time costs
- Financial Validity
- Structural stability of the car
- Safety system deployment
- Additional processes and associated cost

These criteria are closely linked to each other through external factors. For example, supply chain instability could cause parts lead time to increase, which would increase the time from hand over of key to repairer to the time the owner receives their vehicle back. This is known as key-to-key time. The costs may increase due to extended courtesy car duration and other requirements such as the storage cost of the damaged vehicle.

7.2.2 Likelihood of damage causing total loss

Typically, a vehicle which is treated as a total loss (also known as a write-off) is when the cost to repair the vehicle is higher than the actual cash value of the vehicle. A vehicle may become an economic total loss because associated factors with the repair may increase the overall cost. These factors could include the residual value of the damaged vehicle, costs of a hire car over an extended period, etc. Add to this, the possible repair costs of a battery or a replacement battery and the likelihood of total loss becomes significantly higher as the age of the vehicle increases.

As the increase in uptake progresses, it is fair to assume that the repair costs will increase as there will be BEVs waiting longer to be repaired. This delay is due to quarantine recommendations, available facilities, forecasted skill deficit, and available repair methods. See section 5.1: Repair for further information.

7.2.3 Cost of replacement batteries

Thatcham Research owns and maintains a vehicle risk data repository called Plaza, which holds around 2000 other data points per vehicle variant. As part of this database, monthly parts pricing is updated directly from Vehicle Manufacturers. From this, we are able to accurately show what percentage of a repair cost is solely the cost of battery replacement.

Currently, the cost of a replacement HV battery is causing a significant increase in risk of total loss. The cost of HV batteries varies widely from the high-end vehicles, currently costing ~£29,500, to the low-end costing ~£14,200.

The graph in Figure 32 - Depreciation curve of battery cost vs average used value shows how the cost of a replacement battery is more than the used price of the vehicle after only 1 year. Depreciation values for this report are taken from Parkers Guide and hire costs have been calculated using the average Key to Key time of 60 days multiplied by average hire car cost of £30 per day [46].

Year	Age of vehicle	Battery cost	Average repair cost	Hire car costs	Extra cost associated with BEV	Vehicle value
2018	5	18,160	563	1800	500	9,525
2019	4	18,160	743	1800	500	11,690
2020	3	18,160	683	1800	500	13,180
2021	2	18,160	1046	1800	500	15,375
2022	1	18,160	1553	1800	500	16,943

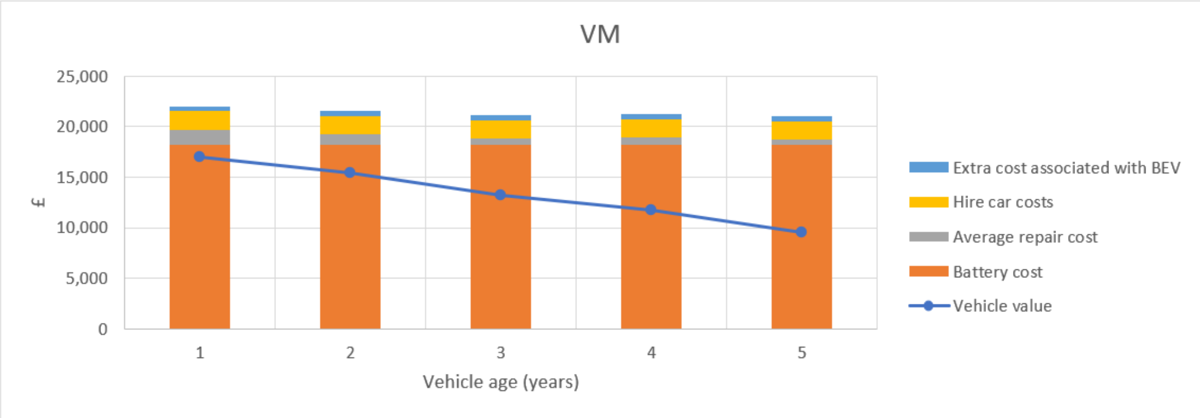

Figure 32 - Depreciation curve of battery cost vs average used value of a vehicle.

The market is still subject to much change and fluctuation, for example, one vehicle list price starts at £43,150 and this has been surpassed by battery price, which Plaza data has shown to have been as high as £54,510 within the last 6 months [47].

Graphs below show the average battery cost vs the average purchase price for our cohorts from 2018 to 2022 denominated VM1, VM2 and VM3. Depreciation values for this report are taken from Parkers Guide and hire car costs are calculated from average hire car cost multiplied by average K2K number of days [46]. Additional costs are an assumed base cost including storage relating to quarantine time, recovery costs, etc.

Year	Age of vehicle	Average battery cost	Average repair cost	Hire car costs	Extra cost associated with BEV	Vehicle value
2018	5	22,377	2265	1800	500	14,493
2019	4	22,377	2265	1800	500	16,263
2020	3	22,377	2265	1800	500	18,275
2021	2	22,377	2040	1800	500	31,023
2022	1	22,377	2040	1800	500	31,023

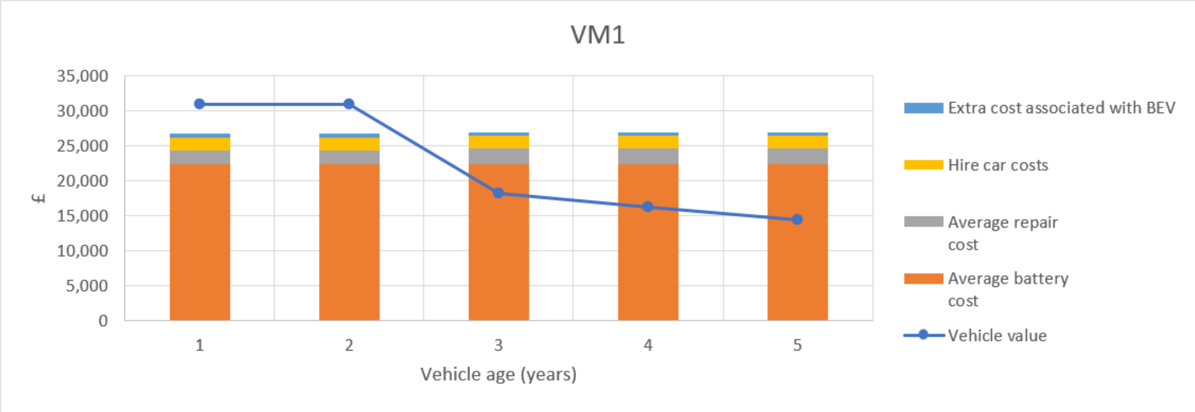

Figure 33 - VM1 depreciation vs battery replacement cost.

Year	Age of vehicle	Average battery cost	Average repair cost	Hire car costs	Extra cost associated with BEV	Vehicle value
2018	5					
2019	4					
2020	3	14,198	1764	1800	500	25,418
2021	2	14,198	1764	1800	500	27,893
2022	1	14,198	1764	1800	500	27,035

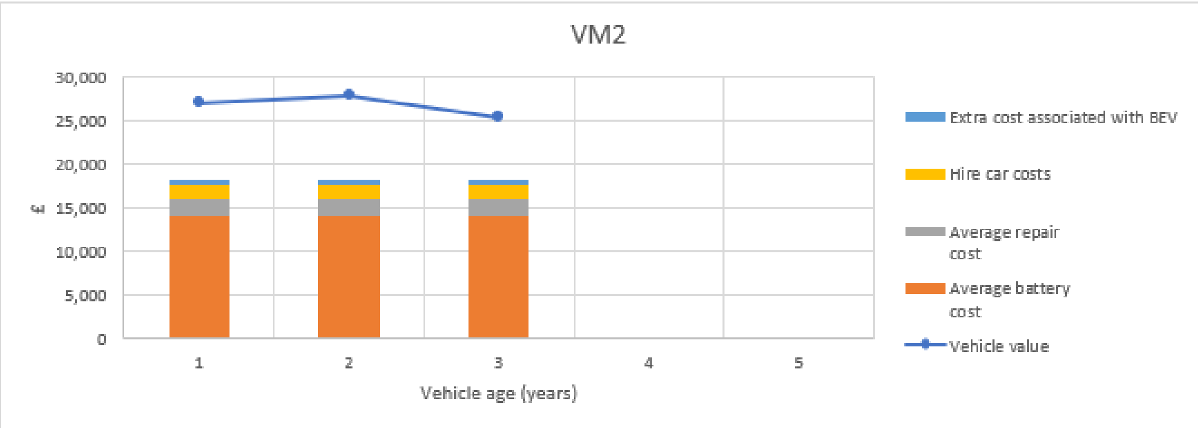

Figure 34 – VM2 depreciation vs battery replacement.

Year	Age of vehicle	Average battery cost	Average repair cost	Hire car costs	Extra cost associated with BEV	Vehicle value
2018	5	29,500	3024	1800	500	31,023
2019	4	29,500	3024	1800	500	31,023
2020	3	29,500	3024	1800	500	34,218
2021	2	29,500	2876	1800	500	37,740
2022	1	29,500	2876	1800	500	43,008

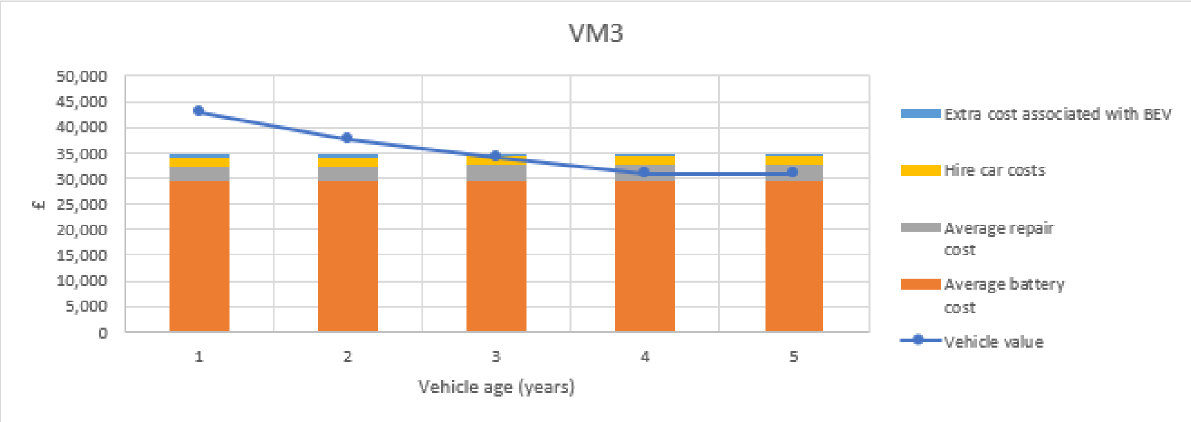

Figure 35 – VM3 depreciation vs battery replacement.

7.3 Total loss rates

There is little or no data on which to reliably estimate relative total loss rates.

However, the charts in section 7.4 highlight that early comparative age cohorts show signs which might indicate that total loss is more likely amongst BEVs. These signs are elucidated after the graphs.

There are a number of confounding factors from the last 2-3 years which will also mean that data comparison is not possible. These include parts shortages, vehicle supply shortages and various geo-political factors.

Data from LV= show that BEV total losses are taking around four times longer to process and handle on average than ICE equivalents. LV= have indicated that BEVs total loss decisions are being made much later into the repair cycle than ICE vehicles. This is likely to be reflective of both technical repair challenges and lack of adjustment to FNOL and VDA processes to accommodate timely decision making.

7.4 ICE vs BEV comparison Charts

7.4.1 Comparable cohorts of ICE vs BEV

Graphs in this section show comparable ICE and BEV Counterparts of a low (VM1), medium (VM2) and high end (VM3) vehicle manufacturer when involved in equal traffic incidents.

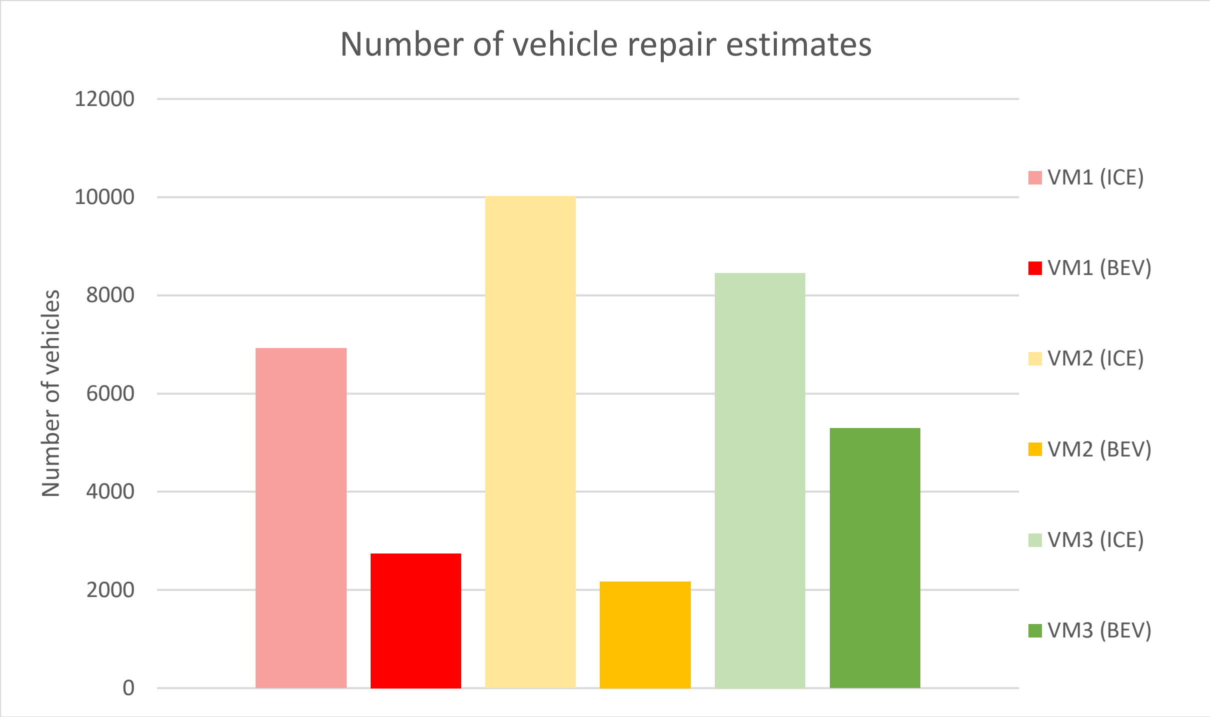

Figure 36 – A graph showing the number of vehicle repair estimates of ICE and BEV counterparts from three vehicle manufacturers for the past 5 years.

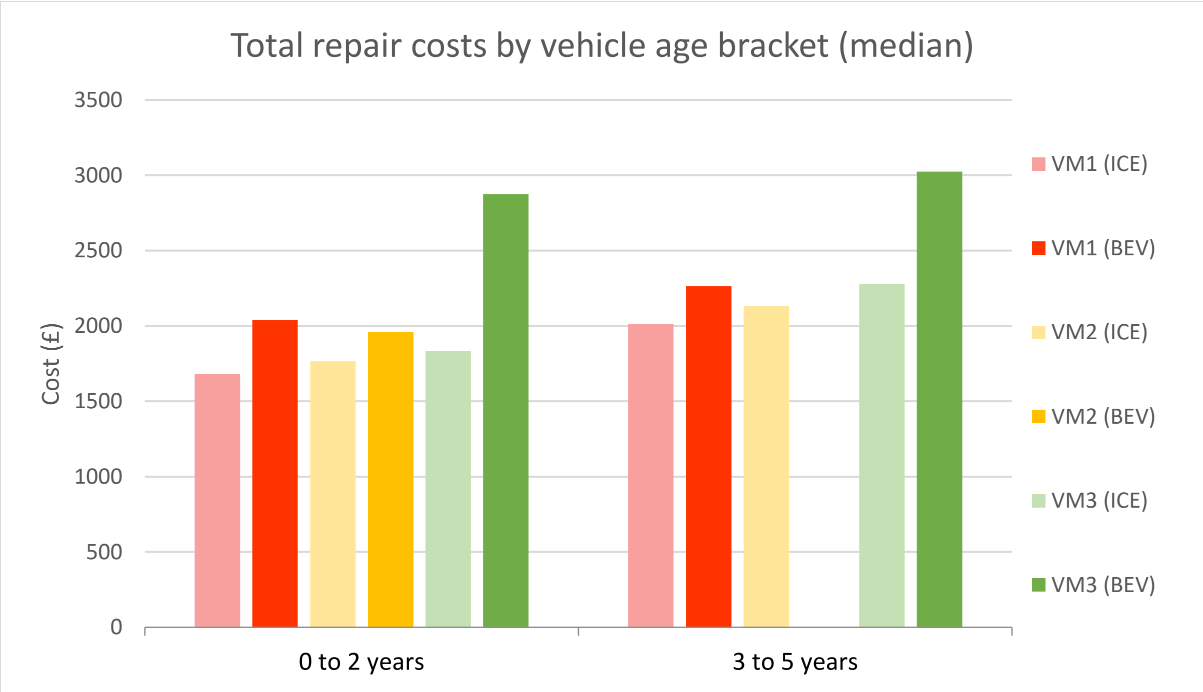

Figure 37 – A graph showing the median total repair cost of ICE and BEV counterparts from three vehicle manufacturers.

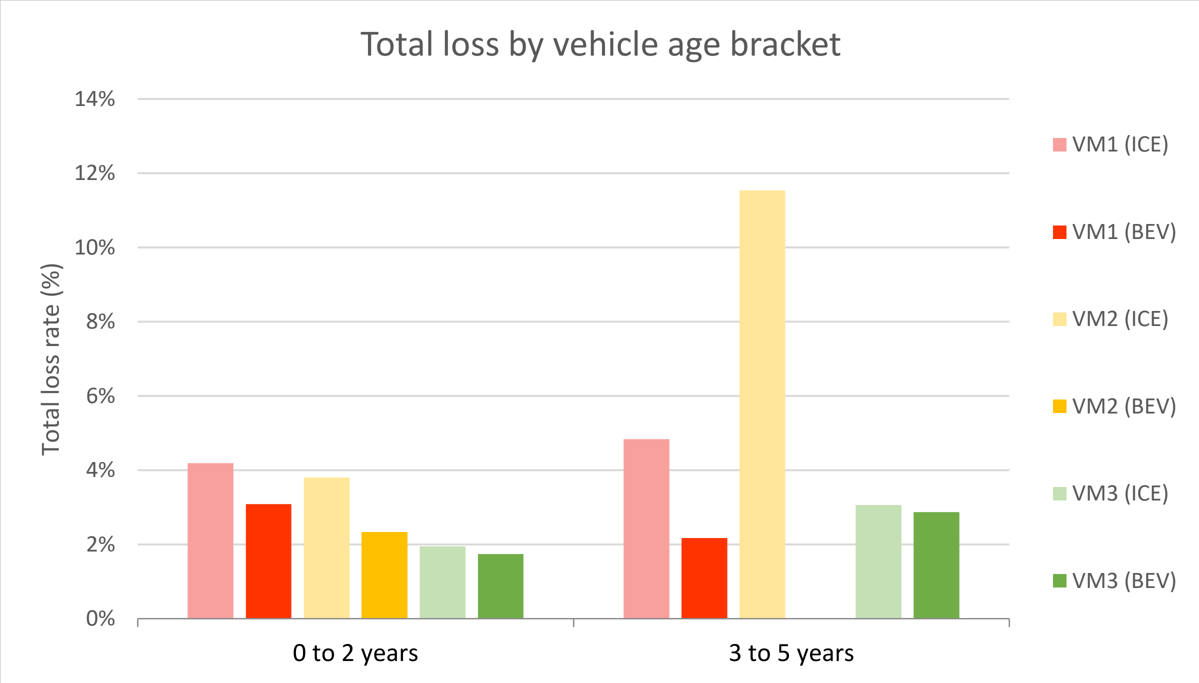

Figure 38 – A graph showing the total loss rates cost of ICE and BEV counterparts from three vehicle manufacturers.

Whilst the graphs allude to total loss rates for ICE vehicles being higher than that of the comparative BEVs, large volumes of BEV vehicles are being returned to customers with undiagnosed battery damage or diagnosis discovering battery damage subsequent to initial repair assessment. This is a result of the infancy of the repair estimate systems responsible for diagnosing BEVs. These graphs act as an early warning to a reality in which far more BEVs are of a total loss state.

8. Situation Forecast

8.1 General Assumptions and Considerations

Thatcham Research have used ICE Vehicle data from 2018 to date, to forecast all sections of this document. 2018 and 2019 are the most recent representative pre-covid years, during which accident patterns, claims, vehicle purchases were standard. During Covid years (2019-2021), fewer vehicles were on the UK roads, and as a result there were fewer accidents, giving us less data to work with. 2022 has seen a significant return to 'normal', however, whilst people continue to work from home more, there are still fewer cars on the roads and therefore fewer claims being made.

All assumptions and forecast methods detailed within this report have been validated via insurer data and insights.

The following assumptions have been made throughout this document:

- The assumption that at First notification of loss (FNOL), there is limited triage taking place to analyse battery state of health, and as a result, it is assumed that more BEVs are classed as total loss than necessary. This is based upon insurer and salvage network experience.

- Any accident resulting in significant side or corner, SRS deployment, or drop will require battery assessment and most likely result in damage to the battery (section 4.3 for basis and section 4.4 for analysis).
- Transport – It is assumed that the current percentage of fleet capable of transporting damaged BEVs is not an issue at present, however with the forecasted increase in Car Parc this will lead to delays in repair time.
- Quarantine – BEVs are required to be stored in quarantine using OEM stated time / space, for which there are currently minimal sources available.

To forecast claims costs, the following factors need to be considered:

- Storage cost – Synetiq have suggested an average storage cost of £25 per day.
- Additional costs to include time required pre and post repair for quarantine and power up / down. For an average repair these have been assumed to be £500
- Additional hire car costs have been approximated at £30/day via member data.
- Where a repair centre has no storage for quarantine, BEVs are required to be stored elsewhere. As a result, an additional second shipping fee is anticipated, along with quarantine costs associated with a secondary location.
- For all claims, it is assumed that the battery will require replacement due to the lack of repair methods currently available. It is difficult to forecast number of accidents where there is a need for replacement as opposed to a battery repair, as this is dependent on vehicle manufacturers publishing repair methods, the level of applicable training, and availability of parts.
- It is assumed that the damage patterns of future BEVs will be similar to current BEVs.

8.1.1 Forecast Assumptions

To meet the UK government Car Parc target dates for passenger vehicles, the current uptake of BEVs requires accelerating significantly. The uptake of BEVs can be predicted using a Richard's logistic growth function curve between 0% BEV registrations in 2010 and 100% BEV registrations in 2035. See 8.2 Forecasts for further detail.

Due to the forecasted uptake shown in Figure 39 - Forecast of new BEV registrations., it is a reasonable assumption to make, that the frequency in which a vehicle with an electrified powertrain is involved in an RTC, and subsequently requires recovery and repair, shall also increase significantly. This leads to the assumption that that not only shall the number of claims rise, as the date moves closer to the 2030 target date for zero sales of ICE vehicles, we can expect this type of powertrain to make up most vehicles in the insurance accident repair park.

8.2 Forecasts

Data detailing New Vehicle registrations by fuel type is published by the Department for Transport and available online under table VEH1153a [4]. This data can be overlaid with predicted BEV registrations to enhance the logistic curve shape between 2010 and 2050, to fit the actuals from 2015-2022, as shown in Figure 39 - Forecast of new BEV . An estimate for 2022 sales was made using the available data up to Q3 2022.

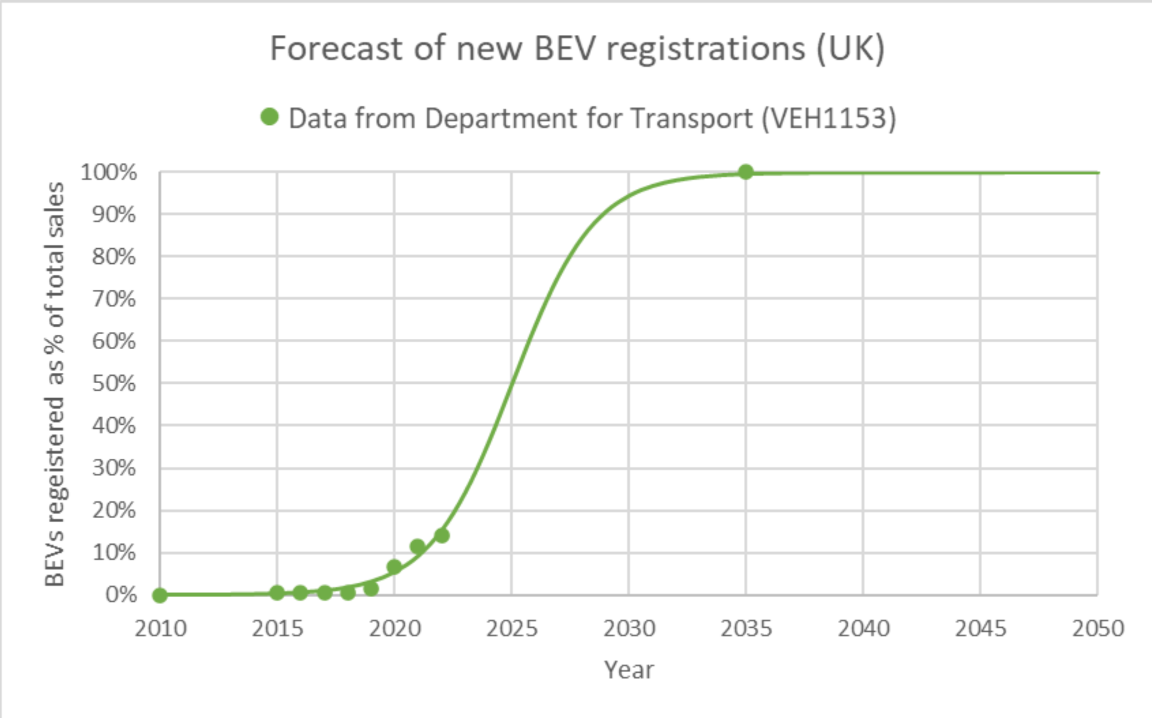

Figure 39 - Forecast of new BEV registrations.

Whilst it is expected that 100% of new car sales will be BEVs by 2035, there will be a significant lag before the UK Car Parc reaches 100% electrification. The number of licensed vehicles on the UK roads in any year can be calculated from the number of new registrations plus the volume of the Car Parc the previous year minus the cars exiting the Car Parc.

$$BEVs_{licensed} = BEVs_{Car\ Parc\ previous\ year} + BEVs_{registered} - BEVs_{exiting}$$

The percentage of newly registered BEVs has been forecast in the previous section from the logistics curve. For the forecast of the total number newly registered BEVs each year, total car sales (all fuel types) are assumed to be 2.3M per annum over the period 2010 – 2050. Whilst this is a simplification (especially since Covid caused a big dip in sales in 2020 and 2021), it is expected that annual new vehicle sales will recover to pre-covid levels.

Vehicles tend to leave the Car Parc as they become old and uneconomical to repair and maintain. Therefore, an assumption can be made about the average lifespan of a car, in that the cars leaving the Car Parc will be approximately equal to the number of cars newly registered the average lifespan ago. For example, if the average lifespan of a car was 14 years, then in 2020, the cars leaving the car park are those cars which are newly registered in 2006. Consequently, the total number of licensed cars is approximately equal to the sum of those registered between 2007 and 2020.

$$\text{BEVs}_{\text{exiting}} = \text{number of BEVs registered 14 years ago}$$

For the modelling in this report, the total annual sales are assumed to be 2.3M cars per annum with a static Car Parc of 32M. This gives an average car lifespan of 14 years (32M/2.3M).

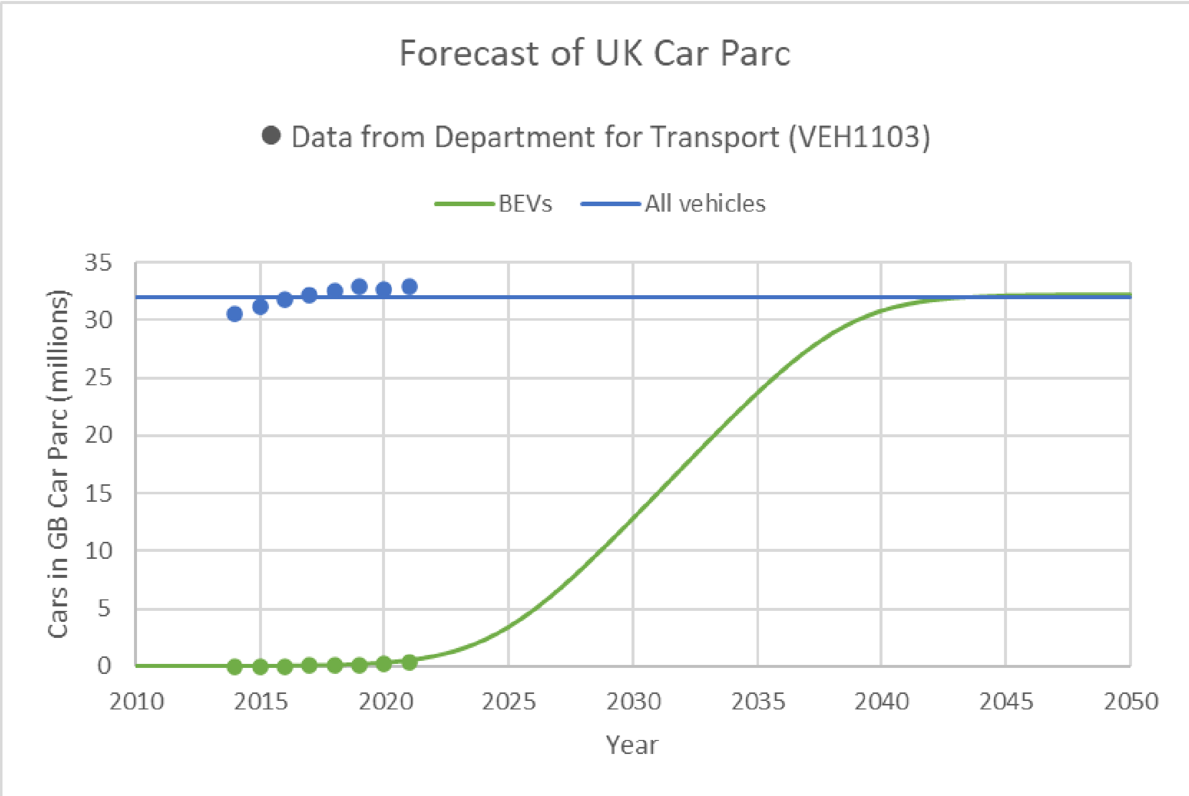

Figure 40 - Forecast of UK Car Parc.

The model forecasts 50% of registered vehicles will be BEVs by 2032. By 2049, 14 years after the sales of ICE and hybrid ban, 100% of the Car Parc is predicted to be BEVs because it assumes that the maximum age of cars in the Car Parc is 14 years old. This method ignores the reality that there are vehicles older than 14 years in the Car Parc, and that younger cars leave the Car Parc each year too. It might be expected that as the availability of new ICE and hybrid cars becomes limited near 2035, there could be a tendency for people to keep ICE vehicles for longer. The average lifespan method therefore is likely to overpredict the speed at which BEVs saturate the UK Car Parc.

The forecast does not consider social - economic factors, such as possible government incentives and disincentives, change in ownership models, availability of charging points or cost of electricity vs cost of petrol which will have a big influence on how quickly BEVs are adopted. The SMMT's "SMMT new car market and parc outlook to 2035 by powertrain type at 11 June 2021" takes some of these factors into account and overlays predictions by the Committee on Climate Change (CCC). They predict 50% of the Car Parc will be BEVs between 2033 and 2036. The forecast made in this report is in line with this view.

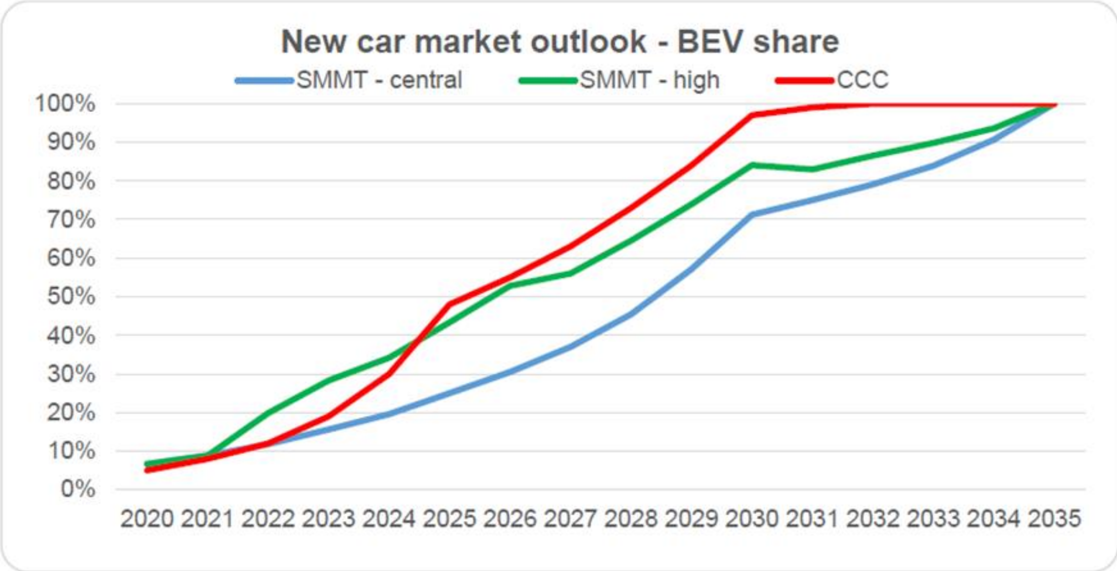

Figure 41 - New car market outlook - BEV share [48].

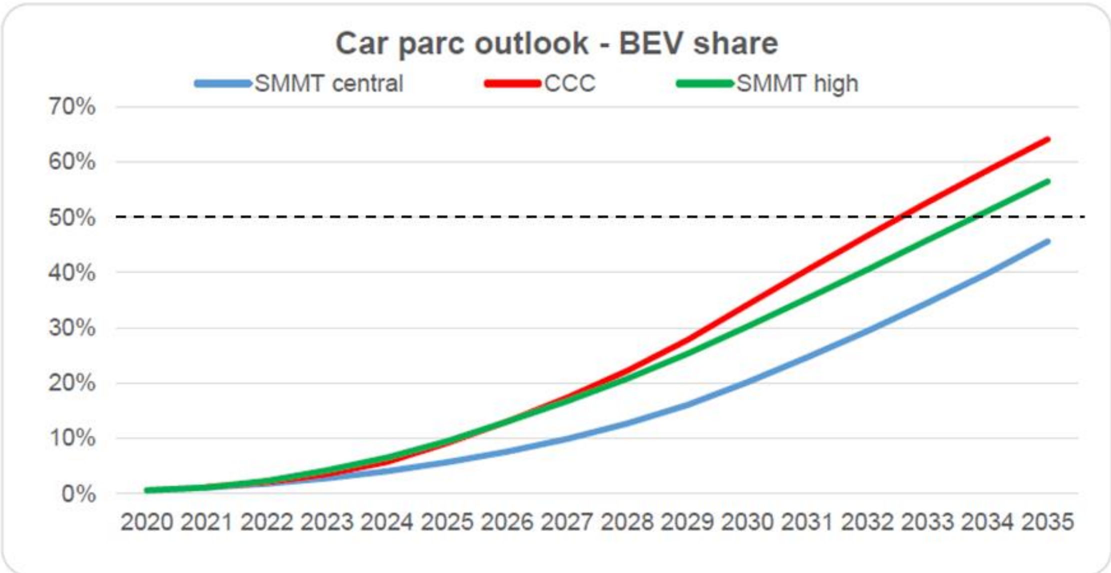

Figure 42 - Car Parc outlook - BEV share [48].

8.3 Viability of BEVs

8.3.1 Forecast of BEV repair volume

By comparing how many cars require repair today to the number of cars in the Car Parc, it is possible to estimate future volume of BEV repairs. This is assuming that BEVs are equally as likely to be involved in accidents as ICE vehicles.

Table 6: Calculated repair rates

Year	Estimated car repairs per annum (millions)	UK Car Parc from DfT VEH1103a (millions)	Calculated repair rate
2018	2.2	32.5	6.7%
2019	2.1	32.9	6.4%
2020	1.5	32.7	4.5%
2021	1.6	32.9	4.8%
2022	1.7		

The data shows a decrease in repair rates during 2020 and 2021. This is highly likely to be due to Covid restrictions, where lockdowns reduced miles driven, and hence the volume of accidents. It is, therefore, sensible to apply the average of 2018 and 2019 (i.e., 6.55%) as an average repair rate for the future. As such, the forecast for the number of BEV repairs can be calculated as follows:

Forecast of BEV repairs = Forecast of BEVs in Car Parc * repair rate

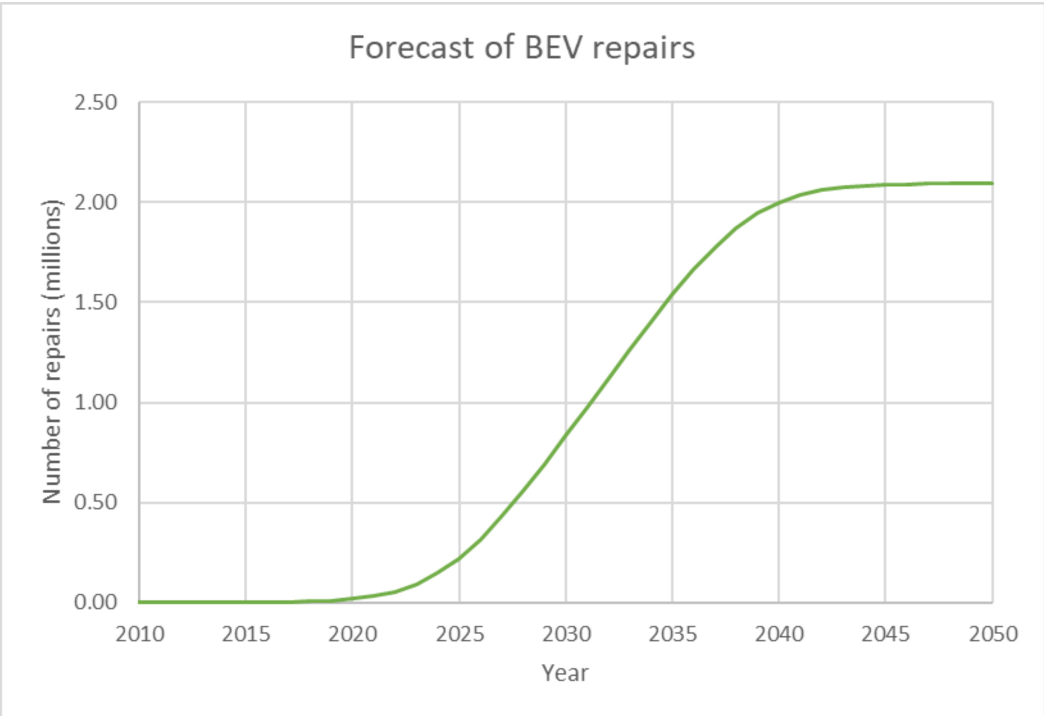

Figure 43 - Forecast of BEV repairs.

A small proportion of all vehicle claims will be a total loss at FNOL and therefore do not appear in the vehicle repair numbers noted above. This could increase the claim rate slightly.

Analysis done for this report shows that only 0.3% of BEV assessments currently include damaged batteries. If the predictions and estimates covered in this report were considered, this figure would rise to 17%. Showing that only 2% of damaged batteries are currently being detected.

Projecting this onto the forecast for BEVs in the UK Car Parc shown in Figure 39 - Forecast of new BEV , and a 6.5% claim rate, it would be anticipated that there would be circa 260,000 damaged batteries per year in 2035, rising to circa 360,000 by 2050.

Using the same basis in section 4.7.1, the effect quarantine has on the claims process can be calculated. 260,000 BEVs would require 130,000 storage areas per year at a rate of 2 cars per 48 hours at an average cost of £5000. This would result in the insurance market having to cover an additional £650 million per year in storage. When this is compared to the ~32 million registered cars in the UK Car Parc, this is a ~£20 increase per policy. With the 2050 forecast of 360,000 this would increase to £900 million per year and a ~£28 increase.

It should be noted that this presumed rise in insurance premiums is just a result of one element of the BEV claims process flow. However as is evidenced within this report, there are many other factors which may also result in further incurred costs on insurance premiums due to the differing processes involved in a BEV accident.

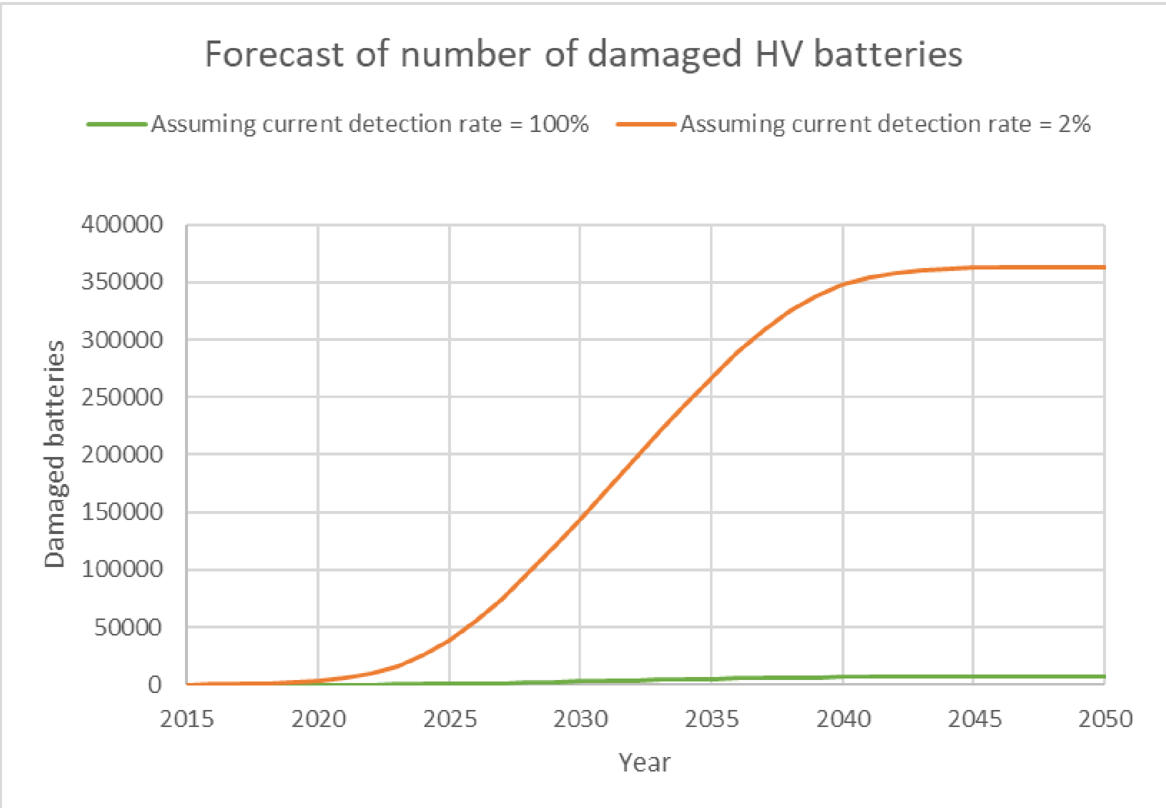

Figure 44 – Forecasted number of damaged HV batteries.

9. Summary

9.1 BEV Challenges to the Post Accident Claims Process

The sheer increase in size and scale of the BEV workflow compared to the long-established ICE claims process shows that there is no part of the Motor Insurance Claims process which is unaffected by BEVs. The workflow impacts are profound and will, over time, force a wholesale change of the industry. Much of that industry is yet to start to adapt to the challenges ahead and the implications remain unquantified on capacity, training and skills, cost, and the lifetime sustainability of BEVs. The lack of engagement and awareness present barriers to quantification of impact as it is highly likely that early BEV performance data paints an incomplete picture of the challenge. There is an understandable reluctance to engage with significant change until there is a higher percentage of BEVs in the UK Car Parc.

The current generation of batteries present most of the challenges to the successful and economically sustainable adoption of BEVs when viewed through the motor insurer lens. Modelling suggest that a significant number of batteries will need assessment and repair or replacement post even some minor accidents. In situations where battery repair is not possible or viable, the UK has little or no infrastructure in place for recycling EV batteries which returns high quality raw materials back into the supply chain. This absence of infrastructure fundamentally loses a significant percentage of the disproportionate value that those batteries represent in today's vehicles.

Whilst the obstacles explored in this report possess technical solutions, the predicted uptake of BEVs may be affected by the complex issues within the supply chain and inflated costs unless ways are found to scale up those solutions. As time progresses and more data is produced, insurance premiums are expected to increase as risk is more actively quantified.

Mass adoption of BEVs will result in technical and financial challenges faced by both the suppliers and customers unless a robust cross-industry framework is constructed. This framework should create an environment for sustainable battery diagnosis, repair, refurbishment, recycling, and second-life opportunities.

Timely implementation of solutions will mitigate the challenges and enable adaptation of the market in parallel with increased and predicted adoption.

9.2 Consumer Confidence

As previously mentioned in this report, the current Car Parc is made up of only 1.65% BEVs [4], with the government forecasting numbers increasing to between 8 and 10 million by 2030. This is a significant increase needed to meet government targets and as part of this project, LV has provided information on consumer confidence relating to BEVs. One of the biggest areas of concern from motorists has been understanding what the move to owning and maintaining an electric vehicle entails. Add that to the issue of long lead times in obtaining a vehicle, the concerns surrounding the likelihood of total loss following a collision due to the battery and the number of public charge-points out of service, there is a definite challenge ahead.

9.3 Recommendations

In order to address the challenges highlighted in the report, its authors would suggest investment in further cross-industry work to identify more detailed solutions and to make direct recommendations about a range of interventions or support to accelerate those solutions.

- Understand the needs of Vehicle Manufacturers / Repairers / Insurers / Salvagers to optimise the supply of new / refurbished / recovered batteries in vehicle repair and more accurately informed decisions can be made an FNOL.

    - Standardisation of diagnostics to include repair needs
    - Development of ‘Battery in repair’ workflow across the supply chain
    - Practical and investment options for centralisation / standardisation of battery refurbishment / vehicle manufacturer accreditation
    - Options and recommendations for simplification of battery transportation
    - Development of improved claims process roadmaps.

- Understand scaling needs and options for HV battery recycling, repurposing, and refurbishment.

    - Current technologies landscape
    - Future and developing technology landscape
    - UK / Global installed base / capacity
    - Economic analysis of investment needed to meet UK demand using landscaped technologies
    - Recommendations for intervention / investment / incentives required to ensure capacity is created for repair, storage, recycling options

- Updated understanding of LCA of BEVs taking into consideration total cost of ownership, battery life, insurance and repair.

    - All factors contributing to lifetime production of CO_2
    - Comparative impact analysis of a range of real-world vehicles
    - Identification of controllable vs. uncontrollable factors plus recommendations for control mechanisms or mitigations
    - Analysis of any future trends and technology development which may positively or negatively affect lifetime environmental impact
    - Recommendations for any interventions

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Annex

European Commission Proposal Options for the Handling of Batteries and Waste Batteries [45].

Measures	Option 2 - medium level of ambition	Option 3 - high level of ambition	Option 4 – very high level of ambition
1. Classification and definition	New category for EV batteries Weight limit of 5 kg to differentiate portable from industrial batteries	New calculation methodology for collection rates of portable batteries based on batteries available for collection	/
2. Second-life of industrial batteries	At the end of the first life, used batteries are considered waste (except for reuse). Repurposing is considered a waste treatment operation. Repurposed (second life) batteries are considered as new products which have to comply with the product requirements when they are placed on the market	At the end of the first life, used batteries are not waste. Repurposed (second life) batteries are considered as new products which have to comply with the product requirements when they are placed on the market.	*Mandatory second life readiness*
3. Collection rate for portable batteries	65% collection target in 2025	70% collection target in 2030	75% collection target in 2025
4. Collection rate for automotive and industrial batteries	New reporting system for automotive, EV and industrial batteries	Collection target for batteries powering light transport vehicles.	Explicit collection target for industrial, EV and automotive batteries
5. Recycling efficiencies and recovery of materials	Lithium-ion batteries and Co, Ni, Li, Cu: Recycling efficiency lithium-ion batteries: 65% by 2025 Material recovery rates for Co, Ni, Li, Cu: resp. 90%, 90%, 35% and 90% in 2025 Lead-acid batteries and lead: Recycling efficiency lead-acid batteries: 75% by 2025 Material recovery for lead: 90% in 2025	Lithium-ion batteries and Co, Ni, Li, Cu: Recycling efficiency lithium-ion batteries: 70% by 2030 Material recovery rates for Co, Ni, Li, Cu: resp. 95%, 95%, 70% and 95% in 2030 Lead-acid batteries and lead: Recycling efficiency lead-acid batteries: 80% by 2030 Material recovery for lead: 95% by 2030	/
6. Carbon footprint for industrial and EV batteries	Mandatory carbon footprint declaration	Carbon footprint performance classes and maximum carbon thresholds for batteries as a condition for placement on the market	/
7. Performance and durability of rechargeable industrial and EV batteries	Information requirements on performance and durability	Minimum performance and durability requirements for industrial batteries as a condition for placement on the market	/
8. Non-rechargeable portable batteries	Technical parameters for performance and durability of portable primary batteries	Phase out of portable primary batteries of general use	Total phase out of primary batteries
9. Recycled content in industrial, EV and automotive batteries	Mandatory declaration of levels of recycled content, in 2025	Mandatory levels of recycled content, in 2030 and 2035	/
10. Extended producer responsibility	Clear specifications for extended producer responsibility obligations for industrial batteries Minimum standards for PROs	/	/
11. Design requirements for portable batteries	Strengthened obligation on removability	New obligation on replaceability	*Requirement on interoperability*
12. Provision of information	Provision of basic information (as labels, technical documentation or online) Provision of more specific information to end-users and economic operators (with selective access)	Setting up an electronic information exchange system for batteries and a passport scheme (for industrial and electric vehicle batteries only)	/
13. Supply-chain due diligence for raw materials in industrial and EV batteries	Voluntary supply-chain due diligence	Mandatory supply chain due diligence	/

Legend: green = preferred option; light green = preferred option pending a revision clause.