Lightweight Vehicle and Powertain Structures

Industry Challenges 2020-2035+

This document outlines the R&D challenges for Lightweight Vehicle and Powertain Structures 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:

2020-2025 | 2025-2035 | 2030-2035+

Technology Challenge	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Flexible and scalable high-volume vehicle platforms	Low-cost manufacturing concepts to enable both high and low volume manufacture of different sized battery enclosures / structures.	2020-2025	●	●	●
	Highly modular vehicle platform designs that maximise part commonality whilst providing multiple product variants.		●	●	●
	Vehicle platforms designs capable of integrating multiple net-zero powertrains for adaptability and flexibility.		●	●	●

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.

○ Not relevant ◒ Somewhat relevant ● Very relevant

Technology challenges and research topics

Technology challenges for lightweighting

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

Flexible and scalable high-volume vehicle platforms — See challenge	High-volume low-cost joining methods for mixed material integrated structures — See challenge
Advances in multi-physics simulation techniques — See challenge	Increased integration of functions across vehicle systems — See challenge
Advances in high-strength aluminium and steel materials — See challenge	Advanced manufacturing methods that deliver significant part count reductions — See challenge
High-volume carbon composite materials in vehicle structures — See challenge	Recycling, remanufacturing and circular economy supporting LCA — See challenge
High-volume polymer materials in vehicle structures — 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.

Lightweighting – technology challenges and research topics (1/10)

The research topics listed below predominately focus on the **Design Led** section of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Flexible and scalable high-volume vehicle platforms	Low-cost manufacturing concepts to enable both high and low volume manufacture of different sized battery enclosures / structures.	2020-2025	●	●	●
	Highly modular vehicle platform designs that maximise part commonality whilst providing multiple product variants.		●	●	●
	Vehicle platforms designs capable of integrating multiple net-zero powertrains for adaptability and flexibility.		●	●	●
	Improved assembly techniques for modular structures that increase assembly speed and maintain join lines for high volume production.	2020-2035	●	●	●
	Future mission-suited vehicles targeting light weighting efficiency gains, based on connected autonomous vehicles and zero-crash principles.	2025-2035	●	◒	◒
	Mixed material blanks created using new forming processes.		●	◒	○

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

Lightweighting – technology challenges and research topics (2/9)

The research topics listed below predominately focus on the **Design Led** section of the light weighting technology roadmap, with linkages to other themes on the roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Advances in multi-physics simulation techniques	Increased fidelity and accuracy of multi-physics simulation software leveraging computational advances for high-speed results.	2020-2025	●	●	●
	Towards zero-prototype engineering, validated and tested, providing high-confidence performance assessments.		●	●	●
	Improved composites and polymer simulation techniques, taking into account complete material characterisation and material manufacturing processes e.g., layup, forming, pressing, curing and flow effects.		●	●	●
	Manufacturing and engineering con-current simulation methods, embedding assembly and production effects into up-front design steps.		●	●	●
	Advances in virtual concept design toolsets, including; manufacturing processes, forming limit diagrams, enhanced material databases etc.		●	●	●
	Data mining and exploitation of big data, digital tools, Computer-aided design and Finite Element capabilities, etc, including physical test information in supporting the delivery of the required simulation and digital support systems.	2020-2035	●	●	●
	Generative design methods and tools that include engineering, manufacturing and performance validation.	2025-2035	●	◒	◒

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

Lightweighting – technology challenges and research topics (3/9)

The research topics listed below predominately focus on the **Materials Led** section of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Advances in high-strength aluminium and steel materials	Developments in design tools that assign the right material to the right place, including advanced manufacturing processes like tailor welded blanks, low temperature forming techniques, etc.	2020-2025	●	●	●
	Alternative metallic coatings for corrosion resistance and reduced weight.		●	●	●
	Innovation in thin-walled panels for increased dent resistance and repairability.		●	◒	◒
	Innovation in steel (materials and manufacturing): • Suited for battery casing design, crash protection and electromagnetic compatibility isolation • Forming at smaller radii (higher ductility) for chassis and subframe parts • Liquid embrittlement solutions	2020-2035	●	●	●
	Advances in high strength steel with sufficient energy-absorption capability delivering weight reductions.		●	●	●
	Capability to produce high performance, fully recyclable aluminium casting alloys across a range of complex geometries at high-volume.		●	●	●
	Advances in high strength aluminium with sufficient energy-absorption capability and ductility (formability) delivering weight reductions.		●	●	●
	Increased integration of high-strength aluminium and steels in body structures to maximum weight saving; including related advances in joining techniques and assembling solutions.		●	●	●

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

Lightweighting – technology challenges and research topics (4/9)

The research topics listed below predominately focus on the **Materials Led** section of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
High-volume carbon composite materials in vehicle structures	Develop carbon fibre composite manufacturing processes, that reduce labour intensity (layup and manual handling), process steps, press moulding and curing times for high volume manufacturing. Includes advanced automated and visual systems that accelerate processes.	2020-2035	●	◒	◒
	Develop novel composite battery carrier designs that increase battery cell integration, overcome EMC limitations, fire resistance, thermal runaways and meet strength requirements to minimise weight.		●	◒	◒
	Develop low-cost lightweight high-pressure hydrogen tanks (type 3 and type 4) that can be manufactured at high-volume (350 bar and 700 bar).		●	●	●
	Develop high volume manufacturing methods for embedding sensors and inserts into composites components that can be used to collect vehicle performance data for subsequent design optimisation, simulation improvements and weight reduction.		●	◒	◒
	Research into production of low-cost, low-energy carbon fibre production from Polyacrylonitrile (PAN) and other sustainable precursors.		●	●	●
	Common standards for carbon fibre materials across the supply chain to enable high volume supplies.	2025-2035	●	◒	◒

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

Lightweighting – technology challenges and research topics (5/9)

The research topics listed below predominately focus on the **Materials Led** section of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
High-volume polymer materials in vehicle structures	Developments in joining and welding techniques for thermoplastic and thermoset composites to improve structural performance.	2020-2035	●	◒	◒
	Improved manufacturing techniques for complex and large-shaped polymer structures that can replace multiple vehicle parts.				
	Develop novel polymer composite battery carrier designs that increase battery cell integration, overcome electromagnetic compatibility (EMC) limitations, fire resistance, thermal runaways and meet strength requirements to minimise weight.				
	Advances in creep modelling of low-cost thermoplastics to increase confidence and use in structural components.				
	Development high-volume foam injection techniques for polymer composites, enabling greater lightweight component solutions.				

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

Lightweighting – technology challenges and research topics (6/9)

The research topics listed below predominately focus on the **Manufacturing and Process Led** section of the light weighting technology roadmap, with linkages to the **Materials Led** section.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
High-volume low-cost joining methods for mixed material integrated structures	Highly integrated structures with reduced joints across assemblies by innovation in manufacturing capability and assembly techniques.	2020-2025	●	●	●
	Develop solutions to address thermal expansion differentials in mixed material body structures during high-heat processes like e-coat and paint ovens e.g., novel joining that mitigate different expansion rates.		●	◒	◒
	Novel joining methods that require zero to low surface preparation and processes that result in no degradation to parent material properties.	2020-2035	●	◒	◒
	Improve multi-material body-in-white (BIW) designs for disassembly and recyclability, whilst maintaining or improving durability.		●	●	●
	Develop techniques for liquid metal embrittlement (LME) joining to other materials, with coatings considered. Riveting and adhesive joining challenges to be addressed.		●	◒	◒
	Develop printed thermoplastics and additive manufactured adhesives for high volume production joining applications.	2025-2035	●	◒	◒
	Novel joining methods for carbon fibre composite panels, e.g. • Fibre to fibre joining techniques • Induction welding of carbon fibre thermoplastic composites to other composites and materials		◒	◒	○

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

Lightweighting – technology challenges and research topics (7/9)

The research topics listed below predominately focus on the **Design Led** and **Manufacturing and Process Led** sections of the light weighting technology roadmap, with linkages to other themes on the roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Increased integration of functions across vehicle systems	Rationalise on-board electrical circuits, increase the use of lighter wires and flexible circuits for weight reduction.	2020-2025	●	●	●
	Develop solutions to integrate high-strength batteries within the vehicle structure, meeting strength, stiffness, durability and serviceability requirements.	2020-2035	●	◒	◒
	Electric vehicle integration of thermal management systems across cooling functions to realise component rationalisation and weight savings.		●	●	●
	Develop conductive body structures and high-volume manufacturing techniques to reduce the need for vehicle wiring and reduce weight.	2025-2035	●	◒	◒
	Develop manufacturing solutions to integrate seat components into Body-in-White assembly manufacturing; e.g., using large assembly single part production methods.		●	◒	◒

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

Lightweighting – technology challenges and research topics (8/9)

The research topics listed below predominately focus on the **Design Led** and **Manufacturing and Process Led** sections of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Advanced manufacturing methods that deliver significant part count reductions	Design and manufacturing concepts that increase the use of single geometry parts to replace multiple parts on vehicle structures.	2020-2025	●	●	●
	Innovation in low-volume production techniques towards high-volume: 1. High-speed and high-volume additive layer manufacturing 2. Advancing polymer forming techniques for complex and large geometries 3. Composite layout and cure techniques for large part assemblies 4. Hollow forming and sandwich construction methods for high volume 5. Mixed material blank manufacturing techniques	2020-2035	●	◒	◒
	Improvements in aluminium casting processes to increase yield and material quality control.		●	◒	◒
	Developments in high hole expansion materials for combining multiple steel parts together and reduce process steps. Applicable to chassis & suspension components.		●	◒	◒
	Develop economically viable complex share manufacturing methods to support part count reduction initiatives.		●	◒	◒

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

Lightweighting – technology challenges and research topics (9/9)

The research topics listed below predominately focus on the **Material Life Cycle** and **Materials Led** sections of the light weighting technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Recycling, remanufacturing and circular economy supporting LCA	Implement lower energy demand production facilities that maximise use of renewable energy, e.g. solar, for manufacturing.	2020-2025	●	●	●
	Design for ease-of-disassembly, to lower recycling / re-use costs and processing steps.				
	Increased recycled material content in raw material production. Develop circular value chains.				
	Develop large scale lower energy intensive recycling methods for carbon fibre composites.				
	Clearly defined common life cycle assessment (LCA) specifications across all net-zero technologies that industry can use to develop products.	2020-2035			
	Develop sustainable bio-based carbon fibre precursor materials that can be scaled up for high-volume manufacturing.				
	Improvements in low-cost, low-energy techniques for precious metals recovery from electric and fuel cell vehicles.				
	Develop material tagging techniques to increase traceability, re-purposing and recycling. Material composition, age, supply chain, etc.	2025-2035			
	LCA focused composite and polymer material production, looking at sustainable raw material supply, lower intensity manufacturing footprint				

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

Technology roadmaps

Roadmap 2020

Lightweight Vehicle and Powertrain Structures

Technology Roadmap

Technology indicators for 2020-2035 can be seen on page 1

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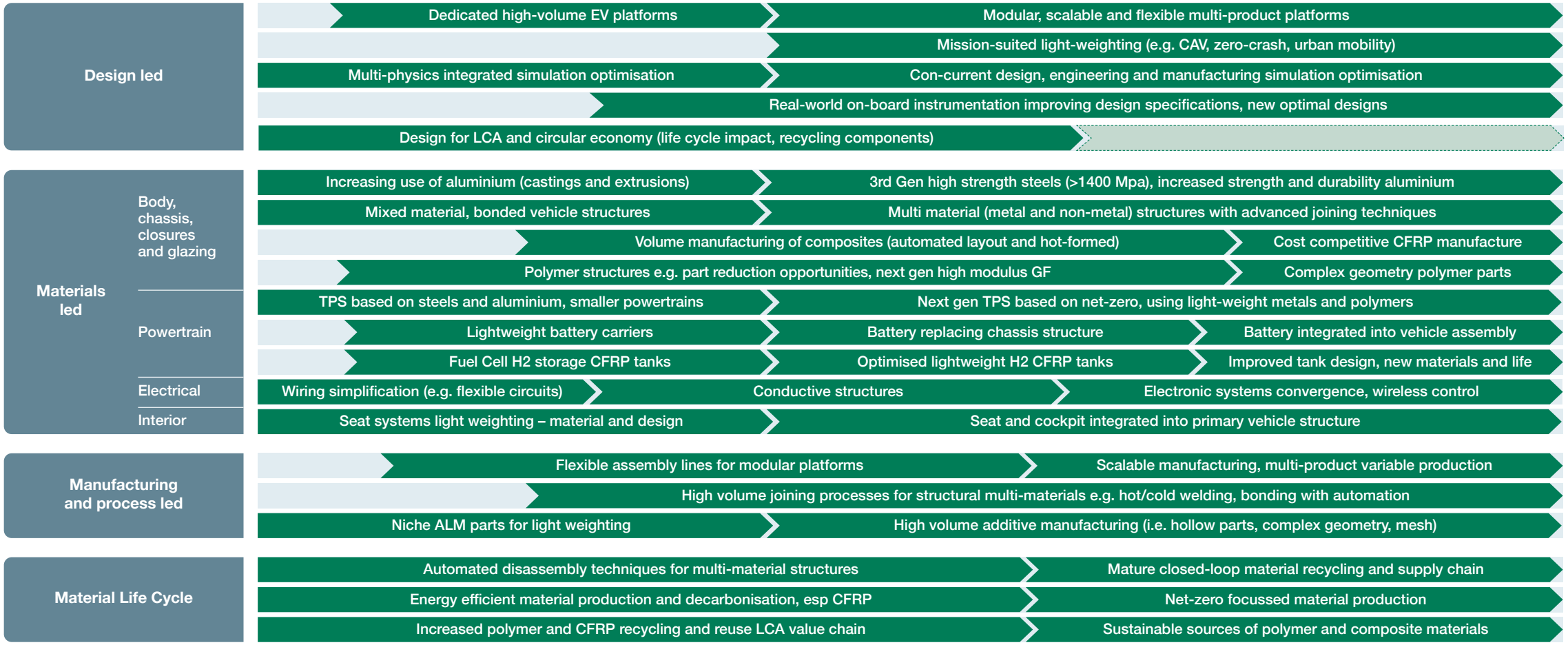
This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.

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.
All vehicle types 	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.

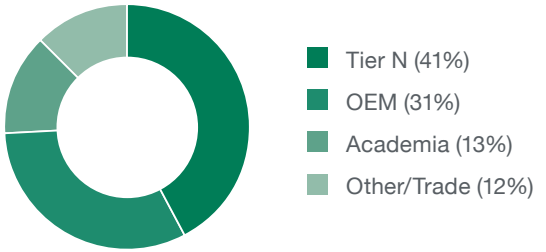
APC Spoke specialists

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

Find all the technology roadmaps and industry challenges at

www.apcuk.co.uk/technology-roadmaps

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The APC would like to acknowledge the extensive support provided by industry, academia and the APC Spokes in developing and publishing the industry challenges.

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