Automotive technologies: The UK's current capability

Technology Strategy Board
Driving Innovation

Research by:
RICARDO

Foreword – Iain Gray
Chief Executive, Technology Strategy Board

- In May 2009 the New Automotive Innovation and Growth Team (NAIGT) produced its final report, which included an industry consensus high level Technology Roadmap for meeting the ambitious carbon reduction targets in road transport. This comprised a Common Product Roadmap, and a Common Research Agenda which presented future technologies needed to deliver the Roadmap to the envisaged timescales.
- However, in order to develop a research strategy for the UK automotive sector several additional elements are needed, including an understanding of current UK strength in each of the key technology areas. This study represents a first step towards gaining that understanding. Requested by the NAIGT and funded by the Technology Strategy Board, and delivered by Ricardo, it analysed work being done in industry and academia and identified the level of UK capability in those areas that are important for delivering the Technology Roadmap. It also identifies our likely long-term capabilities - under an assumed scenario where current levels of R&D investment are at least maintained.

Foreword (cont.)

- The Technology Roadmap and this study have been used to guide the scope and emphasis of several recent public funding opportunities in the automotive sector. However, by their very nature these reports cannot predict disruptive technologies that may emerge, and which any future strategy must also provide for. This report is also a snapshot of current status, and will need to be refreshed in future along with the Technology Roadmap on which it is based.
- I must also point out that the areas highlighted in the study do not themselves represent strategic judgements. Our findings will have different implications for different organisations. For example, areas where the country does not have great strengths at the moment may in fact represent opportunity for some.
- What I do believe is that the solid evidence in this groundbreaking study will enable both government and industry, in particular through the newly-formed Automotive Council, to develop effective strategies for future R&D – as we work together to make the UK a leading player in the low carbon automotive industry of the future.
- We would like to thank all those who contributed to the work which has culminated in this report, especially the NAIGT members, the members of the Technology Expert Group, staff at BIS, DfT, OLEV and the Technology Strategy Board.

Executive Summary (1/2)

- **NAIGT initiated a 3-phase plan for developing an Automotive Technology Strategy**

- The aims of **Phase 1** were to describe a common view of the product directions of the major OEMs, and to identify the technology requirements of those products as they evolve over time.
  - A Consensus Product Roadmap and a Common Research Agenda were developed and reported in the NAIGT report of 2009.

- **Phase 2** sought to broaden consensus, identify specific areas of UK capability & opportunity, and develop a structured R&D funding plan
  - A wider group of OEMs, suppliers and other bodies was approached to validate the Consensus Roadmap and Common Research Agenda
  - An in-depth industry consultation was undertaken to establish the wider R&D capability in the UK using a questionnaire and workshops
  - Organisations were contacted across a balanced range of technology areas; response rates were good despite the short timescale
  - Consultation questionnaires gathered evidence of ongoing, UK-based R&D in eight key technology areas identified by NAIGT as relevant to CO2 reduction
  - Information on publicly-funded R&D projects was also gathered, categorised by technology and maturity level
  - Stakeholder workshops were held in London and Leamington

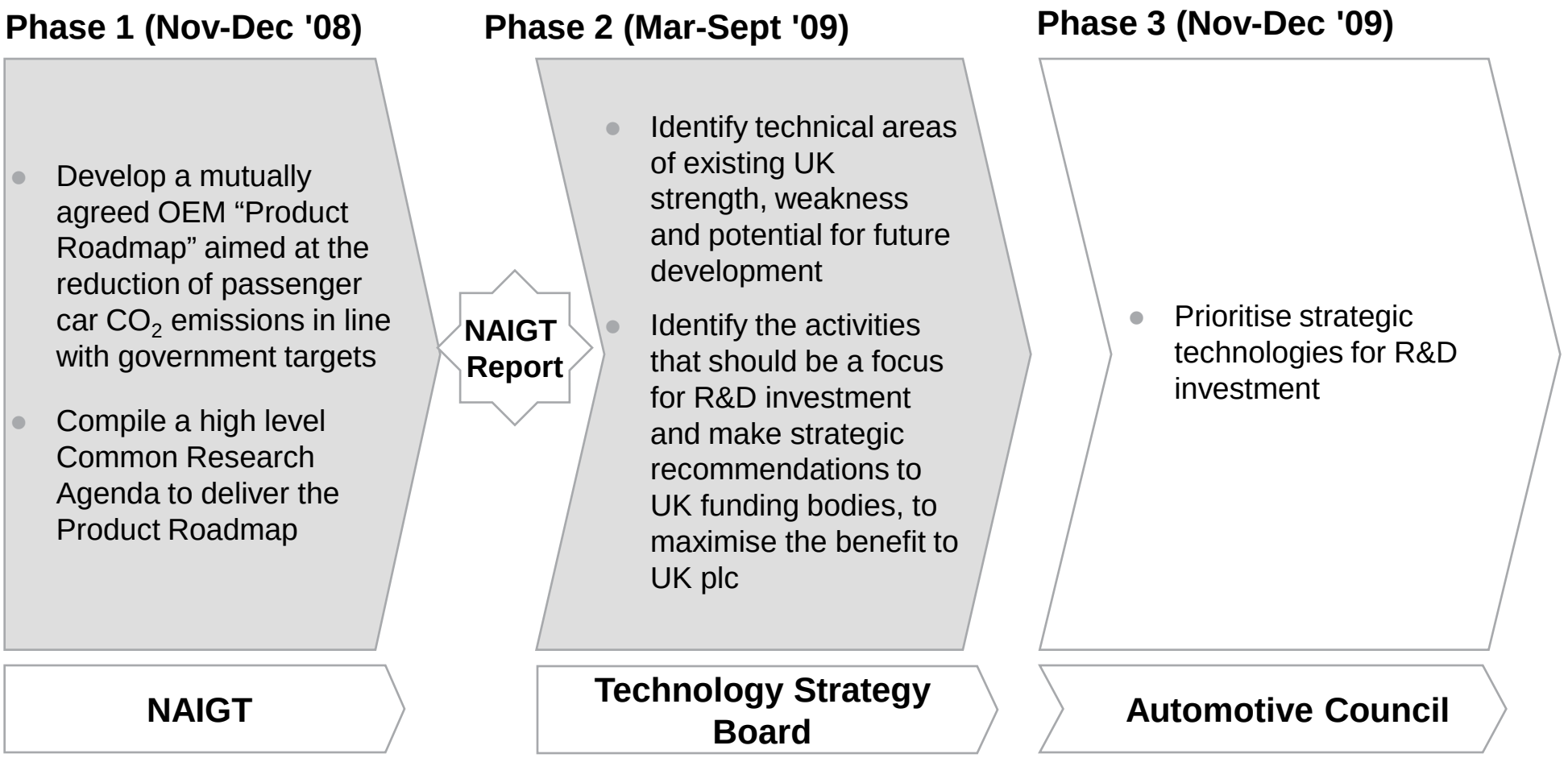
Executive Summary (2/2)

- The key insights and conclusions from these information sources were collated to form a UK capability assessment for each technology
- A simple analysis was then carried out to give an initial indication of likely UK Return On Investment levels across different technologies
- An overall assessment summary using all of the analysis results gives an initial view of the best potential for UK exploitation

- **Following completion of activities by NAIGT, the Automotive Council has taken this process through Phase 3**
  - The results from the NAIGT consultation and this analysis were transferred to the Automotive Council
  - The study is being used by the Automotive Council to inform strategic decision-making around prioritisation of UK automotive technology investment.
  - The Automotive Council will publicise its conclusions separately.

- A robust process has been delivered by NAIGT and Automotive Council and can be used as the basis for on-going regular review
- As the technology and market situation will evolve over time, it is recommended that this process be updated on a 12-18 monthly basis

NAIGT established a 3-phase plan for developing an Automotive Technology Strategy – This report covers Phases 1 and 2



NAIGT Aim:

- “To develop strategies for the future competitiveness of the automotive industry in the UK over the next 15 years”
- “We need to ensure our car industry can build on its strengths and remain competitive” Business Minister – Shriti Vadera

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

e·on Engineering
LAND ROVER
Advantage West Midlands
www.advantagewm.co.uk
ARUP
BMW Group
MINI
MAHLE Powertrain
RICARDO
ITS United Kingdom
Better transport through technology
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BOSCH
LOTUS
NISSAN
THINK
JAGUAR
GM
Ford
BENTLEY
INTELLIGENT ENERGY
Clean fuel and power

Phase 1's aims were to identify high level technology requirements to deliver a product roadmap, and the associated research activities

Phase 1 (Nov-Dec '08)

1. Collect R&D plans & identify technologies required
2. Review technologies identified
3. Link common research agenda to common roadmap

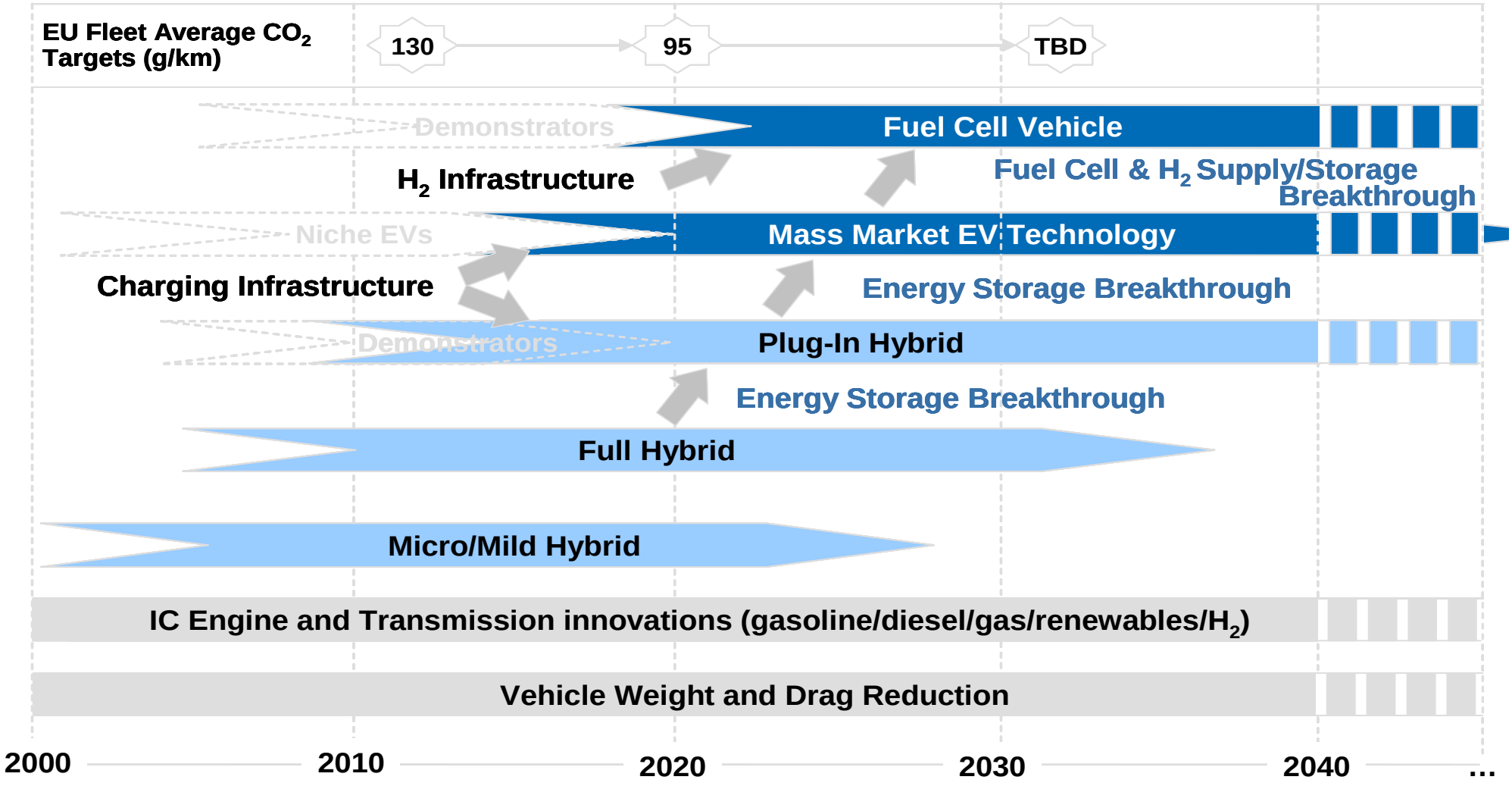
- **Step 1**
  - Confidential R&D plans collated from participating companies
  - Consensus Product Roadmap compiled from OEM input
  - Required technologies identified
- **Step 2**
  - Technologies categorised and sorted into timeframes for delivery to produce Common Research Agenda
- **Step 3**
  - Required research actions correlated with OEM Consensus Product Roadmap

Phase 2 (Mar-Sep '09)

4. Seek wider stakeholder engagement
5. Assess UK R&D position in more detail
6. Create evidence base for strategic prioritisation

NAIGT Report

An output of this activity was a Consensus Product Roadmap describing a commonly held view of passenger car technology roll-out



NAIGT statement based on the Consensus Product 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

A Common Research Agenda was developed - a hypothesis on the R&D required to deliver the Consensus Product Roadmap

	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

Phase 2 sought to broaden consensus, identify specific areas of UK capability, and develop an evidence base for strategic prioritisation

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Phase 2 (Mar-Sep '09)

4. Seek wider stakeholder engagement
5. Assess UK R&D position in more detail
6. Create evidence base for strategic prioritisation

- **Step 4**
  - Wider group of UK OEMs, Tier 1 suppliers & industry bodies consulted to validate existing consensus roadmap and outline research agenda
- **Step 5**
  - In-depth consultation in order to:
    - Assess UK capability & readiness status across CO_2-relevant technology areas
    - Note UK strengths & opportunities
  - Large number of organisations involved in UK-based automotive R&D approached
- **Step 6**
  - Evidence base for strategic prioritisation created, based on Step 4&5 analysis

A wider group of OEMs, suppliers and other bodies was approached to validate the Consensus Roadmap and Common Research Agenda

- No existing database was available to provide a complete listing of UK automotive supply chain members
- Ricardo liaised with BERR, TSB, LowCVP & RDAs to create a list of all organisations believed to be relevant to Steps 4-6
- 11 additional OEMs, 9 Tier 1 suppliers and 9 other representative bodies were consulted on the contents of the roadmap and research agenda and asked to provide feedback on the preliminary draft
- Requests received for changes/modifications were reported anonymously to the NAIGT
- NAIGT decided which of this feedback should be adopted in the final consensus position
- Final product roadmaps were produced for publication in the NAIGT report

one NORTH EAST

LowCVP low carbon vehicle partnership

Advantage West Midlands www.advantagewm.co.uk

Technology Strategy Board Driving Innovation

WDA

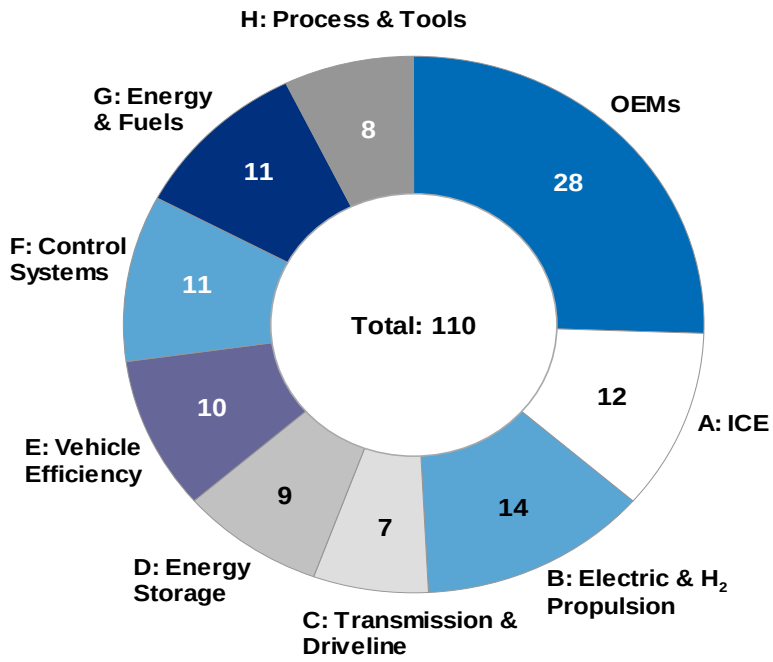
east midlands development agency

SEEDA South East England Development Agency Working for England's World Class Region

BERR Department for Business Enterprise & Regulatory Reform

This was achieved via an in-depth industry consultation to establish the wider R&D capability in the UK using a questionnaire and workshops

- **Objectives of Step 5 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

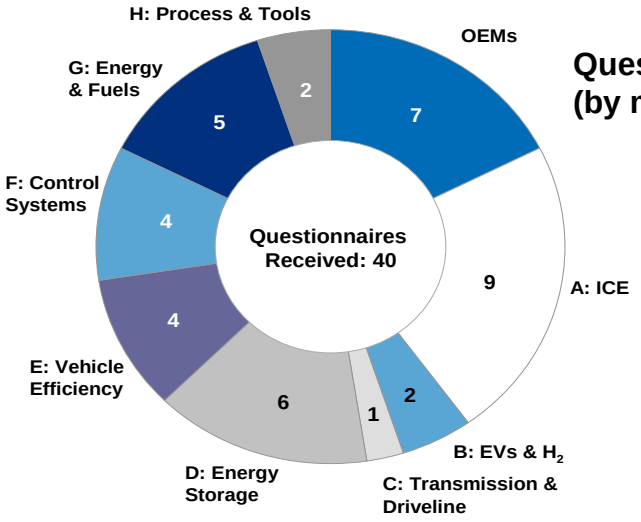


Organisations contacted (by main activity area)

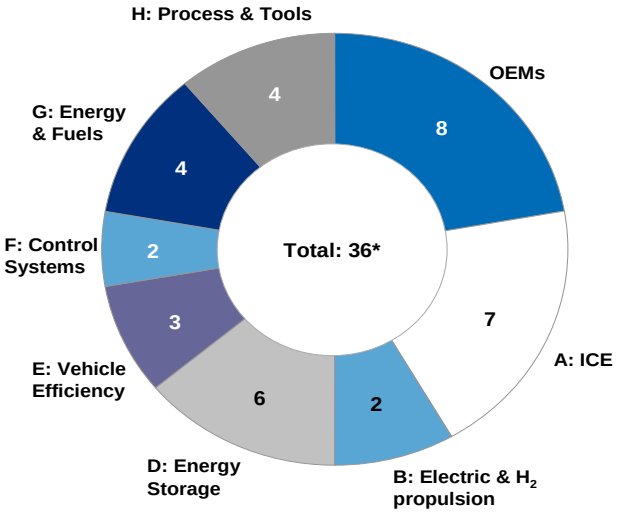
Organisations were contacted across a balanced range of technology areas; response rates were good despite the short timescale

- **Questionnaire responses**
  - 40 out of 110 returned completed questionnaires
  - 36% response rate
  - Balanced across activity areas
- **Workshop attendance**
  - 36 out of 110 organisations contacted were represented at the workshops
  - 33% attendance
  - Balanced across activity areas except Transmission & Driveline
- Overall, 51 different organisations out of the 110 contacted actively participated in the consultation - **47%** response rate
  - 10 Vehicle manufacture
  - 21 Supply Chain
  - 12 Technology and Development
  - 4 Fuel and Energy
  - 4 Other

Questionnaire participants (by main activity area)

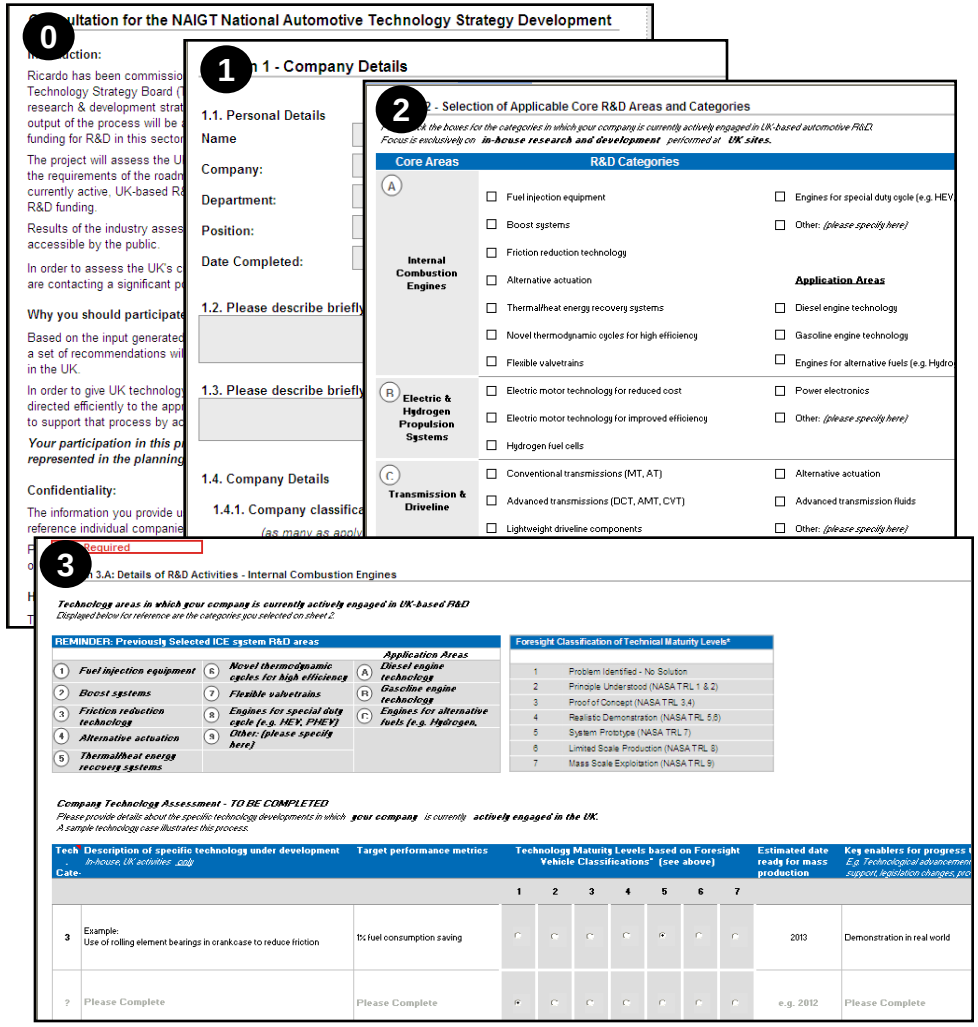


Workshop participants (by main activity area)



Consultation questionnaires gathered evidence of ongoing, UK-based R&D in eight key technology areas relevant to CO_2 reduction

- **A questionnaire was developed, featuring four main sections:**
  - 0 Introduction to the project and the questionnaire process
  - 1 Company details
  - 2 Overview and selection of active R&D areas (based on NAIGT Consensus Research Agenda)
  - 3 Dedicated sections for each R&D area
- All of the 114 companies identified as relevant were invited by email to participate in the NAIGT consultation process
- The invitation contained an explanatory cover letter as well as an spreadsheet-based questionnaire



Full details of the questionnaire can be found in Appendix 1

Information on publicly-funded R&D projects was also gathered, categorised by technology area and assigned a Technology Maturity Level

- Projects funded over the last five years by the TSB, EPSRC, EST & The Carbon Trust were analysed in this workstream
- Projects were included for analysis only if focussed on CO_2 reduction for passenger cars and related technologies
- Ricardo was given access to project titles and public domain abstracts
- Based on the Research and Development work undertaken, each project was assigned a Technology Category and a Technology Maturity Level (TML)
- For ongoing projects a TML was assigned corresponding to the maturity level at the beginning of the project
- For completed projects a TML was assigned corresponding to the intended maturity level of the technology at the end of the project

EPSRC
Pioneering research and skills

energy saving trust

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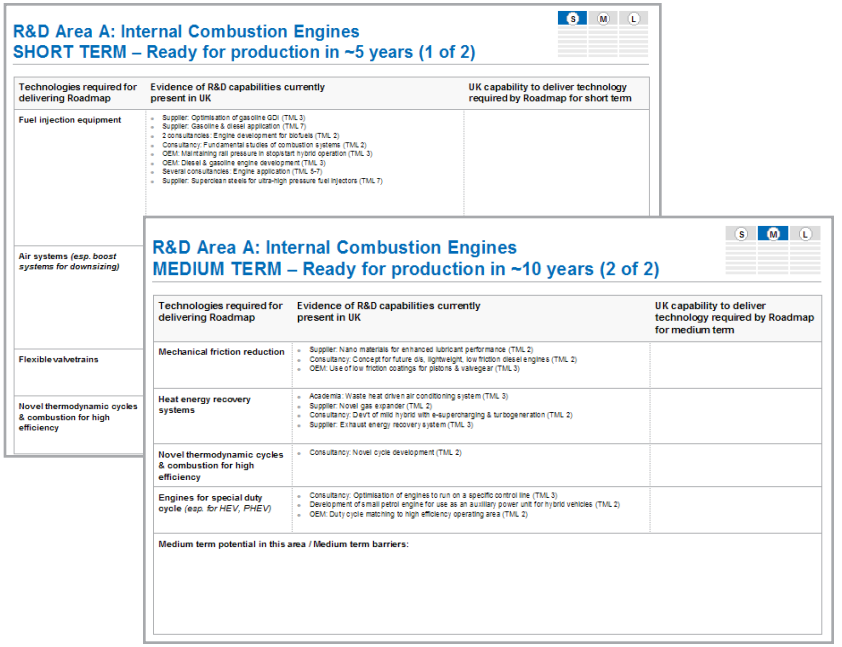
CARBON TRUST

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

- **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

- Information provided in the returned questionnaires was matched to the research agenda required to deliver the OEM product roadmap and formed the start of an assessment of UK capability for each technology area and technology category

- Facilitated discussions with groups of attendees were held to validate information gathered to date and expand on evidence of UK R&D capabilities and to evaluate UK capability to deliver technology required by roadmap in the short, medium and long term



R&D Area A: Internal Combustion Engines
SHORT TERM – Ready for production in ~5 years (1 of 2)

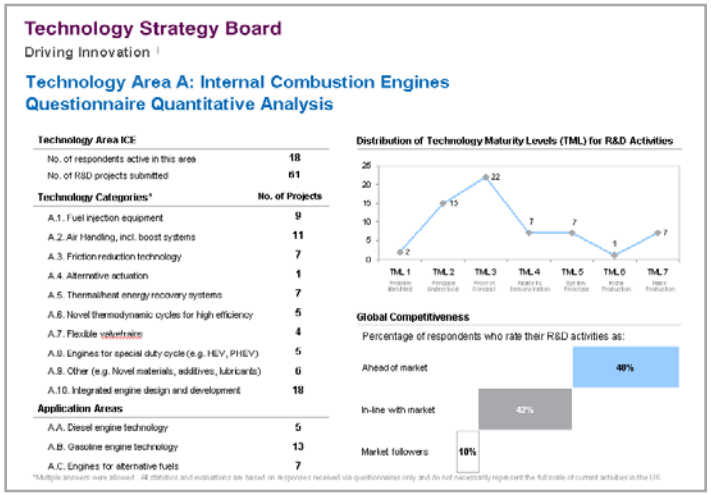
Technologies required for delivering Roadmap	Evidence of R&D capabilities currently present in UK	UK capability to deliver technology required by Roadmap for short term
Fuel injection equipment	Supplier: Optimisation of gasoline GDI (TML 3) Supplier: Gasoline & diesel application (TML 7) 2 consultancies: Engine development for biofuels (TML 2) Consultancy: Fundamental studies of combustion systems (TML 2) OEM: Maintaining rail pressure in stop/start hybrid operation (TML 3) OEM: Diesel & gasoline engine development (TML 3) Several consultancies: Engine application (TML 5-7) Supplier: Superclean steels for ultra-high pressure fuel injectors (TML 7)	
Air systems *(esp. boost systems for downsizing)*		
Flexible valvetrains		
Novel thermodynamic cycles & combustion for high efficiency		

R&D Area A: Internal Combustion Engines
MEDIUM TERM – Ready for production in ~10 years (2 of 2)

Technologies required for delivering Roadmap	Evidence of R&D capabilities currently present in UK	UK capability to deliver technology required by Roadmap for medium term
Mechanical friction reduction	Supplier: Nano materials for enhanced lubricant performance (TML 2) Consultancy: Concept for future cils, lightweight, low friction diesel engines (TML 2) OEM: Use of low friction coatings for pistons & valvegear (TML 3)	
Heat energy recovery systems	Academia: Waste heat driven air conditioning system (TML 3) Supplier: Novel gas expander (TML 2) Consultancy: Devt of mild hybrid with e-supercharging & turbogeneration (TML 2) Supplier: Exhaust energy recovery system (TML 3)	
Novel thermodynamic cycles & combustion for high efficiency	Consultancy: Novel cycle development (TML 2)	
Engines for special duty cycle *(esp. for HEV, PHEV)*	Consultancy: Optimisation of engines to run on a specific control line (TML 3) Development of small petrol engine for use as an auxiliary power unit for hybrid vehicles (TML 2) OEM: Duty cycle matching to high efficiency operating area (TML 2)	
Medium term potential in this area / Medium term barriers:		

Output from the questionnaires, public funding assessment and workshops is presented anonymously to preserve confidentiality

- For each of the three information sources, **full results** are presented in the Appendix, using the following anonymous formats to preserve participants' confidentiality:
  - Statistical analysis of projects, by technology area, TML, etc.
  - Summary of key insights
  - Indication of UK activity levels in each technology area
- Results are based on the evidence available through the consultation only



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Technology Area A: Internal Combustion Engines

Questionnaire Quantitative Analysis

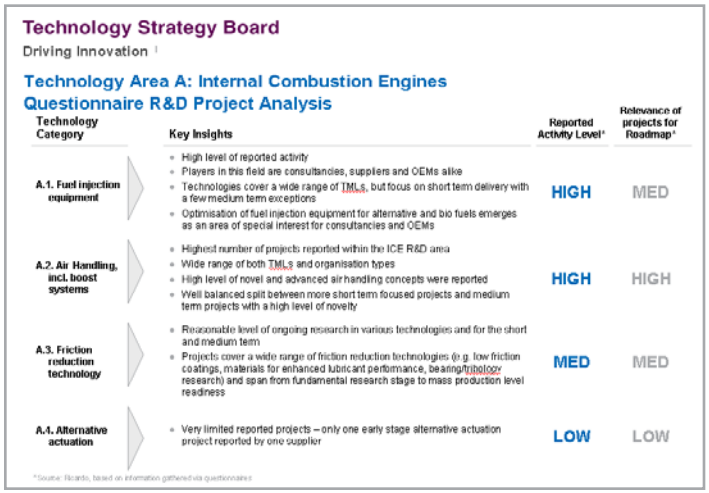
Technology Area ICE	
No. of respondents active in this area	18
No. of R&D projects submitted	61
Technology Categories*	**No. of Projects**
A.1. Fuel injection equipment	9
A.2. Air Handling, incl. boost systems	11
A.3. Friction reduction technology	7
A.4. Alternative actuation	1
A.5. Thermal/heat energy recovery systems	7
A.6. Novel thermodynamic cycles for high efficiency	5
A.7. Flexible valvetrains	4
A.8. Engines for special duty cycle (e.g. HEV, PHEV)	5
A.9. Other (e.g. Novel materials, additives, lubricants)	6
A.10. Integrated engine design and development	18
Application Areas	
A.A. Diesel engine technology	5
A.B. Gasoline engine technology	13
A.C. Engines for alternative fuels	7

Distribution of Technology Maturity Levels (TML) for R&D Activities

Global Competitiveness

Percentage of respondents who rate their R&D activities as:

*Multiple answers were allowed. All statistics and evaluations are based on responses received via questionnaires only and do not necessarily represent the full scale of current activities in the UK



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Technology Area A: Internal Combustion Engines

Questionnaire R&D Project Analysis

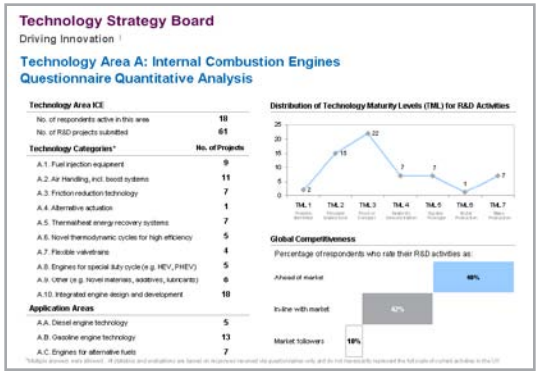
Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
A.1. Fuel injection equipment	• High level of reported activity • Players in this field are consultancies, suppliers and OEMs alike • Technologies cover a wide range of TMLs, but focus on short term delivery with a few medium term exceptions • Optimisation of fuel injection equipment for alternative and bio fuels emerges as an area of special interest for consultancies and OEMs	HIGH	MED
A.2. Air Handling, incl. boost systems	• Highest number of projects reported within the ICE R&D area • Wide range of both TMLs and organisation types • High level of novel and advanced air handling concepts were reported • Well balanced split between more short term focused projects and medium term projects with a high level of novelty	HIGH	HIGH
A.3. Friction reduction technology	• Reasonable level of ongoing research in various technologies and for the short and medium term • Projects cover a wide range of friction reduction technologies (e.g. low friction coatings, materials for enhanced lubricant performance, bearing/tribology research) and span from fundamental research stage to mass production level readiness	MED	MED
A.4. Alternative actuation	• Very limited reported projects – only one early stage alternative actuation project reported by one supplier	LOW	LOW

*Source: Ricardo, based on information gathered via questionnaires

Output from the questionnaire, public funding assessment and workshops can be found in Appendix 2

The key insights and conclusions from the three information sources fed into technology category and area assessments

1 Questionnaire Evaluation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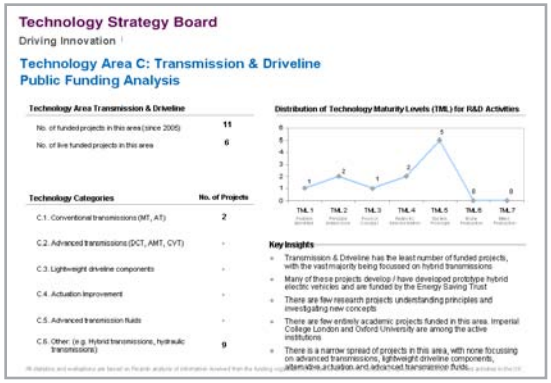
Technology Area A: Internal Combustion Engines
Questionnaire Quantitative Analysis
Technology Area ICE
No. of respondents active in this area 18
No. of R&D projects submitted 61
Technology Categories* No. of Projects
A.1. Fuel injection equipment 9
A.2. Air Handling, incl. boost systems 11
A.3. Friction reduction technology 7
A.4. Alternative actuation 1
A.5. Thermal/heat energy recovery systems 7
A.6. Novel thermodynamic cycles for high efficiency 5
A.7. Flexible valvetrains 4
A.8. Engines for special duty cycle (e.g. HEV, PHEV) 5
A.9. Other (e.g. Novel materials, additives, lubricants) 6
A.10. Integrated engine design and development 18
Application Areas
AA. Diesel engine technology 5
AB. Gasoline engine technology 13
AC. Engines for alternative fuels 7
Distribution of Technology Maturity Levels (TML) for R&D Activities
TML 1 TML 2 TML 3 TML 4 TML 5 TML 6 TML 7
Global Competitiveness
Percentage of respondents who rate their R&D activities as:
Ahead of market 48%
In-line with market 42%
Market followers 10%

2 Public Funding Evaluation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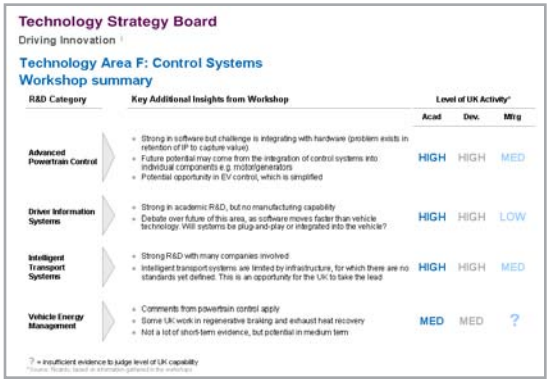
Technology Area C: Transmission & Driveline
Public Funding Analysis
Technology Area Transmission & Driveline
No. of funded projects in this area (since 2005) 11
No. of live funded projects in this area 6
Technology Categories No. of Projects
C.1. Conventional transmissions (MT, AT) 2
C.2. Advanced transmissions (DCT, AMT, CVT) -
C.3. Lightweight driveline components -
C.4. Actuation Improvement -
C.5. Advanced transmission fluids -
C.6. Other: (e.g. Hybrid transmissions, hydraulic transmissions) 9
Distribution of Technology Maturity Levels (TML) for R&D Activities
TML 1 TML 2 TML 3 TML 4 TML 5 TML 6 TML 7
Key Insights
- Transmission & Driveline has the least number of funded projects, with the vast majority being focussed on hybrid transmissions
- Many of these projects develop / have developed prototype hybrid electric vehicles and are funded by the Energy Saving Trust
- There are few research projects understanding principles and investigating new concepts
- There are few entirely academic projects funded in this area. Imperial College London and Oxford University are among the active institutions
- There is a narrow spread of projects in this area, with none focussing on advanced transmissions, lightweight driveline components, alternative actuation and advanced transmission fluids

3 Workshop Evaluation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Technology Area F: Control Systems
Workshop summary
R&D Category | Key Additional Insights from Workshop | Level of UK Activity* (Acad / Dev. / Mfg)
Advanced Powertrain Control
- Strong in software but challenge is integrating with hardware (problem exists in retention of IP to capture value)
- Future potential may come from the integration of control systems into individual components e.g. motor/generators
- Potential opportunity in EV control, which is simplified
HIGH HIGH MED
Driver Information Systems
- Strong in academic R&D, but no manufacturing capability
- Debate over future of this area, as software moves faster than vehicle technology. Will systems be plug-and-play or integrated into the vehicle?
HIGH HIGH LOW
Intelligent Transport Systems
- Strong R&D with many companies involved
- Intelligent transport systems are limited by infrastructure, for which there are no standards yet defined. This is an opportunity for the UK to take the lead
HIGH HIGH MED
Vehicle Energy Management
- Comments from powertrain control apply
- Some UK work in regenerative braking and exhaust heat recovery
- Not a lot of short-term evidence, but potential in medium term
MED MED ?
? = insufficient evidence to judge level of UK capability

Assessment of UK capability for each individual technology category and an overall capability assessment by technology area

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

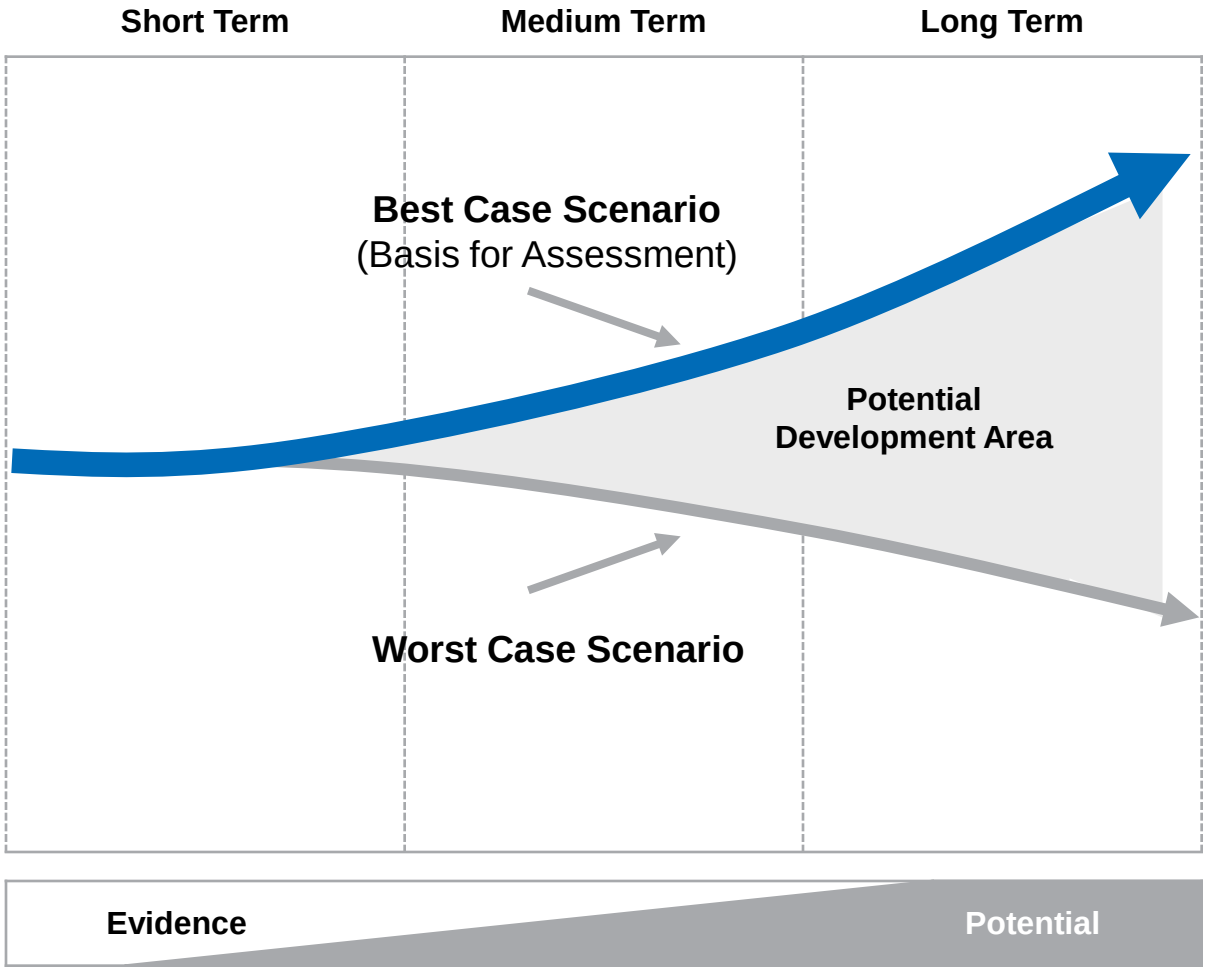
UK Capability Assessment Process – Applied Rating Criteria

Category Assessment	Short Term Requirements	Medium Term Requirements	Long Term Requirements	Justification/ Rationale
	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	• Additional comments provide high level insight regarding the rationale for assigning a certain rating • ….
	• One of the above not fully met	• One of the above not fully met	• Limited fundamental R&D ongoing • 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)

Assessment of the UK's capability to deliver the Roadmap assumed best case scenarios in which necessary enablers are put in place

UK Capability Assessment Process – Underlying Assumptions



- The present capability assessments are based on best case scenarios, where necessary enablers are put in place
- Depending on the individual technology these could include:
  - Financial support for further R&D
  - Investments for scale-up of manufacturing capabilities
  - Collaboration between academia and industry
  - Visibility of available know-how
  - Inter-industry collaboration
  - Existing market demand
  - …
- *Details of necessary enablers for different technologies are provided in Step 6*

Example of current UK capability study output – technology category detail

R&D Category	Short	Medium	Long	Justification/Rationale
D.1.a. Battery cell development				• Limited number of players and active projects and no volume manufacturing capabilities • Significant research into novel cell chemistries with potential for medium term value capture • Little evidence of fundamental research suggests limited long term potential
D.1.b. Battery pack and integration				• Small number of suppliers/assemblers currently present • Strong capability in assembly and vehicle integration of battery packs for niche applications with potential for medium to long term expansion
D.2. Ultracapacitor technology				• No responses received from any organisations with significant focus on this technology • Little evidence of current development or manufacture of ultracapacitor systems • Some evidence of integration R&D • Medium and long term potential limited due to lack of innovation
D.3. Hydrogen storage technology				• Limited number of significant players in this category • Limited evidence of current active development programmes, but potential to meet Roadmap requirements for the medium term • Some early academic research ongoing giving potential for the long term
D.4. Mechanical energy storage technology (flywheels)				• Strong development capability base with several suppliers of various flywheel technologies (amongst world leaders for automotive applications) • Globally competitive manufacturing capability with potential for scaling-up and/or licensing

Output from the UK capability study can be found in Appendix 3

Summary – indicative current status of UK capability to deliver the needs of the NAIGT Roadmap, given required enablers

		Short Term	Medium Term	Long Term	Comments
Propulsion	A: Internal Combustion Engines				• Limited Tier 1 product development and manufacturing, however high levels of integrated engine development by OEMs & consultancies • Many categories have good potential for medium and long term
Propulsion	B: Electric & H2 Propulsion				• Both electric motors and power electronics have good capability to meet product roadmap, especially in medium and long term • Fuel cell systems currently appear slightly weaker
Propulsion	C: Transmissions & Drivelines				• All categories only show low or medium potential for all timescales • Advanced transmission fluids are an exception – here the UK has world-leading capabilities
	D: Energy Storage				• Mechanical energy storage (flywheels) and battery pack and integration are strong categories for the UK • Limited capability and potential in other categories in this area
	E: Vehicle Efficiency				• Strong in the category of lightweight structures • Limited capability and potential in components for low rolling losses. Situation improving for other technology categories in medium to long term
	F: Control Systems				• Evidence shows high capability and potential in many categories in this area when focussed on software development. The UK has limited potential in hardware development and manufacturing
	G: Energy & Fuel Supply				• Most categories show good capability to meet requirements of product roadmap in the correct timescales • More challenges exist relating to hydrogen infrastructure in the long term
	H: Development Processes & Tools				• Evidence suggests this is a strong area for the UK across all categories

Colours in chart above show range of variation within each technology area for which a significant number of individual categories deviate from the average rating

Output from the UK capability study can be found in Appendix 3

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

1. **Qualitative assessment of proximity to market to product roadmap**
   - A qualitative assessment was made of the effort required for UK to meet the requirements of the consensus product roadmap for each technology category
   - The analysis drew on the OEM product roadmap and common research agenda, as well as the results of the UK capability assessment in Step 5
   - A relative 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
   - Inputs to the analysis were the results from Step 5 and the OEM product roadmap
   - An overall rating for the potential UK benefit was derived explicitly from two component ratings: "overall market value" (size of global market opportunity) and "UK value capture potential" (proportion of this market likely to be capturable by the UK)
   - A relative rating scale was utilised
3. **Overall assessment of indicative ROI potential**
   - By comparing the qualitative assessment of effort and benefit a relative overall rating was given for each technology category, representing an indicative "return on investment" potential

Automotive technologies: the UK's current capability

An overall assessment summary using all of the analysis results gives an initial view of the best potential for UK exploitation – format is:

Technology Category

Assessment of UK capability for the Short Medium and Long Term

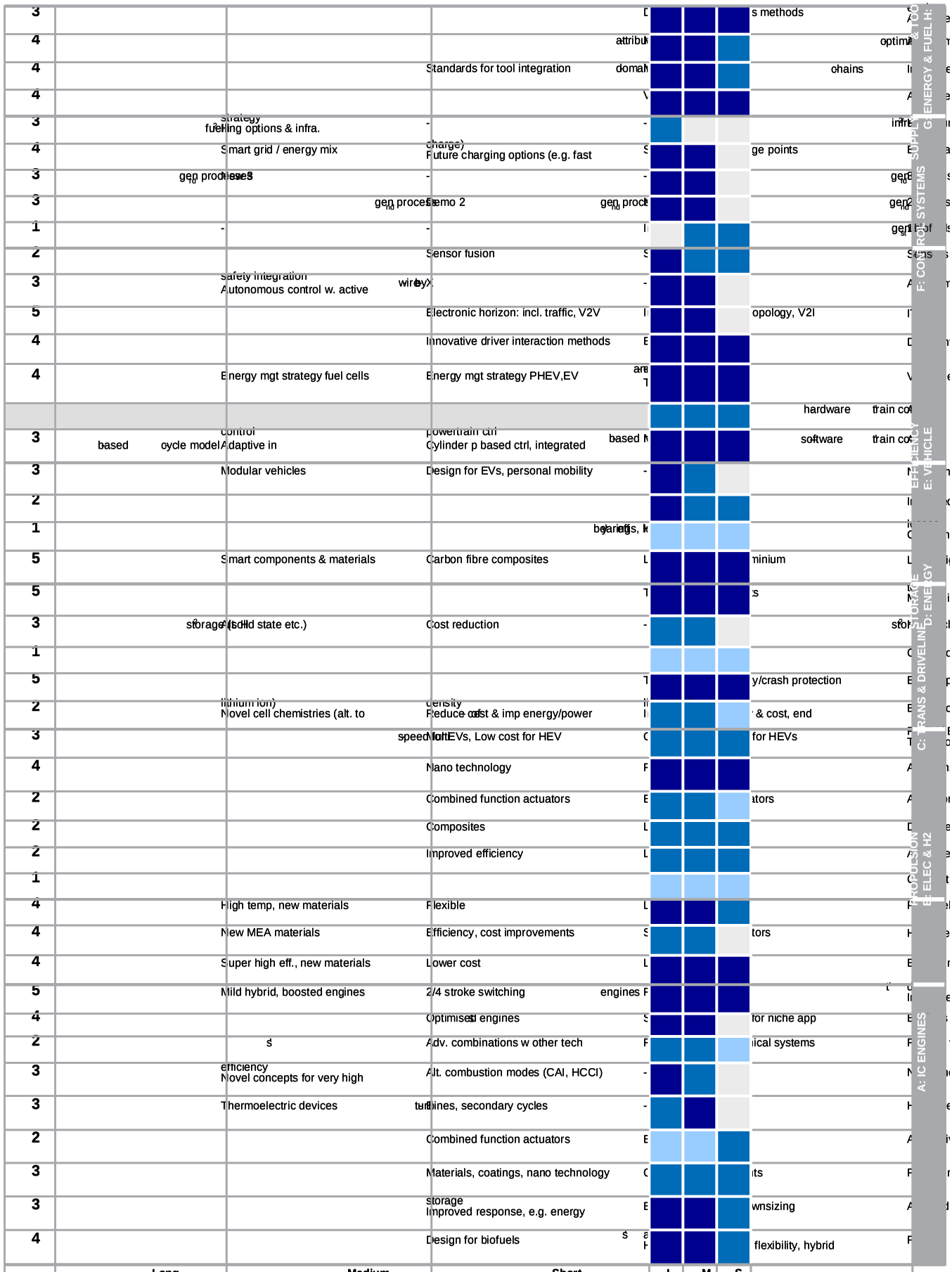
Indicative Return on Investment (ROI) analysis

	hnology Category	UK capability S	M	L	Research Area Focus (selected items of interest) Short	Medium	Long	c- ve OI"
A: IC ENGINES	FIE				gn pressures, more flexibility, hybrid app's	Design for biofuels		4
	Air handling				Boost systems for downsizing	Improved response, e.g. energy storage		3
	Friction reduction				Components, lubricants	Materials, coatings, nano technology		3
	Alternative actuation				Electric actuation	Combined function actuators		2
	Heat energy recovery systems				-	E-turbines, secondary cycles	Thermoelectric devices	3
	Novel thermo cycles				-	Alt. combustion modes (CAI, HCCI)	Novel concepts for very high efficiency	3
	Flexible valvetrains				Fully variable mechanical systems	Adv. combinations w other tech's		2
	Engines for HEV/PHEV				Simple, light engines for niche app's	Optimised engines		4
	Integrated engine design & dev't				Flexfuel engines	2/4 stroke switching	Mild hybrid, boosted engines	5
B: ELEC & H2 PROP	Electric motors				Low cost, compact	Lower cost	Super high eff., new materials	4
	Hydrogen fuel cells				Support to demonstrators	fficiency, cost improvements	New MEA materials	4
	Power electronics				Low cost	xible	High temp, new materials	4
C: TRANS & DRIVELINE	Conventional MT / AT							1
	Advanced DCT / CVT				Lower cost	ved efficiency		2
	Driveline components				Lightweight gearsets	sites		2
	Actuation improvement				Electromagnetic actuators	d function actuators		2
	Adv trans fluids				Fluids for low friction			4
	Trans concepts for HEV / PHEV / EV				Optimised calibration			3
	Battery cell dev				Imp. quality, durability life/recycling	emistries (alt. to		2
	y pack int.				Thermal control, safet			5
	itor tech.							1
							e (solid state	

Technology Area

Research Areas for Focus for Short, Medium and Long term from Common Research Agenda and Questionnaire/Workshop feedback

Overall Assessment Summary in full is on the following page


A: IC ENGINES
B: ELEC & H2 PROPULSION
C: TRANS & DRIVELINE
D: ENERGY STORAGE
E: VEHICLE EFFICIENCY
F: CONTROL SYSTEMS
G: ENERGY & FUEL H:
Long
Medium
Short
L
M
S
Research Area Focus (selected items of interest)
UK capability
Technol
Relative Indic

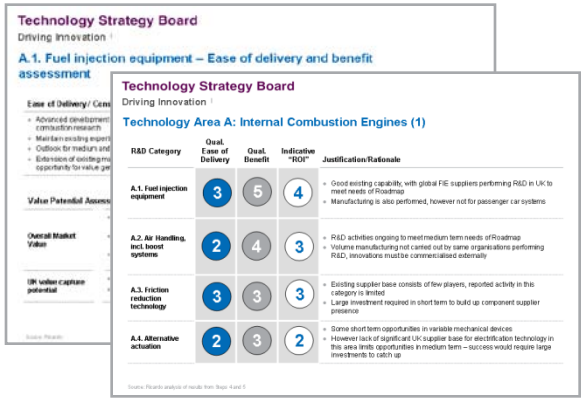
Conclusions and Next Steps

- The purpose of this work has been to develop an evidence base regarding 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 Automotive Council will publicise its conclusions separately.

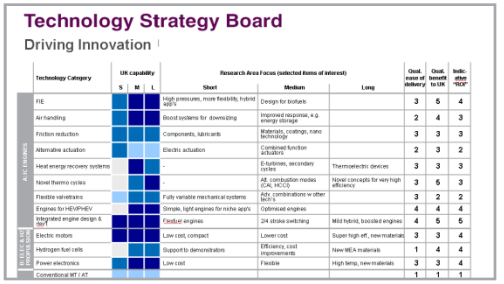
A robust process has been delivered by NAIGT and Automotive Council and can be used as the basis for on-going regular review

1 Capability Assessment

2 Indicative ROI



3 Evidence base for Strategic Decision making



4 Strategic Prioritisation

Strategic prioritisation of technology investments

5 Implementation

Implementation of agreed actions by Industry and Government

6 Regular Reviews

Rolling Reviews:

- Revised capability assessments
- Revised required actions, efforts & potential assessments
- …

Caveat: The output of this process represents a snapshot in time – update will be required on a regular basis to reflect evolutionary changes in technology, market conditions, consumer demands, and economic cycle

- The Consensus Product Roadmap, Common Research Agenda and this UK capability assessment represent a snap shot in time
- As we put actions in place which address the R&D priorities identified, it may become appropriate to redirect efforts towards different technologies
- In addition, we operate in a dynamic environment and markets, consumer attitudes etc will change
- The output of this research is considered appropriate to direct activities over a 12-18 month period but it is strongly recommended that a regular process of review is conducted

Technology Strategy Board

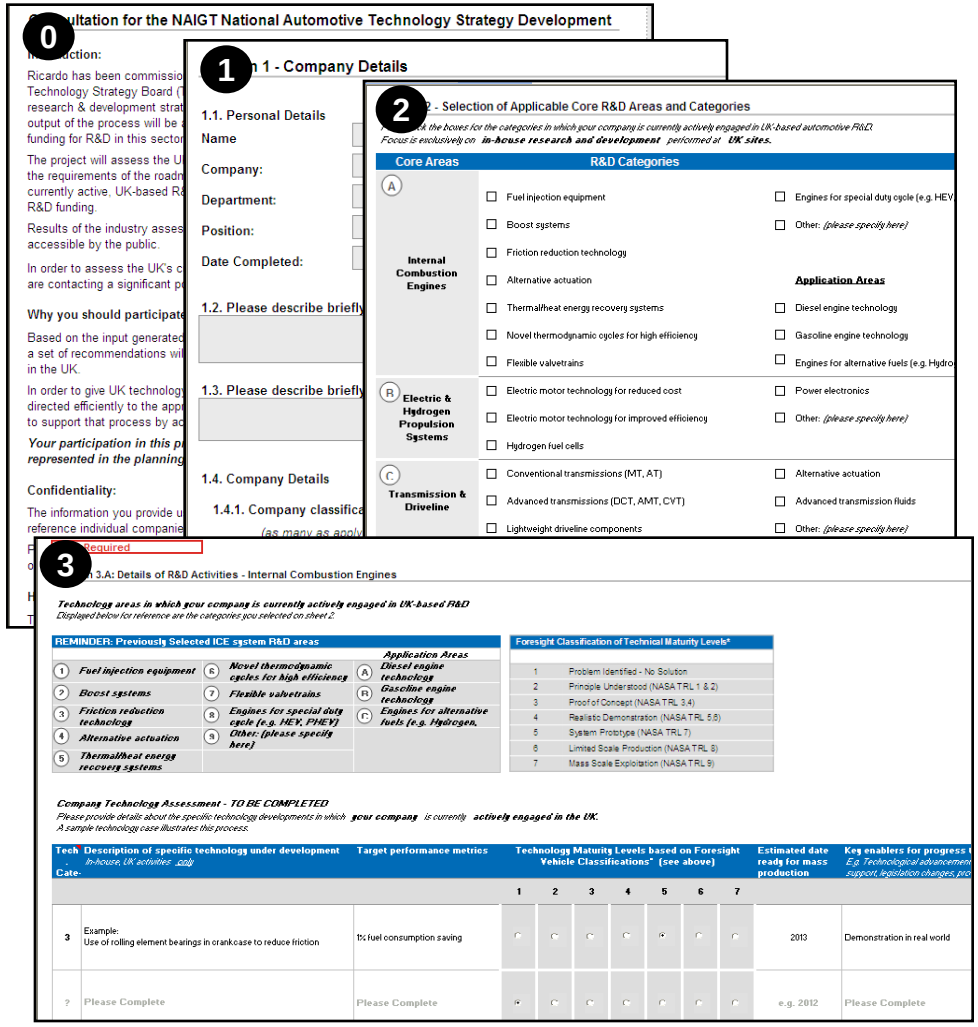
Driving Innovation

Appendices

APPENDIX 1
Questionnaire

Questionnaire

- **A questionnaire was developed, featuring four main sections:**
  - 0 Introduction to the project and the questionnaire process
  - 1 Company details
  - 2 Overview and selection of active R&D areas (based on NAIGT Consensus Research Agenda)
  - 3 Dedicated sections for each R&D area
- The invitation contained an explanatory cover letter as well as this spreadsheet-based questionnaire



Consultation for the NAIGT National Automotive Technology Strategy Development

Introduction:

Ricardo has been commissioned by the New Automotive Innovation & Growth Team (NAIGT) and the Technology Strategy Board (TSB) to assist in preparing industry recommendations for a national automotive research & development strategy. The focus will be on technologies that contribute to CO2 reductions. The output of the process will be a set of recommendations for the structure and scope of all future UK public funding for R&D in this sector. The UK government supports the NAIGT activities and will consider its outputs.

The project will assess the UK's current level of capability in specific technology areas and its ability to deliver the requirements of the roadmap through continued innovation. Please note that the focus is exclusively on currently active, UK-based R&D. The obtained information will be then used to make recommendations for R&D funding.

Results of the industry assessment and recommendations will be published by the NAIGT and will be accessible by the public.

In order to assess the UK's current level of capability in various CO2 reduction related technology areas, we are contacting a significant portion of the automotive industry base with R&D activities in the United Kingdom.

Why you should participate:

Based on the input generated from this questionnaire and after additional validation and clarification sessions, a set of recommendations will be developed which will influence the scope and structure of public R&D funding in the UK.

In order to give UK technology developments the best chance of success, it is important that public funding is directed efficiently to the appropriate technologies at the right stages of their development. This study seeks to support that process by accurately and comprehensively assessing the current state of the industry.

Your participation in this process will help to ensure that your technology interests are fairly represented in the planning of future R&D funding.

Confidentiality:

The information you provide us with will be reported back to the NAIGT in a consolidate form which will not reference individual companies. Records will be kept for auditing purposes only.

Please do not hesitate to contact us if you have any questions or concerns about how your data will be used or any other aspects of confidentiality.

How the questionnaire works:

The questionnaire is divided into three sections:

1. Company Details
2. Research Agenda Overview: Classification of CO2-reduction related technologies into eight core R&D areas, and additional sub-classification into technology type categories.
3. Description of specific R&D activities within the eight categories, listed by technology type

Please fill in the fields indicated in each section. These consist of open text entries and simple tick boxes.

Do not hesitate to contact us if you encounter any difficulties while completing the questionnaire or have any other questions.

Due to the very tight timescale available for completion of this project, we need to receive all responses by Friday, 24th April 2009

We very much look forward to receiving your responses

Stefanie Lang (Stefanie.Lang@ricardo.com, +44 (0) 7912 199994)
Simon Wrigley (Simon.Wrigley@ricardo.com, +44 (0)1273 794104)
Angela Johnson (Angela.Johnson@ricardo.com, +44 (0)1273 794869)

Questionnaire Section 1 – Company Introduction

Consultation for the NAIGT National Automotive Technology Strategy Development

Section 1 - Company Details

1.1. Personal Details

Name	
Company:	
Department:	
Position:	
Date Completed:	

1.2. Please describe briefly your role function and responsibility:

1.3. Please describe briefly your background and particular field of expertise:

1.4. Company Details

1.4.1. Company classification:
(as many as apply)

- ☐ OEM
- ☐ Tier 1 Supplier
- ☐ Tier 2 Supplier
- ☐ Consultancy
- ☐ Recent Start-up
- ☐ Other *(Please specify):* _____

1.4.2. Yearly worldwide revenues:	☐ <£100m	☐ £100-500m	☐ £500-1.000m	☐ >£1.000m
1.4.3. Yearly worldwide R&D spend:	☐ <£10m	☐ £10-50m	☐ £50-100m	☐ >£100m
1.4.4. Yearly UK-based R&D spend:	☐ <£5m	☐ £5-25m	☐ £25-50m	☐ >£50m

1.4.5. Please describe briefly the primary activity of your company:

Questionnaire Section 2 – Selection of Applicable Core R&D Areas and Categories

Section 2 - Selection of Applicable Core R&D Areas and Categories

Please tick the boxes for the categories in which your company is currently actively engaged in UK-based automotive R&D.
Focus is exclusively on ***in-house research and development*** *performed at* ***UK sites.***

Core Areas	R&D Categories	
(A) **Internal Combustion Engines**	☐ Fuel injection equipment	☐ Engines for special duty cycle (e.g. HEV, PHEV)
	☐ Boost systems	☐ Other: *(please specify here)*
	☐ Friction reduction technology	
	☐ Alternative actuation	**Application Areas**
	☐ Thermal/heat energy recovery systems	☐ Diesel engine technology
	☐ Novel thermodynamic cycles for high efficiency	☐ Gasoline engine technology
	☐ Flexible valvetrains	☐ Engines for alternative fuels (e.g. Hydrogen, biofuels)
(B) **Electric & Hydrogen Propulsion Systems**	☐ Electric motor technology for reduced cost	☐ Power electronics
	☐ Electric motor technology for improved efficiency	☐ Other: *(please specify here)*
	☐ Hydrogen fuel cells	
(C) **Transmission & Driveline**	☐ Conventional transmissions (MT, AT)	☐ Alternative actuation
	☐ Advanced transmissions (DCT, AMT, CVT)	☐ Advanced transmission fluids
	☐ Lightweight driveline components	☐ Other: *(please specify here)*
(D) **Energy Storage**	☐ Battery technology	☐ Mechanical energy storage technology
	☐ Capacitor technology	☐ Other: *(please specify here)*
	☐ Hydrogen storage technology	
(E) **Vehicle Efficiency**	☐ Lightweight vehicle structures & components	☐ New vehicle classes and configurations
	☐ Components for low rolling losses (tyres, bearings, brakes etc.)	☐ Other: *(please specify here)*
	☐ Measures for improved aerodynamics	
(F) **Control Systems**	☐ Advanced powertrain control	☐ Autonomous vehicle control
	☐ Optimised vehicle energy management	☐ Sensors & sensor integration
	☐ Driver information systems to reduce fuel usage	☐ Other: *(please specify here)*
	☐ Intelligent transport systems (ITS)	
(G) **Energy & Fuel Supply**	☐ 1st generation biofuels (food crops)	☐ Electrical infrastructure
	☐ 2nd generation biofuels (waste products)	☐ Hydrogen infrastructure
	☐ 3rd generation biofuels (algae, etc.)	☐ Other: *(please specify here)*
(H) **Development Processes & Tools**	☐ Advanced process tools	☐ Advanced testing methods & equipment
	☐ Integrated toolchains	☐ Other: *(please specify here)*
	☐ Auto-optimisation methods	

Section 3.A: Details of R&D Activities - Internal Combustion Engines

Technology areas in which your company is currently actively engaged in UK-based R&D
Displayed below for reference are the categories you selected on sheet 2.

REMINDER: Previously Selected ICE system R&D areas		
		Application Areas
1	6	A
2	7	B
3	8	C
4	9	
5		

Foresight Classification of Technical Maturity Levels*	
1	Problem Identified - No Solution
2	Principle Understood (NASA TRL 1 & 2)
3	Proof of Concept (NASA TRL 3,4)
4	Realistic Demonstration (NASA TRL 5,6)
5	System Prototype (NASA TRL 7)
6	Limited Scale Production (NASA TRL 8)
7	Mass Scale Exploitation (NASA TRL 9)

Company Technology Assessment - TO BE COMPLETED
Please provide details about the specific technology developments in which ***your company*** *is currently* ***actively engaged in the UK.***
A sample technology case illustrates this process.

Tech. Cate-gory	Description of specific technology under development *In-house, UK activities only*	Target performance metrics	Technology Maturity Levels based on Foresight Vehicle Classifications* (see above)							Estimated date ready for mass production (Level 7)	Key enablers for progress to mass production (Level 7) *E.g. Technological advancements, company collaboration, financial R&D support, legislation changes, process/raw material cost reduction, ...*	How would you rate your current UK-based R&D in this technology area against global standards?		
			1	2	3	4	5	6	7			Ahead of market	In-line with market	Market follower
3	Example: Use of rolling element bearings in crankcase to reduce friction	1% fuel consumption saving	○	○	○	○	◉	○	○	2013	Demonstration in real world	○	◉	○
?	Please Complete	Please Complete	◉	○	○	○	○	○	○	e.g. 2012	Please Complete	○	○	○
?	Please Complete	Please Complete	◉	○	○	○	○	○	○	e.g. 2012	Please Complete	○	○	○
?	Please Complete	Please Complete	◉	○	○	○	○	○	○	e.g. 2012	Please Complete	○	○	○
?	Please Complete	Please Complete	◉	○	○	○	○	○	○	e.g. 2012	Please Complete	○	○	○
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?	Please Complete	Please Complete	◉	○	○	○	○	○	○	e.g. 2012	Please Complete	○	○	○

Questionnaire Section 3 – Details of R&D Activities (note there was 1 sheet per technology area)

APPENDIX 2
Outputs from questionnaire, public funding review and workshops

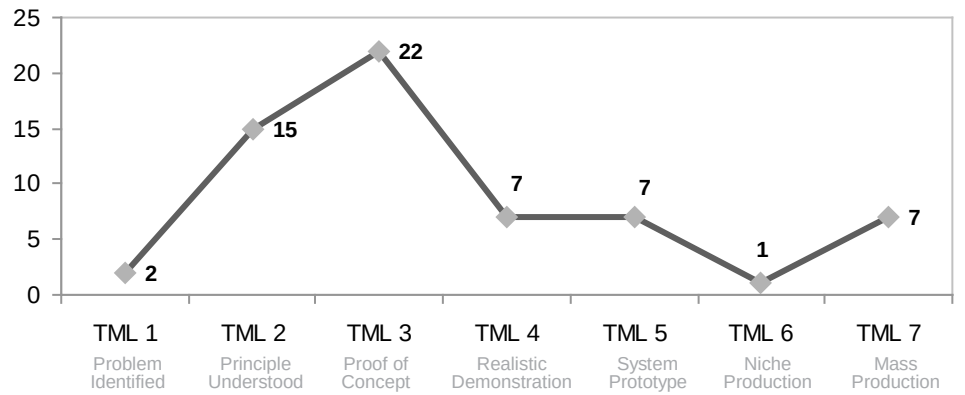
- Outputs from :
  - **Questionnaire Results**
  - Public Funding Review
  - Workshop Summary

Technology Area A: Internal Combustion Engines Questionnaire Quantitative Analysis

Technology Area ICE	
No. of respondents active in this area	18
No. of R&D projects submitted	61

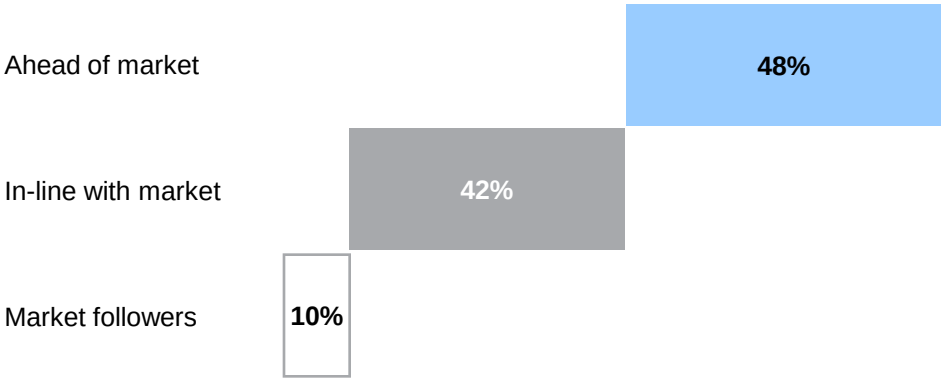
Technology Categories*	No. of Projects
A.1. Fuel injection equipment	9
A.2. Air Handling, incl. boost systems	11
A.3. Friction reduction technology	7
A.4. Alternative actuation	1
A.5. Thermal/heat energy recovery systems	7
A.6. Novel thermodynamic cycles for high efficiency	5
A.7. Flexible valvetrains	4
A.8. Engines for special duty cycle (e.g. HEV, PHEV)	5
A.9. Other (e.g. Novel materials, additives, lubricants)	6
A.10. Integrated engine design and development	18
Application Areas	
A.A. Diesel engine technology	5
A.B. Gasoline engine technology	13
A.C. Engines for alternative fuels	7

Distribution of Technology Maturity Levels (TML) for R&D Activities



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed . All statistics and evaluations are based on responses received via questionnaires only and do not necessarily represent the full scale of current activities in the UK

Technology Area A: Internal Combustion Engines Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
A.1. Fuel injection equipment	• High level of reported activity • Players in this field are consultancies, suppliers and OEMs alike • Technologies cover a wide range of TMLs, but focus on short term delivery with a few medium term exceptions • Optimisation of fuel injection equipment for alternative and bio fuels emerges as an area of special interest for consultancies and OEMs	HIGH	MED
A.2. Air Handling, incl. boost systems	• Highest number of projects reported within the ICE R&D area • Wide range of both TMLs and organisation types • High level of novel and advanced air handling concepts were reported • Well balanced split between more short term focused projects and medium term projects with a high level of novelty	HIGH	HIGH
A.3. Friction reduction technology	• Reasonable level of ongoing research in various technologies and for the short and medium term • Projects cover a wide range of friction reduction technologies (e.g. low friction coatings, materials for enhanced lubricant performance, bearing/tribology research) and span from fundamental research stage to mass production level readiness	MED	MED
A.4. Alternative actuation	• Very limited reported projects – only one early stage alternative actuation project reported by one supplier	LOW	LOW

*Source: Ricardo, based on information gathered via questionnaires

Technology Area A: Internal Combustion Engines Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
A.5. Thermal/heat energy recovery systems	• Medium activity level, but representation of projects from suppliers, consultancies and academia – OEMs did not report any live projects in this category • Focus on usage of waste heat energy recovery • Reported projects have mostly estimated times to market around 2015	**MED**	MED
A.6. Novel thermodynamic cycles for high efficiency	• Only consultancies submitted project reports for this R&D category • Number of live projects is limited and these are still in early development stages	**LOW**	MED
A.7. Flexible valvetrains	• Limited reported activity • One consultancy and one supplier submitted flexible valvetrain projects for the short term • 2/4 stroke switching projects were reported for the medium term	**LOW**	MED
A.8. Engines for special duty cycle (e.g. HEV, PHEV)	• Reported activities are aligned with medium term requirement for special duty cycle engines, but are still at early stage development and very limited in number • Projects were reported by OEMs and consultancies only and are expected to deliver in the medium term	**LOW**	MED

*Source: Ricardo, based on information gathered via questionnaires

Technology Area A: Internal Combustion Engines Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
A.10. Integrated engine design & development	• High reported activity level, concentrated in OEMs and consultancies • Many projects focussing on lightweight, downsized, boosted engines • Reported projects have a range of TMLs with the majority in the early stages of development (TML 2-3)	**HIGH**	**HIGH**

*Source: Ricardo, based on information gathered from analysis of questionnaires only

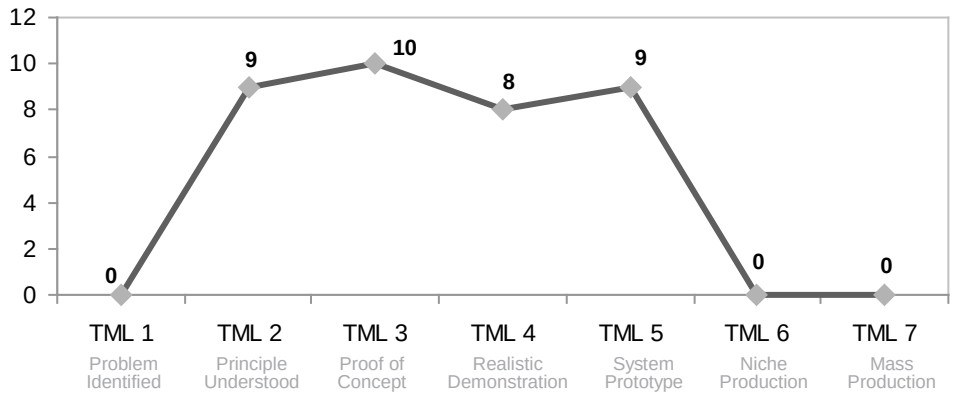
Technology Area B: Electric & Hydrogen Propulsion Systems Questionnaire Quantitative Analysis

Technology Area Electric & Hydrogen Propulsion Systems

No. of respondents active in this area	**16**
No. of R&D projects submitted	**36**

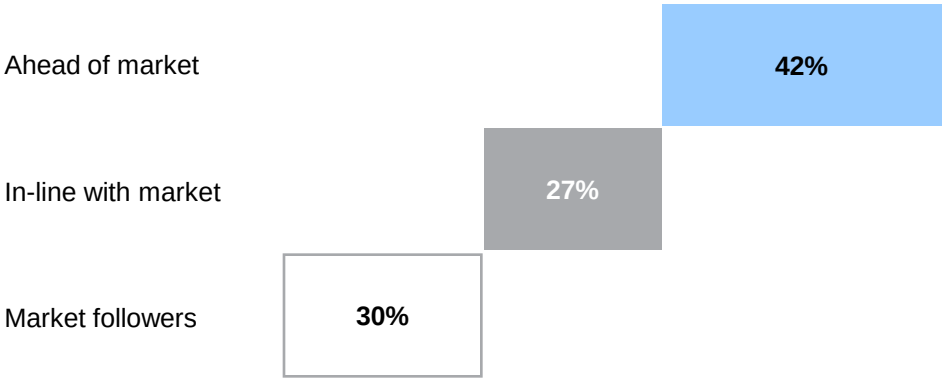
Technology Categories*	No. of Projects
B.1. Electric motor technology for reduced cost	**5**
B.2. Electric motor technology for improved efficiency	**9**
B.3. Hydrogen fuel cells	**7**
B.4. Power electronics	**13**
B.5 Other: (Electrical Steels)	**1**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

All statistics and evaluations are based on responses received via questionnaires only and do not necessarily represent the full scale of current activities in the UK

Technology Area B: Electric & Hydrogen Propulsion Systems Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
B.1 & B.2. Electric Motors for lower costs & higher efficiency	• High number of reported projects, with consultancies, suppliers, and OEMs active in this R&D category • Projects are biased towards early stage research, nevertheless a significant portion of respondents expect to deliver technologies in the short term (before 2015) and no projects are reported for long term delivery • While over 45% of respondents would classify their projects as "ahead of markets" a well above average of almost 40% perceive their projects as "market following" • Some consultancies report activities in more advanced electric motor technology areas	HIGH	MED
B.3. Fuel Cell Systems	• Moderate level of reported fuel cell projects, with most projects estimated to reach maturity already in the short term - only one project each reported for medium and long term maturity • Many technology developments appear less focused than developments in other R&D categories	MED	LOW
B.4. Power Electronics	• Very high level of activity, with projects reported from OEMs, academia, suppliers and consultancies alike • Well balanced maturity split between short and medium term focused developments • Over half of respondents (above category average) perceive their R&D in this category to be "ahead of market" – however, 27% think they are "following the market" rather than being in-line or leading	HIGH	HIGH

*Source: Ricardo, based on information gathered via questionnaires

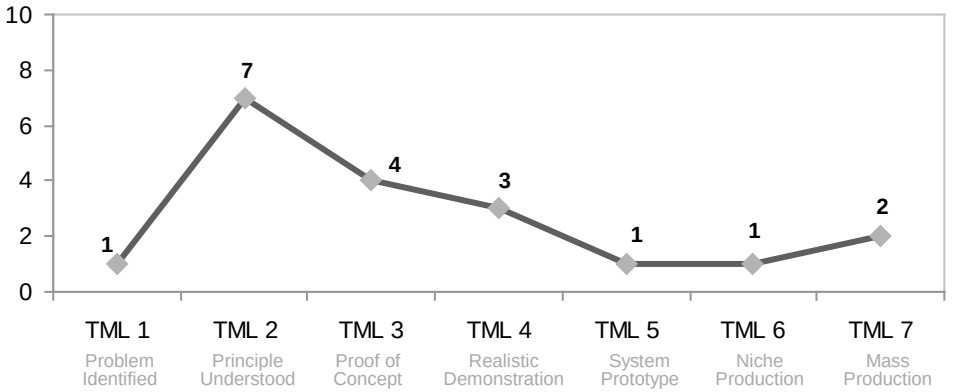
Technology Area C: Transmission & Driveline Questionnaire Quantitative Analysis

Technology Area Transmissions & Driveline

No. of respondents active in this area	**12**
No. of R&D projects submitted	**19**

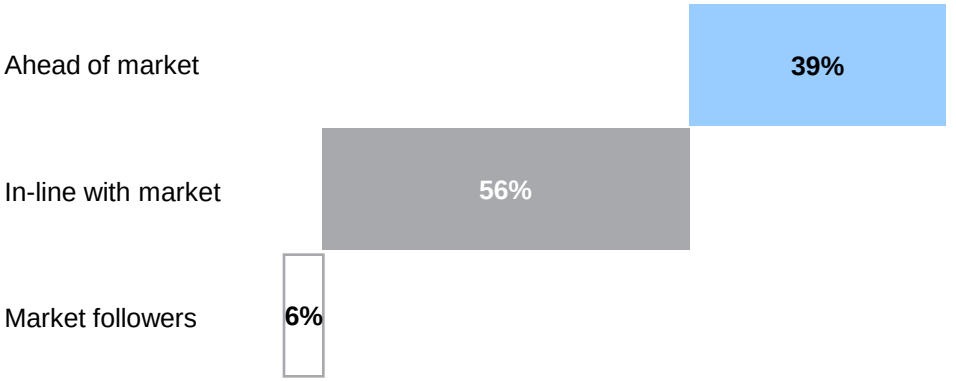
Technology Categories*	No. of Projects
C.1. Conventional transmissions (MT, AT)	**1**
C.2. Advanced transmissions (DCT, AMT, CVT)	**6**
C.3. Lightweight driveline components	**4**
C.4. Actuation Improvement	**2**
C.5. Advanced transmission fluids	**4**
C.6. Other: (e.g. EV, PHEV transmission concepts)	**2**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area C: Transmissions & Drivelines Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
C.1. Conventional transmissions (MT, AT)	• Extremely limited reported evidence of ongoing R&D projects in this category → Only one live project submitted by an OEM	**LOW**	LOW
C.2. Advanced transmissions (DCT, AMT, CVT)	• Moderate ongoing activity • All reported projects were submitted either by consultancies or OEMs • Currently, projects are predominantly focused on understanding principles and proving concepts (TML 2 and TML 3)	**MED**	MED
C.3. Lightweight driveline components	• Medium to low number of projects were reported, spanning maturity levels from TML 2 (understanding principles) to TML 6 (limited scale production) • Suppliers and OEMs are active in this category • Short term focus of all submitted projects	**MED**	LOW
C.4. Alternative actuation	• Very low reported activity level → one short term electric actuation project only	**LOW**	LOW

*Source: Ricardo, based on information gathered via questionnaires

Technology Area C: Transmissions & Drivelines Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
C.5. Advanced transmission fluids	• Medium level of reported activities • Split between short term technologies that are essentially ready for mass production and medium term technologies which are still at early development stages • Varied fields of application of the fluids under development (e.g. additives for ATs, nano materials)	**MED**	**LOW**
C.6. Other: (e.g. EV, PHEV transmission concepts)	• Some development into specalist transmission concepts for EVs and PHEVs transmission concepts • Reported projects currently still at early stage development and are expected to reach mass production readiness in the medium term	**LOW**	**MED**

*Source: Ricardo, based on information gathered via questionnaires

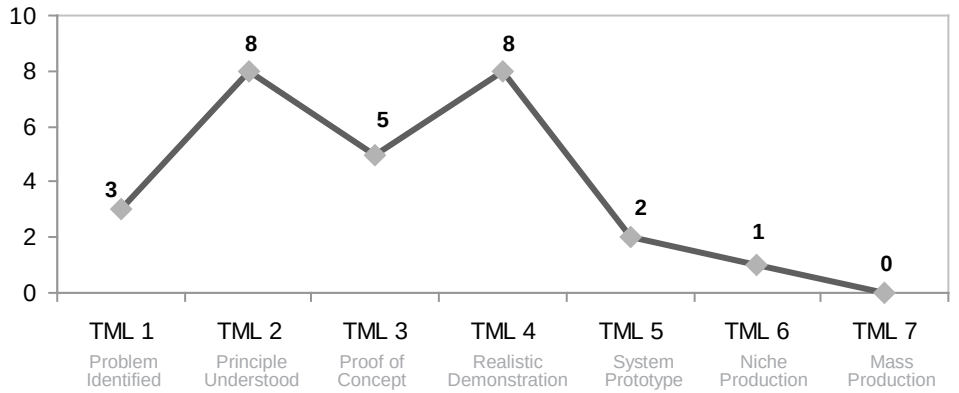
Technology Area D: Energy Storage Questionnaire Quantitative Analysis

Technology Area Energy Storage

No. of respondents active in this area	**14**
No. of R&D projects submitted	**27**

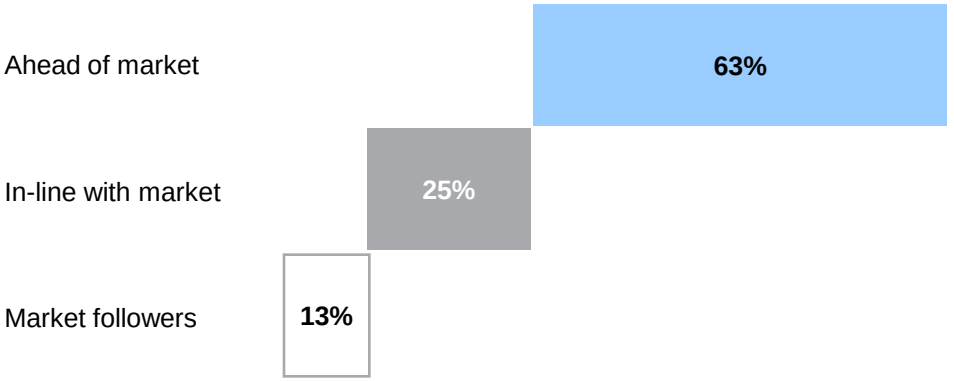
Technology Categories*	No. of Projects
D.1. Battery technology	**14**
D.2. Capacitor technology	**5**
D.3. Hydrogen storage technology	**2**
D.4. Mechanical energy storage technology	**6**
D.5. Other: (please specify here)	**-**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area D: Energy Storage Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
D.1. Battery technology	• Highest level of reported activities within the Energy Storage R&D area • Projects were submitted mostly by suppliers and consultancies, whereby suppliers focus strongly on short term projects. Medium term projects are exclusively being undertaken by consultancies. No reported long term projects • Researched battery chemistries include lead acid as well as various lithium-ion technologies • Reported target metrics vary and deviate from Roadmap requirements • Only 38% of respondents perceive their battery related projects to be "ahead of market", significantly less than the 63% average for this category	HIGH	MED
D.2. Capacitor technology	• Most organisations types have a presence in this area, however, the overall number of reported projects is limited • Noticeable polarisation of projects into short and long term timeframes, no projects were submitted with an estimated medium term delivery • No clear trends regarding specific development goals apparent	MED	LOW
D.3. Hydrogen storage technology	• Very limited activity reported – and only with a long term delivery timeframe • Current activities are still at very early development stages (TML 1, 2), however product Roadmap only requires technologies for hydrogen storage in the long term	LOW	LOW
D.4. Mechanical energy storage technology	• Consultancies submitted most of the reported projects, but suppliers and OEMs are also represented • Balanced split between short and medium term focused projects • All respondents classified their R&D projects as "market leading"	MED	MED

*Source: Ricardo, based on information gathered via questionnaires

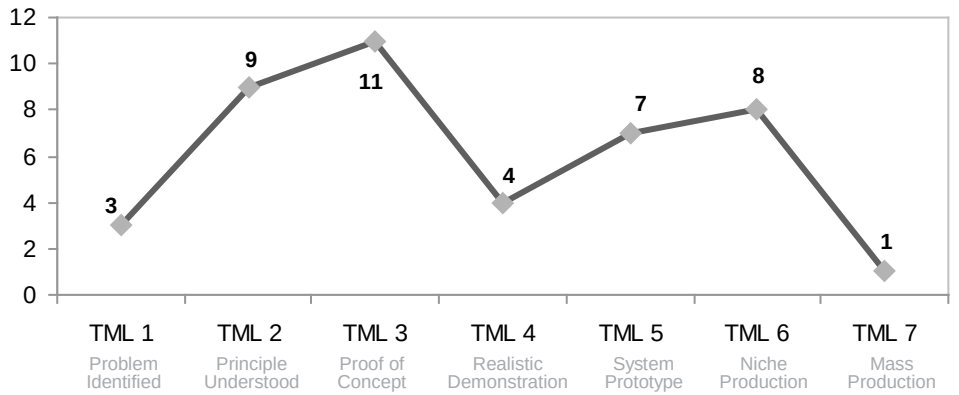
Technology Area E: Vehicle Efficiency Questionnaire Quantitative Analysis

Technology Area Vehicle Efficiency

No. of respondents active in this area	**18**
No. of R&D projects submitted	**44**

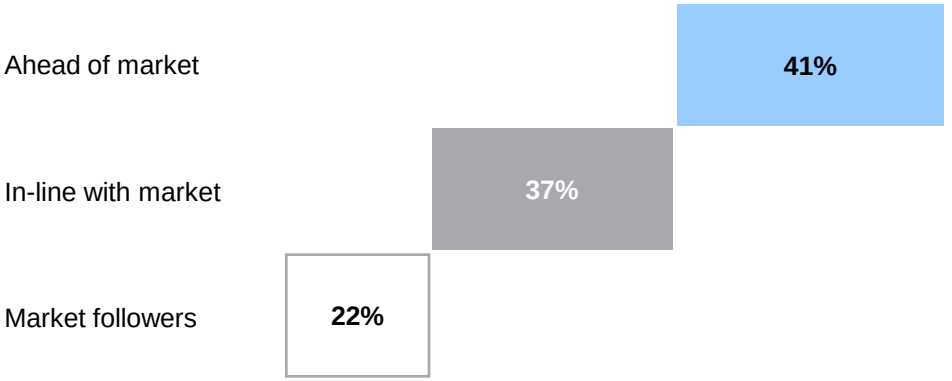
Technology Categories*	No. of Projects
E.1. Lightweight vehicle structures & components	**20**
E.2. Components for low rolling losses (tyres, bearings, brakes etc.)	**4**
E.3. Measures for improved aerodynamics	**6**
E.4. New vehicle classes and configurations	**8**
E.5. Other (e.g. improved vehicle systems)	**6**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area E: Vehicle Efficiency Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
E.1. Lightweight vehicle structures & components	• R&D category with one of the highest reported activity levels • Main research focus is on lightweight body structures (aluminium, composites, lightweight steels) • Fewer, but some R&D projects on lightweight components, such as alternatives to glass • While over 40% of respondents categorize their R&D projects as ahead of the market, an above average of 16% categorize them as market followers	HIGH	HIGH
E.2. Components for low rolling losses	• Extremely limited number of reported R&D projects • No medium and long term activities reported	LOW	LOW
E.3. Measures for improved aerodynamics	• Some reported R&D projects • Reported activities were at early development stages (proof of concept, fundamental research), however with relatively short estimated time to markets • No reported medium or long term activities	MED	MED
E.4. New vehicle classes and configurations	• Moderate level of reported activities • Activities focused on bringing products to market in the medium to long term; current R&D projects are at early development stages only • Variety of organisations are active in this area (Suppliers, consultancies as well as OEMs) • While amount of activities could be further increased, reported projects appear to be well aligned with OEM product roadmap	MED	HIGH

*Source: Ricardo, based on information gathered via questionnaires

Technology Area E: Vehicle Efficiency Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
E.5. Other (e.g. improved vehicle systems)	• Variety of "other" projects reported, predominantly in the area of improved vehicle systems (e.g. low power consumption lighting, high efficiency air con) • Most activities are short term focused at various levels of maturity • Activities are mainly reported by OEMs	**MED**	**LOW**

*Source: Ricardo, based on information gathered via questionnaires

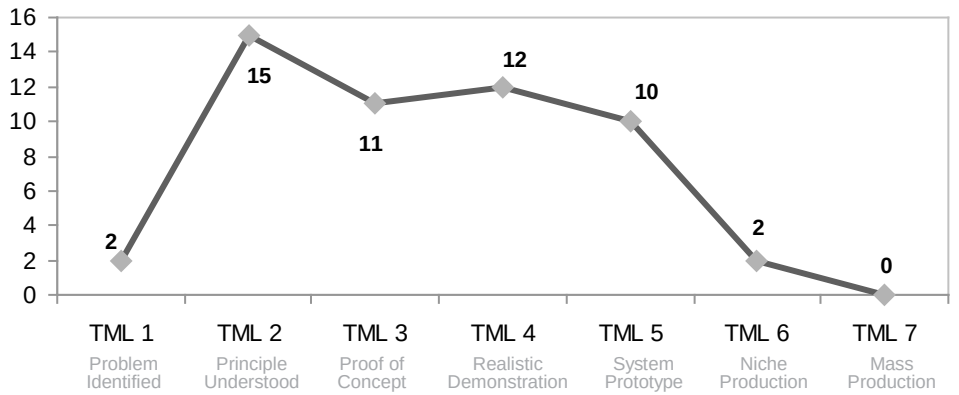
Technology Area F: Control Systems Questionnaire Quantitative Analysis

Technology Area Control Systems

No. of respondents active in this area	**20**
No. of R&D projects submitted	**54**

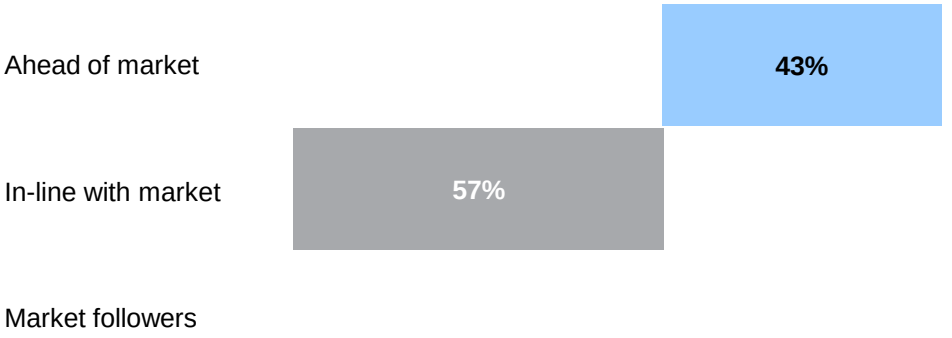
Technology Categories*	No. of Projects
F.1. Advanced powertrain control	**18**
F.2. Optimised vehicle energy management	**13**
F.3. Driver information systems to reduce fuel usage	**14**
F.4. Intelligent transport systems (ITS)	**15**
F.5. Autonomous vehicle control	**4**
F.6. Sensors & sensor integration	**5**
F.7. Other (e.g. generic & domain specific controllers)	**1**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area F: Control Systems Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
F.1. Advanced powertrain control	• Very high activity level in this R&D category by consultancies, suppliers and OEMs alike • Focus mostly on short term projects, with even some fuel cell, EV, PHEV and hybrid control systems reported to be ready for mass production within five years • Reported projects cover a wide range of required technologies for the Roadmap (from ICE to energy storage, EVs, fuel cell vehicles etc.) • Over 50% of respondents categorize their projects as market leading, and no projects were classified as market following	HIGH	HIGH
F.2. Optimised vehicle energy management	• High level of reported activities • Most projects were listed by suppliers and OEMs, comparatively few by consultancies • Projects cover a wide range of topics, but each project area is covered only sparsely • Only 1/3 of projects were classified as market leading, a significantly lower percentage than the average of 43% for this R&D area	HIGH	MED
F.3. Driver information systems to reduce fuel usage	• High number of reported R&D projects, with an even spread in terms of technology maturity levels and organisations (consultancies, suppliers and OEMs alike) • All organisations report a short timescale required to advance technologies to mass exploitation level (before 2015)	HIGH	HIGH

*Source: Ricardo, based on information gathered via questionnaires

Technology Area F: Control Systems Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
F.4. Intelligent transport systems (ITS)	• Very high reported activity level across all organisation types • Organisations are working on short term applications as well as medium term • Broad variety of technology applications are being researched, with one focus area being location aware control systems (e.g. for range optimisation of hybrids, EVs etc) • 2/3 of respondents classified their research as "in-line with market", slightly more than the R&D area average of 57%	HIGH	MED
F.5. Autonomous vehicle control	• Limited evidence of active research projects, which are all still at fundamental research stage (TML 2) • However, with the Roadmap foreseeing autonomous vehicle control as relevant for the long term only, research can still be on course to meet timescales • Majority perceive their research activity to be ahead of the market	MED	HIGH
F.6. Sensors & sensor integration	• Medium level of reported activities, no reported OEM activities • Limited activities for short term delivery • Novel sensing solutions projects ongoing, targeting medium term delivery	MED	MED

*Source: Ricardo, based on information gathered via questionnaires

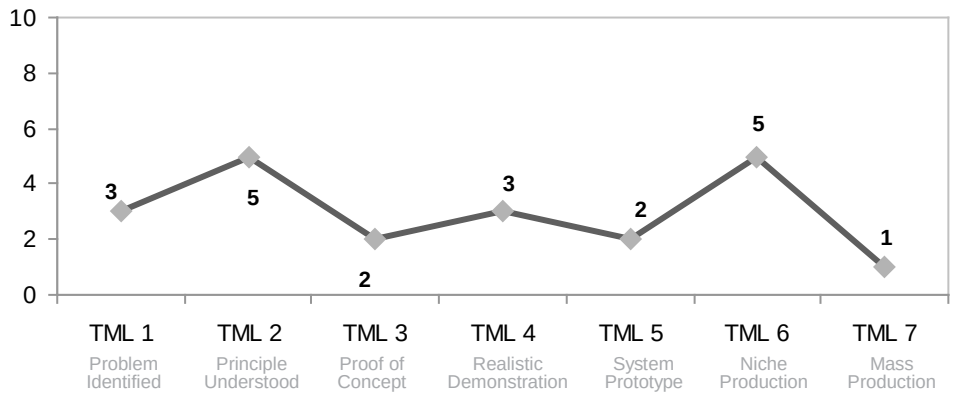
Technology Area G: Energy and Fuel Supply Questionnaire Quantitative Analysis

Technology Area Energy and Fuel Supply

No. of respondents active in this area	**14**
No. of R&D projects submitted	**21**

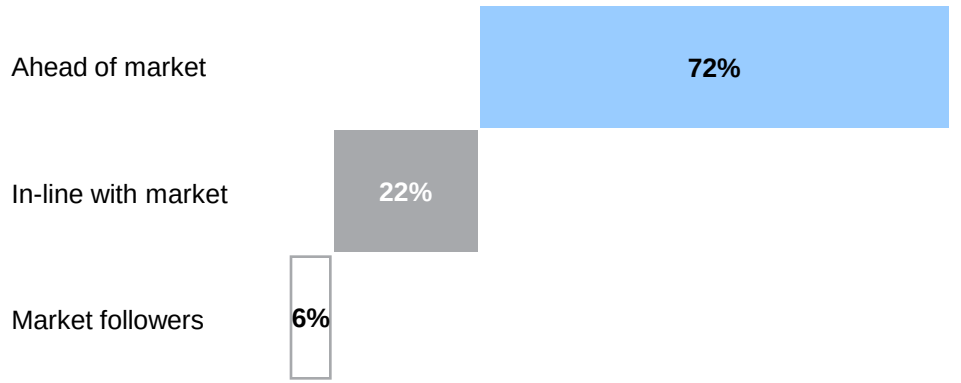
Technology Categories*	No. of Projects
G.1. 1st generation biofuels (food crops)	**4**
G.2. 2nd generation biofuels (waste products)	**5**
G.3. 3rd generation biofuels (algae, etc.)	**5**
G.4. Electrical infrastructure	**6**
G.5. Hydrogen infrastructure	**4**
G.6. Other (e.g. additives)	**2**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area G: Energy and Fuel Supply Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
G.1. 1st generation biofuels (food crops)	• Medium level of reported projects, with most reported activities being close to mass production stage • No submitted projects for medium and long term, which is in line with expected phase-out of 1st generation biofuels in the Roadmap	**MED**	**HIGH**
G.2. 2nd generation biofuels (waste products)	• Concentration of projects with a medium term delivery timeframe → In line with Roadmap requirements • However, 2nd generation biofuel research in the UK is still at very fundamental level (TML 1 and 2)	**MED**	**MED**
G.3. 3rd generation biofuels (algae, etc.)	• Limited number of reported live projects • Some fundamental research ongoing into process development and additives	**LOW**	**MED**

*Source: Ricardo, based on information gathered via questionnaires

Technology Area G: Energy and Fuel Supply Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
G.4. Electrical infrastructure	• Reported projects focused on medium term activities and were dominated by players from consultancies and infrastructure companies • No short term projects were submitted • Vast majority of respondents perceive their projects to be market leading	**MED**	MED
G.5. Hydrogen infrastructure	• Some live projects, all of them at early development stages and predominantly for the long term timescale • Consultancies, suppliers and infrastructure companies report activities • Most projects address distribution aspects rather than generation	**MED**	MED

*Source: Ricardo, based on information gathered via questionnaires

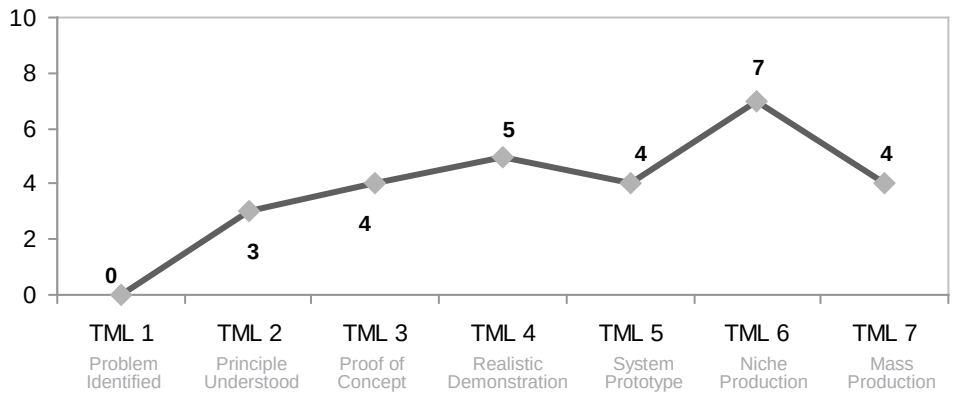
Technology Area H: Development Processes and Tools Questionnaire Quantitative Analysis

Technology Area Development Processes and Tools

No. of respondents active in this area	**10**
No. of R&D projects submitted	**26**

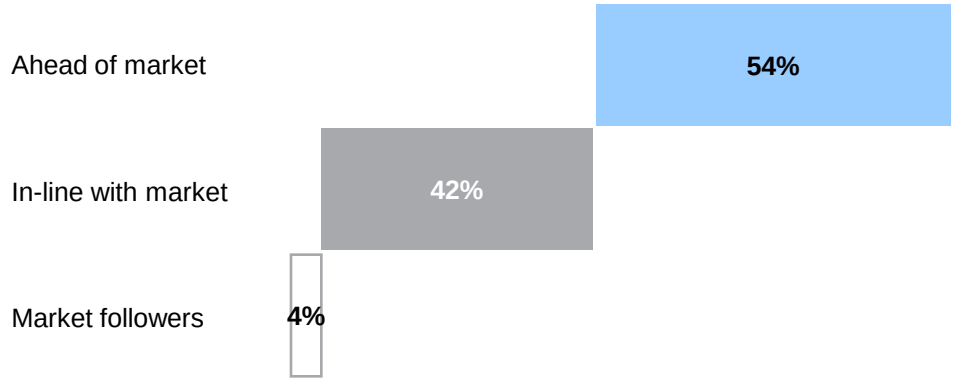
Technology Categories*	No. of Projects
H.1. Advanced process tools	**12**
H.2. Integrated toolchains	**4**
H.3. Auto-optimisation methods	**5**
H.4. Advanced testing methods & equipment	**9**
H.5. Other: (please specify here)	**-**

Distribution of Technology Maturity Levels (TML)



Global Competitiveness

Percentage of respondents who rate their R&D activities as:



*Multiple answers were allowed

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Technology Area H: Development Processes and Tools Questionnaire R&D Project Analysis

Technology Category	Key Insights	Reported Activity Level*	Relevance of projects for Roadmap*
H.1. Advanced process tools	• High number of projects spanning a range of maturity levels, but all are expected to reach mass market production readiness in the short term (before 2015) • Wide variety of organisations report activities (consultancies, academia, suppliers, OEMs) • Hugely varied applications for process tools (e.g. for vehicle architecture, aerodynamics, electric propulsion systems)	HIGH	HIGH
H.2. Integrated toolchains	• Limited reported number of projects • Reported projects are at relatively mature TMLs and estimated to reach mass production readiness in the short term	LOW	LOW
H.3. Auto-optimisation methods	• Moderate activity level, mainly by consultancies and OEMs	MED	MED
H.4. Advanced testing methods & equipment	• Range of companies involved, generally in advanced stages of research • Focus exclusively on short term availability of testing methods and equipment • Development of testing methods and equipment for a wide range of technologies, covering many relevant aspects of the OEM roadmap	HIGH	HIGH

*Source: Ricardo, based on information gathered via questionnaires

- Outputs from :
  - Questionnaire Results
  - **Public Funding Review**
  - Workshop Summary

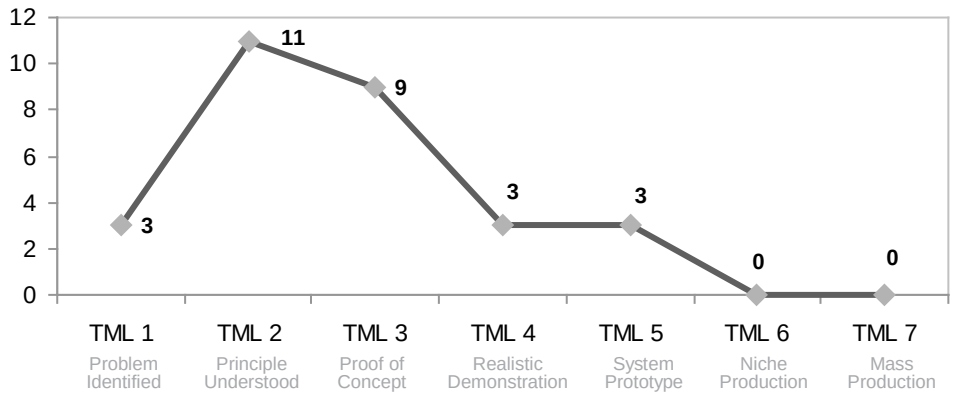
Technology Area A: Internal Combustion Engines
Public Funding Analysis

Technology Area ICE	
No. of funded projects in this area (since 2005)	**36**
No. of live funded projects in this area	**18**

Technology Categories	No. of Projects
A.1. Fuel injection equipment	**3**
A.2. Air Handling, incl. boost systems	**4**
A.3. Friction reduction technology	**6**
A.4. Alternative actuation	**2**
A.5. Thermal/heat energy recovery systems	**-**
A.6. Novel thermodynamic cycles for high efficiency	**10**
A.7. Flexible valvetrains	**3**
A.8. Engines for special duty cycle (e.g. HEV, PHEV)	**1**
A.9. Other (e.g. Novel materials, additives, lubricants)	**-**

Application Areas	
A.A. Diesel engine technology	**8**
A.B. Gasoline engine technology	**4**
A.C. Engines for alternative fuels	**8**

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

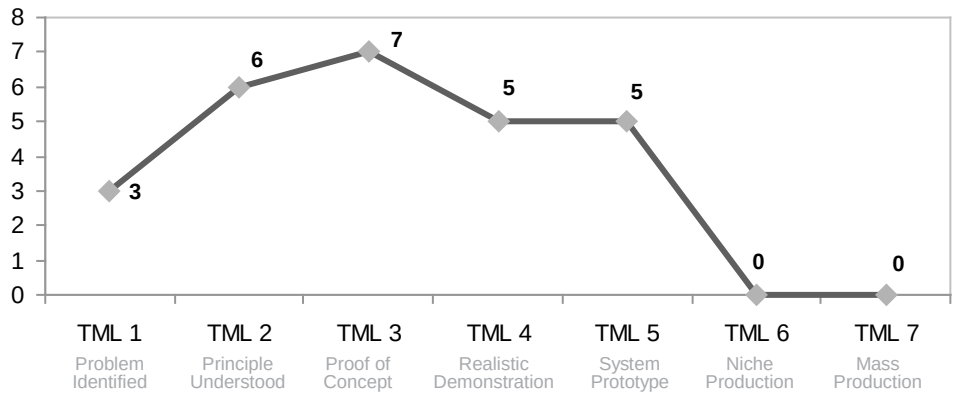
- This technology area has the most number of relevant funded projects since 2005. Many of these projects are based in academia, with few industry led consortia
- Funding is generally focussed on early academic research – understanding of principles and proving concepts
- There are a significant number of funded projects researching novel thermodynamic cycles, many of them at TML 1 & 2
- Universities with numerous projects in this area include: Birmingham, Loughborough, Leeds & Brunel
- Areas of research in alternative fuels for engines include biofuels, hydrogen and compressed air

Technology Area B: Electric & Hydrogen Propulsion Systems Public Funding Analysis

Technology Area Electric & Hydrogen Propulsion Systems	
No. of funded projects in this area (since 2005)	**28**
No. of live funded projects in this area	**18**

Technology Categories	No. of Projects
B.1. Electric motor technology for reduced cost	**8**
B.2. Electric motor technology for improved efficiency	**5**
B.3. Hydrogen fuel cells	**13**
B.4. Power electronics	**5**
B.5 Other	**-**

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

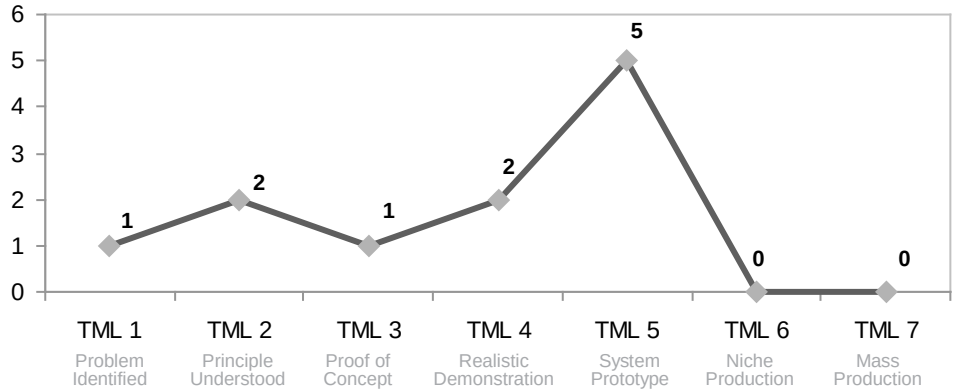
- There is a stronger bias towards industry related projects in this area, with significant numbers of projects reaching TML 4 & 5
- There are a large number of Hydrogen fuel cell projects spanning TMLs 1 to 5
- Many of the projects are headed by a company working in collaboration with other companies and academic institutions
- There are few entirely academic projects funded in this area. Newcastle, Oxford and Manchester Universities are some of those active

Technology Area C: Transmission & Driveline Public Funding Analysis

Technology Area Transmission & Driveline	
No. of funded projects in this area (since 2005)	11
No. of live funded projects in this area	6

Technology Categories	No. of Projects
C.1. Conventional transmissions (MT, AT)	2
C.2. Advanced transmissions (DCT, AMT, CVT)	-
C.3. Lightweight driveline components	-
C.4. Actuation Improvement	-
C.5. Advanced transmission fluids	-
C.6. Other: (e.g. Hybrid transmissions, hydraulic transmissions)	9

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

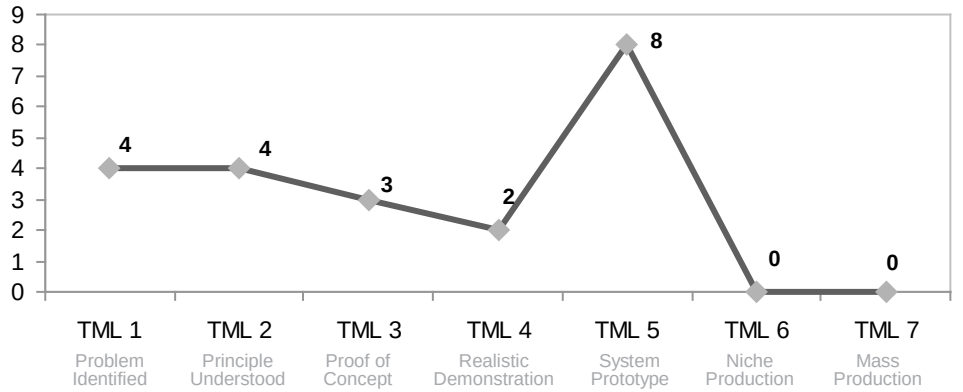
- Transmission & Driveline has the least number of funded projects, with the vast majority being focussed on hybrid transmissions
- Many of these projects develop / have developed prototype hybrid electric vehicles and are funded by the Energy Saving Trust
- There are few research projects understanding principles and investigating new concepts
- There are few entirely academic projects funded in this area. Imperial College London and Oxford University are among the active institutions
- There is a narrow spread of projects in this area, with none focussing on advanced transmissions, lightweight driveline components, alternative actuation and advanced transmission fluids

Technology Area D: Energy Storage Public Funding Analysis

Technology Area Energy Storage	
No. of funded projects in this area (since 2005)	23
No. of live funded projects in this area	13

Technology Categories	No. of Projects
D.1. Battery technology	13
D.2. Capacitor technology	3
D.3. Hydrogen storage technology	5
D.4. Mechanical energy storage technology	4
D.5. Other: (please specify here)	0

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

- There is a strong bias towards battery technology, with many projects focussed on integrating battery packs into hybrid vehicles to create system prototypes - these projects correspond to TML 5
- While some early research exists, there is a decline in projects focussing of proving concepts and realistic demonstrations of the technology before it is integrated into a vehicle
- University funding is focussed on Hydrogen Storage with Cardiff, UCL & UEA represented in this area

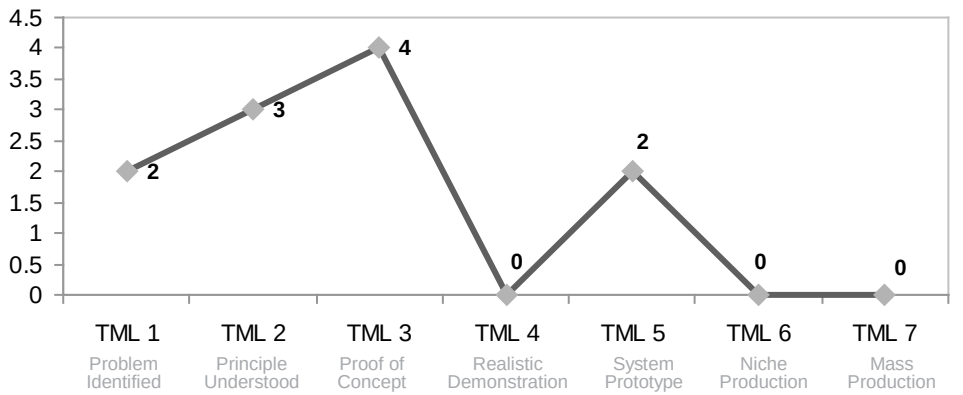
Technology Area E: Vehicle Efficiency Public Funding Analysis

Technology Area Vehicle Efficiency

No. of funded projects in this area (since 2005)	**12**
No. of live funded projects in this area	**7**

Technology Categories	No. of Projects
E.1. Lightweight vehicle structures & components	**8**
E.2. Components for low rolling losses (tyres, bearings, brakes etc.)	**1**
E.3. Measures for improved aerodynamics	**1**
E.4. New vehicle classes and configurations	**1**
E.5. Other (e.g. efficient lamps and air conditionings, self heating glass)	**1**

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

- Vehicle Efficiency is the second least represented technology area, with only 12 relevant funded projects since 2005
- Projects focussing on lightweight structures and components dominate the funding in this technology area
- Half the funded projects in this area are university led. Cardiff, Manchester, Cambridge, Cranfield and Birmingham are among those active

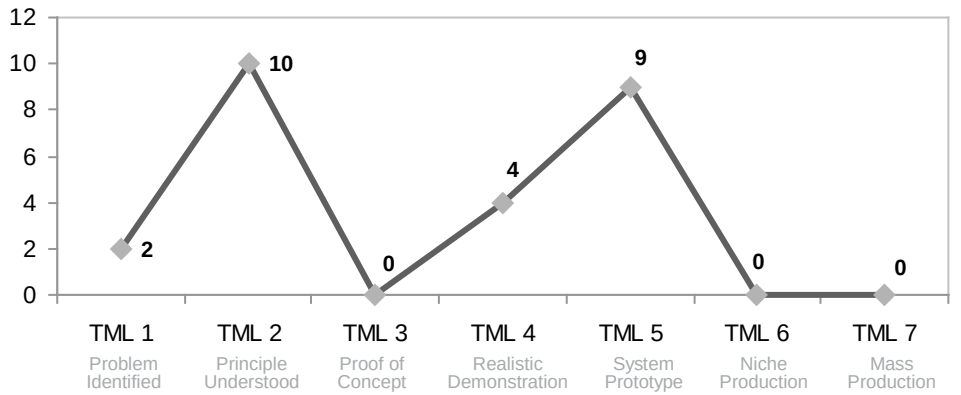
Technology Area F: Control Systems Public Funding Analysis

Technology Area Control Systems

No. of funded projects in this area (since 2005)	**27**
No. of live funded projects in this area	**14**

Technology Categories	No. of Projects
F.1. Advanced powertrain control	**18**
F.2. Optimised vehicle energy management	**7**
F.3. Driver information systems to reduce fuel usage	**1**
F.4. Intelligent transport systems (ITS)	**5**
F.5. Autonomous vehicle control	**-**
F.6. Sensors & sensor integration	**-**
F.7. Other (e.g. generic & domain specific controllers)	**-**

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

- This technology area has a large number of projects which are industry-led, focussing mostly on developing advanced powertrain control systems for hybrid prototype vehicles
- The absence of projects beginning or ending at TML 3 is to be expected for this area, as control algorithms and software typically progress rapidly from proof of concept through to system prototype
- There is a significant amount of early stage (TML 2) research across a variety of categories, which is evenly divided between industry and academia led projects
- Newcastle, Southampton, Warwick and Sussex are among the universities active in this area
- Projects focussing on optimised vehicle energy management largely relate to hybrid electric vehicles

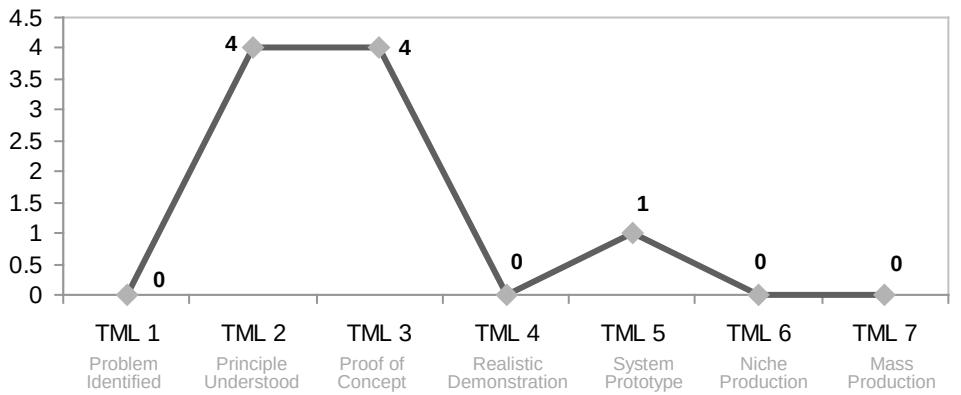
Technology Area G: Energy and Fuel Supply Public Funding Analysis

Technology Area Energy and Fuel Supply

No. of funded projects in this area (since 2005)	**15**
No. of live funded projects in this area	**10**

Technology Categories	No. of Projects
G.1. 1st generation biofuels (food crops)	**1**
G.2. 2nd generation biofuels (waste products)	**7**
G.3. 3rd generation biofuels (algae, etc.)	**1**
G.4. Electrical infrastructure	**1**
G.5. Hydrogen infrastructure	**1**
G.6. Other (Nanofuels)	**1**

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

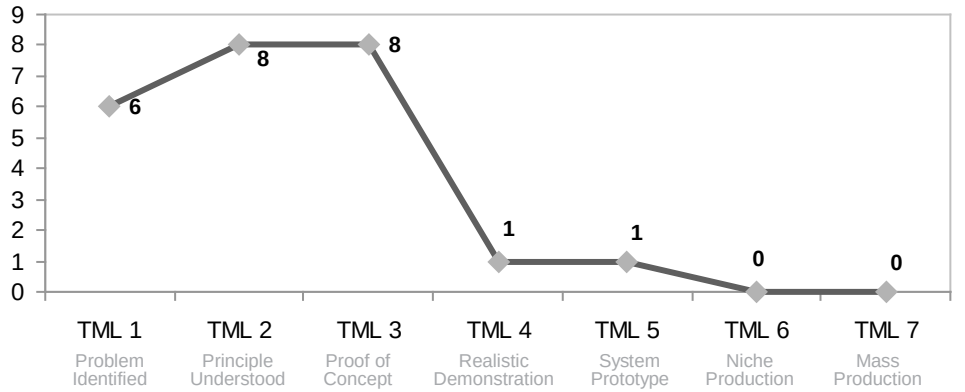
- The vast majority of projects funded in the Energy and Fuel Supply technology area are focussed on early stage development through to proof of concept
- Projects in this area are predominantly relating to 2nd generation biofuels
- Birmingham, Warwick and Strathclyde Universities are among the active academic institutions
- Each of the funding organisations has initiated projects relevant to this area

Technology Area H: Development Processes and Tools Public Funding Analysis

Technology Area Development Processes and Tools	
No. of funded projects in this area (since 2005)	27
No. of live funded projects in this area	14

Technology Categories	No. of Projects
H.1. Advanced process tools	21
H.2. Integrated toolchains	2
H.3. Auto-optimisation methods	-
H.4. Advanced testing methods & equipment	5
H.5. Other: (please specify here)	-

Distribution of Technology Maturity Levels (TML) for R&D Activities



Key Insights

- Funding in this area is predominantly based in academia and focussed on early development of advanced process tools
- The distribution of TMLs in this area is to be expected as the majority of projects are relating to advanced process tools which, once thoroughly tested, progress quickly from a proof of concept through to 'mass production'
- There is a strong focus on combustion modelling with 14 relevant projects. The other projects in this area cover a variety of technologies
- Brighton, Oxford and Loughborough Universities are amongst those represented

Public Funding Evaluation Summary

Technology Area	Key Insights	Reported Activity Level*
A. ICE	• This technology area has the most number of relevant funded projects since 2005. Many of these projects are based in academia, with few industry led consortia	**HIGH**
B. Electric & H_2 Propulsion	• There is a stronger bias towards industry related projects in this area, with significant numbers of projects reaching TML 4 & 5	**HIGH**
C. Transmission & Driveline	• Transmission & Driveline has the least number of funded projects, with the vast majority being focussed on hybrid transmissions	**LOW**
D. Energy Storage	• There is a strong bias towards battery technology, with many projects focussed on integrating battery packs into hybrid vehicles to create system prototypes - these projects correspond to TML 5	**MED**
E. Vehicle Efficiency	• Vehicle Efficiency is the second least represented technology area, with only 12 relevant funded projects since 2005	**LOW**
F. Control Systems	• This technology area has a large number of projects which are industry-led, focussing mostly on developing advanced powertrain control systems for hybrid prototype vehicles	**HIGH**
G. Energy & Fuel Supply	• The vast majority of projects funded in the Energy and Fuel Supply technology area are focussed on early stage development through to proof of concept	**MED**
H. Processes & Tools	• Funding in this area is predominantly based in academia and focussed on early development of advanced process tools	**HIGH**

*Source: Ricardo, based on information about publicly funded projects

- Outputs from :
  - Questionnaire Results
  - Public Funding Review
  - **Workshop Summary**

Technology Area A: Internal Combustion Engines Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Fuel injection & combustion development	• Good strengths in fundamental combustion research, combustion system development & calibration • Full range of capability through to production is present for Heavy Duty, but limited for Passenger Car	HIGH	HIGH	MED
Air handling systems	• Several smaller companies developing innovative products, need to link with OEMs & volume suppliers • Opportunity for crossover from Motorsport	MED	HIGH	MED
Flexible valvetrains	• No major suppliers active in product manufacture, little mainstream development for short term • Considerable consultant expertise for development of advanced valvetrains for longer term, but lack of supplier base means limited scope for uptake	LOW	HIGH	LOW
Mechanical friction reduction	• Strength in fundamental friction research, materials & lubricant development • Development & manufacture of components for low friction are limited	HIGH	MED	MED

*Source: Ricardo, based on information gathered in the workshops

Technology Area A: Internal Combustion Engines Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Reduction of Parasitic Losses	• Some small suppliers involved in development and low volume of relevant ancillary systems: variable mechanically-driven pumps • Little early stage R&D of more advanced systems or volume manufacture in this category	LOW	MED	LOW
Heat Energy Recovery Systems	• Some university and small supplier involvement in research & advanced development • No current manufacturing activities	MED	MED	LOW
Novel Thermodynamic Cycles & Combustion for High Efficiency	• Good base of expertise in universities & consultancies • Little OEM activity	HIGH	MED	
Engines for Special Duty Cycles	• Potential for involvement of existing small suppliers in low volume manufacture of engines for niche vehicles	HIGH	HIGH	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area B: Electric & Hydrogen Propulsion Systems Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Electric Motors	• Good understanding of new technologies in electric motors and good capability, but limited capacity to produce in volume • Good academic research • Niche potential in the short term, but with a significant number of companies already engaged in electric motors → good opportunity to expand existing supply base	HIGH	HIGH	MED
Power Electronics	• Good capabilities in R&D • Fewer active specialists with the ability to grow than in the electric motor section. However, players from adjacent industries (e.g. train, white goods, aerospace, mining, trains) could enter the automotive market place in the medium and long term • Long term potential, but significant actions required to move from pure availability of technology to large scale exploitation	HIGH	HIGH	MED
Fuel Cell Systems	• Lots of academic research, no current manufacturing (for automotive) • Capabilities in integration of fuel cells existent	HIGH	MED	LOW

*Source: Ricardo, based on information gathered in the workshops

Technology Area C: Transmission & Driveline Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Reduction of Transmission & Driveline Losses	• Several small suppliers and consultancies with relevant design & development expertise • However no major operations for development or manufacture of mainstream transmission products • World leading development of transmission fluids is a highlight	MED	MED	LOW
Advanced transmissions (e.g. AMT, CVT, DCT)	• Several smaller suppliers & consultancies with significant expertise in design & development of innovative concepts • Manufacture of low volume transmission products		MED	MED
Actuation Improvement	• Few if any active players, very little activity • Some ongoing R&D to deliver medium term improvements to Roadmap		LOW	LOW
Mass reduction of components	• Very few major suppliers, little reported activity • More radical innovations from smaller suppliers supported by UK strength in alternative materials, but applicability may be limited for volume vehicle applications	HIGH	MED	LOW

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area C: Transmission & Driveline Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Transmissions for hybrids & EVs	• Potential opportunities arise from electrification • Small suppliers well-positioned to support market entry through niche products, though commercialisation may be a challenge • Risk to transmissions industry posed by uptake of full EVs in the very long term (possibility of transmission deletion)	MED	HIGH	HIGH
Alternative transmission architectures	• No comments recorded			

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area D: Energy Storage Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Electrical Energy Storage	• Limited number of companies active in automotive batteries • Short to Medium term academic R&D in the area of new chemistries mainly looking to license IP, no obvious opportunity for cell manufacturing (due to high capital expenditure required) with primary focus on Li-Ion chemistries and some PbA • View that UK is poorly positioned for the future compared to other countries, little global presence • Potential opportunity in end-of-life / recycling technology for batteries	MED	LOW	LOW
Electrical Energy Storage – pack development	• Common view that UK has greater capability in battery pack development and vehicle integration than cell development • UK strength is in developing battery packs to conform to standards	MED	HIGH	MED
Energy Storage Management	• Similar position to pack development, UK leader in short term • This area may phase out in the future as the system is integrated with ECU	MED	HIGH	MED
Mechanical Energy Storage	• Several companies and consultancies involved in the area of flywheels • Leader in flywheel technology, opportunities to extend this to application & implementation in medium term • Flywheels yet to show true benefits for application, but there is potential to scale up and maintain manufacturing in the UK	MED	HIGH	MED

*Source: Ricardo, based on information gathered in the workshops

Technology Area D: Energy Storage Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Hydrogen Storage	• Some research activity in this area in the medium term	MED		
Alternative Energy Storage	• No comments recorded			

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area E: Vehicle Efficiency Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Lightweight vehicle structures & components	• Many suppliers with strong capabilities present in the UK and significant research at universities • Two established OEMs with key capability • Look to maximise knowhow from aerospace industry as well as increase volumes (including possibly process consulting)	HIGH	HIGH	HIGH
Components for low rolling losses	• Tyres: OEMs closely involved in tyre development process, but lack of major tyre development or manufacturing by suppliers in UK; some academic expertise • Bearings: some Tier 1 supplier activity suspected, no clear focus on loss reduction • Brakes: several motorsport-related suppliers (possible crossover expertise), however no mainstream development or manufacture for road cars	MED	LOW	LOW
Improved aerodynamics	• World leader in aerodynamic research & advanced development, with excellent facilities present in the UK (universities, crossover from aerospace & motorsport) • Development of this could be an opportunity, however not clear how to capitalise on this for large scale automotive application – little body design / panels / parts activity in UK	HIGH	MED	LOW
Improved vehicle systems (esp. AC, PAS, braking)	• Most globally active Tier 1 suppliers are based abroad • A few smaller / niche suppliers	LOW	LOW	LOW

*Source: Ricardo, based on information gathered in the workshops

Technology Area E: Vehicle Efficiency Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
New vehicle classes & configurations	• Potential for innovation & opportunity for market entry of initially low volume products by niche vehicle manufacturers & suppliers • Several existing small companies active in promoting innovative concepts		MED	MED
Multi-function actuators (reduced weight & costs)	• No comments recorded			

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area F: Control Systems Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Advanced Powertrain Control	• Strong in software but challenge is integrating with hardware (problem exists in retention of IP to capture value) • Future potential may come from the integration of control systems into individual components e.g. motor/generators • Potential opportunity in EV control, which is simplified	HIGH	HIGH	MED
Driver Information Systems	• Strong in academic R&D, but no manufacturing capability • Debate over future of this area, as software moves faster than vehicle technology. Will systems be plug-and-play or integrated into the vehicle?	HIGH	HIGH	LOW
Intelligent Transport Systems	• Strong R&D with many companies involved • Intelligent transport systems are limited by infrastructure, for which there are no standards yet defined. This is an opportunity for the UK to take the lead	HIGH	HIGH	MED
Vehicle Energy Management	• Comments from powertrain control apply • Some UK work in regenerative braking and exhaust heat recovery • Not a lot of short-term evidence, but potential in medium term	MED	MED	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area F: Control Systems
Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Thermal Management	• Strong in software but challenge is integrating with hardware (problem exists in retention of IP to capture value)	MED	MED	
Sensors & Sensor Integration	• Some development but not manufacturing • Capability in UK universities, crossover from other sectors (e.g. medical)	MED	MED	LOW
Autonomous Vehicle Control	• Work by several companies in this area, potential crossover from military and sub-sea exploration sectors in the long term • Lack of standards in some areas	MED	HIGH	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area G: Energy & Fuel Supply Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Charging Infrastructure – local hardware	• Early stage niche EV market 13amp plug sufficient • Short term development of charging hardware, smart metering & commercial models by suppliers and infrastructure providers • Evidence of research programmes into renewable solar charging	MED	HIGH	
Charging infrastructure – grid systems & strategy	• Longer term developments towards fast charging • Research into inductive charging	MED	MED	
Optimised 1st gen biofuels processes	• UK in position to respond but no change expected • Mature technology – political will drive	LOW	MED	MED
Future generation biofuels (2nd and 3rd gen)	• Academic research in this area • Biotechnology Biological Sciences Research Council (BPSRC) may be working in this area • 2 major oil companies with research facilities in UK • Potential opportunity for process licensing in medium to long term	MED	MED	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area G: Energy & Fuel Supply Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Biofuel distribution infrastructure	• Suppliers generally have the ability to adapt to changing requirements			
Optimised conventional fuels	• Market driven opportunity & challenge • UK well positioned in terms of development if required		HIGH	
H_2 generation & distribution infrastructure	• Insufficient driver for H_2 to initiate significant activity • UK has research capabilities in medium & long term hydrogen infrastructure	MED	MED	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

Technology Area H: Processes & Tools
Workshop summary

R&D Category	Key Additional Insights from Workshop	Level of UK Activity*		
		Acad	Dev.	Mfrg
Advanced development tools	• Significant levels of activity in simulation tools & methods development • Innovation culture & extensive development of tools & methods in all types of organisation (universities, consultancies, suppliers) • Several tools sold, but general challenge to generate visibility of available capabilities and capitalise on knowhow	**HIGH**	HIGH	HIGH
Integrated development toolchains	• Big new area of opportunity • So far limited existing know-how / activity	**MED**	MED	
Advanced testing methods & equipment	• Several world-class automotive testing organisations are UK-based • Wide range of high-calibre testing facilities & equipment available across industry & academia, opportunity to improve return on these through higher levels of visibility & co-ordination • Some manufacture/sale of automotive-related test equipment	**HIGH**	HIGH	MED
Auto-optimisation methods using virtual systems	• UK has good capability for integration of tools to solve multi-dimensional problems • Currently limited activity	**MED**	MED	

Blank = insufficient evidence to judge level of UK capability

*Source: Ricardo, based on information gathered in the workshops

APPENDIX 3
Capability Assessments

Technology Area A: Internal Combustion Engines
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
A.1. Fuel injection equipment				• High level of reported short term activity in terms of projects and players • Passenger car system development, but no players with whole chain capability through to production in UK • Strong combustion system development and calibration, but very limited in product development and manufacturing • Medium term strong FIE and combustion research ongoing → potential for expansion of existing product development to cover relevant technologies • Long term potential for positive development in FIE to continue
A.2. Air Handling, incl. boost systems				• Very high R&D activity level (active organisations and reported projects), but manufacturing is performed by different companies (no tie-in of research and manufacturing) • Development of advanced concepts ongoing, which meet requirements of the roadmap → high potential for medium term • Positive long term potential (continuation from strong medium term base)
A.3. Friction reduction technology				• Friction reduction covers a wide range of technologies, of which lubricant development and to a smaller extent manufacturing emerge as focus areas (e.g. Shell, Infineum, BP) • Lack of significant component development and manufacturing somewhat limits medium term potential • Limited evidence of R&D for long term. Evolutionary developments (esp. in lubricants tech's) will likely continue and enable maintenance of medium rating
A.4. Alternative actuation				• Some capability in variable mechanical pumps for reduced parasitic loss • Very limited evidence of any activity in electric or other advanced actuation systems to meet roadmap needs for medium term and beyond

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area A: Internal Combustion Engines
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
A.5. Thermal/heat energy recovery systems				• No evidence reported for short term – no requirements from roadmap for short term • Strong medium term R&D reported, on track to meet medium Roadmap requirements • Several players active in medium and long term developments • Good prospects for manufacturing potential in medium term (e.g. from air handling suppliers) • Limited evidence of ongoing fundamental research at University level (e.g. no funded projects), no evidence of thermoelectric research
A.6. Novel thermodynamic cycles for high efficiency				• Strong evidence of University research and some evidence of ongoing consultancy projects (on track to meet requirements) • No reported activities from OEMs or suppliers
A.7. Flexible valvetrains				• Manufacturing of engines featuring flexible valvetrains is present, but no evidence of mainstream development or manufacturing in UK for short term • Some evidence of R&D from very small number of organisations for medium term • Long term potential uncertain due to lack of supplier base and limited anticipated requirement of technology by OEMs
A.8. Engines for special duty cycle (HEV, PHEV)				• Good evidence of OEMs and consultancies engaged in development of engines for special duty cycles • Existing manufacturing capabilities could be exploited for medium and long-term manufacturing (both high and low volume manufacturers present)

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area A: Internal Combustion Engines
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
A.10. Integrated engine design & development				• Strong short term strengths in development and manufacturing, with a significant number of OEMs active in this area and existing manufacturing operations in UK • Strong medium and long term R&D reported, on track to meet Roadmap requirements • Several players active in medium and long term developments

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area B: Electric & Hydrogen Propulsion Systems Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
B.1 & B.2. Electric Motors for lower costs & higher efficiency				• Good short term supplier base capability for niche products, several players • Potential for scale-up to volume production in the medium term (e.g. spin-outs from related industries) • Evidence from public funding and questionnaires of strong ongoing fundamental research, qualitatively strong academic base
B.3. Fuel Cell Systems				• Large number of publicly funded projects (broad spread from fundamental research to vehicle applications) • Evidence of component manufacturing, but currently no complete automotive fuel cell stack manufacturing • Majority of reported projects not fully in line with Roadmap requirements
B.4. Power Electronics				• Large number of active players and reported projects • Good R&D presence and low volume manufacturing capability • High medium term potential, if right drivers are in place, adjacent industries could provide base for quick scale up

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area C: Transmissions & Drivelines
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
C.1. Conventional transmissions (MT, AT)				• Some niche manufacture with a focus on motor sport • Very limited reported short term developments in this category • Medium and long term: No evidence that situation is likely to change
C.2. Advanced transmissions (DCT, AMT, CVT)				• Consultancy and some OEM development projects reported for short term and medium term • Evidence that the current technology development projects are in line with Roadmap requirements • Potential for exploitation through technology licensing but no volume manufacturing and unlikely that large scale manufacturing will be built up
C.3. Driveline components				• Some reported volume production of driveline components, but limited number of players • Medium to low level of reported R&D activity with a primary focus on evolutionary product development • Not all reported projects seem to be well aligned with mass market requirements for Roadmap
C.4. Actuation Improvement				• Very low reported activity level, especially for short term delivery • For medium term some applied research in this area • No publicly funded projects in this category, but future trend towards electric/electromagnetic actuation aligns with academic strengths

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area C: Transmissions & Drivelines
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
C.5. Advanced transmission fluids				• Two world leading additive companies active in R&D in UK, with short and medium term activities reported in this specialist category • Little evidence of current fundamental academic R&D to support long term development of breakthrough additive chemistries, however good capability & receptive market for exploitation
C.6. Transmission concepts for HEV, PHEV and EV				• Limited reported industry activity for short term, but significant applied research ongoing • Significant number of publicly funded projects become relevant for the medium term (Over 80% of all publicly funded projects in transmissions fall into this category) • Potential for small suppliers to tap into low volume EV market in the short to medium term

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area D: Energy Storage
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
D.1.a. Battery cell development				• Limited number of players and active projects and no volume manufacturing capabilities • Significant research into novel cell chemistries with potential for medium term value capture • Little evidence of fundamental research suggests limited long term potential
D.1.b. Battery pack and integration				• Small number of suppliers/assemblers currently present • Strong capability in assembly and vehicle integration of battery packs for niche applications with potential for medium to long term expansion
D.2. Ultracapacitor technology				• No responses received from any organisations with significant focus on this technology • Little evidence of current development or manufacture of ultracapacitor systems • Some evidence of integration R&D • Medium and long term potential limited due to lack of innovation
D.3. Hydrogen storage technology				• Limited number of significant players in this category • Limited evidence of current active development programmes, but potential to meet Roadmap requirements for the medium term • Some early academic research ongoing giving potential for the long term
D.4. Mechanical energy storage technology (flywheels)				• Strong development capability base with several suppliers of various flywheel technologies (amongst world leaders for automotive applications) • Globally competitive manufacturing capability with potential for scaling-up and/or licensing

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area E: Vehicle Efficiency
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
E.1. Lightweight vehicle structures & components				• High level of reported R&D activities (large number of players and projects) • Slight R&D bias towards body structures rather than components • Significant current manufacturing activity in lightweight steel and aluminium as well as world leader in carbon fibre • Most available technologies focus on low volume applications (in line with overall market requirements) – opportunity for first exploitation through UK niche vehicle manufacturers • Reported activities are well aligned to Roadmap requirements
E.2. Components for low rolling losses				• Very limited reported activity (some bearings, joints & tyre development and manufacture) • Potential for increase of activities from existing suppliers and possible cross-over from motor sport expertise (e.g. bearings) could give a more positive outlook for the medium and long term, but no evidence received for this
E.3. Measures for improved aerodynamics				• Limited body design and testing done in the UK • Good base of fundamental expertise reported in this category (on academia, supplier, consultancy and OEM level) • Strong aerospace and motorsport expertise would support future advanced concept developments • Potential to expand on existing capabilities if market demand and OEM presence requires
E.4. New vehicle classes and configurations				• Moderate to high number of live projects given that this category is still very much in its early stages • Some good concept incubator organisations present, which could become more relevant as category matures

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area F: Control Systems
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
F.1.a. Advanced powertrain control – software				• Very high reported industry activity levels (both number of active organisations and reported projects) • Very high number of publicly funded projects in this category (slight bias towards more mature TML, but with fundamental research projects as well) • IP retention and capitalization of expertise are key challenges for medium and long term
F.1.b. Advanced powertrain control - hardware				• Fewer active key players at present than for software
F.2. Optimised vehicle energy management				• Moderate short term evidence of activities, but significant evidence for ongoing medium and long term R&D projects • Good capabilities reported for developing energy management strategies • Good number of publicly funded projects in this category
F.3. Driver information systems				• High level of industry based activities reported • Lack of suppliers of complete product solutions for the short term, however rapid transition from research to production gives good short term potential nonetheless • High potential in this category for cross-over of expertise from enabling industries (e.g. gaming industry) • Potential for industry integration in the medium and long term

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area F: Control Systems
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
F.4. Intelligent transport systems (ITS)				• Strong evidence of significant capabilities in this area (number of active players, academia involvement, project characteristics etc.) • Large number of funded projects • Strong players in enabling industries present (e.g. telecoms, navigation system information providers) • Emergence of disruptive technologies could strongly influence the medium and long term capability assessment (positive or negative)
F.5. Autonomous vehicle control				• Already medium reported level of R&D activities, even though Roadmap only requires autonomous control in the long term • High relevance of reported projects for Roadmap, current capability would allow medium term success in meeting requirements • No UK-based OEMs reported activities in this area • Strong supporting foundation from related technologies (e.g. ITS)
F.6. Sensors & sensor integration				• Limited activities for short term delivery (players & projects), and no large scale manufacturing capabilities • Innovative sensor technologies and sensor integration research reported for medium term • Medium and long term potential to capitalise on progress in this category

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area G: Energy and Fuel Supply
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
G.1. 1st generation biofuels (food crops)				• Major companies with significant research presence in the UK • Medium level of reported projects with most of them close to mass production level • Mature technology category, which is expected to be superceded in the medium to long term
G.2. 2nd generation biofuels (waste products)				• Major companies with significant research presence in the UK • Large number of publicly funded projects and reported evidence of company driven research → good potential for medium and long term
G.3. 3rd generation biofuels (algae, etc.)				• Major companies with significant research presence in the UK • Limited number of reported live projects, some fundamental research ongoing
G.4. Electrical infrastructure				• Local infrastructure: Some evidence of technology development by consultancies, suppliers and infrastructure providers • Grid system: Reported activities by infrastructure provider and consultancies
G.5. Hydrogen infrastructure				• Some live projects reported, all at early development stages in line with Roadmap • Good research expertise (academic & industrial) present in the UK • Establishment of infrastructure within 20 years constitutes major undertaking – not clear that conditions are met

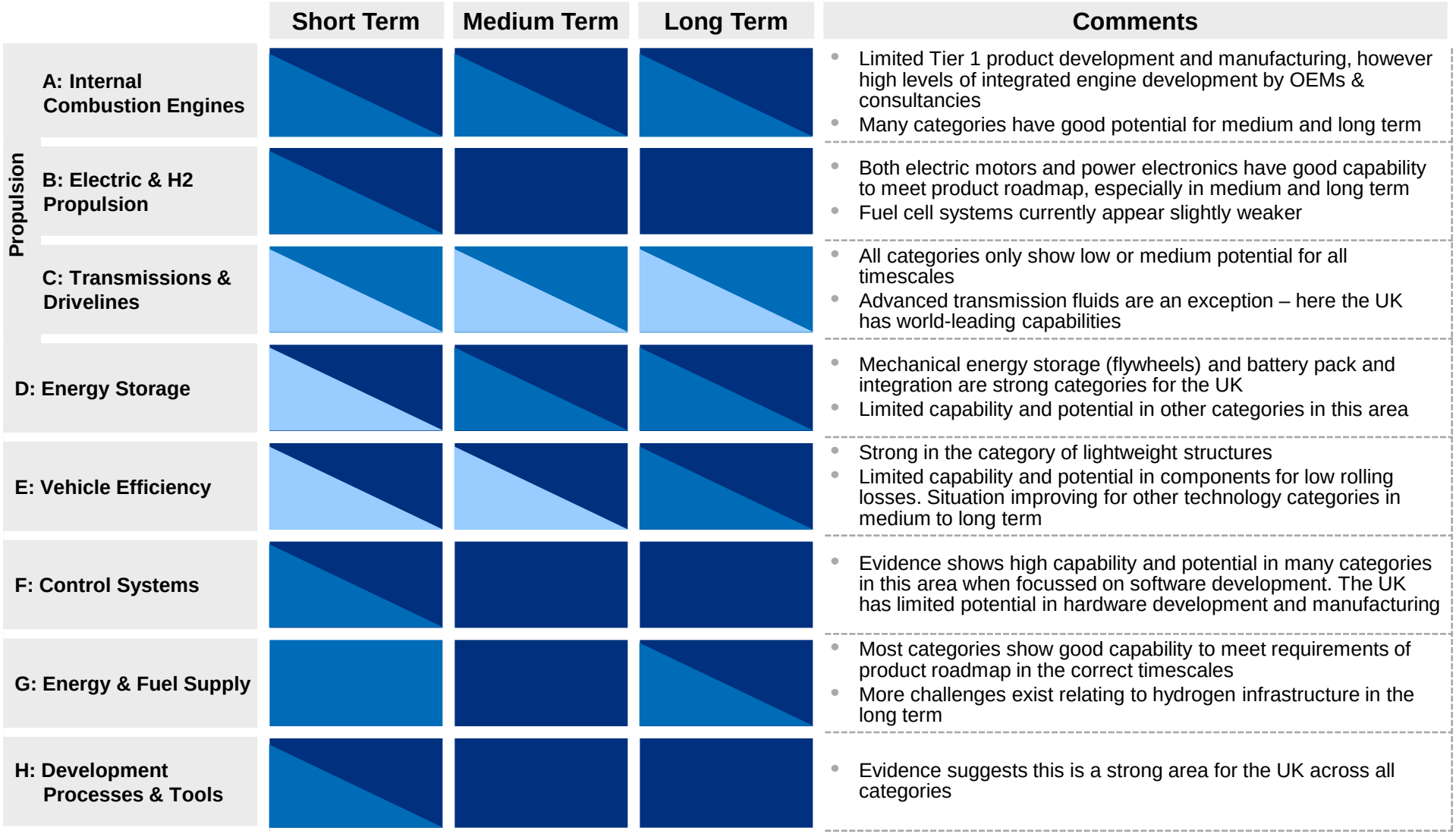
* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Technology Area H: Development Processes and Tools
Assessment results – UK capability to deliver NAIGT Roadmap*

R&D Category	Short	Medium	Long	Justification/Rationale
H.1. Advanced process tools				• High reported number of projects and active organisations in this category • Reported developments highly relevant for Roadmap delivery • Potential to increase value generation through improved visibility of know-how and active commercialisation of products • Existing early stage R&D supports medium and long term prospects
H.2. Integrated development toolchains				• Limited evidence for activity in this category, few players • Early maturity stage of concept means that necessity of this development for Roadmap delivery not widely acknowledged • High level of expertise in process tool development provides good basis for establishing capability in this area
H.3. Auto-optimisation methods				• Moderate level of current activity suggest limited short term commercialisation possibilities • Early maturity stage of concept means that necessity of this development for Roadmap delivery not widely acknowledged • High level of expertise in process tool development provides good basis for establishing capability in this area
H.4. Advanced testing methods & equipment				• High level of reported activities in this category, both in number of players and reported activities/available testing equipment • Good range of maturity levels across industry and academia, including significant • Further opportunities due to available expertise from aerospace and defence sectors • Existing pool of advanced testing equipment could be opportunity for improved value generation

* Indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers

Summary assessment: indicative current status of UK capability to deliver needs of NAIGT Roadmap, given required enablers



Colours in chart above show range of variation within each technology area for which a significant number of individual categories deviate from the average rating

APPENDIX 4
Proximity to Market and Benefits Assessments

Contents

For each technology category a qualitative assessment of ease of delivery to meet product roadmap and UK benefit has been made

Technology Category Ease of Delivery to Product Roadmap and Benefit Summary

PROXIMITY TO MARKET: Qualitative indication of the ease with which UK can deliver the technology category to meet the product roadmap requirements in the short, medium and long term based on Step 5 analyses

BENEFIT: Qualitative assessment of the potential for the UK to capture value in each technology category over whole of short, medium & long term timescale

JUSTIFICATION/RATIONALE: Comments provide justification/rationale for assigning the overall rating

INDICATIVE ROI: By comparing the level of effort required to deliver to the product roadmap and the potential for the UK to capture value a qualitative assessment of the potential "return on investment" has been made

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
D.1.a. Battery cell development	1	2	2	• Limited number of active players in the UK so high l… to deliver to product roadmap • Lack of existing players and limited fundame… research compared to other countries suggests reduced potential for UK value capture despite potentially high overall market value
D.1.b. Battery pack and integration	5	3	5	• Strong capability in UK for battery pack and integra… going activity required to deliver to product roadm… • … less than that of … value
D.2. Ultracapacitor technology	1	2	1	• Limited evidence of current capability in the UK s… required to deliver to product roadmap • UK value capture potential medium-low as despi… market value suggest limited ongoing potential fo… given current low levels of UK capability
D.3. Hydrogen storage technology	1	4	3	• Limited evidence of current capability in the UK. Bi… storage technology required by product roadmap so high level of activities necessary • UK could be in a good position to establish a presence in all value chain steps and capture value • Value capture risk if no breakthrough is achieved in hydrogen storage technology or disruptor present (e.g. technology breakthrough achieved outside of UK)

Note: relative ratings of high (5), medium-high (4), medium (3), medium-low (2) and low (1) have been used

Relative ratings have been used for the proximity to market and benefit assessments based on evidence gathered in previous Steps

Assessment Rating Process and Criteria

UK Proximity to Market Assessment

- For each technology category a qualitative assessment of the relative proximity to market of the product roadmap for the short, medium and long term has been made
- The level of additional activity required to deliver to the product roadmap has been assessed as follows:
  - Comparing the outputs and evidence gathered in Step 5
  - Considering current level of UK capability and the product roadmap requirements
  - In conjunction with the outline research agenda
- Additional considerations / requirements were also noted from questionnaire and workshop input from Step 5
- If a low amount of additional activity is required to meet the product roadmap then the proximity to market is rated high
- Relative ratings have been used:
  - High 5
  - Medium-high 4
  - Medium 3
  - Medium-low 2
  - Low 1

UK Benefit Assessment

- For each technology category a qualitative assessment of the potential for the UK to capture value over short, medium and long term has been made. This has been assessed by considering;
- **Potential overall market value**
  - What is the overall comparative value of this technology → All value chain steps considered (research to manufacturing (value per piece x production value)) and over short, medium and long term product roadmap
- **Potential for the UK to capture that value**
  - What share of the value could UK capture, based on: What section of the value chain could UK play in (e.g. only up to IP licensing) and of this section, how good is UK competitive position/how much of the total value of the relevant value chain section could UK capture
  - Assessment has been made considering the Step 5 UK capability assessment
  - An overall rating for benefit was then assigned as a combination of the two ratings
- The same relative ratings have been used as for the proximity to market assessment

Contents

A.1. Fuel injection equipment – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Advanced development of passenger car FIE systems, applied research in advanced combustion systems, fundamental combustion research • Maintain existing expertise in FIE application (OEMs, suppliers, consultancies) • Outlook for medium and long term dependent on continued UK activity by existing global suppliers • Extension of existing manufacturing activities to include passenger car FIE systems or components would be additional opportunity for value generation	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Critical impact on emissions & fuel economy makes FIE one of the highest value systems in IC engines for conventional powertrains • Less stringent hardware requirements in many hybrid applications, especially for range extender engines, however overall system calibration challenges may be greater, hence also high value • Roadmap indicates continued volume market for conventional IC applications and hybrids for foreseeable future	5
UK value capture potential	• Existing strong UK capabilities across R&D stages & covering some FIE production • Opportunities in academic research, IP licensing, consultancy, product development & manufacturing	5
	Overall	5

Source: Ricardo

A.2. Air handling systems – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Primarily applied research & concept demonstration for low cost, high boost & best transient response • Commercialisation and/or IP exploitation of innovative concepts especially required • Establishment of Tier 1 supplier R&D base would be necessary in order to carry out mainstream product development – currently limited manufacture only • Exploitation of innovative concepts requires strong co-operation between existing smaller suppliers/start-ups, established Tier 1's & OEMs – industry would benefit from improved visibility / platform for commercialisation • Fundamental research requirement limited – should be targeted to needs of industry, e.g. simulation robustness	2

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Critical enabler for IC engine downsizing for conventional & hybrid powertrains – increasing levels of downsizing will require increasingly high value systems to maintain performance • Boosting systems likely to increase market share to cover large majority of IC engines sold in vehicles	5
UK value capture potential	• High current levels of activity & expertise in several organisations of all types • Little existing manufacturing and absence of Tier 1 R&D limits possible short term returns, however good opportunities for exploitation especially in medium & long terms, in IP licensing, consultancy, product development & possibly manufacturing	4
	Overall	4

Source: Ricardo

A.3. Friction reduction technology – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Product development for components, coatings & lubricants/additives, applied research focus on component design concepts, new materials applications, also fundamental research on friction reduction (interaction of lubricants, materials & fuels) • Large increase in UK supplier base necessary to enable significant product development and manufacturing activity for components	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Requirement for friction reduction affects many engine components, trend is for rising levels of technology in mainstream engines • Low unit costs of components limits returns from manufacturing except in largest sales volumes	3
UK value capture potential	• Product developments likely to remain firmly based at existing global suppliers – main UK opportunities limited to IP generation from design concepts & fundamental research, unless existing suppliers are attracted to carry out more development/manufacturing in UK • UK position as significant base for lubricant & additive suppliers represents best opportunity	3
	Overall	3

Source: Ricardo

A.4. Alternative actuation technology – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Some limited activity in the area of variable mechanical pumps (for reduced parasitic losses), including links for manufacture in short term – requirement is for product development – on track to meet short term Roadmap requirements • Medium term product delivery (more radical would require extensive licensing of existing technologies/IP outside of UK and substantial investments into UK supplier base in order build up a competitive industry • R&D required for medium term delivery includes applied research & demonstration of benefits of new actuator concepts • Academic fundamental research into actuator principles required for long term	2

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Alternative actuation to reduce engine parasitic losses can significantly improve engine overall efficiency, as well as enabling other beneficial developments, e.g. thermal management • Short term requirement for proven, low cost technology, e.g. variable mechanical pumps • Increasing electrification of vehicles makes advantages of electric actuation more attractive • Growing market, mainstream by medium term, high value components	5
UK value capture potential	• Some short term opportunities, however lack of significant UK supplier base for electrification technology in this area limits opportunities in medium term • If wider supplier base could be established, manufacturing of high-value components would be good opportunity for UK, however uncertainty about likelihood of this taking place is large	3
	Overall	3

Source: Ricardo

A.5. Heat energy recovery systems – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• No Roadmap requirement for short term delivery • Medium term requires applied research into e.g. e-turbine & secondary cycle systems • Long term requires fundamental research into e.g. thermoelectric devices • Manufacturing potential exists for medium term product delivery by air handling suppliers, however collaborative links and commercialisation ventures must be set up in advance • Step-up of academic research in this area required to establish capability in order to meet long term Roadmap requirements	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Widespread adoption of heat energy recovery systems not likely until medium-long term • Uptake likely to be limited to higher duty cycle applications (typically extra-urban), unlikely in hybrids • All types of systems likely to be high value products (complex mechatronic products & advanced materials)	3
UK value capture potential	• Good opportunities for academia (principles) and consultancies (system integration) • Some opportunities for UK manufacturing, dependent on establishment of supplier links	3
	Overall	3

Source: Ricardo

A.6. Novel thermodynamic cycles for high efficiency – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• No roadmap requirement for short term • Requirement for investment to enable demonstration of novel engines before OEMs will show interest – this may come from VC, other private sector investors • R&D organisations require clear vision for commercialisation and significant industry backing of academic research in order to drive results through to application • OEM backing required for progress to product development – concepts must have been thoroughly proven	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Significant product uptake not likely until long term – long payback • Benefits of successful developments potentially very high compared with most other branches of automotive technology • Control and exploitation of IP is a challenge, availability of credit is a critical condition for success • High risk associated with non-evolutionary technologies, with significant development hurdles to be overcome to compete with existing concepts	5
UK value capture potential	• Strong expertise and reputation of UK academic organisations and consultancies in this area, makes UK well-placed to pioneer any successful outcomes • High risk activity	5
	Overall	5

Source: Ricardo

A.7. Flexible valvetrains – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Evidence suggests that UK is not in a position to deliver product Roadmap in the short term • Lack of existing supplier base makes product development for short term introduction & manufacture impossible • Medium term product delivery would require extensive licensing of existing technologies/IP outside of UK and substantial investments into UK supplier base in order build up a competitive industry • Continuation of current innovation by consultancies & OEMs required to secure future chances	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Potential for low cost systems to achieve majority penetration in conventional powertrains, however technical benefit of flexible valvetrains is largely eliminated in hybrid powertrains • Large number of competing designs makes IP exploitation and/or full commercialisation challenging • Largest value capture likely to be in high value, volume manufacturing by suppliers	2
UK value capture potential	• Lack of existing supplier base prevents UK short term value capture except through OEM and consultancy demonstration and IP exploitation • Future establishment of supplier base would increase value capture significantly, however competition from incumbents would be strong	2
	Overall	2

Source: Ricardo

A.8. Engines for special duty cycles (esp. PHEV) – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• No indicated roadmap requirement – however early demonstration would be advantageous • Main R&D activities required are – Definition, development & demonstration of engine concepts for PHEV range extender vehicles – Applied research into optimised engines for HEV applications • Opportunity for UK niche engine and component suppliers, as well as consultancies • Collaboration between engine suppliers & OEMs required to define and demonstrate suitable concepts • Product commercialisation support may be required for niche engine and component suppliers	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Potential for low cost systems to achieve majority penetration in conventional powertrains, however technical benefit of flexible valvetrains is largely eliminated in hybrid powertrains • Large number of competing designs makes IP exploitation and/or full commercialisation challenging • Largest value capture likely to be in high value, volume manufacturing by suppliers	3
UK value capture potential	• Lack of existing supplier base prevents UK short term value capture except through OEM and consultancy demonstration and IP exploitation • Future establishment of supplier base would increase value capture significantly, however competition from incumbents would be strong	4
	Overall	4

Source: Ricardo

A.10. Integrated engine design and development – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Evidence gathered indicates good alignment of projects to the roadmap requirements • Complexity of activities required is high, and many integration activities require collaboration between large Tier 1 suppliers and OEMs • However established expertise & running programmes already in place	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Whole engine design & development is high value activity • Largest value capture likely to be in high value, volume manufacturing by OEMs • Some value in IP sales/licensing but majority in volume supply	5
UK value capture potential	• Presence of OEMs & consultancies with full range of whole engine design & development capability to production • Both R+D and manufacture are present in the UK, but not always within the same organisations	4
	Overall	5

Source: Ricardo

Contents

B.1.-2. Electric motors – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Good fundamentals in place and current niche production capacity sufficient to meet short term demand • Scale up of existing capabilities/capacity required to meet expected medium and long term demand (consider integration of adjacent industries) • Route to market required, esp. cooperation with OEMs to demonstrate motor capabilities on a large scale • Investigations into long-term viability of the UK as a production location and depending on the outcome – a) further scale-up of manufacturing capacity e.g. via spin-outs from adjacent industries or – b) generation of alternative business models (e.g. IP licensing, Joint Ventures with LCC)	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring electric motors are expected to be high • While electric motors will not have the same value importance that e.g. ICE hold for 'traditional' vehicles now, they will still play a key role. However, over time a commoditisation of electric motors - at least for volume applications - is possible	3
UK value capture potential	• UK in a good position to meet demand for electric motors for niche applications over the entire value chain (in short, medium and long term) • Volume manufacturing potential exists, especially due to cross-over potential from adjacent industries, however it is less certain that the UK can remain in the volume manufacturing business once commoditisation of motors commences	3
	Overall	3

Source: Ricardo

B.3. Fuel cell systems – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Good evidence for ongoing fundamental research • Evidence for good integration capabilities and niche component manufacturing provide some industrial base for commercial activities • Build-up of sufficient hydrogen infrastructure prerequisite • Cooperation with OEMs required to allow for larger scale road testing of FC vehicles • Strong involvement of industry to further increase existing component manufacturing and integration capabilities	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Hydrogen vehicles are expected to reach niche and volume production state only in the long term, but could then become significant → But: Currently still very low visibility of expected sales volume • FC systems are the key value and cost driver and significantly more expensive than current ICE systems	5*
UK value capture potential	• UK could be in a good position to establish a presence in selected component development and manufacturing (but current evidence indicates that this is more challenging for fuel cell stack development) as well as in integration services for complete FC systems • However, due to the long timeframe an emergence of disruptors (e.g. development of large scale capabilities in China,.) is possible	3*
	Overall	4*

*Uncertain, due to long time scale

Source: Ricardo

B.4. Power electronics – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Good industrial presence • Scale-up of manufacturing capacity critical factor (capabilities from existing adjacent industries could potentially be utilized) • Development of clear commercialisation strategy • Investigations into long-term viability of the UK as a production location and depending on the outcome – a) further scale-up of manufacturing capacity – b) generation of alternative business models (e.g. dedicated niche production, IP licensing, LCC Joint Ventures)	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring power electronics are expected to be high • Power electronics are an important aspect of alternative propulsion systems and will be required for the electrification of the vehicle fleet (independent from e.g. the choice of energy storage methods) • Power electronics system value is less than e.g. the cost for energy storage systems, but they are still high-value components	3
UK value capture potential	• Good fundamental base and potential for further development of capabilities in the power electronics category could lead to a strong UK position across the value chain in this category • Key challenge will be the ramp-up of manufacturing capacity (potential cross-over from other industries active in power electronics). Strong case for joint consideration of electric motors and power electronics strategy, as these are often commercially linked	3
	Overall	3

Source: Ricardo

Contents

C.1. Conventional Transmissions – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Supplier base for passenger car applications must be built up from very low level if UK is to play a significant role in product development or manufacturing • Good visibility of UK academic research and existence of significant industrial base required to progress fundamental research to applied research	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Continued large sales of conventional transmissions in short term for developed markets and longer term for developing markets • Loss of market share to advanced transmissions over medium and long term • Increasingly mature and commoditised product	3
UK value capture potential	• Lack of existing UK supplier base limits potential for future value generation from mainstream product development or manufacturing significantly	1
	Overall	1

Source: Ricardo

C.2. Advanced Transmissions – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Little short-term product development possible by existing supplier base, except niche • Strengthening of existing niche supplier network required to support any growth of future activity • Exploitation of IP could take place via local development or licensing to foreign suppliers • Future product development could be for own manufacture or on consulting basis	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Continued large sales of conventional transmissions in short term for developed markets and longer term for developing markets • Loss of market share to advanced transmissions over medium and long term • Increasingly mature and commoditised product	4
UK value capture potential	• Lack of existing UK supplier base limits potential for future value generation from mainstream product development or manufacturing significantly	3
	Overall	2

Source: Ricardo

C.3. Driveline Components – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Relatively low effort R&D required - primary research requirements to meet Roadmap are: – Applied research into low cost, lightweight construction for driveline components suitable for volume production – Applied research and demonstration of active driveline components for AWD – Limited fundamental research into low friction and lightweight materials • Some current R&D activity, however few UK suppliers, hence need to build up supply base & medium overall effort rating	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Value of components varies significantly; highest values in active control and advanced materials • Mainstream components relatively low value • Greater value products for vehicles with more complex drivelines (typically AWD, RWD systems) and niche/premium products, however these are sold in small numbers so total market value is limited	3
UK value capture potential	• Current low level of activity and small number of suppliers reduces opportunities for short term value generation • Relatively low value of mainstream components likely to make high volume manufacturing unattractive in the UK • Scope for more specialist product development & manufacturing – synergies with UK niche OEMs & lightweight components suppliers	2
	Overall	3

Source: Ricardo

C.4. Actuation Improvement – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Primary R&D requirement is for applied research and demonstration of electric/electromagnetic actuation technology for transmission shifting • No evidence of existence of current UK supplier base – suggests that **UK is not in a position to deliver product Roadmap in the short term** • Medium term product delivery would require extensive licensing of existing technologies/IP outside of UK and substantial investments into UK supplier base in order build up a competitive industry	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Several engine systems can use alternative actuation methods, and adoption is likely to become very widespread in medium term • Products are high value, with scope as well for exploitation of IP generated by academia or consultancies	5
UK value capture potential	• Current low level of activity and lack of evidence of suppliers all but rules out short term value generation • Market currently dominated by a small number of large global suppliers • Some potential for first development and manufacturing in the UK in medium-long term if supply base can be established • Opportunities for academia	2
	Overall	2

Source: Ricardo

C.5. Advanced transmissions fluids – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• R&D required is continuous evolutionary development, with activities targeted at all timeframes • Much of fluids R&D is carried out in-house by large suppliers	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Large global market exists • Fluids for low transmission losses offer opportunity for premium pricing by suppliers	4
UK value capture potential	• Existing UK strength in lubricant & fluid development – several of the few global players have significant R&D operations in the UK (in terms of both fluid and additive suppliers)	4
	Overall	4

Source: Ricardo

C.6. Transmission concepts for HEV, PHEV & EV – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Required delivery is for short and medium term only, in order to fit initial emergence of these new vehicle types • Long term requirements likely to be defined by future EV architecture – as yet unclear • Need for collaboration between suppliers and OEMs & consultancies to define product requirements • Commercialisation support and manufacturing investments likely to be required by small suppliers in short term • Business strategy required for medium term assumption of higher volume production for HEVs & EVs – UK manufacturing vs. licensing or JVs with existing foreign-based suppliers / LCC operations	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Roadmap indicates rising market share of hybrid vehicles to mainstream in medium term, and EVs & PHEVs from niche to larger volume production in medium term • HEV, all-mech. hybrid app's: complex development & integration activities, high value products • EV app's: likely to be low complexity, relatively low value – however opportunities for short-medium term value generation in production for niche vehicles, also specification & dev't of new concepts • Risk that future EVs will require no transmission (direct drive motors)	3
UK value capture potential	• UK presence of some niche transmission manufacturers, as well as consultancies and start-up suppliers – well-placed to exploit potential short term requirement for specialist low vol. transmissions • Longer term trend towards larger volumes and commoditisation could reduce this advantage	3
	Overall	3

Source: Ricardo

Contents

D.1.a. Battery cell development – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Limited number of companies active in automotive, some expertise in chemistries, but no manufacturing capability– significant scale-up of capabilities would be required • Development of clear routes to market necessary (cooperation with OEMs, large scale demonstration) • Strong Academia base for fundamental research in novel chemistries for medium and long term required • Evaluate potential for market entry in end-of-life/recycling technologies for batteries • Good cooperation between Academia and Industry required to move fundamental research into applied research stage	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring energy storage are expected to be high • With electrification of vehicle fleet batteries emerge as the highest value single technology in a vehicle, to which battery cell technology is the main contributor	5
UK value capture potential	• Lack of existing industrial players limits commercial exploitation potential (esp. manufacturing) of battery cell technology • Limited evidence of fundamental research suggests reduced potential for exploitation	2
	Overall	2

Source: Ricardo

D.1.b. Battery pack & integration – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Strong capability in UK for battery pack development • Sufficient battery pack development and integration capabilities for short term requirements • Commercialisation strategies for battery pack development and integration capabilities (i.e. cooperation with OEMs)	5

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring energy storage are expected to be high • With electrification of vehicle fleet, batteries emerge as the highest value single technology in a vehicle. While the value generation potential for pack development and integration is less than that of battery cell technology, it is still significant	3
UK value capture potential	• Good existing pack development and integration expertise and industry presence provides good starting base for successful activities in this category, if existing capabilities are further developed and marketed	3
	Overall	3

Source: Ricardo

D.2. Ultracapacitors – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Little evidence of current development or manufacture of ultracapacitor systems • Short term product delivery would require licensing of existing technologies/IP outside of UK • Medium term delivery is still likely to require some investment into external IP • For short, medium and long term delivery significant investments in UK skill-set/industry (both Academia and Industry) would be required • Development of routes to market required	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring energy storage are expected to be high • With the electrification of vehicle fleet, ultracapacitors could potentially evolve to play an important role in addressing power density shortcomings of batteries. If they succeed to do so, ultracapacitors could capture a very significant value share	3
UK value capture potential	• Little evidence of UK capability in this segment (over all timeframes) suggest limited ongoing potential for commercial exploitation	1
	Overall	2

Source: Ricardo

D.3. Hydrogen storage – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Very limited activity in this area reported • Initial/Fundamental investments into hydrogen infrastructure required • Fostering of knowledge transfer from adjacent industries, such as aerospace and defence • Strong academic base required to establish good fundamental knowledge base	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• In the product roadmap hydrogen vehicles are expected to reach niche and volume production state only in the long term, but could then become significant → But: Visibility of expected sales volume is still very low (especially as for example a breakthrough in other energy storage technologies could substantially limit FC potential) • Hydrogen storage system are one of the key value (& cost) drivers in FC system	5*
UK value capture potential	• UK could be in a good position to establish a presence in all value chain steps, as R&D is supported by strong innovation culture present in the UK and manufacturing requires high tech, high value capabilities suited to UK • However, due to the long timeframe an emergence of disruptors (e.g. development of large scale capabilities in China,.) is possible	4*
	Overall	4*

*Uncertain, due to long time scale

Source: Ricardo

D.4. Mechanical energy storage – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment		Qual. Prox. to Market
	• Good fundamentals in place, several companies and consultancies involved in the area of flywheels. UK leader in flywheel technology • Route to market key challenge (technology backing by OEMs required) • Continued advanced research to maintain and further expand high expertise level	4
Value Potential Assessment		**Qualitative Benefit**
Overall Market Value	• With the expected importance of HEVs and increase of PHEVs and EVs volumes in medium and long term, sales volumes of vehicles requiring energy storage are expected to be high • With the electrification of vehicle fleet, mechanical energy storage could potentially evolve to play an important role in addressing power density shortcomings of batteries and capture a significant share of the market • Mechanical energy storage (i.e. flywheels) are often significantly less costly on a per piece basis than batteries or ultracapacitors, increasing attractiveness (volume potential) but reducing the part value	3
UK value capture potential	• Strong existing capabilities provide good starting base to establish a leading role for the UK in mechanical energy storage • Good potential for licensing technology, consulting and manufacture of product • Key challenges are the further development of expertise and a clear strategy for marketing technologies and products	5
	Overall	4

Source: Ricardo

Contents

E.1. Lightweight vehicle structures & components – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Very good current capability with strong expertise base in academia and industry • Existing range of niche OEMs should be involved to develop successful route to market • Fostering of active cooperation between automotive industry and highly relevant aero-space/defence to accelerate build up of advanced lightweight expertise	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• The majority of vehicles are expected to undergo weight reduction initiatives, particularly in premium and low volume vehicles (though full lightweight body structures likely to remain restricted to niche applications for the foreseeable future) • As long as cost premiums per g/km CO_2 justify them, market demand will increase for measures that offer significant weight reductions – with higher cost tolerance for premium and low volume vehicles	3
UK value capture potential	• Strong existing capabilities within the automotive industry (Industry and Academia), availability of niche OEMs, and significant expertise in adjacent aerospace and defence industry provide good starting base to establish a leading role for the UK • Opportunity to exploit synergy between lightweight vehicle expertise and niche & premium vehicle OEM business models • Key challenges are the further development of expertise and a clear strategy for marketing technologies and products	5
	Overall	5

Source: Ricardo

E.2. Components for low rolling losses – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• **Evidence suggests that UK is not in a position to deliver product Roadmap in the short term** • Virtually no UK players or R&D activity, high product maturity required, high level of competition from established players • Medium term product delivery would require extensive licensing of existing technologies/IP outside of UK and substantial investments into UK supplier base in order build up a competitive industry	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• The majority of vehicles are expected to undergo weight reduction initiatives, particularly in premium and low volume vehicles (though full lightweight body structures likely to remain restricted to niche applications for the foreseeable future) • As long as cost premiums per g/km CO_2 justify them, market demand will increase for measures that offer significant weight reductions – with higher cost tolerance for premium and low volume vehicles	5
UK value capture potential	• Strong existing capabilities within the automotive industry (Industry and Academia), availability of niche OEMs, and significant expertise in adjacent aerospace and defence industry provide good starting base to establish a leading role for the UK • Opportunity to exploit synergy between lightweight vehicle expertise and niche & premium vehicle OEM business models • Key challenges are the further development of expertise and a clear strategy for marketing technologies and products	1
	Overall	1

Source: Ricardo

E.3. Measures for improved aerodynamics – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Good base of fundamental expertise reported in this category (on academia, supplier, consultancy and OEM level), however little R&D activity with direct relevance to Roadmap • Requirement for clear commercialisation strategy, fostering of expertise transfer from motorsport sector, collaboration with OEMs	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Limited requirement for aerodynamic improvements for CO_2 reduction in passenger car applications • Predominantly an OEM-led process, external market value considered comparatively low	2
UK value capture potential	• With a high capability level both in infrastructure (wind tunnels etc.) and expertise, UK would theoretically have a good fundamental base • But limited body-in-white development in UK substantially restricts value capturing potential	3
	Overall	2

Source: Ricardo

E.4. New vehicle classes and configurations – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Promotion & support of innovation culture in UK • Cooperation with innovative OEMs required to improve commercialisation chances	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Novel vehicle concepts will initially be restricted to a niche market • Market value potential is very much dependent on uptake of new vehicle concepts → It could be substantial, if it for example promotes the development of successful, specialised niche OEMs	3
UK value capture potential	• Innovation culture, already existing players in this category and experience with niche OEMs could position the UK well for a role as incubator of novel vehicle concepts • But success of UK-based vehicle concept ideas is highly variable – lasting commercial success of niche vehicles has historically been rare	4
	Overall	3

Source: Ricardo

Contents

F.1.a. Advanced powertrain control, software – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Strong in software • Understanding how to capture IPR / know-how on control system software (algorithms) or "sell-it" – route to market required • Links between academia and industry – integration of software into hardware • IP retention and capitalization of expertise	5

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• All vehicles require "powertrain control" and with increasing complexity of vehicles, control systems are becoming an increasingly important part of the vehicle system • Software has the potential to be adopted into the marketplace at a quicker rate than hardware	3
UK value capture potential	• Very high level of activity in advanced powertrain control – software by consultancies, suppliers and OEMs • Software is not usually independent of hardware and unless software is integrated with hardware it is currently difficult to capture any value from the software. Value capturing potential for UK is limited, if powertrain control hardware cannot be provided	3
	Overall	3

Source: Ricardo

F.1.b. Advanced powertrain control, hardware – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Not enough evidence gathered through consultation to be able to define R&D required on advanced powertrain control – hardware	

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Not enough information to be able to assess overall market value	
UK value capture potential	• No reported evidence of UK activities in hardware for for advanced powertrain control	
	Overall	

Source: Ricardo

F.2. Optimised vehicle energy management – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Many players active in this area, strong in software, weaker in hardware • Understanding how to capture IPR / know-how on software (algorithms) or "sell-it" – route to market required	5

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• All vehicles require "vehicle energy management" and with increasing complexity of vehicles (EV, hybrid etc.), efficient vehicle energy management is becoming increasingly important	3
UK value capture potential	• Suppliers, OEMs and consultancies active in this area, strong in software but weaker in hardware (some manufacturing in UK) • Opportunities for consulting in this area • Problem exists in capturing value for software and finding route to integrate into/with existing hardware	3
	Overall	3

Source: Ricardo

F.3. Driver information systems – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Strong in R&D, but no manufacturing capability • Understand future of this area of technology concerning route to market – will systems be fitted retrospectively or will they be integrated into the vehicle by OEMs • Internet in vehicles may change marketplace for driver information systems in the medium to long term	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Dependent on system, potential to be applied to all vehicles, either at OEM level or retrofit	3
UK value capture potential	• Strong in R&D through academia, consultancies, suppliers and OEMs but no manufacturing capabilities • Potential to license technology, provide consulting services	3
	Overall	3

Source: Ricardo

F.4. Intelligent transport systems – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Strong in R&D with many organisations involved • Common protocols and standards required to ensure universal applicability • ITS limited by infrastructure • Progress in ITS will require cooperation between automotive and telecoms sectors and government (infrastructure)	2

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Potential to be applied to all vehicles in the medium to long term • Value of infrastructure build-up could be significant	5
UK value capture potential	• Strong R&D across broad variety of categories through academia, suppliers, OEMs and consultancies • Potential to capture value through licensing, consulting	4
	Overall	4

Source: Ricardo

F.5. Autonomous vehicle control – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Work by several companies in this area, potential crossover from military and sub-sea exploration sectors in the long term • Common protocols and standards required • Potential crossover from military and sub-sea sectors • Infrastructure required for large scale vehicle to infrastructure and vehicle to vehicle communication	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Product roadmap sees autonomous vehicle control appearing in the long term, potential to be applied to all vehicles	2
UK value capture potential	• Limited amount of fundamental research underway (consultancy/supplier) but as roadmap foresees this as relevant for long term only UK could still develop capability to capture value in the long term	3
	Overall	2

Source: Ricardo

F.6. Sensors & sensor integration – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Some development but no evidence of manufacturing • Common protocols and standards required • Potential crossover from military and sub-sea sectors	3

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Increasing levels of vehicle complexity and OBD requirements increase need for many different sensors and sensor integration into vehicles • However, long term a near commoditisation of sensors is likely to emerge	3
UK value capture potential	• Some limited product development (suppliers). Capability in academia (good fundamentals), potential crossover from other sectors • Medium/longer term potential for licensing technology	1
	Overall	2

Source: Ricardo

Contents

G.1. 1st generation biofuels (food crops) – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Mature technology – political will will drive requirement • 1st generation biofuels are expected to be superseded in the medium to long term by 2nd gen biofuels	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Market demand for first generation biofuels likely to be driven by political will / legislation e.g. RED (European Renewable Energy Directive) and UK RTFO (Renewable Transport Fuels Obligation) • Volumes of 1st generation biofuels will be limited by availability of food crop as feedstock	1
UK value capture potential	• 1st generation biofuel processes are mature technology • Limited evidence of research by academia, some manufacturing in UK	1
	Overall	1

Source: Ricardo

G.2. 2nd generation biofuels (waste crops) – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Significant activity currently underway in this area, 2 major oil companies with research facilities in the UK • Political will to drive the requirement • R&D Steps required need to be reviewed against amount and type of R&D being funded by other public funding bodies e.g. CCC, Carbon Trust, BPSRC (Biotechnology Biological Sciences Research Council) and projects conducted by non-automotive related organisations in this area as this consultation only included organisations conducting "automotive" specific R&D	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Market demand for second generation biofuels likely to be driven by political will / legislation as for 1st generation but 2nd generation biofuels more sustainable, potential volumes could be higher	3
UK value capture potential	• Evidence of academic research in this area relating to process development, potential for process licensing in the medium to long term • Large scale manufacturing of 2nd generation biofuels may be limited by local availability of feedstock	3
	Overall	3

Source: Ricardo

G.3. 3rd generation biofuels (algae etc.) – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Evidence of some academic research in this area • R&D Steps required need to be reviewed against amount and type of R&D being funded by other public funding bodies e.g. CCC, Carbon Trust, BPSRC (Biotechnology Biological Sciences Research Council) and projects conducted by non-automotive related organisations in this area as this consultation only included organisations conducting "automotive" specific R&D	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Value only likely to be realised in the long term • Potential demand could be high if efficient, cost effective processes that are sustainable can be developed to turn non food crops into fuels	3
UK value capture potential	• Evidence of some fundamental research by academia (may be further work on-going in this area not captured by this consultation process e.g. funded by other bodies: BPSRC, Carbon Trust, CCC or by non-automotive related companies) • Possible potential for process licensing in the longer term	3
	Overall	3

Source: Ricardo

G.4. Electrical infrastructure – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Some evidence of technology development by consultancies, suppliers and infrastructure providers • Charging infrastructure standards required • R&D Steps required need to be reviewed against amount and type of R&D being funded by other public funding bodies e.g. CCC, Carbon Trust, and projects conducted by non-automotive related organisations in this area as this consultation only included organisations conducting "automotive" specific R&D	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Assuming a breakthrough in energy storage technology electrical infrastructure is a very important part of being able to take PHEV/EVs to mass market volumes in the long term • Significant local hardware (in-home e.g. smart metering, public charging points) and grid systems & strategies required to cope with demand	5
UK value capture potential	• Evidence of development of charging hardware, smart metering and commercial models by suppliers, infrastructure providers and consultancies provides good base for value capture in this area	4
	Overall	5

Source: Ricardo

G.5. Hydrogen infrastructure – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Some activity reported • Establishment of infrastructure within 20 years (to deliver to product roadmap) constitutes major undertaking • Sufficient driver for hydrogen required to initiate significant activity • Amount and type of R&D being funded by other public funding bodies e.g. CCC, Carbon Trust, and projects conducted by non-automotive related organisations in this area need to be reviewed as this consultation only included organisations conducting "automotive" specific R&D	1

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• Assuming fuel cell stack and hydrogen storage breakthrough implementation of a hydrogen infrastructure to support mass market fuel cell / H2 IC vehicles is a major undertaking as no current infrastructure exists and potential market value is high in the long term	4*
UK value capture potential	• As roadmap foresees this as relevant for long term only UK could still develop capability to capture value in the long term, if decisive actions are taken in the short and medium term	3
	Overall	3

*Note: rating has been made on the basis of the product roadmap holding true. If no breakthrough in fuel cell stack / H2 storage technologies to support hydrogen economy then hydrogen infrastructure market value will be significantly reduced (medium-low)

Source: Ricardo

Contents

H.1.-3. Advanced Development Tools (incl. Tool Integration & Optimisation Methods) – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Highly competitive starting base with a high level of activity and expertise within the UK • Key challenge is development of successful commercialisation strategies for developed tools • Ongoing promotion & support of innovation culture in UK • Research into integration of engineering tools via shared datasets in common formats to increase efficiency and reduce overall costs	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• High level of efficiency gains (reduced costs & reduced time-to-market) can be expected from optimizations of used development tools and process • Monetising efficiency gains effectively is key challenge, especially where improvements benefit all, but are difficult to charge for (e.g. establishment of common standards to enable integrated tool-chains) • Expected trend towards increasingly automated system optimisation tools leads to positive outlook for future market value development in this category	3
UK value capture potential	• Strong existing capability base both in number of players and level & type of activities puts UK in good position to capture value in this category - if commercialisation strategies can be developed further	5
	Overall	3

Source: Ricardo

H.4. Advanced testing methods & equipment – Proximity to market and benefit assessment

Proximity to Market / Considerations / Requirements Assessment	Qual. Prox. to Market
• Clear commercialisation strategies for testing methods & equipment • Promote UK wide platform where available testing methods & equipments are made visible to increase testing efficiency and create new value generation potential	4

Value Potential Assessment		Qualitative Benefit
Overall Market Value	• High level of efficiency gains (reduced costs & reduced time-to-market) can be expected from optimizations of used development tools and process • Monetising efficiency gains effectively is key challenge, especially where improvements benefit all, but are difficult to charge for (e.g. establishment of common standards to enable integrated tool-chains) • Expected trend towards increasingly automated system optimisation tools leads to positive outlook for future market value development in this category	3
UK value capture potential	• Strong existing capability base both in number of players and level & type of activities puts UK in good position to capture value in this category - if commercialisation strategies can be developed further	5
	Overall	3

Source: Ricardo

APPENDIX 5
Indicative ROI Assessments

Technology Area A: Internal Combustion Engines (1)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
A.1. Fuel injection equipment	3	5	4	• Good existing capability, with global FIE suppliers performing R&D in UK to meet needs of Roadmap • Manufacturing is also performed, however not for passenger car systems
A.2. Air Handling, incl. boost systems	2	4	3	• R&D activities ongoing to meet medium term needs of Roadmap • Volume manufacturing not carried out by same organisations performing R&D, innovations must be commercialised externally
A.3. Friction reduction technology	3	3	3	• Existing supplier base consists of few players, reported activity in this category is limited • Large investment required in short term to build up component supplier presence
A.4. Alternative actuation	2	3	2	• Some short term opportunities in variable mechanical devices • However lack of significant UK supplier base for electrification technology in this area limits opportunities in medium term – success would require large investments to catch up

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area A: Internal Combustion Engines (2)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
A.5. Heat energy recovery systems	3	3	3	• No roadmap requirement until medium term • Roadmap needs can be met if collaborative links between suppliers, developers and academia are strengthened to enable successful exploitation of innovations and achieve progress towards long term goals
A.6. Novel thermodynamic cycles for high efficiency	3	5	3	• Investment required to develop and demonstrate concepts • High risk technology, but with high potential returns if IP is well managed
A.7. Flexible valvetrains	3	2	2	• UK cannot meet needs of Product Roadmap in short term (no supply base) • Longer term success would require large investments to catch up
A.8. Engines for special duty cycle (HEV, PHEV)	4	4	4	• UK well-placed to deliver requirements of Roadmap from short term, with required expertise and manufacturing capacity for niche products all present • Relatively low assumed R&D activity level required
A.10. Integrated engine design & development	4	5	5	• Evidence gathered suggests roadmap requirements will be met • Complexity of activities is high, but established expertise and running programmes already in place • High potential for value capture, especially in high volume manufacturing, with OEMs and consultancies present with required capabilities

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area B: Electric & Hydrogen Propulsion Systems

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
B.1 & B.2. Electric Motors for lower costs & higher efficiency	3	3	4	• Good fundamentals in place and several players, medium level of activities required to deliver to product roadmap • Good potential for UK to capture value over entire value chain
B.3. Fuel Cell Systems	1	4	3	• High level of activity required to deliver to product roadmap due to low level of current capability and immaturity of technology • Product roadmap shows fuel cell vehicles reaching volume production only in the long term, but fuel cell systems high value part and given timescale UK could be in a good position to establish a presence to capture value • Value capture risk for UK if no breakthrough is achieved in fuel cells or system technology (as required by product roadmap) or disruptor present (e.g. key technology breakthrough achieved outside of UK)
B.4. Power Electronics	3	3	4	• Good R&D presence and manufacturing capability, medium level of activity required to deliver to product roadmap • Power electronics are an important aspect of alternative propulsion systems and UK in a good position to capture value

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area C: Transmissions & Drivelines (1)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative ROI	Justification/Rationale
C.1. Conventional transmissions (MT, AT)	1	1	1	• UK cannot meet short term Roadmap needs - high level of investment required to catch up expertise and/or volume manufacturing capabilities • Future value capture limited by time required for catch-up as, well as falling market share and increasing commoditisation of conventional transmissions in longer term
C.2. Advanced transmissions (DCT, AMT, CVT)	1	2	2	• UK can support short term Roadmap needs to very limited extent only – investment required to build up supplier base • Opportunities for value capture through innovation by existing players increase potential benefit in medium term
C.3. Driveline components	3	3	2	• Evolutionary improvements & cost reduction of low loss and weight components over short, medium and long terms • Limited evidence of Roadmap-relevant UK supplier R&D activities, except for niche products • Value capture potential limited by market size
C.4. Actuation improvement	1	2	2	• UK cannot meet short term Roadmap needs - high level of investment required to catch up expertise and/or volume manufacturing capabilities • Future value capture limited by time required for catch-up, however market is growing sharply and high-value manufacturing opportunities exist for the UK

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area C: Transmissions & Drivelines (2)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
C.5. Transmission Fluids	3	4	4	• R&D required is continuous evolutionary development, with activities targeted at all timeframes • Global market is large, with significant proportion of total R&D currently carried out by large suppliers in UK
C.6. Transmission Concepts for HEV, PHEV, EV	3	3	3	• Potential to meet short term and medium term needs for niche and other low volume hybrids and EVs • Possible supplier base exists for this market, requirement is for development and demonstration of concept products

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area D: Energy Storage (1)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
D.1.a. Battery cell development	1	2	2	• Limited number of active players in the UK so high levels of activities required to deliver to product roadmap • Lack of existing players and limited fundamental research compared to other countries suggests reduced potential for UK value capture despite potentially high overall market value
D.1.b. Battery pack and integration	5	3	5	• Strong capability in UK for battery pack and integration so low levels of on-going activity required to deliver to product roadmap • Overall value generation potential for pack development and integration is less than that of battery cell technology but UK is well positioned to capture value
D.2. Ultracapacitor technology	1	2	1	• Limited evidence of current capability in the UK so high levels of activities required to deliver to product roadmap • UK value capture potential medium-low as despite high potential for overall market value suggest limited ongoing potential for commercial exploitation given current low levels of UK capability
D.3. Hydrogen storage technology	1	4	3	• Limited evidence of current capability in the UK. Breakthrough in hydrogen storage technology required by product roadmap so high level of activities necessary • UK could be in a good position to establish a presence in all value chain steps and capture value • Value capture risk if no breakthrough is achieved in hydrogen storage technology or disruptor present (e.g. technology breakthrough achieved outside of UK)

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area D: Energy Storage (2)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
D.4. Mechanical energy storage technology (flywheels)	4	4	5	• Leading capability in UK (flywheels), medium level of activity required to deliver to product roadmap to prove concepts & continue advanced research to maintain and further expand high expertise level • Good potential for UK to capture value through licensing technology, consulting and manufacture

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area E: Vehicle Efficiency

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
E.1. Lightweight vehicle structures & components	3	5	5	• Potential for high value capture through existing leading R&D and manufacturing capability from niche & premium OEMs, as well as many suppliers • Priority activities are commercialisation of lightweight products & optimisation of manufacturing processes
E.2. Components for low rolling losses	1	1	1	• UK cannot meet short term Roadmap needs - high level of investment required to catch up expertise and/or volume manufacturing capabilities • Future value capture limited by time required for catch-up, as well as relatively low value products and barrier of well-established foreign supplier base
E.3. Measures for improved aerodynamics	4	2	2	• Good base of fundamental expertise in all organisation types • However limited body in white development carried out in UK, little evidence of R&D with strong roadmap relevance • Little opportunity for significant economic benefit to UK automotive industry except on limited consulting basis
E.4. New vehicle classes and configurations	4	3	3	• Activities in this category tend to be high risk, with high potential returns but considerable uncertainty and long timescales • UK is well-placed to deliver roadmap requirements and capture value in long term, if routes to market can be found (e.g. links between OEMs and innovators)

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area F: Control Systems (1)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
F.1.a. Advanced powertrain control – software	5	3	3	• Very strong existing UK capability, activities required to deliver to product roadmap low • Software has the potential to be adopted by the market at a quicker rate than hardware. Benefit good if UK can capture value of IP
F.1.b. Advanced powertrain control - hardware				• Not enough evidence gathered through consultation to be able to define activities required to meet product roadmap or provide an overall assessment of this technology category
F.2. Optimised vehicle energy management	5	3	4	• Good existing UK capability, activities required to deliver to product roadmap low but value capture potential medium-low. Suppliers, OEMs and consultancies active in this area, strong in software but weaker in hardware, potential for consulting and niche vehicle development
F.3. Driver information systems	3	3	4	• High level of industry based activities reported, medium level of activities required to deliver to product roadmap • Strong in R&D through academia, consultancies, suppliers and OEMs, potential to capture value through licensing / consulting • Risk that internet in vehicle may change the market for these systems

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area F: Control Systems (2)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
F.4. Intelligent transport systems (ITS)	2	4	4	• Activities required to deliver to product roadmap medium-high but significant UK capabilities developing in this area with potential for value capture in the medium-long term • Progress in ITS will require cooperation between different sectors: automotive, telecoms and government (infrastructure) and definition of common protocols and standards
F.5. Autonomous vehicle control	3	2	3	• Fundamental research on-going in this area, medium effort for activities required to meet product roadmap in the long term. UK value capture potential medium-low as not required by product roadmap until long term
F.6. Sensors & sensor integration	3	2	2	• Medium effort for activities required to meet product roadmap (sensors and sensor integrations cover a very wide range of possible applications) as limited activities in the short term • UK value capture potential medium-low. Some limited product development (suppliers) and capability in academia, medium/longer term potential for licensing technology. Some sensors may become commoditised in the longer term

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area G: Energy and Fuel Supply (1)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
G.1. 1st generation biofuels (food crops)	4	1	1	• Mature technology, activities required to meet product roadmap medium-low • Some UK activity in this area but value limited as likely to be superseded by 2nd and 3rd generation biofuels in the medium to long term
G.2. 2nd generation biofuels (waste products)	1	3	3	• Significant activity currently underway but activities required to meet product roadmap still require high level of effort • Potential for UK to capture value through process licensing in the medium term • May already be further work on-going in this area not captured by this consultation process e.g. funded by other bodies BPSRC etc.
G.3. 3rd generation biofuels (algae, etc.)	1	3	3	• Some current reported activity by academia in this area, high level of activity required to meet product roadmap in the long term • Potential demand could be high in the long term, UK could be in a position to capture value through process licensing • May already be further work on-going in this area not captured by this consultation process e.g. funded by other bodies BPSRC etc.
G.4. Electrical infrastructure	1	5	4	• High level of activity required to meet product roadmap but significant local hardware (in-home e.g. smart metering, public charging points) and grid systems & strategies required to deliver. UK well placed to capture this value • There is a risk that the breakthroughs required in energy storage technologies to move EVs/PHEVs etc. to mass market are not made and therefore value potential of electrical infrastructure requirements is significantly reduced

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area G: Energy and Fuel Supply (2)

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
G.5. Hydrogen infrastructure	1	3	3	• Good research established but high level of activity required to deliver hydrogen infrastructure for the product roadmap in the long term • As no current infrastructure exists the potential market value is high but will only be realised in the long term, UK could still develop capability to capture part of this market • May already be further work on-going in this area not captured by this consultation process e.g. funded by other bodies, other companies not included in this consultation • There is a risk that the breakthroughs required in fuel cell stacks and hydrogen storage to move fuel cell vehicles / H2 ICEs to mass market are not made and therefore value potential of hydrogen infrastructure requirements is significantly reduced

Source: Ricardo analysis of results from Steps 4 and 5

Technology Area H: Development Processes and Tools

R&D Category	Qual. Prox. to Market	Qual. Benefit	Indicative "ROI"	Justification/Rationale
H.1. Advanced process tools **H.2. Integrated development toolchains** **H.3. Auto-optimisation methods**	4	3	4	• Highly competitive starting base with a high level of activity and expertise within the UK, with existing market routes • Increasing role of advanced development tools in future, with high value capture potential for cutting edge products & services • Tool development activities are relatively low cost if carried out in parallel with associated technology development activities
H.4. Advanced testing methods & equipment	4	3	3	• UK is significant player in global market for testing services & equipment • High value products & services, however market is relatively small & specialised • As with advanced tools development, activities are relatively low cost if carried out in parallel with associated technology development activities

Source: Ricardo analysis of results from Steps 4 and 5

Technology Strategy Board

Driving Innovation

Published by the Technology Strategy Board,
May 2010

Research by Ricardo UK Ltd

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