Fuel Cells

Industry Challenges 2020-2035+

This document outlines the R&D challenges for Fuel Cells 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.

May 2021 | Version 1.0

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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
Industry tools for stack design and systems optimisation	Increase accuracy and fidelity of stack simulation capability, including: • H_2 and N_2 cross over membranes • Start-up and shut-down cycling • Temperature gradients • Material degradation	2020-2025	●	●	●

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 fuel cells

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

Industry tools for stack design and systems optimisation See challenge	Energy efficient cold start support for SOFC See challenge
Increasing durability of fuel cell stacks See challenge	Waste energy recovery and thermal efficiency improvements See challenge
Improving efficiency of fuel cell systems See challenge	Low-cost hydrogen storage suitable for high-volume production See challenge
Low-cost fuel cell stacks See challenge	Alternative fuel carriers for future PEMFC and SOFC See challenge
High power density fuel cell stacks See challenge	Control systems and sensors to extend stack life and performance See challenge
Balance of system components tailored to fuel cell stacks (minimise weight and increase efficiency) See challenge	LCA focussed manufacturing methods and carbon-neutral production See challenge

PEMFC: Proton exchange membrane fuel cell SOFC: Solid oxide fuel cell LCA: Life cycle assessment

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

Fuel cells – technology challenges and research topics (1/10)

The research topics listed below predominately focus on the **Fuel Cell Stack** section of the fuel cell 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
Industry tools for stack design and systems optimisation	Increase accuracy and fidelity of stack simulation capability, including: • H_2 and N_2 cross over membranes • Start-up and shut-down cycling • Temperature gradients • Material degradation	2020-2025	●	●	●
	Stack design, sizing and optimisation with balance of system software engineering tools.				
	Advance multi-physics simulation capability that accurately model thermal, chemical, electrical and mechanical effects within the stack.				
	Stack design tools that work across a library of membrane electrode assembly (MEA), gas diffuser layer (GDL) and sealing solutions to provide stack solutions for user inputted requirements.				
	Software and tools that support diagnostics and on-board system health check to provide automated maintenance and service scheduling.	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

Fuel cells – technology challenges and research topics (2/12)

The research topics listed below predominately focus on the **Fuel Cell Stack** section of the fuel cell 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
Increasing durability and life of fuel cell stacks	Proton exchange membrane fuel cell (PEMFC): Develop low platinum group metals (PGM) content that can achieve a high durability. Consider PGM free cathode solutions.	2020-2025	●	●	●
	Improve test and validation methods for a cell fault detection and develop techniques to enable rapid in-line production testing.		●	●	●
	PEMFC: Develop low-thickness bi-polar plate materials and coatings whilst achieving durability requirements.	2020-2035	●	◒	◒
	PEMFC: Anodes capable of handling a variation of fuel quality and purity levels from national supply routes e.g., pipeline.		●	●	●
	Advanced catalysts delivering; performance, practicality, low-cost and manufacturability at scale that are stable and durable.		●	●	●
	Novel polymers and catalyst supports that increase stack life.	2025-2035	◒	●	●
	Software and tools that support diagnostics and on-board system health check to provide automated maintenance and service scheduling.		●	●	●

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

Fuel cells – technology challenges and research topics (3/12)

The research topics listed below predominately focus on the **Fuel Cell Stack, Balance of System and Control Systems** sections of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Improving efficiency of fuel cell systems	Solid oxide fuel cell (SOFC): Increase fuel efficiencies and lifespan of the stack, tailored to automotive traction drive cycles.	2020-2025	◒	●	◒
	Dedicated and optimised balance of systems for multiple stack designs.		●	●	●
	Improvements in air compressors, hydrogen blowers and controllers to increase system efficiency, addressing high contributors to balance of system losses.		●	●	●
	Fully passive variable orifice ejector systems that allow high turn down ratios of fuels.		●	●	●
	Embedded health monitoring systems and associated software for stack and system diagnostics, correction and optimisation.	2025-2035	●	●	●
	PEMFC: Low thickness, high-conductivity and high-performance gas diffusion layers.		◒	●	●
	Higher operating temperature acceptance stacks with reduced cooling demand that decrease total energy demand.		●	●	●
	PEMFC: Increase operating temperatures >120°C of PEM stacks for a higher energy conversion efficiency, whilst achieving durability targets.		◒	●	●
	PEMFC: New polymer materials capable of proton conductivity at low relative humidity.		●	◒	◒

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

Fuel cells – technology challenges and research topics (4/12)

The research topics listed below predominately focus on the **Fuel Cell Stack** section of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Low-cost fuel cell stacks	SOFC: Electrode materials tolerant to a larger variants of net-zero fuels, providing adaptability to future net-zero carbon fuels and increased use.	2020-2025	◒	●	●
	Application-led fit for purpose stack design to reduce cost.		●	●	●
	A total systems design approach to cost reduction, including the fuel system, valves, sensors, thermal management, air paths, gas management, fluid management, stack construction and a combination of functions designed and developed together.		●	●	●
	Improvements in MEA quality measurement techniques and manufacturing control to reduce rejects and increase production rates.		●	●	●
	Optimised and improved stack production techniques for high volume manufacturing, low scrappage, low-energy use and reduced complexity. Includes; catalyst-coated membrane (CCM), bipolar plates (BPP), GDL and MEA assembly steps.	2020-2035	●	●	●
	Develop high-volume MEA sealing systems for low-cost stack production.	2025-2035	●	●	●
	PEMFC: Significant reduction of platinum use in stacks to reduce cost, whilst maintaining performance and durability.		●	●	●
	PEMFC: BPP materials, coating and high-volume production techniques that reduce cost.		●	●	●

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

Fuel cells – technology challenges and research topics (5/12)

The research topics listed below predominately focus on the **Fuel Cell Stack** section of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
High power density fuel cell stacks	Application-specific and duty-cycle based high power stack designs achieving the required durability targets.	2020-2035	●	●	●
	High power fuel cell stack tailored designs for performance vehicles.		●	◒	○
	Off-highway high-power modular stacks that can apply economies of scale across applications within a family of products.		○	●	○

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

Fuel cells – technology challenges and research topics (6/12)

The research topics listed below predominately focus on the **Balance of System** section of the fuel cell 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
Balance of system components tailored to fuel cell stacks (minimise weight and increase efficiency)	Rationalise onboard power demand and create simplified, more efficient, fuel cell systems that reduce power and heat losses.	2020-2025	●	●	●
	Develop solutions to integrate fuel cell power electronics components, e.g., the DC/DC convertors, with the propulsion system High Voltage Power Distribution Unit and other on-board vehicle systems.		●	●	●
	Develop architectures that integrate on-board vehicle thermal management systems with the fuel cell balance of system to reduce components and achieve rationalisation.		●	●	●
	SOFC: Heat exchangers for high thermal shock, at low cost and mass, for SOFC warm-up.		○	●	◒
	SOFC: Develop smaller and more efficient fuel reformer systems suited to net-zero fuels that reduce the demand on balance of systems.		◒	●	◒
	Develop air handling systems; e.g., filters, compressors and humidifiers, better matched to the fuel cell stack to increase system efficiency which are lighter and more compact.	2020-2035	●	●	●
	PEMFC: Optimise water handling systems for smaller, lighter and lower pressure stacks to seek benefits in overall efficiency of a simplified system.		●	●	●

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

Fuel cells – technology challenges and research topics (7/12)

The research topics listed below predominately focus on the **Balance of System** section of the fuel cell 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
Balance of system components tailored to fuel cell stacks (minimise weight and increase efficiency)	Low cost and high efficient compact heat exchangers, optimised for fuel cell stack.	2020-2035	●	●	●
	Improvements in compressor efficiency and costs.		●	●	●
	Standardisation of balance of systems components across applications, tailored to the fuel cell stack for maximum efficiency.	2025-2035	●	●	●
	Developing single system solutions that fulfil multiple functions e.g., valves, ejectors & blowers.		●	●	●
	Develop embedded balance of system monitoring, diagnostics and self-correcting sensors and related software that reduce service interventions and increase lifespan.		●	●	●
	SOFC: Develop efficient closed loop water handling systems to optimise water recirculation and leverage vehicle onboard thermal management opportunities.		◒	●	◒

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

Fuel cells – technology challenges and research topics (8/12)

The research topics listed below predominately focus on the **Balance of System** section of the fuel cell 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
Energy efficient cold start support for SOFC	SOFC: Develop lower running temperature fuel cells (<600°C), to reduce demand on start-up battery power supply and overall energy consumption of the system.	2020-2035	◒	●	◒
	SOFC: High performance, low-mass and low-cost solutions for thermal insulation.		◒	●	◒
Waste energy recovery and thermal efficiency improvements	Develop compact and efficient heat exchanges to match the fuel cell stack requirements for higher efficiency gains.		●	●	●
	SOFC: Develop an energy-efficient start-up heating solutions for solid oxide cells e.g., customised batteries, thermal inertia storage, onboard heat recovery and storage.		◒	●	◒
	SOFC: Integrate waste heat recovery into fuel cell systems to recirculate heat exhausts and increase stack efficiency.		◒	●	◒
	Integrate thermal management solution across the vehicle functions to rationalise component count, weight, cost and increase total system efficiency.		●	●	●
	Develop dedicated e-boost and e-turbine solutions for single stack and multi-stack configurations.	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

Fuel cells – technology challenges and research topics (9/12)

The research topics listed below predominately focus on the **Fuel Storage and Management** section of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Low-cost hydrogen storage suitable for high-volume production	PEMFC: Develop lighter and cheaper type 3 and 4 carbon fibre reinforced tanks; optimising materials layout & production processes for high volume manufacture.	2020-2035	●	●	●
	PEMFC: Develop 350 bar and 700 bar H_2 storage tanks that are light-weight and low-cost, meeting automotive safety and high-volume manufacturing targets.				
	PEMFC: Improve pumps, regulators, connectors, values and nozzles adapted to hydrogen purity levels required for high efficiency fuel cell systems.				
	PEMFC: Develop cost-effective light-weight solutions for liquid hydrogen storage and on-board delivery systems, including high performing insulation materials to contain H_2 boil-off.				
	SOFC: Develop fuel storage and management for handling blended, alternative fuels and future net-zero carbon fuels.				
	PEMFC: Develop cost-efficient solid state hydride hydrogen storage and on-board delivery systems.	2025-2035+			
	PEMFC: Investigate advanced materials capable of storing hydrogen that have a weight or volumetric space advantage.				

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

Fuel cells – technology challenges and research topics (10/12)

The research topics listed below predominately focus on the **Fuel Storage and Management** section of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
Alternative fuel carriers for future PEMFC and SOFC	Develop low-carbon sustainable blended fuels, e.g. Hydrogen and natural gas matched to available supply suitable for fuel cells.	2020-2035	●	●	●
	Develop an understanding of ammonia fuel cells and their attributes for automotive applications, e.g., storage, odour issues, range, efficiency, after-treatment, purity levels etc.		◒	●	◒

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

Fuel cells – technology challenges and research topics (11/12)

The research topics listed below predominately focus on the **Control Systems** section of the fuel cell 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
Control systems and sensors to extend stack life and performance	Improve data harvesting for enhancing simulation modelling and developing control systems.	2020-2025	●	●	●
	Improve sensors for air and fuel toxins, including impurity monitoring.		●	●	●
	Develop advanced modelling and controls systems for optimising hybridised fuel cell and batteries powertrain systems.		◒	●	◒
	Develop advanced on-board diagnostics for stack and system health monitoring.	2020-2035	◒	●	◒
	On-board fuel flow sensor for different fuel blends and types, e.g., H_2/NG blends, ammonia.		●	●	●
	Develop in-situ sensors that support stack diagnostics and health management data that feeds advancing control systems.	2025-2035	●	●	●
	Improve model-based control, advanced AI technology and machine-learning technologies to enable connected fuel cells for self-diagnostics and corrective stacks.	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

Fuel cells – technology challenges and research topics (12/12)

The research topics listed below predominately focus on the **Life Cycle** section of the fuel cell technology roadmap.

Technology Challenge See all challenges	Examples of research topics	Time Horizon	LDV	HGV & OH	Bus & Coach
LCA focussed manufacturing methods and carbon-neutral production	Develop specific life cycle assessment (LCA) standards and protocols for fuel cell manufacturing that can be adopted across industry.	2020-2025	●	●	●
	Develop energy efficient manufacturing for intensive processes, e.g., electrolyte membranes, catalyst coating, gas diffusion layers.	2025-2035			
	Develop closed-loop circular supply chains for high value stack materials that are energy efficient and economically viable, including; end-of-life reuse.				
	Develop solutions to eliminate environmental hazardous substances in manufacturing, including attention to volatile organic compounds (VOC) and water, for LCA improvements.				
	Develop a fuel cell health passport that allows for second life or end-of-life re-use and recycle across the supply chain.				

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

Fuel Cell

Technology Roadmap

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

automotive council UK

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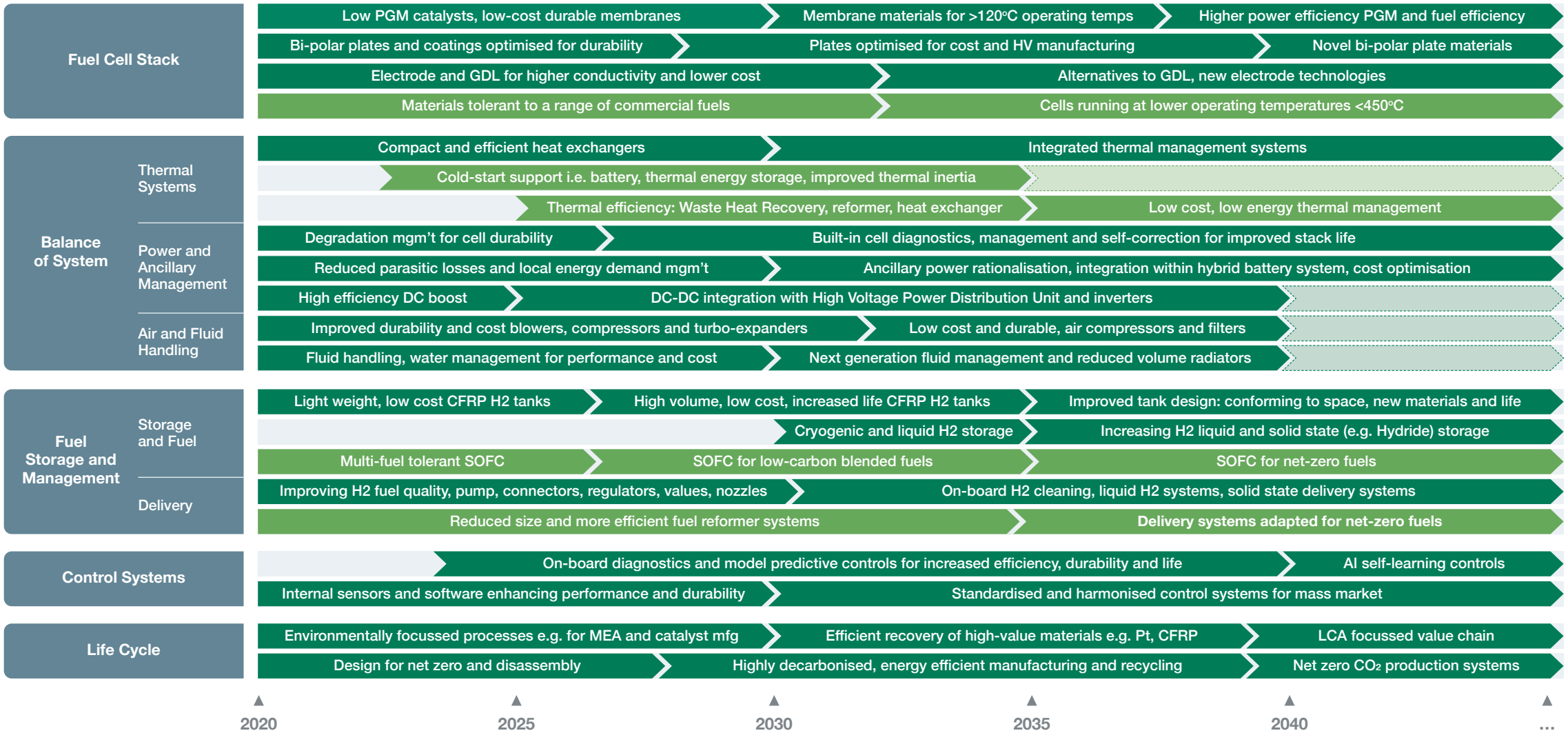
This roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass market adoption. Specific application-tailored technologies will vary from region to region.

Light bar: *SOFC Specific technologies for mass market application*

Dark bar: *Common or PEM – 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.

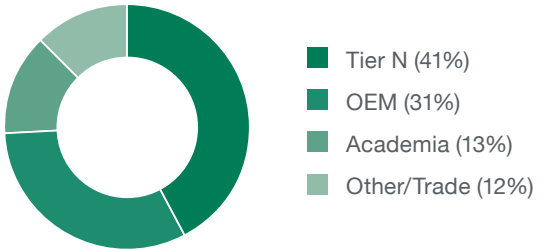
APC Spoke specialists

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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