

# Electric machines innovation opportunities for the UK

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ADVANCED  
PROPULSION  
CENTRE UK

Accelerating  
Progress

# Automotive Council UK roadmaps 2024

## Two System-level Roadmaps

### Mobility of People



- Private
- Shared

### Mobility of Goods



- Localised
- Long-haul
- Off-highway (including NRMM)

## Six Technology Roadmaps

### Hydrogen Fuel Cell and Storage



H<sub>2</sub> Fuel Cell H<sub>2</sub> storage

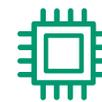
### Internal Combustion Engines



### Lightweight Vehicle and Powertrain Structures



### Power Electronics



### Electric Machines



### Electrical Energy Storage (EES)



Digitalisation, software and control systems

Materials and manufacturing / circularity and life cycle impact

Energy and infrastructure

# How do our technology roadmaps look?: A sample from Electric motors

	2025	2030	2035	2040
<b>Machine architectures</b> - Technologies - Integration <a href="#">Click to expand (page 6)</a>				
<b>Thermal management</b> - Materials - Design <a href="#">Click to expand (page 7)</a>				
<b>Material development</b> - Windings - Hard magnetics - Soft magnetics - Other <a href="#">Click to expand (page 8)</a>				
<b>Manufacturing and processing</b> - Housing - Windings - Stator / rotor - Other <a href="#">Click to expand (page 9)</a>				
<b>Noise, vibration and harshness (NVH)</b> <a href="#">Click to expand (page 10)</a>				
<b>Software and drive controls</b> <a href="#">Click to expand (page 11)</a>				
<b>Life cycle</b> - Life cycle impact - Material recovery <a href="#">Click to expand (page 12)</a>				

## Technology indicators

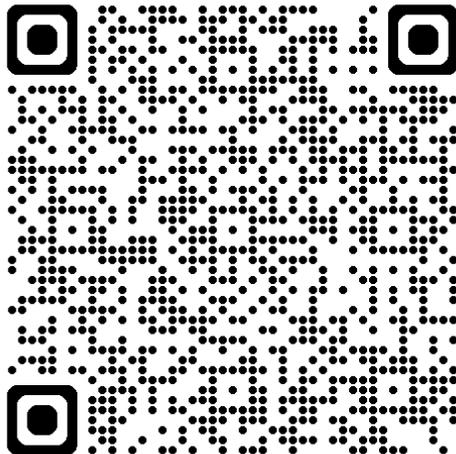
		2025	2035	2040
<b>Mass-volume technology</b>	Volumetric power density (kW/l)	25	35	40
	Gravimetric power density (kW/kg)	8	12	16
	Peak power (kW)*	120-250	>250	>250
	Continuous power (kW)*	50-150	150	≥150

		2025	2035	2040
<b>HDV</b>	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
<b>Luxury technology</b>	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

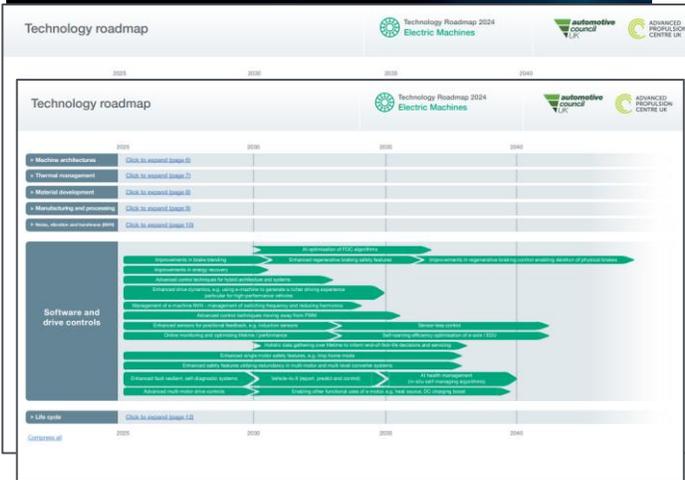
		2025	2035	2040
<b>Off-highway (including NRMM)**</b>	Volumetric power density (kW/l)	6	10	14
	Gravimetric power density (kW/kg)	4	6	8
	Peak power (kW)*	<100	<150	<150
	Continuous power (kW)*	<55	<75	<75
	Continuous torque (Nm)	480-800	800-1200	1000-1200+
	Peak torque (Nm)	800-1500	1500-2000	2000+

		2025	2035	2040
<b>High-performance technology</b>	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

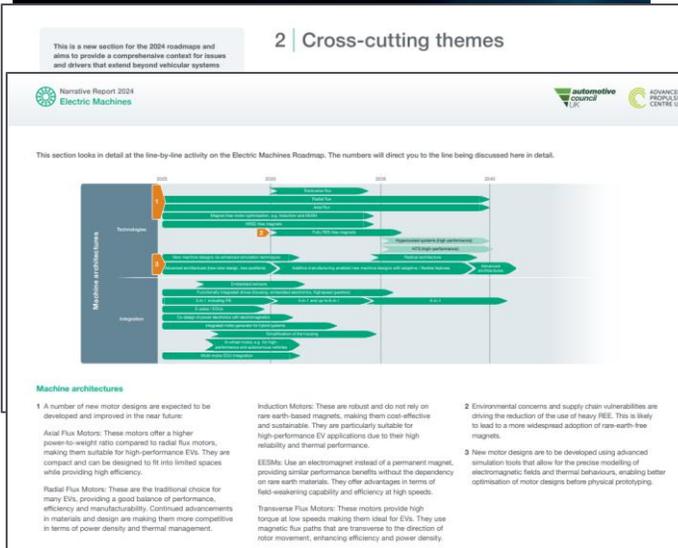


\*potentially delivered by multiple motors  
 Power density is based on the e-motor only (including active and passive mass of e-motor)  
 Continuous power and torque should be sustainable for at least 15 minutes (for NRMM 260 minutes)  
 Power is Net Power, as defined in ECE R85  
 \*\*NRMM with lower power requirements such as forklifts

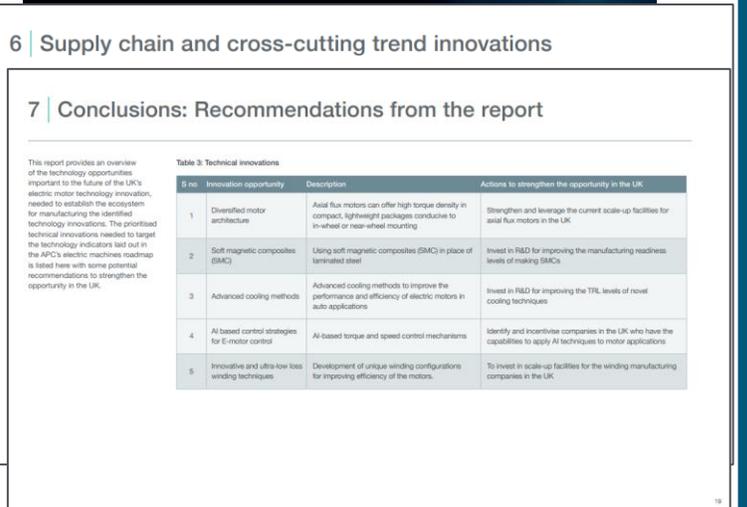
## Executive roadmaps - launched



## Narrative reports - launched



## Innovation opportunities - 2025/2026



# Structure for the innovation opportunity report

## Innovation opportunities for electric machines

### Technical innovations

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	Gravimetric power density (kW/kg)	8	12	16
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### Supply chain and cross-cutting trend innovations

Rare-earth resilience

Security of supply

Cross-cutting technology trends

Enablers and opportunities to tackle supply chain and technology trends

### Enablers and opportunities to hit technological indicators

Thermal management

Energy efficiency

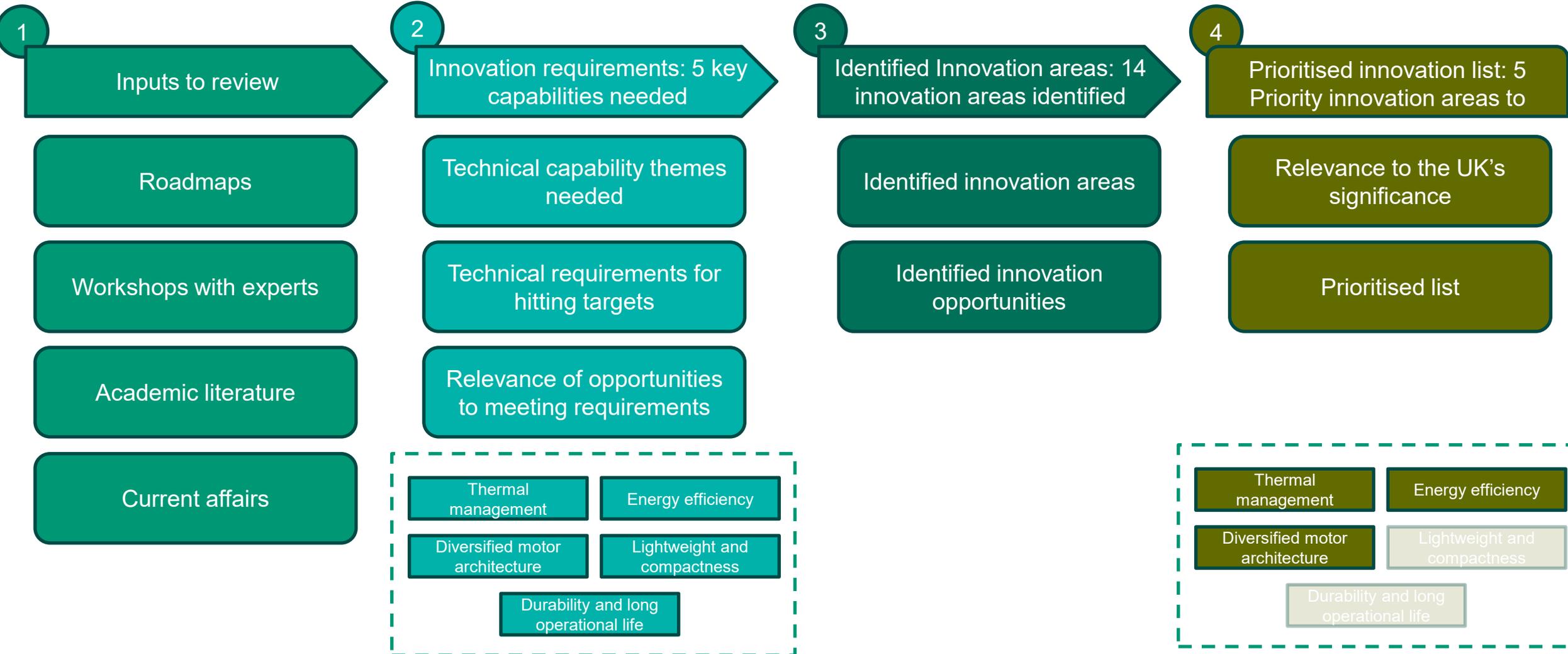
Durability and long operational life

Lightweight and compactness

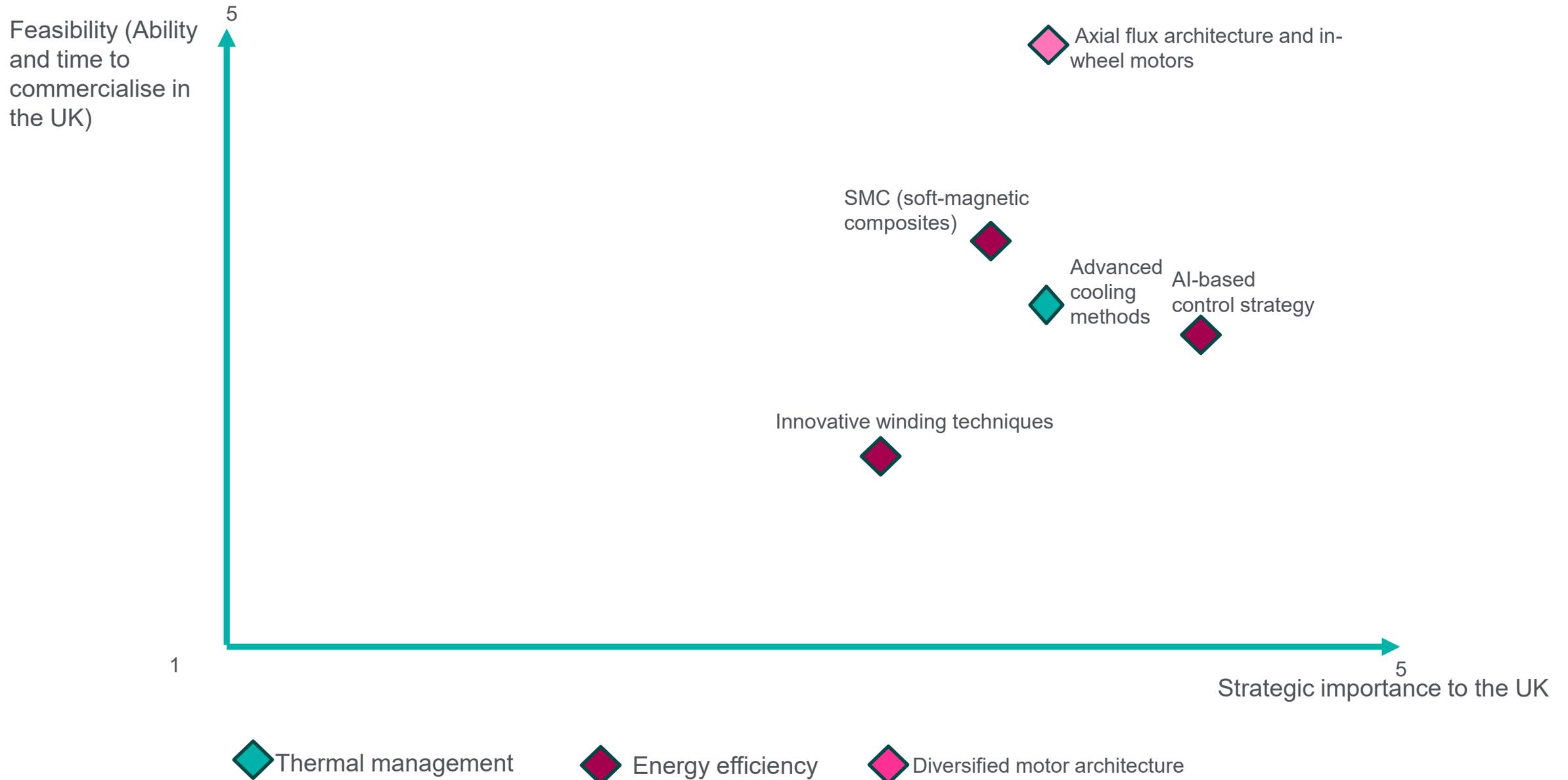
Diversified motor architecture

# Methodology for the innovation on technical pathway

There were 14 identified innovation technology priorities for the five capabilities. Within these identified innovation areas, based on the significance and the feasibility to the UK's capability, the opportunities were further aggregated into the following five prioritised innovation opportunities



# Prioritised opportunity for technical innovations



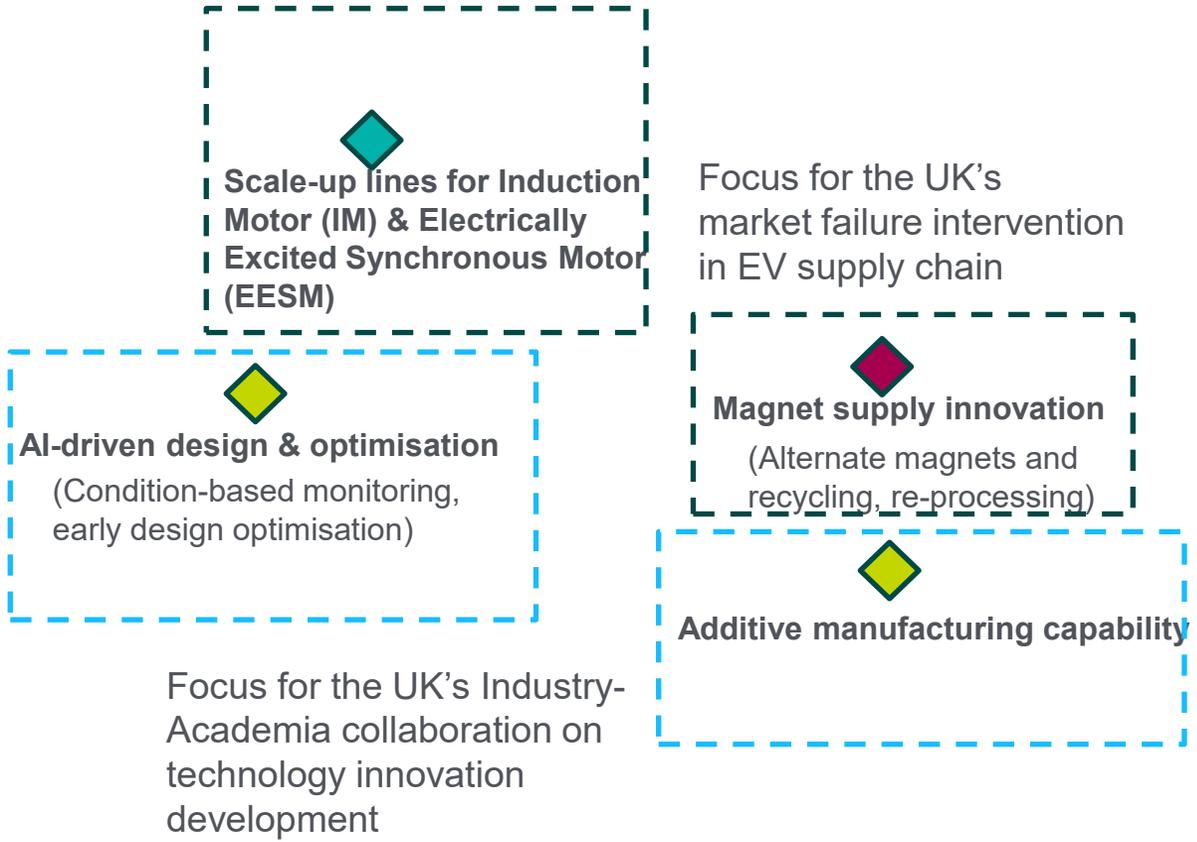
# Prioritised opportunity for supply chain and cross-cutting innovations

Feasibility (Ability and time to commercialise in the UK)

5

1

5  
Strategic importance to the UK



Focus for the UK's market failure intervention in EV supply chain

Focus for the UK's Industry-Academia collaboration on technology innovation development

-  Security of supply
-  Cross-cutting technology trends
-  Rare-earth resilience

# Summary recommendations for technical innovations

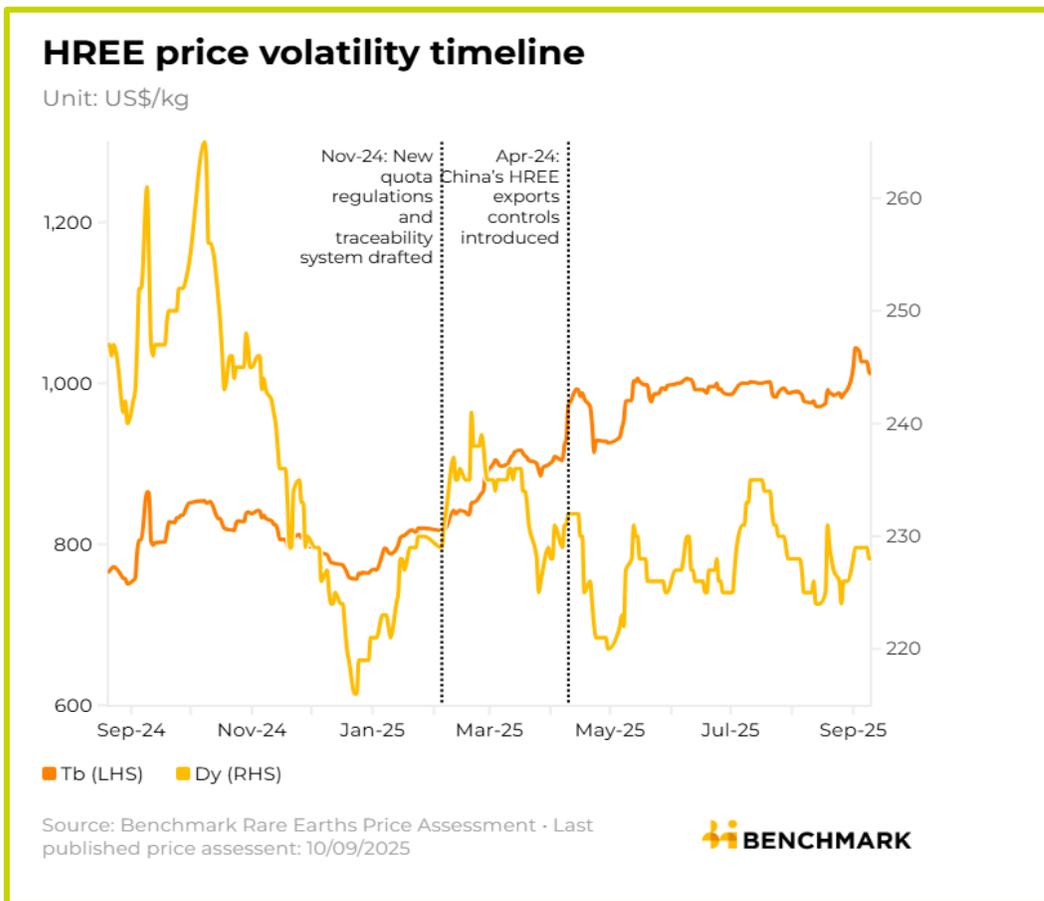
S no	Innovation opportunity	Description	Actions to strengthen the opportunity in the UK
1	<b>Diversified motor architecture</b>	Axial flux motors can offer high torque density in compact, lightweight packages conducive to in-wheel or near-wheel mounting	<b>Strengthen and leverage</b> the current scale-up facilities
2	<b>Soft magnetic composites (SMC)</b>	Using soft magnetic composites (SMC) in place of laminated steel	<b>Invest in R&amp;D</b> for improving the manufacturing readiness levels
3	<b>Advanced cooling methods</b>	Advanced cooling methods to improve the performance and efficiency of electric motors in auto applications	<b>Invest in R&amp;D</b> for improving the TRL levels
4.	<b>AI based control strategies for e-motor control</b>	AI-based torque and speed control mechanisms	<b>Identify and incentivise companies</b> in the UK who have the capabilities
5.	<b>Innovative and ultra-low loss winding techniques</b>	Development of unique winding configurations for improving the efficiency of the motors.	<b>To invest in scale-up facilities</b> for the winding manufacturing companies in the UK

# Summary recommendations for supply chain and cross-cutting trend innovations

S no	Innovation opportunity	Description	Actions to strengthen the opportunity in the UK
1	<b>Magnet supply innovation</b>	To provide opportunities in the UK for de-risking the rare-earth supply vulnerabilities	<b>Establishing advanced facilities</b> for the recycling of NdFeB magnets
2	<b>Scale-up lines for Induction motor and EESM</b>	To de-risk and accelerate the adoption of rare-earth-free motor types, which has clear environmental and supply chain benefits	<b>Set up scale-up facilities and e-motor foundries</b> for non-PM motors in the UK
3	<b>AI-driven design and optimisation</b>	To leverage the strengths of AI-driven technology trends	<b>Identify and invest in R&amp;D use cases</b> that can provide real-world objective data on the AI applications
4.	<b>Additive manufacturing</b>	Additive manufacturing for stators and rotors also presents an area of opportunity, particularly for innovative winding techniques	Work closely with <b>Industry and academia to form a collaborative research network</b>

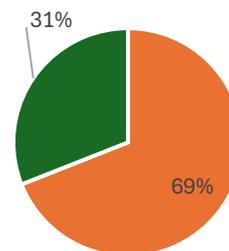
# Rare-earth export controls incoming from China

China's Ministry of Commerce (MOFCOM) has announced sweeping new export controls on lithium-ion battery components and rare earth elements. The 9 October 2025 announcement expands restrictions beyond raw materials to encompass production technologies and processing equipment, marking a major expansion of Beijing's export controls.



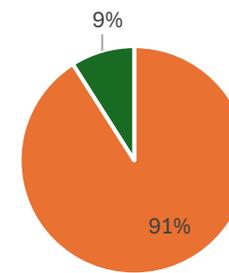
## Vertically integrated Chinese rare-earth supply chain poses a significant challenge for the European critical industries

Rare-earth mining



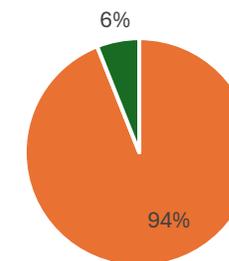
■ China ■ RoW

Rare-earth refining



■ China ■ RoW

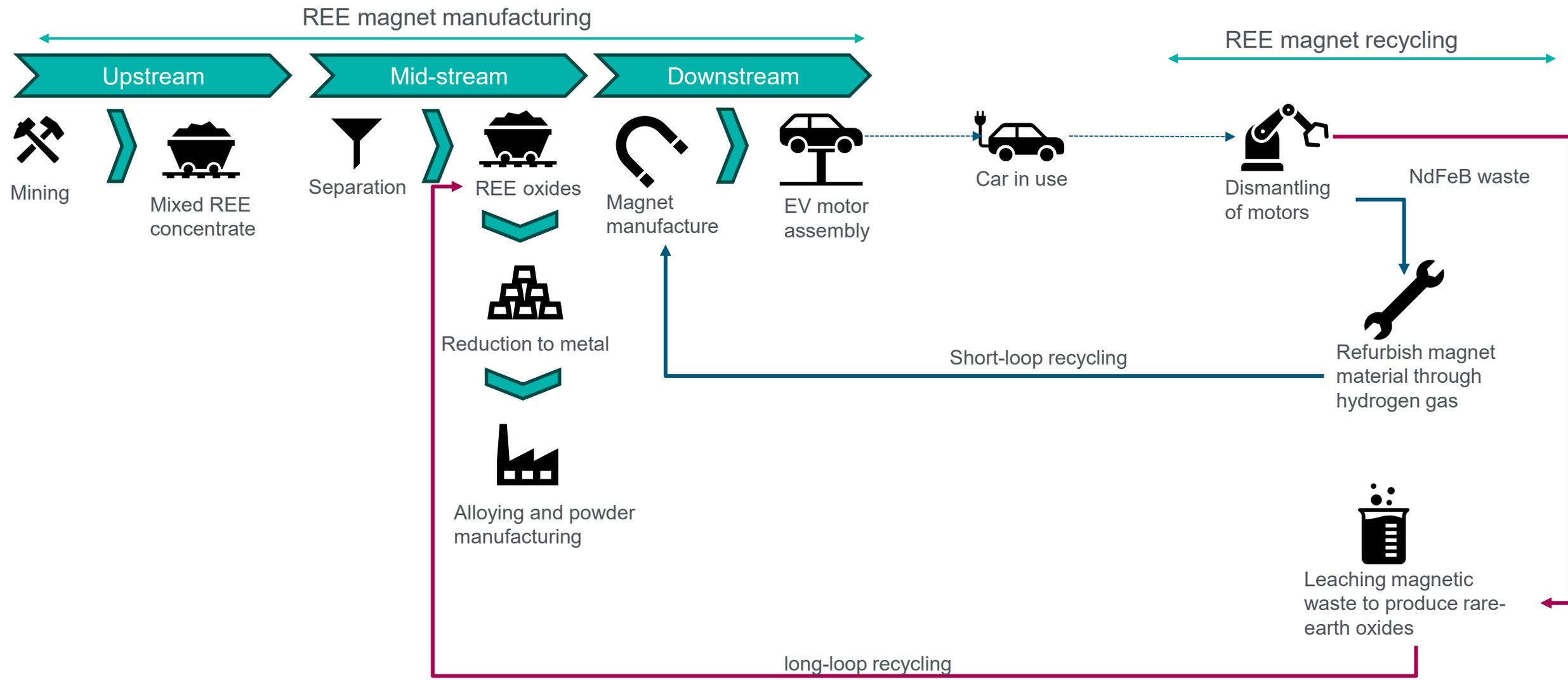
Magnet manufacturing



■ China ■ RoW

99% of the rare-earth permanent magnets are made of NdFeB, and 95% of the NdFeB used in EVs are sintered magnets.

# Magnet recycling value chain can play a key role in securing future of automotive electrification in the UK



# Developments within UK for permanent magnet recycling in short and long-loop recycling



## Site visit: HyProMag opens UK's first rare earth magnet recycling facility



HyProMag inaugurated the UK's first commercial rare earth magnet recycling and manufacturing facility on 15 January at an event attended by Benchmark rare earth analysts *Neha Mukherjee* and *Evelyn Zhou*.

Source: Benchmark Intelligence

ionic  
technologies

## Rare earth recycling plant wins £12M UK govt grant offer

Ionic Technologies' commercial-scale Belfast magnet recycling plant edges nearer

*James Stent*



UK government visit to Ionic Technologies' demonstration plant in Belfast | Credits: Ionic Rare Earths

Source: Mining Magazine

# Comparison of key rare-earth free motor technologies

The comparison shown in the table above highlights why **PMSMs remain the dominant EV motor**, combining very high efficiency and torque density with strong startup performance

Feature / Motor Type	PMSM (permanent magnet synchronous motor)	HEPM (hybrid excited permanent magnet motors)	EESM (electrically excited synchronous motor)	SRM (Switched Reluctance)	Ferrite Magnet Motor	IM (Induction motor)
<b>Efficiency</b>	Very high	High	Medium–high	Medium–high	Medium–high	Medium
Speed range	Wide (with reluctance torque)	Very wide (flux weakening)	Wide (controlled excitation)	Very wide	Moderate–wide	Wide
<b>Torque density</b>	Very high	High	Moderate	Moderate–high	Moderate	Moderate
Flux control	Fixed (limited weakening)	Fully tuneable	Fully tuneable	Limited / indirect	Fixed	Tuneable via current
Demagnetisation risk	Possible (overload/heat)	Low	None	None	Moderate–high	None
Thermal management	Challenging (rotor magnets)	Moderate–high	Moderate	Easier (robust rotor)	Moderate	Moderate
Control complexity	Medium	High	High	High	Medium	Medium
Startup torque	Excellent	Excellent (flux boosting)	Good	Very good	Good	Moderate
Cost	Moderate–high (rare earths)	Moderate–high	High (excitation system)	Low–moderate	Low–moderate	Low
<b>Rare earth use</b>	Heavy	Partial	None	None	None	None

# Rare-earth free motor landscape is evolving to cater supply chain needs

The current geopolitical risks and supply chain shocks countries outside China face due to export controls, has pushed OEMs to innovate on alternate technologies

## Externally excited / wound rotor synchronous motors (EESM aka WRSM)



## Switched reluctance and synchronous reluctance motors (SRMs & SynRM)



## Ferrite magnet motors



## Induction Motor



Source: APC Analysis  
Note: list is non-exhaustive and is constrained to traction motor applications only. Some auto OEMs not shown here may be exploring EESM/WRSM in the future but no publicly available information was found.



**Thank you for listening**

QR code links to our Knowledge Base

**Contact:**

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