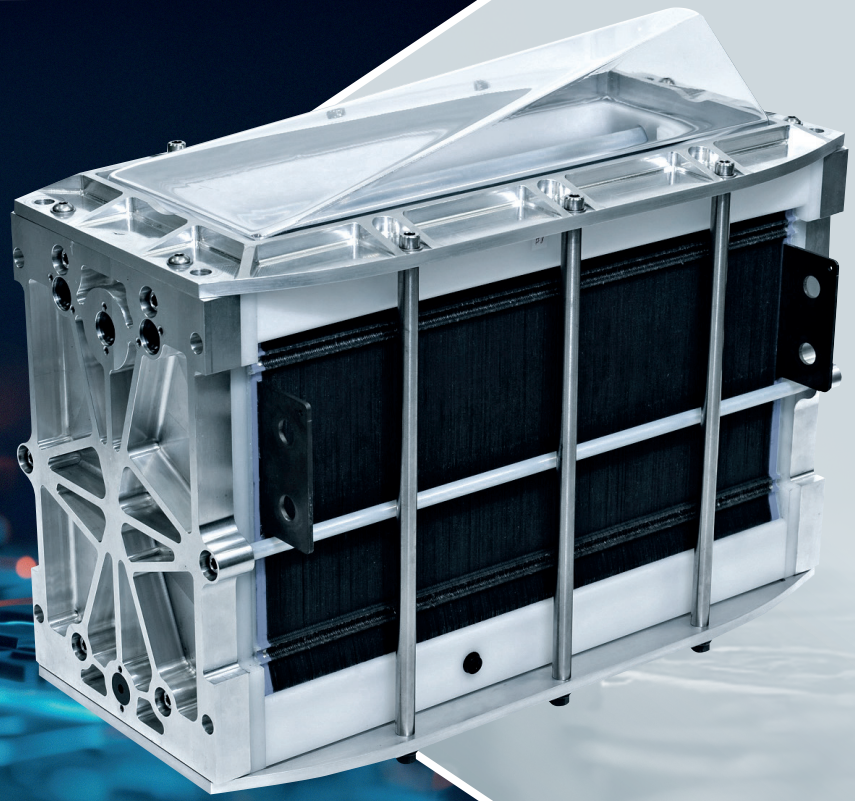
Hydrogen Fuel Cell System and Hydrogen Storage

Technology Roadmap

2024



automotive council UK

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Produced by the Advanced Propulsion Centre UK on behalf of the Automotive Council UK
Information correct at time of publication

Introduction to the technology roadmap

The 2024 technology roadmaps provide a view of technology adoption in the automotive industry. These roadmaps help academia, industry and policy-makers understand where research and development (R&D) efforts are likely to be focussed, highlight key milestones in technology adoption, and through the supporting documents explore challenges and opportunities.

The documents available for each roadmap are as follows:

The executive roadmap

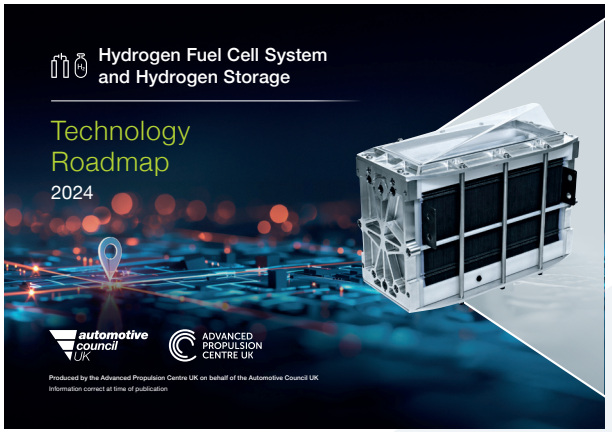
The executive roadmap provides a high-level view of forecast mass adoption of technology within the automotive industry. Mass adoption requires technology, supply-chain, manufacturing and market readiness and in some instances, regulatory readiness.

The narrative report

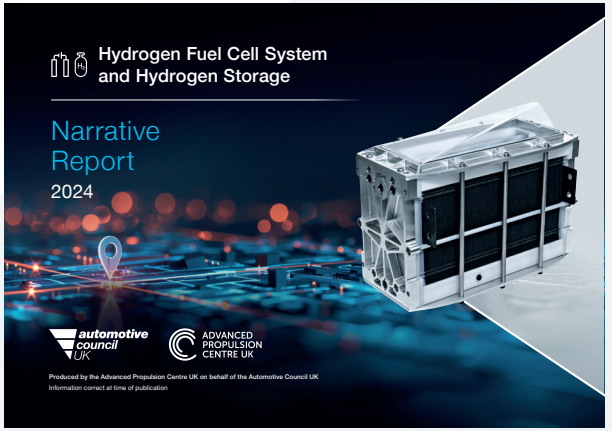
The narrative report supports the executive roadmap by providing the context behind the technologies on the roadmap. The narrative considers regulatory and market drivers alongside the work required to develop individual technologies and their supply chain.

The innovation opportunities report

The innovation opportunities report is intended to take a deeper dive in to the R&D steps required to enable technologies on the roadmap.



Technology roadmap

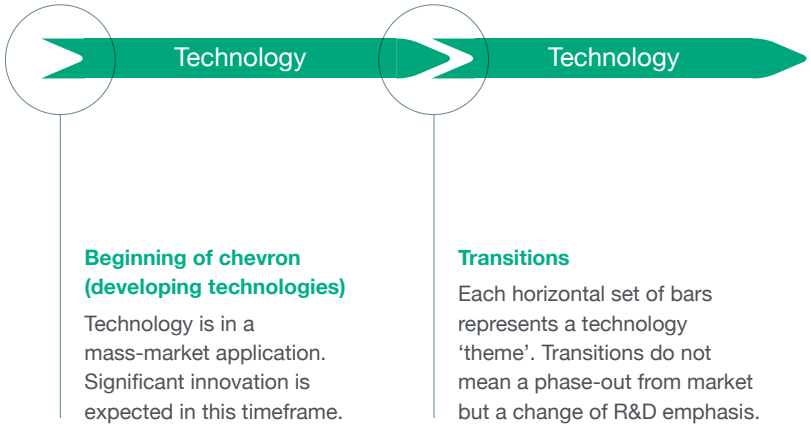


Narrative report

Introduction to the technology roadmap

This technology roadmap represents a snapshot-in-time view of the global automotive industry propulsion technology forecast for mass-market adoption.

- Chevrons with text describing a technology indicate when a technology is expected to reach mass-market adoption in the automotive industry.
- Technology adoption will vary from region to region, this is recognised and discussed in the narrative report that accompanies this executive roadmap.
- Technology adoption varies within different sectors of the automotive industry and, where appropriate, this is indicated on the roadmap and discussed in the accompanying narrative report.
- Some technologies may be feasible before appearing on the roadmap, many technologies that do not appear until later are technically feasible now. However, the roadmap considers not just technology maturity but also market, supply chain and regulatory impacts. These are discussed in the accompanying narrative report.
- Some chevrons appear to start on the 2025 line, this is considered as equivalent to a technology being available now.



Beginning of chevron (developing technologies)

Technology is in a mass-market application. Significant innovation is expected in this timeframe.

Transitions

Each horizontal set of bars represents a technology ‘theme’. Transitions do not mean a phase-out from market but a change of R&D emphasis.

Fuel cell system roadmap

See page 6

Hydrogen storage roadmap

See page 11

Technology indicators for light-duty and heavy-duty applications

Technology indicators that industry is likely to achieve in a mass-market competitive environment. All the cost and performance metrics are ambitious but relate to the same technology.

		2025	2030	2040
Light-duty vehicles	System ($/kW)	112	68	40
	Stack ($/kW)	70	40	20
	System efficiency (%)	65	68	70
	Stack durability (Hrs)	6,000	7,000	8,000

		2025	2030	2040
Hydrogen storage tank	Onboard hydrogen storage cost ($/kg of H_2)	365	266	200

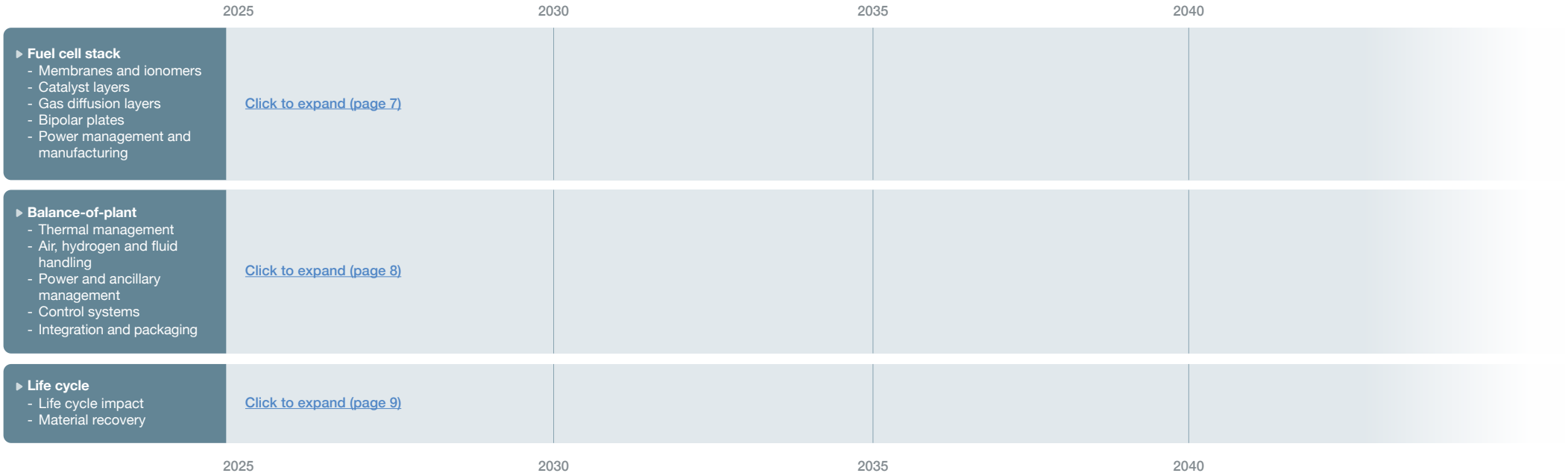
		2025	2030	2040
Heavy-duty vehicles	System ($/kW)	285	200	80
	Stack ($/kW)	180	118	40
	System efficiency (%)	65	68	70
	Stack durability (Hrs)	22,000	27,000	32,000

Notes:

- All indicators are based on averaged data and volume-corrected figures from the following published data – US Department of Energy (DoE), the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), Strategy Council roadmaps from China and Japan, supplemented with industry opinions.
- System efficiency values are based on specific rated load values for PEM. These do not represent a fuel cell system target and cannot be compared as such.
- Although single point efficiency values are shown, these are not accurate indicators of real-world vehicle efficiency, which will vary across propulsion technologies and product applications.
- Indicators are based on the following global FCEV production volumes:

2025	2030	2035	2040
40,000	600,000	>1,000,000	>3,000,000

Technology roadmap: fuel cell system



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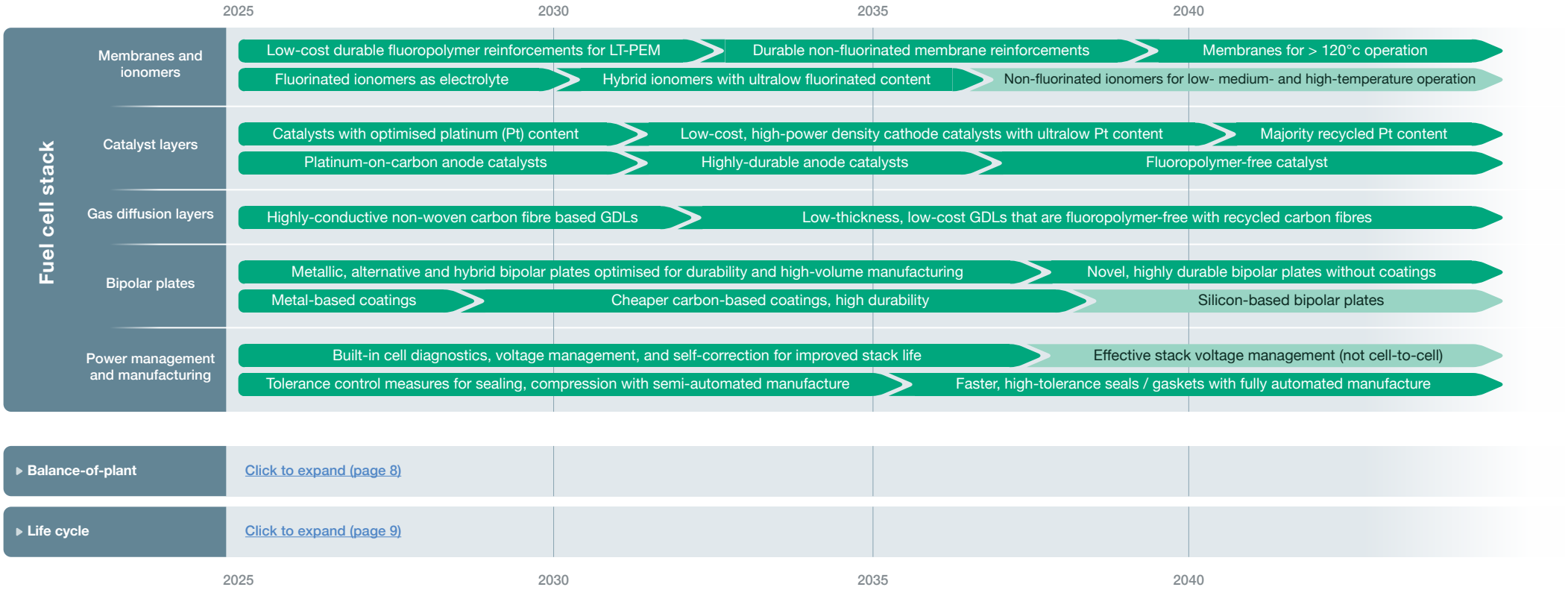
Specific application-tailored technologies will vary from region to region.

Technology roadmap: fuel cell system



Compress all

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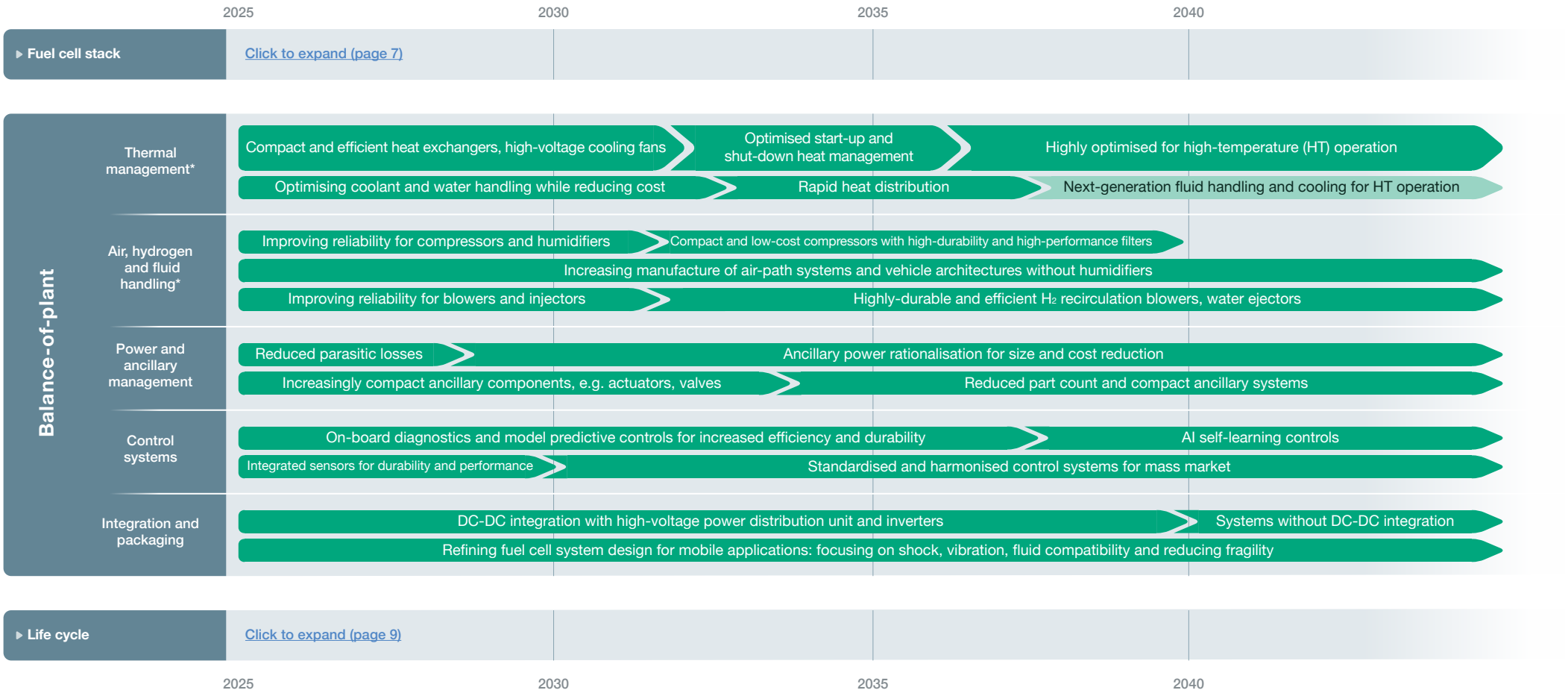

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*Hydrogen storage

Hydrogen storage is crucially important to the growth of the hydrogen fuel cell market. There is an inherent link between the technology growth in fuel cells and growth in hydrogen storage solutions, especially in the route to mass-market applications. Such technologies include:

- Type 3, Type 4 and Type 5 gaseous storage alongside cryo-compressed, liquid hydrogen and solid-state storage (page 11)
- Pressure regulation moving to consistent 700 bar with fuel supply flow rates increasing towards 5 kg / min and beyond (page 12)

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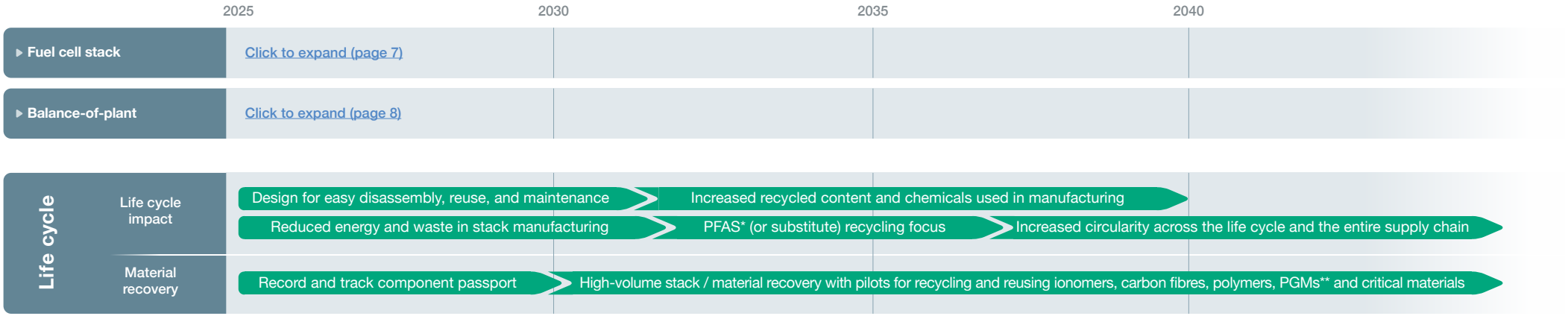

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* Per- and polyfluoroalkyl substances
** Platinum group metals

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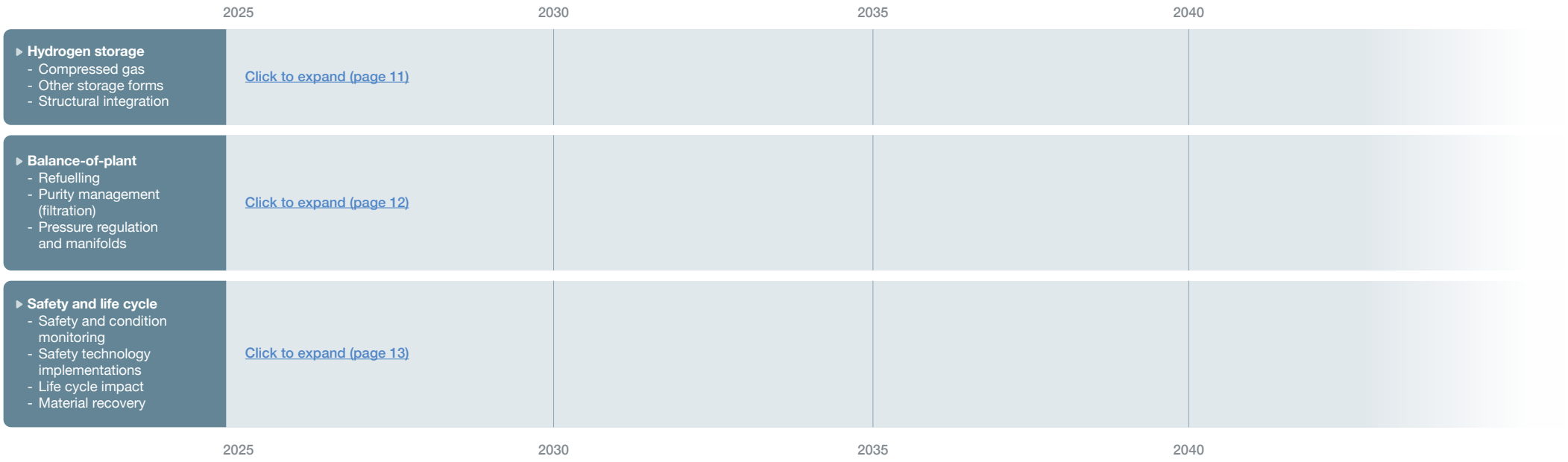

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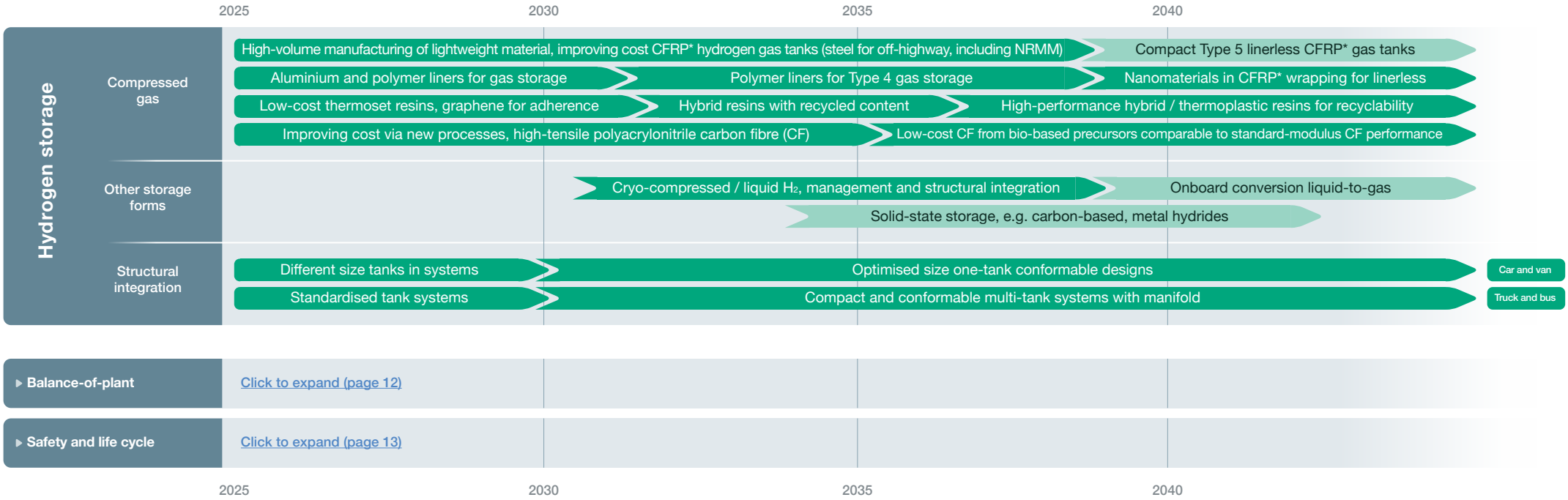

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* Carbon fibre reinforced plastics

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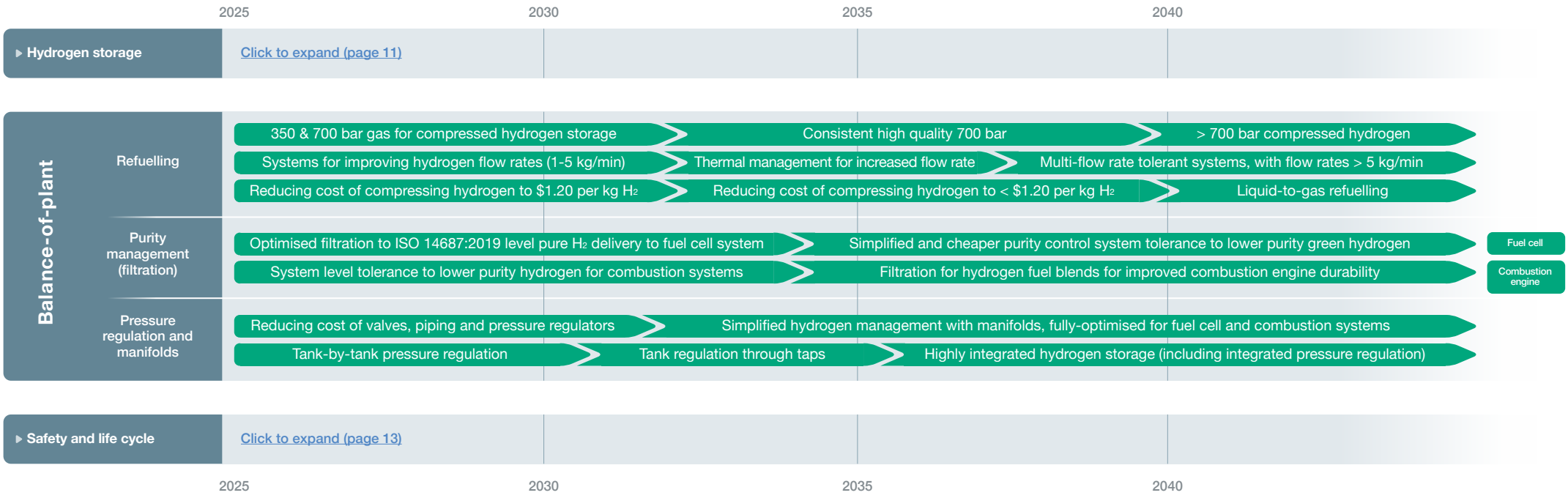

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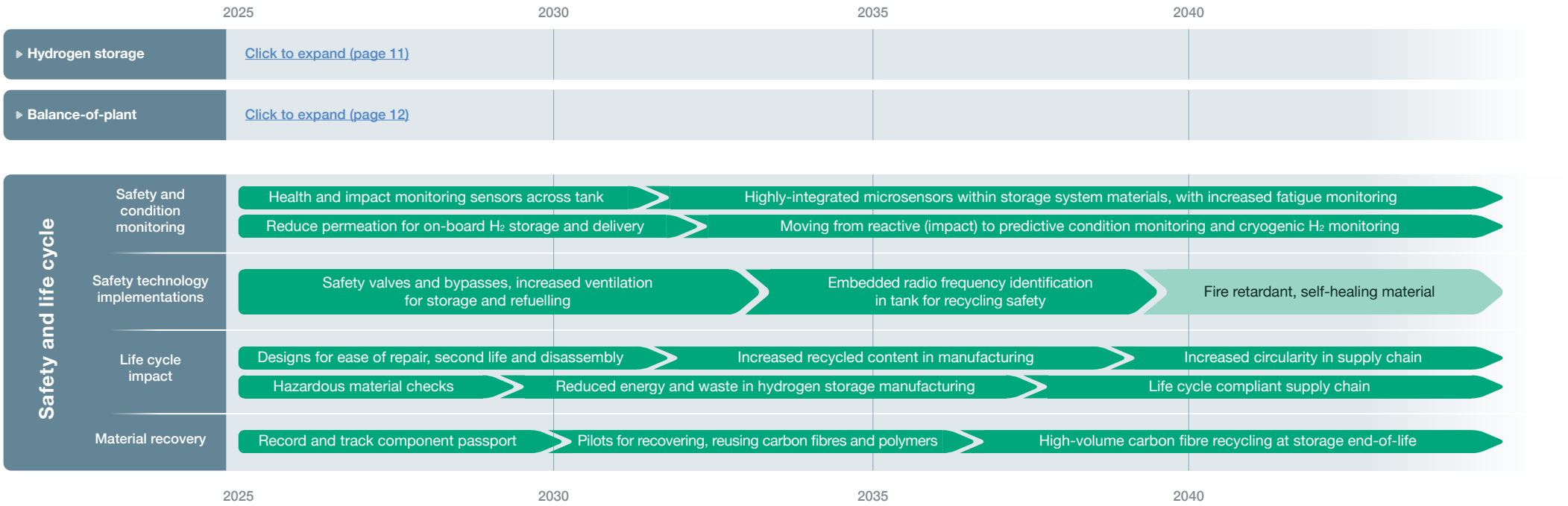

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Glossary

AFIR	Alternative fuels infrastructure regulation
AI	Artificial intelligence
BEV	Battery electric vehicle
CFRP	Carbon fibre reinforced plastic
CO_2	Carbon dioxide
CVM	Cell voltage monitoring
DoE	Department of Energy
EEA	European Environment Agency
EU	European Union
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
GDL	Gas diffusion layer
H_2	Hydrogen
HDV	Heavy-duty vehicle
HGV	Heavy goods vehicle
HT	High temperature
ICE	Internal combustion engine
MEA	Membrane electrode assembly
MOF	Metal-organic frameworks
NFC	Near field communication
NRMM	Non-road mobile machinery
OEM	Original equipment manufacturer
PEMFC	Proton exchange membrane fuel cell (or polymer electrolyte membrane fuel cell)
PFAS	Perfluoroalkyl substances
PFHxS	Perfluorohexanesulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PGM	Platinum group metals
POP	Persistent organic pollitants
Pt	Platinum
R&D	Research and Development
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RFID	Radio frequency identification
SOFC	Solid oxide fuel cell
TBO	Time between overhaul
TCO	Total cost of ownership
TEN-T	Trans-European Transport Network
UK	United Kingdom

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System-Level Roadmaps

- Mobility of People
- Mobility of Goods

Technology Roadmaps

- Electric Machines
- Power Electronics
- Electrical Energy Storage
- Lightweight Vehicle and Powertrain Structures
- Internal Combustion Engines
- Hydrogen Fuel Cell System and Storage

Find all the roadmaps at

www.apcuk.co.uk/technology-roadmaps

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Established in 2013, the Advanced Propulsion Centre UK (APC), with the backing of the UK Government's Department for Business and Trade (DBT), has facilitated funding for 304 low-carbon and zero-emission projects involving 538 partners. Working with companies of all sizes, this funding is estimated to have helped to create or safeguard over 59,000 jobs in the UK. The technologies and products that result from these projects are projected to save over 425 million tonnes of CO_2.

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

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