Technology Roadmap, the R&D agenda & UK Capabilities

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NAIGT Organisation and Participants

NAIGT Steering Group
Chair: Richard Parry-Jones

Expert Groups

- Supply Chain Development Chair: Bob Gibbon (NSA-M)
- Technology & Low Carbon Product Development Chair: Jerry Hardcastle (Nissan)
- Technology & Low Carbon Infrastructure Chair: Jerry Hardcastle (Nissan)
- Business Environment Chair: David Smith (Jaguar Land Rover)
- Key Performance Indicators Chair: Matthias Holweg (Cambridge University)

Cambridge Business School, BMW, Retail Motor Strategy Group, National Skills Academy for Manufacturing, Bosch, GKN, Ricardo, JCB, Jaguar Land Rover, Nissan, BIS Secretariat

The Automotive Council was formed following a recommendation from the NAIGT - A key objective is to define a UK Automotive Technology Strategy

Phase 1 (Nov-Dec '08)

- Develop a mutually agreed OEM "Product Roadmap" aimed at the reduction of passenger car CO_2 emissions in line with government targets
- Compile a high level Common Research Agenda to deliver the Product Roadmap

NAIGT

Co-ordinated by RICARDO

NAIGT Report

Phase 2 (Mar-Sept '09)

- Identify technical areas of existing UK strength, weakness and potential for future development
- Identify the activities that should be a focus for R&D investment and make strategic recommendations to UK funding bodies, to maximise the benefit to UK plc

Technology Strategy Board

Co-ordinated by RICARDO

Phase 3 (Nov '09 on)

- Establish Technology Group within Automotive Council
- Identify strategic technology direction for "Automotive UK plc"
- Set short term objectives to drive technology development towards the Product Road Map

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Individual manufacturers will prioritise certain technologies to fit with brand values, but OEMs share a common view of a high level Technology Roadmap

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Phase 1 Phase 2 Phase 3

- NAIGT initiative revealed that UK Passenger Car OEM's and associated Stakeholders have developed similar views on the potential rollout of low CO_2 technologies
- Recognition that a commonly agreed "OEM Consensus Roadmap" may be of assistance to the UK in prioritising its R&D investments in meeting CO_2 challenges

Key Points related to the OEM Consensus Roadmap

- OEMs share a common product technology roadmap and recognise the same technical and commercial barriers.
- Individual manufacturers will implement technologies which best address their own brand values and market sectors.
- In the near to medium term, improvement of conventional powertrains and transmissions can have a significant impact on fleet average CO_2 by providing moderate benefits for a large proportion of the fleet.
- In the medium to longer term it is anticipated that a technology shift to alternative powertrains and transmissions will be required to achieve the CO_2 reduction targets from transport. Supported by alternative fuel delivery including grid electricity and hydrogen.
- Both electrification and fuel cell vehicle technologies rely on the concurrent development of a "clean and sustainable" supply of energy

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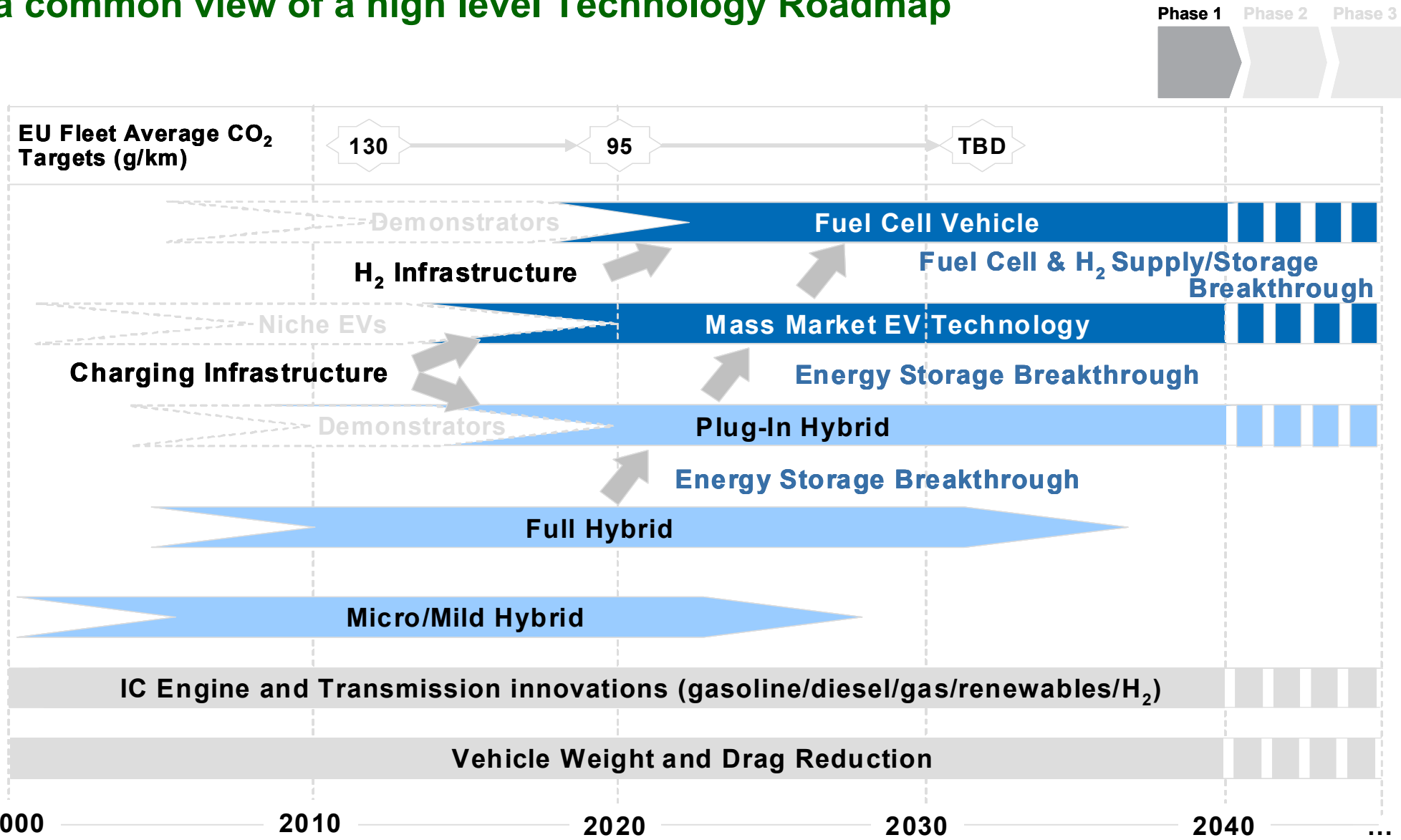
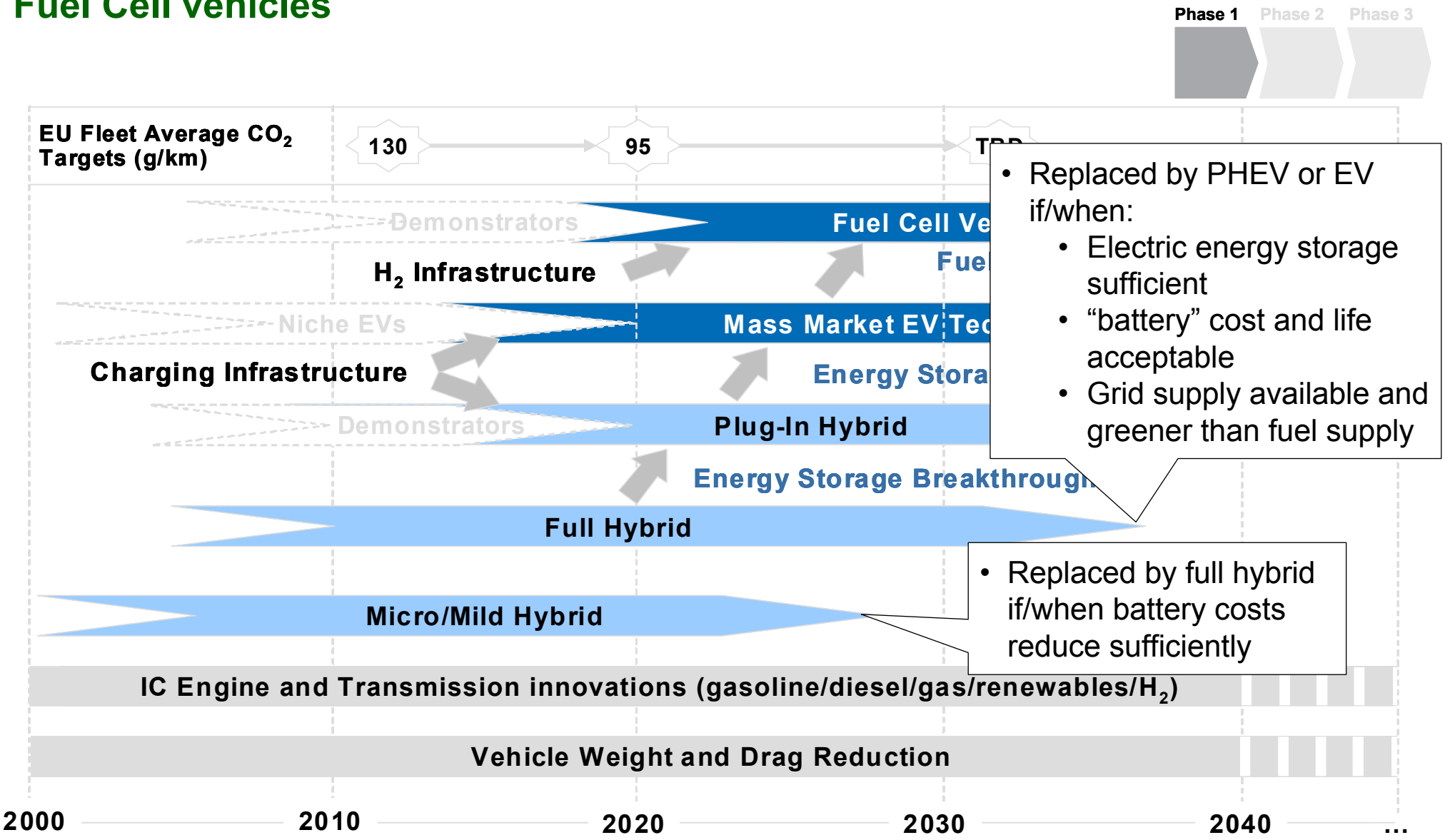
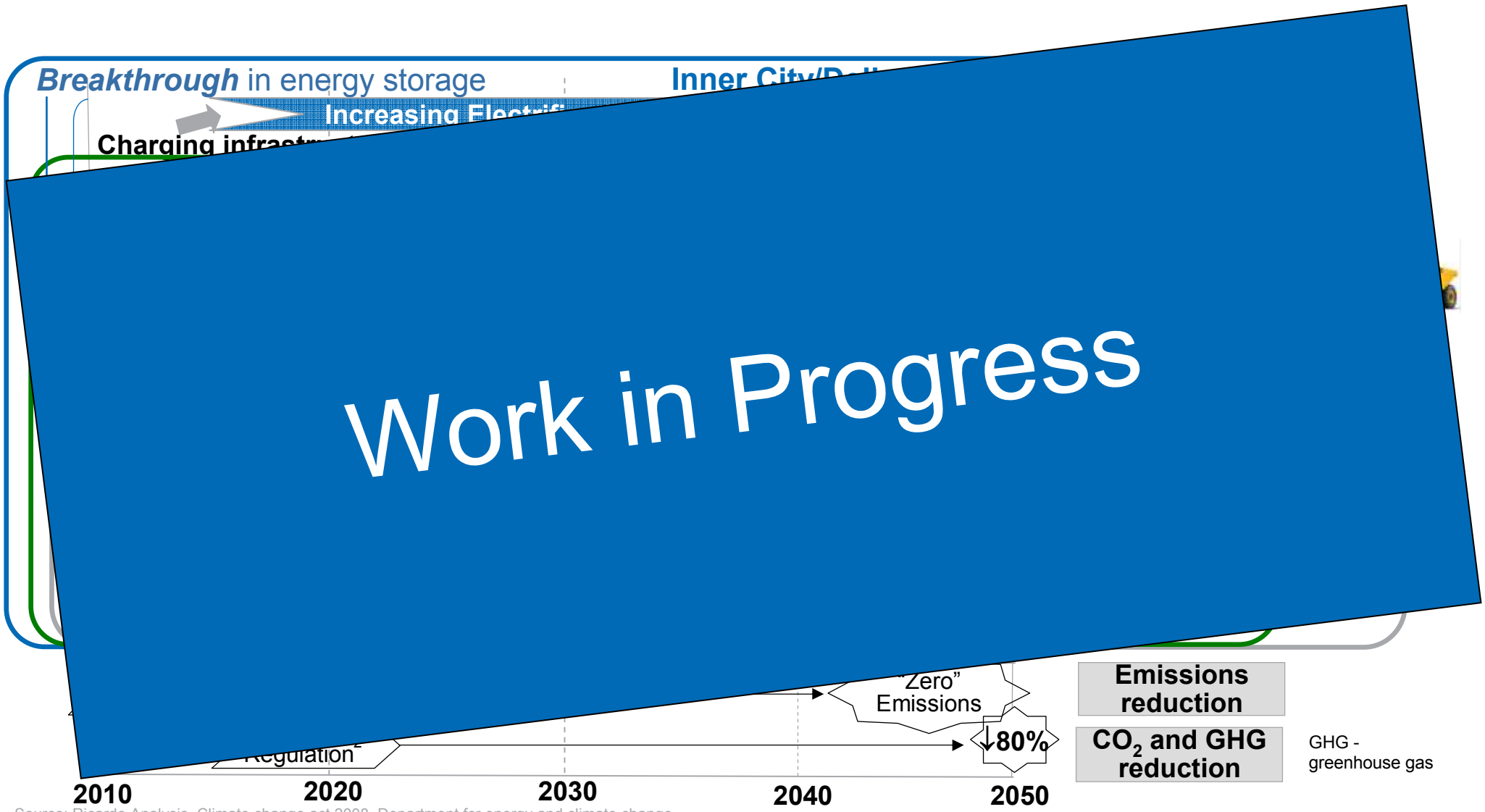


Source: An Independent Report on the Future of the Automotive Industry in the UK – New Automotive Innovation & Growth Team (NAIGT)

Consensus OEM Product Roadmap describes a longer term migration from Mild/Full hybrids to PHEV, EV or Fuel Cell vehicles



Long term low carbon *Commercial Vehicle & Off-Road* roadmap features parallel technology streams depending on duty cycle



Source: Ricardo Analysis, Climate change act 2008, Department for energy and climate change

The research required to deliver the consensus product roadmap has been outlined for three stages of investment

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- Research requirements have been compiled with input and agreement from the organisations who developed the consensus OEM Product Roadmap
- Research is categorised according to six technical areas:
  - **Propulsion** technology
  - **Energy storage** technology
  - **Vehicle efficiency** technology
  - **System control** technology
  - **Energy & fuel supply** technology
  - **Processes & tools**
- The timeframe for research is defined in terms of three stages:
  - **Short term:** pre-competitive development, 5-10 years from production
  - **Medium term:** industrial research, 7-15 years from production
  - **Long term:** fundamental research, 10-20 years from production
- Timeframes determined by the available time to target product release, assuming that research starts now – at this stage was not connected to current UK capability

Common Research Agenda to deliver Consensus OEM Roadmap:

Phase 1 Phase 2 Phase 3

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	SHORT TERM 5 – 10 years from production	MEDIUM TERM 7 – 15 years from production	LONG TERM 10 – 20 years from production
	INDUSTRY		UNIVERSITIES
Propulsion	• IC engine optimisation • Boost systems for downsizing • Flexible valve/actuation for engines/transmissions • Low cost compact e-motors	• Higher efficiency IC engines • Capacitive boost systems • All electric actuation systems • Optimised range extender engine • Lower cost e-motor • Heat energy recovery (e.g. E-turbine)	• Super high efficiency motors (superconducting) • New IC engines with 70%+ thermal efficiency • Advanced heat energy recovery (e.g. thermoelectric) • Motor/Fuel Cell materials
Energy Storage	• Improved quality / durability 200+ Wh/kg & $800/kW.h cost battery systems • Low cost power electronics	• Next gen batteries 300+ Wh/kg and $500/kW.h cost • Flexible power elec. modules • Other forms of energy recovery (mechanical/chemical etc)	• 3rd gen batteries 400+ Wh/kg & $200/kW.h cost • New low cost solid state power conversion systems • Hydrogen storage technology
Vehicle Efficiency	• Lightweight structures and interiors • Low rolling resistance tyres / brakes	• New vehicle classes and configurations • Combination of function to reduce weight / cost • Minimised weight / losses	• Flexible re-configurable multi-utility vehicle concepts • 50% weight reduction from 2008 • Advanced aerodynamic concepts
System Control	• Information enabled control (Topology, V2V, V2I, traffic etc.) • Optimised vehicle energy mgmt. • Intelligent thermal management	• Advanced information enabled control • Intelligent P/T and HVAC mgmt.	• Autonomous P/T and vehicle control integrated with active safety
Energy + Fuel Supply	• Optimised 1st gen biofuels processes • New 2nd gen biofuel processes	• Intelligent energy / re-fuelling infrastructure (e.g. fast charge) • Industrial scale demonstration of new 2nd gen biofuel processes	• 3rd gen biofuel processes • 2nd gen industrial scale biofuel production infrastructure
Processes + Tools	• Process + delivery tool development and connectivity	• Auto-optimisation methods using virtual systems	• Artificial Intelligence to deliver complex multi-criteria system optimisation

Source: An Independent Report on the Future of the Automotive Industry in the UK – New Automotive Innovation & Growth Team (NAIGT)

An in-depth industry consultation was carried out to establish the wider R&D capability in the UK using a survey and workshops

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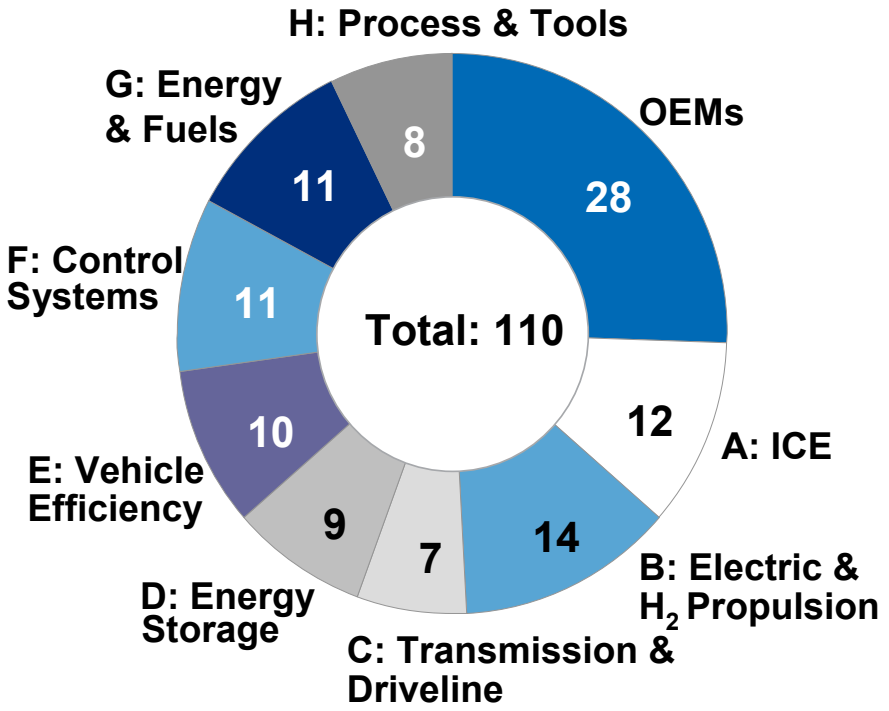
- **Objectives were to:**
  - Assess current levels of UK activity (research, development, supply chain base) and current technology maturity levels of R&D activities underway across CO_2-relevant technology areas
  - Note UK strengths & opportunities
- Over 110 companies were invited to participate in the consultation via a **questionnaire** and 2 structured **workshops**
- Additionally, the UK's main **public R&D funding** bodies were approached for information on currently running and recently completed research projects within industry and academia
- From these different sources, the evidence collected of UK R&D activity was assessed against the requirements of the Consensus Roadmap for each of a range of 8 technology areas



Organisations contacted (by main activity area)

In addition, all organisations consulted via the questionnaire were invited to attend a one-day stakeholder workshop

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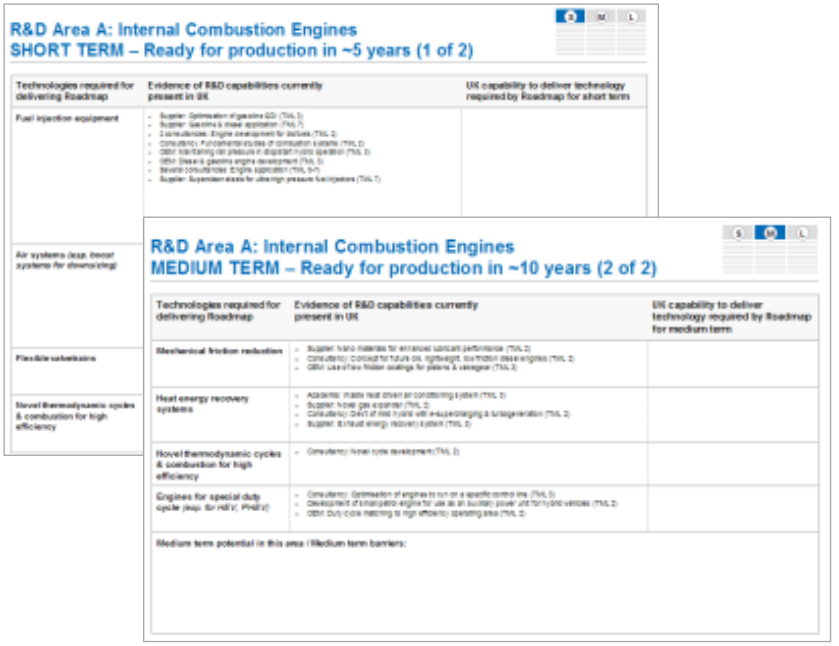
Phase 1 **Phase 2** Phase 3

- **Workshop objectives were to:**
  - Capture and validate evidence on UK capability and readiness status across short, medium and long term technology requirements to deliver the OEM product roadmap
  - Reach consensus view of status of UK R&D capabilities and assess the potential for the UK R&D base to deliver to the future requirements of the OEM product roadmap

- Data from questionnaire used as basis for discussion:
  - matched to the research agenda required to deliver the OEM product roadmap
  - focused on UK capability for each technology area and technology category

- Facilitated discussions with groups of attendees:
  - validate information gathered to date
  - expand on evidence of UK R&D capabilities
  - evaluate UK capability to deliver short, medium and long term requirements



Clearly defined criteria were defined to judge the capability of the UK to deliver the short, medium and long term requirements of the roadmap

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UK Capability Assessment Process – Applied Rating Criteria

Category Assessment	Short Term Requirements	Medium Term Requirements	Long Term Requirements
	Clear evidence of: • Availability of required technology at right development stage • Significant number of substantial players & high level of reported activities • Existing manufacturing facilities with potential for meeting market demand in the short term	**Clear evidence of:** • Strong R&D ongoing for required technology, on track to meet Roadmap time scale • Several substantial players with relevant projects • Some existing manufacturing presence with potential scale up to meet medium term requirements (scale up of existing facilities, partnerships, market entry from adjacent industries)	**Clear evidence of**: • Strong university or other fundamental R&D activities underway with good potential to meet long term Roadmap requirements • Appropriate industrial base in place to develop & commercialise technology
	• One of the above not fully met	• One of the above not fully met	• Limited fundamental R&D • Potential to exploit expertise from other, relevant industries
	• Two or more of the above not fully met	• Two or more of the above not fully met	• No evidence of relevant expertise
	• Technology not required for short term	• Technology not required for medium term	• Technology not required for long term

Note: Applied rating criteria were slightly adjusted for categories where they did not fully apply (e.g. manufacturing presence for software)

A simple analysis was then carried out to give an initial indication of likely Return On Investment levels across different technology areas

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1. **Qualitative assessment of effort required to deliver roadmap requirement:**
   - Effort required for UK to meet the requirements of the consensus product roadmap for each technology category
   - A qualitative rather than quantitative rating scale was utilised
2. **Qualitative assessment of potential for UK benefit:**
   - The potential for UK benefit (value capture) was estimated by qualitatively rating the “overall market value” and the “UK value capture potential” for each technology category
   - Overall rating for the potential UK benefit derived from two component ratings:
     - "overall market value" (size of global market opportunity)
     - "UK value capture potential" (proportion of this market likely captured by the UK)
   - A relative rating scale was utilised
3. **Overall assessment of indicative ROI potential:**
   - A summary qualitative assessment was then produced based on effort and benefit to give an indicative “return on investment” rating

Phase 1 **Phase 2** Phase 3

Existing or potentially strong UK capability
Strong UK capability in some aspects
Medium UK capability in some aspects
Capability not required for Roadmap

↑ High
→ Medium
↓ Low

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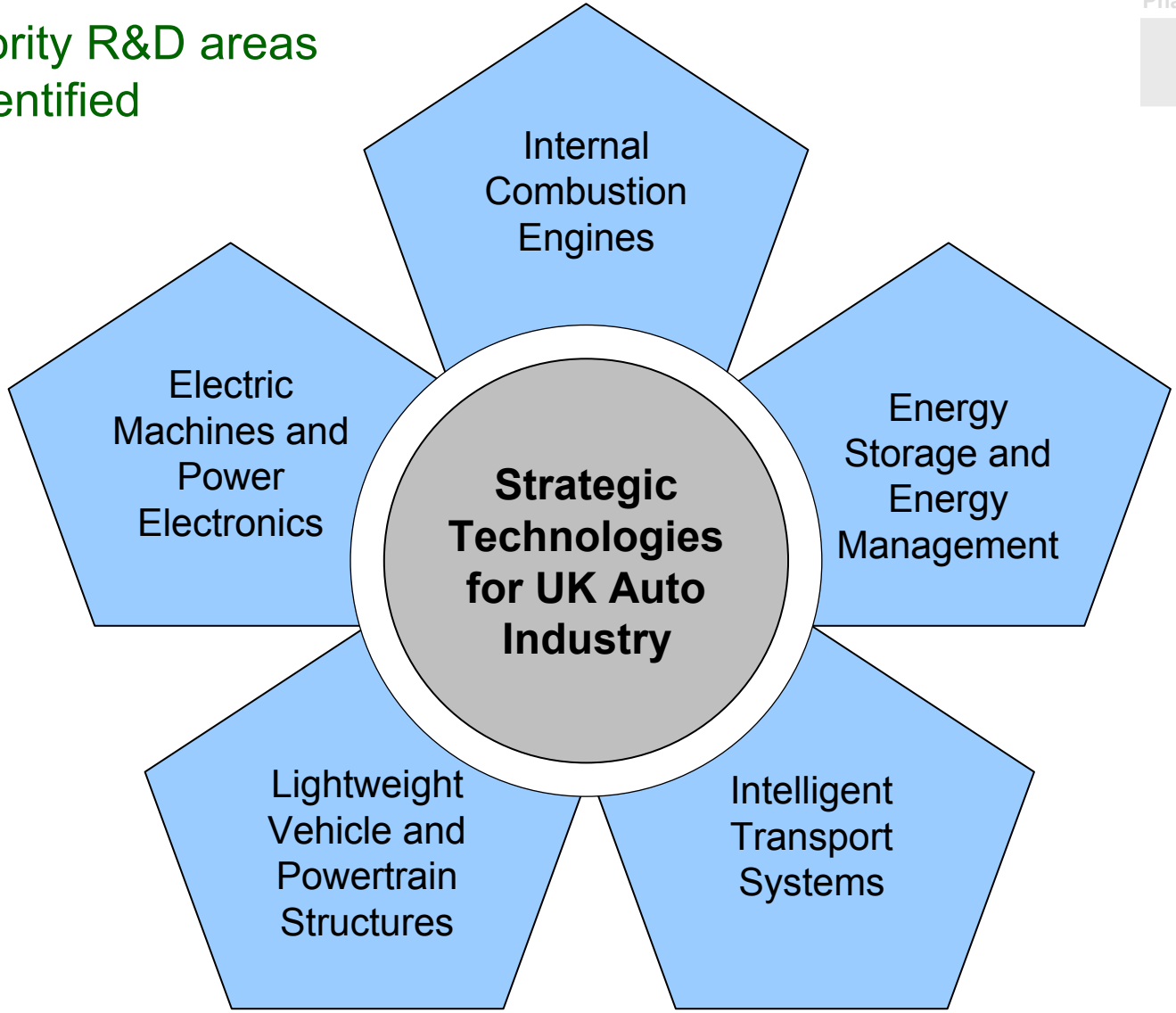
	Technology Category	UK capability			Research Area Focus (selected items of interest)			Qual. Ease of Delivery	Qual. Benefit to UK	Indicative "ROI"
		S	M	L	Short	Medium	Long			
A	FIE	Y	G	G	High pressures, more flexibility, hybrid app's	Design for biofuels		→	↑	↗
	Air handling	Y	G	G	Boost systems for downsizing	Improved response, e.g. energy storage		↘	↗	→
	Friction reduction	Y	Y	Y	Components, lubricants	Materials, coatings, nano technology		→	→	→
	Heat energy recovery systems		G	Y	-	E-turbines, secondary cycles	Thermoelectric devices	→	→	→
	Novel thermo cycles		Y	G	-	Alt. combustion modes (CAI, HCCI)	Novel concepts for very high efficiency	→	↑	→
	Engines for HEV/PHEV		G	G	Simple, light engines for niche app's	Optimised engines		↗	↗	↗
	Integrated engine design & development	G	G	G	Engine optimisation for biofuels	Extreme downsizing concepts		↗	↑	↑
B	Electric motors	G	G	G	Low cost, compact	Lower cost	Super high eff., new materials	→	→	↗
	Hydrogen fuel cells		Y	Y	Support to demonstrators	Efficiency, cost improvements	New MEA materials	↓	↗	→
	Power electronics	Y	G	G	Low cost	Flexible	High temp, new materials	→	→	↗
C	Adv trans fluids	G	G	G	Fluids for low friction	Nano technology		→	↗	↗
	Trans concepts for HEV / PHEV / EV	Y	Y	Y	Optimised calibration for HEVs	Multi-speed for EVs, Low cost for HEV		→	→	→
D	Battery pack int.	G	G	G	Thermal control, safety/crash protection			↑	→	↑
	H_2 storage tech.		Y	Y	-	Cost reduction	Alt. H_2 storage (solid state etc.)	↓	↗	→
	Mechanical energy storage tech.	G	G	G	Tech demonstration for benefits			↗	↗	↑
E	Lightweight structures	G	G	G	Lightweight steel, aluminium	Carbon fibre composites	Smart components & materials	→	↑	↑
	New vehicle classes		Y	G	-	Design for EVs, personal mobility	Modular vehicles	↗	→	→
F	Adv. p'train control – software	G	G	G	Model-based multivariable control	Cylinder p based ctrl, integrated powertrain ctrl	Adaptive in-cycle model-based control	↑	→	→
	Vehicle energy mgmt	G	G	G	Thermal mgt, e-ancillaries	Energy mgt strategy PHEV,EV	Energy mgt strategy fuel cells	↑	→	↗
	Driver info systems	G	G	G	Economy aids	Innovative driver interaction methods		→	→	↗
	ITS		G	G	Info enabled control: topology, V2I	Electronic horizon: incl. traffic, V2V		↘	↗	↗
	Autonomous vehicle control		G	G	-	X-by-wire	Autonomous control w. active safety integration	→	↘	→
G	2nd gen biofuels		G	G	New 2nd gen process	Demo 2nd gen process		↓	→	→
	3rd gen biofuels		G	G	-	-	New 3RD gen processes	↓	→	→
	Electrical infra.		G	G	Smart metering / charge points	Future charging options (e.g. fast charge)	Smart grid / energy mix	↓	↑	↗
	H_2 infrastructure			Y	-	-	H_2 fuelling options & infra. strategy	↓	→	→
H	Advanced process tools	G	G	G	Virtual prototyping			↗	→	↗
	Integrated tool-chains	Y	G	G	Multi-domain modelling	Standards for tool integration		↗	→	↗
	Auto-optimisation methods	Y	G	G	Multi-attribute optimisation			↗	→	↗
	Advanced testing methods & equip	G	G	G	Design of Experiments methods			↗	↘	→

Source: Ricardo analysis

To date 5 priority R&D areas have been identified



Conclusions and Next Steps

- Individual manufacturers will prioritise certain technologies to fit with brand values, but OEMs share a common view of a high level Product Roadmap
- An initial view of the research required to deliver the consensus Product Roadmap has been defined based on 6 categories and short/medium/long term priorities
- An evidence base has been developed for the current capability base of the UK automotive industry
- It has revealed an industry which under the correct conditions can compete effectively in the future global marketplace for low carbon vehicle technologies
- This evidence base has been extensively peer reviewed
- The study is being used by the Automotive Council to inform their strategic decision-making around prioritisation of UK automotive technology investment
- The Technology Group of the Automotive Council is now focused on a number of specific themes to support development of a Technology Strategy