Automotive Council Technology Work Groups

Consensus Roadmaps and workstream feedback

September 2013

Jerry Hardcastle

Technology Group Chairman

Global Chief Marketability Engineer & Technical Director Global Motorsports

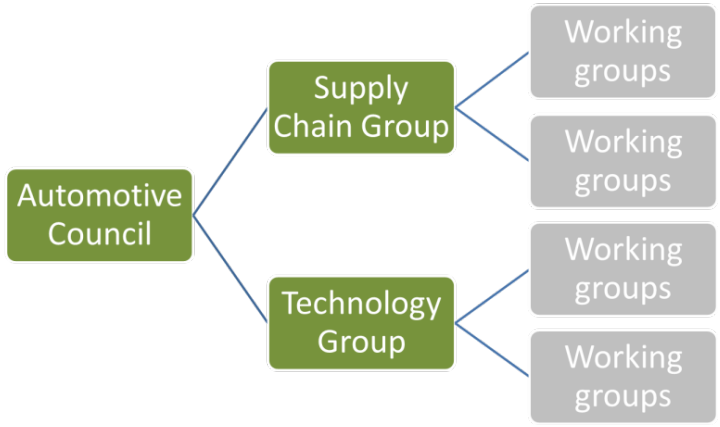
Nissan Motor Company

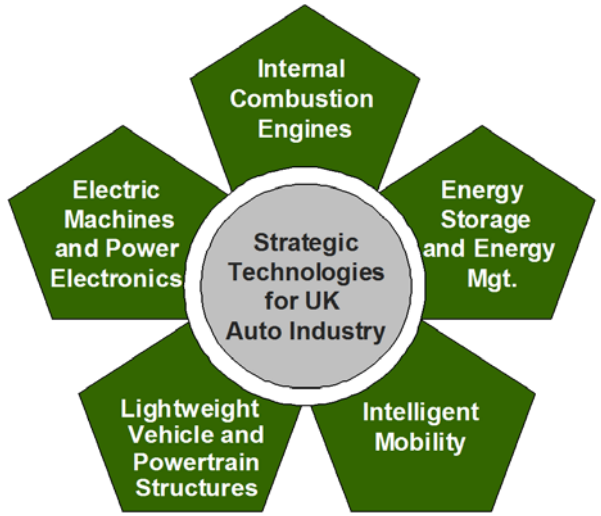
Low Carbon Vehicle Event 2013

Millbrook Proving Ground

The UK's Premier Low Carbon Vehicle (Technology Showcasing & Networking) Event

Our journey continues





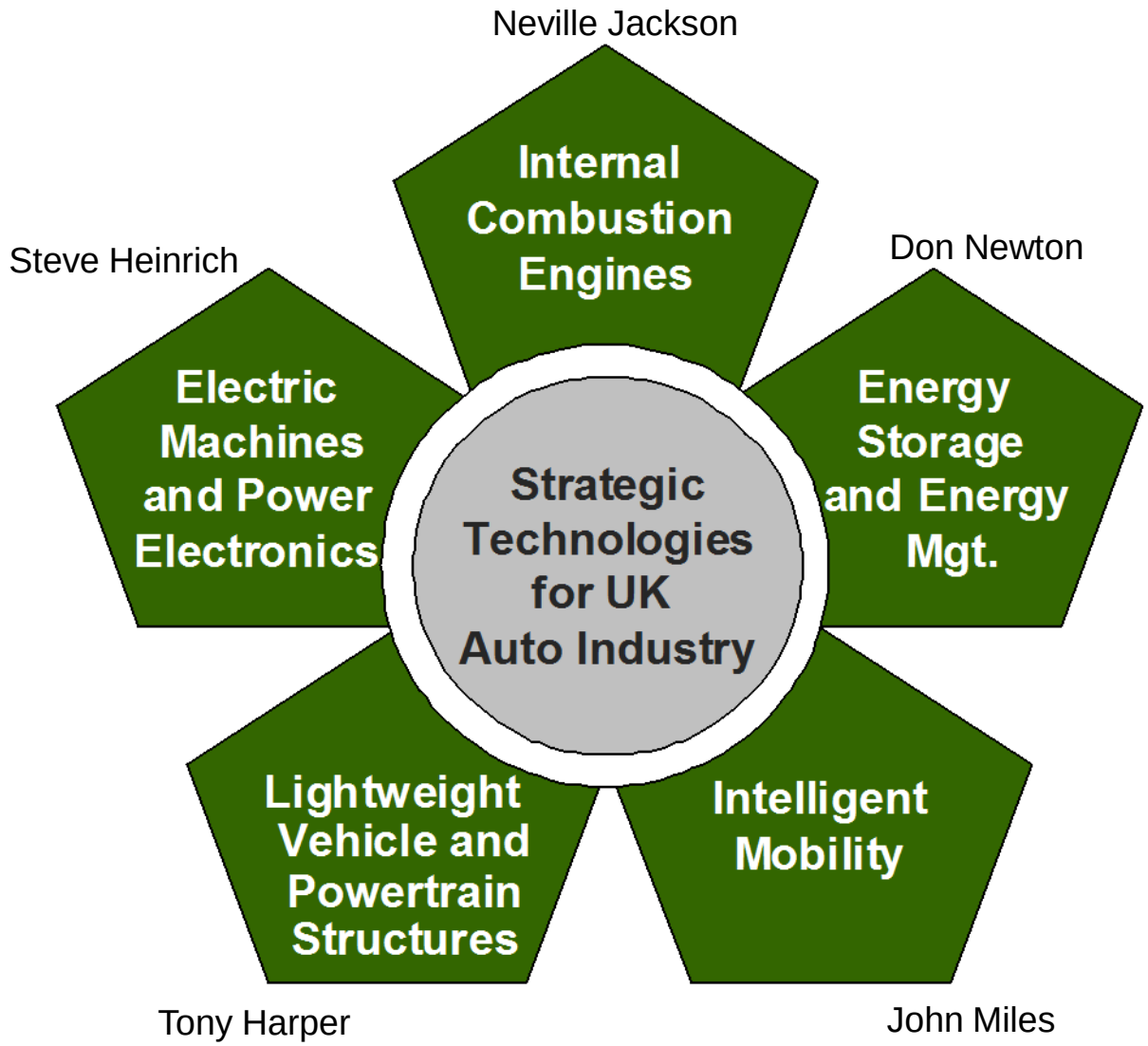
2008 - 2009

2009 - today

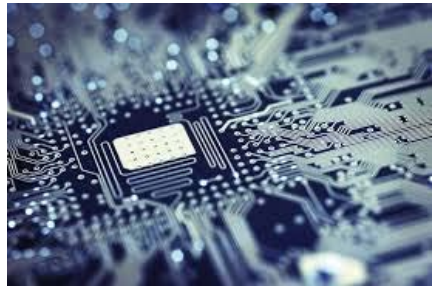
2013 ++

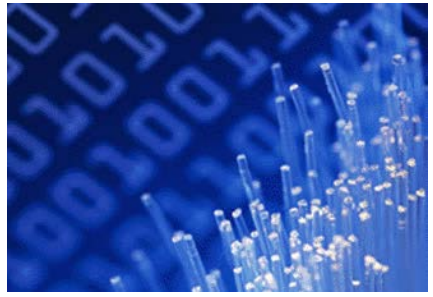
Workstream Overview

- **Worksteam topics agreed Mid 2011:**
- **All members volunteers and funded by employing organisations**
- **Workstream leaders represent voice of the workgroup**
- **Workgroups have created consensus roadmaps**
- **LCV2013 is the official release of roadmaps**
- **Filming allows for sharing of knowledge with wider audiences**



Technology challenge and future support





- Lower emission vehicles required.

- Traditional propulsion systems are changing.
- New solutions are emerging.
- Immature supply chains provide UK opportunity.
- Roadmaps from the Technology focus areas directing research opportunities.

- Capitalising on existing powertrain strengths.
- Strengthening co-ordination between academia and industry.
- Alternative solutions to help bridge the valley of death.

- Advanced Propulsion Centre open for business in 2014

Advanced Internal Combustion Engines Workstream Conclusions & Consensus Roadmap

September 2013

Neville Jackson

Chief Technology & Innovation Officer

Ricardo plc

Low Carbon Vehicle Event 2013
Millbrook Proving Ground
The UK's Premier Low Carbon Vehicle (Technology Showcasing & Networking) Event

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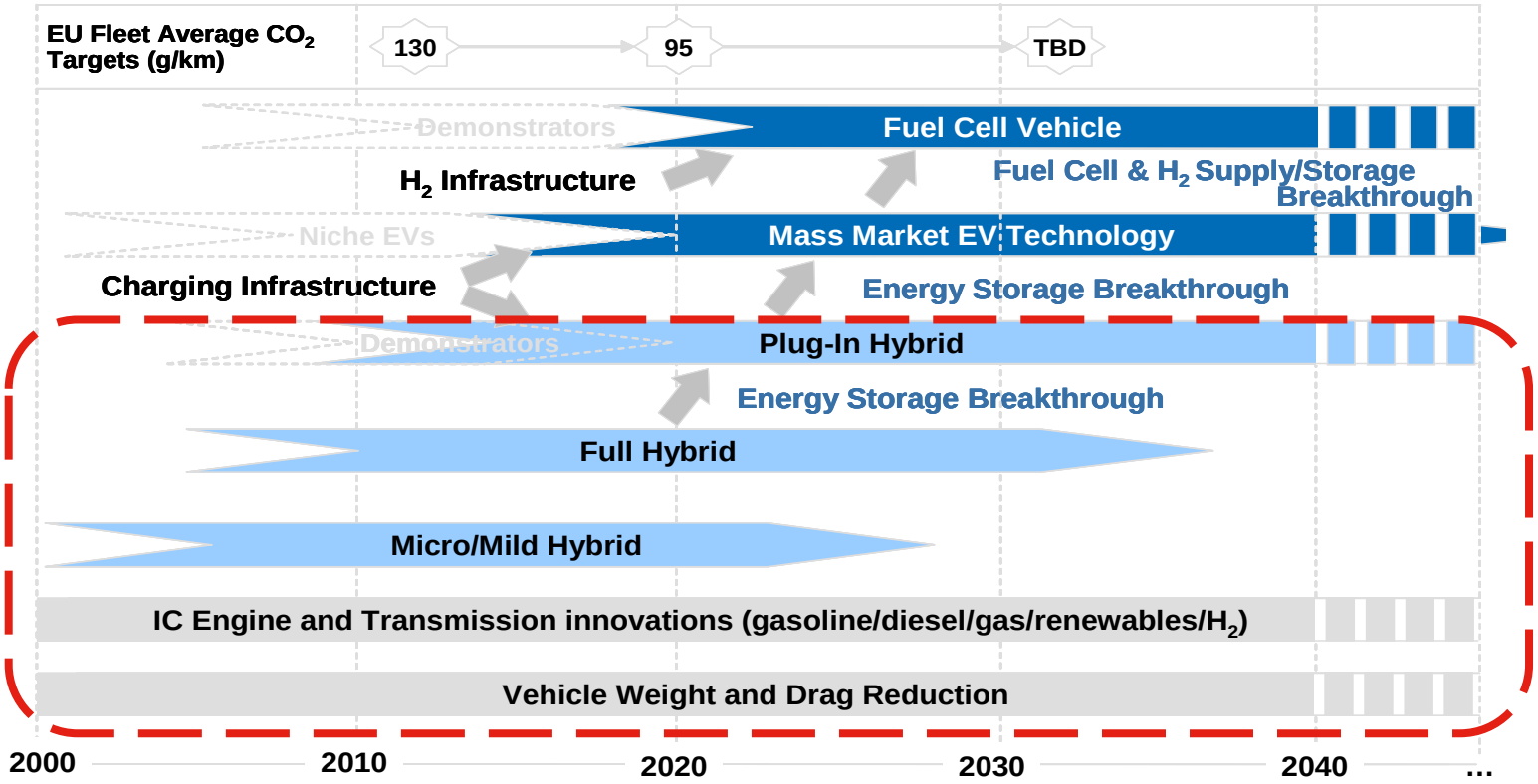
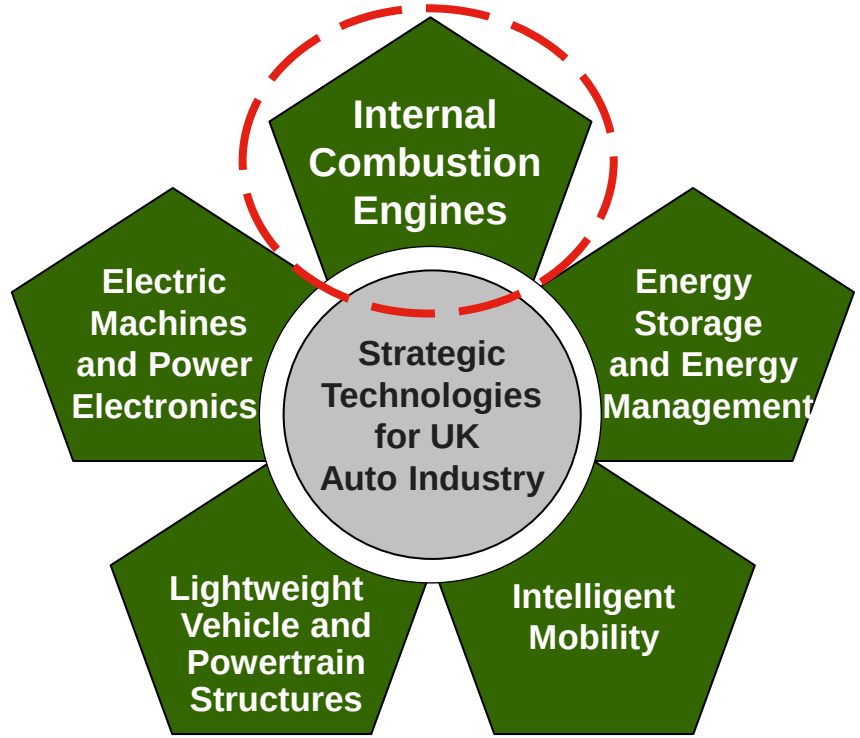
Advanced Internal Combustion Engines vital for vehicle CO_2 are a key feature of the consensus roadmap & core UK focus area





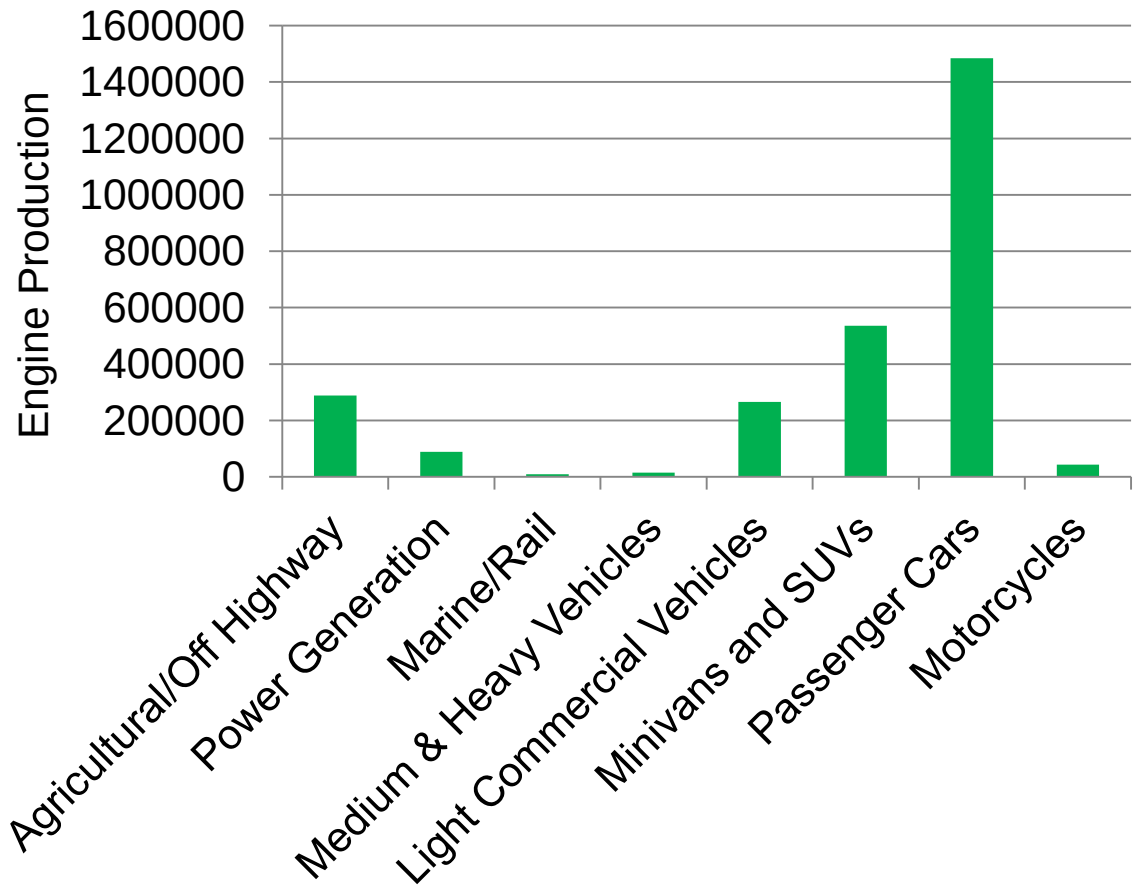
Advanced high efficiency Internal Combustion Engines key feature of roadmap & UK focus area

- Most effective short term route to CO_2 reduction.
- UK has all the elements of the supply chain from research to mass production.
- Companies with a fundamental expertise in combustion technology, active fuels and lubricants companies and expertise in motorsport engine technology.
- Opportunity is to grow Tier1 supplier capability & presence

UK is a leader in the manufacture of Advanced Internal Combustion Engines – High Value Exports in passenger car & off-highway products

Internal Combustion Engines important for Economy

- UK produces ~ 2.7* million engines/year
- Associated value to UK is ~£7bn
- Majority of engines made in UK exported



UK ICE Characterised by:

- **Leading University/Industry Partnerships**
  - Around £36m over 3 yrs invested in ICE research
  - Internationally leading University research teams
    - Turbomachinery and boosting
    - Advanced clean/high efficiency combustion
- **Product Development & Manufacture**
  - High efficiency downsized boosted engines
  - Leading construction & off-highway engines
  - World beating high performance engines

INTERNATIONAL engine of the year awards 2013
Presented by engine technology international magazine

BRITISH MADE

Ford 1.0l Ecoboost

BMW-PSA 1.6-litre turbo

McLaren 12C M838T

3 of 8 International Award winning engines in 2013 made in UK
Award winning engines also a key feature of Off-Highway sector

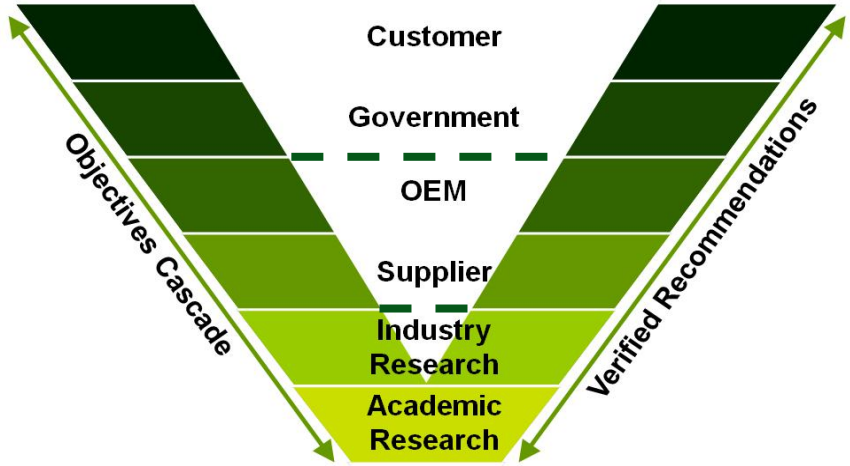
Source: PSR Enginlink Database

Broad multi-sector team created to develop Internal Combustion Engine Technology Strategy with an objective to grow UK value & capability

- Objective – To create a UK Internal Combustion Engine strategy that defines a consensus industry view on what needs to be done to grow the UK capability in technology, infrastructure and market development

The Team & Group Leaders*			
Neville Jackson	Ricardo (Chair)	David Skipp*	Ford (Co-ordinator)
Richard Banks*	BMW	Steve Richardson*	Jaguar LandRover
John Turton	Nissan	Steve Faulkner	Caterpillar
Jamie Turner	Lotus	Brian Gush	Bentley
Martyn Hawley	SAIC	Colin Garner	Loughborough Univ.
Colin Loud	JCB	Pierre French	Cummins Turbo Tech
Dave Yuill	BIS	Richard Hall	Schaeffler
Marco Warth	Mahle	John Laughlin	Tech. Strategy Board
John Kell	UKTI	Ian Bacon	SMMT

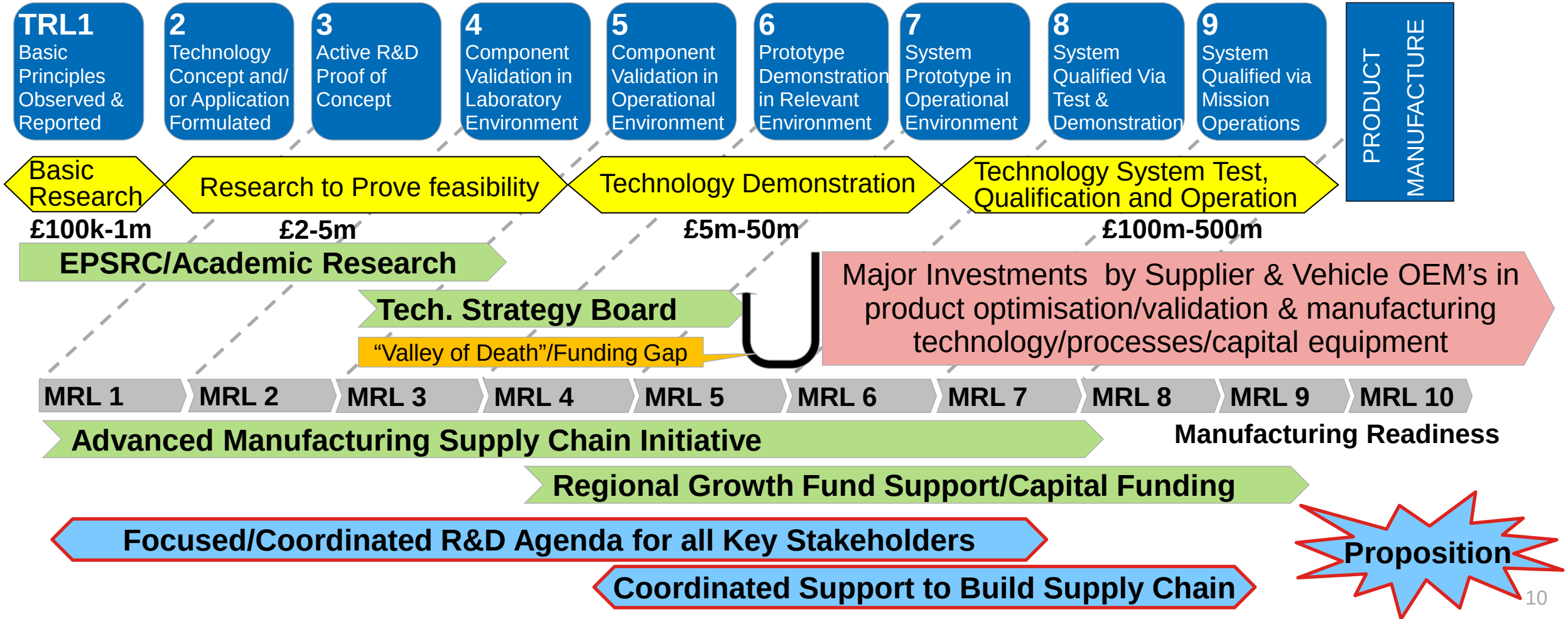
The Approach



- Focus on Passenger Car, Commercial Vehicle and Off Road Equipment
- Canvas & Consolidate data & points of view from key stakeholders
- Input from survey of Academic Research Capability/Activities and TSB Automotive Capability Study
- Develop ICE and related Technology Roadmap to highlight key future focus areas
- Outline likely ‘Mobility’ transition pathways comparing ICE with other technologies
- Propose ICE opportunities/enablers for wealth generation & CO_2 reduction via investment & training

UK Innovation Chain has key strengths but we need to coordinate & focus R&D agendas & build capable supply chains in added value systems

- UK has significant design & manufacturing capability, largely dominated by assembly
  - Many of the high added value, fuelling, control and electrical systems imported from overseas
- UK strong academic & vehicle OEM R&D capability, less homogenously strong R&D capability in supply chain
- Support Structures for TRL 1-5 but many technologies fail to reach TRL 6-9:



Future key technologies identified to improve ICE efficiency supported by enabling technologies – Focus areas defined via impact & UK benefit

- Future technologies categorised into improved thermal efficiency, improved system efficiency, enabling technologies and carbon reduction for fuels/production

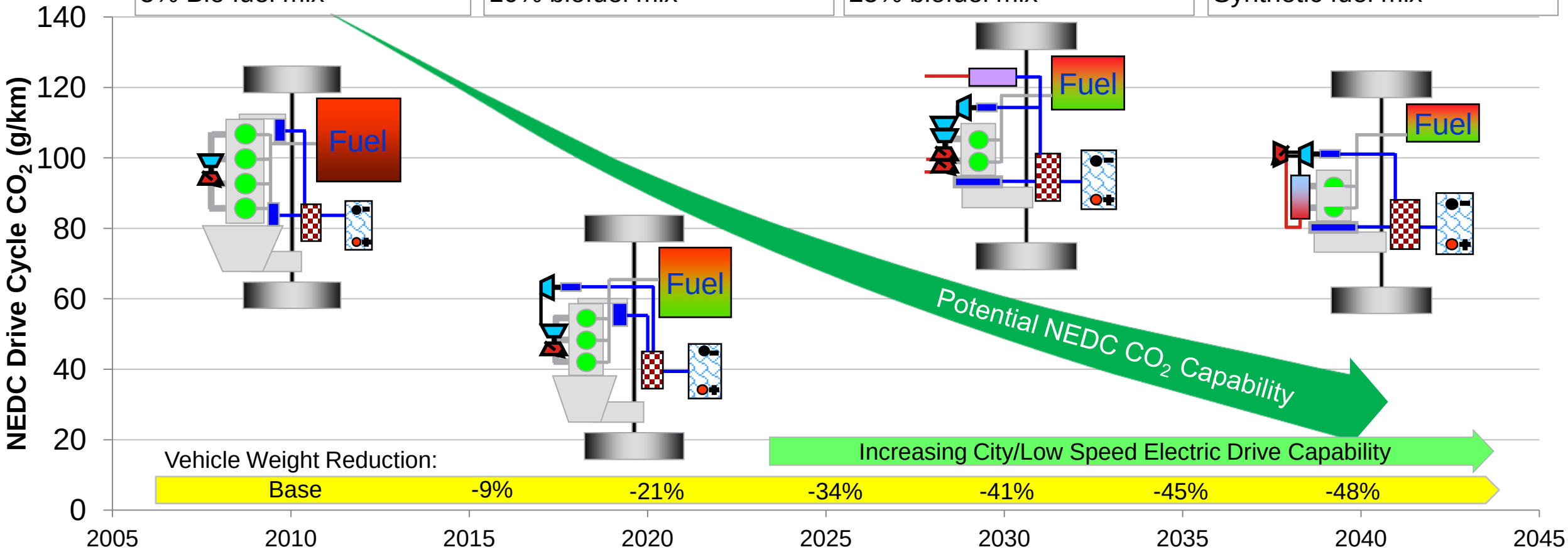
Thermal Efficiency	System Efficiency	Enabling Technologies	Carbon Reduction
Reduced Comb. Heat Losses	Downsizing & Boosting	Charge Thermal Management	1st Gen Biofuels (Crop Based)
Fuel Injection Optimisation (CI)	Lower Mech. Friction	Flexible/Fast Response Boost	2nd Gen Biofuels (Waste Re-use)
High Efficiency Combustion	Thermoelectric Generators	Thermal Energy Storage	3rd Gen Biofuels (Biotech)
Improved boost Eff/operating range	Electrification or Energy Recovery	Flexible Valve Trains	CNG/Biogas
Mechanical/Elec Turbocompound	Variable Power Ancillaries	Pm & NOx Emissions Control	Liquified Natural Gas
Organic Rankine Cycles	Low Inertia Fast Warmup	Advanced Control Approaches	Re-cycling & Re-manufacturing
Adv. Regen or Split Cycle	Downspeeding	Advanced/New Materials	

- Potential UK R&D focus areas identified via UK TSB capability study, Impact & likely UK benefits
- Further detailed analysis required to define priorities

Many pathways to improve pass car powertrains – Example: downsizing/ electrification/heat recovery combination could achieve 30 g/km CO_2

automotive council UK

Boosted Engine	Downsized 40% v Today	Downsized 70% v Today	Extreme Downsizing
Variable Geometry Turbo	Turbo/Supercharged	Dual Stage Boost	Advanced Cycle/Heat Rec.
12 Volt Elec System	48 Volt Motor/Generator	Integrated Electric Machine	Integrated Systems
Stop/Start	Low Cost Energy Store	Thermoelectric Generator	Advanced Thermoelectrics
5% Bio fuel mix	10% biofuel mix	25% biofuel mix	Synthetic fuel mix



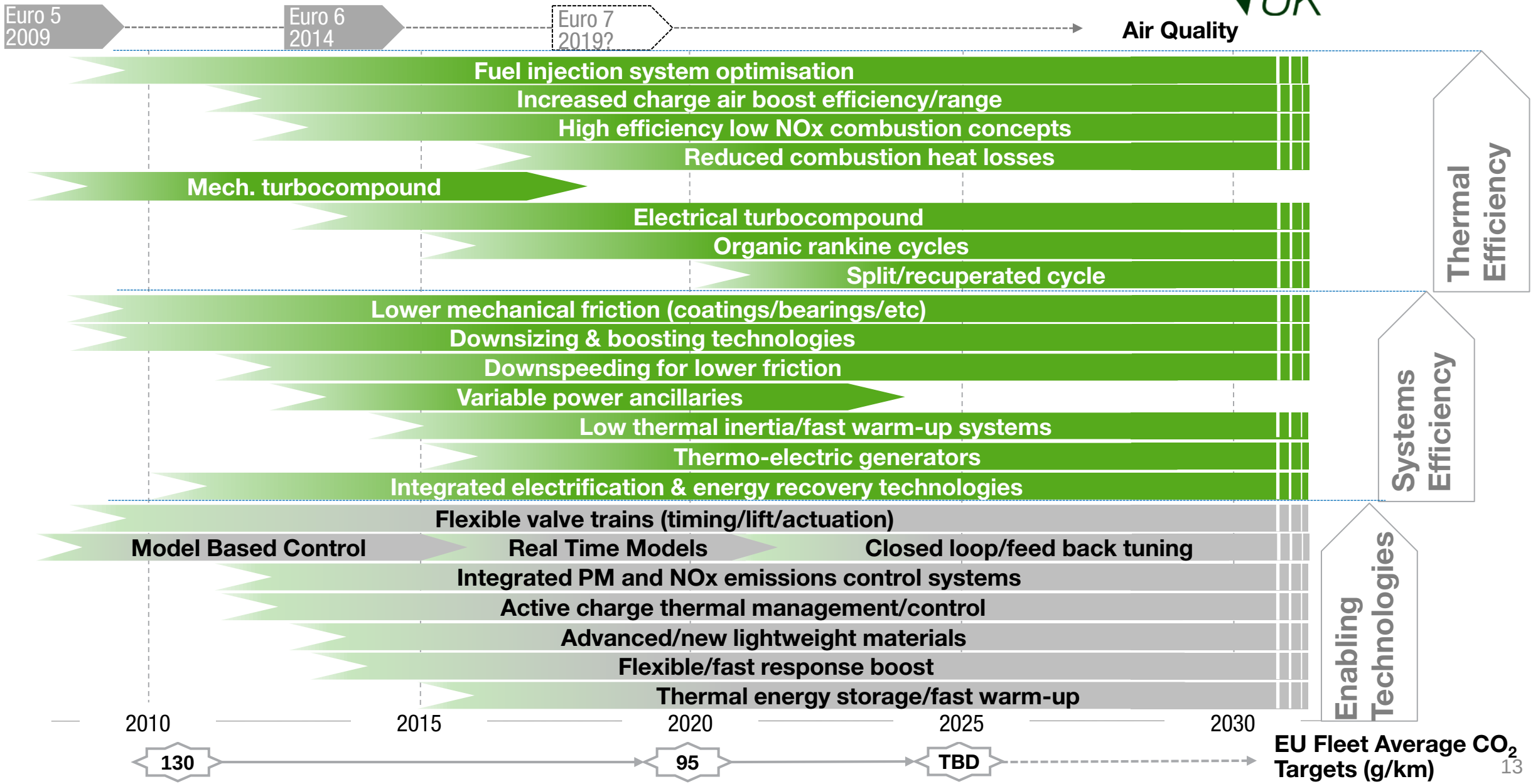
ICE/System efficiency improvements & low carbon fuels could deliver ~ 30 g/km CO_2 by 2040

ICE based systems competitive with EV's on life cycle carbon basis

Source: Ricardo Analysis

ICE roadmap defines role & phasing for future technologies to meet future regulatory and commercial needs – similarities between On & Off Highway

automotive council UK



The ICE will be a core feature of low CO_2 propulsion systems for decades
Collaborative investment in supply chains could deliver £2b/year to UK

Key Messages:

- ICE research, development & manufacture is a **UK strength**, providing significant benefit to the UK economy
- Detailed analysis shows that the Internal Combustion Engine, operating on low carbon fuels, with varying degrees of electrification, is the most logical route to future on & off highway regulatory & commercial needs
- Increased global demand for low carbon propulsion systems offers an opportunity for the UK to grow a supply chain for added value systems through investment in skills, capabilities & advanced manufacturing technology

Recommendations:

- Improved coordination of ***R&D agendas*** via an Auto Council advisory group to connect our academic & industrial base in propulsion systems & research to manufacture, supporting high value low CO_2 propulsion technologies
- Stable, long-term policy required by Government to encourage collaboration and focused investment across fuel supply and ICE/vehicle industries, and to bring these ***new low carbon sustainable fuels*** to market
- Support development of ***advanced manufacturing supply chains*** to deliver ***added value low carbon systems*** for the next generation of on & off highway powerplants rather than purchasing these from outside the UK

Core Proposition:

- **An investment of £1bn over 10 years in a co-ordinated collaborative program is recommended to grow a *demand led* supply chain for low carbon added value automotive propulsion systems establishing global leadership for UK 'research to manufacture' capability & skills. This could deliver £2b/year to the UK**

Electric Machines and Power Electronics Workstream Conclusions and Consensus Roadmap

September 2013

Steve Heinrich

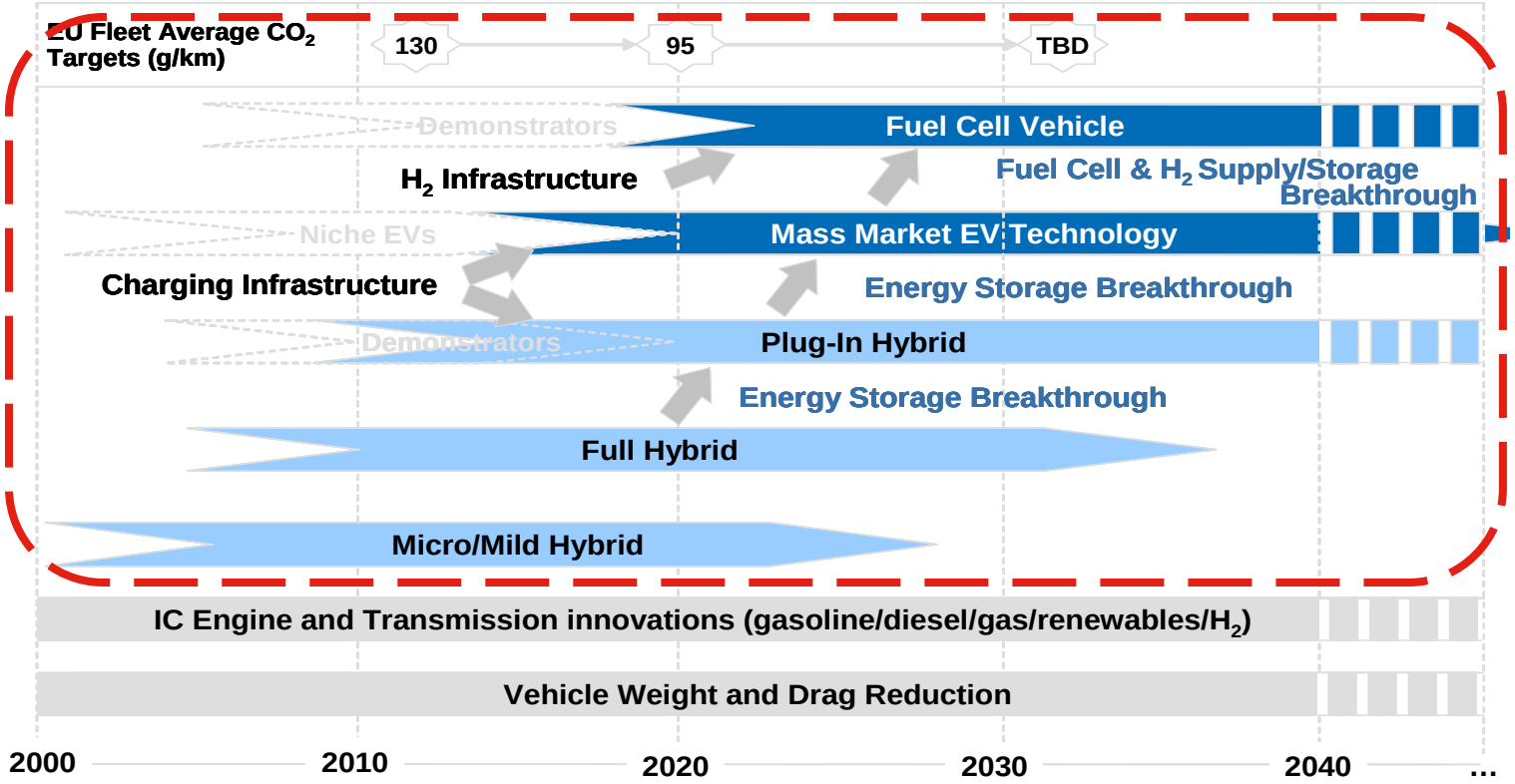
Group Chief Engineer - Advanced Engineering and Research

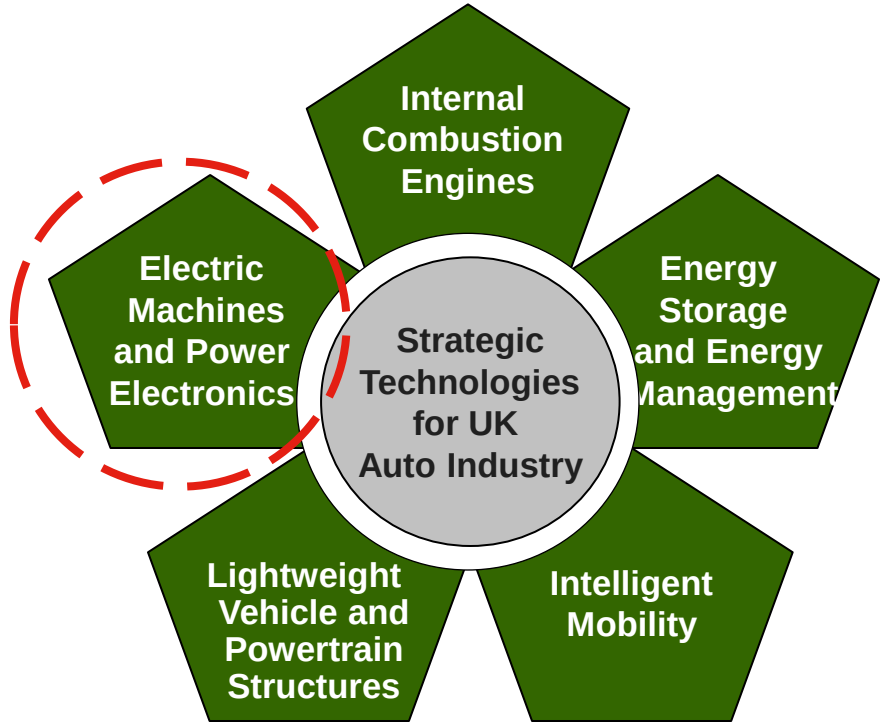
Lotus Engineering

Contents

- Introduction & Background
- Team members and objectives
- Consensus Roadmap
- Challenges and Conclusions
- Future activities

Electric Machines and Power Electronics are essential for vehicle CO_2 strategy and key to the consensus roadmap & core UK focus





Electric Machines and Power Electronics are an essential feature of roadmap & UK automotive focus area

- Essential to medium and long term CO_2 reduction.
- UK has excellent fundamental technology around EM and PE design.
- Good innovation companies with first time technology application expertise looking to commercialise.
- Opportunity to develop supply chain for these technologies to mass production and to compete with the emerging competitive countries

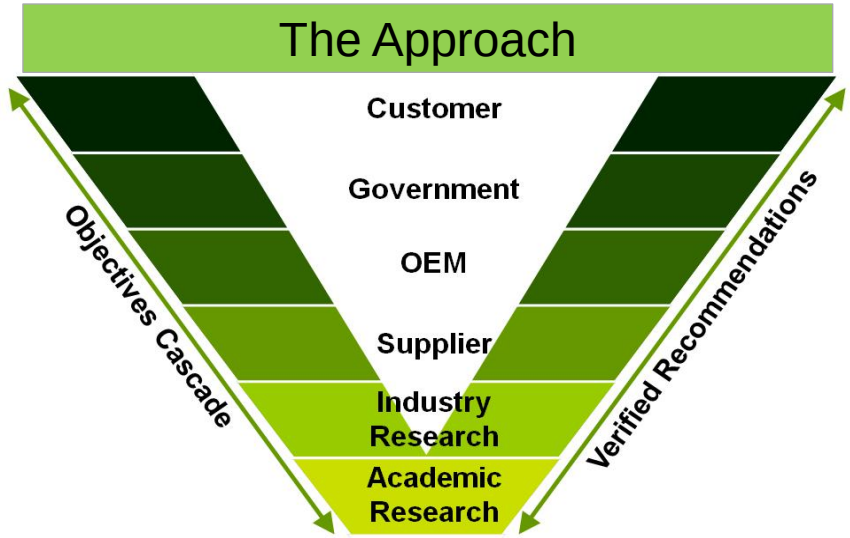
Cross Sector Team Representing Key Stakeholder Groups from OEM and Tier1 through Innovation SME's to Academia

Objectives :–

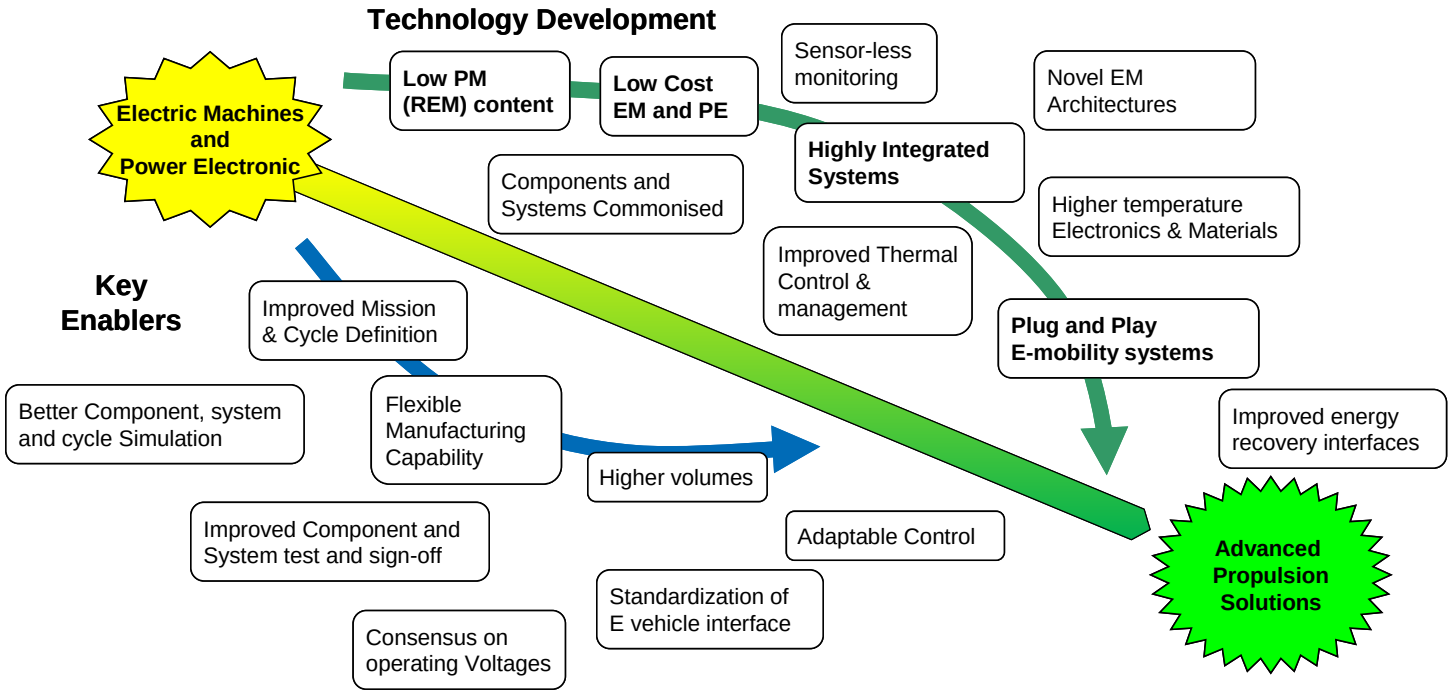
- To create a strategy to promote investment in the R&D of Electric Machine & Power Electronics systems
- Identify significant technologies
- Study how to develop an integrated UK supply chain for these technologies

Workstream Team			
Steve Heinrich	Lotus (Chair)	John McLuskie	GKN/EVO
Alex Michaelides	Jaguar Land Rover	Jon Horsley	TSB - LCV
John Reeve	Ricardo	Chris Connelly	Ford
Joachim Post	BMW	Bryn Parry	Amantys
Iain Urquhart	Nissan	Mark Begbie	BIS
Aidan Gregory	Zytek	Prof. Jiabin Wang	Sheffield Uni.
Tim Strafford	McLaren	David Latimer	EVO

Additional contributors	
Graham Gest	Tata
Dave Lamb	Sevcon
Prof Qiang Zhu	Sheffield Uni.
Joachim Tachtler	BMW



Sector Growth will depend on Collaborative Supplier Innovation and Development across Systems and Components



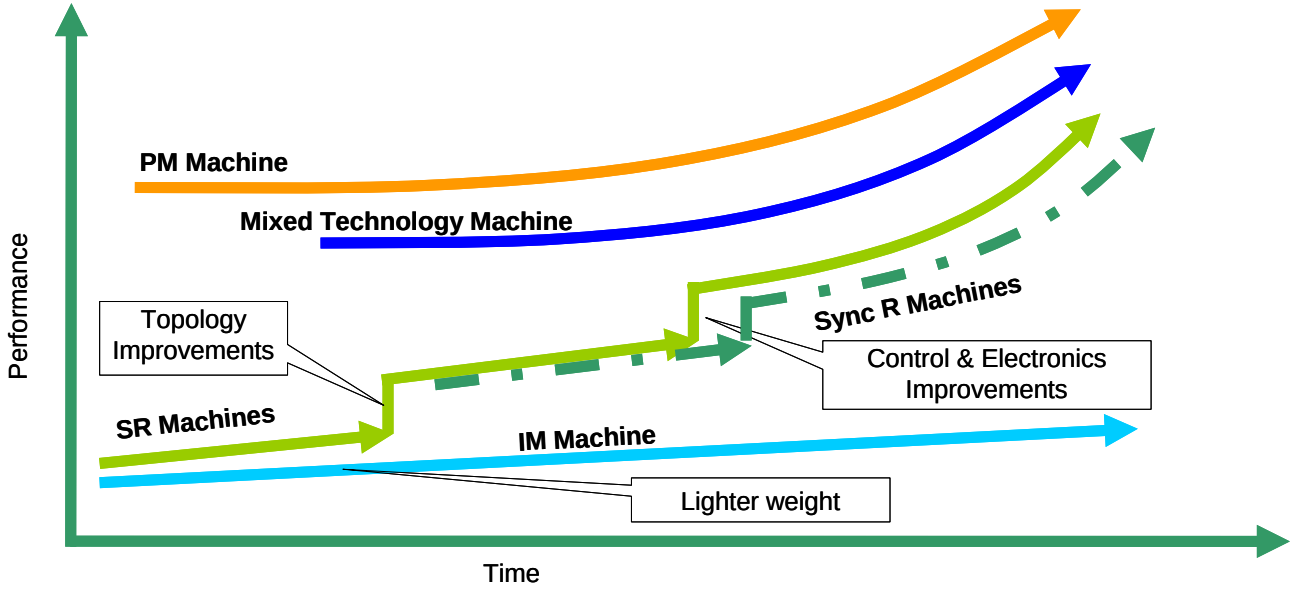
- **An integrated electric drive train solution**
  - Shared cooling solution
  - Increased system operation temperature 105 deg C
  - OBD/EOBD standardised
  - Minimal cabling and connectors
  - Multiple applications, planned future enhancement/development
  - Minimal disruption of the current vehicle architecture

- **Performance focused Electric Machines**
  - PM focused topology driven by package, weight performance criteria
  - Move to reduced Rare Earth material and move to non strategic rare earth materials
- **Medium performance and Low cost/Power motors**
  - Greater opportunities for alternative topologies
  - SR and Hybrid greatest potential for future step change in technology but dependent on advancements in control and electronics at an acceptable cost
- **Hybrid power units ie EM and ICE**
  - Seen as a market that will develop and mature potentially quicker than pure EV market.
  - Potential for significant near future opportunities in UK as there is currently limited UK technology activity in this area but core skills exist.
- **Power electronics**
  - Combined DC/DC, Inverter and charger to enable increased bus voltage with comparable battery sizes and rates
  - Modular power electronics building blocks which can be built into bespoke packages

Traction Drive Systems				
Year	Cost €/kW	kW/Kg	kW/l	Efficency
2015	18 to 30	1.2	3.5	>93%
2020	10 to 16	1.5	3.5	>94%
2025	8 to 15	1.6	5	>95%

Specification : 55kW peak for 18 sec, 30kW continuous: 15 year life

Key Technology Step Changes can be identified which open the opportunities for establishing a strong automotive supply sector



- Initial Focus on topology to understand fundamental machine parameters.
- Moving focus to the advanced control and electronics to provide the step performance change and rapid acceleration in machine efficiency
- Mixed technology and Switched Reluctance are cost effective solutions with the most future potential for step improvements
- Permanent Magnet Motors are best topology for performance but needs to migrate to a Low/No rare earth material architecture

Key Technology Barriers

High Volume / Low Cost - Switched Reluctance

- Torque Ripple Issue – Manageable with Control Electronics and Topology
- Availability of suitable power convertors
- NVH but proof of concept have been demonstrated with 6-8 db improvement.
- SR more emphasis on control and electronics but this is a future area for greatest step changes
- PE/controls and topology potentially the significant key break through contributors
- Topology for improved torque density
- Improved topology and control leading to breakthrough on Synchronous Reluctance Machines

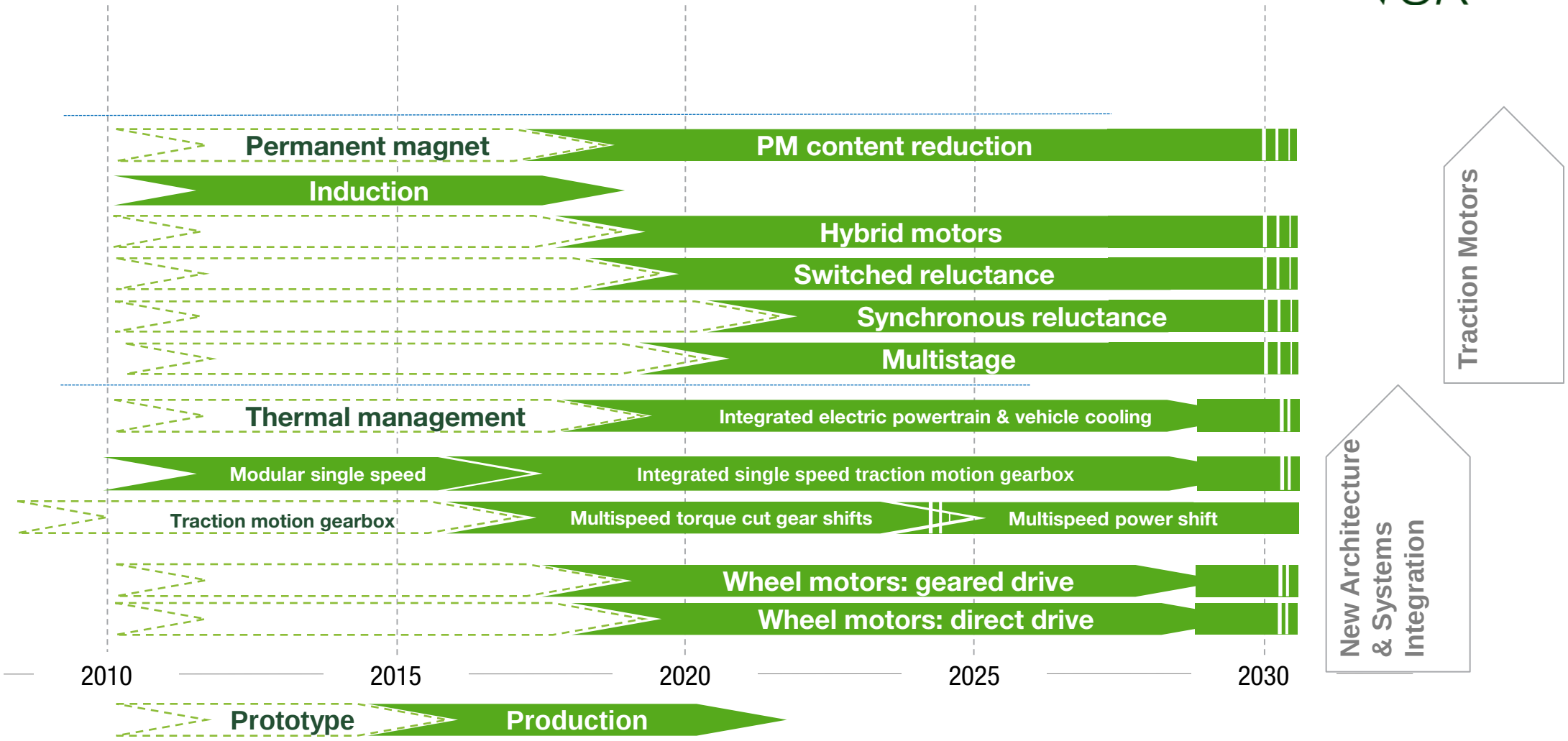
Performance Drives – Permanent Magnet

- Low/no Rare Earth Material content
- Higher Temperature materials

All motors

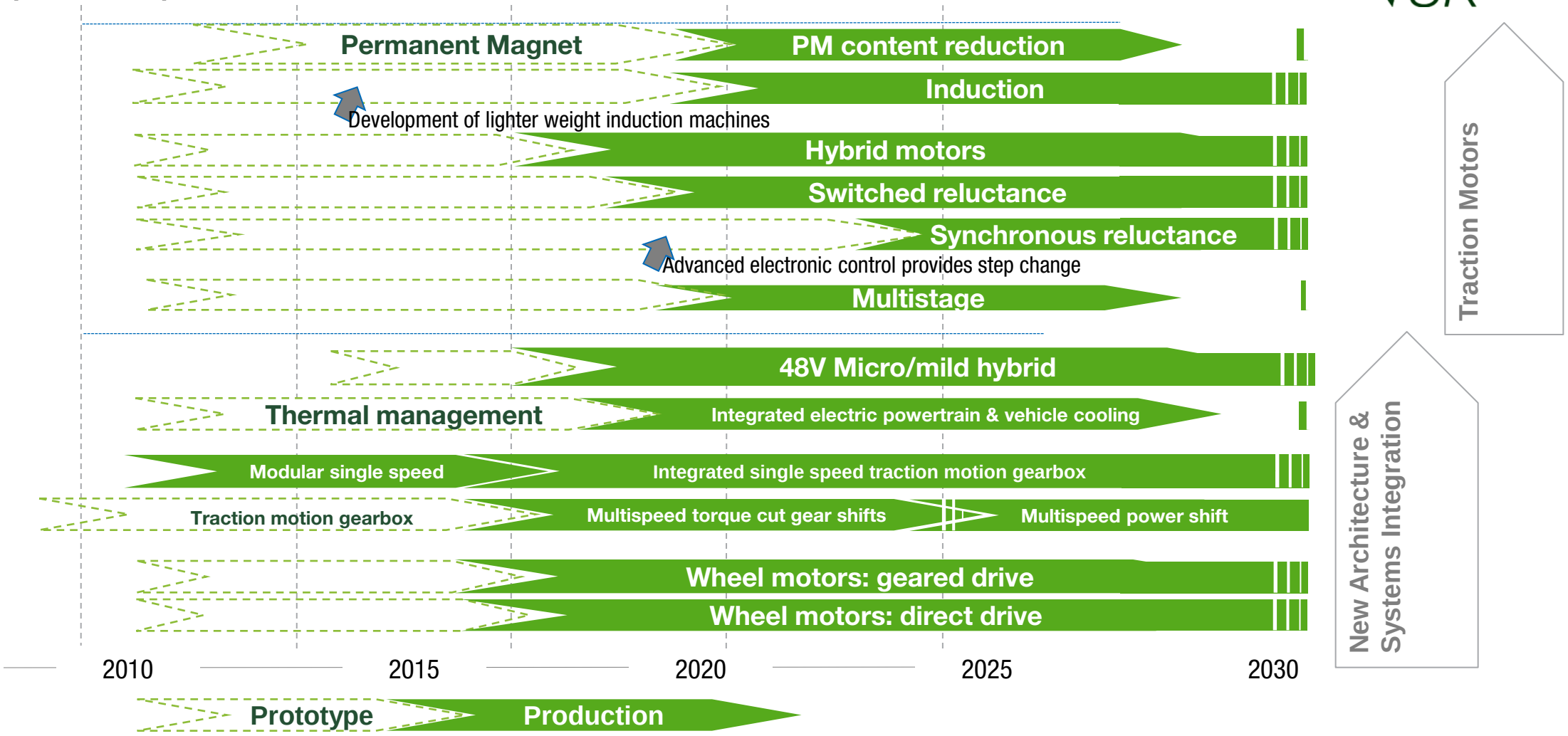
- Winding technology materials, manufacturing and insulation

Traction motors & generators roadmap (100kW +)



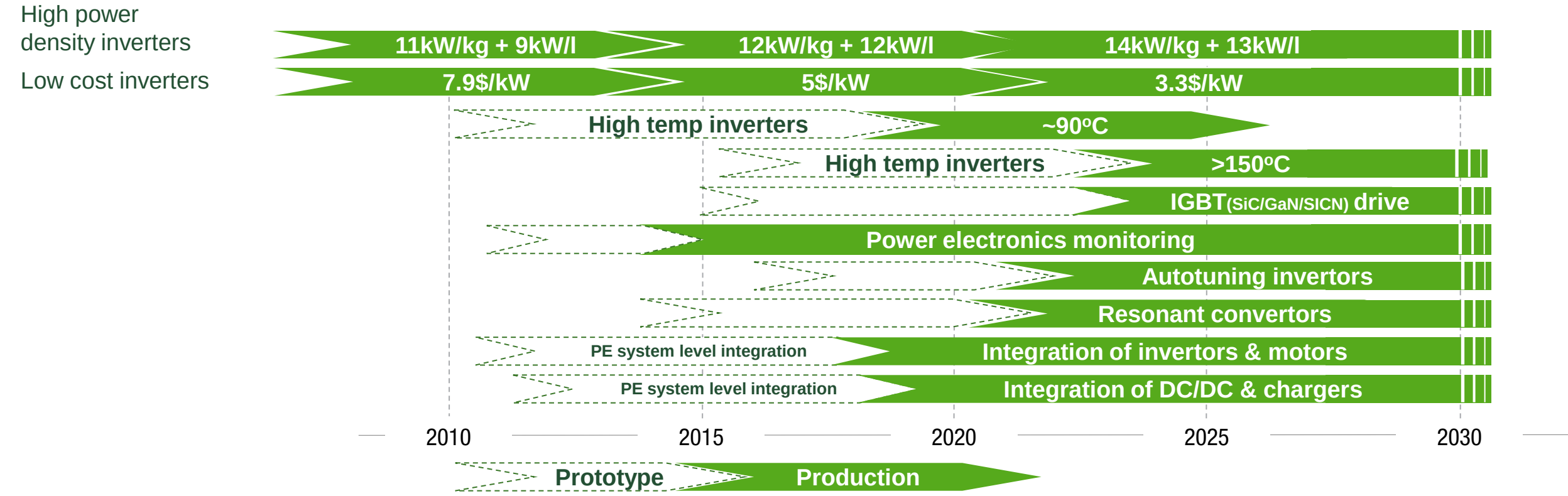
Source:Automotive Council Technology Group 2013

Traction motors & generators roadmap (<40kW)



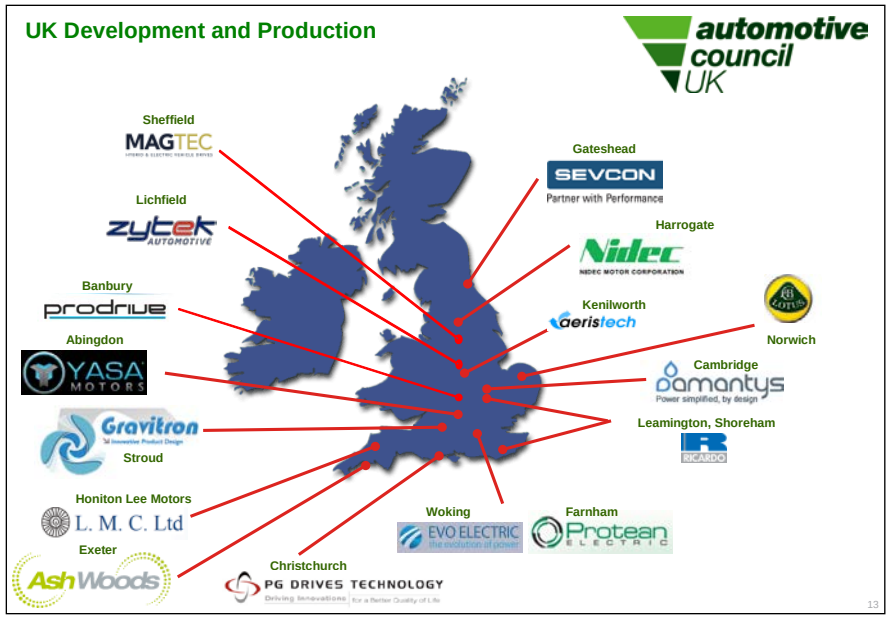
Source:Automotive Council Technology Group 2013

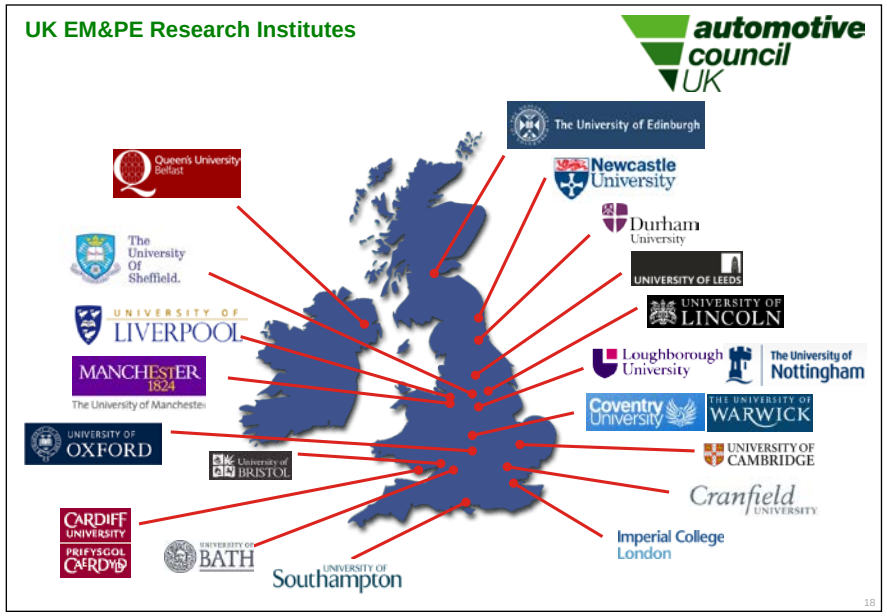
Power electronics roadmap



Source:Automotive Council Technology Group 2013

Defining the research needs and encouraging development and investment in innovation manufacture will stimulate the sector





Focus the strong R&D capability (TRL 1-3)

- Improved definition of the automotive sector needs
- Promote direction of a world class capable resource at the specific needs of the Automotive sector
  - Technologies, targets, costs, power, mission profile
- Software and control a key capability to unlock topology and designs

Encourage and develop the SME's and new entrants (TRL 4-7)

- Promote growth in SME experience and knowledge of OEM quality levels in components and systems
- Promote initial contact of OEM/Tier 1 to SME with technical rather purchasing team
- Scale up and strengthen technology companies towards manufacturing
- Improved facilities to allow prove out at vehicle and environmental level
- Improve the integration of facilities to HIL/SIL systems to allow virtual integration driven test assessment

Encourage OEMs/Tier1s to invest in UK supply (TRL 7-9)

- Develop a flexible UK EM&PE manufacturing base
- Improved definition of vehicle sign-off criteria for highly electrified vehicles
- OEM rationalization of E-product needs to allow volume growth

Excellent Opportunities exist for High Value Manufacturing in an emerging worldwide market

Challenges

- To **promote investment** in R&D of EM&PE systems which are aligned with the vehicle CO2 strategy and to align the strong academic capability with this global opportunity
- Improve the focus on product and system level design, development and testing **to improve attractiveness** of technical offerings to OEM
- Promote greater **collaboration of SME's** to achieve product based solutions focused on automotive sector needs.
- **Move** from a technology/know how supply sector to a component/system manufacturing sector
- **Incentivise** the SME and their backers further up **the TRL maturation process,** and the Tier1 and OEM's to engage and mature technologies further down the TRL maturation process
- Provide a **central focus** for UK Automotive EM&PE activities and engagement with other Technology development sectors and geographical areas

Promote and deliver high value manufacturing solutions in a technology area open to a new supply base and supply chain which is key to delivering both the short and long term Low CO2 Strategy

Conclusions

- Electric Machine and Power Electronics **are essential** to the medium and long term CO2 reduction and in assisting the continued **development of the ICE** manufacturing base..
- The UK has a significant number of **good innovation** companies with first time technology application expertise looking to commercialise.
- Advanced topology and hybrid design ideas **ready** on the bench
- This in a sector where there is **no dominant** player
- There is a significant **opportunity to develop** the supply chain for these technologies to mass production and to compete with the emerging competitive countries.
- Significant **investment from overseas** in UK academic research
- The UK has a **strong academic** R&D capability with worldwide recognition but this is **not aligned** to the automotive sector demands.

An emerging future technology and manufacturing opportunity with a worldwide demand leveraged through aligning a strong academic and innovation resource (SMEs)

Investment in a co-ordinated collaborative program can grow a *demand led* supply chain for low carbon added value automotive propulsion systems

Supply Chain

•To move this sector on to the next stage of development and into an area of continued sustainable growth **requires development of the technology companies** into high value manufacturing companies.

•Typically many of the UK technology companies provide initial concept and then the product exits the UK just as it is starting to demonstrate the potential for moving into the manufacturing development phase

•**Investment** in EM and PE manufacturing is key to developing the **UK supply chain** for this sector.

Potential Future Technology development with EU and overseas OEMs Tier 1s

•Indications are that when the output is available on UK EM&PE manufacturing, facilities and technology activities this would broaden opportunities for EU collaboration.

•European OEM “we have a successful record working with and in the UK but currently have limited visibility of companies/activities in EM&PE”

Work Stream

•Provide a technical focal point for UK Automotive EM&P technologies

•Maintain and further develop the Roadmaps

•Support alignment of Research and Innovation to sector ambitions

•Support improved connection of the SME to the OEM /Tier 1 through Technical rather than purchasing teams

Infrastructure

•**Encourage investment** in development and production capacity in automotive volume levels for both Electric Machines and Power Electronics

•**Improve R&D facilities** that are accessible to the core innovation companies (SME’s) for system level and vehicle level test and development.

•**Improve availability of environmental system/vehicle** development test capability for EV propulsion systems and vehicles

•**Develop adaptable /flexible/accessible winding facility** for volumes up to 5000 pa

Lightweight Vehicle and Power Train Structures. Workstream Conclusions and Consensus Roadmap

September 2013

Tony Harper

Head Of Research

Jaguar Land Rover

Low Carbon Vehicle Event 2013
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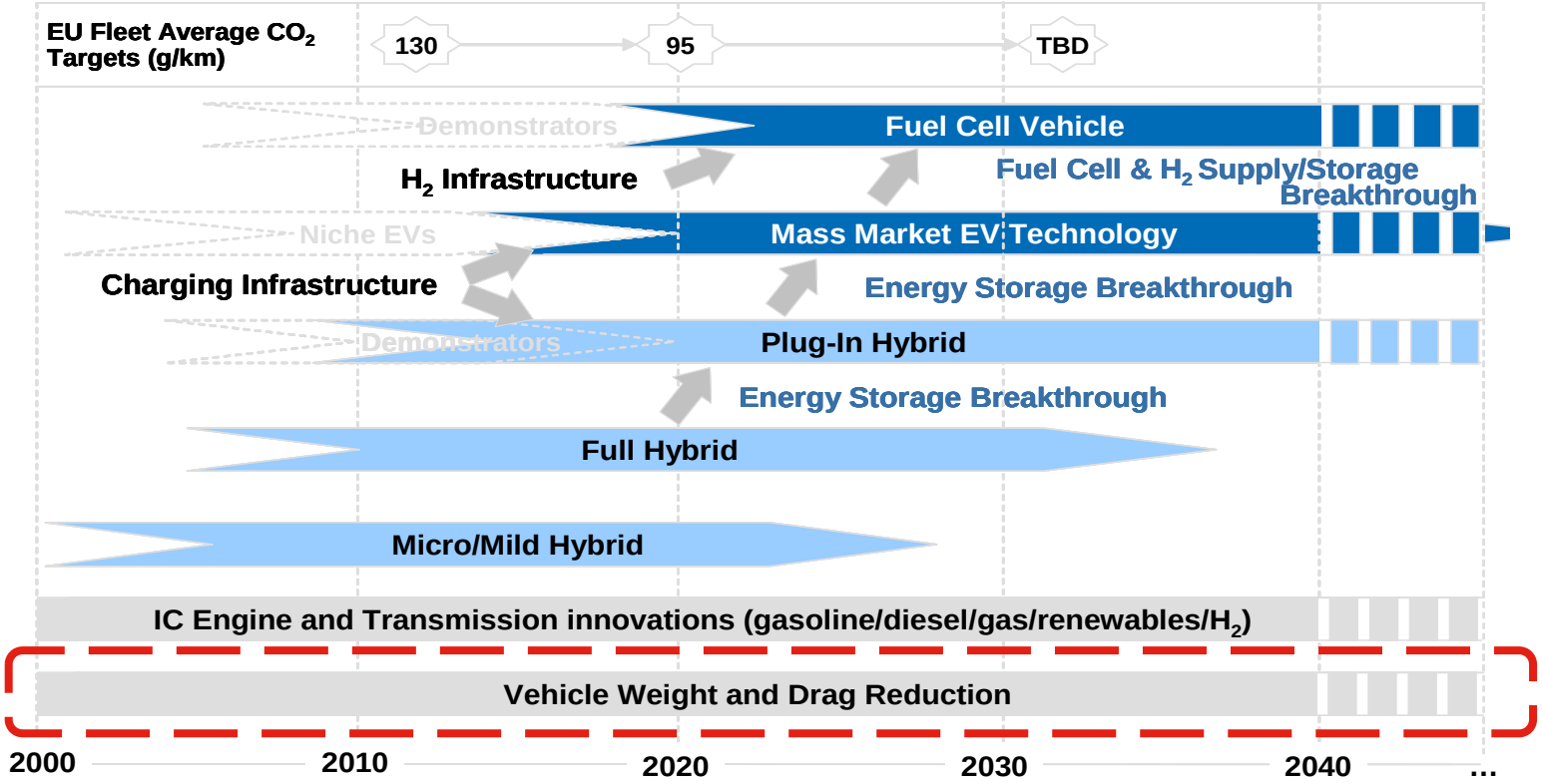
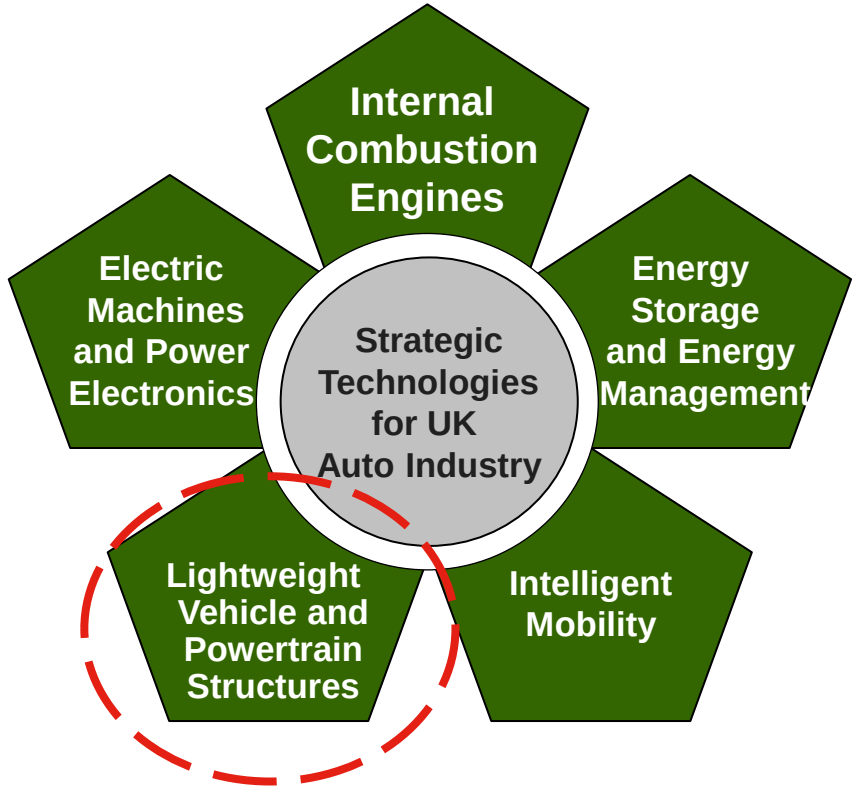
- Introduction & Background
- Team Members, Objectives
- Challenges & Opportunities
- Technology Options & Consensus Roadmap
- Key Messages, Recommendations & Future Plan

Vehicle weight reduction is vital for vehicle CO_2 and is a key feature of the consensus roadmap & core UK focus area





Vehicle weight reduction key feature of roadmap & UK focus area

- Envisaged vehicle CO_2 targets will not be met by PT efficiency improvements alone.
- UK has many of the elements of the supply chain from research to mass production.
- Significant scope to turn this challenge into an opportunity for increased UK manufacturing of Lightweight materials, components & systems.

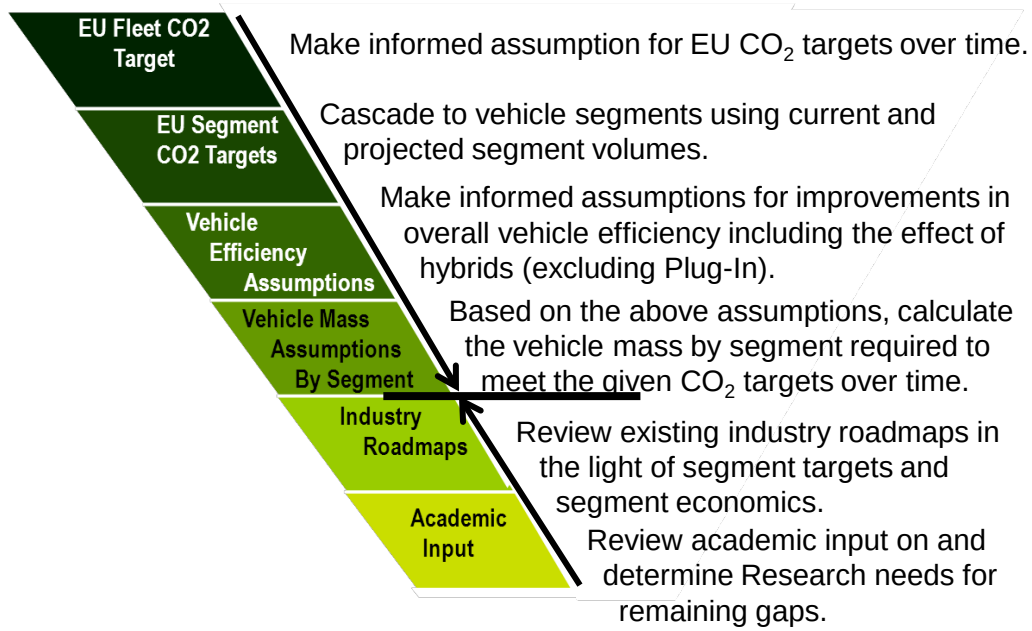
Lightweight Vehicle & Powertrain Structures– Objective, Team Members & Approach.

- Objective – To determine the likely vehicle weight reduction requirements over the next 10-20 years, identify economically viable technology roadmaps and identify resulting growth and innovation opportunities for the UK

The Team

Tony Harper	Jaguar Land Rover (Lead)
Mark White	Jaguar Land Rover (Pilot)
Peter Sendal	Nissan
Peter Chivers	National Composite Centre
Richard Dashwood	Warwick Manufacturing Group
Paul Sills	Lotus
Jules Carter	GKN
Damian Dry	SAIC
Neil Butcher	ARUP
John Morlidge	TSB
Bob Moran	OLEV
Nigel Taylor	JLR (Targets Modelling)
Arafat Bhatti	JLR – Graduate support
As required	Williams F1
	Prof Richard Folkson

The Approach



The UK has academic strength and low volume capability in new Lightweight materials technology but this will not solve the mass market challenge.

- Of the 1.5 million cars the UK manufactures per annum, all but a handful use materials and processes which have **remained largely unchanged** for years.
- After a long period of vehicle weight gain due to increased safety, functionality and durability requirements, recent years have seen a **small fall** thanks to the use of computer aided engineering optimisation and some application of higher performance materials.
- The UK has an **impressive science base** in lightweight materials & structures, a **thriving** world-class motor-sport industry with lightweight vehicle technology/skills and aerospace industry with world leading lightweight technology.
- The UK also has **strength** in numerically intensive computing and the **multi-physics simulation/optimisation** methods required to drive further vehicle weight reduction.
- The key challenge is achieving the **required weight reduction** to meet anticipated future CO2 targets whilst **maintaining or increasing functionality** and without adding to material cost or at least maintaining cost of ownership.
- The primary route to meeting this challenge in the next 7-10 years is **unlikely to be** the widespread adoption of exotic motorsport or aerospace technology.
  - The vast majority of cars manufactured in the UK are in the B, C, CD, small and midsize SUV segments. These will be unable to stand the material cost associated with such technology.

The weight challenge is clear, volume OEM investments will be made. The Challenge/Opportunity for he UK is to ensure they are made in new LW technology and here.

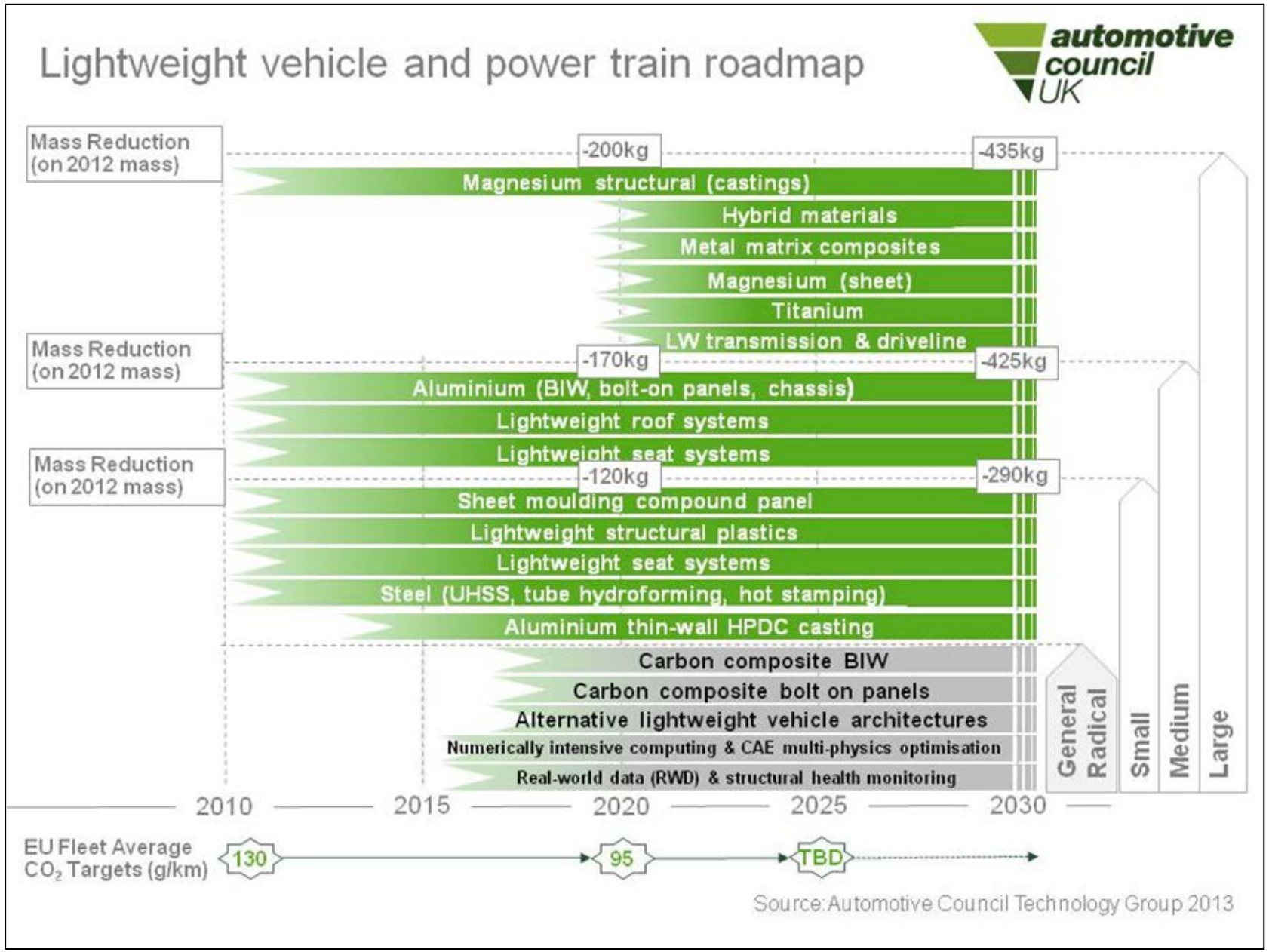
- It has been calculated by this group, that in order to meet projected vehicle 2020 CO_2 targets, the **average mass** of Large (F, Large SUV) segment vehicles will need to **reduce** by some 200Kg over today's average.
- The corresponding figure for Medium (CD, DE, Mid SUV) segment vehicles is 170Kg and 120Kg for Small (A,B,C small SUV).
- The challenge becomes even **more acute** beyond 2020 toward 2030, by when **approx. 1.5 times** the above reduction will be required over and above the 2020 figures. These figures have been calculated assuming increases in propulsion efficiency and reductions in drag will also occur simultaneously.
- The adoption of new materials and topologies for Lightweight Vehicle and Power Trains is extremely **investment intensive**.
- This, in and of itself, is not the problem. These investments are made in any event for new platforms and Power Train families. The questions are:
  - "What is required for these substantial investments to be made in New Technologies rather than evolution of known technology?" and
  - "If investments are made in New Technologies, what is required for them to me be made in the UK?"
- The challenge, therefore, is that the UK could **lose out** to international competition where **confidence to invest** is higher.

The Key Challenge For The UK.

- Confidence to invest in New Technology for a ***volume*** OEM requires a whole host of conditions but as a minimum, it requires:
  - Technology Maturity (demonstrated to Technology Readiness Level 7)
  - Manufacturing Maturity (to at least Manufacturing Readiness Level 6)
  - A supply chain that can deliver at volume, quality and cost,
  - A skills base to support all of the above.

- The problem exists because, in the UK, many of the New Technologies on the Lightweight Vehicle and Power Train Roadmap do not meet some or all of these requirements.

Lightweight Vehicle and Power Train Roadmap



3 Key Technology Challenges

- Cost effective migration of mature premium sector technologies.
- Adoption of new / alternative technologies from other areas / sectors.
- More revolutionary solutions developing “next generation” design tools integrating vehicle design and material optimisation.

Recommendations to turn the challenges into opportunities.

- **Technical Development: Required Collaborative R&D programmes (for volume application of known technology as well as new technology)**
  - **Joining Technology**
  - **Materials and Manufacturing Process Technologies**
  - **Material Characterisation**
  - **Recycling/Sustainability**
  - **Modelling & CAE**
  - **Coatings & Corrosion**

Recommendations to turn the challenges into opportunities.

- **Skills**
  - **Training and “up-skilling”** in new Lightweight materials is required not just for Product Development Engineers. Need to target all key business functions (Purchase, Quality, Manufacturing, etc) and at all levels of the supply chain. This is required for:
    - Automotive Composites & Advanced Plastics
    - New to Automotive Light Metals.
  - Training funding/support required to develop the workforce skills to encourage inward investment in **Advanced High Strength Steel** automotive component manufacturing.

Recommendations to turn the challenges into opportunities.

- **Infrastructure**
  - Encourage investment in development and **production capacity** in "**New To Automotive**" light metals. Specifically Magnesium, Titanium and Metal Matrix Composites.
    - Development capacity for these technologies could be realised through further investment in High Value Manufacturing Catapult.
    - Production capacity for these technologies should be investigated as an opportunity through the Automotive Council Supply Chain Group.
  - Encourage investment in **production capacity** in the UK for **Advanced High Strength Steel** automotive components.
    - These components today are sourced largely outside the UK.
    - These are in relatively small quantities today but the roadmap points to the need to significantly increase the HSS content small and medium size cars.
  - Limited **R&D facilities** in the UK for **Sheet Moulded Compound (SMC)**.
    - Currently OEMs undertake development work with T1 suppliers or the likes of Fraunhofer ICT outside of the UK.
  - Initial investment in facilities to support automotive R&D in composites is underway.
    - The on-going roadmap is likely to require further investment in development infrastructure to support the subsequent phases of R&D required to get to automotive volume and cost.
  - Next generation **Numerically Intensive Computing and Multi-Physics design optimisation** have been identified as a significant route to lower vehicle weights whilst maintaining vehicle performance.
    - There is an opportunity for the UK to lead in this area but investment is required in Collaborative R&D infrastructure to support.

Technology Strategy Board Competitions have already made a great start on some of the Technology Challenges and are starting to focus on the cost and Manufacturing maturity challenges.

- ***TSB IDP 6***
  - *Lightweight vehicle and powertrain structures*
    - *Projects focused on achieving significant vehicle mass reduction.*
    - *Be innovative beyond the current state of the art, cost-effective & scalable for mass production.*
    - *Take into consideration the life cycle analysis of the structure and overall environmental impact.*
- ***TSB IDP 8&9***
  - *Technology challenge 4 - lightweight vehicle and powertrain structures*
    - *We are looking for projects aimed at the development of lightweight vehicle and powertrain structures focused on achieving significant vehicle mass reduction.*
    - *For example, for the C/D class, the industry through the automotive council has identified that a weight reduction of at least 150kg is required by 2020 with a further reduction of 150kg by 2030.*
- ***TSB IDP 10***
  - *Technology Challenge 3 - lightweight vehicle and powertrain structures.*
    - *"Each project is expected to include a work package focused on a route to production and on taking manufacturing maturity past MRL 4 towards MRL 5 and 6 by the end of the project."*

Future Plan

- Future proposals to re-configure the Automotive Council Technology Group Workstreams into new topic areas provides opportunity to continue and expand on this work icluding:

  Considering Future Technology / R & D – could include working with EPSRC, new technologies, EU funding, collaboration with motorsport and workstream responsibility for the roadmaps.

  - Develop and maintain the Lightweight Vehicle & Power Train Roadmap.
  - Continue to identify required technology development /C R&D for new to Automotive LW materials and the “Radical” end of the roadmap.
  - Create stronger strategic alignment between the Roadmap and University based Research.

  Considering Manufacturing Technology – could include light weighting, carbon fibre and the battery scale up centre.

  - In particular for LWV & PTS, actively explore how the HVM Catapult can address the Manufacturing Maturity, R&D Infrastructure, Cost, Modelling/Simulation & Skills challenges/opportunities identified by this workstream.

- Production Capacity Opportunities
  - Work with the Automotive Council Supply Chain Group to identify strategies for increased investment in capacity for:
    - High Strength Steels, Sheet Moulded Compound, Carbon Composites and New To Automotive Metals.

Energy Storage & Energy Management Workstream Conclusions and Consensus Roadmap

September 2013

Don Newton

Group Technical Director

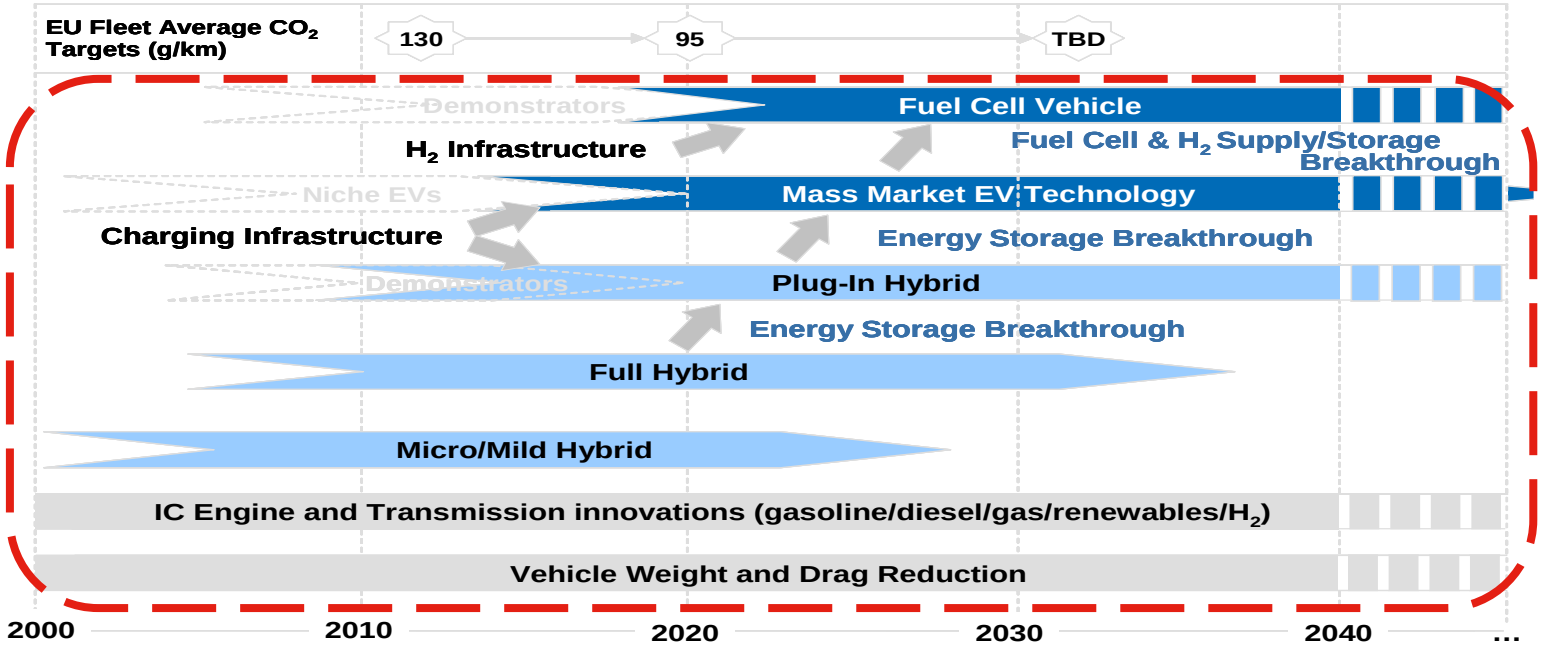
Johnson Matthey Battery Systems

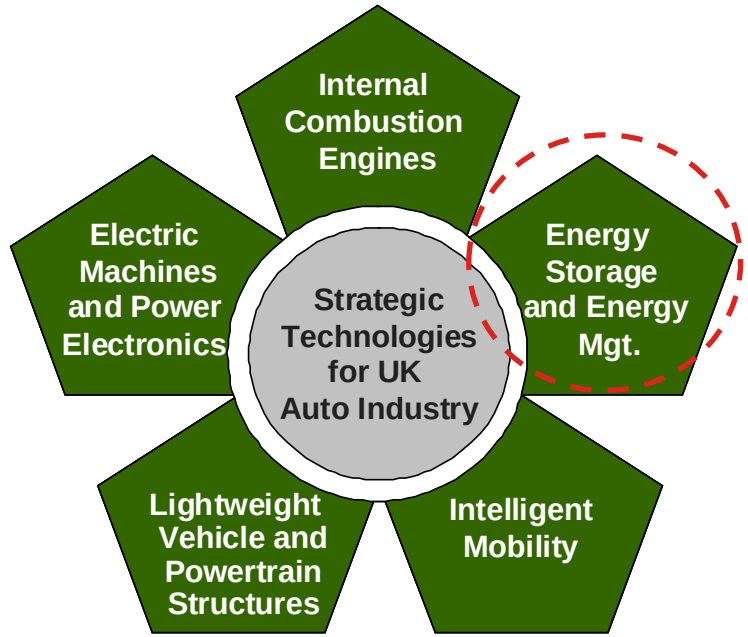
Low Carbon Vehicle Event 2013
Millbrook Proving Ground
The UK's Premier Low Carbon Vehicle (Technology Showcasing & Networking) Event

Contents

- Introduction & Background
- Team Members, Objectives
- Challenges & Opportunities
- Technology Options & Consensus Roadmap
- Key Messages, Recommendations & Future Plan

In the pursuit of Low Carbon Vehicles new market opportunities are emerging with respect of Energy storage and Energy Management





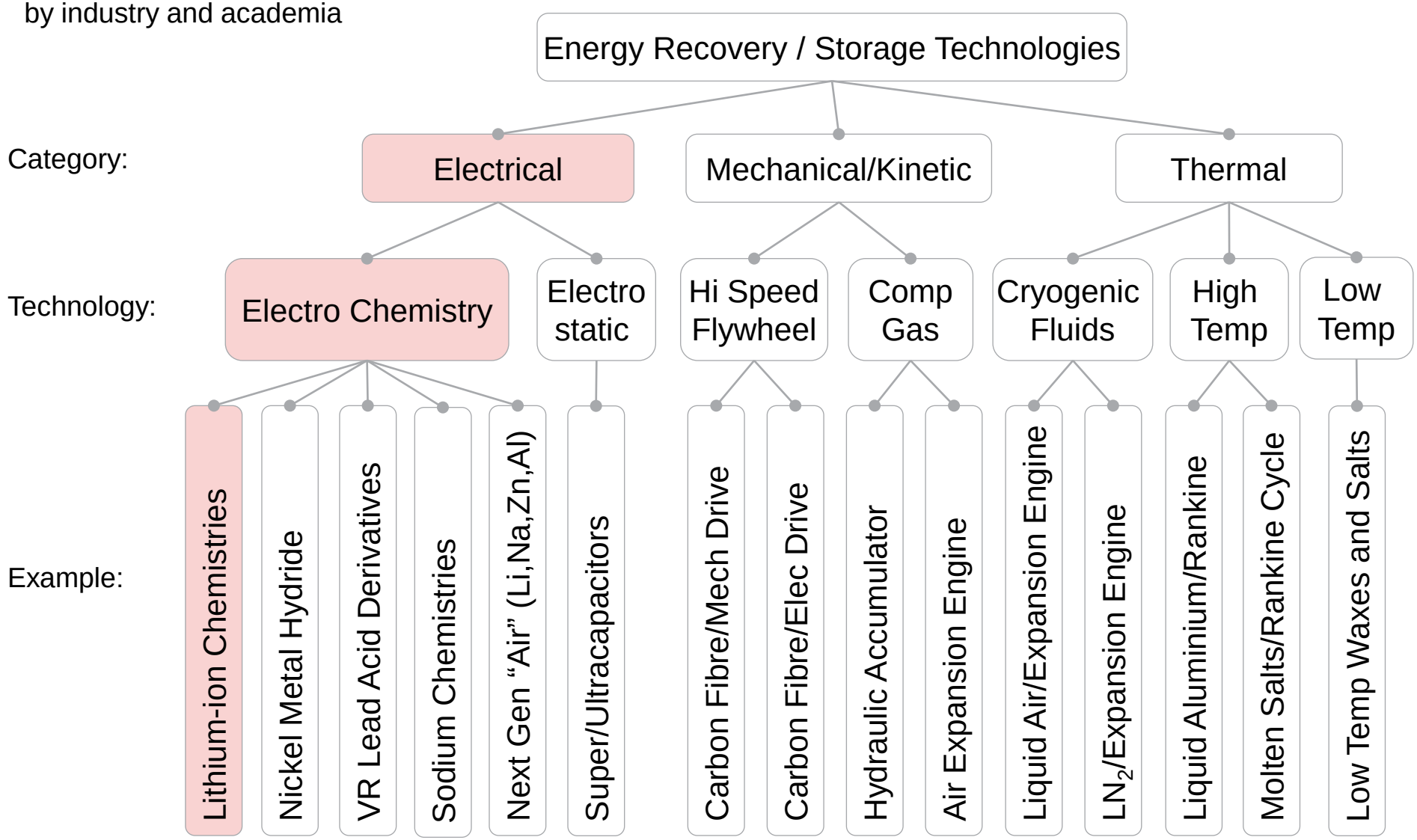
Energy Management is key to supporting all threads of the roadmap and provides many opportunities for UK supply chain

- A wide variety of alternative technology solutions are emerging from UK supply chain
- Electro-chemical technology a key enabler for mass market take up of EV's and supporting Hybrid market growth
  - Regional centres set up in competing national markets
  - Lack of a UK National centre to support innovation
- Increasing interest in alternative fuel vectors could create new supply chain opportunities

Vehicle Energy Recovery & Storage overview

automotive council UK

A wide range of technologies are being studied by industry and academia



Workstream members and objectives

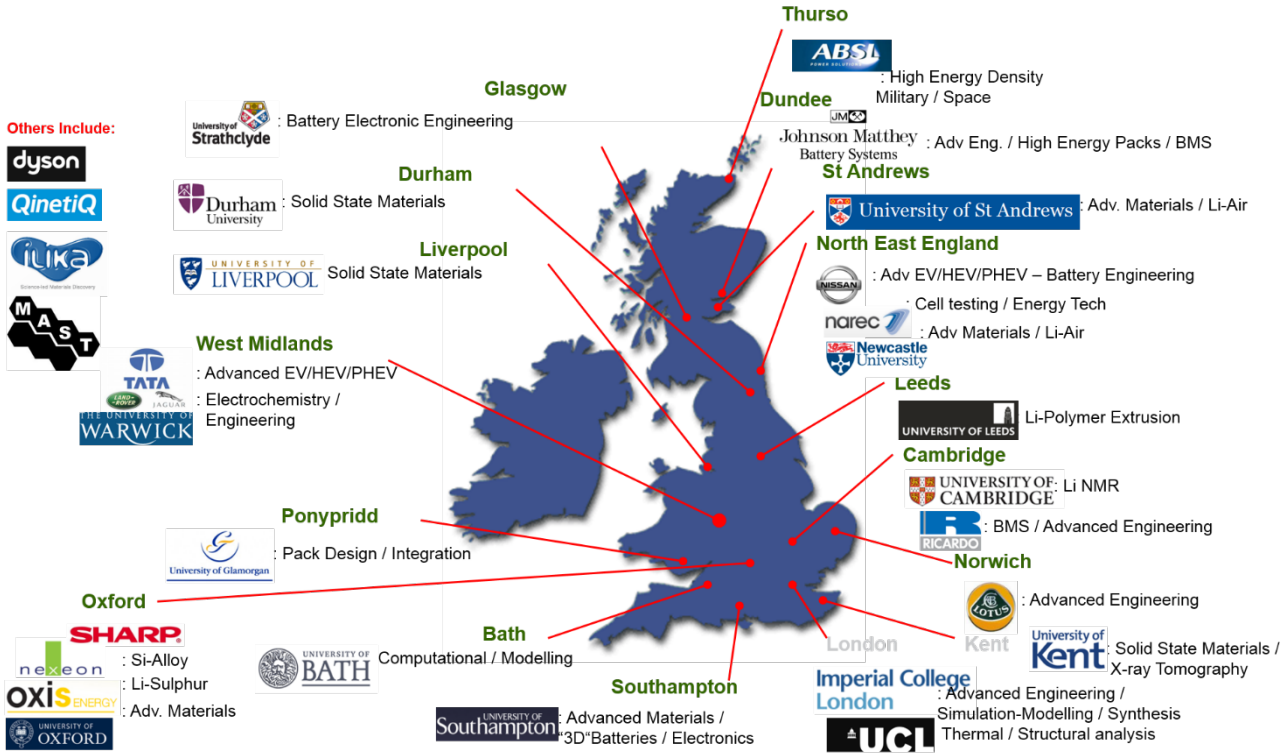
- **Core team:- Prof. Peter Bruce (University of St. Andrews), Dr. Peter Miller (Ricardo), Dr. Allan Paterson (Johnson Matthey Battery Systems – Pilot), Dr. Valerie Self (TATA), Steve Boyes (Nexeon - Anode Chemistry).**
- **Extended Industrial Membership**
  - **Johnson Matthey :** Advanced Materials.
  - **Morgan Crucible** – Graphite supplier.
  - **Ilika Technologies** – Fast Throughput Materials Screening
  - **Enersys :** High performance materials and niche cell production .
  - **Mast Carbon :** Anode materials.
  - **Oxis Energy :** Advanced materials developer.
  - **Qinetiq :** Advanced materials and cells.
  - **MW Group** – Lithium Ion facilities provider.
  - .
  - **Extended Academic Support :**
    - **Oxford : Prof. Patrick Grant**
    - **Imperial : Prof. Nigel Brandon**
    - **Warwick : Warwick Manufacturing Group**

Objectives

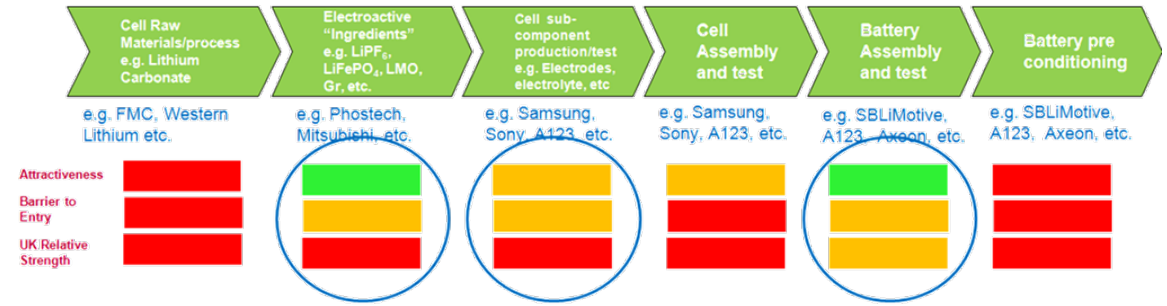
- **Benchmark International electro-chemical research**
- **Identify opportunities for UK research of “next generation“ technologies**
- **Review UK development capability and propose “gap bridging” solutions**

Benchmarking

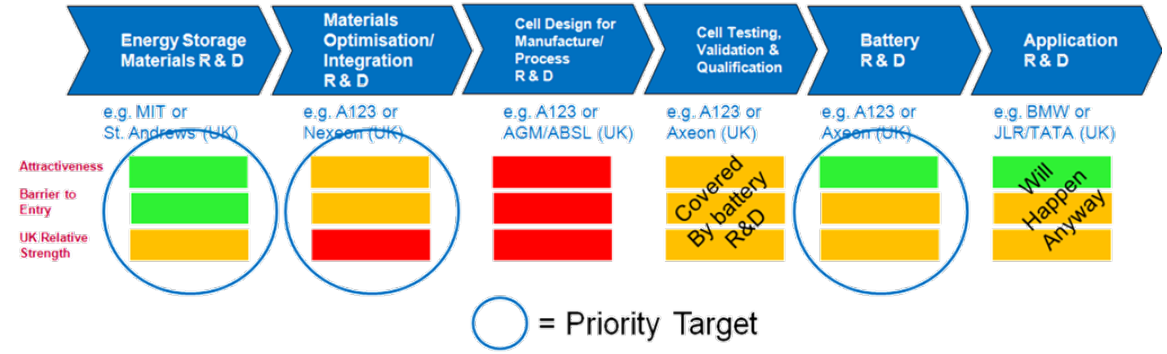
automotive council



Operations Value Chain



R & D Value Chain



❑ **Argonne National Laboratory (USA)**

❑ **Fraunhofer ISIT (Germany)**

Conclusions from Benchmarking

- The technical barriers to entry for developing ‘Next Generation’ electro-chemistries (e.g. improved energy density) are relatively low at ‘gram’ scale i.e. this can be achieved in a University laboratory.
- The barriers to entry in moving from ‘gram’ scale to ‘kilogram’ scale are much higher due to:-
  - Increase in scale has a direct impact on the electrochemical properties of the materials i.e. more complex than making “more of the same” – the scale up process is a science in itself.
  - Capital required to move from ‘gram’ to ‘kilogram’ scale is around £5M ($7.5M) and outside of the budget scope of Universities.
- UK University grant funding mechanisms do not currently incentivise the research required to move from grams to kilograms – this is classed as outside of basic research
  - Currently only private companies have the capital equipment , however, they are focussed on their own unique chemistries
  - Universities are not incentivised to move to kilogram level - promising chemistries can “stall” in the pure research phase
- Governments in Germany, France and the USA have invested in strategic materials scale-up and cell pilot-line facilities within their “National Labs”
  - These facilities are “open” and allow promising chemistries to be fast tracked to kilogram level and resultant know how and IP remains within the national competence
  - The facility acts as a focal point and catalyst for aligning academic research with industry needs and also as flagship to crystallise the strategy and direction of a national competence network linking academia, industry and the state
  - The facility enables vehicle OEM’s, battery suppliers and materials companies to accelerate the higher levels of validation and maintain companies at the leading edge of technology

Strong Academic knowledge
Multiple small scale developments
No large scale cell manufacture
No National labs or scale up facilities
Value chain low connectivity

“Open” Materials Scale Up & Cell Pilot Line

- http://www2.warwick.ac.uk/fac/sci/wmg/research/hvmcatapult/research/batterycharacterisationvideo/
- The facility will be ideally positioned to select and support the spin out of companies as new and potentially winning technologies and processes are identified
- The facility will provide a focal point for linking complementary academic research groups e.g. Oxford University's research into advanced materials manufacturing technology
- The technologies developed will have applicability in non Automotive applications such as grid storage, defence, aerospace, rail, marine and other consumer products
- It is proposed that the facility focuses on electrochemical energy storage in the short to medium term in response to the benchmark data from Germany, France and the US, however, the facility can expand into other technologies e.g. Supercap’s, Ultracap’s, flywheels etc once the critical mass of the facility has been established

05 September 2012 11:45 Skip to downloads »

Department for Business, Innovation and Skills

BIS | Department for Business Innovation & Skills

Government has pledged further support for the automotive industry today (5 September) by announcing the creation of a new ‘UK Energy Storage R&D Centre’ for the advancement of electric and hybrid vehicle batteries.

Co-funded by Government (£9 million) and industry (£4 million), the £13 million centre will be created to capitalise on the growing electric and hybrid vehicle battery market, which has been estimated to be worth £250 million for the UK by 2020.

The centre is the latest move by Government to secure future growth opportunities for the UK’s automotive sector, building on its £400m commitment over the next four years to supporting electric cars and other ultra-low carbon vehicles.

Business Minister Michael Fallon said:

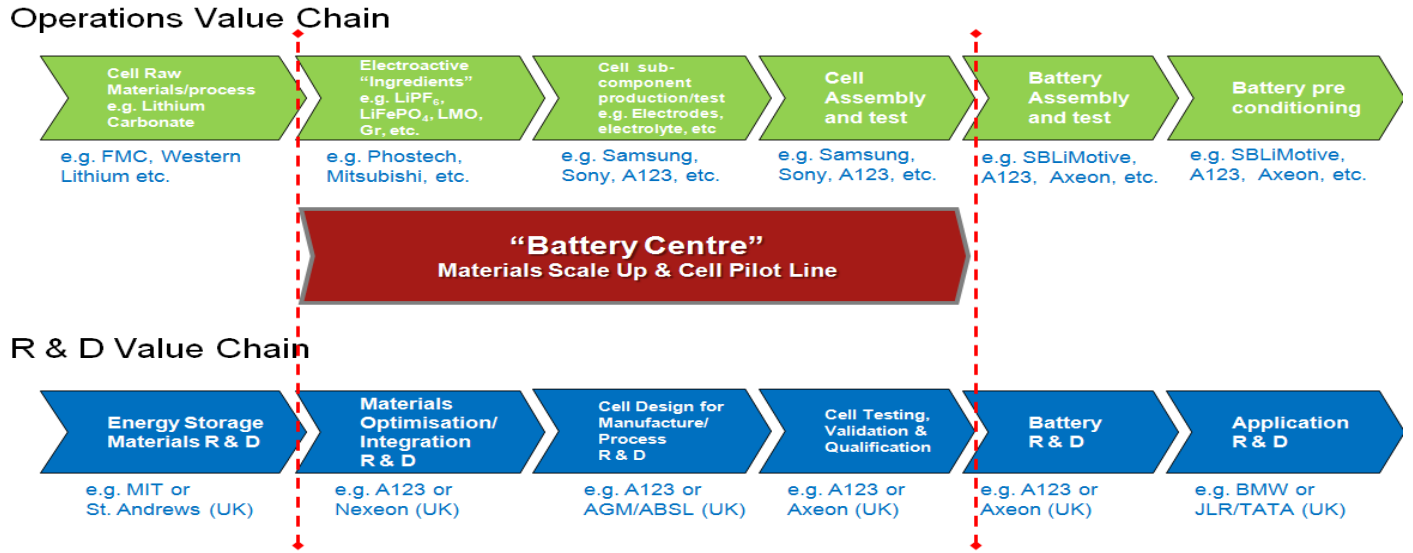
“I’m pleased to announce this joint Government and industry project to develop an energy storage R&D centre at the University of Warwick. It will put the UK in a much stronger, competitive position to capitalise on a growing worldwide market for low carbon vehicles, alongside other world leaders in the field including the United States, Japan and Germany.

“This £13 million facility will help accelerate the development of battery cells for the next generation of vehicles, is a vital investment in the future of the automotive sector. It complements over £5.5 billion that global vehicle manufacturers have committed to UK projects in the last 18 months.”

The Automotive Council Technology Group worked alongside Government to secure the funding for the new R&D centre.

Jerry Hardcastle, Chairman of the Group and Global Chief Marketability Engineer at Nissan Motor Company, said:

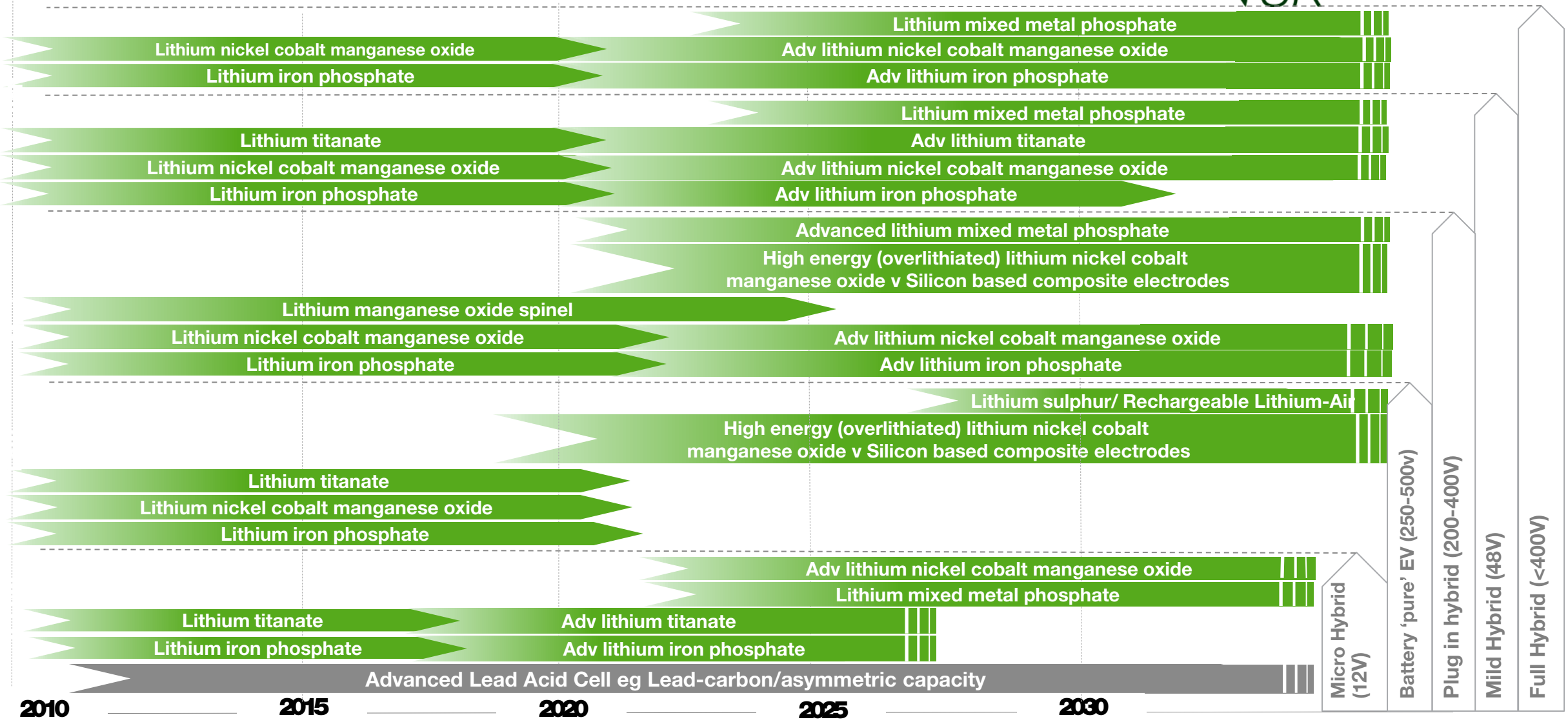
“The announcement of the UK Energy Storage R&D Centre is great news and is further evidence that collaboration between the Government, industry and academic institutions in the UK continues to create opportunities to increase innovation and further develop the supply chain in the automotive industry.”



Duration / Status : 40months – Procurement underway **on Track for Q1 2014 Launch**

Passenger Car LCV Energy Storage Echem Tech Roadmap

automotive council UK



Source :Automotive Council Technology Group 2013

Next Steps

- Complete installation and commissioning of pilot line
- Promote use of facility to develop new chemistrys’ / solutions
- Create pipeline of promising future formulations
- Maintain watch on international development and competitive landscapes
- Ensure academic engagement and use of the facility
- Develop and share learning from the facility and developments

Automotive Council Technology Work Groups

Conclusions & Consensus Roadmaps

September 2013

Jerry Hardcastle

Technology Group Chairman

Global Chief Marketability Engineer & Technical Director Global Motorsports

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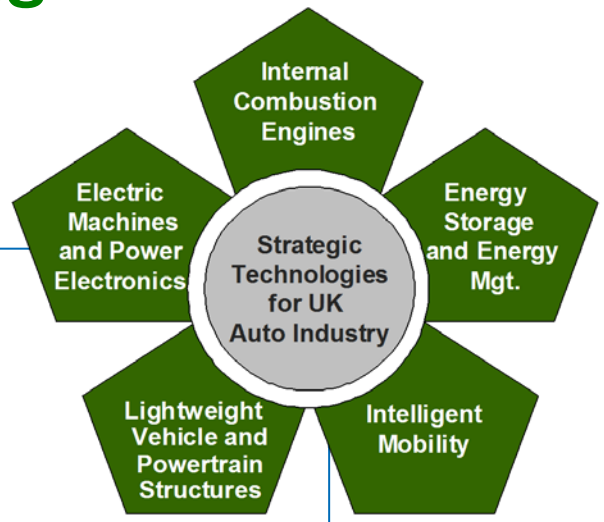
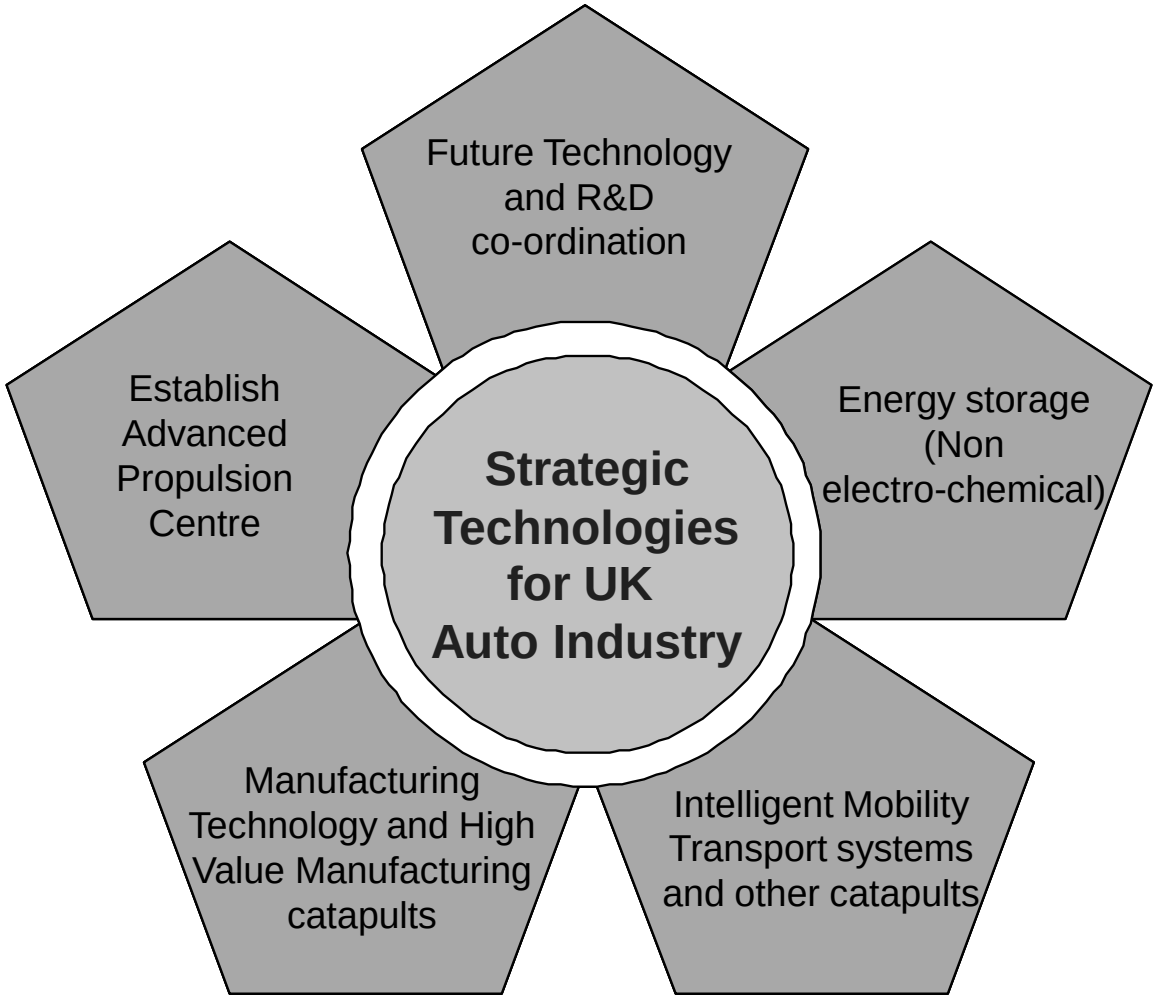
Next steps



- **Formally publish roadmaps and workstream reports**
- **Promote aligned initiatives supporting the roadmaps through early stage, collaborative & pre-industrialisation research**
- **Establish new work groups to develop roadmaps for other vectors within existing workstreams**
- **Review alternative technology workstreams**

Our journey continues



- **Ensure alignment of current and future activities with the Automotive Industrial Strategy**
- **Integration of activities (as appropriate) with the Advanced Propulsion Centre**
- **New “theme” workstreams being reviewed, opportunity for new volunteers to join the working groups**
- **Organisational review**

Thank you for listening

Welcome back the presenters to the stage

Any Questions.