



## Electrical Energy Storage

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# Industry Challenges 2020-2035+

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This document outlines the R&D challenges for Electrical Energy Storage across a diverse range of automotive applications. The industry challenges are intrinsically linked with the 2020 Automotive Council roadmaps and should be read in conjunction with the narrative report to provide a context and background to the rationale behind the challenges.

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# An introduction to the industry challenge report



The industry challenges present the technical barriers to commercialising automotive powertrain technology in the short, medium and long term. Developed via a consensus process, this report highlights the most significant technology themes and specific R&D examples to springboard innovation. A list of recommendations on how this content can be taken forward by industry, academia and government is provided below:



## Industry

- Review in-house R&D priorities against the industry consensus challenges provided in this report
- Provide guidance to companies wanting to transition into low-carbon automotive propulsion technologies
- Provide a sense-check for start-ups to help guide their technology focus



## Academia

- Address the long-term scientific challenges that need to be overcome
- Align internal university research with the needs of the automotive industry
- Build a bridge with industry to execute and industrialise research



## Government

- Understand the R&D challenges required to industrialise low-carbon propulsion technologies
- Identify R&D challenges that may require additional funding
- Understand the challenges facing different mobility sectors and adjust policy, strategy and funding support accordingly

# A guide to reading the industry challenges



## Technology Challenge

A Technology Challenge is a broad issue that OEMs and the supply chain face when commercialising technologies for the automotive industry.

## Examples of research topics

Examples of research topics illustrate potential projects that could overcome the Technology Challenge. These are not intended to be an exhaustive list but a snapshot of areas captured in the industry engagement process.

## Time horizon

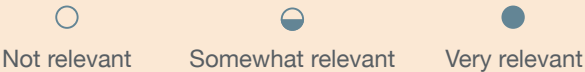
The filled bar represents when research is likely to be completed. For example:



Technology Challenge	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Cost effective chemistries and manufacturing methods for battery cells	New cell formats (e.g., 4680) that reduce costs and improve energy / power density.	2020-2025 	●	●	●	●
	Enhancing the energy and power density of Lithium Ferrophosphate (LFP) e.g., Lithium Iron Manganese Phosphate (LFMP).		●	◐	◐	○
	Innovation in cell assembly manufacturing equipment that reduces energy consumption and optimises floor space.		●	●	●	●

## Attributes and vehicle applications

The columns refer to the different attributes or vehicle applications related to each technology theme. The dots represent how relevant overcoming this topic would be to each application area. The four attributes are explained in more depth in the following pages.

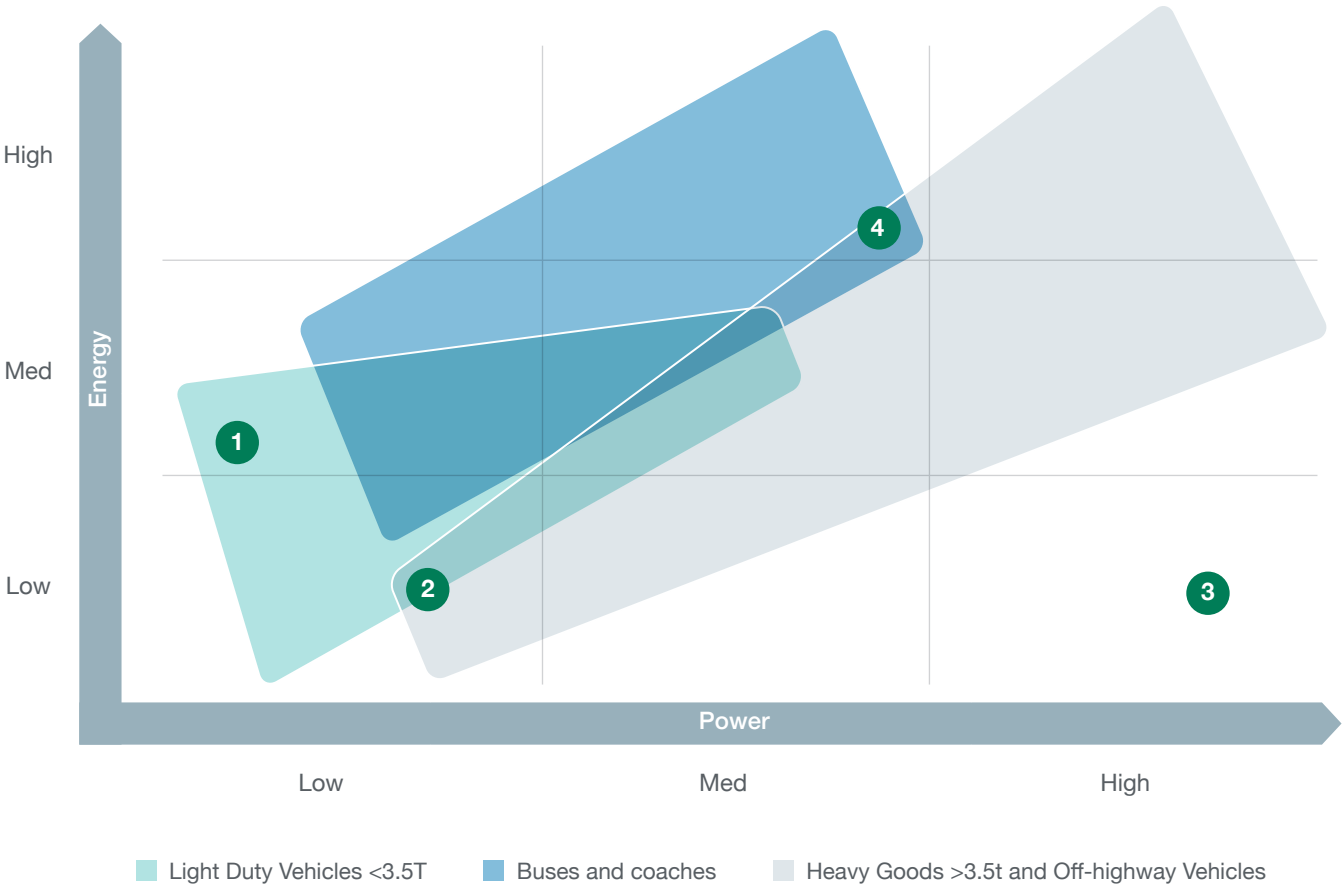


# Attributes and vehicle applications



## Energy-power spectrum across applications

Propulsion systems are tailored to specific power and energy demands, based on their use case and duty cycle. The graph below presents an outline of principle mass-market products.



The 2020 roadmap provides values for (1) Energy focused, cost sensitive indicators.

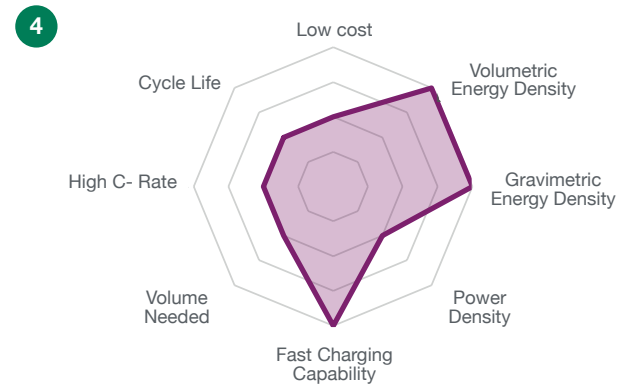
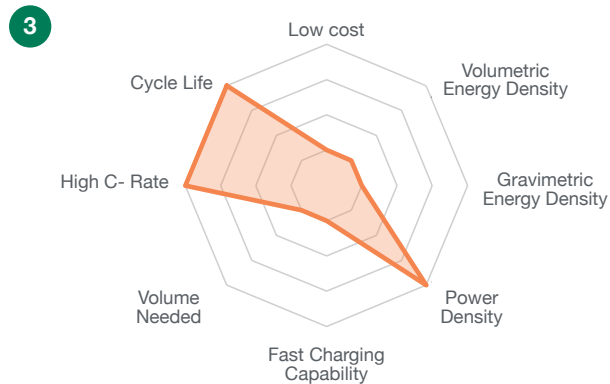
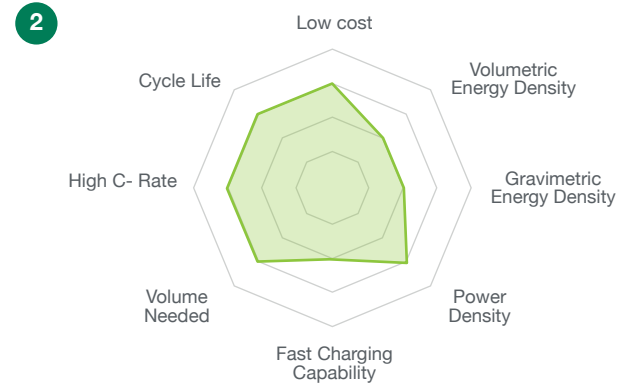
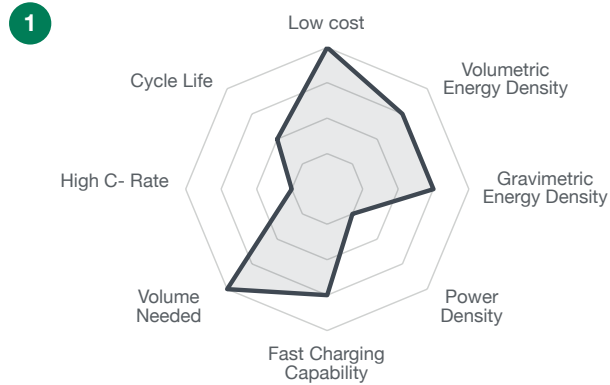
Other values are available from the KTN Cross-sector Battery Systems ([CSBS](#)) Innovation Network.

- 1 Energy focused, cost sensitive**  
The key strategic drivers are for lower pack level costs and better continuous charge acceptance whilst maintaining or improving energy density levels. This is because a large capacity and faster charging capability / capacity is required to meet attribute requirements.
- 2 Power focused, cost sensitive**  
The key strategic driver for this cluster is transient power handling at an affordable price, the applications would benefit from increased power and energy density but not at the expense of cost.
- 3 Power focused weight sensitive**  
The key strategic driver for this cluster is power handling with minimal weight impact with a range of energy density requirements. Cost is less of a consideration than volume automotive.
- 4 Energy focused, weight and power sensitive**  
The key strategic drivers are better gravimetric energy density and achieving better continuous discharge power density for more repeatable performance with greater range or reduced vehicle weight. The report is intended for experts in the field. The roadmap report is a precursor to industry challenges.



## Attributes and vehicle applications – typical performance characteristics

The purpose of the radar plots is to demonstrate the attributes industry prioritises across this technology. Each attribute is ranked from 1-4 to show the varying emphasis per application. Note: the plots are not constructed using absolute values.



**1 Energy focused, cost sensitive**

The key strategic drivers are for lower pack level costs and better continuous charge acceptance whilst maintaining or improving energy density levels. This is because a large capacity and faster charging are required to meet attribute requirements.

**2 Power focused, cost sensitive**

The key strategic driver for this cluster is transient power handling at an affordable price, the applications would benefit from increased power and energy density but not at the expense of cost.

**3 Power focused weight sensitive**

The key strategic driver for this cluster is power handling with minimal weight impact with a range of energy density requirements. Cost is less of a consideration than volume automotive.

**4 Energy focused, weight and power sensitive**

The key strategic drivers are better gravimetric energy density and achieving better continuous discharge power density for more repeatable performance with greater range or reduced vehicle weight.

# Technology challenges and research topics



## Technology challenges for electrical energy storage

The technology challenges listed here represent the highest priority R&D themes that industry and academia regard as critical for innovation.

Cost effective chemistries and manufacturing methods for battery cells

[See challenge](#)

Effective thermal management strategies to optimise cell and pack performance

[See challenge](#)

Energy dense solutions for current Li-ion chemistries

[See challenge](#)

Develop an economically viable value chain for 2nd life reuse

[See challenge](#)

Increased power density in existing Li-ion

[See challenge](#)

Increase recyclability, reduce CO<sub>2</sub> intensity and minimise the environmental and health impacts of battery manufacturing

[See challenge](#)

Next generation chemistries and manufacturing routes that provide a step-change in energy or power density

[See challenge](#)

Increasing the safety and extending the first life of battery packs

[See challenge](#)

Advanced BMS systems and electrical architectures

[See challenge](#)

Using in-situ data to inform health management, end of life and next generation products

[See challenge](#)

Integrating energy storage more effectively into the vehicle

[See challenge](#)

The above challenges are not listed in a prioritised order. They represent all the themes industry and academia regard as critical for innovation.

# Electrical energy storage – technology challenges and research topics (1/10)



The research topics listed below predominately focus on the **Cathodes** and **Anodes** sections of the roadmap. More subtle linkages with **Cell formats and Design** and **Solvents, Binders and Additives** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Cost effective chemistries and manufacturing methods for battery cells	New cell formats (e.g., 4680) that reduce costs and improve energy / power density.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Enhancing the energy and power density of Lithium Ferrophosphate (LFP) e.g., Lithium Iron Manganese Phosphate (LFMP).		<div></div>	<div></div>	<div></div>	<div></div>
	Innovation in cell assembly manufacturing equipment that reduces energy consumption and optimises floor space.		<div></div>	<div></div>	<div></div>	<div></div>
	Reduce hazardous processing chemicals to reduce cell manufacturing costs (e.g., electrodepositing electrode materials, water-based solvents).	2020-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Manganese rich cathodes that overcome voltage fade and poor cycle life e.g., manganese rich Nickel Manganese Cobalt Oxide (NMC), LFMP.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Techniques to shorten the cell formation process to optimise cell through-put (e.g., pre-lithiation).		<div></div>	<div></div>	<div></div>	<div></div>
	Innovating the way that precursor materials and anodes / cathodes are refined and mixed to reduce processing costs.		<div></div>	<div></div>	<div></div>	<div></div>
	Electrode chemistries and structures that enable sub \$50/kWh battery packs (e.g., sodium or zinc-based chemistries).	2025-2035+ <div></div> +	<div></div>	<div></div>	<div></div>	<div></div>





# Electrical energy storage – technology challenges and research topics (2/10)

The research topics listed below predominately focus on the **Cathodes, Anodes & Electrolytes** section of the roadmap. More subtle linkages with **Cell formats and Design**, **Current Collectors & Electrical Distribution Systems** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Energy dense solutions for current Li-ion chemistries	Ultra-nickel rich cathode materials (e.g., NMC9.5.5) and complementary electrolytes that maintain cycle life and are safe.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Strategies to achieve higher blends of silicon alongside graphite (i.e., graphene encapsulation, nano-particles).		<div></div>	<div></div>	<div></div>	<div></div>
	New cell formats (e.g., 4680) that reduce costs and improve energy density.		<div></div>	<div></div>	<div></div>	<div></div>
	Understanding how to use more of the batteries capacity safely without degrading the battery through better cell-to-cell management.		<div></div>	<div></div>	<div></div>	<div></div>
	Pre-lithiation techniques to increase lithium utilisation and increase energy density but without contributing to lithium plating.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Electrolytes that can enable high voltage spinel cathodes (e.g., fluorinated electrolytes).		<div></div>	<div></div>	<div></div>	<div></div>
	Blending different active materials within the same cathode to achieve higher energy (e.g., hybrid cathodes, bimodal cathodes, colloidal cathodes).		<div></div>	<div></div>	<div></div>	<div></div>
	Highly concentrated liquid electrolytes that can enable lithium metal anodes (e.g., LiTFSI and acetonitrile electrolytes).		<div></div>	<div></div>	<div></div>	<div></div>
	Enhanced current collector manufacturing techniques to enable lower weight and better slurry adhesion (e.g., nanowire foils).		<div></div>	<div></div>	<div></div>	<div></div>
			<div></div>	<div></div>	<div></div>	<div></div>

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.

# Electrical energy storage – technology challenges and research topics (3/10)



The research topics listed below predominately focus on the **Cathodes, Anodes & Electrolytes** sections of the roadmap. More subtle linkages with **Separators** and **Thermal** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Increased power density in existing Li-ion	>30C rate cell chemistries for high performance applications.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Targeted cooling during rapid charge to optimise the health of the battery to maintain high charge acceptance.		<div></div>	<div></div>	<div></div>	<div></div>
	Different electrode designs tailored for power density (e.g., structured anodes, multifunctional electrodes, laser patterned electrodes).	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Cost effective scale up of rapid charge anode chemistries that enable under 10-minute charges (e.g., niobium-based anodes).		<div></div>	<div></div>	<div></div>	<div></div>
	Enable rapid fast-charging with graphite-based anodes via enhanced electrolyte salts and additives. This can prevent lithium plating alongside separators that can cope with high temperature gradients.		<div></div>	<div></div>	<div></div>	<div></div>
	Enabling energy dense chemistries to accept >4C charging rates without significantly degrading battery life.		<div></div>	<div></div>	<div></div>	<div></div>
	Blending different active materials / supercapacitor materials within the same cathode to achieve higher energy / power densities (e.g., hybrid cathodes, bimodal cathodes, colloidal cathodes).		<div></div>	<div></div>	<div></div>	<div></div>



# Electrical energy storage – technology challenges and research topics (4/10)

The research topics listed below predominately focus on the **Cathodes, Anodes & Electrolytes** sections of the roadmap. More subtle linkages with **Solvents, Binders and Additives, Separators** and **Current Collectors** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Next generation chemistries and manufacturing routes that provide a step-change in energy or power density	Processes that cost effectively scale up the manufacture of lithium metal.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Improve the discharge current, volumetric energy density and electrolyte cost of Li-S batteries so they can be adopted for automotive applications.		<div></div>	<div></div>	<div></div>	<div></div>
	High volume manufacturing processes for sulfide and oxide based solid state electrolytes.		<div></div>	<div></div>	<div></div>	<div></div>
	Achieving good ionic conductivity of hybrid / semi-solid / solid state batteries at room temperature (20-30°C).		<div></div>	<div></div>	<div></div>	<div></div>
	Strategies to commercialise silicon dominant anodes that overcome differences in surface chemistry, solid electrolyte interface (SEI) stability, conductivity, volume expansion and cycle life.		<div></div>	<div></div>	<div></div>	<div></div>
	Manufacturing processes that remove the need for solvents and binders in electrode slurries (e.g., powder coating, flexible electrode printed films).	2025-2035+ <div></div> +	<div></div>	<div></div>	<div></div>	<div></div>
	Explore the viability of multivalent rechargeable batteries (e.g., Mg, Zn, Al) for automotive applications.	2030-2035+ <div></div> +	<div></div>	<div></div>	<div></div>	<div></div>
	Lithium air batteries suitable that achieve adequate cycle life and current densities suitable for automotive applications.		<div></div>	<div></div>	<div></div>	<div></div>
	Energy dense conversion reaction cathodes with acceptable volumetric energy density, low expansion rates and good cycle life.		<div></div>	<div></div>	<div></div>	<div></div>
	Step-change dielectric materials that enable supercapacitors to reach energy densities comparable to batteries.		<div></div>	<div></div>	<div></div>	<div></div>

# Electrical energy storage – technology challenges and research topics (5/10)



The research topics listed below predominately focus on the **Electrical Distribution System** section of the roadmap. More subtle linkages with **Cell formats and Design** and **Life Cycle** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Advanced BMS systems and electrical architectures	Standardisation of battery management system (BMS) communication protocols to aid greater design efficiencies and reduce development cost.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Optimising the cost and weight of busbars using multi-material (e.g. Cu & Al) and reducing nickel plating.		<div></div>	<div></div>	<div></div>	<div></div>
	Enhanced BMS charging regimes that can manage ultra rapid charging events (e.g., multi-stage constant current charging strategies).		<div></div>	<div></div>	<div></div>	<div></div>
	BMS capability enhancement to allow self-regulating BMS, monitoring and degradation prediction, with full discharge at end of life (EOL) of packs.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Commercialising >800V battery architectures for high performance applications.		<div></div>	<div></div>	<div></div>	<div></div>
	Battery module monitoring / sensing integrated into busbars.		<div></div>	<div></div>	<div></div>	<div></div>
	Cost effective cell instrumentation to enable distributed BMS architectures.	2025-2035+ <div></div>	<div></div>	<div></div>	<div></div>	<div></div>

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.

# Electrical energy storage – technology challenges and research topics (6/10)



The research topics listed below predominately focus on the **Pack Integration** section of the roadmap. More subtle linkages with **Cell formats and Design** and **Mechanical** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Integrating energy storage more effectively into the vehicle	Standardised cell format in cylindrical, pouch, prismatic for better cell-to-pack integration.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Rationalisation of battery structures, materials and busbars to reduce part count.		<div></div>	<div></div>	<div></div>	<div></div>
	Modular and scalable battery pack designs and structures that can fit across multiple vehicle platforms.		<div></div>	<div></div>	<div></div>	<div></div>
	Gel polymer electrolytes enabling “stacking” of electrodes to improve packing densities.		<div></div>	<div></div>	<div></div>	<div></div>
	Complex, net-shape busbars to reduce pack size and enable easy integration into the vehicle chassis.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Enabling cell-to-pack and cell-to-chassis concepts with chemistries that experience high thermal expansion e.g. NMC and nickel manganese aluminium (NMA).		<div></div>	<div></div>	<div></div>	<div></div>
	Structural batteries where energy is stored and transmitted in the vehicle body structure.	2030-2035+ <div></div>	<div></div>	<div></div>	<div></div>	<div></div>

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.

# Electrical energy storage – technology challenges and research topics (7/10)



The research topics listed below predominately focus on the **Thermal** section of the roadmap. More subtle linkages with **Pack Integration** section are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Effective thermal management strategies to optimise cell and pack performance	Integration of battery thermal systems within the vehicle thermal management to reduce complexity and increase synergy.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Targeted cooling during rapid charge to optimise the health of the battery to maintain high charge acceptance.		<div></div>	<div></div>	<div></div>	<div></div>
	Low-cost phase change materials that can store excess heat from the battery or powertrain to pre-heat the battery / cabin.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Multifunctional thermal interface materials that act as sealants and adhesives.		<div></div>	<div></div>	<div></div>	<div></div>
	Cost effective submerged cooling concepts for high charge and discharge events.		<div></div>	<div></div>	<div></div>	<div></div>
	Enhanced materials that have a better thermal conductivity than aluminum and copper (e.g., metal matrix composites).		<div></div>	<div></div>	<div></div>	<div></div>
	Cells designed to dissipate heat outwards to enable simplified liquid cooling solutions.		<div></div>	<div></div>	<div></div>	<div></div>
	Cell chemistries that can operate at elevated temperatures and only require passive cooling.	2030-2035+ <div></div> +	<div></div>	<div></div>	<div></div>	<div></div>

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.

Not relevant

Somewhat relevant

Very relevant



# Electrical energy storage – technology challenges and research topics (8/10)

The research topics listed below predominately focus on the **Life Cycle** section of the roadmap. More subtle linkages with the **Electrical Distribution Systems** section are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Develop an economically viable value chain for 2nd life reuse	Open access of BMS information, standardisation of data and interoperable BMS communication protocols to encourage 2nd life.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Designing modular batteries that can be mechanically disassembled easier for 2nd life use (e.g., reversible joining).					
	Develop second and third life battery application and value chain modules to find viable routes to extend battery use, including cross-sectoral applications.	2025-2035 <div></div>				
	Develop an in-depth battery passport that allows for second life and end of life efficient re-use and recycle across the supply chain.					
	Develop comprehensive diagnostic tools and automated machinery to assess and sort end of life cells, modules and packs to decide their state of health (SoH).					
	Develop novel electrical connectors that allows easy disassembly but can maintain electrical connectivity during standard operation.	2030-2035+ <div></div> +				

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.



# Electrical energy storage – technology challenges and research topics (9/10)

The research topics listed below predominately focus on the **Life Cycle** section of the roadmap. More subtle linkages with the **Cathodes and Anodes** sections are also present.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive								
Increase recyclability, reduce CO <sub>2</sub> intensity and minimise the environmental and health impacts of battery manufacturing	Assembling battery packs and localising refining closer to the point of use for a low-carbon footprint impact of manufacturing.	2020-2025 <div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>								
	Develop specific life cycle assessment (LCA) standards and protocols for battery manufacturing that can be adopted across industry.													
	Development of sustainable electrolytes and solvents with fewer hazards e.g., lithium hexafluorophosphate (LiPF6) decomposing to hydrofluoric acid (HF).	2025-2035 <div><div></div></div>					<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>				
	Hydrometallurgical cell recycling methods that can separate a diverse range of cell chemistries that can be refined to a high purity.													
	Step change in energy efficiency in graphite, battery chemical and cathode active materials processing against current state of art.													
	Designing modular batteries that can be mechanically disassembled easier for recycling (e.g., reversible joining).													
	Manufacturing processes that remove the need for solvents and binders in electrode slurries (e.g., powder coating, flexible electrode printed films).	2025-2035+ <div><div></div></div> +									<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>
	Zero harmful discharge in battery grade raw materials processing.	2030-2035+ <div><div></div></div> +												
	Using more abundant and recyclable materials in electrodes such as iron, aluminum, sodium.													
	Net zero CO <sub>2</sub> emissions in critical battery materials extraction and processing compared to current state of art with no impact on local water scarcity.													

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.





# Electrical energy storage – technology challenges and research topics (10/10)

The research topics listed below are cross cutting challenges and apply to all areas of both **Cells Materials and Manufacturing** roadmap as well as the **Module and Pack** roadmap.

Technology Challenge <a href="#">See all challenges</a>	Examples of research topics	Time Horizon	Energy focused, cost sensitive	Power focused, cost sensitive	Power focused, weight sensitive	Energy focused, weight and power sensitive
Increasing the safety and extending the first life of battery packs	Increased testing and validation (physical and virtual) of high power and energy battery packs.	2020-2025 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	High tensile strength, cost effective materials to structurally support vulnerable areas from impact (e.g., composite casings).		<div></div>	<div></div>	<div></div>	<div></div>
	Cells with inbuilt fire suppression to deal with rapid charging and high power discharge events (e.g. polymer-metal current collectors).		<div></div>	<div></div>	<div></div>	<div></div>
	Self-healing agents in existing Li-ion and next gen chemistries to increase safety and applicability for automotive applications.	2025-2035 <div></div>	<div></div>	<div></div>	<div></div>	<div></div>
	Developing non-flammable liquid electrolyte solvents, additives and binders that are less reactive and safer.		<div></div>	<div></div>	<div></div>	<div></div>
Using in-situ data to inform health management, end of life and next generation products	Using BMS and sensor data to inform next generation battery cell and pack designs.		<div></div>	<div></div>	<div></div>	<div></div>
	New cost-effective sensors with high sensitivity and accuracy embedded into safety critical components (e.g. separators and current collectors) linked to the BMS.					
	Master wireless communication between sensors and an advanced BMS relying on new AI protocols to achieve fully operational smart battery packs.	2030-2035+ <div></div> +				

**Notes:** The examples of research topics are intended to provide topics emerging from industry workshops while developing the roadmaps. These are not a complete and exhaustive list and make no reference to priorities within R&D.

# Technology roadmaps



This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.

**Dark bar:**

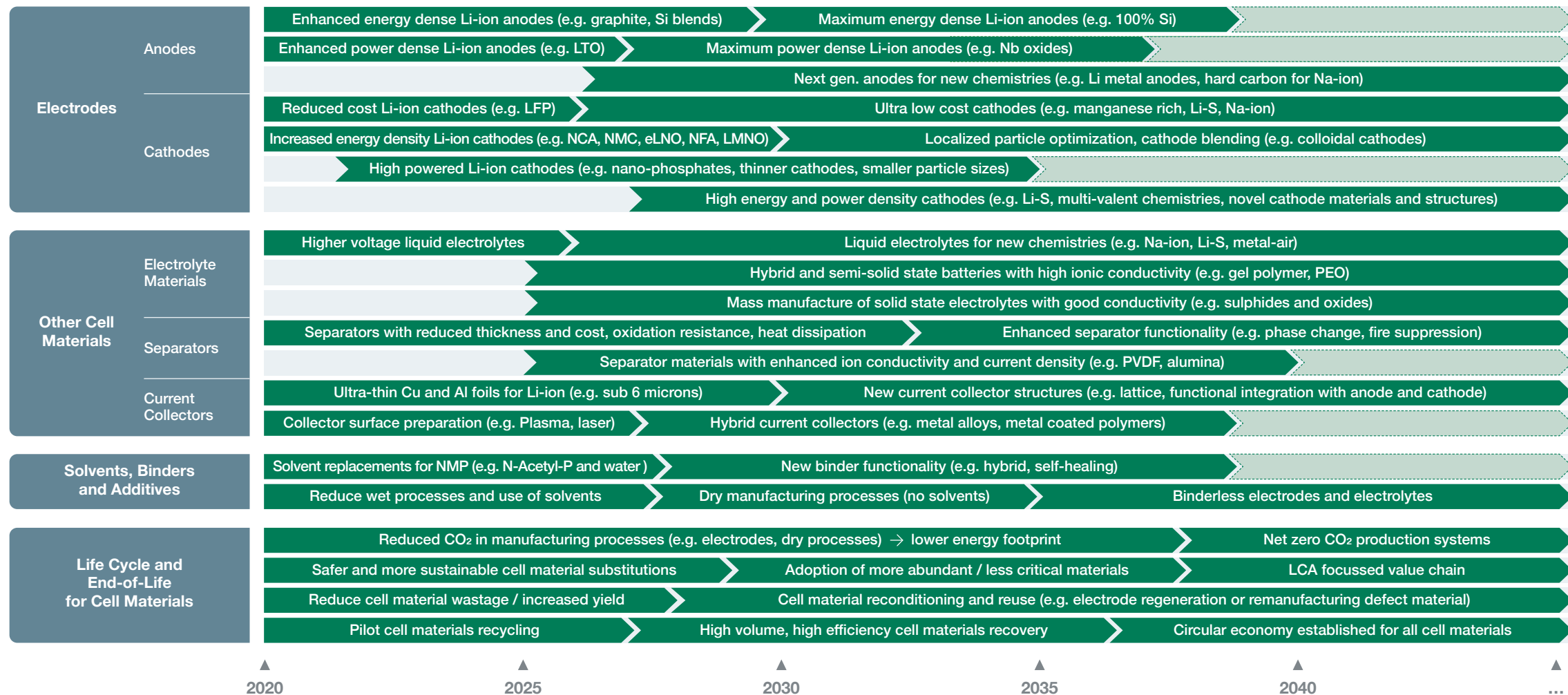
Technology is in a mass market application. Significant innovation is expected in this time frame

**Transition:**

Transitions do not mean a phase out from market but a change of R&D emphasis

**Dotted line bar:**

Market Mature – technology has reached maturity. Likely to remain in mass market until it fades out where it's superseded





This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.

**Dark bar:**

Technology is in a mass market application. Significant innovation is expected in this time frame

**Transition:**

Transitions do not mean a phase out from market but a change of R&D emphasis

**Dotted line bar:**

Market Mature – technology has reached maturity. Likely to remain in mass market until it fades out where it's superseded



# Changing powertrain technology options across a range vehicle applications in the short, medium and long term



		Short Term (2020-2025)	Medium Term (2025-2035)	Long Term (2035+)
LDV		Significant growth in vehicle electrification, to be supported by higher battery energy density, faster charging and lower costs.	Mature battery electric vehicle platforms achieving cost parity with conventional ICE and an increasing number of PEM fuel cell vehicles for long range journeys.	New battery chemistries, based on access to raw materials, LCA focus and low-energy production. Mature fuel cell applications with associated hydrogen infrastructure.
HGV and OH		Focussed propulsion selection tailored to vehicle type, duty cycle and use case aiming for net-zero carbon emissions; optimised for TCO.	Growth in fuel cells for heavy goods vehicles together with maturing net-zero combustion engines and more efficient BEV platforms.	Emerging catenary transport for certain heavy goods vehicles with collaborative support and infrastructure from government.
Bus and Coach		Operator specific actions to increase electrification and PEM fuel cells fleet migration.	Mature BEV and fuel cell platforms designed with second use, higher utilisation and increased economic return.	Tailored public transport solutions, new vehicle types and route management for customised journeys.

Continued innovation in thermal propulsion systems achieving decarbonisation through net-zero fuels

Increasing LCA focus across all activities to deliver environmentally sustainable manufacturing and products

LDV: Light Duty Vehicle  
ICE: Internal Combustion Engine

HGV: Heavy Goods Vehicle  
LCA: Life Cycle Assessment

OH: Off-highway  
TCO: Total cost of ownership

BEV: Battery Electric Vehicle  
PEM: Proton Exchange Membrane

# Appendix

# Background to the industry challenge report



## The opportunities for industry research (and academic)

This report aims to bring industrial research to market-readiness faster, with a fresh approach to R&D challenges, directly linked to the technology roadmaps published by the Advanced Propulsion Centre (APC) on behalf of the Automotive Council UK in 2020.

For electrification technologies (Electrical Energy Storage, Electric Machines and Power Electronics) the challenges are matched to cost and performance metrics related to electrified powertrains. The Thermal Propulsion System, Lightweight Vehicles and Powertrain Structures and Fuel Cell technology challenges are matched to the relevant product types; light duty, heavy goods and off-highway and bus and coach.

Separate challenges are provided for integrated electric drives within the Electric Machines and Power Electronics reports.

All technology solutions will need a balanced selection from the challenges, specific to each application, and require careful management of their trade-offs.

## Industry and academia working together

The report provides a common platform for industry and academia to collaborate in a drive to overcome technology challenges and advance net-zero propulsion systems. Many topics involve fundamental research that can later be industrialised into market-ready products.

## Links to the Automotive Council Roadmaps

The industry challenges have been developed to support the net-zero Automotive Council roadmaps published by the APC in November 2020.

The roadmaps and the Industry Challenges report can be used by organisations and institutions to prioritise their research objectives to meet their technology goals.



# Developing the industry challenges

Data collection, engagements and validation



The data analysed and shaped into the Industry Challenges report came from several sources:

### Roadmap survey responses

We received a total of 130 responses from different types of organisations such as; vehicle manufacturers, SMEs, technology developers, engineering consultancies and service providers, Tier 1, Tier 2 or below, academia, local/national government and research technology organisations. Whilst around 60% of the respondents were UK-based, contributions were also received from Germany, USA, Japan, China, Belgium, and Sweden.

### APC competitions insights

Information has been gathered from the APC competitions where specific technical challenges have been highlighted.

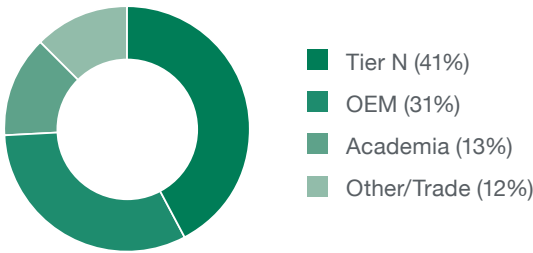
### APC Spoke specialists

Data compiled from the survey responses and insights were validated through the APC Spokes. Where necessary more input was provided to fill in specific gaps. The 2017-2018 research challenges were reviewed to include the relevant ones into the new industry challenges list.

### Industry workshops

Six events were held, one for each technology area: Electrical Machines, Power Electronics, Electrical Energy Storage, Thermal Propulsion Systems, Fuel Cells and Lightweighting. Industry experts provided feedback on technology challenges and details of research topics for each technology relevant to the product types (Light-duty Vehicles, Heavy Goods Vehicles and Off-Highway, Bus and Coach). A split by organisation type attending the industry challenges workshops is shown below.

Organisation types at the industry workshops







# The APC approach to defining the industry challenges

In order to provide a well-informed industry and academia-led propulsion technology list of research challenges that informs and mobilise innovation in propulsion technologies, the APC approached the work as follows:

August 2020

April 2021



## Roadmap workshops and online survey

This was completed prior to the industry challenges workstream and fed into the technology roadmap development - a precursor to the industry challenges.

Our online survey collected data from a wide range of stakeholders by asking experts for specific challenges. These have been analysed according to the main technology themes.



## Updated technology roadmaps

These were launched at LCV2020, followed by supporting narrative reports for each technology roadmap detailing context, background data and insights that fed into updated technology roadmaps.



## APC Spokes challenges (Academia)

A fresh eyes review of the 2017-2018 research challenges by the APC Spokes provided an up-to-date list for the current report.

Further research topics were added from the roadmap workshops output.



## Industry workshops and consensus (Industry)

Six industry workshops were run with roadmaps experts to develop, validate and further populate the examples of the research list.

A draft of the Industry Challenges was provided for comment in order to gather final consensus from the workshop groups.



## Industry Challenges published

The report is ready and available to download from the APC website.

[www.apcuk.co.uk/technology-roadmaps](http://www.apcuk.co.uk/technology-roadmaps)

Find all the technology roadmaps and industry challenges at  
[www.apcuk.co.uk/technology-roadmaps](http://www.apcuk.co.uk/technology-roadmaps)

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