"11. Adaptation to scientific and technical progress of exemptions 2(c)(i). 3 and 5 of Annex II to Directive 2000/53/EC (ELV)"

To: Consultant Consortium of Bio Innovation Service (biois) and The United Nations Institute for Training &Research (UNITAR) and Fraunhofer Institute for Reliability & Microintegration (IZM))

Via Email to: elv@biois.eu

Cc:	DG ENV	Ms. Artemis Hatzi –Hull,	Mr. Mattia Pellegrini
	DG GROW	Ms. Joanna Szychowska,	Mr. James Copping
	Via Email		

Submission of ACEA, CLEPA, JAMA, KAMA et al. representing the affected automotive industry including the supply chain to the stakeholder consultation published by Biosis on 15.Sept. 2020 on the review of three entries in EU ELV Directive Annex II. 08. December 2020

Foreword

This set of documents provides the consolidated stakeholder submissions of the automotive industry associations ACEA, CLEPA, JAMA, KAMA, and associated industrial stakeholders to the "11th adaptation to scientific and technical progress of exemptions 2(c)(i)., 3 and 5(b). of Annex II to Directive 2000/53/EC (ELV)". In the entry specific submissions, the names of the participating associations are listed separately.

The consultation was announced on 15 September 2020 and concludes on 08th December 2020 and addresses the following entries (exemptions) to be reviewed:

Under category Lead as an alloying element following entries are in our scope:

- 2(c)(i). "Aluminium alloys for machining purposes with a Lead content up to 0,4 % by weight"
- 3 "Copper alloys containing up to 4% Lead by weight"

And under category Lead and Lead compounds in components we address:

- 5(b)."Lead in batteries for battery applications not included in entry 5(a)."

ACEA and the joint associations welcome the opportunity to provide submissions to the stakeholder consultation of reviewing the three entries of ELV Annex II 2(c)(i). , 3 and 5(b). and are pleased by outlining technical requirements to address the necessity to continue these exemptions.

For meeting the antitrust conditions in prospects into the future and to support the evidence of our applications we mandated also studies at independent consultants. Their findings and opinions may differ from our direct views. Where appropriate, critical reviews by third parties were conducted.

The summaries of the studies mandated for entry 5 topics are published on the websites of ACEA (www.acea.be/publications) and EUROBAT. The detailed studies can be requested via the EU Commission for taking a look. The rights remain at disposition of the associations.

Introduction

The automobile industry actively supports environmental policy efforts to design products free of hazardous substances and as environmentally sound as possible. All car manufacturers and actors in the supply chain have set up internal goals and environmental guidelines relating to products as well as production processes.

As self-responsible partners of the manufacturers, the suppliers are affected in a special way, having to deal with their global supply chain, sometimes down to the raw material basis and missing availability of specific materials due to import restrictions. The automotive industry and their associations fully accept their product responsibility, but emphasize the need for proportionate actions or initiatives. The represented industry stakeholders agree upon the minimization of negative environmental impacts during all phases of a vehicle life.

In order to reach this common goal to manufacture, market, operate service and recover products with the lowest possible impact on environment or human health, the environmental impact, the relevance of certain substances and their technical and economic implications need to be understood prior mandating substance restrictions. In addition, at our opinion, interference with EU flagship initiatives like circular economy[1] resp. critical resources strategy[2] or the EU general safety regulation and the new waste framework directive needs to be considered. E.g. Bismuth, which is under consideration to replace Lead in some applications, is part of EU critical resources strategy[2] and is recommended to be used with preference in essential applications and has today challenges in recycling.

Achieved progress in heavy metals reduction

The automotive industry has been continuously reducing the amount of heavy metals including Lead necessary for the production of vehicles since the year 2000. Cadmium, hexavalent chromium and mercury have no more meaning in actual car production. As concluded in previous submissions the statement remains valid that – battery excluded because of being used in closed loop - the intentional use of Lead per vehicle is now in the range of background level concentration of all the raw materials used therein. Based on the fact that the potentials for significant and impacting Lead reduction have been realized, any further measures with real benefits for the environment are missing in our opinion.

Further comments to stakeholder contribution

The enclosed entry specific contributions reflect the work of our industry expert groups since the last review of these exemptions in 2014. With high effort we took the challenges addressed to our industry within the consultant report from 2016. In general, technical information given in the course of previous consultations, is seen still as valid and not all times reproduced explicitly in the current submissions.

Where possible and necessary our search for Lead-free alternative metal alloys was supported by external expertise but without public funding over the last few years.

Our working groups are supported by well-educated and excellent experts with external acknowledged expertise in the vehicle and material producing industry.

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1 https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf; last accessed 04.12.2020

2 COM(2020) 474 final Brussels, 3.9.2020 Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0474&from=EN Annex I last accessed 04.12.2020

We ask to keep wording for the entries and in addition to avoid any further split into new subentries. The total amount in the alloys for Copper resp. Aluminum applied alloying Lead sums up for around 185 t resp. 13 t related to the volume of vehicles placed on the EU market in 2019. This Lead is bound physically in the metal matrix and during use there is no significant release by corrosion, friction or wear observed. Even recycling is feasible without challenges and realized since decades.

For all the submissions the following data for vehicles new placed (registered) on the EU market and the year 2019 were used as basis for quantity calculations[3] :

Vehicles (passenger cars and light commercial vehicles) new registered in year 2019 in EU (28) including EFTA.

Registrations 2019	Passenger cars	Light commercial vehicles up to 3,5 t	Total
EU28 (without Malta)	15,340,188	2,115,650	
EFTA	465,564	73,674	
EU + EFTA	15,805,752	2,189,324	17.995.076
(Malta sales 2019)			8495
			18.003 571

Table 1: registration figures 2019; 2019 new registrations figures for Malta were not yet available in ACEA pocket guide so we added the corresponding OICA sales figures instead as new registrations. (OICA reports total vehicle sales in 2019 of 8495 vehicles)

As ACEA et al. do not have access to technical data of vehicles in some specific markets, worldwide figures on applications would be incomplete and therefore we concentrate on figures of EU market only. This matches also with EU ELV legislation.

In addition as communicated in previous stakeholder contributions, the development period for implementation of lab validated solutions into production is still 3 to 6 years if no failures occur. The average model cycle is typically around 8 years.

We would like to emphasize that vehicles and their components have to face harsh ambient conditions in Europe. Ambient temperatures from - 40 up to 50°C outside and interior temperatures to above 100°C have to be tolerated and operating temperatures e.g. of some engine components may exceed 800°C. Components e.g. like electronic control units have to be robust against vibrations and acceleration figures above 70 g_0. With more and more electronic assisting driving functions and sensor or camera signals triggered actions of software, also IT related endurance is an important task. - During vehicle use all components and their functions undergo long termed high levels of mechanical and thermo-mechanical stress and dynamic load conditions.

This is valid not only for a short period but over a use period of ten to fifteen years and sometimes longer. That is one of the reasons why development and validation of new components require such long development periods. This ensures that safety and reliability demands are fulfilled.

Furthermore the continued improvement of the overall environmental performance of vehicles and their production processes requires that we also assess the environmental performance of substitute materials in order to allow long lasting decisions for optimized materials in each application.

The entire industry, however, needs a reliable planning basis for these substitute materials for at least one development cycle of a vehicle. This needs to be considered in any future phase out recommendation and plans and EU Commission decisions.

[3] ACEA Pocket guide edition July 2020 p.28, ACEA Brussels and OICA; https://www.acea.be/publications/article/acea-pocket-guide last accessed 03.11.2020

Attached you will find the submissions with technical justifications compiled by expertise of the entire automotive industry (together with the Copper, Lead and battery producers and their organizations) regarding Lead in Copper and Aluminum materials and Lead in batteries, based on the current knowledge.

We ask to recommend a succeeding consultation or review not before a time period of eight years to reflect developments of one product cycle and to enable current research efforts to find their way in a future volume production.

The automotive industry would also like to remind all decision makers in this subject that the still ongoing challenges of COVID 19 is significantly impacting our industry globally. Transformation towards E-Mobility, fulfillment of the very challenging EU CO_2 limits, realizing the General Safety Regulation (GSR) [4] and future autonomous drive modes, consume major parts of the R&D capacities.

We would welcome the opportunity to continue the open discussions with the Commission and the consultants also during the assessment process of the consultation and are willing to answer to further possible questions on the subject.

Should you need any further information, please address your requests in writing to the listed contact person below Cc'ing the listed associations representatives.

In conclusion, the automotive industry requests the extension of the exemptions as specified in the attached documents.

We would appreciate it if you could confirm the receipt of the present document.

We thank you in anticipation.

With best regards,

Amelie Salau & Reinhard S. Hoock

On behalf of the Joint Industry Associations and the Associated Industry Stakeholders

Enclosures: ./.

[4] EU General Safety Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019

Enclosures:

Submission for entry 2(c)(i): ACEA et al response 11th SC_entry_2ci_08_12_2020

Submission for entry 3: ACEA et al response 11th SC_entry_3_08_12_2020

Submission for entry 5(b): ACEA et al response 11th SC_entry_5(b)_08_12_2020

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(for details on the associations see next page)

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Associations [5] (Registration ID number listed in EU transparency register can be found below)

Association of European Automotive and Industrial Battery Manufacturers (EUROBAT)

EUROBAT is the association for the European manufacturers automotive, industrial and energy storage batteries. EUROBAT has more than 50 members from across the continent comprising more than 90% of the automotive and industrial battery industry in Europe. The members and staff work with all stakeholders, such as battery users, governmental organisations and media, to deve- lop new battery solutions in areas of hybrid and electro-mobility as well as grid flexibility and renewable energy storage.

The European Automobile Manufactures Association (ACEA)

The European Automobile Manufacturers' Association (ACEA) represents the 16 major Europe-based car, van, truck and bus makers. BMW Group, CNH Industrial, DAF Trucks, Daimler, Ferrari, Fiat Chrysler Automobiles, Ford of Europe, Honda Motor Europe, Hyundai Motor Europe, Jaguar Land Rover, PSA Group, Renault Group, Toyota Motor Europe, Volkswagen Group, Volvo Cars, and Volvo Group.

ACEA works with a variety of institutional, non-governmental, research and civil society partners - as well as with a number of industry associations with related interests.

ACEA has permanent cooperation with the European Council for Automotive R&D (EUCAR), which is the industry body for collaborative research and development.

ACEA has close relations with the 29 national automobile manufacturers' associations in Europe, and maintains a dialogue on international issues with automobile associations around the world

Japan Automobile Manufacturers Association, Inc. European Office (JAMA)

Japan Automobile Manufacturers Association, Inc. (JAMA) is a non-profit industry association which comprises Japan's fourteen manufacturers of passenger cars, trucks, buses and motorcycles. JAMA works to support the sound development of Japan's automobile industry and to contribute to social and economic welfare

Korea Automobile Manufacturers Association (KAMA)

The Korea Automobile Manufacturers Association (KAMA) is a non-profit organization representing the interests of automakers in Korea. We are promoting the sound growth of the automobile industry and also the development of the national economy.

International Lead Association (ILA)

ILA is the only global trade association dedicated to representing lead producers and companies with a direct interest in lead and its use. The Association's team of technical, regulatory, environment and health experts work with stakeholders to promote the benefits of lead and the safe and responsible use of the metal in manufacturing and other applications.

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5 The associations are registered at the EU Transparency register as follows:

European Automobile Manufacturers Association (ACEA) Identification No. 0649790813-47

European Association of Automotive Suppliers (CLEPA) Identification No. 91408765797-03 Japan Automobile Manufacturers Association, Inc. (JAMA) Identification No. 47288759638-75

Korea Automobile Manufacturers Association (KAMA

Association of European Automotive and Industrial Battery Manufacturers (EUROBAT) ID. No. 39573492614-61

International Lead Association (ILA) Identification No. 311414214793-82

European Copper Institute (ECI) Identification No. 04134171823-87

The European Association of Automotive Supplier (CLEPA)

CLEPA, the European Association of Automotive Suppliers, represents over 3,000 companies supplying state-of-the-art components and innovative technologies for safe, smart, and sustainable mobility.

CLEPA brings together over 120 global suppliers of car parts, systems, and modules and more than 20 national trade associations and European sector associations. CLEPA is the voice of the EU automotive supplier industry linking the sector to policy makers.

- The automotive sector accounts for 30% of R&D in the EU, making it the number one investor.
- European automotive suppliers invest over €30 billion yearly in research and development.
- Automotive suppliers register over 9,000 new patents each year.
- Automotive suppliers in Europe generate close to five million direct and indirect jobs.

For entry •2(c)(i). "Aluminium alloys for machining purposes with a Lead content up to 0,4 % by weight"

For entry 3 "Copper alloys containing up to 4% Lead by weight

Japan Auto Parts Industries Association (JAPIA)

The Japan Auto Parts Industries Association (JAPIA) is an industry organization that was established in August 1969, when its predecessor, the Auto Parts Industries Association was reorganized as an incorporated association with a higher level of public interest. Today, the value of shipments of auto parts from member companies has reached approximately 20 trillion yen, supporting the manufacture of automobiles not only in Japan but also around the world.

Each and every one of these high-quality parts makes a significant contribution to the safety and comfort of automobiles. The environment surrounding the automotive parts industry is becoming more and more severe, and the industry is facing many challenges such as responding to structural changes, dealing with environmental issues, and promoting international cooperation.

JAPIA will continue to develop proactive business activities to contribute to the growth of the Japanese economy and society while promoting the sound progress of the "motorized society" through the automotive industry.

For entry •3 "Copper alloys containing up to 4% Lead by weight"

European Copper Institute (ECI)

The European Copper Institute (ECI) is the voice of the International Copper Association (ICA) in Europe. The International Copper Association, with its 35 members, represents a majority of the world's primary copper producers, and some of the largest mid-stream smelters/refiners, and 10 of the world's largest copper fabricators. It aims to bring together the global copper industry to develop and defend markets for copper and to make a positive contribution to society's sustainable development goals.

Exemption Evaluation under Directive 2000/53 EC

ACEA et al. Answers to Stakeholder Questionnaire
of Bio Innovation Service, UNITAR and Fraunhofer IZM dates 15.9.2020

ENTRY 5(b) Lead in Batteries (for battery applications not included in entry 5(a))

This application, and the information provided in his document is supported by the following associations

- ACEA, the European Automobile Manufacturers Association, Brussels
  - (transparency registration ID number 0649790813-47)
- JAMA, the Japan Automobile Manufacturers Association, Tokyo / Brussels
  - (transparency registration ID number 71898491009-84)
- KAMA, the Korea Automobile Manufacturers Association, Seoul / Brussels
- CLEPA, the European Association of Automotive Suppliers, Brussels
  - (transparency registration ID number 91408765797-03)
- EUROBAT, The Association of European Automotive and Industrial Battery Manufacturers, Brussels
  - (transparency registration ID number 39573492614-61
- ILA, The International Lead Association, London
  - (transparency registration ID number 311414214793-82

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1. SCOPE

This document aims to provide a comprehensive overview about Exemption 5 (b) (Lead in batteries) of the European ELV Annex II, by describing the related activities that have been carried out in the past years, the last findings and the challenges for future developments of Lead-free batteries.

The main focus of this document is the answers of the above-mentioned associations to the questions of the Consultation Questionnaire for the upcoming revision of Exemption 5 (b) of ELV Annex II and provides arguments for supporting the extension of this exemption.

2. CURRENT SITUATION

The last review of ELV Annex II Exemption 5 started in the end of 2014 and resulted in the Commission Directive (EU) 2017/2096, which split Entry 5 into, 5 (a) "Lead in batteries in high voltage systems (2a) that are used for propulsion in M1 and N1 vehicles" and 5 (b) "Lead in batteries for battery applications not included in entry 5 (a)". An expiry date has been set for Exemption 5 (a) for vehicles type approved after 1st January 2019, for 5 (b) a review date for 2021 has been set. During the last stakeholder consultation in 2014, automotive associations (ACEA, JAMA, KAMA), ILA and CLEPA proposed a review time of 8 years for the ELV Exemption 5 (b).

Since the last revision of the ELV Annex II Exemption 5, many stakeholders put a lot of effort in developing and identifying Lead-free alternatives with technological and safety related properties comparable to those of Lead-containing batteries. However, even if some good results have been achieved, it is still mostly not possible to substitute Lead batteries due to new technical and safety reasons, as well as market context.

From a Technology and market need point of view:

The automotive industry not only faces accelerating pressure to reduce vehicles' environmental impact, but is also experiencing rapid technological change, in the shape of electrification, connectivity, autonomy, and new business models. As we enter the 2020s, effective deployment of a suite of suitable battery technologies to support these changes, is paramount.

The future European parc will comprise a complex suite of partially and fully electrified products, including micro-hybrids, mild hybrids, full-hybrids and plug-in hybrids, and battery electric vehicles. Through 2030, almost all light-duty vehicles are likely to feature a 12 V board net, and thus require either a 12 V Starting Lighting Ignition (SLI) battery, or a 12 V auxiliary battery.

If European Commission targets for light-duty vehicles are met, the European light-duty parc will be dominated by vehicles that feature internal combustion engines through 2030. As of 2018, Ricardo [1] estimated that the European market annually required over 20 million OEM 12 V SLI batteries and over 40 million aftermarket 12 V SLI batteries. Light-duty vehicles require, and will continue to require for at least a decade, tens of millions for 12 V batteries to perform critical functions. Therefore, the use of 12 V batteries in vehicles will remain critical through 2030 and 12 V auxiliary battery applications will grow in importance in this time period.

The adoption of autonomous driving features will necessitate the use of at least two battery chemistries per vehicle and Lead batteries are the only known technology that currently meet all OEM requirements for 12 V applications.

12V Li-Ion technologies have made significant improvements in terms of cold-cranking and are now reported by their manufacturers to be comparable to Lead batteries. However, further research is required into Li-Ion batteries in terms of high-temperature durability, safety and other challenges in order to achieve mass market availability.

Although Li-Ion technologies have some performance advantages applicable to 12 V SLI applications they remain costly, are not commercially mature enough and do not currently meet all critical OEM specific requirements in terms of vehicle compatibility, safety, high temperature sensitivity, range of required temperature performance and recyclability. Due to higher temperature sensitivity and challenging board net compatibility, Li-Ion batteries so far are excluded be used as ‘drop- in replacements’ for Lead SLI batteries.

From an Environmental point of view:

The Lead battery is an excellent example of the EU circular economy with an almost complete end-of-life recycling including all components. Used automotive Lead-based batteries in the EU are typically returned to the point of sale – vehicle workshops, vehicle dealerships, accessory shops, and DIY stores – or returned to recycling businesses or metal dealerships from authorised end-of-life-vehicles treatment facilities (ATFs).

In all cases, the returned batteries are sent to collection points to be picked up by specialist companies that transport and deliver the spent batteries to car battery recycling plants operating under strict environmental regulations according EU legislation.

During the review of the 8th adaptation to scientific and technical progress of exemptions to Annex II to Directive 2000/53/EC it was highlighted that significant numbers of cars are exported from the EU and that the impact of this on the collection rate of used Lead batteries had not been evaluated by IHS Markit.

For the review of the 9th Adaptation to scientific and technical progress of exemptions to Annex II to Directive 2000/53/EC ACEA, JAMA, KAMA, CLEPA, EUROBAT and ILA instructed IHS Markit to undertake a further and more intensive Recycling Flows Study. Data from 14 countries was analysed, representing about 92% of the parc of in-use vehicles in the EU in 2017 (Austria, Belgium, Czech Republic, France, Germany, Greece, Hungary, Italy, the Netherlands, Poland, Portugal, Spain, Sweden and the UK) for the time period 2015, 2016, and 2017. Moreover, the new study also attempted to evaluate the impact of exportation of used cars containing Lead batteries on overall collection rates.

The result of this evaluation is that the impact of exports of used cars represents only 0.8% of the total made-available end-of-life Lead automotive batteries.

3. BACKGROUND

The use of Lead in the application addressed under Exemption 5(b) of Annex II of the EU ELV Directive is still unavoidable and therefore Art. 4(2)(b)(ii) of the ELV Directive has to justify the continuation of this exemption.

This is elaborated in detail in our answers in this document. The answers to this and the following questions regarding exemption 5(b) of the ELV Directive represent the current knowledge of the Associations outlined above. It should be added that vast majority of these associations are technology agnostic, representing a range of battery technologies. Due to EU competition and antitrust rules it is not possible to give information on future OEM or supplier strategies, new products, expected costs or market shares.

The information referred to in the following responses is an elaboration on consultant notes addressed within the last review of exemption 5 under the ELV, and represents extensive work and data collection from 2015 to October 2020.

It should also be noted that all the existing arguments made during the last ELV stakeholder consultations still apply and are referenced in the document below. The answers below take information from three reports which have recently been published. The executive summaries are available on the ACEA website. (https://www.acea.be/publications/article/reports-provide-input-to-11th-amendment-of-annex-ii-to-the-end-of-life-vehi)

1. **Lead battery automotive technology trends report. Ricardo 2020.** [1] This study reviews the current and future situation for automotive batteries. It concludes that Lead batteries are the only technology that meets all the OEM requirements for 12 V applications, and therefore that a mass market alternative to Lead batteries is not available.

2. **Recycling Flow Study. IHS 2020** [2]**.** This assessment gives evidence that Lead batteries placed on the market are collected and recycled in a closed loop in Europe, and that very little (<0.8%) of Lead batteries are exported from the EU in used vehicles.
3. **Comparative LCA of Lead and LFP Batteries for Automotive Applications Sphera 2020** [3]**.** This is peer reviewed study of the comparative environmental impact of 12 V Lithium Iron Phosphate (LFP) and Lead batteries using life cycle assessment methodology. Over the complete life cycle from cradle-to-grave the difference between all batteries assessed for most impact categories was found to be small. However, the environmental impact (GWP) of LFP battery manufacturing is currently around a factor 6 times higher than the impact of manufacturing equivalent lead batteries. This conclusion is based upon a scenario of a 12kg LFP battery with a lifetime of 8 years that is considered by OEM's to best represent 60 Ah LFP 12 V SLI batteries currently on the market.

4. ABBREVIATIONS

LIST OF ACRONYMS

ABS: Anti-lock Braking System

ACEA: European Automobile Manufacturers Association

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road

AGM: Absorbed Glass Mat

ATFs: Authorised end-of-life-vehicles Treatment Facilities

AI: Automotive Industry

BEV: Battery Electric Vehicle

BMS: Battery Management Systems

CBI: Consortium for Battery Innovation

CCA: Cold-Cranking Amps

CLEPA: European Association of Automotive Suppliers

DC/DC converter: Direct Current/Direct current converter

DCA: Dynamic Charge Acceptance

DoD: Depth of Discharge

EFB: Enhanced Flooded Batteries

ELV: End of Life

EoL: End of Life

ESP: Electronic Stability Program

EUROBAT : Association of European manufacturers of automotive, industrial and energy storage Batteries

FMEA: Failure Mode & Effects Analysis

GWP: Global Warming Potential

HEV: Hybrid Electric Vehicles

IATA: International Air Transport Association

ICE Internal Combustion Engine

ILA: International Lead Association

IMDG: International Maritime Dangerous Goods Code regulations

JAMA: Japan Automobile Manufacturers Association

KAMA: Korea Automobile Manufacturers Association

LAB: Lead Acid Battery

LCA: Life Cycle Assessment

LFP: Lithium Iron Phosphate Batteries

LIB: Lithium Ion Batteries

MHEV: Mild Hybrid Electric Vehicle

NiMH: Nickel Metal Hydride

NMP: N-Methyl-Pyrrolidone

PHEV: Plug-in Hybrid Electric Vehicle

PSoC: Partial State of Charge

REACH: Registration, Evaluation and Authorisation of Chemicals

SLI: Starting Lighting and Ignition

SEI: Solid Electrolyte Interface

SoC: State-of-Charge

5. QUESTIONS

5.1 The last adaptation report [4] on exemption 5 concluded with the following statement: "It is also presumed that in cases where a dual battery system is in use, the use of a LAB [Lead-Acid-Battery] as an auxiliary battery would not be avoidable even where starter functionality is not needed. This is based on the understanding that there is a lack of experience with batteries other than LAB for this function, though this could change over the next few years, as Li-Ion batteries [LIB] are understood to provide a suitable candidate for such cases. Three to five years are envisioned to be needed in this case to allow reaching parity of cold cranking performance. As replacement with Li-Ion batteries is not yet implemented in vehicles on the market, it can be followed that more time would be needed to finalise testing and type approval processes once parity was established."

5.1.1 (Q.1.a.) Has parity been reached in terms of cold cranking performance of LIB (lithium iron phosphate-based batteries in particular) and LAB as expected? What is the status of testing and the type approval process? Please describe the progress that has been made since the last revision.

The cold-cranking performance of Li-Ion batteries has improved significantly in the past few years; Li-Ion battery manufacturers now report parity with 12 V Lead batteries in terms of cold cranking with new batteries. However, this has still not yet been demonstrated over the full lifetime of the battery and is an area of ongoing research and development.
For auxiliary batteries Lead batteries are still the state of the art in vehicles, and the only chemistry used in this application. There is no experience or knowledge of the suitability of other battery chemistries for this function.

Lithium Iron Phosphate (LFP) is the most common chemistry discussed in relation to Li-Ion 12 V starter batteries. When we refer to Li-Ion batteries below we are always referring to LFP chemistry.

In the earlier stages of development for Li-Ion starter batteries, providing sufficient current discharge in cold temperatures (cold cranking amps) was not possible at -25°C due to issues with increased internal resistance. In extremely low temperatures (< -10°C), the power and energy available from Li-Ion batteries declines due to increased internal cell resistance [1]. At extremely low temperatures, Li-Ion batteries' electrolyte conductivity decreases, and a reduction in solid-state diffusion occurs. In addition, Lithium plating can occur under certain conditions, which leads to dendrite formation. As a result of this degradation mechanism, the internal resistance of the battery increases, resulting in reduced energy and power capability. This mechanism will lead to performance failure. Dendrite formation has the potential to create internal short circuits, which may cause a thermal runaway event.

LFP Li-Ion battery manufacturers now report that their 12 V starter batteries have reached cold cranking parity with Lead batteries. Reportedly, they have achieved this by optimising the electrolyte using materials with lower freezing points within the battery and using electrolyte additives [1].

However, OEMs remain concerned as there is still insufficient evidence that LFP batteries can provide this cold cranking capability over the full lifetime of the battery. This issue still needs to be addressed before use in mass market vehicles could be considered.

The use of new electrode materials to ensure Lithium batteries can meet cold cranking requirements, has resulted in a trade-off in high-temperature performance and safety.

Li-Ion batteries generate heat during the reversible electrochemical reaction process that occur during charging and discharging. Several irreversible processes can occur which generate heat including active polarisation, ohmic heating, and enthalpy change. As temperature rises above 35°C, the performance of the battery is degraded and will result over time in an irreversible loss of capacity and power. Longer periods of elevated temperature also effect component lifetimes.

Polarisation occurs due to overpotential between the operating potential and open circuit potential and results in an increase of charge transfer resistance at the solid electrolyte interface (SEI). When Lithium ions overcome this resistance at the interface, heat is produced. However, if and when the heat produced results in a cell temperature of circa 85°C, the SEI layer breaks down, which can lead to a thermal runaway event [1].

Newer technologies that have improved cold cranking capability use thinner electrode material, which means anodes are in closer contact with electrolytes; this contact results in the production of additional SEI in an exothermic process and effects a further temperature increase. As the temperature increases, the separator melts which causes internal short circuits and eventually venting and/or a thermal runaway event. To reduce the likelihood of this occurring, separators that increase resistance above a critical temperature, and provide a shut-down mechanism, can be used. In addition, ceramic composite separators with a higher melting point and improved mechanical stability can be deployed. The use of electrolyte formulations for lower temperature operation will also tend to lower the flash point which increases the risk of fire, intensified electrolyte off-gassing and explosion in a thermal runaway. More generally, the increase in power density to meet specification requirements may increase the overall risk of incendive failure. Further R&D work in chemistry and component design is still required to address these challenges.

If a Lithium battery is located in the engine compartment of a vehicle the battery may be subjected to very high (elevated) surrounding temperatures exceeding 75°C, and in some cases up to 100°C. This high temperature can cause high temperature durability and safety challenges with the battery requiring appropriate countermeasures.

This means that although cold cranking requirements may be met by new LFP technologies, it remains a significant challenge for this technology to meet the technical and safety requirements at temperatures that occur in the engine compartment of typical vehicles (higher than 65 °C indicated as the safe operating limit). In addition, cold charging requires more complex battery management and risk management which is not currently validated and can only be at system level. This wide range of operating temperature is still a problem for 12 V Li-Ion technology. Further research is needed to ensure that such Lithium batteries can meet these requirements (for all climate conditions in Europe-from Lapland in Finland to Andalusia region in Spain). This would involve research into new materials, and new electrolytes. This is a focus of several R&D projects in Europe.

The current research work into Li-Ion batteries is explained in question 5.7. A survey of current EU R&D in this area in general is attached in Annex 1.

There are also potential safety concerns with Li-Ion batteries for service replacement. If Li-Ion batteries are not fitted as original equipment, there are severe risks that any replacement batteries may not conform to the safety standards prescribed by original equipment manufacturers with clear risks of fire or explosion. There are safety standards for Li-Ion cells defined by the International Electrotechnical Commission, Underwriters Laboratories and the United Nations which should be respected for consumer safety but suppliers to the replacement market may not be controlled to the same extent as vehicle manufacturers [1]. It should be noted that a lead battery in a modern car has to be replaced by specified spare parts.

5.1.2 (Q.1.b.) What is the typical temperature range for the operation of 12 V LAB and the viable alternatives?

12 V Lead Batteries

> ***-30°C to +75°C-80°C for service (e.g. driving)***
> ***-40°C to +60°C for storage (e.g. garage or warehouse)***

Lead batteries are generally resistant to cold conditions, and have been shown over many years to have excellent performance at -30°C. Different OEMs have particular requirements for low temperature performance - some as low as -40°C.

When talking about maximum temperatures occurring in the vehicle with respect to as 12 V starter battery, a distinction has to be made between ambient temperature, surface temperature and electrolyte temperature (the same as the temperature of the active masses) and the application time of these temperatures has to be taken into account.

Ambient temperatures surrounding the engine compartment can regularly be up to 75-80 °C, and in some cases as high as 100°C.

Some OEMs place their batteries below the trunk of the vehicle. As there is the exhaust system nearby, temperatures of 75-80°C are possible. If the vehicles have an exhaust system on both sides (mostly for high performance engines) it is even harder.

And also, some OEMs explicitly require battery to be able to perform in the range 75-80°C. Furthermore, peak temperatures of up to 100°C can be seen in the engine compartment. Lead batteries have shown to be able to withstand brief excursions to such peak ambient air temperatures in the range 80-100°C.

For example, a specification/test standard for Lead batteries run by some OEMs contains tests that must run at a temperature of 75°C (ambient temperature, electrolyte temperature is allowed to rise higher during the measurement). For example, 75°C is used by the SAE Standard J240 (since Oct.2002). In addition, the EN 50342 is under revision and a new key life test (nKLT) is under development and in scope of the standardization efforts. This nKLT is performed half of the time at 75°C. Measured air temperatures in the surrounding of Lead batteries in the engine compartment can grow up to 100°C for a short time.

12 V LFP Batteries

> ***- 30 °C to + 55 -65 °C for service (e.g. driving)***
> ***- 40 °C to + 60 °C for storage (e.g. garage or warehouse)***

Generally, the optimum temperature range for Li-Ion batteries (current potential of the battery itself) is between +15°C and +35°C. The lifetime of 12 V LFP Li-Ion batteries depends to a high degree on efficient thermal management, both in storage and in-use as the contribution of thermal energy to the battery system is much higher during its operation, due to Joule heating, than during storage environmental effects. The maximum permanent temperature exposure stated by Li-Ion battery suppliers is 55°C, although some manufactures have claimed temperatures as high as 65°C. There are no low voltage Li-Ion batteries known, which meet OEM specified requirement of 75°C.

5.1.3 (Q: 1.c.) For which temperature range do such 12 V batteries need to be tested and validated for the different vehicle classes (ICE, hybrid, fully electric)?

The currently used Lead batteries are standardized products which are able to fulfil the requirements with one straightforward component fitting for all vehicle classes.

12 V batteries need to be tested over the full temperature range for service in extreme conditions. For normal engine starting at -18°C is used but for cold conditions -30 °C is specified. These requirements are the same for all 12 V batteries used in all the vehicles addressed above. In general, longer periods of very high temperatures decrease the lifetime of all battery variants.

It needs to be stated that successful component tests are only the entrance card for subsequent tests in prototype vehicles, where the batteries have to perform under different ambient and functional conditions (e.g. sharp temp. gradients, acceleration, vibrations, crash etc.).

Likewise, a normal high ambient temperature would be +40 °C but under-hood temperatures may go up to 75-80 °C, and in some cases up to 100 °C. As explained in our earlier answers, Lead batteries have been shown over many years of use to survive conditions up to +75-80 °C, and can withstand brief excursions to temperatures up to 100 °C. Exposure to Li-Ion (LFP) batteries to permanent temperatures significantly above 55-65 °C for a longer period of time may result in thermal runaway and stability concerns that can result in consumer safety issues, if appropriate countermeasures are not met.

One very important temperature standard is IEC SAE J2801, which requires testing at 75°C.

For an auxiliary battery cold cranking is not an issue. However, performance at these temperature ranges are still relevant.

In addition to cold cranking, high currents are required to operate fuses in the event of a hard short to isolate circuits if there is a fault. For example a 100 A fuse would require ~1500 A to operate (blow) in <100 ms.

The main standards for 12 V SLI batteries are for Lead batteries: EN 50342 (7 parts) and IEC 60095 (7 parts). Both standards have been established decades ago and are periodically updated.

Development of standards for 12 V Li-ion batteries for automotive applications is at a very early stage and only addresses a limited range of the necessary parameters necessary for broad application. The standards committee responsible considers that battery performance should be defined to cover a wider range of service conditions with particular emphasis on the temperature range required for the electric power supply of safety relevant car systems and durability and to ensure cold cranking performance in all regions.

The working group responsible for this is IEC (IEC TC21 WG2). The project number is “Project IEC 63118” or "12 V Lithium Secondary Battery for Automotive SLI Applications.

5.1.4 (Q 1.d.) What is the cold cranking ability of current 12 V batteries according to common testing standards?

A typical L3 size 12 V automotive battery has Cold Cranking Amps (CCA) of 700-760 A at -18°C to EN 50342-1 (20 h capacity 70 Ah). Commercial or other specific vehicle categories are not considered here and assumedly may have specifically harsher requirements.

12 V Li-Ion batteries should be able to provide cold cranking performance over the full temperature range indicated above. The requirements differ according to vehicle type, territory of use and application. In some cases, service temperatures will be less than -30°C and this would exclude the use of a Li-Ion battery.

5.2 (Q: 2) Drop-in alternatives for 12 V LAB are available on the market (commonly but not limited to lithium iron phosphate). Several vehicle models from different OEMs have been reported to use 12 V LIB in 2014, in addition to a range of other alternative technologies (e.g. supercapacitors). It was further reported that in 2014 an estimated 900.000 vehicles were in service with a 12 V LIB on board

Please provide reasoning as to why such (drop-in) alternatives are commercially available and are already widely in use but are currently not the default battery system employed in new vehicles.

From a market standpoint, 12 V Li-Ion batteries are still very much an emerging and high cost product. Some OEMs have now deployed a very limited number of 12 V Li-Ion batteries (<<1% of current vehicles)—in particular, in applications where light-weighting is more important than cost. These are typically motor sport oriented with specific use profiles (e.g. less use in low temperatures) use rather than for normal road driving. A web search showed that the majority of **12 V Lithium batteries are offered in the aftermarket for marine and for motor caravan applications, for E-Scooter and E-bikes, as accumulators/power supply. Here again different use profiles apply -for example lower demands concerning e.g. crashworthiness and operating temperatures. Supercapacitors are not covered in our answer below as they are not widely used, but are extensively covered in the previous stakeholder consultation** [4]

Some aftermarket and speciality suppliers offer Lithium-ion batteries claimed to be suitable for some vehicles. However, they are not approved by OEMs for use in their vehicles because the vehicle will have been homologated with a specific battery and because of safety concerns regarding replacement a battery with a non-qualified or OEM approved battery.

Vehicle homologation to validate the CO_2 and other emissions from vehicles with ICEs has been at the forefront of concerns to reduce the environmental impact of road transport. Modern cars with start-stop and micro-hybrid systems are qualified by dynamometer and road testing with batteries and battery management systems (BMS) designed for a specific type of battery required to establish the emissions under prescribed testing procedures.

Based on negative experiences in the past, software and software versions now may be binding part of homologation procedures.

Modern vehicles are designed either with enhanced flooded batteries (EFB) or absorptive glass mat batteries (AGM). These are both Lead battery types but are not interchangeable as they have different electrical characteristics and different mechanical characteristics. The operating manual and the dealer network will know which type is fitted by the OEM and a service replacement must be of the same type e.g. to maintain function of the start-stop features. These are widely available as standardized products not only from the OEM supplier but also from several other manufacturers. The use of an unknown Li-Ion battery as a drop in solution is never recommended -including for older cars- as the electrical characteristics are different and it will not be adapted to the BMS installed in the newer vehicle. As a result, the vehicle emissions are unlikely to be in line with the homologated levels and the BMS is likely to inhibit the operation of the start-stop or micro-hybrid system increasing emissions accordingly. If a Li-Ion battery is used, the vehicle systems and vehicle structure have to be designed for this chemistry.

Another relevant function is the brake energy recuperation. In vehicles with a Lead battery a typical recuperation voltage level is up to 15.0 V. Operating a Li-Ion battery at 15.0 V may cause an emergency shutdown of the battery and then may be a safety problem in the vehicle.

Safety is therefore a major task. Li-Ion batteries have a higher energy and power density which increases the risk of fire and explosion under fault conditions or in an accident. They also have liquid organic electrolytes which are intrinsically flammable whereas the aqueous electrolyte used in Lead batteries is non-flammable. The battery should therefore be located in an area of the car where it is unlikely to be damaged severely in an accident. There are also some concerns regarding the installation of Li-Ion batteries in the engine compartment because of high operating temperatures as explained in answers to other questions. An additional cooling system may be limited by packaging restrictions which can cause other challenges in terms of CO_2 emissions and weight issues. There are systems used for Li-Ion batteries which can disconnect the battery in case of a crash but there remains a requirement for emergency power after an accident-for example for an automated emergency call. This may be met e.g. by the use of a Lead auxiliary battery.

There is a further criterion which has to be considered. A Lithium battery can provide much more current in the case of a short circuit. There is the likelihood that the built-in fuse boxes would not function in this instance.

Over the last several years many mechanical systems have been replaced by electrical systems such as brake by wire and steer by wire. A safety margin is essential for the functional safety of braking, steering, lighting, wipers, communications, remote parking and other essential systems as well as higher levels of autonomous driving. Vehicles are fully dependent on the correct operation of software systems for all functions and the sensors and actuators as well as the control units need to have reliable and secure power supplies. As of today, these functions are assured by the known and predictable behaviour of standardized Lead batteries. More "intelligent" batteries need software for to ensure they function properly. This software needs to communicate trouble-free with vehicle proprietary software and has to fulfil specific homologation requirements for software. Inadequate performance of alternative battery chemistries would impact these safety critical functions. There are no standardized Lead alternatives available and so it is not possible to specify these technologies for competitive supply. There are also major technical and economic barriers to be overcome to ensure volume supply of 12 V Li-Ion batteries. Lead batteries are well known to provide a safe and reliable power supply, and it should be noted that even electric vehicles also have a 12 V Lead battery for the 12 V board net power supply.

Vehicle board nets have to be designed to be compatible with standardised Li-Ion batteries. It cannot be assumed that a drop-in Lithium battery would be suitable for a board net that was designed for a Lead-based battery. Because Li-Ion 12 V batteries are niche products that have not been standardised then it should not be assumed that the vehicles either have a suitable board net, or a safe component position, for both Lead and Lithium 12 V batteries.

The concept of a 'drop in' Li-Ion battery replacement is therefore flawed and not recommended. Vehicles are designed to use specific types of battery and cannot readily accept alternatives.

5.3 (Q. 3) Please describe the mission profiles of 12 V batteries in the different vehicle classes. According to information available to the consultant, ICE vehicles require a high power draw for cold cranking, but otherwise only require relatively low power for other functions powered by the 12 V system, leading to overall shallow depth of discharge (DoD) and low cycle frequency requirements. Battery electric vehicles do not require such high power for cold cranking, but draw comparatively more power that ICE both in "on" or "off" mode to supply the board computer, battery management system, and "comfort features", therefore requiring a battery that can withstand higher DoD and provide a higher cycle life. It has been described in the last adaptation report that some hybrid vehicles use the 12 V battery for engine cranking, while others do not.

Please provide specific data for the technical requirements mentioned above regarding the 12 V battery for each vehicle class and provide reasoning regarding the substitutability of LAB with alternative technologies (including LIB) for each vehicle class.

Lead batteries are current used in virtually all vehicles on the road from ICE all the way up to full electric vehicles. These batteries are used either as a 12 V SLI battery or a 12 V auxiliary battery. There are a range of requirements for these applications that include cold cranking, high temperature durability, safety, functional safety, cost, 12 V board net compatibility, manufacturing base and ability to be highly recycled. Only Lead batteries meet all these criteria.

We would like to refer to the technical submissions we made during the last ELV stakeholder consultation, which outlines many of these issues in detail. The content is still relevant for the current stakeholder consultation. The technical information below is taken from the Ricardo Report [1].

Automotive batteries fall into several categories, and are utilised in a range of vehicle types:

- 12 V Starting-lighting-ignition (SLI) batteries
- 12 V Auxiliary batteries
- Higher voltage traction batteries

Tables 1 and 2 summarises the battery requirements for each vehicle type. This is then explained further in the following text

Table 1 Battery types are requirements for different vehicle types [1]

	ICE	**S/S Micro-hybrid**		**Mild-hybrid**		
	12 V SLI	12 VSLI	12 V Aux*	12 V SLI	48 V	12 V Aux
CCA (°C)/ cold temp performance (°C)	-30	-30	-30	-30	-30	-30
Cycling or Start-Stop	No	High	No	No	High	No
High Temp (°C)	> 75	>75	> 75	> 75	> 75	> 75
Board net	12 V compatible	12 V	12 V	12 V	12 V	12 V
Calendar life (years)	5 to 7	5 to 7	5 to 7	5 to 7	5 to 7	5 to 7
Safety	High	High	High	High	High	High
Functional Safety	High	High	High	High	High	High
Cost	Low	Low	Low	Low	Low	Low
Manufacturing base	EU extensive	EU extensive	EU extensive	EU extensive	EU extensive	EU extensive
Recycling	High	High	High	High	High	High

* only small number of models

** only batteries with voltages less than 75 V under scope of this exemption

Table 2 Battery types are requirements for different vehicle types

	Full-hybrid			PHEV/EV	
	12 V SLI	12 V Aux	HV Traction* *	12 V Aux	HV Traction**
CCA (°C)/ cold temp performance (°C)	-30	-30	N/A	-30	N/A
Cycling or Start-Stop	No	No	High	No	High
High Temp (°C)	> 75	> 75	N/A	> 75	N/A
Board net	12 V	12 V	N/A	12 V	N/A
Calendar life (years)	5 to 7	5 to 7	N/A	5 to 7	N/A
Safety	High	High	N/A	High	N/A
Functional Safety	High	High	N/A	High	N/A
Cost	Low	Low	N/A	Low	N/A
Manufacturing base	EU extensive	EU extensive	N/A	EU extensive	N/A
Recycling	High	High	N/A	High	N/A

* only small number of models
** only batteries with voltages less than 75 V under scope of this exemption

12 V SLI type batteries power the following functions (majority are key safety features):

- Starting, lighting, ignition
- Start-stop and micro-hybrid functions
- Power supply in sleep mode and in vehicle wake-up
- Emergency illumination and hazard warning lights
- Electronic locks
- ABS (anti-lock braking system) control units
- ESP (Electronic Stability Program) control units
- Independent heating systems
- Emergency call support after a crash
- Defrosting systems
- Displays for car information
- Power steering
- Electric windows levers
- Infotainment

12 V Auxiliary batteries

In addition to the functions listed above (except start-stop and micro-hybrid functionality) 12 V Auxiliary batteries for hybrid and electric vehicles also provide the functions listed below:

Battery management system The Lead battery powers the battery management system, which is an electronic system that manages another battery (e.g. a battery powering an electric/electrified vehicle), such as by protecting the battery from operating outside its Safe Operating Area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it and/or balancing it. Essentially a battery powering an electric/electrified vehicle (e.g. hybrid vehicles which include electric power trains, plug-in hybrid vehicles and full electric vehicles) could not function without a battery management system, which is provided for in all such vehicles by a 12 V Lead battery.

Range extender A range extender is an auxiliary power unit built-in or externally attached to all-electric or plug-in hybrid electric vehicle to increase its all-electric range (AER). The most used range extenders are internal combustion engines that drive an electric generator which in turn supplies the battery and electric motor with electricity. These range extenders are powered by a 12 V Lead battery in such vehicles.

Higher Voltage Traction Batteries

A traction battery is a battery used to power the electric motors of a battery electric vehicle or hybrid electric vehicle. These batteries have different technical requirements than 12 V batteries. Lead batteries are not used in this application and are therefore, not discussed in this document.

The response to the question below will focus on 12 V SLI and 12 V Auxiliary batteries.

The requirements for 12 V Lead batteries in SLI applications are as follows [1]**:**

Cold Cranking Performance

This concerns the battery's ability to effectively start an engine at low temperatures (typically OEMs require down to at least -30°C). Vehicles with an internal combustion engine (ICE) feature an electric cranking motor which requires a high current to convert the electrical energy to sufficient mechanical energy. As temperatures decrease, the ability of a battery to provide enough current also decreases. As a result, higher cranking amps are required to assure OEMs that the battery will be able to crank an engine in extremely cold conditions. In addition to cranking the engine at these low temperatures, the battery must also be able to recharge at low temperatures, down to-30 °C.

As explained in the answer to question 5. 1, OEMs believe that Li-Ion batteries still need further development to meet these requirements. There is no clear evidence that cold cranking performance of LFP batteries are equal to the cold cranking performance of Lead-batteries across the entire lifetime of the battery.

High Temperature Durability

In order to meet cold cranking requirements, the preferred battery location is as close as possible to the engine. This means that 12 V batteries must be able to operate at the temperatures that can exist in the engine compartment-as already explained in our answer to question 1. Locating the battery away from the engine compartment requires long lengths of heavy-duty cable and a higher battery performance may be needed to compensate for any voltage drops.

As explained in question 5.1 and 5.6, to the best of our knowledge, only Lead batteries currently meet the requirement for high temperature durability.

Compatibility with 12 V Board Net

Any 12 V battery used must be compatible with the vehicle's 12 V board net.

There are concerns about the board net compatibility of Li-Ion batteries compared to Lead-based batteries. Specifically, with highly efficient board nets, under peak loads the voltage requirements can rapidly reach 14 V or more for limited periods of time. This could result in lithium batteries overheating due to their higher charge acceptance allowing a greater current at the same voltage.

With respect to electrical architectures, both Lead and Lithium 12 V batteries are generally compatible with 12 V board nets. However, depending on the vehicle and its board net wiring specifications from the OEM, some vehicles may not be suitable for the higher short-term current draw from Lithium batteries.

As mentioned above, board net wiring can become damaged if an over-specified battery is deployed, which would increase the current through the wiring. However, if the board net wiring is designed to accept higher currents, there should be no compatibility issues. Alternatively, if there is no 12 V battery, and a 48 V battery is being used to power the 12 V board net, a DC/DC converter may ensure there are no integration issues between the 12 V board net and a 48 V battery.

We are not aware of any OEM developing a board net without a 12 V battery. Removing the 12 V battery will automatically lead to massive requirements at the corresponding DC/DC converter (highly transient loads, functional safety). Also, aspects of short circuit protection have to be considered.

In simple terms, the standard vehicle architecture relies on a 12 V board net for most vehicle systems which is powered by a 12 V battery. If a 48 V battery is used on the vehicle, it is primarily used specifically for kinetic energy recuperation and power assist as it is optimised for this function.

Vehicle board nets have to be designed to be compatible with standardised Li-Ion batteries. It cannot be assumed that a drop-in 12 V Lithium battery would be suitable for a board net that was designed for a Lead-based battery. Because Li-Ion 12 V batteries remain niche products it should not be assumed that all vehicles have either a suitable board net, or a safe component position, for both Lead and Lithium 12 V batteries. Missing standardized products make it difficult to adopt a future system.

Only Lead batteries are considered state-of the art and only this technology meets this requirement.

Calendar Life

Current 12 V Lead SLI batteries used in Stop/Start vehicles are expected to have a calendar life of between five and seven years before replacement. The calendar life requirement for future battery technologies is likely to remain the same for the next decade, due to consumer satisfaction levels when purchasing a product; they do not want the cost or inconvenience of having to replace their 12 V battery more frequently than this. Calendar life is impacted by high temperatures as previously mentioned. There are R&D activities conducted to further increase lifetime of lead batteries-driven by the work of the Consortium for Battery Innovation [5]

Lead batteries have proven their performance over vehicle lifetime. For Li-Ion batteries such data over lifetime and calendar life can only be estimated due to missing market experience. It should also be noted that Lead battery performance lifetime are continuously optimised by OEMs.

Safety and functional safety

All automotive batteries must be safe and stable in all service environments. Battery manufacturers and OEMs are required to ensure that batteries are located in suitable places where ambient temperatures will not exceed the operating requirements of the batteries, and in a location that is unlikely to be severely impacted during a crash or designed in such a manner that high mechanical impact prevents damaging/deformation of the battery. Significant differences in materials and components exist between 12 V Lithium- and Lead-based batteries. Therefore, behaviour in a crash situation will be very different; these differences need to be taken into consideration when specifying a battery for a given application.

Once more, it needs to be stated that Lead batteries have demonstrated over decades that they can meet OEM specific safety requirements. This is further explained in the answer to question 5.6.

Cost

Lead SLI batteries are a globally standardised, mass-market technology, essential for all vehicles that use an ICE globally. The cost of the product is a key differential for OEMs and consumers and allows the optimisation of vehicle costs to maintain competitiveness. As there are multiple manufacturers of Lead-based batteries, OEMs have a choice and the industry remains cost-competitive. However, for newer technologies, such as Li-Ion batteries, there are significantly fewer battery manufacturers which is likely to affect the economic competitiveness of these products.

The Ricardo 2020 reports that 12 V Lithium batteries are at least four times more expensive than Lead-based equivalent batteries. This is further explained in our response to question 5.4.

In addition, the following topics are very important when considering a 12 V battery technology

Manufacturing Base and Resource Availability

As automotive batteries are required in all vehicles globally (including BEVs which use a 12 V auxiliary battery), there is a very large demand for these globally standardised batteries. A sufficient battery manufacturing and recycling base and balanced availability of resources required for battery technologies should be considered when considering a change in battery technologies

Lead batteries can meet this requirement, having a well-established manufacturing and recycling industry in Europe.

Recycling

Recycling is also very important for circular economy and material efficiency. As explained in question 5.5, automotive Lead batteries are collected and recycled in Europe in a closed loop [2]. There are several legislative demands in Europe ensuring that this happens with minimal environmental impact. As any uncontrolled Lead emissions could have adverse effects, Lead battery production, and recycling procedures operate with strict and controlled measures. All variants of automotive LAB´s can be processed together in the same recycling procedure.

Low voltage Lithium batteries have several challenges to overcome with regard to recycling which is elaborated on in answer to question 5.5.

As explained in other responses to other questions, Lead batteries are currently the only known battery technology that meets all these requirements.

The section below explains the different batteries used in each vehicle type.

Conventional vehicle (internal combustion engine-ICE)

Conventional ICE-powered vehicles typically use a standardised conventional flooded 12 V Lead-based batteries for SLI applications and to power the 12 V board net. The duty cycle in ICE vehicles is cold engine start and the alternator is able to supply all the vehicle loads except in engine-off or an emergency (alternator failed). The battery is maintained close to a full state-of-charge (SoC) in normal use.

Start-stop vehicle/micro-hybrid

In a start-stop vehicle, the engine is switched off when the vehicle is stopped for short periods, for example while waiting at traffic lights. Alternators are designed to enable this based on the power characteristics of Lead batteries.

Start-stop and micro-hybrid applications are defined as follows

- Stop/Start technology-in this technology, the vehicle engine is switched off when stationary, for example in traffic. This technology can result in fuel and therefore CO_2 savings of up to approximately 2% to 4% [3].
- *Micro-hybrid* charge management and regenerative braking systems are used to switch the alternator charging system off to improve fuel economy; regenerative braking recovers energy that would have otherwise been lost as heat during vehicle braking. These vehicles also feature Stop/Start technology. In addition, some hybrids replace the alternator and starter motor with a combined starter/generator unit which is located between the engine and the transmission or on the accessory drive belt. Micro-hybrid technology can result in fuel savings of up to approximately 7% to 9.5% [3].

Due to the increased number of engine starts that the battery is expected to deliver in these start-stop/micro-hybrid applications in comparison to a conventional ICE vehicle, advanced Lead-based batteries had to be further developed to ensure adequate longevity and performance.

Micro-hybrid vehicles require AGM or EFB batteries, which have a better cyclic life and operation at low states of charge than conventional flooded Lead-based batteries. Regenerative systems also require the use of an AGM battery or EFB, as the lower inner resistance of these batteries enables more efficient charge acceptance of energy to the battery. For the most advanced micro-hybrid vehicles AGM batteries, available as standardised products, are recommended to support the additional functions.

In addition to starting the ICE and ensuring electrical energy is supplied to electrical components, batteries within micro-hybrid vehicles are expected to reduce CO_2 emissions and fuel consumption of the vehicle by:

- Allowing the engine to switch off via the Stop/Start function
- Mechanical energy recuperation (regenerative braking)
- Reducing the mechanical load of the alternator on the accessory belt.

Micro-hybrids use the battery to achieve fuel savings by active Electric Energy Management (EEM) and use the battery temporarily as a source and a sink of electric power. During charge recuperation steps, dynamic charge-acceptance of the battery should be high enough to absorb energy and recharge the battery in a short time.

During ‘stop’ phases where the engine and alternator are off, loads are supported by the battery only and the battery is therefore subjected to deeper micro-cycling with more self-heating and a much higher cumulated energy throughput. For these applications, EFBs or AGM batteries are necessary to fulfil this requirement.

Micro-hybrid vehicles require batteries with improved high-rate discharge behaviour, increased Dynamic Charge Acceptance (DCA) at Partial State of Charge (PSoC) and extended micro-cycle life with low and constant internal resistance.

For start-stop or micro-hybrid the cold engine start is the same that for ICE, however in service the engine is stopped to reduce CO_2 emissions and the battery supplies the electrical loads. The battery also restarts the engine, but it is warm (as the car has been travelling) which reduces the energy required. For engine-off or alternator fail the battery will supply the loads required. In start-stop or micro-hybrid service the battery is not fully charged, typically 80-85% SoC, so that it can accept recuperative energy. The difference between start-stop and micro-hybrid is the intensity of use and greater recuperation of energy.

The key technical requirements for a 12 V battery in start-stop and micro-hybrids are the same as for ICE. However, as explained above the battery also needs good DCA. DCA is the ability of a battery to recover and store energy generated through regenerative braking.

Mild-hybrid vehicles

The medium-electrification vehicle category encompasses hybrid vehicles including mild-hybrid, full-hybrid and plug-in hybrid vehicles. The 12 V battery can be either used as an SLI to start the engine, or may only act as an auxiliary battery, dependent on the OEMs requirements.

Within medium-level electrified vehicles sit mild-, full- and plug-in-hybrid vehicles. These vehicles feature two board nets. Hence, these vehicles all feature a main battery, with a typical voltage of between 48 V (for 48 V MHEVs) and 400 V (HEVs), and a conventional 12 V battery that is used to power the 12 V board net. This 12 V battery is sometimes used to start the engine.

Modern mild-hybrid vehicles typically use a 48 V battery to support enhanced recuperation of kinetic energy into electrical energy. This technology can be either Lead based or Lithium based. Significant performance enhancements are being seen in Lead batteries with regard to DCA, making them a good candidate for this application in the future [5]. As explained in section 7. 12 V batteries are used to power electromechanical and electronic components such as control systems, cooling, comfort features, security, electric windows, windscreen wipers, central locking and many other functions, whilst the 48 V battery powers higher powered electrical systems, especially power assist.

In mild-hybrid electric vehicles (MHEVs), an electric motor powered by a battery (typically 48 V) is used to assist the acceleration of the vehicle. The electric motor is bidirectional so that it can operate as a generator and recover energy on deceleration. Power assist is provided to the ICE, but the motor does not propel the vehicle in an electric-only mode. In addition to the main battery, a 12 V AGM battery is often implemented, to support electric auxiliary components.

The technical requirements for the 12 V Lead battery in these applications are the same as that for standard SLI batteries as the stop and start or micro-hybrid capability is superseded by the power assist capability and recuperation performance enabled by the 48 V battery system.

Auxiliary 12 V Lead Batteries

Vehicles may require a 12 V SLI battery and /or a 12 V auxiliary battery. A 12V auxiliary battery powers essential safety features (e.g. brakes, air bags, power steering and other systems, depending on the vehicle). For example, if an electric vehicle battery malfunctions or runs out of charge, the 12V auxiliary battery will take over and ensure that the vehicle can pull over safely. The auxiliary battery also powers the battery management system (BMS) in vehicles with high degrees of electrification. The BMS ensures that the high voltage Lithium battery operates safely. The requirements for an auxiliary battery are the same as an SLI battery except that is will not start the engine. However, unlike SLI batteries, which are installed as close as possible to the engine, auxiliary batteries can be installed in other locations of the vehicle. All auxiliary batteries currently employed are Lead based batteries-the board net being designed based on 12 V Lead battery. There is no experience with other chemistries and no evidence that other chemistries can meet these technical requirements.

Full-hybrid vehicles

These vehicles will usually require high-voltage (>75 V) and 12 V Lead SLI batteries and in some cases a 12 V Lead auxiliary battery.

Full hybrids (HEVs) feature a both an engine and a traction battery. These vehicles still use start/stop and regenerative braking technologies. However, these vehicles can sometimes be driven on electric power only. The combustion engine remains the primary source of power and the 12 V battery is charged by the alternator with power from the ICE and/or regenerative braking. Most HEVs require both a HV battery and a 12 V SLI battery to power the 12 V board net. In some cases, a full hybrid will also employ a 12 V Lead auxiliary battery or a DC/DC converter.

Plug-in-hybrid vehicles (PHEV)

PHEV require both high-voltage and 12 V Lead SLI and often an auxiliary battery.

Similar to a HEV, a PHEV utilises at least two batteries: a standard 12 V Lead SLI battery and a HV Li-Ion battery (as the main source of power). A 12 V Lead auxiliary battery can also be utilised in a safety function and to power the BMS.

The main difference between a HEV and PHEV, is that a PHEV typically uses larger Lithium-based batteries to offer an extended all-electric driving range and that a plug-in HEV can be charged externally.

Fully Electric vehicles (EVs)

Full EVs will require both HV and 12 V auxiliary batteries. For auxiliary batteries the 12 V battery is required for safety purposes. The 12 V board net powers e.g. warning lights, airbags, door locking/unlocking and emergency communications.

Similar to a PHEV, EVs utilises two batteries: a standard 12 V auxiliary and a HV Li-Ion battery (as the main source of power). The 12 V auxiliary battery powers safety features as explained above and the BMS.

In addition, the high voltage system has to be switched off in case of accident as it can be dangerous. The 12 V Lead auxiliary battery will ensure this happens.

5.4 (Q. 4) The last adaptation report cited data from 2014 illustrating the considerable difference in cost between LAB, NiMH, and LIB for automotive 12 V application. Please provide information regarding the development of the cost per kWh / kW as well as per market-available unit (12V battery) since then. Please also refer to the expected price development in the next few years.

We represent several associations and therefore we cannot discuss prices for anticompetitive reasons. However, the Ricardo 2020 report highlights that 12 V Lithium batteries are currently approximately four times more expensive than Lead-based equivalent batteries [1]***.***

The information below is only relevant to 12V Li-Ion batteries and not high voltage Li-Ion traction batteries.

There are several elements of cost for a Li-Ion battery. These are the cell costs, internal components, internal circuitry for battery monitoring, control of charging, thermal management, the outer case and ultimately the costs associated with recycling.

The cells are built with thin copper and aluminium foils as current collectors which have an intrinsic cost but a high manufacturing cost. The active materials are graphite/carbon formulations for the anode and Lithium iron phosphate (LFP) for the cathode. There are high purity requirements for both and the LFP is highly processed to provide the required electrochemical activity. The organic electrolytes also have high purity requirements especially in respect of contamination with water. The separators are very thin microporous plastic membranes. The outer packaging is an aluminium foil/polymer laminate. All these materials are highly specified and have complex manufacturing processes. Battery assembly is highly automated and has to be carried out in clean and dry conditions. Cell costs are expected to decline further over time through volume effects, but it is unlikely that costs will fall substantially over time because many of the materials are intrinsically expensive.

The internal components are clamps and fastenings to hold the cell pack together and internal connectors, mostly copper, which are large and expensive.

The internal circuitry will comprise of a control board for all functions, voltage sense wiring, temperature measurement and current transducers with power semiconductors for charge and safety management. Volume manufacture of electronic components will drive costs downwards, but e.g. power semiconductor devices are costly.

The outer battery case may be moulded in polypropylene to provide the same external features to fit the car as a Lead battery. For safety reasons in case of crash the housing may be equipped as appropriate with additional metal structures to avoid cells to be crushed.

Li-Ion batteries are much more complex than equivalent Lead batteries with a number of high cost components and raw materials. Higher complexity means a range of safety features need to be put in place. For example, currently available Li-Ion chemistry requires the use of flammable electrolytes which requires more stringent built in crash protection measures to protect the battery. This adds further costs to including this technology in a vehicle.

It should also be added that as there is no known LFP cell manufacturer currently operating in Europe the raw materials and cells need to be imported to EU which will also add additional transportation costs. Lead batteries have no resourcing availability issues and are manufactured within Europe with a high content of secondary raw materials originating from European waste-as explained in our response in question 5.6.

Costs of Li-Ion batteries are expected to fall with volume but will not approach the costs achieved by equivalent 12 V Lead batteries. Manufacturing efficiencies will lead to lower costs, but raw materials and processing costs mean that there is a floor below which costs will not fall.

5.5 (Q. 5) The recycling rate for LAB has been reported to be very high. Please provide any information regarding the current and expected recycling rate for alternative technologies including LIB, for mass percentage of the battery as well as individual elements (e.g. metals such as lead, cobalt, nickel, manganese, lithium, as well as electrolytes and other elements of the batteries). Please also refer to the economic feasibility of recycling now and in the future.

Automotive Lead batteries are the "gold standard" for a closed loop product operating in a circular economy. The efficiency of Lead battery recycling processes is very high with >95% of the available Lead being recycled. On average approximately 80% of a new automotive Lead battery is manufactured from raw materials recovered from recycled batteries collected in the EU. In contrast there is little economic incentive in collecting and recycling spent 12 V LFP batteries as they contain no economically valuable metals. Any materials recovered are currently subject to downcycling and are not used to manufacture new LFP cells [2]***.***

Recycling rate is a function of the percentage of batteries available for collection that are actually presented to the recycling facility and the recycling efficiency of the process that the facility uses to recover valuable raw materials.

For automotive Lead batteries IHS have undertaken two independent studies [2] [6] that have analysed the current situation with respect to used Lead battery recycling. The studies use similar methodology to calculate an amount of made-available Lead automotive batteries, based on the parc of vehicles and the estimated lifetime of batteries, that should be entering the waste stream and thus be collected each year. Both highlight the fact that Lead based automotive batteries are essentially handled in a closed loop with nearly all batteries that reach the end of life being collected and recycled in licensed recycling facilities.

Used automotive Lead-based batteries are typically returned to the point of sale – vehicle workshops, vehicle dealerships, accessory shops, and DIY stores – or returned to recycling businesses or metal dealerships from authorised end-of-life-vehicles treatment facilities (ATFs).

In all cases, the returned batteries are sent to collection points to be picked up by specialist companies that transport and deliver the waste batteries to secondary recycling plants operating under strict environmental regulations**.** The extremely high collection rate is driven by the economic value of the recycled Lead (as of October 2020 about €1500 /tonne) and other products recovered from the used battery. Our studies have calculated collection rates of between 97.3-99% and this is consistent with collection rates calculated in other regions of the world where mature, economically driven infrastructure exists [7]

The recycling efficiency of processes adopted by secondary Lead recycling plants is highly efficient as nearly all the components of the used lead battery can be recovered. In most processes adopted by companies operating in the EU;

- **The lead components** (battery plates, paste and terminals), representing approximately 60% of the weight are recycled and refined to be used to make new batteries.
- **The battery casing**, which is made of plastic (approximately 7% of the weight), is usually separated before the Lead is recycled, depending on the method used. It is then reprocessed and re-used for batteries or for other products in the automobile industry for example in bumpers, wheel arches, and other parts.
- **The spent electrolyte** of diluted sulphuric acid (approximately 30% of the weight) is treated in a variety of ways. In some processes the spent electrolyte is separated and filtered to make it suitable for regenerating fresh acid. Other processes convert the spent electrolyte into calcium sulphate (gypsum) or sodium sulphate (soda), which can be used to manufacture building products or detergents.

Recycling efficiencies are somewhat dependent upon the smelter type used to recover the Lead and whether the battery casing is recycled or used for fuel but typically range from 75-90% with most processes recovering >95% of the available Lead. As close to 100% of the Lead in a recycled battery can be used to make new batteries this is one of the best examples of a closed loop system operating in the EU where the materials are recovered and recycled for the same application.

12 V LFP Li-Ion battery recycling is somewhat in its infancy and does not have the mature collection and recycling infrastructure available in the EU for Lead based batteries. As 12 V Li-Ion automotive batteries are present in relatively few vehicles on the road there is no formal collection infrastructure currently available in the EU. Cost of collection, storage, and transportation of used Li-Ion 12 V batteries will be comparatively high given the inherent safety and dangerous goods rules pertaining to this chemistry.

Therefore Li-Ion SLI battery type producers should be equally responsible as Lead battery producers. This includes the mandate to collect spent batteries, their proper treatment and active contribution to EU circular economy targets.

Information available from members of the International Lead Association undertaking battery recycling has highlighted that 12 V Li-Ion batteries have been included in pallets of used Lead automotive batteries presented to secondary Lead smelters in efforts to avoid cost of disposal. This practice has regrettably resulted in a number of fires and even explosions at storage facilities and in the battery, breakers associated with the Lead battery recycling plant [8]. It is too early in the deployment of 12 V Li-Ion batteries in automotive applications to provide a definitive conclusion about the potential future collection and recycling rates but given current experience, we believe that they are unlikely to meet the high levels established for Lead given the lack of economic viability in recycling (see below) and high costs associated with collection, separation into chemistry type and storage of used Li-Ion chemistries.

As commented in relation to collection rates, the recycling infrastructure of Li-Ion batteries is too immature to be able to provide a definitive opinion on potential recycling efficiencies of the recovery processes that could be employed in future. However, as all known 12 V automotive Lithium batteries offered on the market are based upon LFP chemistries it is possible to make some general statements from current experience to date in recycling this chemistry. LFP batteries contain no known significant economically valuable metals beside some copper and thus have very low intrinsic incentive for recycling. Producer responsibility of components and cells is very important if this is to be addressed.

For other possible low voltage Lithium ion battery chemistries, such as NMC or LTO, economic incentives for material recycling varies, but cobalt and nickel content (not present in LFP) are typically the primary driving factors. Current recycling processes for Li-Ion batteries are predominantly pyrometallurgical, although some novel hydrometallurgical processes are being developed at the pilot plant level. They have to date not been transferred to production scale as the economy of the recycling processes is not compensated by the revenues of the recovered products.

It is not currently economic viable to recover the materials from the cathode (Lithium, Iron and Phosphorus compounds) of the LFP battery system and the use of a pyrometallurgical process means that, together with organic electrolytes and aluminium, these are incinerated, and the resulting slag is processed for other applications, such as fillers in building material. Unlike Lead batteries, materials recovered from used LFP cells are not currently used to manufacture new batteries. As such there is no comparable closed loop or circular process and recovery of secondary materials should be in major parts as considered as a case of “downcycling”.

Typically, only copper is recovered in the form of a high value product and it can therefore be estimated that a theoretical recycling efficiency for a 12 V LFP battery is in the order of 30-35%. It is therefore likely that to meet the existing 50% recycling efficiency target specified in the EU Battery Directive, LFP cells would need to be mixed with other battery chemistries with before processing. However, there are experiences from tests from other markets that each low voltage Li-Ion chemistry needs to be treated separately as different chemistries would interfere negatively.

5.6 (Q. 6) More generally, please explain whether the use of lead in the application(s) addressed under the above exemption is still unavoidable so that Art. 4 (2) (b) (ii) of the ELV Directive would justify the continuation of the exemption. Please be specific with your answer, for example clarify, if applicable, what types of vehicles your answer refers to, i.e., conventional vehicles and various types of hybrid and electric vehicles, and which functionalities and applications the exemption still needs to cover.

The use of Lead batteries under Art. 4 (2) (b) (ii) of the ELV Directive is still unavoidable. Despite extensive research by the European Automotive industry, there currently exists no mass market, or standardised alternative to Lead batteries in automotive applications.

In order for a battery to be selected by an OEM for automotive use, it has to meet the following requirements

- ***Cold cranking at -30°C***
- ***Robust performance in start-stop and micro-hybrid functions***
- ***High temperature performance at 75°C (or OEM specific temperatures see Q1)***
- ***Specific safety standards on battery and vehicle level***
- ***Calendar life of 5-7 years***
- ***Compliance with applicable international standards and specific OEM requirements for performance, durability and safety***

In addition, the technology should be

- ***Low cost***
- ***Standardised***
- ***Compatible with the 12 V board net***
- ***Fully recyclable at end of life***
- ***Easy to handle in service procedures***

As reported in our answers above, significant progress has been made technically by LFP batteries for automotive applications. Parity in cold cranking capability is reported by Li-Ion battery manufactures-a key requirements for automotive use. However, Lithium batteries still do not meet all the OEM requirements listed above, and need to make further progress with regard to:

- ***High temperature durability***
- ***Wide range of temperature spread***
- ***Safety***
- ***FIT-Rates: Availability for safe energy supply***
- ***Cost (first cost and lifetime cost)***
- ***Interchangeability***
- ***Recycling***
- ***Availability of parts for the replacement market***

The following section addresses the challenges of Lithium-ion batteries for the applications mentioned

High temperature durability

The temperature of a battery within the vehicle architecture is a key parameter for the safety and the lifetime of the battery. There are still a lot of research and development activities to conduct on this topic. This could have major impact on vehicle and platform architecture.

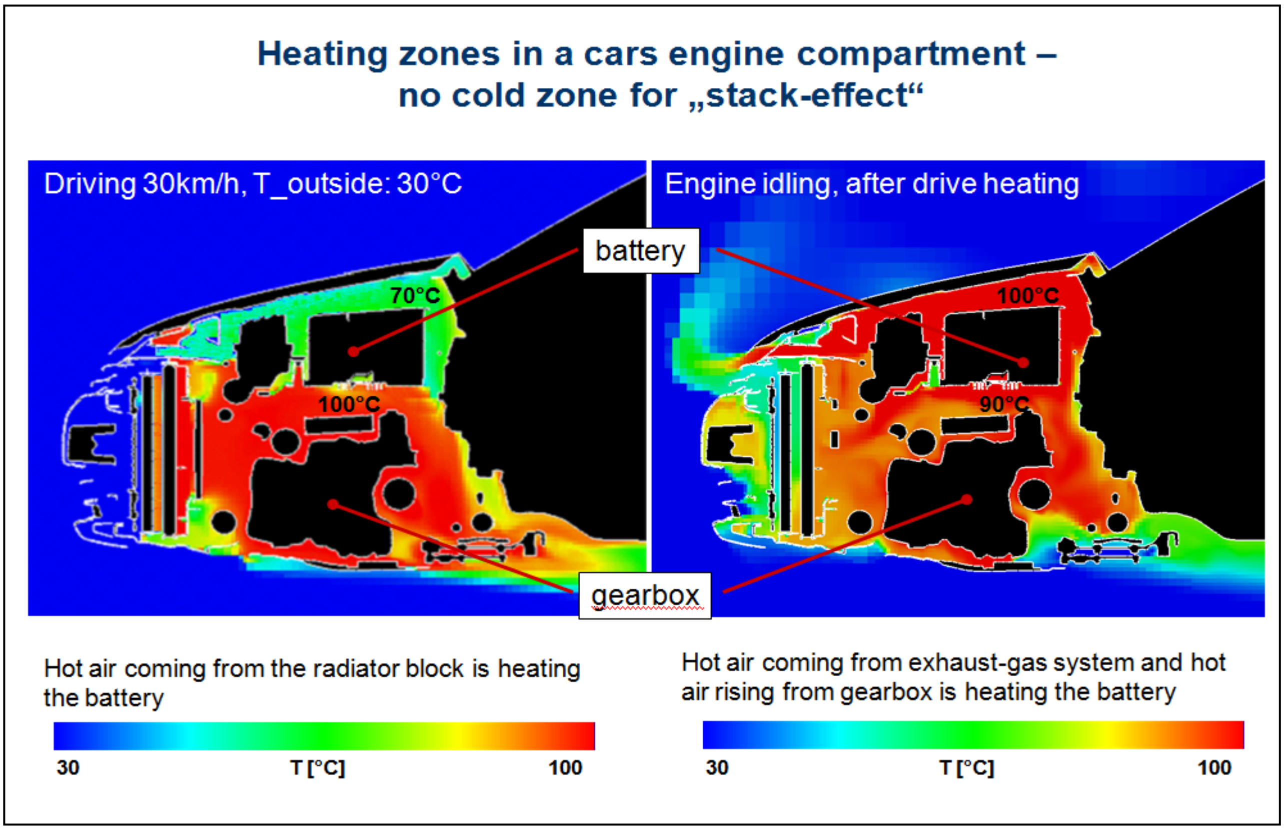

Figure 1. Heating Zones in vehicle engine under different driving conditions

High temperature durability is important. As explained in question 5.3, Lead-based batteries can withstand up to 75°C internal temperatures, which covers all scenarios; for example, under-hood ambient temperatures can reach 75°C. In comparison, the upper process windows for operating temperature range for a Li-Ion battery is 55-65°C, although this will depend upon battery chemistry.

This difference can be readily explained. Lead batteries have a very high thermal mass with a high volume of aqueous electrolyte and weight of active materials and therefore take a lot of time to heat up. However, Li-Ion batteries have a much lower thermal mass than a Lead-based battery. This means that that passive heating can quickly become a problem and the battery will heat up quickly. At elevated temperatures the off-gassing processes in a Li-Ion battery will exponentially increase with increasing temperature, which leads to increasing damage to the cell, an increase in internal resistance, a decline in capacity and therefore the lifetime of the battery will decrease. The electrolyte may be formulated to have better high temperature stability, but this inevitably leads to a reduction in low temperature performance.

In addition, heat from the vehicle in operation can transfer quickly to a Li-Ion battery. Furthermore, if a Li-Ion battery is used for energy recuperation, this will result in an increase in internal heating due to the higher energy throughput at high power ratings.

Thermal management

The lifetime of Li-Ion batteries depends to a high degree on efficient thermal management. If the thermal load on these batteries is too high rapid ageing will occur and the battery will fail prematurely.

Internally generated heat from the component during charging and discharging over the battery lifetime is important as are the local ambient temperature levels. If temperatures are too high, additional specific cooling systems will become necessary and this has to be considered in the component, location, package, and vehicle design.

Because of the lower thermal conductivity and lower heat capacity of the materials used in 12 V Li-Ion batteries, it can take longer to time to cool down the battery.

This means that additional cooling devices have to be more efficient and operate for a significant period after parking. This will also be a challenge in energy management of the vehicle.

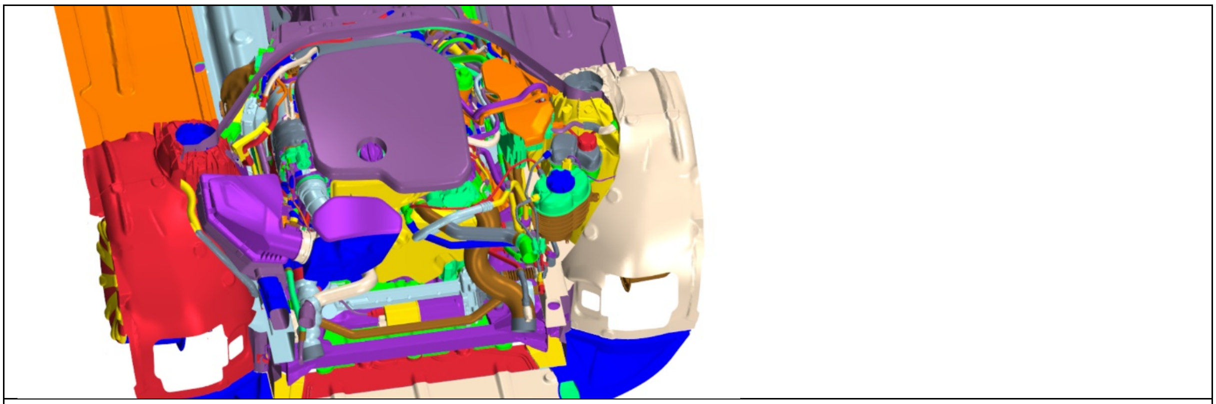

Figure 2 Thermal environment in the engine compartment (engine off, before start)

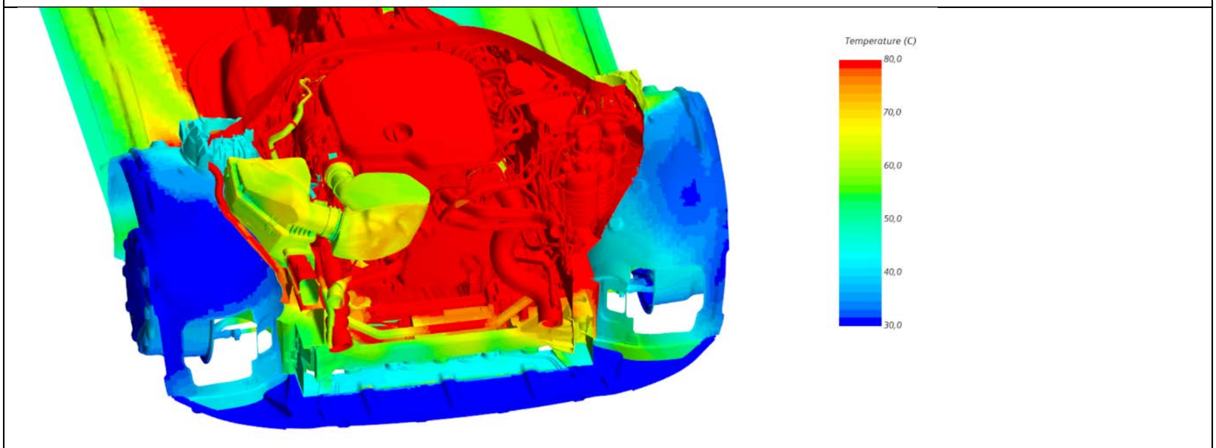

Figure 3 Thermal environmental under harsh conditions in summer (Temperature fields>80° C colored red)

Figure 2 shows the temperature distribution in the engine compartment when the engine is started and Figure 3 shows the temperature distribution after/ under harsh driving conditions (summer, mountainous territory, with a trailer or caravan load). In most areas however temperatures exceed 60°C and are generally at 80°C.

The heat from the source and the hot air from the heat exchanged by the radiator fan may cause the battery to be exposed to heat and cause the temperature to rise. In addition, Li-Ion batteries have a higher charging current than Lead batteries and the resultant self-heating leads to a further increase in temperature. Unlike SLI which is installed as close as possible to the engine, auxiliary batteries can be installed in other locations.

If an additional cooling system is necessary, energy loss of the system at cold and hot temperatures needs to be considered. This also contributes to increased fuel consumption.

A further issue is that the sound absorption in the engine compartment has increased (sound insulating foam and aerodynamic shields under vehicles) due to stricter requirement for noise emissions (limiting values of 72dB in 2016, 70dB in 2020 and 68dB in 2024). The sound absorption systems contribute to heat conduction and convection and make the cooling of Li-Ion batteries more difficult. The aerodynamic shield under the vehicle also contributes to reduced CO_2 emissions.

A North American OEM operating internationally has provided the following comment: Lead batteries will operate over the temperature range from -40°C to 75-80°C measured internally and will survive excursions to 100°C but Li-Ion batteries will switch to open circuit when the temperature, applied voltage or current conditions exceed safe limits. This disconnects the battery from the vehicle and no power is available from the battery for normal or emergency functions.

It should be noted that the requirement for cold cranking at -30°C is not changed but Lead batteries are not damaged at -40°C and will continue to operate. Unless and until Li-Ion batteries can provide robust performance over a full temperature range, they cannot be specified to replace Lead batteries without significant restrictions.

In addition to the thermal environment for the battery crash and safety aspects need to be considered.

Safety at battery and vehicle level

Safety is key requirement for OEMs, and any component must meet all the relevant safety standards~~.~~

Lead batteries do not pose a major risk of catching fire and have been shown to be inherently safe, with thermal events extremely rare. In general, they are outside the scope of component approval as required by ECE–R 100. It should be stated that the following section refers only to 12 V Li-Ion SLI batteries and does not refer to Li-Ion traction batteries. Li-Ion batteries fully adapted for SLI applications will necessarily have a higher power density than those used for traction applications and as a result product safety needs to be carefully evaluated. For example, Li-Ion SLI batteries will have to be tested against stringent standards to ensure the safety of passengers is not compromised in case of an accident. This is explained further in the following section.

The battery needs to be robust / resistant to mechanical damage in the form of compression, shock and puncture.

To comply with product safety requirements with regard to crash behaviour, methods to avoid fire and explosions have to be considered. This is an issue for Lead batteries but can be very demanding for low voltage Li-Ion batteries. For batteries defined as rechargeable energy storage systems (RESS), there should be no leakage to the battery during the crash test and no thermal runaway.

For example, vehicle crash tests, with battery case deformation of around 40% have shown that a deformed Lead battery is still able to still provide energy for supplying emergency functions. In the best case it is estimated that a current LFP battery under the same conditions will start venting and shutdown.

The car industry would therefore have to locate Li-Ion starter batteries in a crash protected area or embedded in a crash safe structure. This is demonstrated in Figure 4 which highlights the risks of deformation of different areas for vehicle electronics considering crash behaviour.

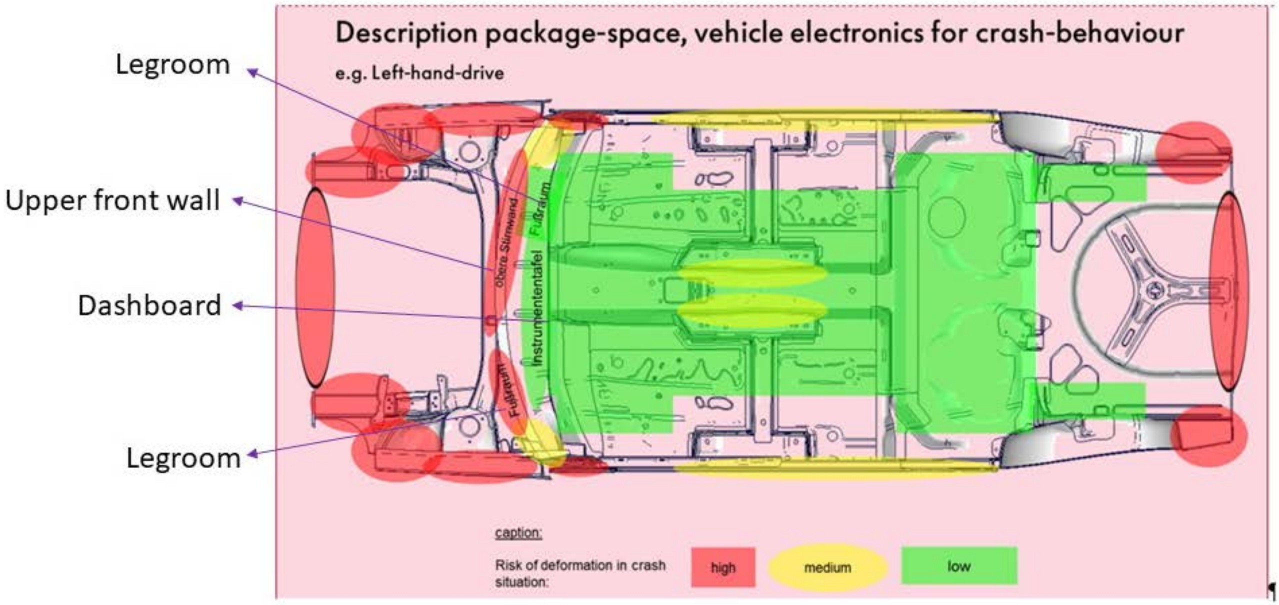

Figure 4 Package space for vehicle electronics considering crash behaviour, demonstrating risk of deformation for different areas of a vehicle.

This is a packaging issue and generally a full redesign of the vehicle platform is required. This highlights the importance of having the Li-Ion battery in the green section to prevent impact/deformation to the Li-Ion battery in the event of a collision.

Even if a full redesign was possible, not every position of the battery makes sense. Putting the battery in the centre of the vehicle will result in a long main power wiring harness, which results in loss of voltage and efficiency.

Figure 5 demonstrates the impact of a crash on a component in a crumple zone. Reinforcing the car body area to establish a crash safe cage for a component needs to be implemented in the total crash behaviour design of a vehicle. Locating the Li-Ion battery as the same place as the Lead battery (under the bonnet) would result in even more complicated technical issues (thermal and crash). This is a key concern of all OEMs, and no vehicle can be offered for sale until crash safety has been correctly established.

Figure 5 Potential impact of a crash on a component in the crumple zone of a vehicle.

It should also be added that in high voltage vehicles, safely protecting the high voltage battery is essential. This means it will have significant crash protection-adding further crash protection for a 12 V Lithium battery would be very difficult and costly to add. It would also add weight to the vehicle.

In addition to the overall requirements given in EN 50342 there are special requirements for the implementation in cars; the installation-space issue. The use of starter batteries in cars is very installation-space sensitive, because there are two very important restrictions. The first, in case of a crash, is that the battery should not catch fire and the second is that during normal operation the battery should not be destroyed or ruptured by heating. In the majority of European cars starter batteries are installed in hot installation spaces, i.e. in the engine compartment or in the vicinity of the exhaust pipes. Hot installation spaces typically have a starter battery in the engine compartment and the ambient peak temperatures, as explained, are too hot for a safe installation of any available batteries working with an organic electrolyte (e.g. Li-Ion batteries or high capacity electrolytic capacitors).

In addition, batteries containing a flammable electrolyte (such as Li-ion batteries) are recommended not be located in the crumple zones of the car due to possible risks of thermal incidents in certain crash situations as discussed above. For example, positions behind the headlamps or major part of the trunk are crumple zones. Positions such as the passenger cabin are not crumple zones. It is a key requirement that the starter battery has to withstand crash loads without the risk of fire and also that the starter battery has to withstand a thermal environment with temperatures up to 100°C.

A final serious challenge is the off-gassing from Lithium-ion battery in case of venting. This could mean that it is not possible to integrate the battery in the passenger compartment. Countermeasure for collision and appropriate gas discharge is mandatory, therefore the allocation is limited to set a mechanism for discharging it towards the outside of the vehicle with tubes.

Safety testing

Safety testing has a wider scope than component safety under conditions of external impact or operational abuse. Functional safety has to be secured as well, meaning safe and reliable functionality of the vehicle and its components. In the case of a battery this is especially relevant for components which require electrical energy for operation and are essential for a safe vehicle operation.

Essential components such as electronic stability programmes (ESP), power steering, power braking, active suspension systems and emergency illumination and hazard warning lights all have to be supported. All of the systems are operating at a 12 V level and their power supply is the 12 V battery whenever the alternator (or another primary power source such as a DC/DC convertor) is not operating (engine off) or does not provide sufficient energy (overload of the vehicle system), or has failed (alternator defect, broken belt or similar fault).

For safety reasons, some Li-Ion batteries have a switch for disconnecting the battery from the vehicle in case of operating conditions which the battery is not able to withstand. If the vehicle is equipped with such a switch it is integrated into the BMS and internal to the battery. This is invariably the case for high-voltage Li-Ion batteries where an auxiliary battery provides a secure power source in the event of an emergency but for vehicles with an ICE equipped with a 12 V Li-Ion battery, unless the vehicle is equipped with an auxiliary battery the Li-Ion main battery cannot be disconnected as it is required for functional safety. This is an area where further research and development is essential to ensure safe operation under all conditions.

Such conditions include detected battery defects, but also charging at high temperature (when charging would result in degradation to the electrode and electrolyte materials, and gas evolution) and high recharge voltages especially at low temperatures, deep discharge and other conditions. They may also disconnect the battery in a crash but that only de-energises the vehicle and not the battery itself. If, however, for safety reasons it is possible that a battery autonomously disconnects itself from the electrical system, it cannot provide energy to the vehicle. In case of an emergency situation, an under voltage may result or zero voltage, and the electronic systems (e.g. the control unit for the ESP, power steering or braking) may fail and even if the voltage dip or disruption is only transient it may result in a reboot of the control electronics which could be dangerous in vehicle operation as there would be a short time when one or more of these systems was inoperative.

- Furthermore, the switches inside a Li-Ion battery and the electronic controls activating and controlling the switches are additional potential for failure sources and need careful development, testing and implementation in the system environment of the board net design.
- Lead-based batteries do not need and do not have such switches or relays nor sophisticated electronic management systems. They are much more robust at high and low temperatures, even under abuse conditions, and always remain safely connected to the electrical system and do not present the same hazard challenges to be tackled as Li-Ion batteries.
- All potential use cases and incidences have to be thoroughly considered during development of new energy storage systems providing power and functional safety.
- The steps needed to validate the safety of a new battery technology are summarised below:

    i. Crash testing is required to verify robustness against physical damage and also against the risk of fire, explosion, or leakage.
    ii. Assessment of the robustness of the power net controller is required to ensure that the battery will not be overcharged.
    iii. Assessment of the battery against abuse charge and discharge to verify robustness against explosion and fire or chemical leakage.

iv. Assessment of the battery during vehicle power system operation such that Lithium plating, short circuits and other faults do not occur due to standard vehicle operation.

v. Assessment of the robustness against the fitment of a different and non-OEM approved battery such that the vehicle safety case will not be compromised.

vi. Assessment of robustness of battery management system to ensure that the battery is protected as necessary to meet the whole vehicle safety case, (power connected/disconnected only when necessary and reliability proven to avoid incorrect and unsafe operation. Accuracy and robustness of battery state detection algorithms and signals).

vii. Assessment of safety impact in workplace of manufacturing, logistics and service environments.

Storage is also a safety concern

Li-Ion batteries require the implementation of a temperature-controlled storage facility and from a legal perspective are subject to special transportation requirements.

The correct storage conditions are crucial for the safe handling of all batteries, but Li-Ion batteries require additional safety requirements compared with Lead equivalents. Li-Ion batteries require a temperature-controlled storage facility and the addition of a fire suppression system within the storage facility. A gas monitoring system is also recommended when storing large quantities of Lithium batteries due to the likelihood of gas venting that can be toxic to humans. The temperature within the facility should be controlled to between 5°C and 15°C.

Li-Ion batteries are classified as Class 9 Dangerous Goods and as such, must adhere to stringent shipping requirements. Special transport requirements need to be adhered to when transporting the goods on roads, including completion of a dangerous goods note, and carrying a suitable fire extinguisher in the mode of transport that is being used.

When transported, as a general rule, Li-Ion batteries should be individually packed in approved packaging's which have to be labelled and marked as defined by the ADR (The European Agreement concerning the International Carriage of Dangerous Goods by Road), IATA (International Air Transport Association), and IMDG International Maritime Dangerous Goods Code) regulations. As waste or damaged batteries, they have to be placed in an inner packaging surrounded by non-combustible and electrically non-conductive insulation material. In addition, for granting transport authorization, Li-Ion batteries must be tested to the UN Manual of tests and criteria, section 38.3 and to exceed safety tests and manufactured under an appropriate quality assurance standard. Required tests include testing the battery at altitude (can be simulated in a low-pressure chamber), in thermal scenarios, vibration and shock testing, and passing an impact test. Li-Ion cells and batteries are forbidden for transport as cargo on passenger aircrafts but can only be transported in cargo aircraft. It must also be noted that, recalled, damaged or non-conforming Lithium cells or batteries cannot be transported by air freight due to the safety concerns surrounding ignition of the Li-Ion battery whilst in the aircraft (Ricardo 2020).

A further complication surrounds damaged batteries. After damage, it is not possible to ensure Li-Ion batteries comply with the UN standards. Therefore, damaged batteries cannot be transported without further special measures. Simplifications and new solutions are needed to improve this issue and make it less complicated.

Lead batteries are classified as class 8 dangerous goods and are subject to ADR as well. However, due to the intrinsic safety of Lead batteries a special provision is defined that removes the carrier from ADR obligations for the transport of new and spent Lead batteries

In summary, the additional safety requirements for storage and transportation of 12 V Li-Ion batteries (both new and at end-of-life) will increase substantially the cost associated with this technology compared to Lead batteries.

Cost

The Ricardo 2020 [1]report states that (beside the technical challenges) cost is a major drawback of Li-Ion 12 V batteries-stating that Lithium batteries are approximately four times more expensive than Lead-based equivalent batteries.

Information relating to cost is explained in our answer to question 5.4.

Interchangeability and parts availability

12 V lead batteries for automotive service are widely available as replacement parts across the EU from a wide variety of sources. These include the service networks of car suppliers, independent garages, specialist battery suppliers, retail outlets for spares and motor factors. Lead batteries are interchangeable between suppliers given that the container size, terminal arrangements and electrical performance meet the vehicle requirements. The same considerations need to apply for 12 V Li-ion batteries in order to provide user convenience and competitive supply. Many other parts such as tyres and brake pads are supplied from a wide range of outlets and competition law prevents the major car manufacturers from controlling the market for service and spares. It would be a retrogressive step to mandate the use of 12 V Li-ion batteries until widespread availability was established.

Closed loop recycling.

As explained in detail in question 5.5, and in the IHS study (2020), Lead batteries are collected and recycled in a virtual closed loop. The Lead battery is the state-of the-art example of a product designed for complete end of life recycling, with every component available for recycling at end of life, and currently on average approximately 80% of a new Lead battery comprising recycled material. This is not the case for any alternative battery technology and explains why manufacturing Lead batteries has a lower environmental footprint when assessed using life cycle analysis (LCA) [3].

Economic benefit in Europe

Lead 12 V batteries benefit from a mature supply chain and manufacturing base and a track record of consistent performance. In Europe alone, the battery industry produces in excess of 60 million Lead batteries for both OEM and aftermarket applications. In contrast, the supply chain for Lithium-based 12 V batteries is relatively immature, and the volume capability does not currently exist. One leading producer estimates it could in the future, produce and assemble around 600,000 Lithium 12 V battery units per year, but this is only equivalent to 1% of the total European market for 12 V batteries.

5.7 (Q. 7) Please explain the efforts your organisation has undertaken to find and implement the use of lead-free alternatives for automotive uses. Please refer to alternatives, which at least reduce the amount of lead applied or eliminate its necessity altogether.

A lot of work has been undertaken by the automotive industry into developing new vehicles and new battery technologies since the last stakeholder consultation [9]. The cold cranking performance of 12 V Lithium batteries was and remains a concern of OEMs, and therefore a lot of work was undertaken looking to develop dual battery systems that utilised both Lead and Lithium battery technologies [10]. This also involved investigation of Battery Management Systems (BMS) to try and control the behaviour of new chemistries but these were prototypes rather than series products. Combining a Lithium and a Lead battery in one housing was initially seen as possibility to use the benefits of these two different chemistries and in addition to reduce the amount of Lead per car needed for low voltage batteries and also to realize some weight reduction potential. However, these concepts have not gained major market traction. This is due to the fact that the need to implement battery technologies that can store energy generated from braking (regenerative braking) to comply with CO_2 reduction targets would also require more battery capacity which couldn't be delivered by the dual battery approach [11].

Work has also been conducted splitting the battery functions of SLI and recuperation into a 12 V and a 48 V system with batteries for each voltage level for a mild hybrid system. In the next 5 years more 48 V vehicles are expected to come to market, with a 12 V and a 48 V board-net. These systems will utilise a 12 V Lead battery and a 48 V battery that could either be Lithium or Lead based. This is explained further in our response to question 5.3.

A major trend in vehicle development is autonomous driving ability and a new legislative driver is the new general safety regulation (REGULATION (EU) 2019/2144 from 16.12.2019). Therein new demands are defined like advanced emergency braking systems, intelligent speed assistance, emergency lane-keeping systems, driver drowsiness and attention warning, advanced driver distraction warning and reversing detection. Implementation of these safety systems and autonomous driving modes will require a sophisticated battery concept to ensure proper function of sensors, camera systems and other devices. As Lead batteries are well understood and known components with tolerant function characteristics, they are essential elements in high reliable power availability concepts. A combination of batteries with different chemistries is in discussion, to enable sufficient power availability if one battery would a failure, so that another battery with different chemistry can provide sufficient power for emergency modes.

Development of hybrid powered cars and battery electric vehicles absorbs R&D capacities and battery development is focussed on traction batteries. In the longer-term low voltage batteries will benefit from these R&D activities.

As Lead batteries are globally standardized products, potential substitutes should also be standardized products. In consequence standardized new BMS systems for substitutes, which need more control than LABS, could be beneficial. The electronics industry is responding to this challenge and a first developments are becoming available. However, volume scale standardized BMS systems suitable for low voltage Li-Ion batteries are not yet commercially available. There are prototypes announced on the market by one supplier of electronics. These new BMS systems claim to be able to fulfil demands of ASIL D safety level especially for zero cobalt battery chemistries.

These new developments require further evaluation and testing in components and vehicles. The new approach tries to make several mechanical components including connectors, cables and wiring harnesses obsolete, which may be sensitive to potential mechanical failure in high-vibration automotive environments.

With regard to specific battery technologies, significant research work has been undertaken into Li-Ion batteries. As explained in question 5.1, Li-Ion battery manufacturers report that parity has now been achieved in terms of cold cranking ability. However, the improvement in CCA has been achieved using new materials, and thinner electrodes which has resulted in further safety and high temperature issues. This means that current 12 V LFP batteries have yet to achieve parity on all the requirements for 12 V automotive batteries. Further research is needed in order to address this issue

In addition, significant advancements have also been made with regard to Lead batteries

Enhanced Flooded Batteries (EFB) and Absorbent Glass Mat (AGM) batteries provide significant improvements in charge acceptance and cyclic durability and have been deployed for micro-hybrid applications

Rapid adoption of stop-start technology has necessitated battery improvements. As indicated, AGM and EFB batteries have been developed for micro-hybrid applications. These batteries have improved deep cycle resistance and charge recovery in comparison to flooded SLI batteries. EFB and AGM batteries are necessary, not only to cope with frequent stops and starts of the engine, but also to provide enough power supply to the electrical system while the engine is in stop mode. In addition, micro-hybrids require improved DCA in order to facilitate regenerative braking.

EFBs are based on a conventional flooded Lead-based battery design but their specification and performance has been substantially improved. EFB batteries are well suited to entry-level vehicles as this application has a lower requirement in terms of the range of State-of-Charge (SoC) and cyclic endurance in comparison to premium vehicles. In comparison to conventional batteries, EFBs have:

- A 15-20% improvement in CCA
- 50% improved cyclic durability endurance at deep discharge levels and greater improvements for shallow cycling
- Improved cyclic operation in a partial state of charge.

AGM batteries are valve-regulated Lead-based batteries characterised by closed cells and an immobilised electrolyte held in a glass microfibre separator. AGM batteries were designed specifically for vehicles with significant electrical equipment levels including micro-hybrids but are more expensive than EFB Lead-based batteries. AGM batteries have a lower self-discharge rate and higher cyclic endurance in comparison to conventional Lead-based batteries. The DCA of an AGM battery is three times greater than a conventional flooded Lead-based battery [1].

Lead batteries also have significant potential to improve their performance further. Significant research is underway through the Consortium for Battery innovation, looking at ways of improving performance parameters such as DCA, which would maximise their performance in vehicles with higher degrees of electrification. This work has involved research into bipolar constructions. In a bipolar battery, apart from the end-plates, the plates have one side operating as the positive and the other as the negative separated by a membrane that is impervious, electronically conductive and corrosion resistant. This technology provides significant opportunity to increase performance such as DCA, whilst also using less Lead metal and reducing the overall weight of the battery. Other constructions replace the negative electrode current collector with a specially treated carbon felt which reduces the Lead content of the battery and substantially improves DCA.

Lead batteries are essential for auxiliary batteries for HEVs, PHEVs and EVs and as requirements for this application evolve more efficient designs are being developed to reduce the Lead content without sacrificing technical performance. In addition to that new grid alloys and production technologies such as punched grids also accomplish some weight reduction

5.8 (Q.8) Please provide a roadmap specifying the necessary steps/achievements in research and development including a time scale for the substitution or elimination of lead in this exemption.

As explained in question 5.7, significant further research is still needed to address safety and high temperature performance of Li-Ion batteries. As with any research, it is not possible to put precise timings on how long it will take to overcome these issues.

As already indicated, there are a large number of R&D programmes, many publicly funded, ongoing for energy storage devices for vehicles and the projects are still in progress-see Annex 1. The outcomes of these projects are important for the market development and production of the most efficient energy storage systems for vehicle applications in Europe. We strongly recommend allowing these projects to proceed to completion to allow the preferred solutions an opportunity to find their way into European vehicle production after a full evaluation.

After research at component level is completed and elementary component tests have characterised their properties, the next step towards vehicle specific integration can be assessed and developed. It has to be clear that efficient use of new mobile energy storage devices needs specific electronic control units embedded in the software and energy management of a vehicle´s board net design. Pilot applications will deliver the necessary know how needed to start development for volume production including safety and reliability aspects.

At first, before focussing on vehicle level, component development needs to be considered-see Figure 6.

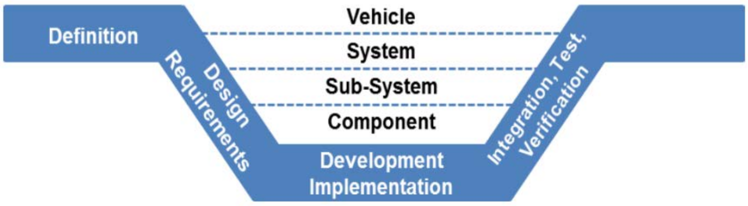

Figure 6 Design requirements, development implementation and integration and test verification needed for future vehicles

Figures 7 and 8 below give an overview of different development tasks at component and vehicle level. This is an iterative process at each stage.

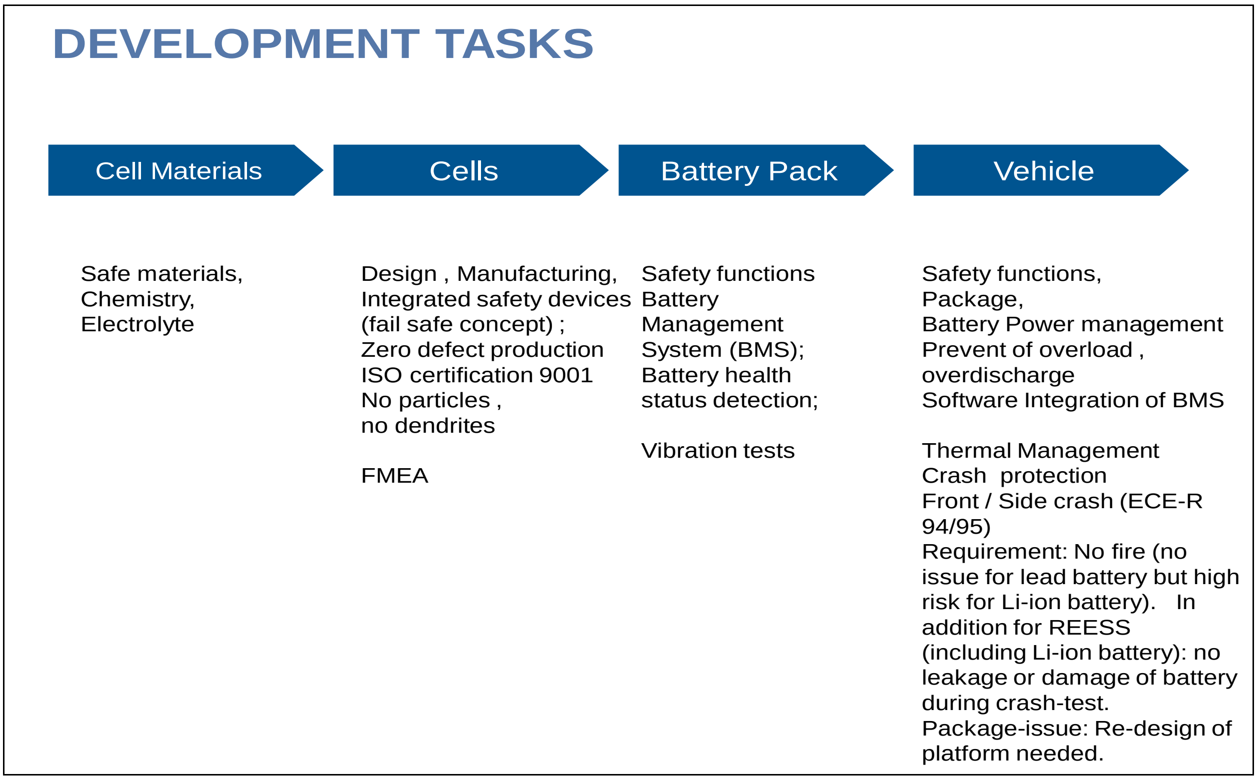

Figure 7 Vehicle development tasks.

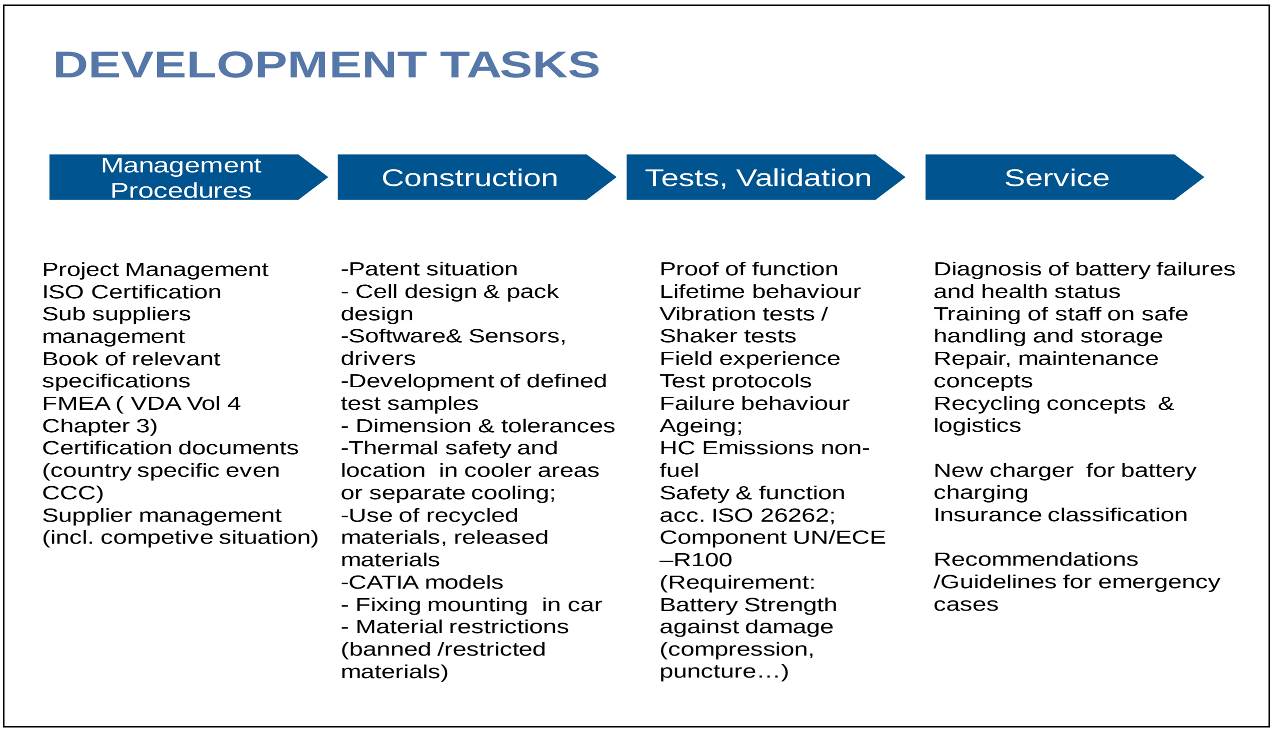

Figure 8 Vehicle development tasks.

As explained, there are still obstacles and challenges for 12 V Li-Ion batteries to overcome before they can be considered as a volume scale alternative technology in SLI applications. Even if these are overcome and an alternative technology is developed, due to the considerable vehicle development tasks listed above, it is not possible to predict how long this will take to overcome.

This process involves many stages, starting with tests at cell level, component tests under a range of different conditions followed by the development of prototype vehicles. If these are successful, summer and winter tests need to be carried out and then pilot applications will be undertaken to ensure correct and reliable operation.

Car manufacturers have to follow strictly defined development processes in order to get to robust and safe vehicle implementations. This is particularly true for Li-Ion SLI batteries, considering the impact of Li-Ion technology on vehicle safety with regard to both component safety (hazards caused by the battery as well as the impact of abuse or accident to the battery) and vehicle safety in general (e.g. functional safety of electrified chassis or driver assistance systems affected by power supply failure).

Those cars that are presently equipped with Li-Ion starter batteries have run through modified pilot processes which are not applicable for mass volume production. Hence applications are restricted for example to moderate climate markets because of the limitations of Li-Ion technology already described. The current field trials feature over dimensioned Li-Ion batteries with a very high cost impact and very high integration efforts, linked with functional limitations and are only feasible in order to obtain first long-term field experience.

Furthermore, volumes are kept very low, with the customer vehicles being closely monitored by OEMs. An additional reason for these very low volumes is the present limitations in service and recycling capabilities. These early adopter applications have to be considered as early field trials rather than as regular series applications.

Technology development and integration for automotive products typically occurs in 3 phases: advanced engineering, and vehicle development (product and platform level). A simplified project plan for the research, development and the required test-phases for a new battery system is presented in the figure below (Figure 9 below):

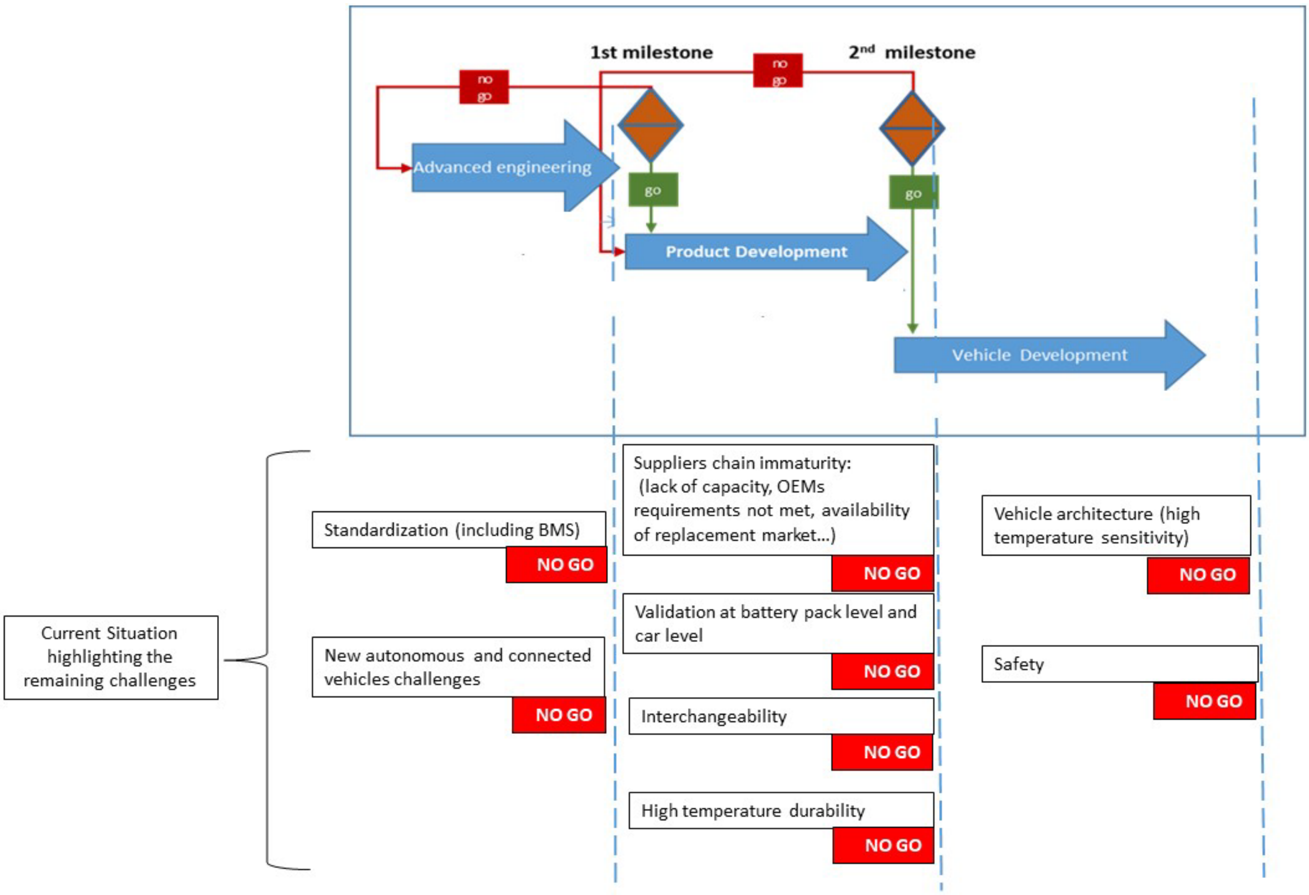

Figure 9 Project plan for a first volume application

As indicated in Figure 9 milestones have to be integrated to validate the possibilities for further development. In the event of technological problems and drawbacks further development loops have to be considered. Many of these tasks can be run simultaneously. However, Figure 9 highlights the situation since the last stakeholder consultation, showing many areas where issues have yet to be overcome and that significantly more work and research is required.

Many of these steps can run in parallel for SLI batteries but the total time required cannot be predicted since there are multiple technical obstacles that have to be overcome. For Li-Ion batteries for SLI applications the programme would commence when robust batteries become available meeting all the various technical and safety requirements. All these stages must be addressed before type approval.

Up to now, even the cell materials used in 12 V Li-Ion SLI batteries (e.g. electrolyte) have significant challenges to survive engine bay temperatures without massively deteriorating the winter performance. In consequence, the full timescale including cell chemistry research has to be considered.

Further assumptions are as follows:

- The cell technology available today would not allow an engine bay package which also has crash zone package issues. For these applications, suppliers have still to do fundamental material and cell research and development work for which 3 years duration is a very optimistic assumption.
- Based on that, the usual A/B/C/D cell pack sample development stages has to be carried out sequentially (further explained in Annex I). No OEM program (with significant volume) can be initiated without pack system A samples successfully tested.
- In parallel, OEMs would have to investigate and package/protect platform modifications that will include some passive or active cooling. However, it is impossible to move all starter battery locations into cool and crash protected locations for all global platforms.
- Given the high technological risk, fast adaptation for mainstream volumes would require standardisation of requirements, avoiding the need for multiple OEM specific parallel tests and reducing the engineering risk. Four years is an optimistic timing assumption for this process that will include life tests validation in several iterations. The recent development of EN 50342-6 for 12 V Lead micro hybrid-batteries took four years from kick-off to a decision about the draft for voting (the voting and administrative process steps are still pending and causing another 8-12 months delay before the standard is in force). Notwithstanding this, mass production was already launched several years before, and field data is available. Collaborative working relationships between OEMs and the battery supply base have been established for decades and there have been no newcomers to the automotive tier-one supply base. Still, no harmonization with other regions (e.g. North America, Japan and China) has been possible within this time frame. In addition, it has taken six years from May 2008 (kick-off meeting for ISO 12405-1) to May 2014 (ISO 12405-3 published) to create ISO 12405 ("Electric road vehicles – test specification for Li-Ion traction battery systems").

As the supply base is already active in research, and to some extent advanced engineering, for the 12 V SLI battery application, there are some applications for which Li-Ion could enter the advanced engineering stage earlier. These applications would, as absolute minimum requirements, have to:

- accept some degradation on winter performance (both cranking and recharging e.g. luxury cars that are unlikely to be parked outdoors under harsh winter conditions and have a fuel fired heater that can warm the battery),
- provide a package location that avoids temperatures above 60°C,
- provide a package location outside crash zones,
- not require any significant platform/architecture modifications.

If the available cells are compatible with package and technical requirements of a given vehicle, the research phase can be significantly shortened. This may apply only to a fraction of the vehicles that have the battery at least not packaged in the engine bay. Nevertheless, as outlined in the other parts of this document, roll-out to mainstream applications even if they fulfil the above conditions is far from straightforward. Moreover, in many battery locations outside the engine bay, the 55-60°C temperature limits would still be exceeded, e.g. in the vicinity of the exhaust system. It was not possible to quantify this fraction more precisely due to the competitively sensitive nature of the information involved.

5.9 (Q. 9) What is the amount of lead that would be contained in vehicles?

5.9.1. Placed on the EU market

According to *ACEA* publications [12] approximately 18 million vehicles (M1, N1) were newly registered in the EU28 (Table 4).

Table 3 Vehicle registrations in 2019

Registrations 2019	Passenger cars	Light commercial vehicles up to 3,5 t	Total
EU28 (without Malta)	15,340,188	2,115,650	
EFTA	465,564	73,674	
EU + EFTA	15,805,752	2,189,324	17.995.076
(Malta sales 2019)			8495
			18.003 571

Every new vehicle contains a Lead battery; therefore 18 million Lead batteries were placed on the market by OEMs in a newly registered vehicle. As a standard Lead SLI battery contains approximately 10.95kg of lead and lead compounds, it can be estimated that in 2019 new passenger cars placed on the market contained 198,000 metric tonnes of lead.

5.9.2. Worldwide

No figures are published so it is not possible to provide accurate data for worldwide scope.

However, in 2019 the EU represented approximately 20% of new vehicle (M1 and N1) registrations of global market. It can therefore be estimated that approximately 90 million new M1 and N1 were registered globally, containing approximately 985,000 metric tonnes of lead in their batteries.

5.10. (Q. 10) Overall, please let us know whether you agree with the necessity to continue the exemption and sum up your arguments for or against the continuation.

This is answered in our response to question 5.6, including a summary at the start of the response. We agree that it is necessary to continue the exemption.

5.11 (Q. 11) Is there any other information which you deem important in the context of the review and which you would like to provide?

Whilst we maintain that use of Lead in automotive batteries is still unavoidable, we also believe that even if this were not the case, the replacement of a 12V Lead battery with a 12V LFP alternative would be a case of regrettable substitution.

This is illustrated by the following points:

- **Alternative batteries contain and/or require use of hazardous substances**

The criteria for defining hazardous substances in the ELV Directive is limited to heavy metals. This does not adequately reflect wider definitions of ~~a~~ chemical hazards. All mass market batteries use or take benefit from the properties of chemicals which are classified as hazardous under CLP. Either they are contained in the product (and are not accessible to users given that batteries are sealed articles) or are needed during the manufacturing process where their use is governed by occupational health and environmental regulations. Regulatory driven substitution of 12 V lead based automotive batteries with LFP would be a case of regrettable substitution in that both require the functionality of hazardous substances.

- **12 V automotive batteries are removed from vehicles before shredding**

The stated aim of the ELV Directive is to encourage the marketing of new vehicles without hazardous substances, *so their parts can later be reused*. The fact that 12 V automotive batteries are replaced several times during the lifetime of a vehicle and at the end-of-life of the vehicle are removed before shredding means that there is no opportunity for this waste stream to contaminate end-of-life vehicles.

In fact, use of 12 V lead batteries delivers environmental credits for a vehicle due to the fact that 100% enter the recycling process, the high efficiency of the battery recycling process itself and the fact that >75% of the content of a new automotive 12 V lead battery is secondary material resulting from lead battery recycling. This would not be the case for a replacement LFP battery that has a higher environmental footprint to manufacture, has few components that can be economically recycled and currently could not be used to produce battery grade raw materials to manufacture new batteries.

- **Raw material security and transparency in supply chains**

A secure and sustainable supply of raw materials is a prerequisite for a resilient economy**.** The primary source of raw materials for 12 V lead automotive batteries is secondary lead generated from the used lead battery waste stream that results from replacement batteries and ELVs originating in Europe. The use of lead as secondary raw materials for batteries is not restricted to lead automotive batteries, it is also used in lead industrial batteries for various application.

In contrast currently nearly all cells for Lithium-based batteries are imported from Asia and the raw materials they rely on such as Lithium and natural graphite are also sourced from non-renewable primary resources and as yet there are no economically viable options for recycling and re-use.

Several OEM s have started to make their supply chains transparent and disclose origin of raw materials such as metals. This includes the Lead used to manufacture batteries and e.g. is described in the drive sustainability initiative [15]. In addition, the Lead battery value chain has also recently announced a material stewardship programme with a focus on promoting continuous improvement in EHS performance and globally shared best practices [16]

These facts highlight that new 12 V Lead batteries currently represent a more sustainable source of rechargeable energy than 12 V LFP batteries.

- **Prioritisation of battery raw material use**

In order to meet the EU's ambitious climate goals there will be a greater reliance on battery storage. Production of battery materials such as graphite, Lithium and cobalt will have to increase by nearly 500% by 2050 [17] to meet the growing demand for clean energy technologies. In this context we question whether it the best policy to divert critical battery raw materials to applications such as 12 V automotive batteries that will play a relatively small role in decarbonising mobility compared to high voltage traction batteries required for hybrid and full electric vehicles.

In terms or available of cell volumes/production capacities as well as raw materials 12V and HV-systems are currently in competition to each other.

- **Lifecycle environmental impacts of Lead and LFP battery manufacturing**

LCA is one of the tools that is increasingly being used to examine the environmental impact of a product through its entire life cycle. In a recent study by Sphera [3], commissioned to evaluate the cradle to grave environmental impacts of 12 V Lead and LFP batteries in automotive applications it was concluded that "the environmental impact (GWP) of LFP battery manufacturing is currently around a factor 6 times higher than the impact of manufacturing equivalent lead batteries." This conclusion is based upon a scenario of a 12kg LFP battery with a lifetime of 8 years that is considered by OEM's to best represent 60 Ah LFP 12 V SLI batteries currently on the market.

The main advantage of Lead batteries is that >75% of the raw material present in the battery is recycled Lead compared to the use of virgin raw materials in LFP manufacture.

This benefit is maintained during the full life cycle for conventional internal combustion vehicles. For both the start-stop and the micro-hybrid applications, the baseline scenario shows only small environmental lifecycle differences between battery chemistries due to the benefits of the use phase fuel savings achieved by using these technologies**.**

Table 4 Global Warming Potential [kg CO_2 eq.] for ICE, Start-stop and Micro-hybrid vehicles

	Conventional ICE		Start-Stop		Micro-hybrid	
Life Cycle Stage	PbB	LiB-LFP	PbB	LiB-LFP	PbB	LiB-LFP
Manufacturing stage	45	254	35	254	47,8	254
Use stage	44	0	-970	-1030	-1990	-2060
EoL	-6	-12	-4	-12	-2	-12
Total Life Cycle	**83**	**243**	**-938**	**-788**	**-1944**	**-1818**

- **Service and maintenance requirements**

As for all new systems and features education of servicing staff and availability of test facilities and service information need to be available and implemented before market introduction.

- **Europe's lead battery value chain contributes little to environmental lead emissions**

As for with most battery types, 12 V Lead automotive batteries are sealed articles that do not release any lead during their use, storage, or transportation. Lead emissions are therefore restricted to battery manufacturing and recycling facilities. Both phases of the value chain are governed by environmental regulations that require permitting of the industrial facilities, use of best available pollution prevention methods and establish strict emission limits. This legislative framework has been successful in reducing lead emissions (see Figure 10).

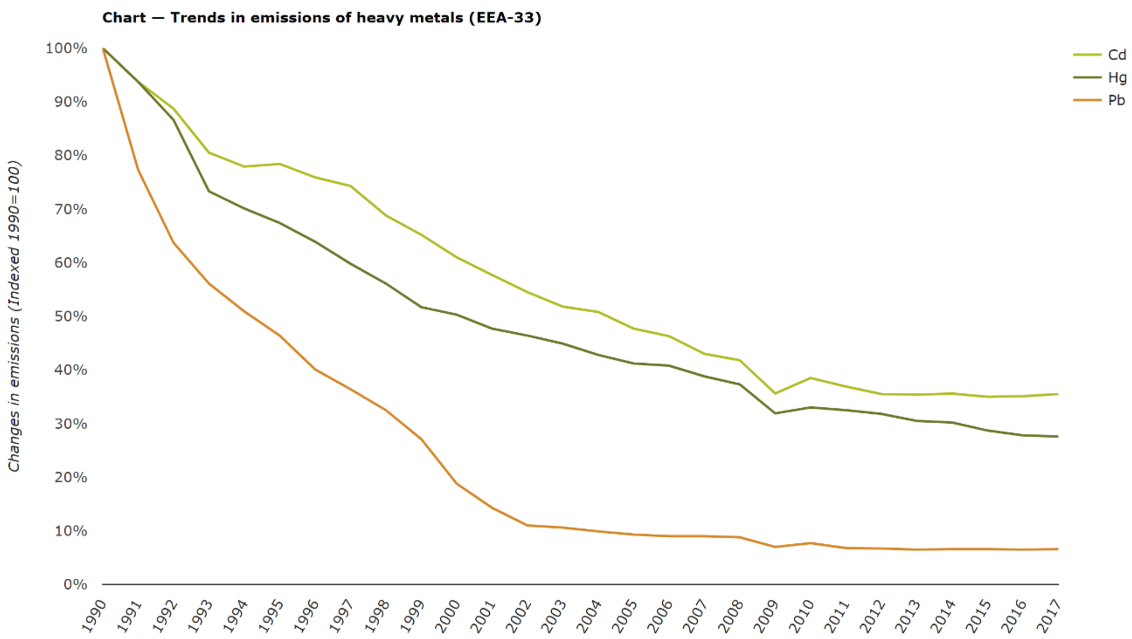

Figure 10 Trends in emissions of heavy metals (EEA-33)

Although automotive and industrial Lead batteries represent >85% of the total volume of lead used in Europe, a recent study highlights that in the EU Lead battery manufacturing and recycling contributes between 1-2% of the total air emissions of Lead measured across the EU compared to 30% from waste management, 25% from pig iron and steel production and 11% from the energy sector [18]. The report concluded that restricting use of Lead in batteries would not significantly reduce overall Lead emissions to the environment.

- **Financial viability of Authorised Treatment Facilities (ATFs)**

According to the recent ELV Evaluation, used 12 V Lead batteries provide valuable income for authorised treatment facilities (~€5-10 per vehicle) and currently are one of the profitable waste streams that make ATF's economically viable. LFP batteries present safety and transportation issues that will entail a net cost for ATFs and contain few economically viable components that can be a revenue stream. The net consequence is that replacement of Lead with LFP 12 V batteries will severely impact the financial variability of ATFs and could be a driver for the further loss of ATFs across the EU and replacement with more informal vehicle treatment facilities with associated risks.

- **Socio-economics**

Substitution of Lead with LFP 12 V LFP batteries, as concluded in the Sphera study, offers no significant environmental benefits [3], yet it increases costs throughout the value chain, from manufacturing to end-of-life management. Importantly a regulatory mandate to effect this change would significantly increase the cost of purchase and replacement of the vehicle battery for the consumer.

In 2020 the cost of purchase of a replacement 12 V lead battery is between €110-150 [19], whereas according to Ricardo (2020) an equivalent LFP alternative is expected to be 4x this (i.e. up to € 600). This would undoubtably increase the purchase price of new vehicles but importantly, as it is estimated that approximately 50 million replacement 12 V batteries were sold in 2019, it would represent significant additional costs for the consumer for after-sales replacements.

In addition, there is a lack of Li-Ion SLI battery suppliers at present. This is in conflict with the EU's legislative and regulatory framework guaranteeing a fair competition between suppliers. Currently there are no European Li-Ion battery suppliers that can provide and promote a cross-border and integrated European approach to battery manufacturing. These have to be developed [1].

- **Unintended impacts on economic viability other metal value chains**

The removal of the Lead battery Annex II exemption from the ELV would dramatically reduce the EU demand for Lead metal as automotive lead battery use represents approximately 55% of the current market. Lead is usually found in ore with zinc, silver and copper and is extracted together with these metals. Many zinc and copper mines (and associated primary smelters) therefore produce Lead as an important commercial by-product and rely it to be commercially viable.

Reduction in the demand for Lead from the EU automotive sector will dramatically increase the production costs for the other base metals associated with Lead ores, due to the loss of a saleable product (Lead concentrates) and requirement to treat it as hazardous waste. It will also potentially have unintended impacts on the availability of silver as approximately 70% of world silver production comes from Lead concentrates.

- **Creation of EU wide waste mountain**

Automotive Lead batteries are one of the few consumer products that can be considered to be operating in a closed loop circular economy in the EU. Removal of the Annex II exemption could in effect break the loop and eventually convert saleable products into waste that would have no market. According to a recent study by IHS Markit, 3,121,409 tonnes of waste automotive Lead batteries were collected in the EU between 2015-2017. Given the very high recycling efficiency of recovery process, most of the components of these used batteries would be converted back into new battery raw materials. This suggests that over a million tonnes of Lead batteries per year would be taken out of the EU circular economy and would either require disposal or would be recycled only for the resulting products to be exported to other regions where lead battery manufacturing still exists.

5.12 Additional remarks

At the end of this contribution we would like to state that product safety and reliability over the vehicle life cycle are the responsibility of the car producers. The producers are responsible for vehicle safety and long-term reliability in volume production of the cars they supply.

In order to fulfil this responsibility, sufficient experience and development time is required. As stated, several times there are currently many research and development projects in progress with open results. Important further developments are expected.

The automobile industry has provided proven evidence that it is active in seeking new and constantly improved solutions.

In our opinion any alternatives for current used and proven technologies such as Lead-based batteries should have a better environmental performance over their life cycle. Up to now there is no information available for such a development with proven and applicable alternative technologies.

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7. ANNEX

Here, EU funded R&D projects on batteries and E-Mobility as available in the EU CORDIS database, are listed. The intensity indicates that there are still many challenges to solve.

7.1 Survey on EU R&D projects for batteries, battery technologies, materials and production

Summary:

There is intensive R&D work in EU ongoing to optimize electrical energy storage systems. In scope are e.g. cell chemistry, anode materials, within EU available raw materials, membranes, solid state batteries, charging, infrastructure, simulation models to predict long time behaviour. As scale down low voltage batteries will in long term take profit from technologies and chemistries developed for traction batteries. The high amounts of funding show the political will to create the basis for better, more environmentally compatible, competitive battery products produced in EU.

An EU CORDIS database search for battery related projects was conducted in October 2020. It was found that the EU funding budget for 70 running projects directly related to battery technology research was: €240,086,922.

In addition, it was noted that 25 projects were directly linked to EU battery research with a funding budget €88,657,516.

Moreover, there are further projects at national level in EU member states and world-wide.

The figure below gives an example for a hit in the CORDIS database under the Horizon 2020 cluster.

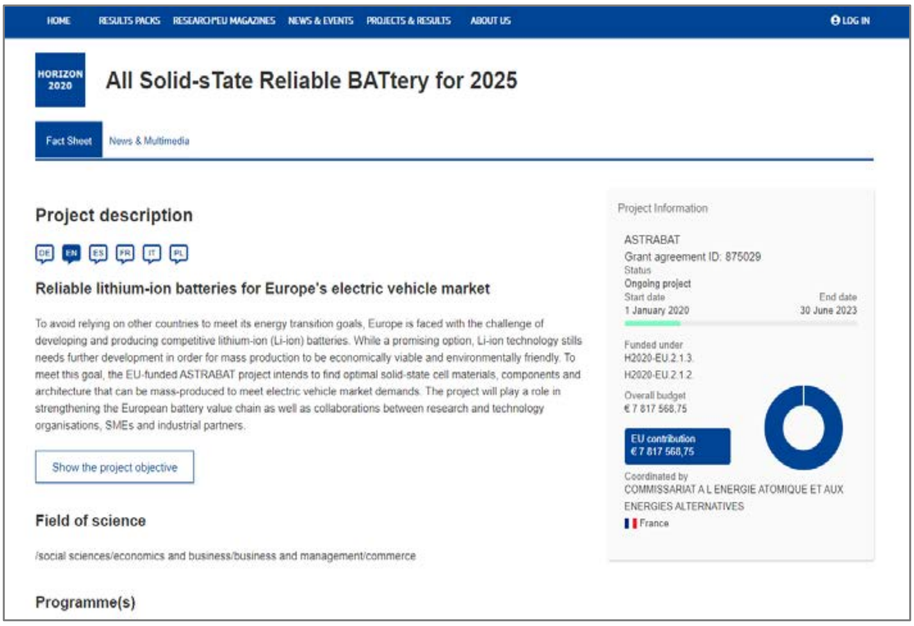

Figure 1: Example CORDIS Screenshot AstraBat

Source: https://cordis.europa.eu/search/de?q=contenttype%3D%27project%27%20AND%20(%27battery%27)%20AND%20(programme%2Fcode%3D%27H2020%27)&p=1&num=10&srt=Relevance:decreasing last accessed 7.11.2020.

7.2 Comprehensive list of EU Battery related EU funded projects

Acronym	Title	Teaser	Duration	EU contribution [€]	Country
VIDICAT	Versatile Ionomers for DIvalent CAlcium baTteries	Improving energy management is vital for the future. It implies greener production ways and smarter conversion and storage devices. For the latter, lithium batteries (LiB) have flooded the market of electronic devices and are now also powering electric vehicles and stationary...	01.03.2019-28.02.2023	3997783,75	Spain
BOIL-MODE-ON	unraveling nucleate BOILing: MODEling, mesoscale simulatiONs and experiments	Cooling efficiency is of the upmost importance in several crucial technological applications, e.g. fuel cells and battery cooling, hybrid airplanes, drones and satellite thermal management. They have a value of several billions dollars around the world, with a critical...	20.05.2019-19.05.2021	213933,76	United Kingdom
ULTIMATE	ULtra-ThIck Multi-mAterial baTtery Electrodes	Over the past decades, significant advances have been achieved in the performance of Li-ion batteries by the development of new active materials and better understanding of energy storage and degradation mechanisms. One aspect of batteries that has received little attention so...	01.04.2019-31.03.2021	225933,76	United Kingdom
LiAnMAT	Ultra-high energy storage Li-anode materials	Lithium (Li) ion batteries “ present in all consumer electronics and battery-powered vehicles “ are produced in a capital and know-how intensive way, in particular during the initial steps of materials synthesis and cell manufacturing. The anodes of Li-Ion batteries are...	01.07.2020-31.12.2021	150000,00	Germany
FOCALSPEC	Solving the Root Cause of Battery Short Circuits:Focal Spec high-speed 3D imaging sensors revolutionise industrial quality control	With the market appetite for electric cars and consumer electronics increasing globally, battery manufacturers need to pack higher capacities into ever-smaller battery sizes. This sets extreme demands on manufacturing precision to ensure battery safety. Failing to do so caused...	01.10.2019-30.09.2021	2494800,00	Finland
VISION-xEV	Virtual Component and System Integration for Efficient Electrified Vehicle Development	The major challenge the European automotive industry is currently faced with is the 2020 CO2 fleet emission target of 95g/km and the envisaged further reduction of the CO2 emission limits in the European Union for the period after 2025. The European OEMs are also challenged by...	01.01.2019-31.12.2021	4995061,25	Austria

DANUBIA GRAPH	The graphene-based resistance temperature sensors application	Many fast-growing industries, such as aerospace, automotive, power generation, oil & gas require fast-response, light-weight, flexible, stable, large-area temperature measurement. These requirements are particularly relevant for the battery industry which faces renaissance and...	01.08.2019-31.01.2020	50000,00	Slovakia
BATT3RY	The first integral repairing method for electric and hybrid vehicle batteries which considers their full life-cycle	TARANIS is a Spanish company with objective of providing disruptive technology in the field of Electric and Hybrid Vehicles (EV/HEV), making them more efficient and positively impacting on environment and society. Over the last 2 years we have developed BATT3RY, the first...	01.01.2020-30.04.2020	50000,00	Spain
BatteryCheck	Take the mystery out of battery life.	"Energy accounts for 60% of global greenhouse gas emissions and this share continues to further deteriorate. Rapid transition to renewable resources and electric vehicles seemingly could be a good cure but require a lot of rechargeable batteries for higher efficiency. The key...	01.07.2019-31.01.2020	50000,00	Czechia
PhotoFluo	Synthesis and photopolymerisation of new fluorinated macromonomers for the obtaining of high performance fluoropolymers	The PhotoFluo project consists in a consortium of three teams (two from Europe and one from Canada) committed to work for developing novel fluoropolymers suitable for optical and electronic devices, membranes for fuel cells and Li batteries, microfluidics, and biomaterials...	01.02.2016-31.01.2020	139500,00	Italy
SALBAGE	Sulfur-Aluminium Battery with Advanced Polymeric Gel Electrolytes	Sulfur-Aluminium Battery with Advanced Polymeric Gel Electrolytes (SALBAGE).In SALBAGE Project, a new secondary Aluminium Sulfur Battery will be developed. The focus will be put in the synthesis of solid-like electrolytes based on polymerizable ionic liquids and Deep Eutectic...	01.11.2017-31.10.2020	3998130,00	Spain
SORCERER	Structural pOweR CompositEs foR futurE civil aiRcraft	In SORCERER revolutionary lightweight electrical energy storing composite materials for future electric and hybrid-electric aircraft are to be developed. Building on previous research novel lightweight supercapacitor composites, structural battery and structural energy...	01.02.2017-31.07.2020	2650632,50	United Kingdom
SOLVOLi	Solvometallurgy for battery-grade refining of lithium	To allow the rollout of e-mobility and stationary renewable energy storage in Europe, a secure, affordable and sustainable supply of battery-grade lithium salts for Li-Ion batteries (LIBs) is key. However, Europe`s lithium supply chain is extremely vulnerable: European s...	01.10.2020-31.03.2022	150000,00	Belgium

SEED	Solvated Ions in Solid Electrodes: Alternative routes toward rechargeable batteries based on abundant elements	Storing large amounts of electrical energy is a major challenge for the forthcoming decades. Today, lithium-ion batteries (LIBs) are considered the best option for electric vehicles and grid storage but these rising markets put severe pressure on resource and supply chains...	01.06.2020-31.05.2025	2997811,00	Germany
SUBLIME	Solid state sUlfide Based LI-MEtal batteries for EV applications	Wide global deployment of electric vehicles (EVs) is necessary to reduce transport related emissions, as transport is responsible for around a quarter of EU greenhouse gas (GHG) emissions, and more than two thirds of transport-related GHG emissions are from road transport...	01.05.2020-30.04.2024	7892792,50	Germany
SENTINEL	Single-Entity NanoElectrochemistry	Electrochemistry is the enabling science to address key problems of major societal relevance, spanning from electro-catalysis, in the context of energy conversion (e.g. fuel cells and solar cells) and energy storage (battery and water splitting technologies), to the development...	01.01.2019-31.12.2022	4167823,68	United Kingdom
SINTBAT	Silicon based materials and new processing technologies for improved lithium-ion batteries	According to the European Energy Storage Technology Development Roadmap towards 2030 (EASE/EERA) energy storage will be of the greatest importance for the European climate energy objectives. The SINTBAT project aims at the development of a cheap energy efficient and...	01.03.2016-29.02.2020	8334786,25	Germany
Si-DRIVE	Silicon Alloying Anodes for High Energy Density Batteries comprising Lithium Rich Cathodes and Safe Ionic Liquid based Electrolytes for Enhanced High VoltagE Performance.	Si-DRIVE will develop the next generation of rechargeable Li-Ion batteries, allowing for cost competitive mass market EVs by transformative materials and cell chemistry innovations, delivering enhanced safety with superior energy density, cycle life and fast charging...	01.01.2019-31.01.2023	8999492,50	Ireland
SELFIE	SELF-sustained and Smart Battery Thermal Management SolutIon for Battery Electric Vehicles	Strong efforts would be required to drastically reduce the fossil dependency and the CO2 emissions reductions in the transport sector, in line with the 2011 White paper on Transport i.e. a 20% reduction in the CO2 emissions by 2030 (relative to 2008 levels) and a 60%...	01.12.2018-31.05.2022	4999455,13	Belgium
SGHES	Second-Generation Hybrid Electrolyte Supercapacitor	The transition from fossil fuels to renewable energy has created an eminent demand for energy-storage solutions because of the intermittent nature of these energy sources. Batteries are the most common solution but other less known technologies like fuel cells and...	01.11.2019-31.10.2020	111500,00	Denmark

1000kmPLUS	Scalable European Powertrain Technology Platform for Cost-Efficient Electric Vehicles to Connect Europe	The need for common, scalable and brand-independent technology platforms for the key elements of EV, like the inverter-motor-transmission/gearbox (powertrain) and the battery, is evident. The project 1000kmPLUS will ensure the superiority of European automotive key...	01.01.2019-30.06.2022	5405286,26	Germany
SPIDER	Safe and Prelithiated hIgh energy DEnsity batteries based on sulphur Rocksalt and silicon chemistries	Knowledge-based improvements of Li-Ion battery cost, performance, recyclability-knowledge-based improvements of Li-Ion battery cost, performance, recyclability and safety are needed to enable electric vehicles to rapidly gain market share and reduce CO2 emissions. SPIDER...	01.01.2019-31.08.2022	7975192,50	France
MIGHTY	Roll-to-Roll Manufacturing of Hierarchical Li-Ion Battery Electrodes	Research in the field of micro and nanotechnology has led to the development of materials with fundamentally new or improved functionality, which have the potential to revolutionise electronics, drug delivery, water purification, and energy storage. These scientific...	01.02.2020-31.01.2025	1997723,00	United Kingdom
ENERZ	REVOLUTIONIZING STATIONARY ENERGY STORAGE COST: Pilot Plant and Go To Market Plan For Zn-ion Rechargeable Batteries	The global market for Stationary Energy Storage is estimated to reach a value of â,¬26 billion by 2022, with a compound annual growth rate (CAGR) of 46.5 percent, fueled mostly by the rapid growth of Renewable Energy Sources (RES), which are dependent on energy storage...	01.11.2020-31.10.2022	1634472,00	Sweden
LeydenJar	Pure Silicon Anodes Boosting the Energy Density of Li-Ion Batteries	Lithium-ion (Li-Ion) batteries are everywhere: They power smartphones, laptops, electric vehicles, hearing aids, and drones, for example. The crucial aspect in Li-Ion batteries is their energy density; that is, how much energy a battery of a given volume and weight can store...	01.04.2019-31.03.2021	2152106,25	Netherlands
OMICON	Organic Mixed Ion and Electron Conductors for High-Energy Batteries	Energy storage is undeniably amongst the greatest societal challenges. Batteries will be key enablers but require major progress. Battery materials that promise a step-change in energy density compared with current Li-Ion batteries rely on fundamentally different reactions to...	01.04.2015-31.03.2020	1494253,75	Austria
eJUMP	Organic Ionic Plastic Crystals Nanocomposites for Safer Batteries	Nowadays, important safety concerns limit large-scale use of lithium batteries for electric vehicles and stationary storage. Despite their high ionic conductivity, conventional liquid electrolytes for lithium batteries are highly flammable and can leak out of the battery case...	01.01.2019-31.12.2021	245440,80	Spain

TEESMAT	OPEN INNOVATION TEST BED FOR ELECTROCHEMICAL ENERGY STORAGE MATERIALS	Despite more than 200 years of development of batteries, the physical limits of battery performance are far from being reached. The complexity of physio-chemical processes inside batteries render any development strongly dependent on a proper description and monitoring of the...	01.01.2019-31.08.2022	8900252,16	France
GAlBs	Novel porous graphite as cathodes for advanced aluminium-ion batteries	The demand for electric vehicles (EVs) is expected to rise significantly to ~55% of all new car sales by 2040. This would necessitate ~0.8 million metric tons of Li-metal for standard lithium ion battery (LIB) production. However, a market dominant EV-industry would only have...	01.05.2019-30.04.2021	196590,72	Ireland
NANOSTACKS	Nanostack printing for materials research	When compared to fossil fuels only one decisive disadvantage remains for electricity from solar cells and wind mills, namely the difficulty to store this energy in very large quantities and in high energy density. State of the art batteries have a low energy density, and, in...	01.08.2020-31.07.2024	3992000,00	Germany
NanoEvolution	Nanoscale phase evolution in lithium-sulfur batteries	Lithium-sulfur (Li-S) batteries are considered a strategic candidate to achieve both significantly higher energy storage and better sustainability than current Lithium-ion batteries. They operate by converting sulfur into lithium sulfide and back on discharge/charge. However...	01.07.2020-30.06.2022	191149,44	Switzerland
NAIMA	NA ION MATERIALS AS ESSENTIAL COMPONENTS TO MANUFACTURE ROBUST BATTERY CELLS FOR NON-AUTOMOTIVE APPLICATIONS	The EU is transitioning to The EU is transitioning to a secure, sustainable and competitive energy system as laid out in the EC`s Energy Union strategy. The growing penetration of renewable energy sources in the EU energy market, go hand in hand with a high-competitiveness...	01.12.2019-30.11.2022	7999897,03	France
MATISSE	Multifunctional Hierarchically-Structured Systems for Energy Storage Devices	The widespread use of portable devices, as well as the electrification of transport, require a new generation of energy storage devices that deliver higher specific performance than Li-Ion batteries. By designing multifunctional materials that combine structural and...	08.07.2019-07.07.2021	212933,76	United Kingdom
LiBTR	Modelling of thermal runaway propagation in lithium-ion battery packs	Lithium-ion batteries (LIBs) are widely used in many applications, such as the customer electronics, electrifying transport and energy storage systems. However, despite endeavour and progresses, the number of incidents and recalls related to LIBs are far rising. Abuse...	01.09.2021-31.08.2023	224933,76	United Kingdom

MODALIS2	MODelling of Advanced LI Storage Systems	For a competitive EU battery sector, the development of next-generation battery systems needs cost-efficient processes. MODALIS² will make a significant contribution to a cost-down for EV battery cells through an all-integrated development process based on numerical tools...	01.01.2020-31.12.2022	4846105,00	France
SeNSE	Lithium-ion battery with silicon anode, nickel-rich cathode and in-cell sensor for electric vehicles	The SeNSE proposal aims at enabling next generation lithium-ion batteries with a silicon-graphite composite anode and a nickel-rich NMC cathode to reach 750 Wh/L. Cycling stability is the key challenge for the adoption of this cell chemistry. The objective is to reach 2000...	01.02.2020-31.01.2024	10251678,75	Switzerland
BatCon	Lithium-ion battery control for faster charging and longer life	Meeting the European industrial and political ambition of making the transport sector free of fossil fuel in the near future depends heavily on continued advancement of battery technology. Safe and optimal use of battery systems is crucial but difficult due to the lack of...	01.08.2020-31.07.2022	191852,16	Sweden
LISA	Lithium sulphur for SAfe road electrification	Li-Ion batteries are still the limiting factor for mass scale adoption of electrified vehicles and there is a need for new batteries that enable EVs with higher driving range, higher safety and faster charging at lower cost. LiS is a promising alternative to Li-Ion free of...	01.01.2019-31.07.2022	7920587,50	Spain
SOLiDIFY	Liquid-Processed Solid-State Li-metal Battery: development of upscale materials, processes and architectures	The SOLiDIFY project proposes a unique manufacturing process and solid-electrolyte material to fabricate Lithium-metal solid-state batteries known as Gen. 4b on the EU battery roadmap. The concept is based on a solid nanocomposite electrolyte or nano-SCE. It is made by a...	01.01.2020-31.12.2023	7823927,50	Belgium
LiPLANET	LI-ION CELL PILOT LINES NETWORK	The development of cost-effective, reliable, and high-performance battery cells will be essential to strategic sectors in Europe such as the automotive industry (electro-mobility) and the electric power sector. However, the world production of battery cells is largely...	01.01.2020-31.12.2021	1998636,25	Germany
ReSuNiCo	Inverted Reactive Spray Processes for Sulphide/Nitride High Surface Area Electrode Coatings	Highly pure, binary and ternary metal sulphides/nitrides are increasingly important materials for energy storage, electrocatalysis, optoelectronics and battery materials. To fully use their potential, radical new technologies that allow the synthesis of complex, and...	01.01.2019-31.12.2023	2361130,00	Germany
i-HeCoBatt	Intelligent Heating and Cooling solution for	The envisaged European CO2 fleet emission limits for 2025-2030 already require a massive market introduction of	01.01.2019-31.12.2021	3287012,43	Spain

	enhanced range EV Battery packs	EVs. However, there are still some obstacles for user acceptance of EVs: high cost, slow charging, limited range, perceived lack of added value and concerns of...			
SYS2WHEEL	Integrated components, systems and architectures for efficient adaption and conversion of commercial vehicle platforms to 3rd generation battery electric vehicles …	SYS2WHEEL will provide brand-independent components and systems for integrated 3rd generation commercial battery electric vehicles (cBEVs) for CO2-free city logistics. High efficiency, performance, packaging and modularity enable efficient integration. Mass production costs of...	01.01.2019-31.12.2021	4873421,75	Austria
GHOST	InteGrated and PHysically Optimised Battery System for Plug-in Vehicles Technologies	The GHOST project addresses all the H2020 topic GV-06-2017 aspects including also important contributions on the innovative Dual Battery System (DBS) architecture based on next generation of battery technologies (i.e. Li-S) and its impact on the reduction of complexity of the...	01.10.2017-31.03.2021	7151165,30	Italy
iPES-3DBat	Innovative Polymeric Batteries by 3D Printing	One of the actual limitations of the current batteries is their rigidity and limited shape availability (cylindrical or flat). Furthermore, the manufacturing of current electrodes/cells is a long process which requires big investments for battery fabrication facilities. The...	01.12.2018-31.05.2020	150000,00	Spain
INSTABAT	Innovative physical/virtual sensor platform for battery cell	The ambition of INSTABAT is to monitor in operando key parameters of a Li-Ion battery cell, in order to provide higher accuracy States of Charge, Health, Power, Energy and Safety (SoX) cell indicators, and thus allowing to improve the safety and the Quality, Reliability and...	01.09.2020-31.08.2023	3999522,50	France
IMAGE	Innovative Manufacturing Routes for Next Generation Batteries in Europe	As of today, Europe remains not competitive in terms of Lithium battery cell development and especially manufacturing. This lack of competence and competitiveness could quickly spiral down into a complete loss of this key technology for electrification in the EU. Thus IMAGE...	01.11.2017-30.04.2021	4948026,25	Austria
UP2DCHEM	Upscaling of fluorographene chemistry for supercapacitor electrode material	The world population is significantly increasing and its reliance on energy-based devices is higher than ever before. This leads to a continuous rise in global energy consumption. Considering that fossil fuel resources are strictly limited and have a detrimental effect on our...	01.04.2020-30.09.2021	150000,00	Czechia
Addionics	Innovative 3D electro-printing method to	missions from transport currently represent a global environmental	01.07.2020-30.06.2022	2253689,38	Israel

	improve power, capacity and safety of lithium ion-batteries	disaster, accounting for approximately 25% of Europe's greenhouse gas emissions. Electric Vehicles (EVs) offer the most likely solution to reducing the environmental impact of transport in the EU, however...			
iModBatt	Industrial Modular Battery Pack Concept Addressing High Energy Density, Environmental Friendliness, Flexibility and Cost Efficiency for Automotive Applications	iModBatt stands for Industrial Modular Battery Pack Concept Addressing High Energy Density, Environmental Friendliness, Flexibility and Cost Efficiency for Automotive Applications. The aim of iModBatt is to design and manufacture, with minimum environmental impact, a high...	01.10.2017-30.09.2020	5180794,01	Spain
AVILOO bcheck	Independent test of the battery health in electric vehicles	Batteries are subject to degradation over time, which results in a decrease in available power and range of electric vehicles (EV). When buying a used electric car, it is therefore of great importance for buyers and sellers to know the exact state-of-health of the battery as...	01.10.2020-31.03.2022	2228847,25	Austria
LIB STRESS	In situ stress analysis of lithium-ion battery cell	Lithium-ion batteries (LIB) are found in many applications such as consumer electronics, electric vehicles and airplanes. However, despite of the high safety standards being imposed, there have been many reported accidents as well as recalls by some manufacturers. Most...	30.07.2018-29.07.2020	195454,80	United Kingdom
I-BAT	Immersed-cooling Concepts for Electric Vehicle Battery Packs using Viscoelastic Heat Transfer Liquids (I-BAT)	The penetration of plug-in EVs on the world market faces considerable technological challenges. The performance of battery electric drives is influenced among other things by the power density and efficiency of the EV Battery Thermal System (BTMS), the heating and cooling...	01.10.2020-30.09.2024	2954952,50	Germany
Hydra	Hybrid power-energy electrodes for next generation lithium-ion batteries	The core technological approach of the HYDRA project consists of using hybrid electrode technology to overcome the fundamental limits of current Li-Ion battery technology in terms of energy, power, safety and cost to enter the age of generation 3b of Li ion batteries. HYDRA...	01.05.2020-31.08.2024	9401701,25	Norway
HIDDEN	HINDERING DENDRITE GROWTH IN LITHIUM METAL BATTERIES	The HIDDEN project develops self-healing processes to enhance the lifetime and to increase the energy density of Li-metal batteries 50 % above the current level achievable with current Li-Ion batteries. The HIDDEN	01.09.2020-31.08.2023	3993476,25	Finland

		consortium develops materials and their processes to functional...			
BATTERY PLUS	High performing batteries for accelerated uptake of hybrid and electric vehicles	Boosted by the threat posed by climate change and high dependency on fossil fuels, electric/hybrid vehicles are keys of the mobility of tomorrow. So far, e-mobility still presents many customer paint points, the main ones reliant on optimal battery technologies. Electric...	01.12.2019-30.11.2021	1198225,00	Spain
NanoBat	GHz nanoscale electrical and dielectric measurements of the solid-electrolyte interface and appli-cations in the battery manufacturing line	Sustainable storage of electrical energy is one of this century´s main challenges, and battery production is one of the future key industries with an estimated market potential of 250 Billion Euros by 2025 as stated by the European Commission. We contribute to this by...	01.04.2020-31.03.2023	4966912,50	Austria
GEVACCON	Geographies of Value Chain Construction in Emerging Complex Technologies: A Comparative Study of the Electric Vehicle Lithium-ion Battery Industry in China and Germany	We are currently witnessing accelerating shifts of global leadership in many emerging industries, fueled by increasing digitalization and globalization, as well as pressing concerns about grand socio-ecological challenges. GEVACCON maintains that the challenge for gaining...	01.08.2020-31.07.2022	191149,44	Switzer-land
FUN POLYSTORE	FUNctionalized POLYmer electrolytes for energy STORagE	Besides the need for large-scale implementation of renewable energy sources, there is an equivalent need for new energy storage solutions. This is not least true for the transport sector, where electric vehicles are expanding rapidly. The rich flora of battery chemistries “...	01.09.2018-31.08.2023	1950732,00	Sweden
POLYTE	European Industrial Doctorate in Innovative POLYmers for Lithium Battery TEchnologies	POLYTE-EID European Industrial Doctorate will offer excellent training opportunities to 3 Early Stage Researchers in the area of Polymers for Electrochemical Energy Storage. POLYTE-EID puts together the expertise in batteries for automotive of Toyota Motor Europe (TME) with...	01.01.2018-31.12.2021	743618,88	Spain
M-ERA.NET3	ERA-NET for research and innovation on materials and battery technologies, supporting the European Green Deal.	M-ERA.NET 3 aims at coordinating the research efforts in the participating EU Member States, Regions, and Associated States in materials research and innovation, including materials for future batteries, to support the circular economy and Sustainable Development Goals. A...	01.03.2021-28.02.2026	15000000,00	Austria
Electroscopy	Electrochemistry of All-solid-state-battery Processes using Operando Electron Microscopy	All-solid-state batteries(ASSB) enabled by electrochemically stable solid electrolytes represent a promising alternative to the conventional lithium batteries with liquid electrolytes which	01.11.2020-31.10.2022	174806,40	Germany

		jeopardize battery safety. However, the complex charge transfer at solid-solid...			
EVERLASTING	Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management	Batteries are not yet the ideal energy container they were promised to be. They are expensive, fragile and potentially dangerous. Moreover the current EV cannot compete yet with traditional vehicles when it comes to driving range and flexibility. EVERLASTING intends to...	01.09.2016-28.02.2021	8201423,75	Belgium
ECO2LIB	Ecologically and Economically viable Production and Recycling of Lithium-Ion Batteries	After the successful project Sintbat, this project aims to continue the effort with the modified objectives of LC-BAT-2-2019. This new call moves the focus to a new KPI, the cycle related costs per energy: kWh/cycle. It very well reflects the real need of the customers if...	01.01.2020-31.12.2023	7999730,00	Germany
DESTINY	Doctorate Programme on Emerging Battery Storage Technologies INspiring Young scientists	"In the global context of the launched ""European Battery Alliance"" and ""European Technology & Innovation Platform, Batteries Europe"", many Universities, Research Centres and supporting organisations have agreed to build the Battery 2030+ consortium as an ambitious European...	01.10.2020-30.09.2025	4068000,00	France
DisorMetox	Disorder and Order in the Conversion Mechanism of Metal Oxides in Lithium-ion Batteries	Binary transition metal oxides (MxOy) have been studied as anode electrode materials for Li-Ion batteries (LIBs) for many years. Defined as a class of conversion material, these MxOy undergo multi-electron reactions (per formula unit) leading to highly desirable capacities and...	01.08.2018-31.07.2020	195454,80	United Kingdom
BATMAN	Development of Quantitative Metrologies to Guide Lithium Ion Battery Manufacturing	Lithium ion batteries offer tremendous potential as an enabling technology for sustainable transportation and development. However, their widespread usage as the energy storage solution for electric mobility and grid-level integration of renewables is impeded by the fact that...	01.05.2016-30.04.2021	1500000,00	Switzerla nd
LiBAT	Development of a High Voltage Lithium BATtery	Hybrid and electric propulsion systems for aeronautics represent an enormous potential for innovation, especially with regard to CO2 savings. In order to achieve a reliable, efficient and safe operation of such battery systems, they must be optimized in terms of energy storage...	01.11.2018-31.10.2020	584225,00	Germany
BATNMR	Development and Application of New NMR Methods for Studying Interphases and Interfaces in Batteries	The development of longer lasting, higher energy density and cheaper rechargeable batteries represents one of the major technological challenges of our society, batteries representing the limiting components in the shift from	01.10.2019-30.09.2024	3498219,00	United Kingdom

		gasoline-powered to electric vehicles. They are...			
DEMOBASE	DEsign and MOdelling for improved BAttery Safety and Efficiency	Electric mobility is a reality we can experience on our roads and cities. Electromobility is moving forward, driven by drastic cost reductions, higher performances and improved availability to support new business models of autonomous driving passenger cars and new vehicle...	01.10.2017-30.11.2020	7451520,00	France
DEMAND	Density Modulated Silicon Anode for Lithium Ion Batteries	The overall lithium ion battery market is expected to grow from \$37.4B in 2018 to \$100.4B by 2025, at a CAGR of 17.1%. The growth of this market is being fueled by increasing demand for smart devices and other industrial goods. One of the major cost centers for lithium-ion...	01.12.2019-31.05.2020	50000,00	Turkey
3beLiEVe	Delivering the 3b generation of LNMO cells for the xEV market of 2025 and beyond	3beLiEVe aims at delivering the 3b generation of LNMO cells for the electrified vehicles market of 2025 and beyond. The project addresses the full scope of the LC-BAT-5-2019 call by delivering: 3b generation batteries with LNMO cathodes, LiFSI electrolyte, and a 10-20 wt.%...	01.01.2020-30.06.2023	10833759,99	Austria
CYMEIT	Cyanated macrocycles for electron and ion transport	The aim of the proposed project is to develop redox-active macrocycles for excellent electron and ion transporting materials. Such mixed ionic-electronic conductors are important for various state-of-the-art applications, for example organic battery electrodes, electrochemical...	01.09.2018-31.08.2020	183454,80	United Kingdom
URCHIN	continUous flow ReaCtor for Hierarchically desIgned Nanocomposites	Since the release of the first lithium ion battery in 1991, this technology has been growing continuously and has been pivotal in enabling new technologies ranging from consumer electronic devices to electric vehicles (EVs). However, the currently used intercalation-based...	01.03.2018-29.02.2020	183454,80	United Kingdom
COBRA	CObalt-free Batteries for FutuRe Automotive Applications	COBRA aims to develop a novel Co-free Li-Ion battery technology that overcomes many of the current shortcomings faced by Electrical Vehicle (EV) batteries via the enhancement of each component in the battery system in a holistic manner. The project will result in a unique...	01.01.2020-31.12.2023	11857352,50	Spain
SENSIBAT	Cell-integrated SENSIing functionalities for smart BATtery systems with improved performance and safety	SENSIBAT`s overall objective is to develop a sensing technology for Li-Ion batteries that measures in real-time the internal battery cell temperature, pressure (e.g. mechanical strain, gas evolution) conductivity and impedance (separately for the anode, cathode and...	01.09.2020-31.08.2023	3333930,00	Spain

CATHDFENS	CATHode Development For Enhanced iNterfacial Studies (CATH-DFENS)	Lithium-ion batteries have established themselves as the leading power source for mobile applications, however to meet ever increasing demands in energy density and durability, significant improvements must be realised. Whilst advances in each battery component (anode...	01.09.2016-04.07.2020	269857,80	United Kingdom
DEBIMAX	Carbon coated Silicon Production Scaling Up for Li-Ion batteries	The booming need for batteries and higher storage capacities are well identified challenges. Increase production capacities can meet the higher demand but improved storage capacities require innovation and new battery materials. The critical application for better capacities...	01.11.2019-31.10.2021	1756953,63	France
CARBAT	CAlcium Rechargeable BAttery Technology	"We propose calcium based rechargeable batteries to be a FET helping to solve some of the Grand Challenges our modern society is facing: pollution, oil-dependency, and climate change. Today transportation contributes to >25% of the total CO2-emissions globally and while...	01.10.2017-31.03.2021	2036981,25	Spain
CAMBAT	Calcium and magnesium metal anode based batteries	Li-Ion battery is ubiquitous and has emerged as the major contender to power electric vehicles, yet Li-Ion is slowly but surely reaching its limits and controversial debates on lithium supply cannot be ignored. New sustainable battery chemistries must be developed and the most...	01.01.2017-31.12.2021	2688705,00	Spain
BATTERY 2030PLUS	BATTERY 2030+ large-scale research initiative: At the heart of a connected green society	Batteries are one key technology enabling a climate-neutral Europe by 2050. A pan-European research and innovation action is necessary to tackle the challenges preventing batteries to reach ultrahigh performance and to rapidly find new sustainable battery materials. The...	01.09.2020-31.08.2023	3098702,50	Sweden
BATTERY 2030	BATTERY 2030+ At the heart of a connected green society	Batteries will play an essential role in many years to come if the batteries of the future can provide reliable and safe energy at low cost, while reducing our dependence on critical raw materials and adopting sustainable value chains from mining to recycling. The emerging...	01.03.2019-31.05.2020	500456,00	Sweden
BAT4EVER	Autonomous Polymer based Self-Healing Components for high performant LIBs	Electrochemical reactions in battery materials normally lead to structural changes, which may cause degradation and damage, and thus causing the loss of functionality of the battery with cycling. Next-generation electrode materials for lithium-ion batteries are especially...	01.09.2020-31.08.2023	4264237,50	Belgium

ARPEMA	Anionic redox processes: A transformational approach for advanced energy materials	Redox chemistry provides the fundamental basis for numerous energy-related electrochemical devices, among which Li-Ion batteries (LIB) have become the premier energy storage technology for portable electronics and vehicle electrification. Throughout it´s history, LIB technology...	01.10.2015-31.03.2021	3249196,25	France
ASTRABAT	All Solid-sTate Reliable BATtery for 2025	"Europe is facing a major challenge to develop and produce a competitive Li-battery product in order to avoid dependency on third countries in its energy transition models. The Li-Ion cell innovations should meet specific technical and economical requirements to sustain the...	01.01.2020-30.06.2023	8817568,75	France
CoFBAT	Advanced material solutions for safer and long-lasting high capacity Cobalt Free Batteries for stationary storage applications	The project main goal is to develop new generation batteries for battery storage with a modular technology, suitable for different applications and fulfilling the increasing need of decentralized energy production and supply for private households and industrial robotized...	01.11.2019-31.10.2023	8957796,25	Spain
ARTISTIC	Advanced and Reusable Theory for the In Silico-optimization of composite electrode fabrication processes for rechargeable battery Technologies with Innovative Chemistries	The aim of this project is to develop and to demonstrate a novel theoretical framework devoted to rationalizing the formulation of composite electrodes containing next-generation material chemistries for high energy density secondary batteries. The framework will be...	01.04.2018-31.03.2023	2976445,00	France
SAFELiMOVE	advanced all Solid stAte saFE LIthium Metal technology tOwards Vehicle Electrification	Transport is responsible for around a quarter of EU greenhouse gas (GHG) emissions, and more than two thirds of transport-related GHG emissions are from road transport. Countries around the world are betting on EVs to meet sustainability targets. Battery cells are considered...	01.01.2020-31.12.2023	7875406,25	Spain
AMPERE	Accounting for Metallicity, Polarization of the Electrolyte, and Redox reactions in computational Electrochemistry	Applied electrochemistry plays a key role in many technologies, such as batteries, fuel cells, supercapacitors or solar cells. It is therefore at the core of many research programs all over the world. Yet, fundamental electrochemical investigations remain scarce. In...	01.04.2018-31.03.2023	2588768,75	France
Coldab	A unique multi-layer deposition process for optimised production of the next generation of Li-Ion batteries.	Despite being an ideal solution to the global challenge of tackling the effects of transport emissions, Electric Vehicles (EVs) have not yet achieved significant mass market penetration. This is mostly due to the fact that the development in the EV battery industry has been...	01.10.2020-31.03.2023	2301250,00	Finland
Worlds of Lithium	A multi-sited and transnational study of	Worlds of Lithium is a multi-sited and transnational study that examines how	01.02.2020-31.01.2025	1500000,00	Netherlands

	transitions towards post-fossil fuel societies	the strategic replacement of fossil fuels with electric transport powered by lithium-ion batteries is taking place in Chile, the largest lithium producer worldwide, China, the world leader in...			
VOLT	Innovative high VOLTage network battery concept	The VOLT Consortium will develop an innovative high voltage network (using 270 VDC) inspired by a Clean Sky architecture. This new architecture requires an innovative battery solution that will provide mainly pre-flight and starting power to the rotorcraft. The objective of...	16.02.2016-15.04.2021	800000,00	France
BLU-SPARK	The first Hybrid Power Unit Retrofit Solution for airplanes	BLU-SPARK aims at designing, developing and testing the first parallel hybrid airplane ever produced offering the pilot top dynamic performances, more flying safety and environment protection. The proposed hybrid airplane will represent a quantic step in the general aviation...	01.04.2020-30.09.2022	2781625,00	Italy
TRIPOD	The transition to a renewable electricity system and its interactions with other policy aims	In order to meet its long-term climate targets, the European Union has decided to reduce its power sector carbon emissions by 93-99% by 2050. This means that Europe aims to transition to a largely, or fully, renewable power system. This is however not the only energy policy...	01.08.2017-31.07.2022	2499940,00	Germany
3D-PRESS	3D-PRintable glass-based Electrolytes for all-Solid-State lithium batteries	The main goal of the 3D-PRESS project is to advance in the 3D printing concepts for safer, cheaper and customizable all-solid state Li-Ion batteries (LIB). More specifically, the project is focused on the design, production, characterization and testing of 3D printed...	02.03.2020-31.05.2022	160932,48	Spain