



Electric Machines

Technology Roadmap

2024



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

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

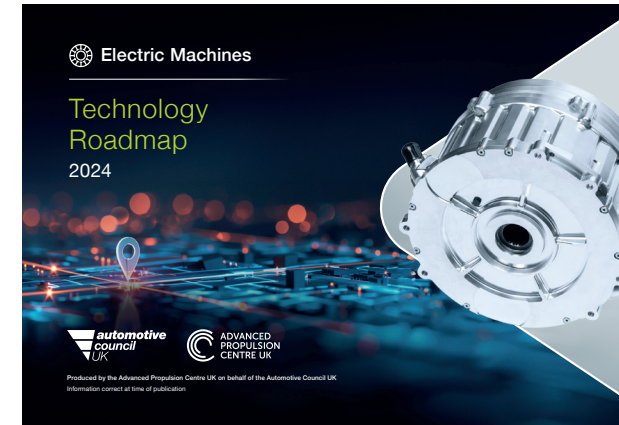
The executive roadmap provides a high-level view of forecast mass adoption of technology within the automotive industry. Mass adoption requires technology, supply-chain, manufacturing and market readiness and in some instances, regulatory readiness.

The narrative report

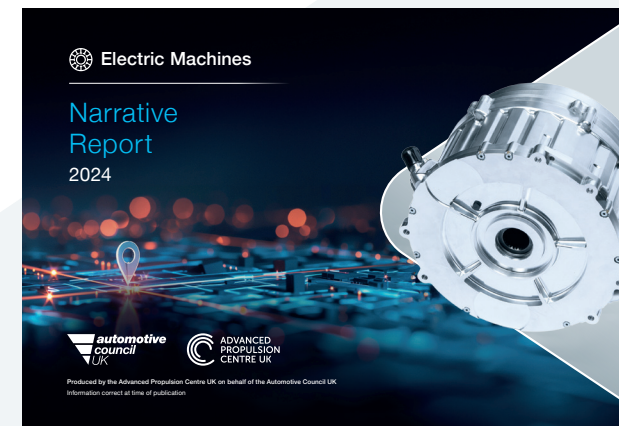
The narrative report supports the executive roadmap by providing the context behind the technologies on the roadmap. The narrative considers regulatory and market drivers alongside the work required to develop individual technologies and their supply chain.

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.



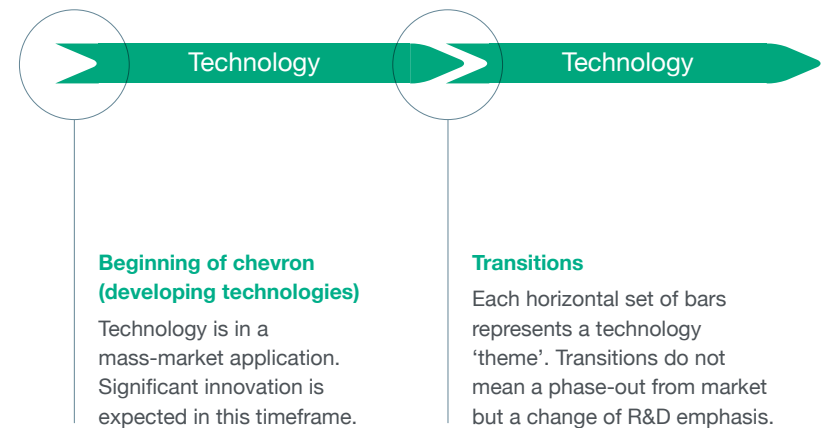
Technology roadmap



Narrative report

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.



		2025	2035	2040
Mass-volume technology	Volumetric power density (kW/l)	25	35	40
	Gravimetric power density (kW/kg)	8	12	16
	Peak power (kW)*	120-250	>250	>250
	Continuous power (kW)*	50-150	150	≥150

		2025	2035	2040
HDV	Volumetric power density (kW/l)	6	10	14
	Gravimetric power density (kW/kg)	4	6	8
	Peak power (kW)*	250-500	300-500	400-500+
	Continuous power (kW)*	150-350	180-350	250-350+
	Continuous torque (Nm)	480-800	800-1200	1000-1200+
	Peak torque (Nm)	800-1500	1500-2000	2000+

		2025	2035	2040
Luxury technology	Volumetric power density (kW/l)	35	50	60
	Gravimetric power density (kW/kg)	8	14	18
	Peak power (kW)*	350	500	>500
	Continuous power (kW)*	230	400	>450

		2025	2035	2040
Off-highway (including NRMM)**	Volumetric power density (kW/l)	6	10	14
	Gravimetric power density (kW/kg)	4	6	8
	Peak power (kW)*	<100	<150	<150
	Continuous power (kW)*	<55	<75	<75
	Continuous torque (Nm)	480-800	800-1200	1000-1200+
	Peak torque (Nm)	800-1500	1500-2000	2000+

		2025	2035	2040
High-performance technology	Volumetric power density (kW/l)	35	50	65
	Gravimetric power density (kW/kg)	10	15	23
	Peak power (kW)*	>500	500-800	>800
	Continuous power (kW)*	450	650	>650

*potentially delivered by multiple motors

Power density is based on the e-motor only (including active and passive mass of e-motor)

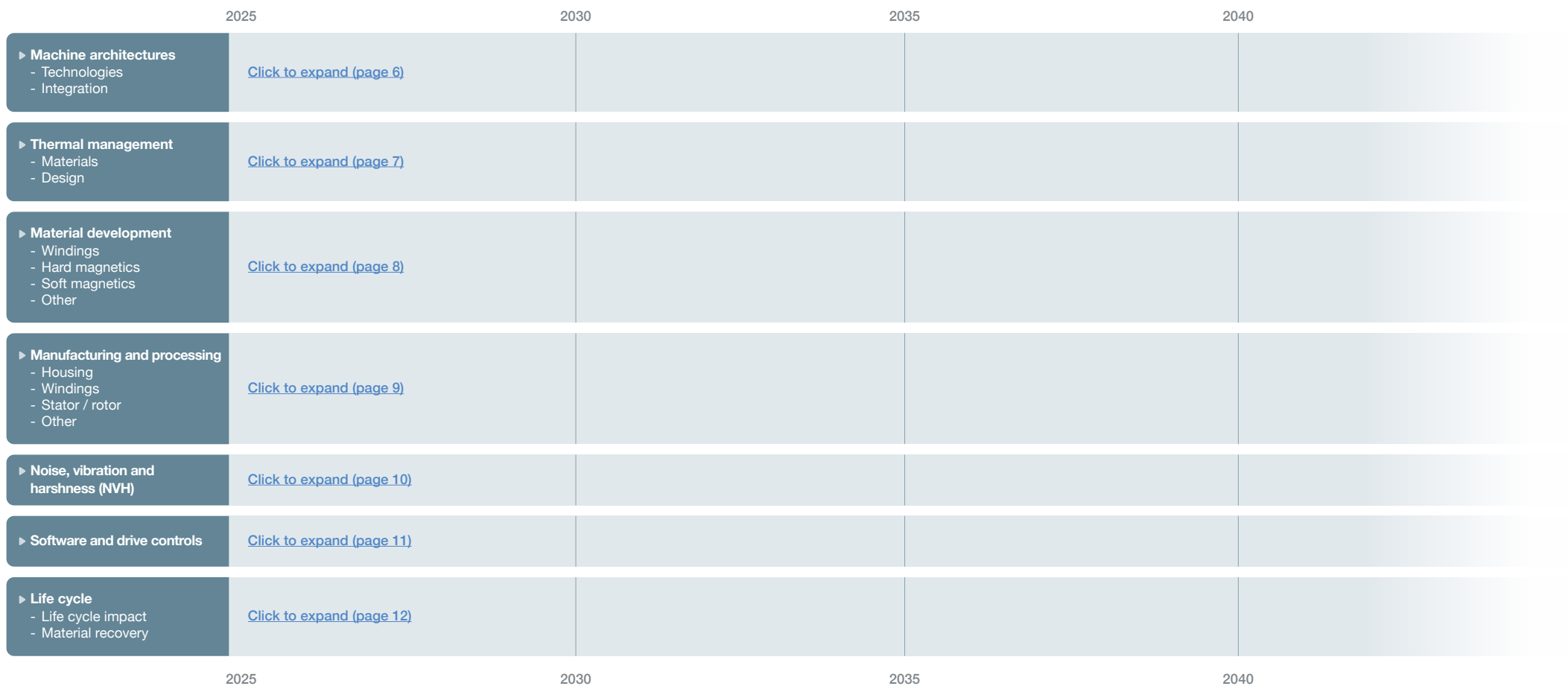
Continuous power and torque should be sustainable for at least 15 minutes (for NRMM 260 minutes)




Power is Net Power, as defined in ECE R85

**NRMM with lower power requirements such as forklifts

- ▶ Technology is in a mass market application. Significant innovation is expected in this timeframe.
- ▶ Transitions do not mean a phase-out from market but a change of R&D emphasis.
- ▶ Fluid timings: these technologies have less consensus on when they will occur on the timeline, and may be implemented earlier or later than they appear. They may be adopted in niche vehicle applications.

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.



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- ▶ Thermal management
- ▶ Material development
- ▶ Manufacturing and processing
- ▶ Noise, Vibration and harshness (NVH)
- ▶ Software and drive controls
- ▶ Life cycle

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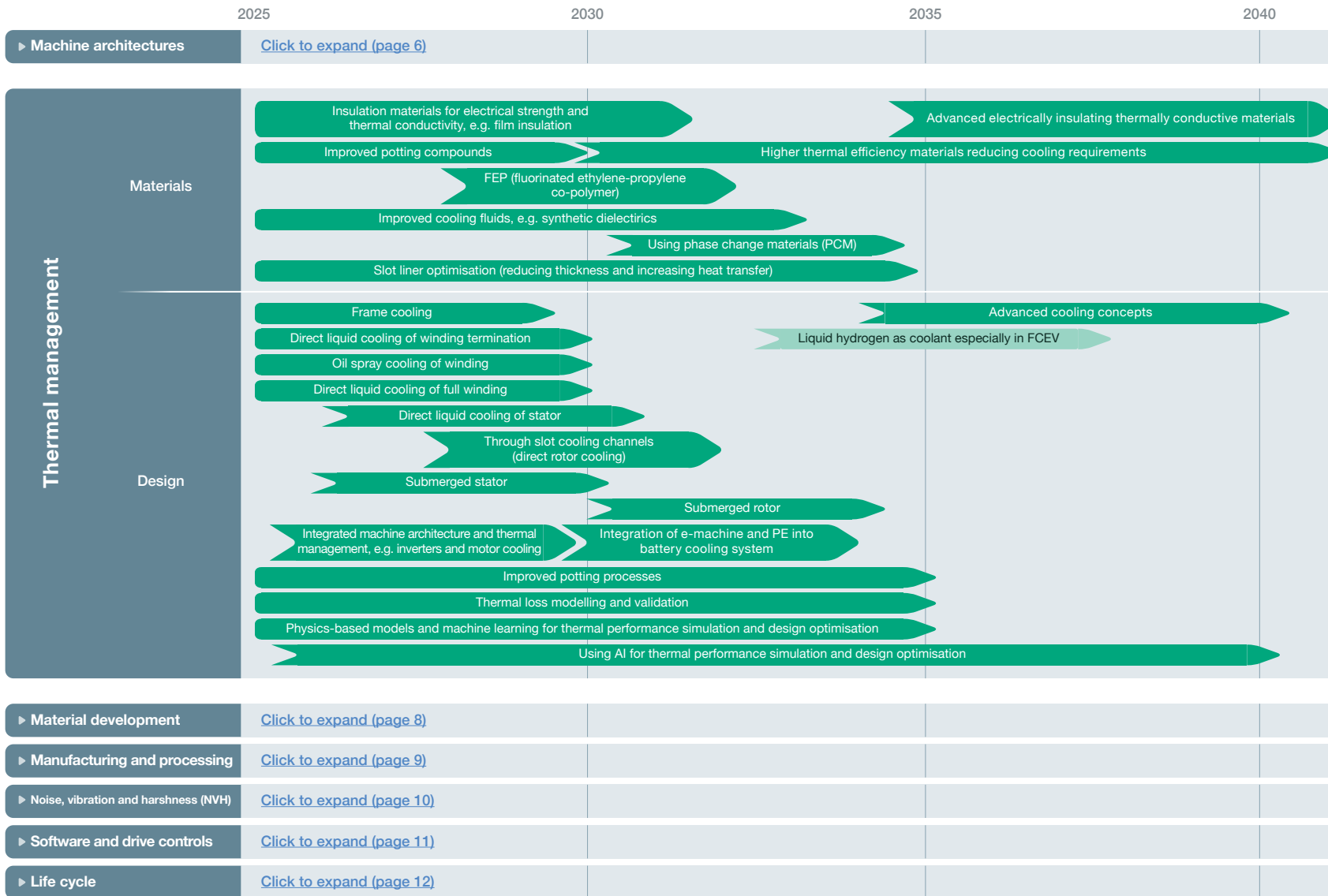
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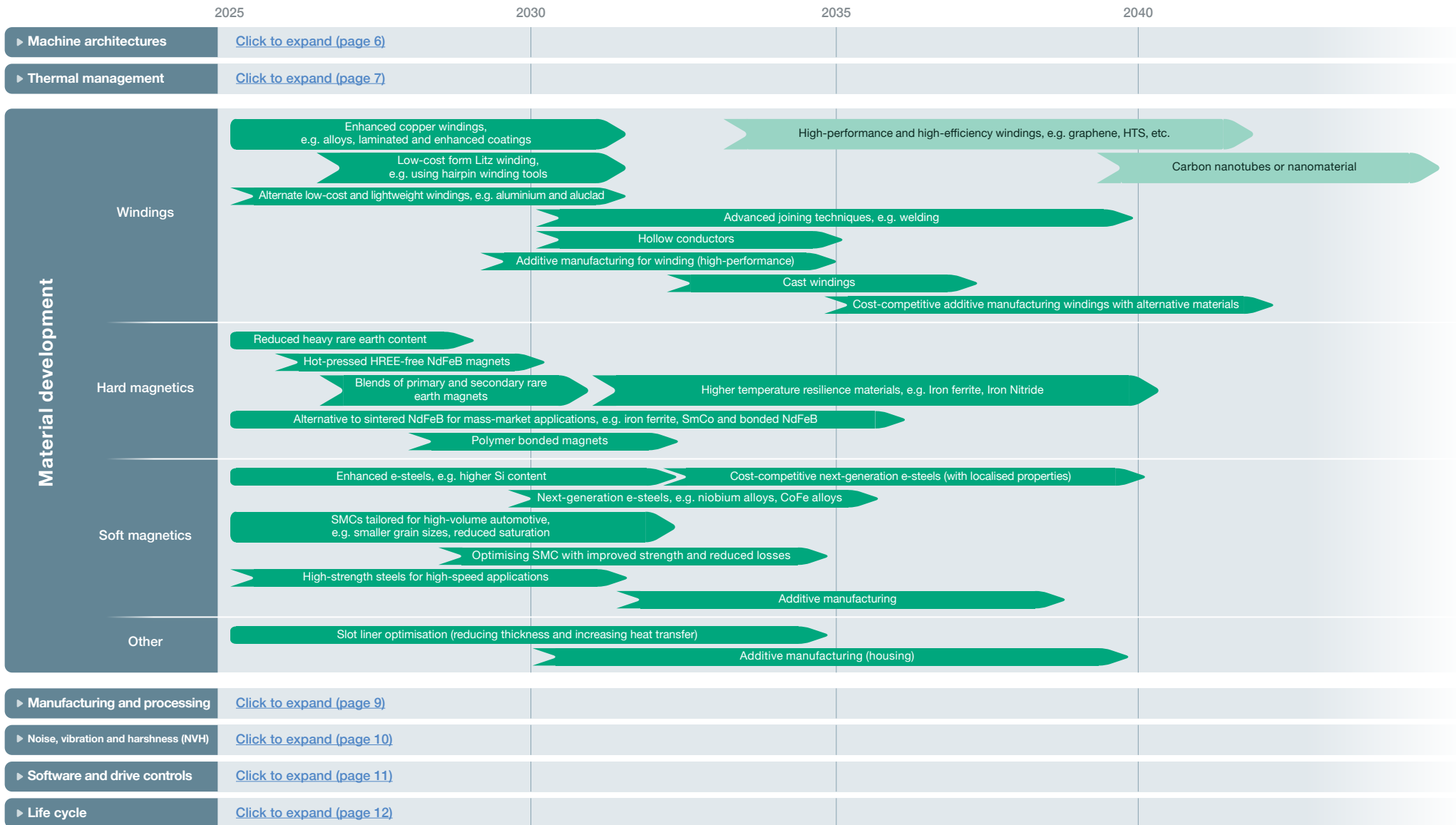
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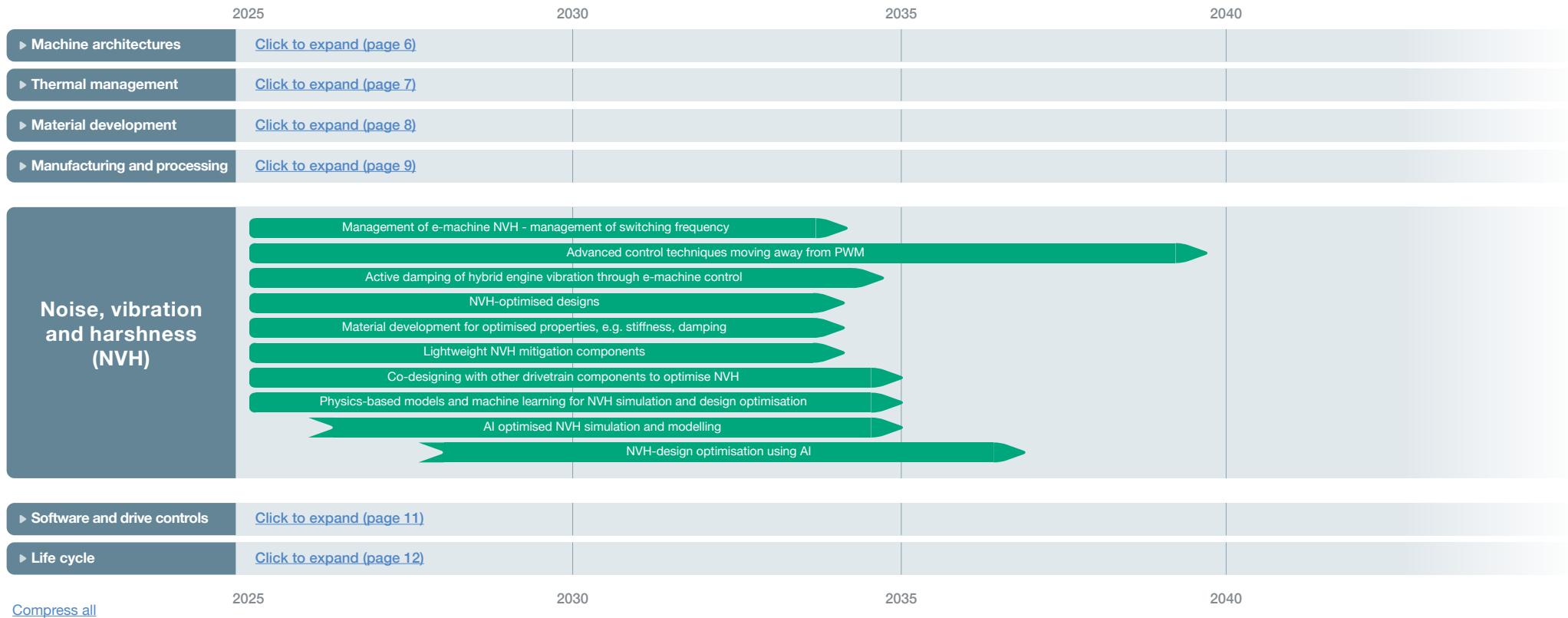
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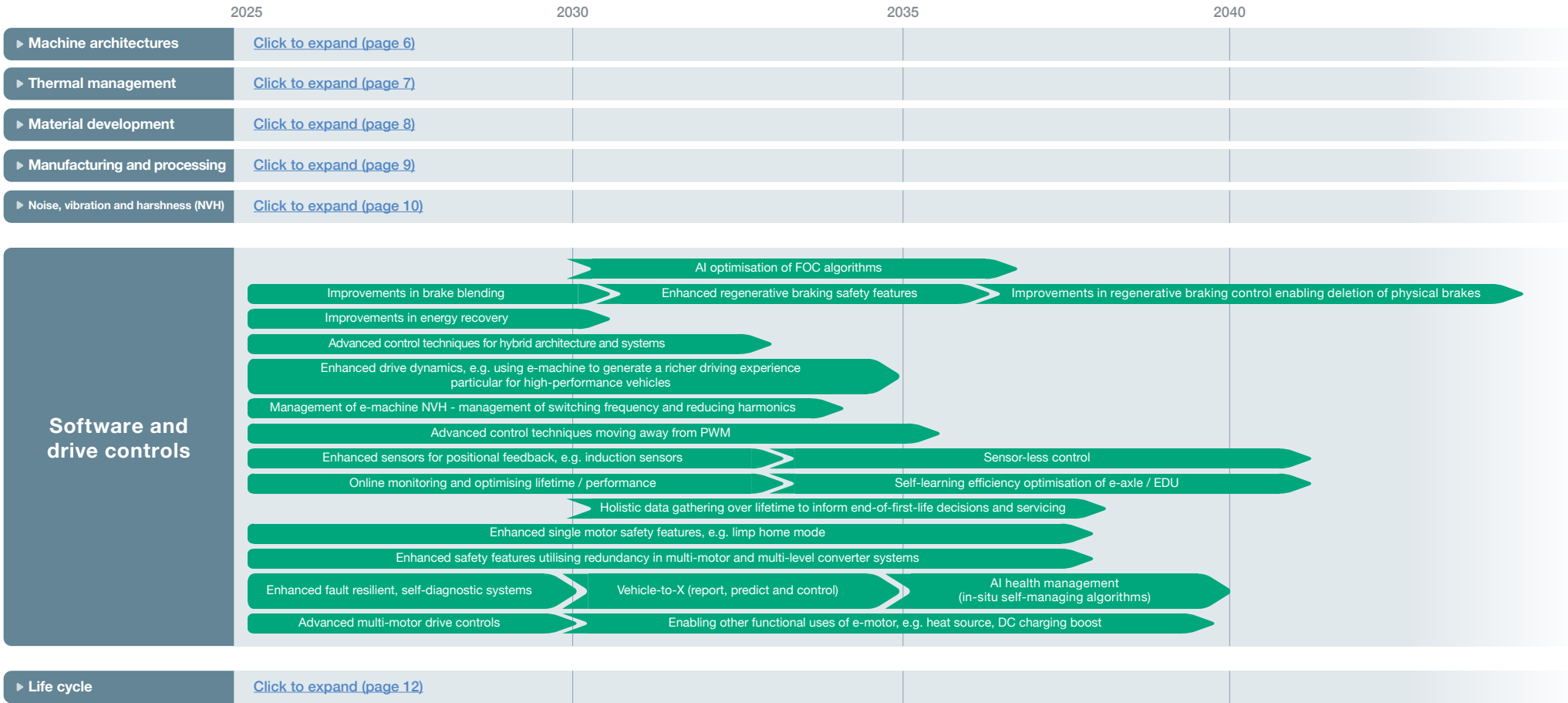
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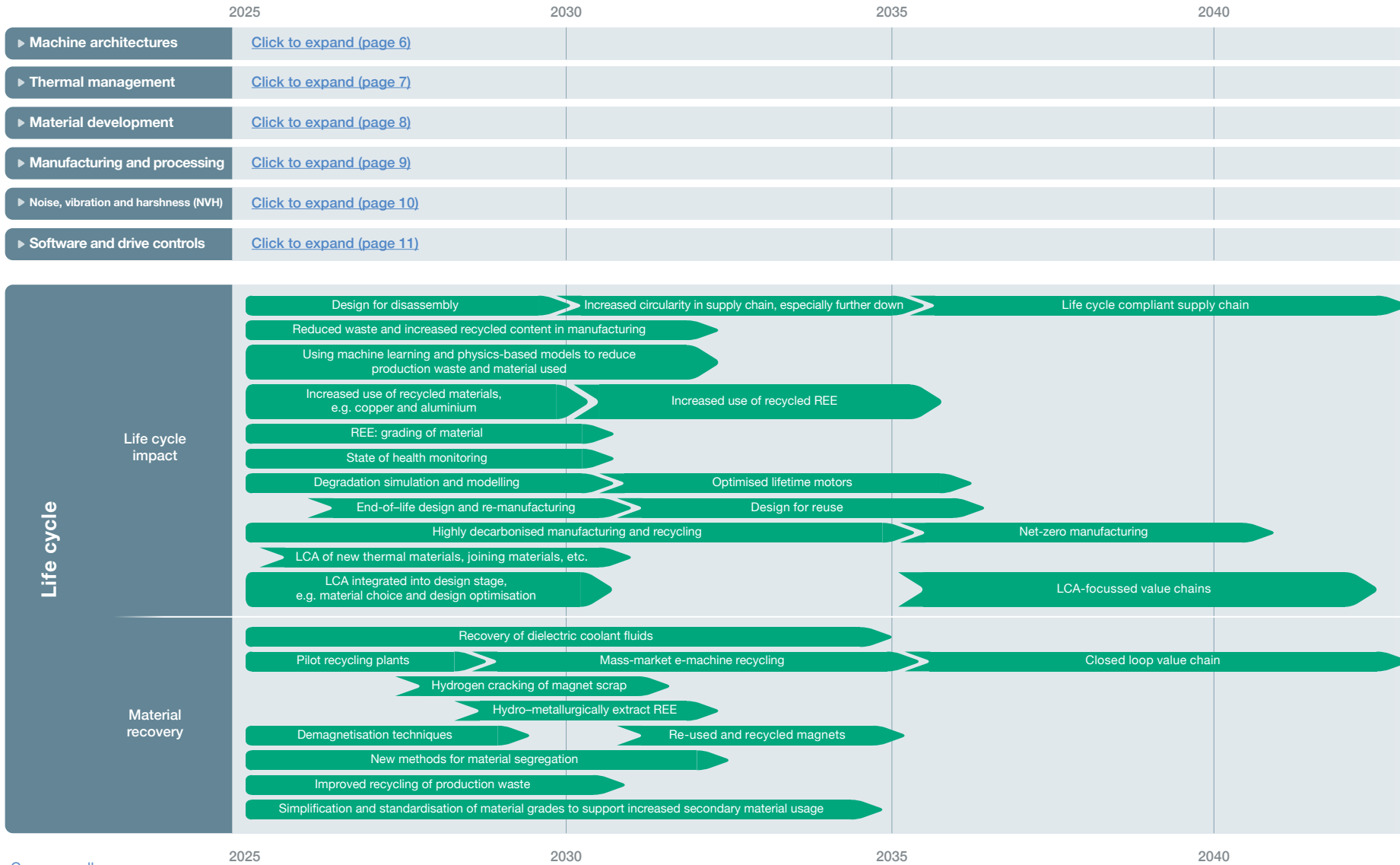
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APC	Advanced Propulsion Centre UK	LLM	Large language models
AI	Artificial intelligence	LCA	Life cycle analysis
BEV	Battery electric vehicle	LDV	Light-duty vehicle
BMS	Battery management system	ML	Machine learning
CO ₂	Carbon dioxide	MPC	Model predictive control
CO ₂ -eq	Carbon dioxide equivalent greenhouse gas effect	NEV	New energy vehicle
EDU	Electric drive unit	NdFeB	Neodymium iron boron
EESM	Electrically excited synchronous motors	NRMM	Non-road mobile machinery
EV	Electric vehicle	NVH	Noise, vibration and harshness
EU	European Union	OEM	Original equipment manufacturer
FOC	Field oriented control	R&D	Research and Development
FEP	Fluorinated ethylene propylene	REE	Rare earth elements
FCEV	Fuel cell electric vehicle	SMC	Soft magnetic composites
HDV	Heavy-duty vehicle	SmCo	Samarium-cobalt
HTS	High-temperature superconductors	xEV	Electromotive vehicle
ICE	Internal combustion engine	ZEV	Zero emissions vehicle
IoT	Internet of things		

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



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 CO₂.

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