



Decarbonisation of Transport 'The challenge for technology'

Andy Eastlake

Low Carbon Vehicle Partnership – UK

March 2014

LowCVP – The Low Carbon Vehicle Partnership

The LowCVP is an independent, not-for profit stakeholder partnership funded mainly through government grants and member contributions.

The LowCVP is the only organisation in the UK – or Europe – which brings stakeholders together to facilitate the development of better policy and accelerate the shift to low carbon vehicles and fuels.

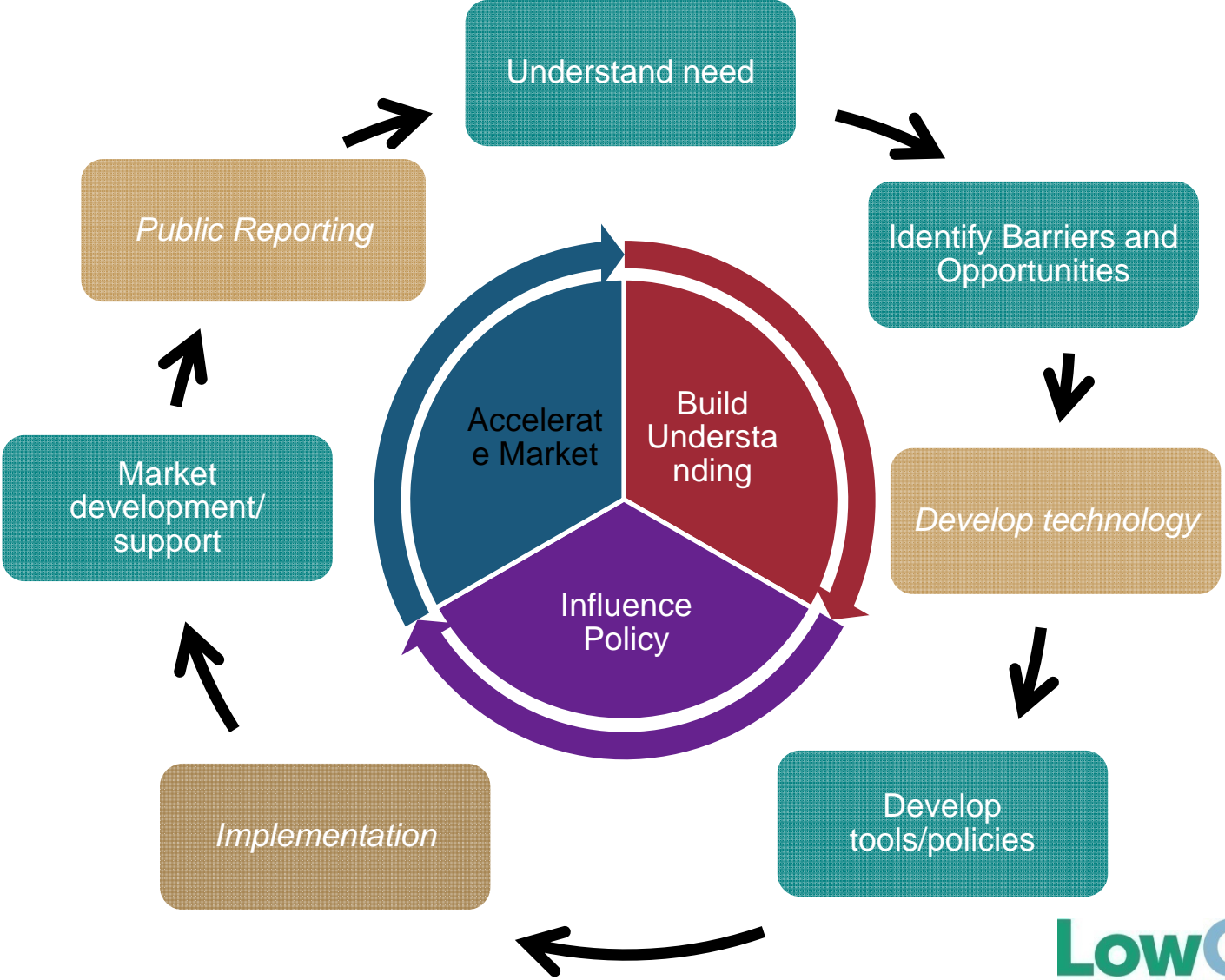
“The LowCVP is a unique organisation which is effective in bringing stakeholders with widely differing perspectives together.”

Prof Neville Jackson, Chief Technology and Innovation Officer, Ricardo UK Ltd
and Chair of the LowCVP Board

LowCVP – Vision, Mission and Aims

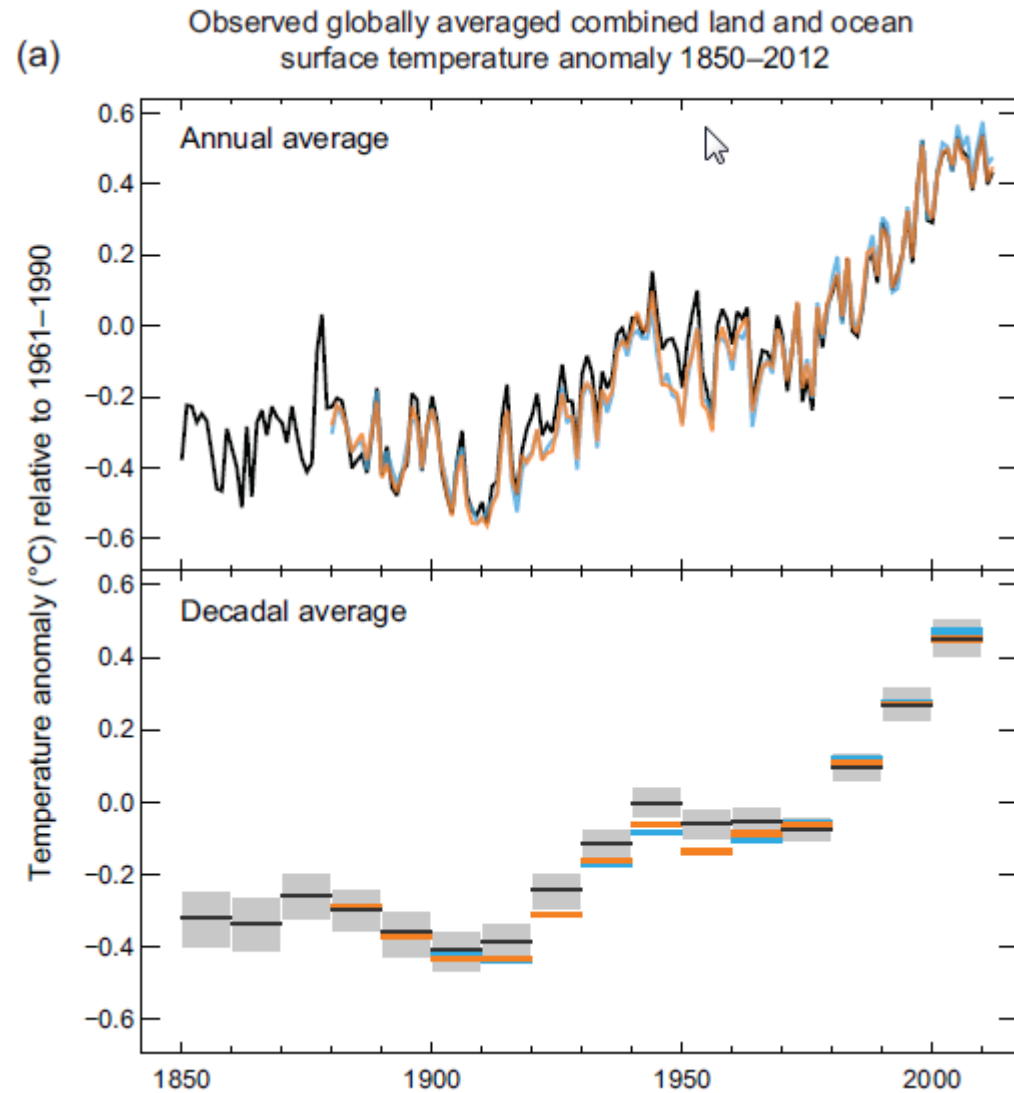
- Our aspiration is for “**Sustainable and efficient global mobility with zero life cycle impact**”
- We will work towards this by “**Accelerating a sustainable shift to low carbon vehicles and fuels and stimulating opportunities for UK businesses**”
- Through:
 - **Connecting** stakeholders to build understanding and consensus regarding the optimal pathways to low carbon road transport.
 - **Collaborating** on initiatives that develop the market for low carbon vehicles and fuels.
 - **Influencing** Government and other decision makers on future policy directions and optimal policy mechanisms.

LowCVP activity cycle



Why Decarbonise

- Rising Temperature
- Extreme weather
- Sea level rise
- Ice melt



It's the Law!

UK signed The Climate Change act in 2008

Sets binding targets for 2050


Creates alignment across departments

Forces all government departments to publish plans regularly

Creates an independent monitoring body The CCC (Committee on Climate Change)

Transcends political changes of government terms

A series of “Carbon Budgets” for 5 yr objectives



Climate Change Act 2008

CHAPTER 27

CONTENTS

PART 1

CARBON TARGET AND BUDGETING

The target for 2050

- 1 The target for 2050
- 2 Amendment of 2050 target or baseline year
- 3 Consultation on order amending 2050 target or baseline year

Carbon budgeting

- 4 Carbon budgets
- 5 Level of carbon budgets
- 6 Amendment of target percentages
- 7 Consultation on order setting or amending target percentages
- 8 Setting of carbon budgets for budgetary periods
- 9 Consultation on carbon budgets
- 10 Matters to be taken into account in connection with carbon budgets

Limit on use of carbon units

- 11 Limit on use of carbon units

Indicative annual ranges

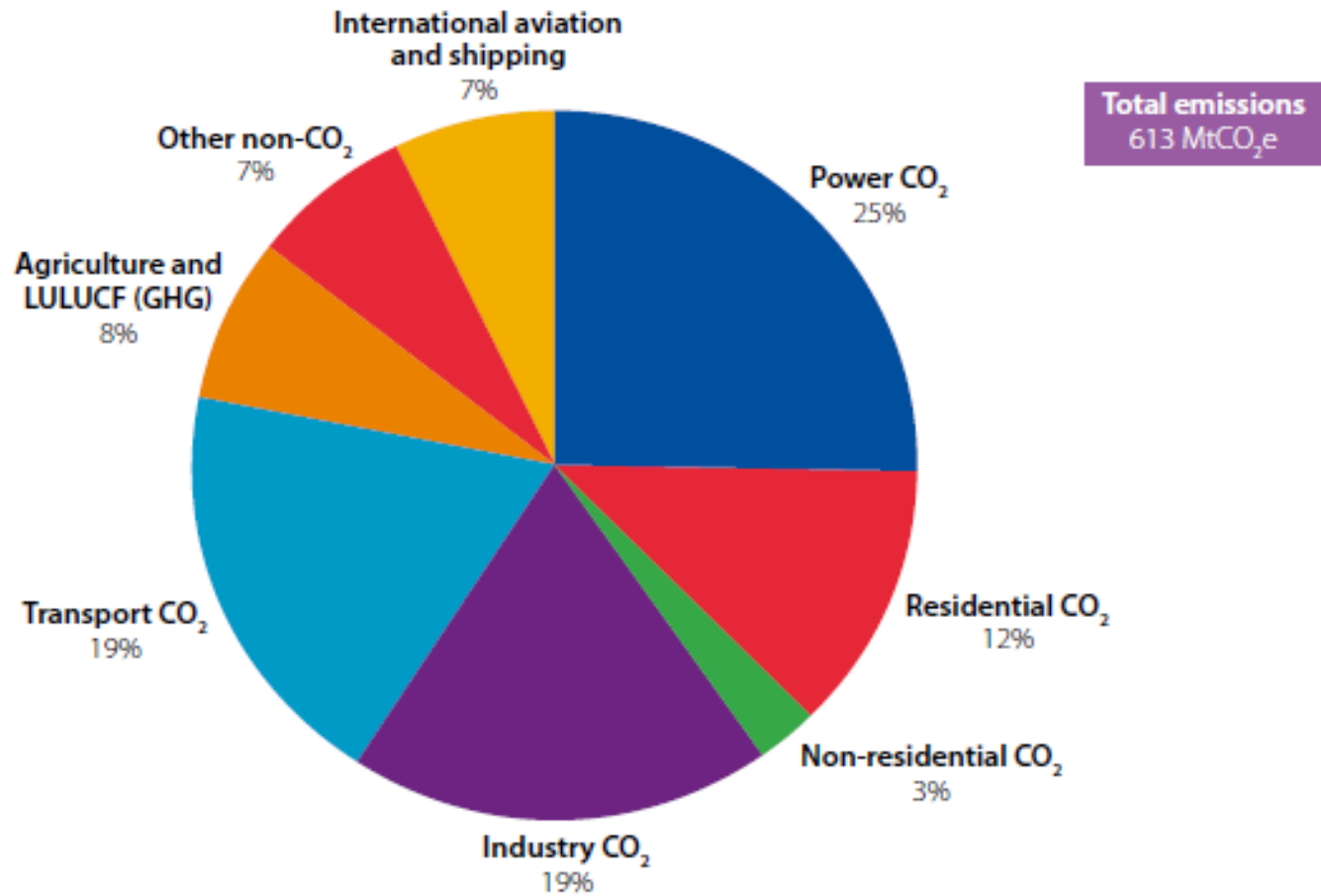
- 12 Duty to provide indicative annual ranges for net UK carbon account

Proposals and policies for meeting carbon budgets

- 13 Duty to prepare proposals and policies for meeting carbon budgets
- 14 Duty to report on proposals and policies for meeting carbon budgets
- 15 Duty to have regard to need for UK domestic action on climate change

What is causing the problem?

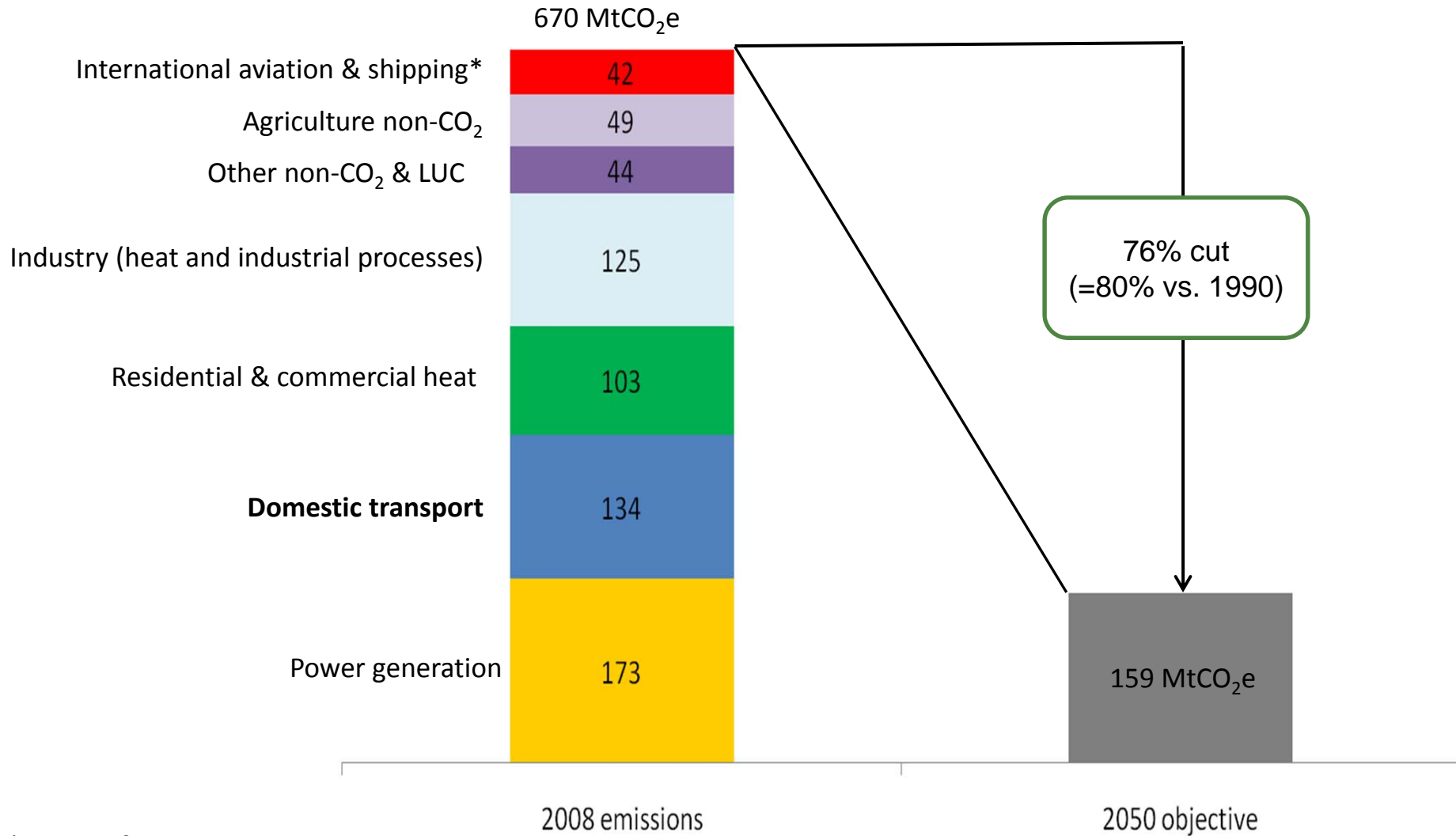
Figure 1.1: UK greenhouse gas emissions in 2012



Source: DECC (2013) Provisional emissions estimates; NAEI (2013) Final emissions estimates.
Notes: International aviation and shipping are currently not included in carbon budgets.

The 2050 target for UK is very challenging

(source CCC)

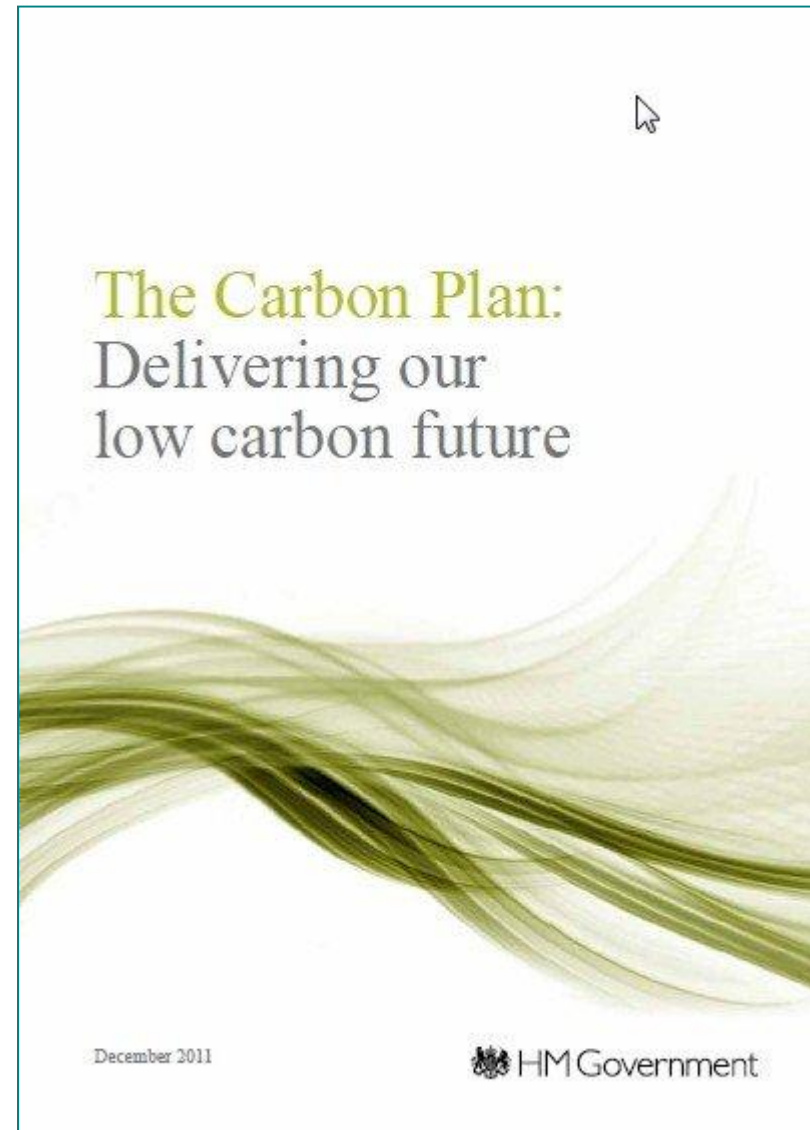


* bunker fuels basis

The government strategy

Identifying the range of energy pathways required to deliver the Government Carbon plan targets

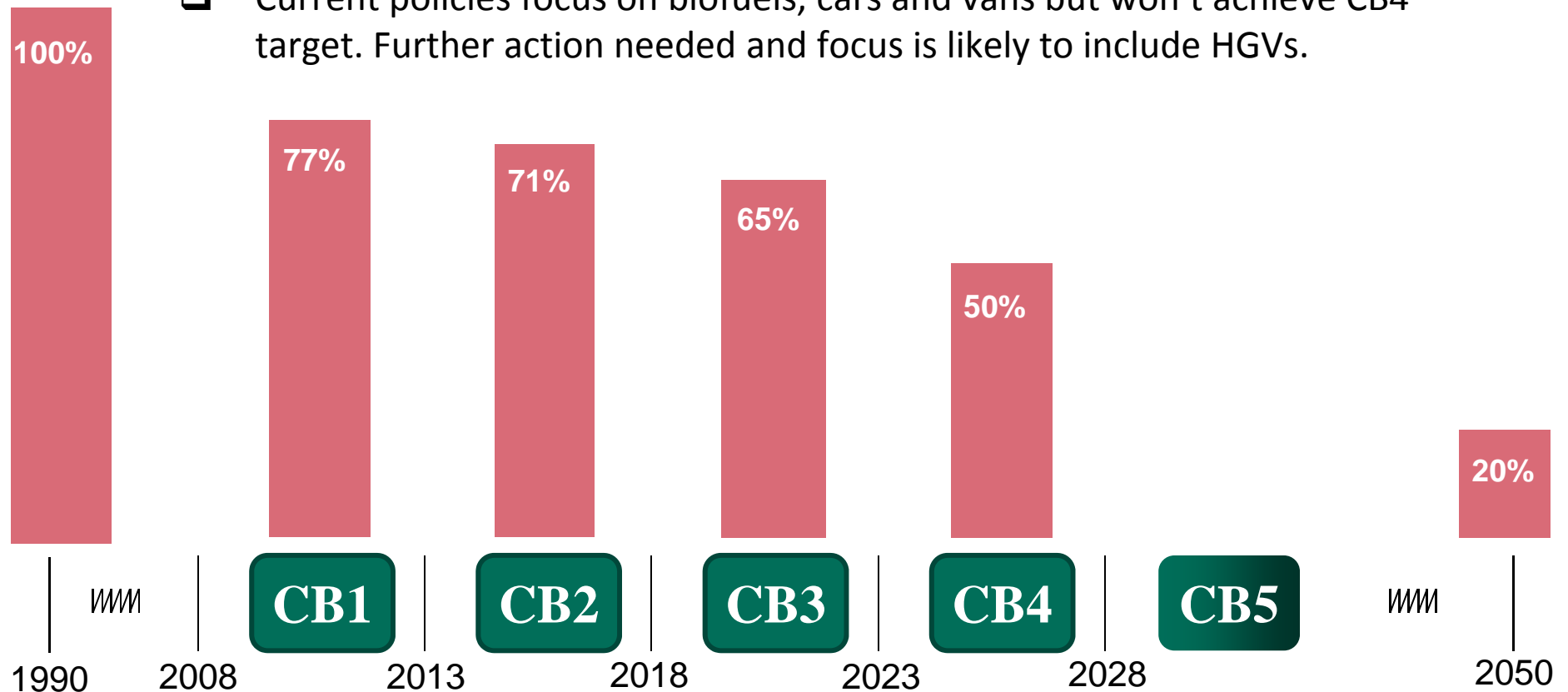
Review the existing data and fill in the gaps for other energy systems



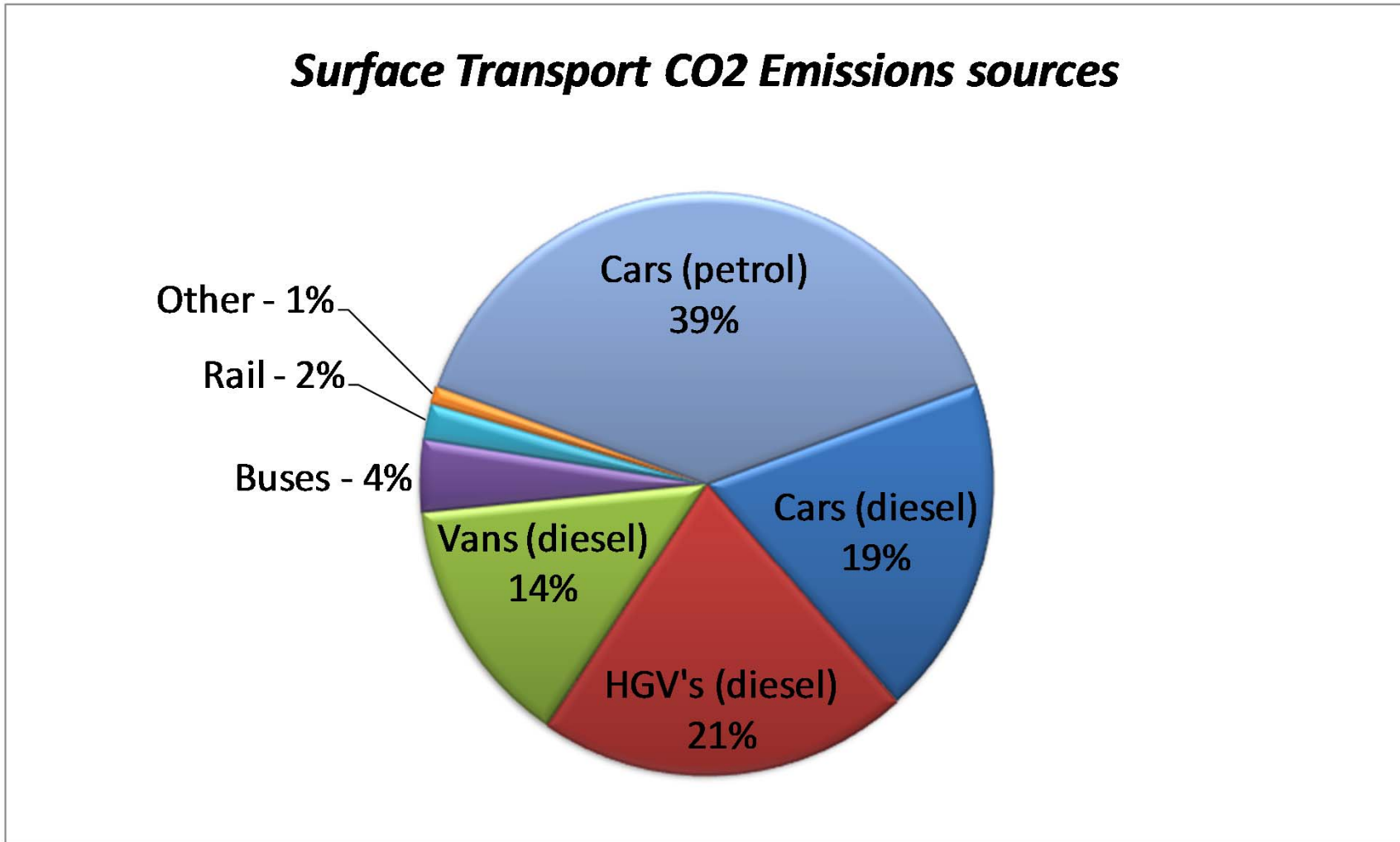
UK is committed to reducing GHG emissions by 80% by 2050 compared to 1990 through a series of “carbon budgets”

The overall goal:

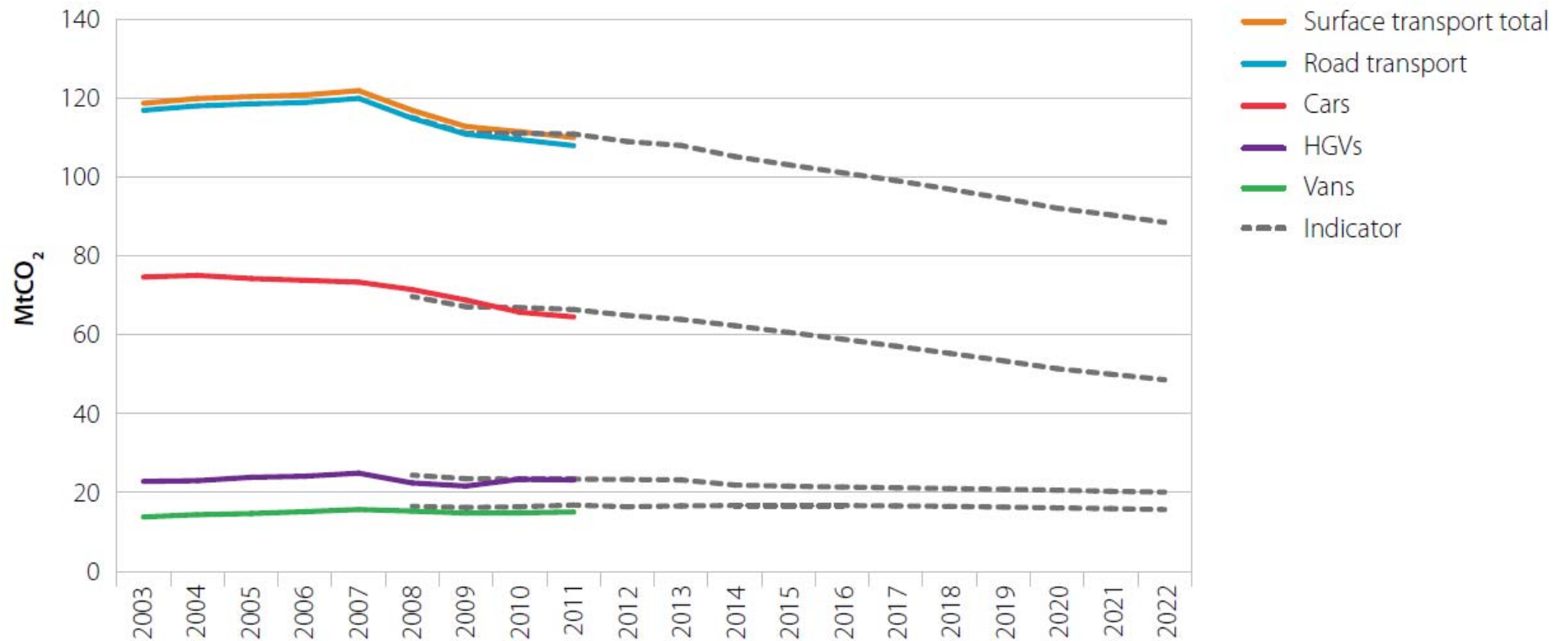
- ❑ 80% GHG reduction below 1990 levels by 2050
- ❑ Carbon budgets set interim targets
- ❑ Surface transport will need to be ‘near zero’ GHG by 2050
- ❑ Current policies focus on biofuels, cars and vans but won’t achieve CB4 target. Further action needed and focus is likely to include HGVs.



Petrol and diesel currently account for the vast majority of surface transport emissions (99.7%).

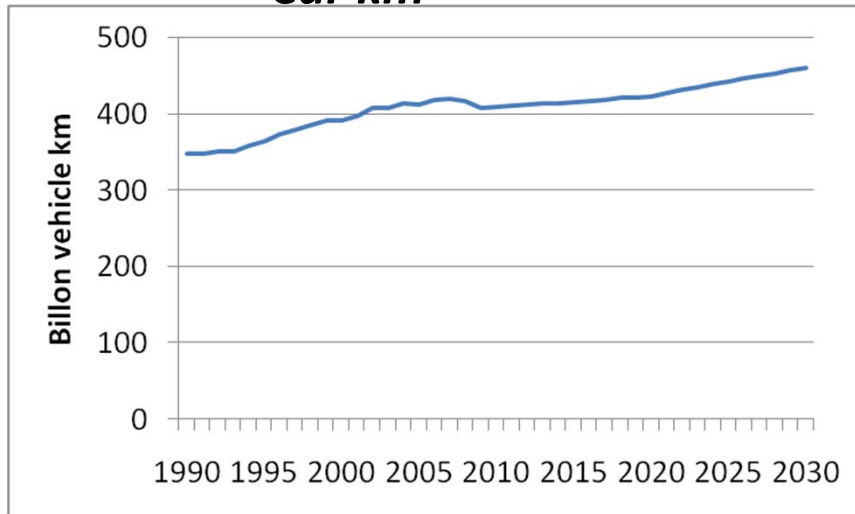


Surface transport emissions fell by 1.3% in 2011. (source ccc)

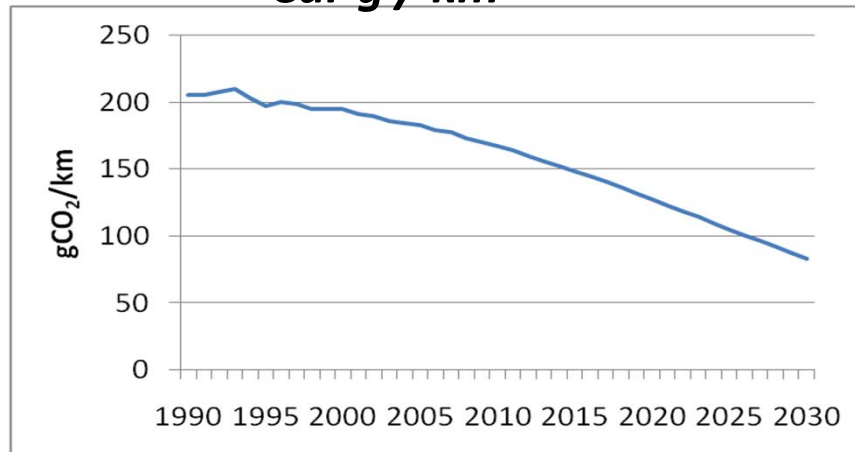


Transport: Emissions reduction will come from reducing g/km, while km likely to increase (Source CCC)

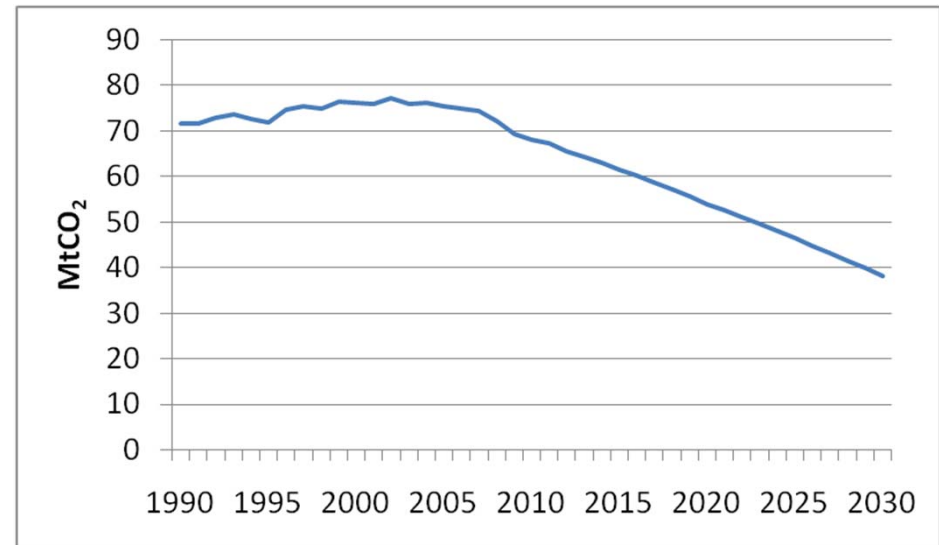
Car km



Car g / km



Car emissions

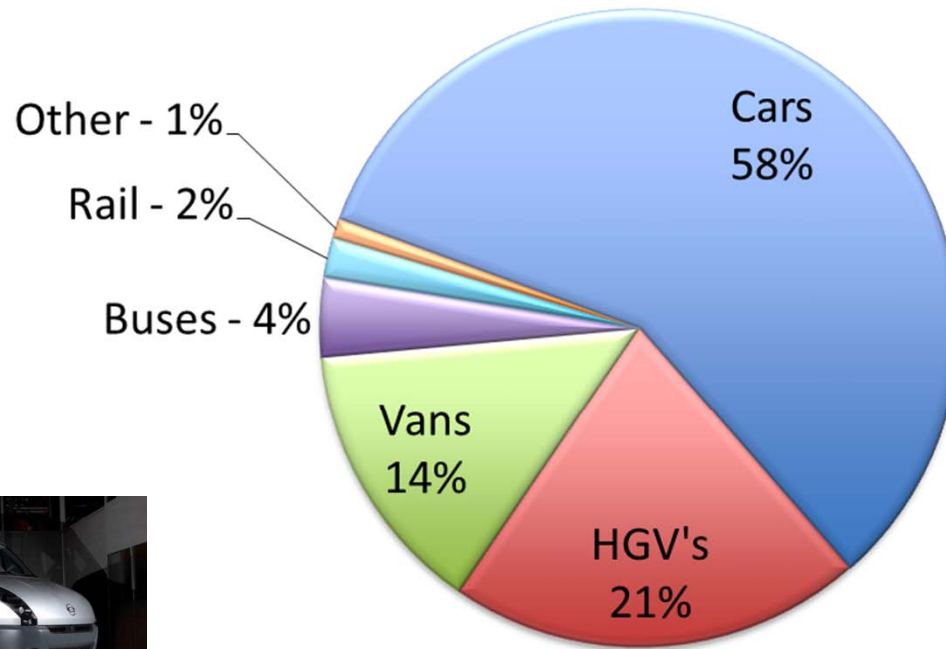


Vans: 17% emissions reduction to 2030

HGVs: 33% emissions reduction to 2030

A wide range of innovative vehicle technology options to reduce carbon are emerging on the market

Core progress made through improvements in vehicle efficiency and with low blend Biofuels

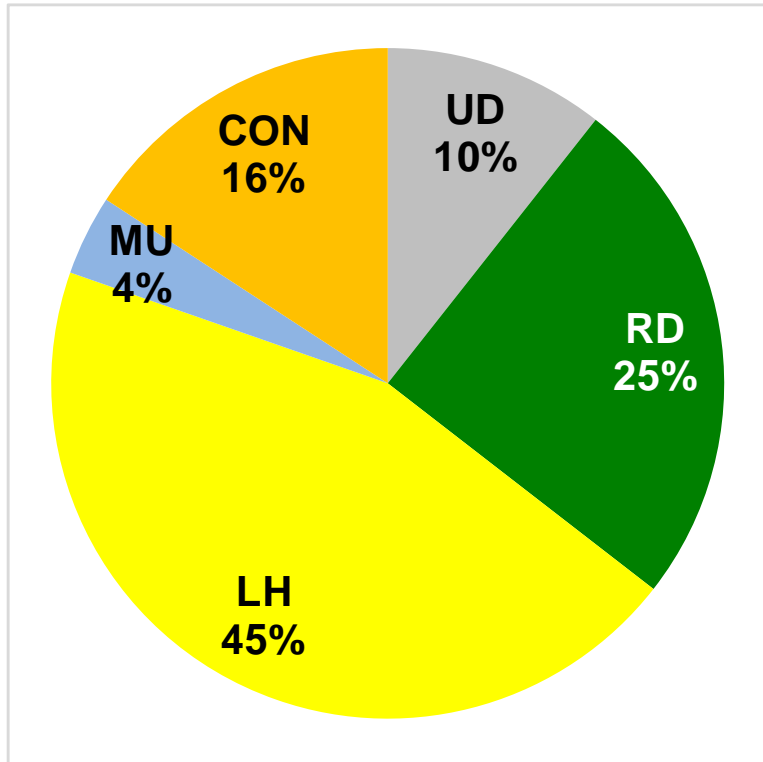


Decarbonising Road Freight – the opportunities

- Research on behalf of DfT
- Joint report published 3rd Dec '12
- LowCVP/Transport KTN/SMMT
- Supported by Industry bodies
 - CiLT
 - FTA
 - RHA



Where does the HGV CO₂ come from



Ranking of duty cycles by CO₂ emissions share:

- 1. LH Long haul (44-46 %)**
- 2. RD Regional Delivery (24-25 %)**
- 3. CON Construction (15-16 %)**
- 4. UD Urban Delivery (10-12 %)**
- 5. MU Municipal Utility (4 %)**

The ranges indicate the variation due to low, central and high distance estimates.

70% of fuel is used in Long Haul and Regional Delivery operation in Larger Trucks

Recommended technologies & fuels

| | Technology / fuel | Applicable duty cycles | Total UK HGV WTW CO ₂ e saving potential* | Additional considerations |
|---|---|---|--|--|
| 1 | Dedicated natural gas engines | All | 5-16% (methane) 61-65% (biomethane) | Significant particulate emission & noise reduction benefits. CO ₂ reduction benefit substantially greater when running on biomethane. |
| 2 | Dual fuel engines | Long haul, regional delivery and construction | 13% (methane) 33% (biomethane) | Some particulate emissions & noise reduction benefits when running on gas. Payback and CO ₂ savings very dependent on gas substitution rates (higher for higher speed duty cycles). CO ₂ reduction benefit substantially greater when running on biomethane. |
| 3 | Aerodynamic improvements | Long haul, regional delivery and construction | 5-6% | Benefits dependent on correct fitting / adjustment / average duty cycle speeds. Does not suit some body types / operations. |
| 4 | Pure electric vehicles | Urban delivery | 5% | Highest local air quality and noise reduction benefits. Lifecycle impacts of batteries need to be considered. Currently maximum available GVW is 12 tonnes. |
| 5 | Hybrid electric / hydraulic hybrid / flywheel hybrid vehicles | Urban delivery and municipal utility | 3-4% | Air quality and noise reduction benefits particularly if able to run in electric only mode. Lifecycle impacts of batteries need to be considered. Flywheel hybrids are not yet commercially available, but are expected to offer a lighter weight and possibly lower cost alternative to battery-electric hybrids. |
| 6 | Low rolling resistance tyres / single wide tyres | All | 1-5% | Lower rolling resistance tyres are available for all duty cycles. May have slightly shorter lifespan than standard tyres but CO ₂ savings expected to outweigh any negative environmental impact. |

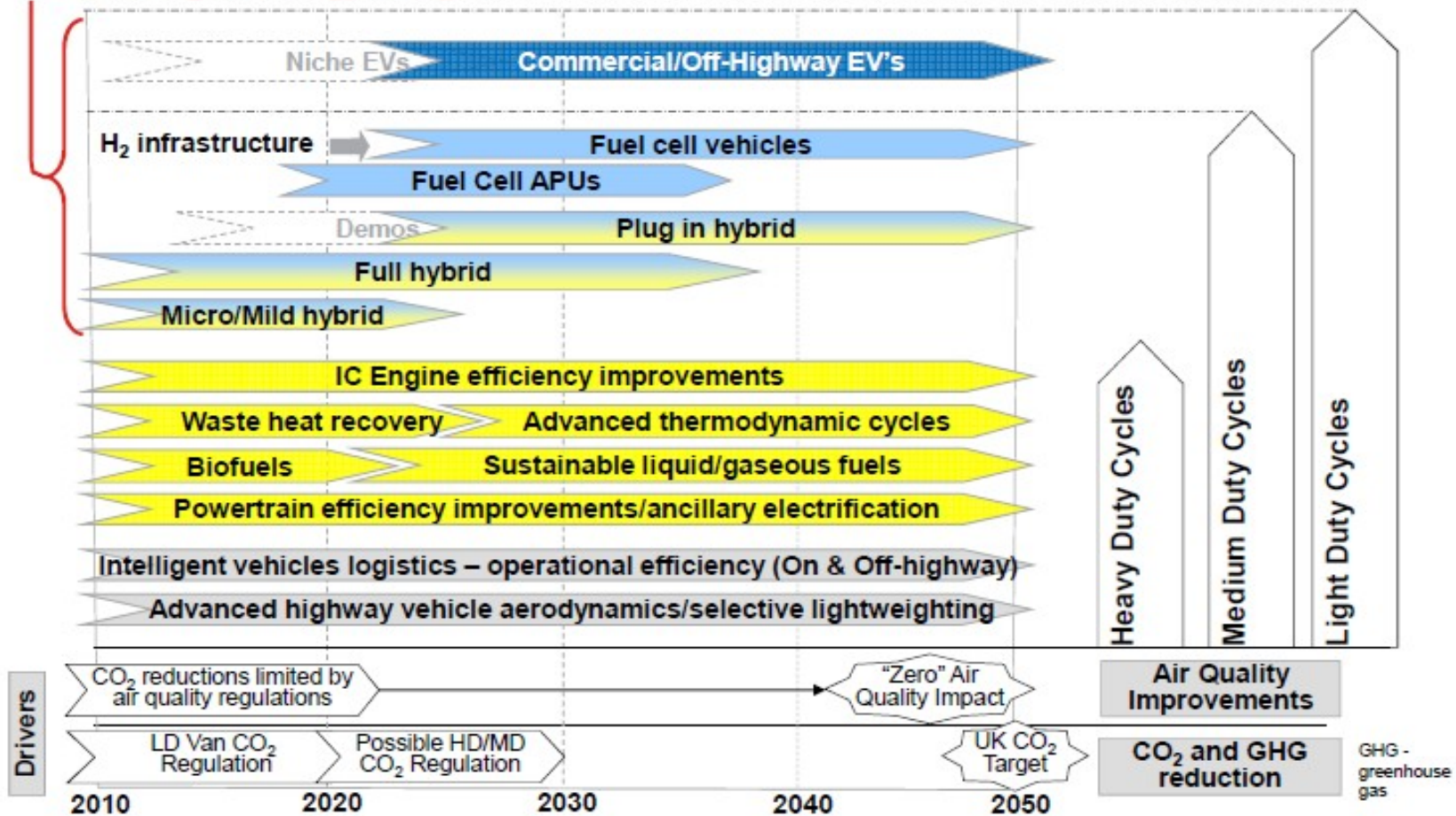
*The overall % saving of total UK HGV CO₂ emissions if technology/fuel applied to all relevant vehicles/duty cycles.

Road Freight road map

Low carbon Commercial Vehicle & Off-highway roadmap has parallel technology streams depending on duty cycle



Breakthrough in energy storage

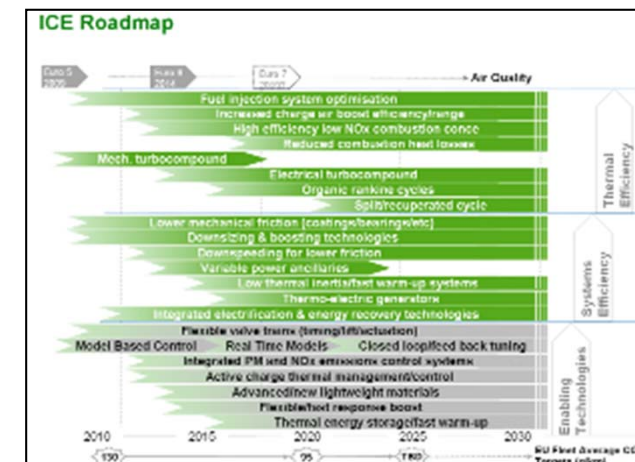
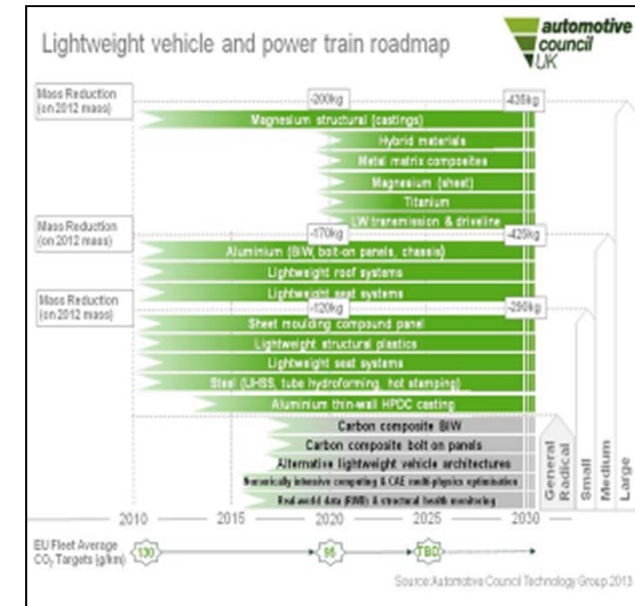
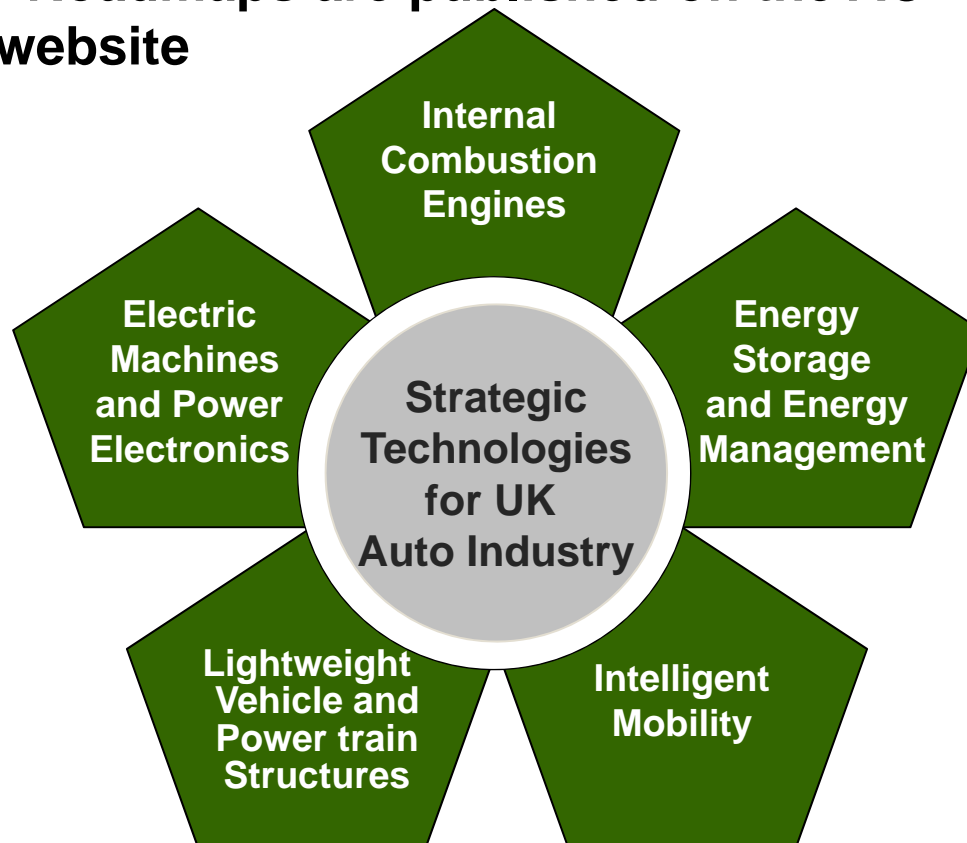


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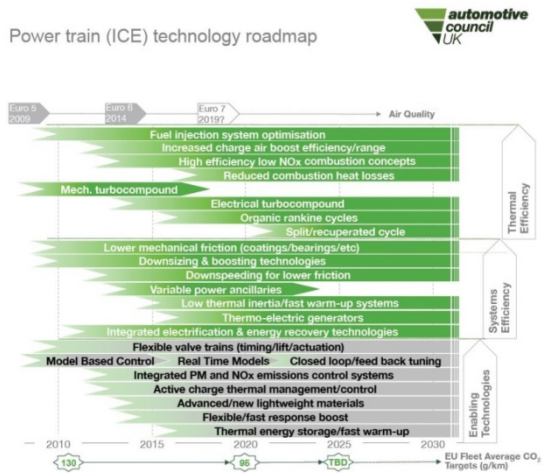
Technology Roadmaps

- Strategic Technology Roadmaps have been developed, were approved by Automotive Council and announced at LCV 2013
- Roadmaps are published on the AC website

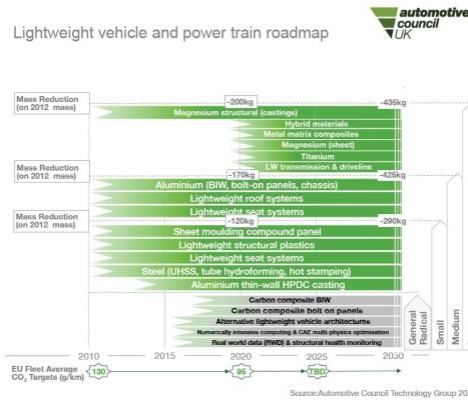


Range of roadmaps for technology areas

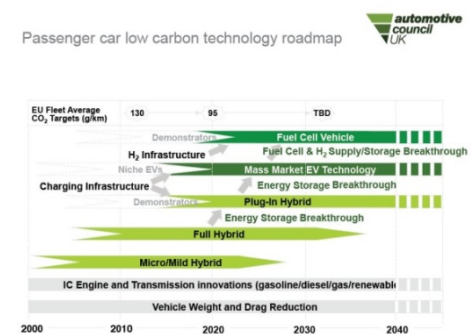
Power train (ICE) technology roadmap



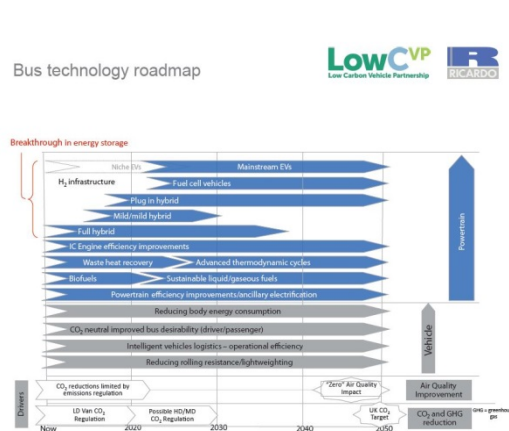
Lightweight vehicle and power train roadmap



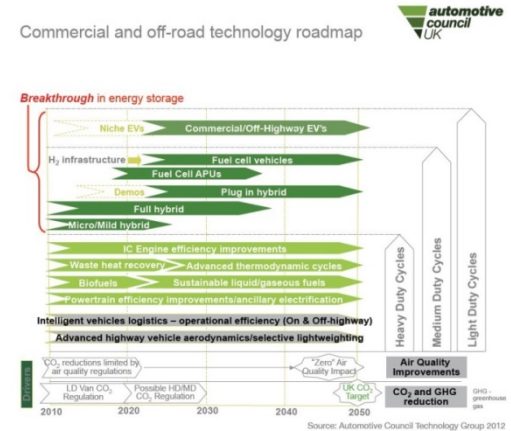
Passenger car low carbon technology roadmap



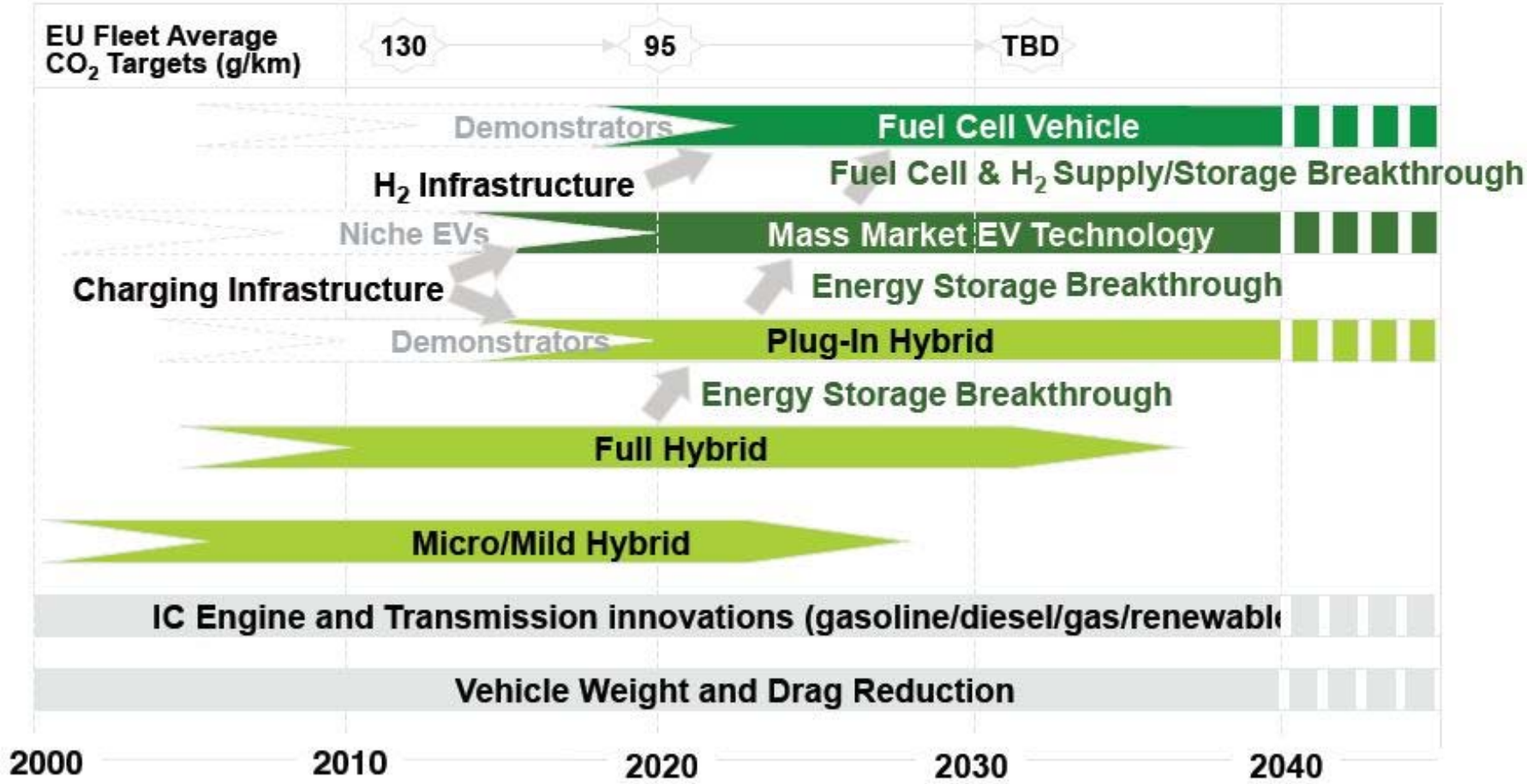
Bus technology roadmap



Commercial and off-road technology roadmap



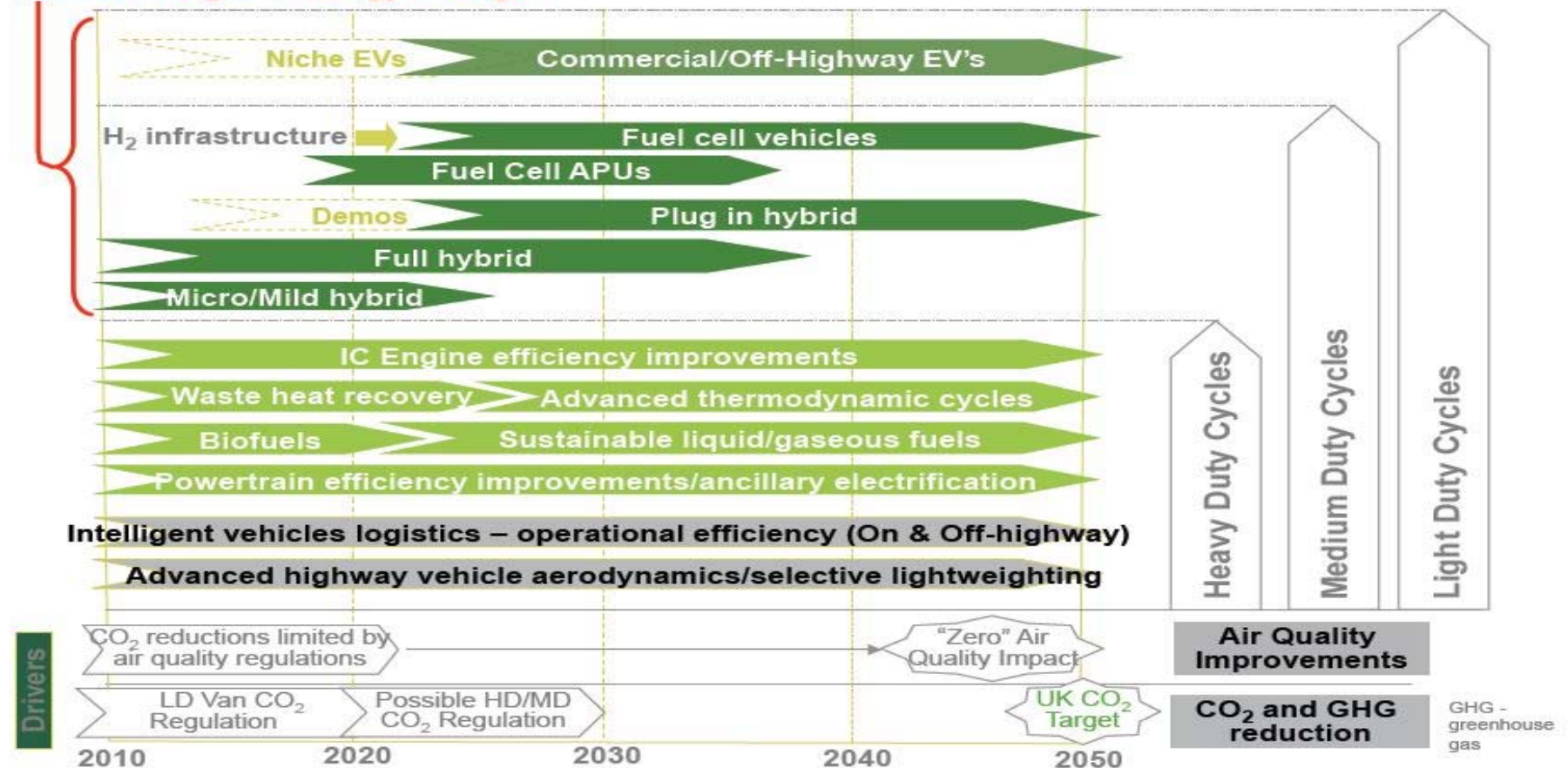
Passenger car low carbon technology roadmap



Commercial and off-road technology roadmap



Breakthrough in energy storage



Source: Automotive Council Technology Group 2012

Penetration of technology is slow

SMMT Motor industry facts 2013

New technology is a key carbon reduction strategy (eg new car CO2 progress, EV's)

Annual sales of new vehicles as percentage of road fleet:- - average sales % over last 10yrs

Cars 7.3%

Vans 8.2%

Trucks 8.5%

Bus 4.1%

Existing vehicles will remain in the fleet for many years and fuel must remain compatible

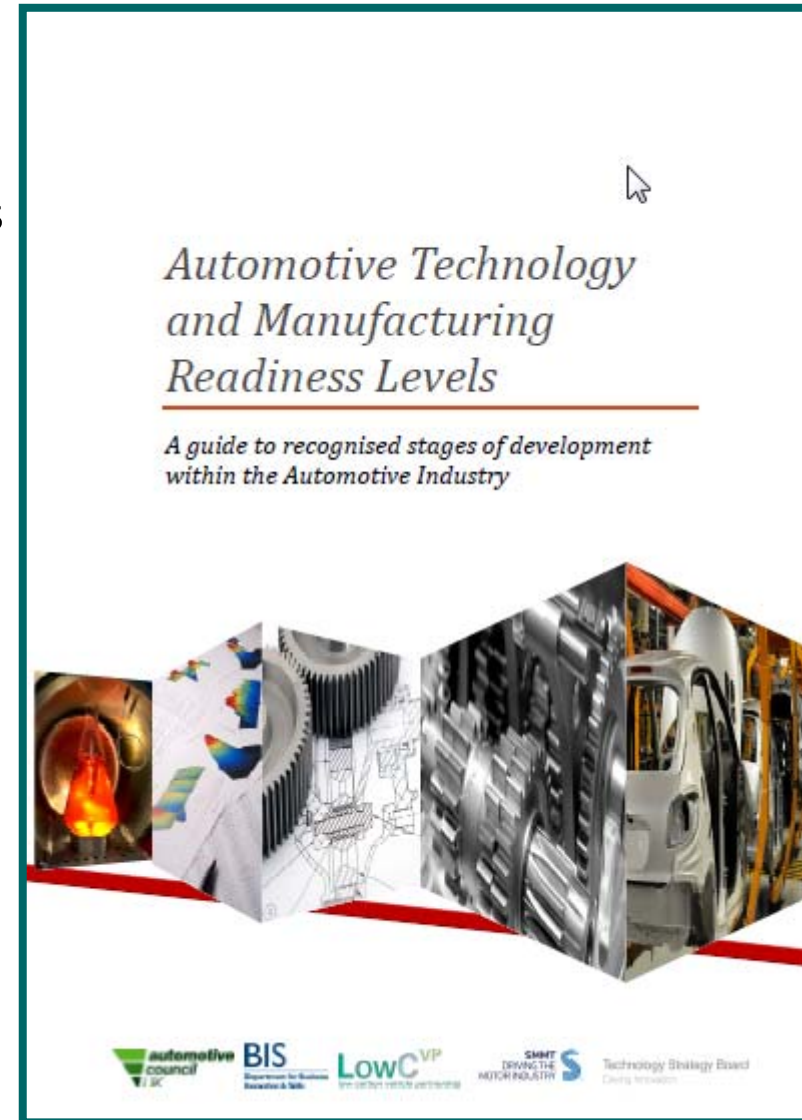
Sales of plug-in cars doubled in 2012 but were just 2254 in a new car market of over 2M (and total fleet of 31.5M)

Talking the same language

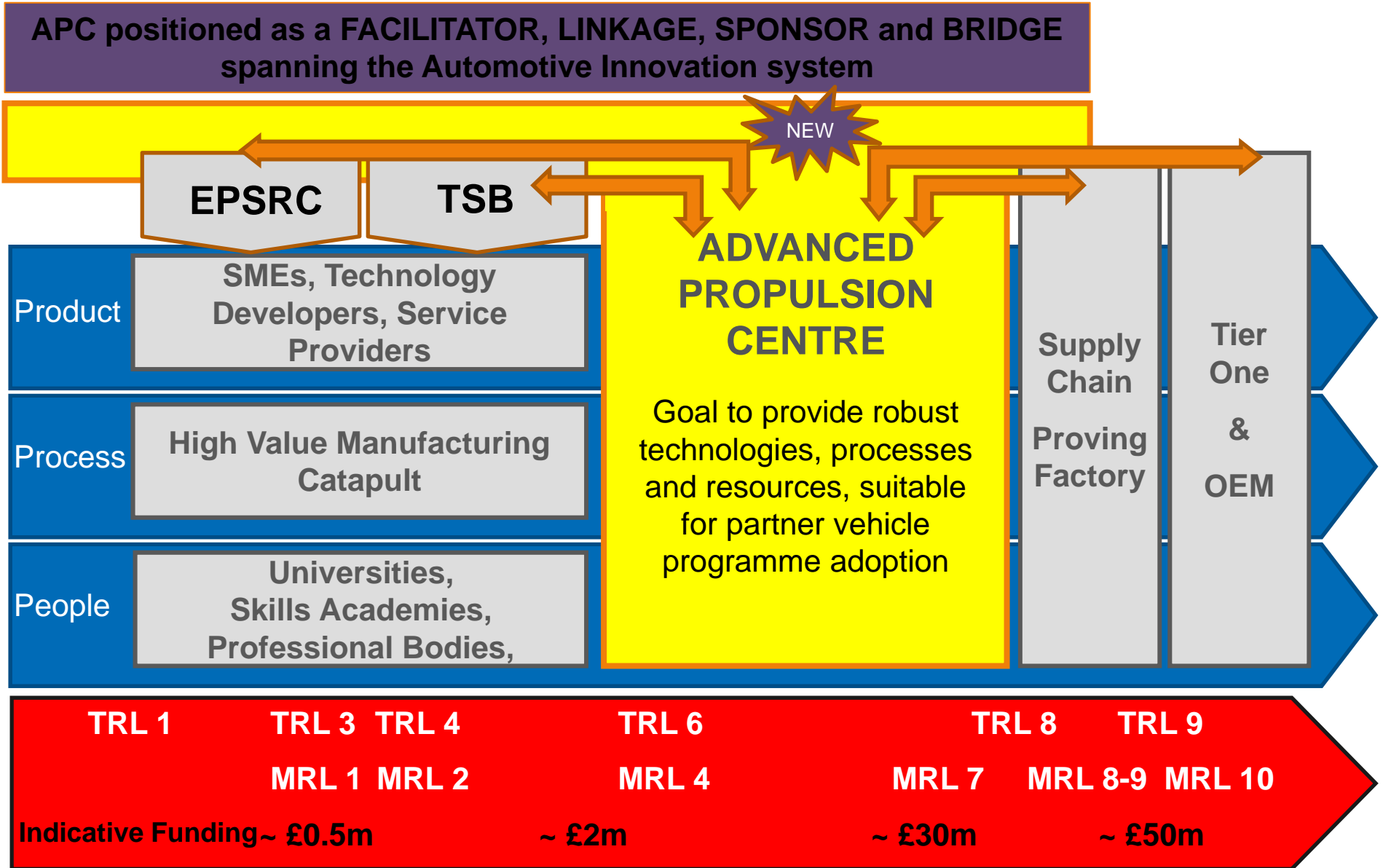
A key challenge has been to get all stakeholders to use common language and common understanding/expectations of technology maturity

Guide developed by LowCVP, Auto Council, BIS, SMMT, TSB.

Identifies language and is now used to define positioning for major initiatives

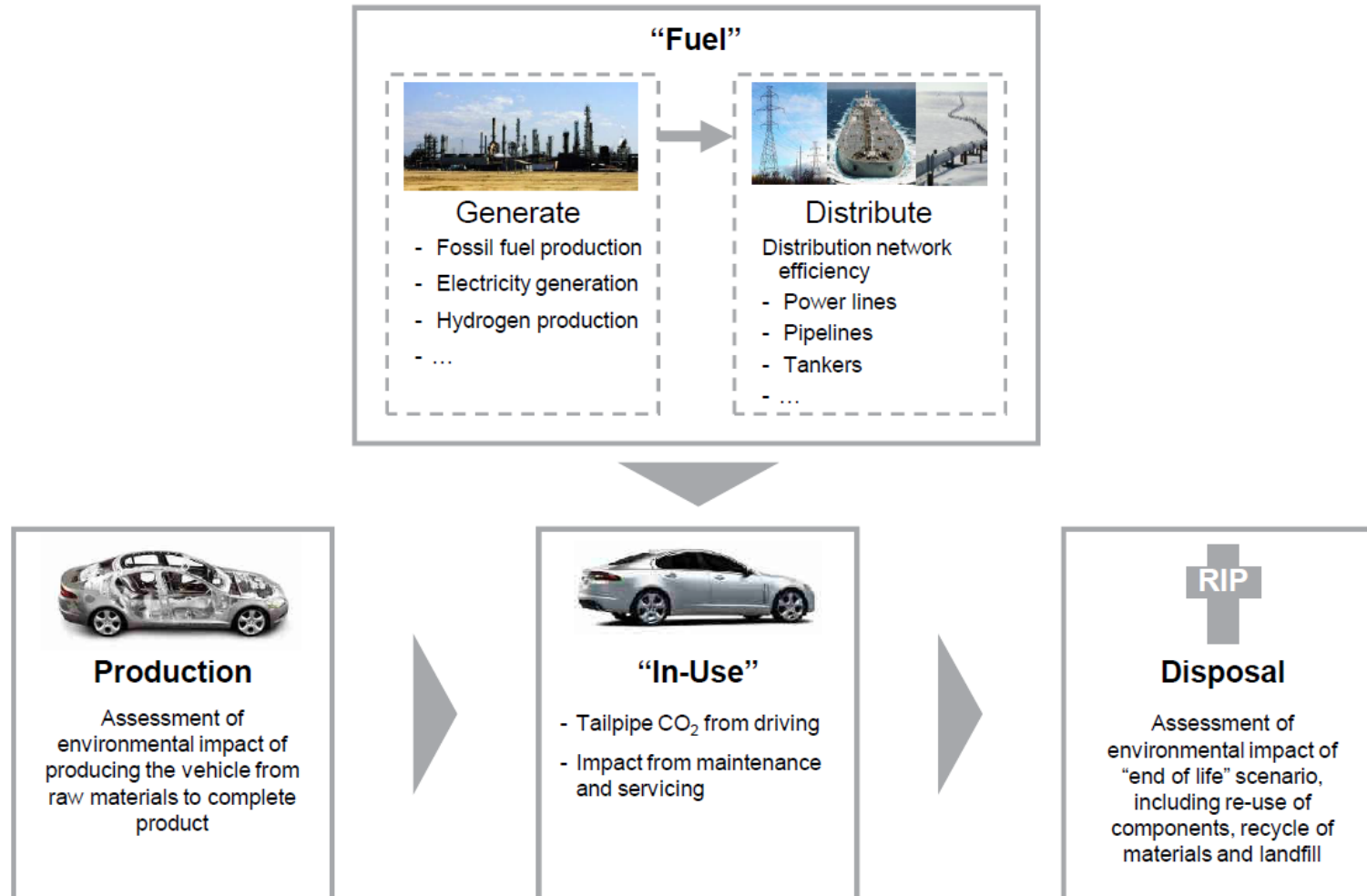


Automotive R&D Value-Chain



Carbon comes from more than just the tailpipe

A vehicle's life cycle can be divided into four "blocks" – production of the vehicle, production of the fuel, "in-use", and disposal

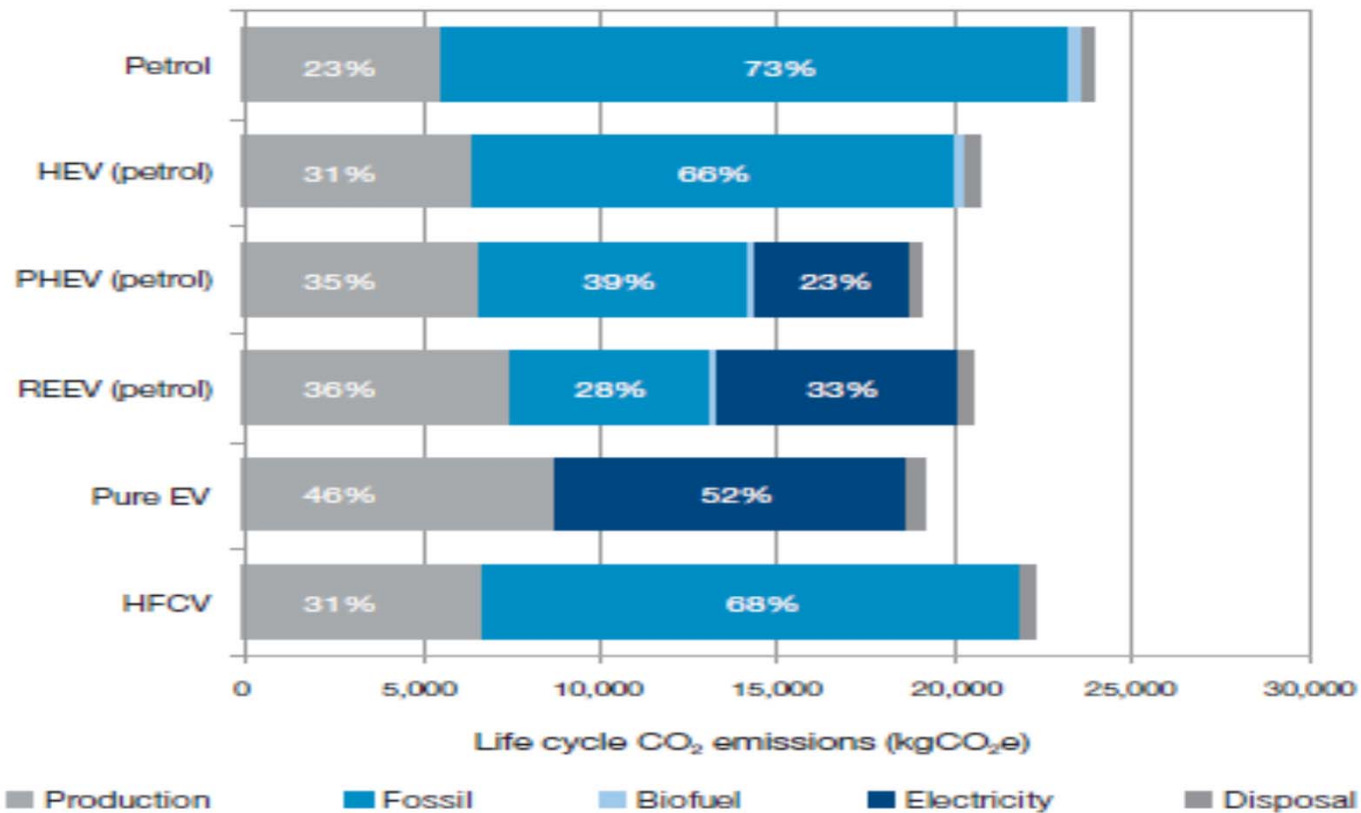


Source: Ricardo



The way we measure carbon impact needs to change in 2011 – LowCVP highlighted technology variations

Figure 2.4: Life cycle CO₂e emissions for various medium-sized vehicle technologies in 2015



Source: Ricardo (2011)

Preparing for a Life Cycle CO₂ Measure – Report for LowCVP 2011

In 2013 – LCA analysis gathers momentum

RICARDO-AEA

Current and Future Lifecycle Emissions of Key 'Low Carbon' Technologies and Alternatives
Final Report

Naser Odeh
Nikolas Hill
Daniel Forster

Project carried out for the Committee on Climate Change (CCC)

17th April 2013

www.ricardo-aea.com

Figure 4.10: Comparison of estimated average well-to-wheel greenhouse gas emissions in real-world conditions for various powertrains from 2010 to 2050

| Powertrain | 2010 | 2025 | 2050 |
|-------------|------|------|------|
| Petrol ICE | 230 | 130 | 70 |
| Diesel ICE | 190 | 110 | 60 |
| Petrol HEV | 180 | 100 | 60 |
| Diesel HEV | 150 | 90 | 50 |
| Petrol PHEV | 150 | 80 | 40 |
| Diesel PHEV | 140 | 70 | 30 |
| Petrol REEV | 130 | 60 | 20 |
| Diesel REEV | 120 | 50 | 10 |
| BEV | 100 | 40 | 10 |
| FCEV | 120 | 50 | 10 |
| H2FC PHEV | 110 | 40 | 10 |
| H2FC REEV | 100 | 30 | 10 |
| NG ICE | 180 | 100 | 50 |
| LPG ICE | 200 | 110 | 60 |

Source: Ricardo-AEA (2012)

Powering Ahead
The future of low-carbon cars and fuels

Duncan Kay, Nikolas Hill and Dan Newman
Ricardo-AEA
April 2013

UK RAC Foundation

Figure 3.4: Estimated lifecycle emissions of different car technologies, now and in 2030

| Technology | Scenario | Disposal | Infrastructure | Operation | Transport | Manufacture | |
|-----------------|----------|----------|----------------|-----------|-----------|-------------|-----|
| Petrol ICE car | Current | 0 | 0 | 240 | 0 | 20 | 260 |
| | 2030 | 0 | 0 | 140 | 0 | 10 | 150 |
| Petrol PHEV car | Current | 0 | 0 | 150 | 0 | 20 | 170 |
| | 2030 | 0 | 0 | 80 | 0 | 10 | 90 |
| BEV car | Current | 0 | 0 | 0 | 0 | 50 | 50 |
| | 2030 | 0 | 0 | 0 | 0 | 20 | 20 |

Source: CCC analysis based on estimates developed by Ricardo-AEA.
Notes: Base scenario. Reflects power sector decarbonisation over vehicle lifetimes. Assumes biofuels at their 2012 average levels for public refuelling stations.

Reducing the UK's carbon footprint and managing competitiveness risks
Committee on Climate Change | April 2013

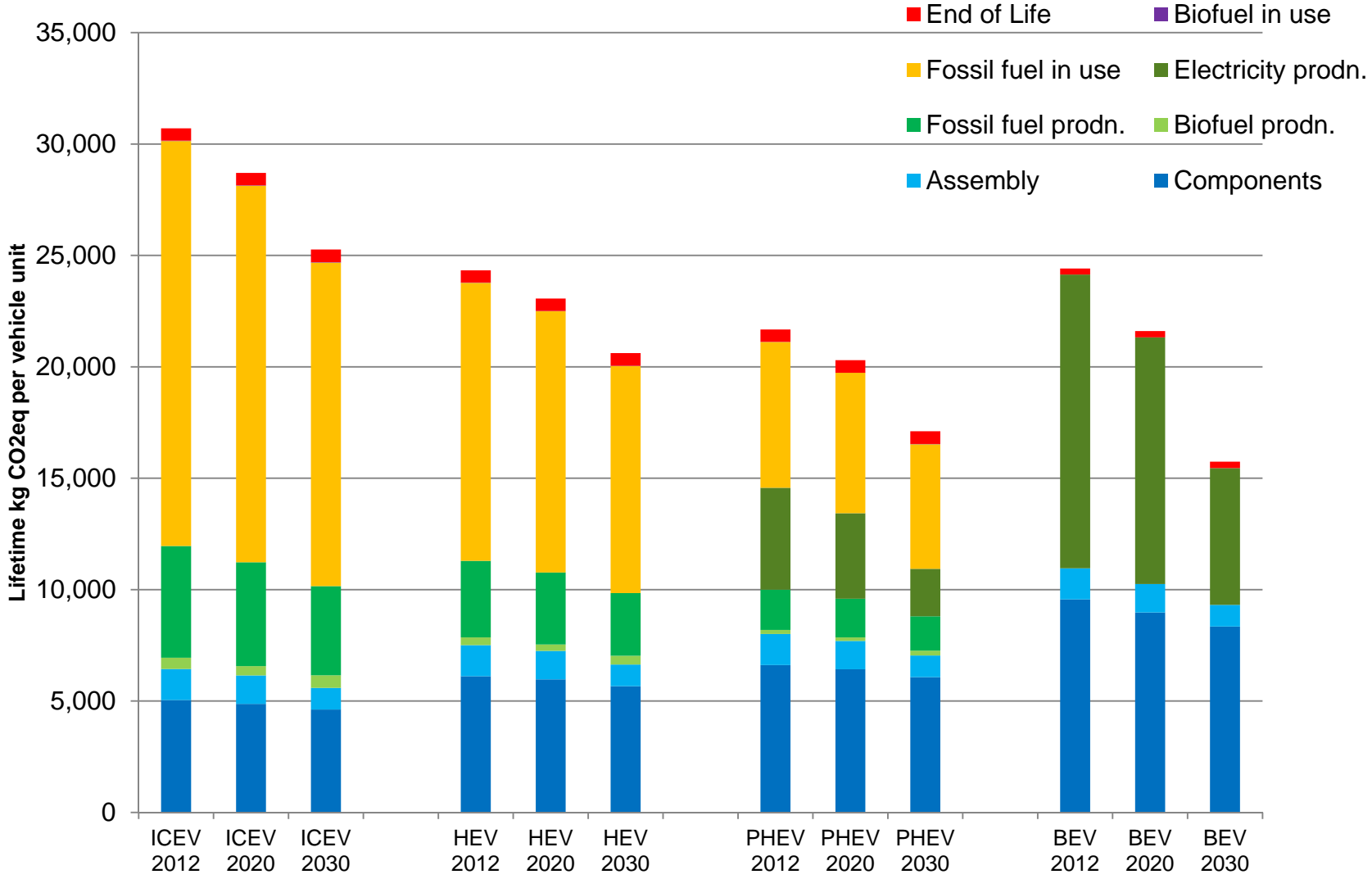
LowCVP Report 2013 on Life Cycle assessment

Building on the previous LowCVP work:-

- To study how the change in technology will affect the life-cycle impact
- To identify the most carbon intensive phases of a vehicle life now and in the future
- To review key areas of sensitivity in input assumptions
- Considers four technology options
- (Petrol only) ICEV, HEV, PHEV, BEV
- From 2012, forecast for 2020, 2030
- Identifies potential of 'best' case options



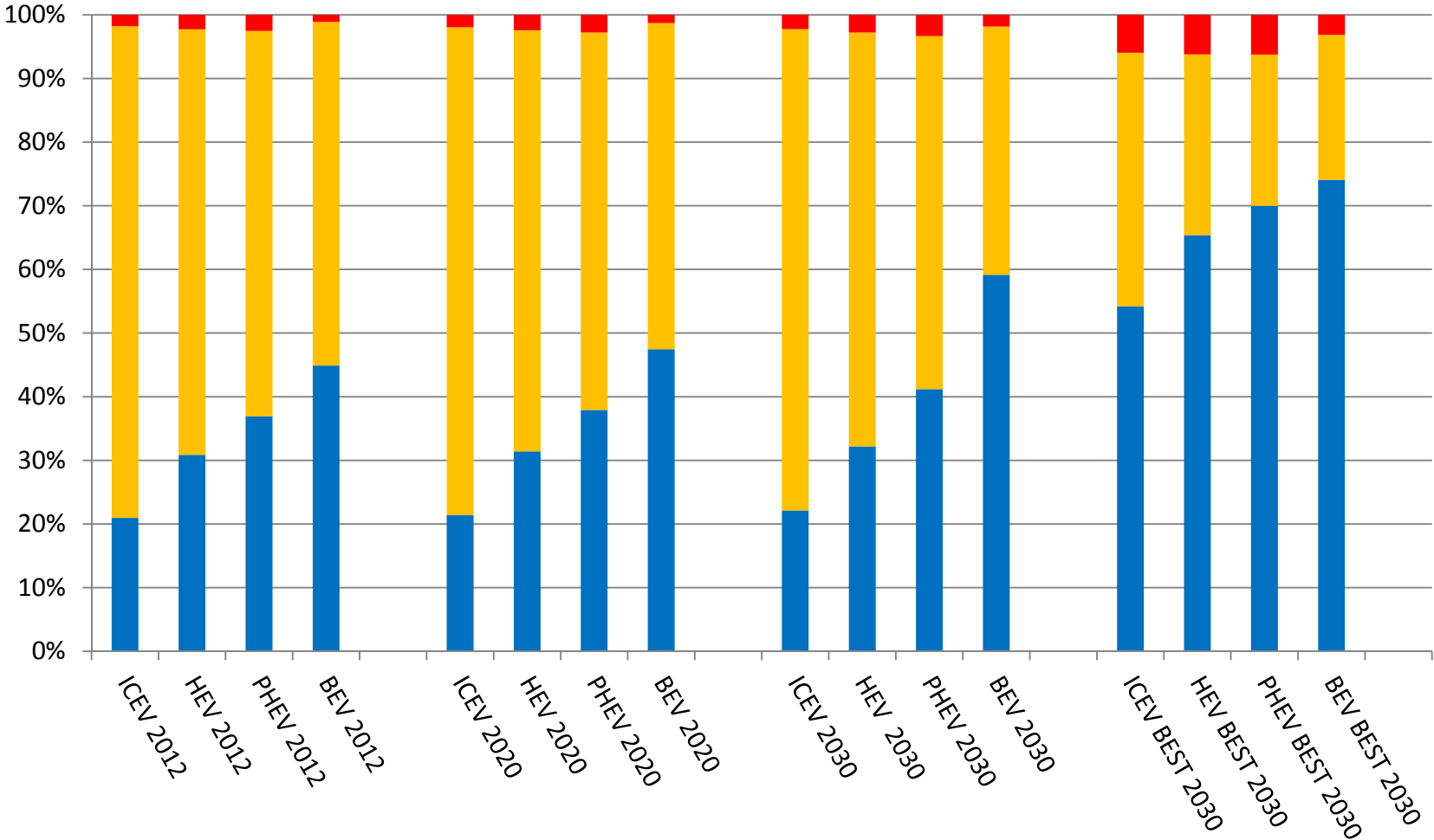
Life-cycle impact improves with time.



In-use phase still dominates before 2030

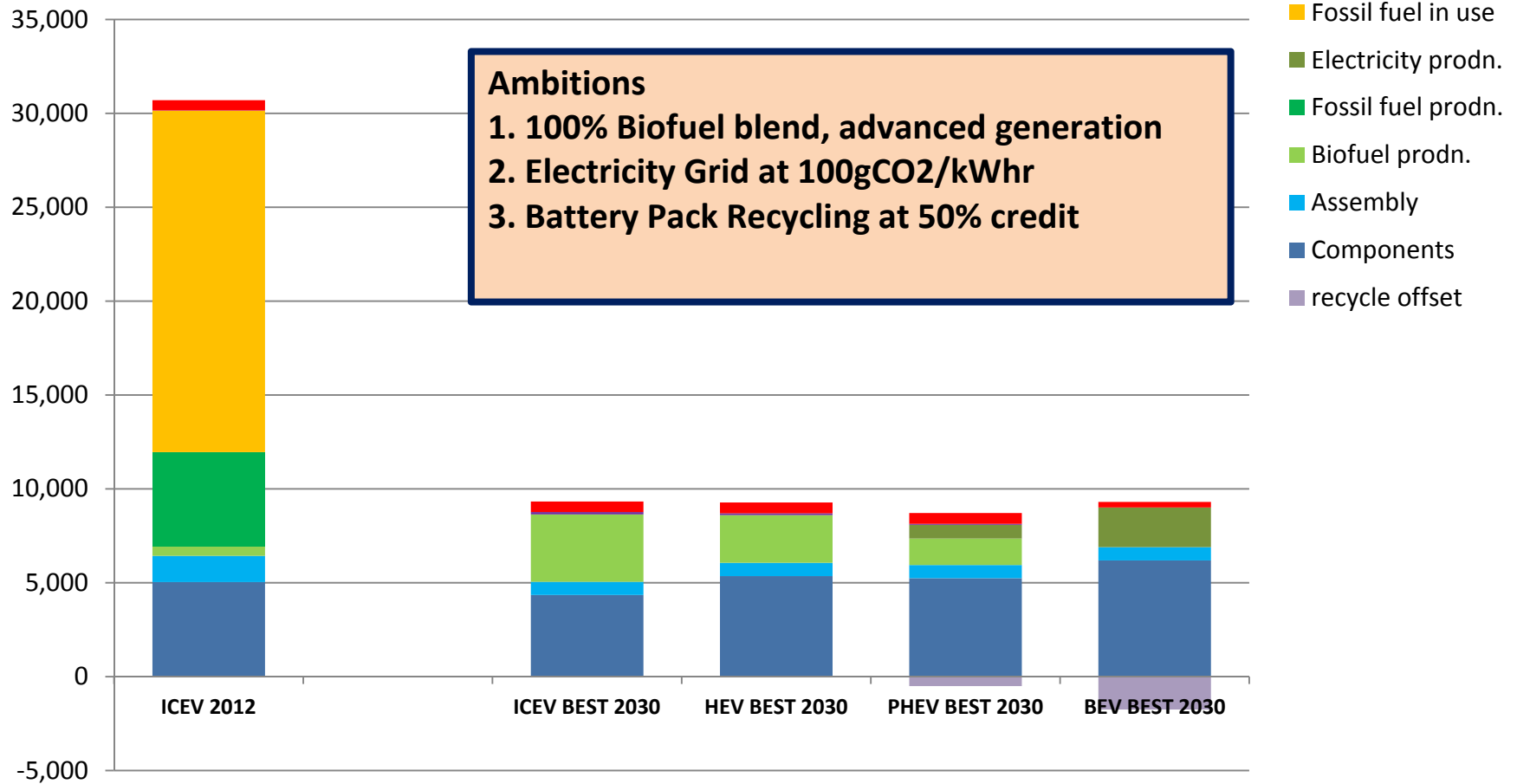
Proportion of Life Cycle CO2eq for primary phases

■ End of Life ■ USE ■ PRODUCTION



Ambitious policies could deliver >65% reductions by 2030 for all technologies

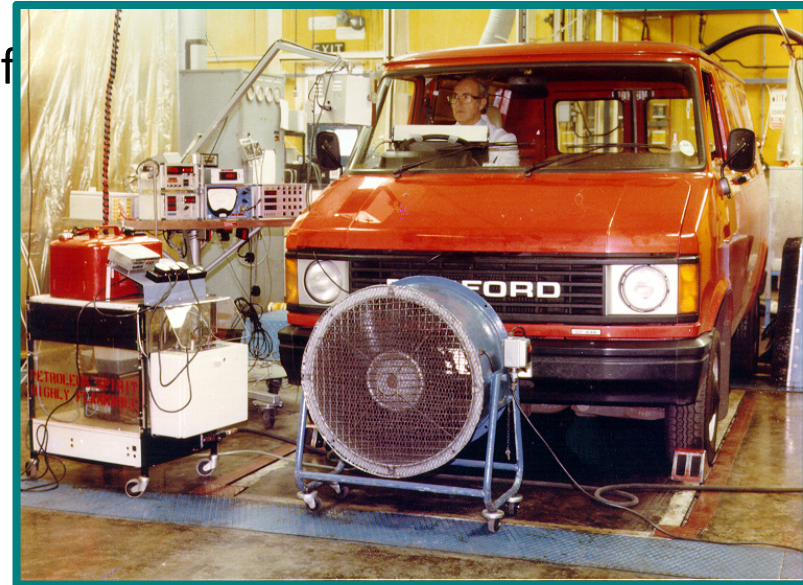
CO2eq life-cycle impact 'best' case 2030 using 'ambitious' policies



*100g/CO₂/kWhr relates to electricity generation at the point of consumption

How is Carbon measured

Starting in early 1970's the basic method for measuring carbon emissions is broadly stable to this day.



BUT ... real world fuel use higher than test

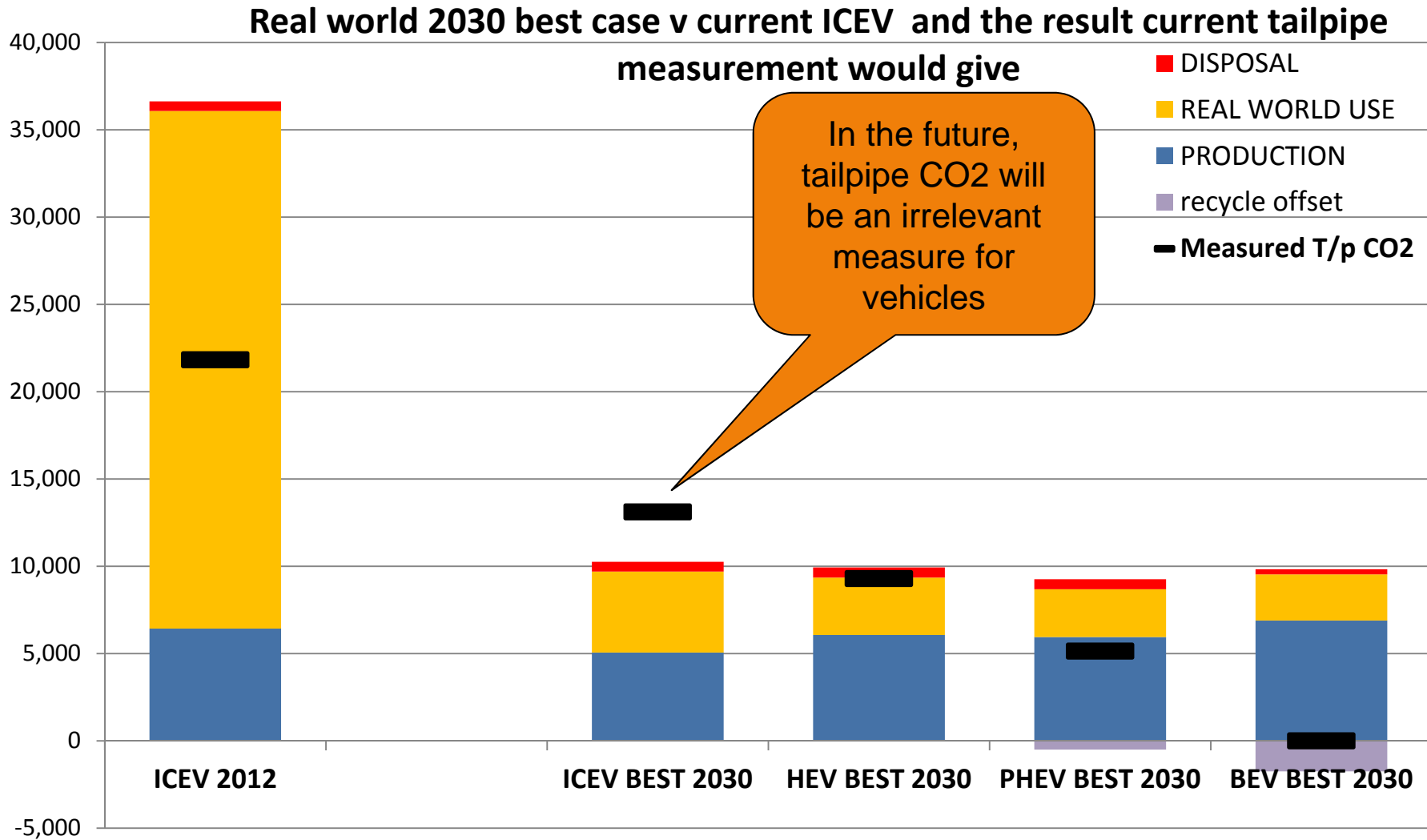
Recent reports have noted that consumers fuel consumption typically exceeds test cycle results by an average of 25%

- ICCT report May 2013 –25% average increase based on users own data input
- Emissions Analytics/WhatCar? True mpg - 25% higher

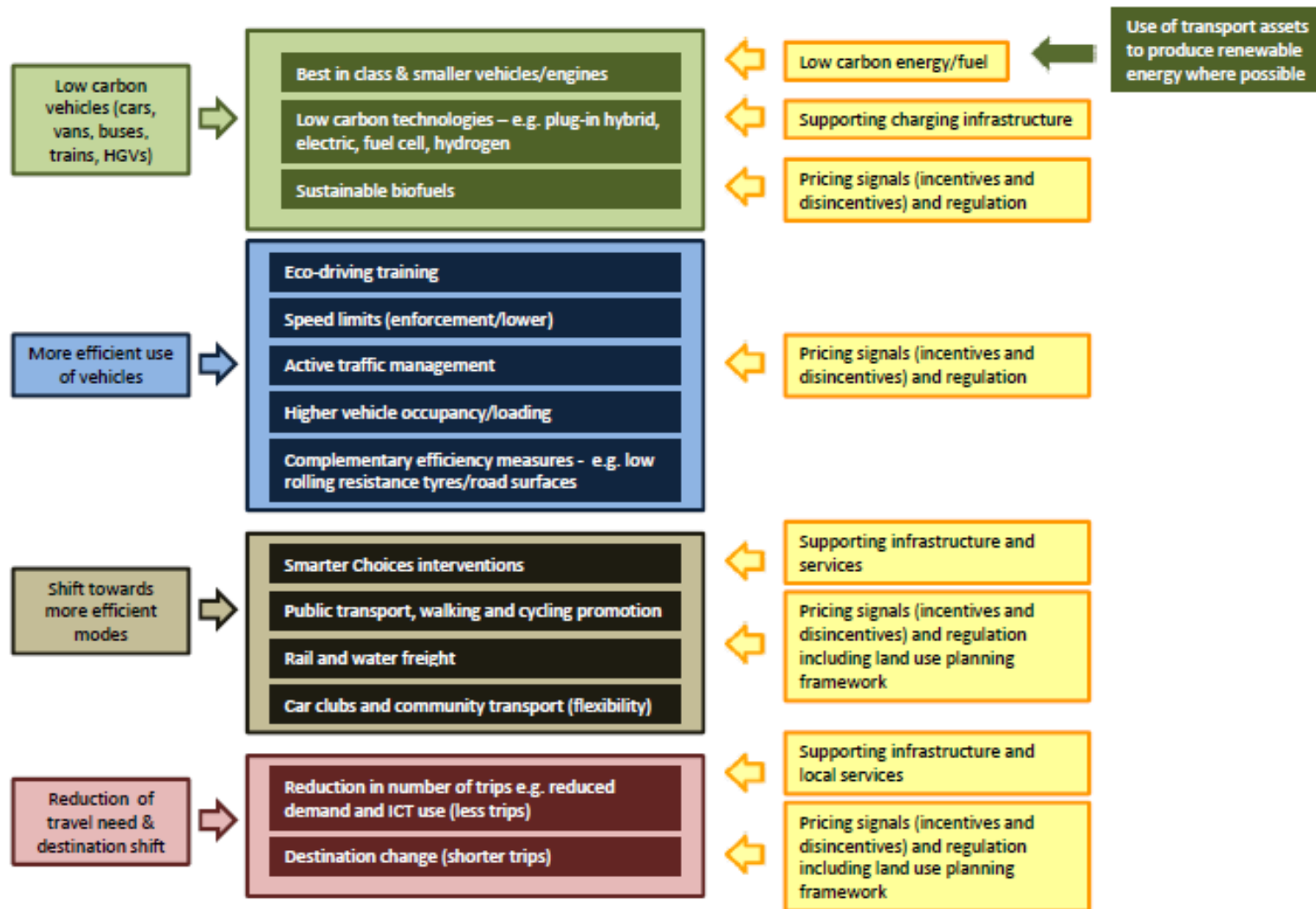
Interestingly the results are very consistent even though some data are from a large dataset of users own fuel measurements and other from on-road testing using Portable Emissions Measurement System (PEMS)



Tailpipe CO₂ is no longer representative



Low carbon transport framework requires an integrated approach



Source: ATKINS

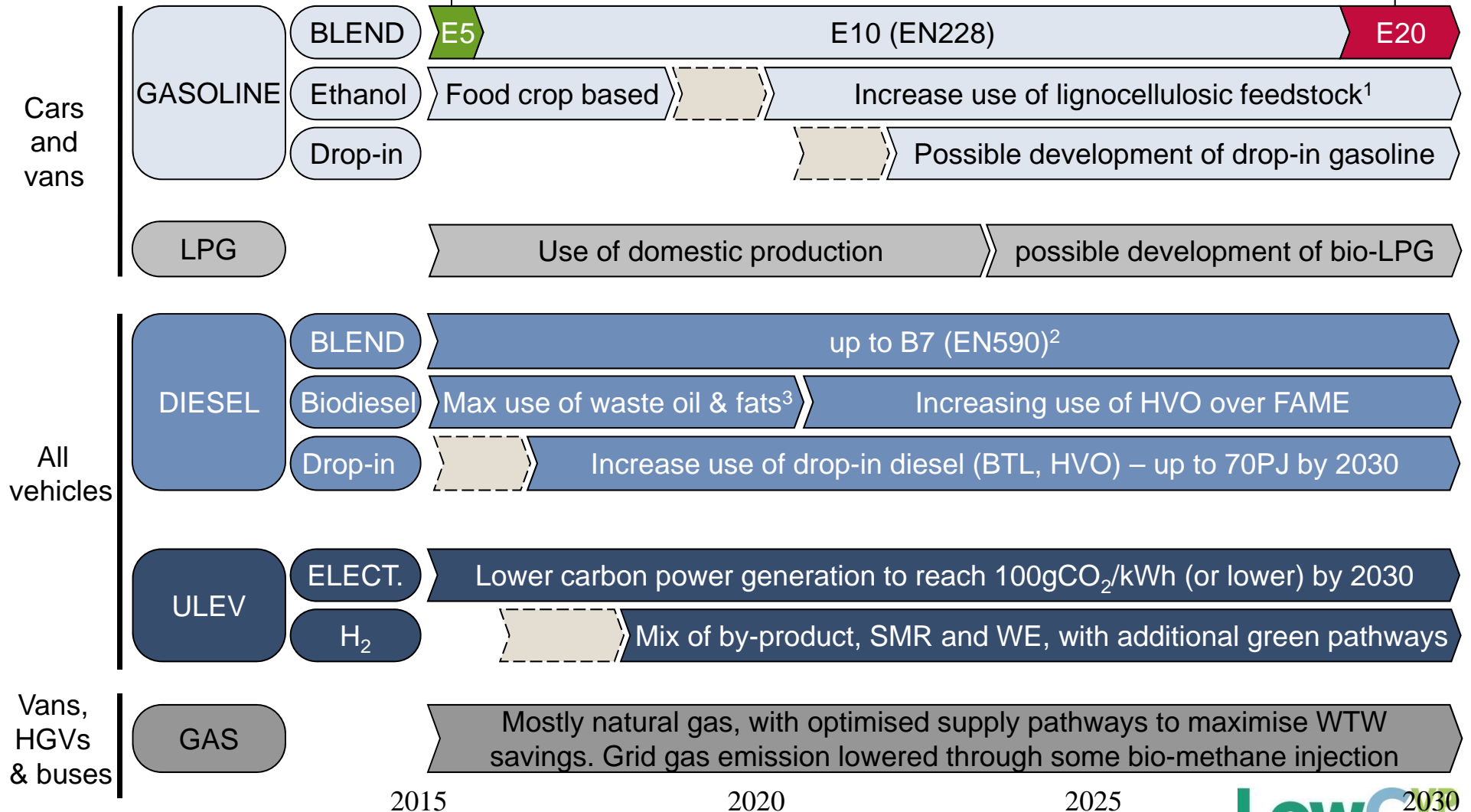
2015-2030 fuel roadmap: fuel types and blends



Uncertain ramp up start or rate,
dependent on policy support or framework

SMR: Steam Methane Reforming; ULEV: Ultra Low Emission Vehicles; WE: Water Electrolysis; 1 – Possible development of butanol 2 – Effective blend likely to stay at B2 for Non Road Mobile Machinery 3 – With measures in place to ensure fuel quality

2016 E10 becomes the certification fuel, latest introduction date for E10
Possible introduction in late 2020s; dependant on EC level decisions



BUT ... Well-to-Wheel assessment is needed

No current options completely eradicate carbon from the fuel use chain, however all have significant opportunities to reduce carbon

- Liquid fuels (petrol/diesel) – higher biofuel blends and substitution
- Electricity - renewables and the low carbon grid
- Gas – Biomethane
- Hydrogen – production from water electrolysis.

Only by combining a WTW approach **together** with in-use vehicle energy efficiency will the lowest carbon pathway for the use phase become apparent.

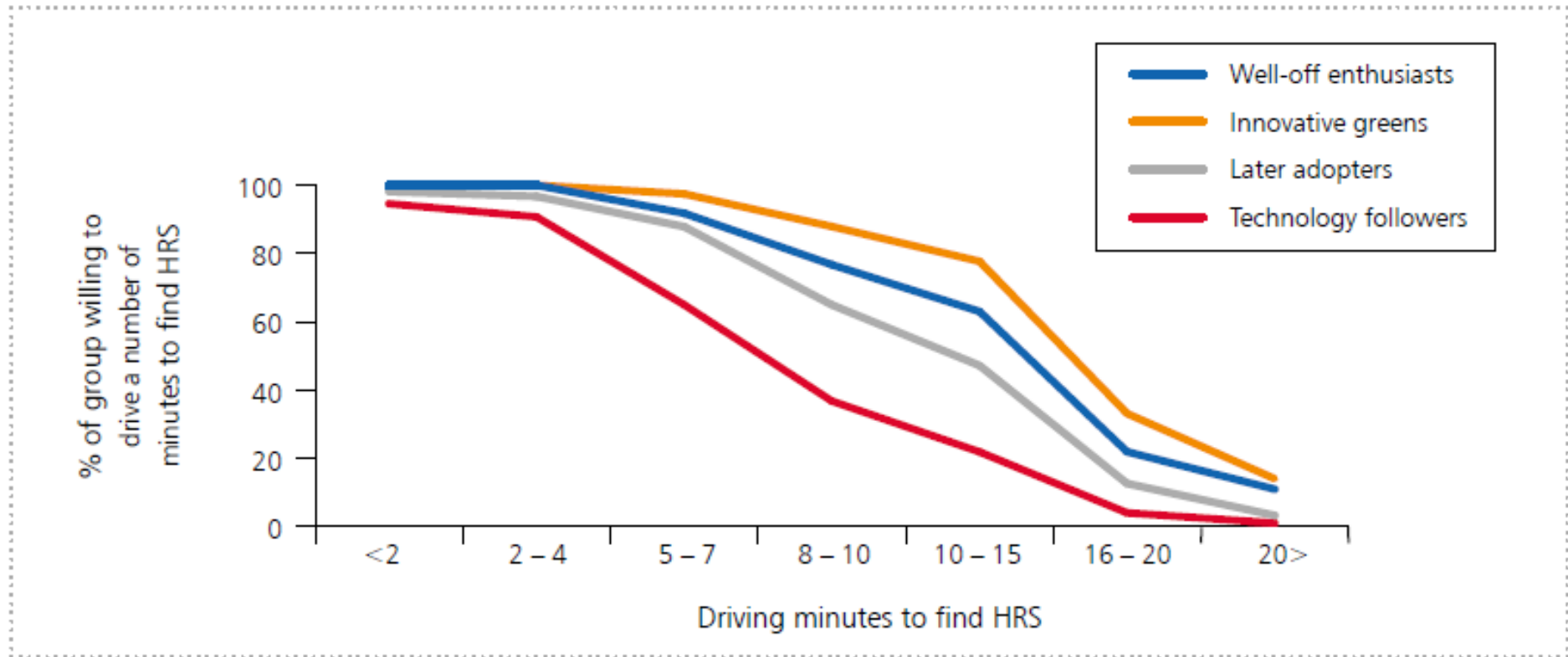
There is no single solution so keeping our options open allows optimum combinations and applications of transport energy pathways

A new transport energy infrastructure

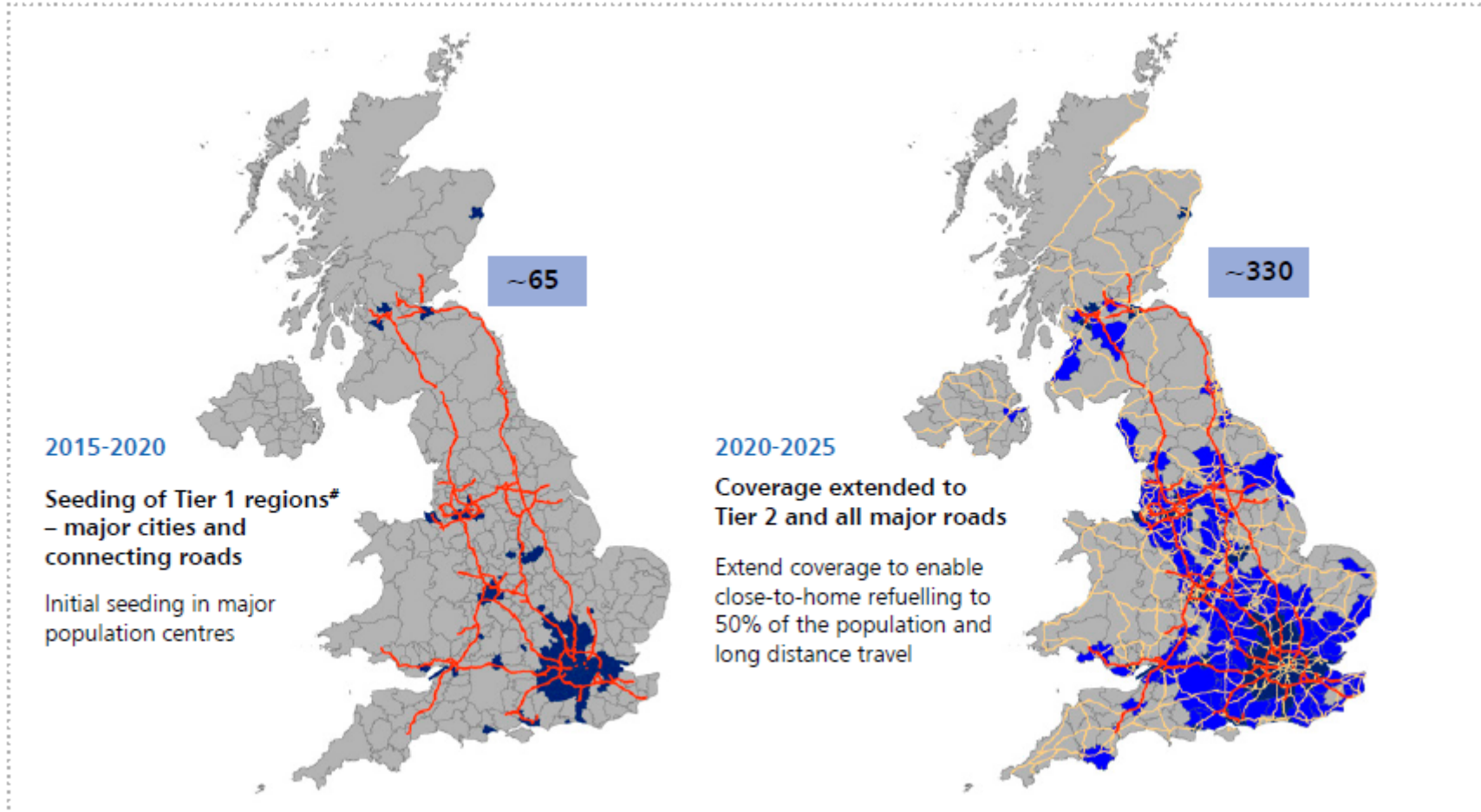
- There are significant challenges over the energy infrastructure for transport.
- Currently transport and residential energy are discrete supply and infrastructure.
- Combining users energy demands to a single source has substantial implications.
- The cost and climate impact of a “new” transport energy infrastructure must be incorporated in the long term plans (recent proposals from Europe appeared to ignore this!)

Finding fuel

H2 Mobility study mapped how much people will go out of their way to refuel



Mapping the development of infrastructure

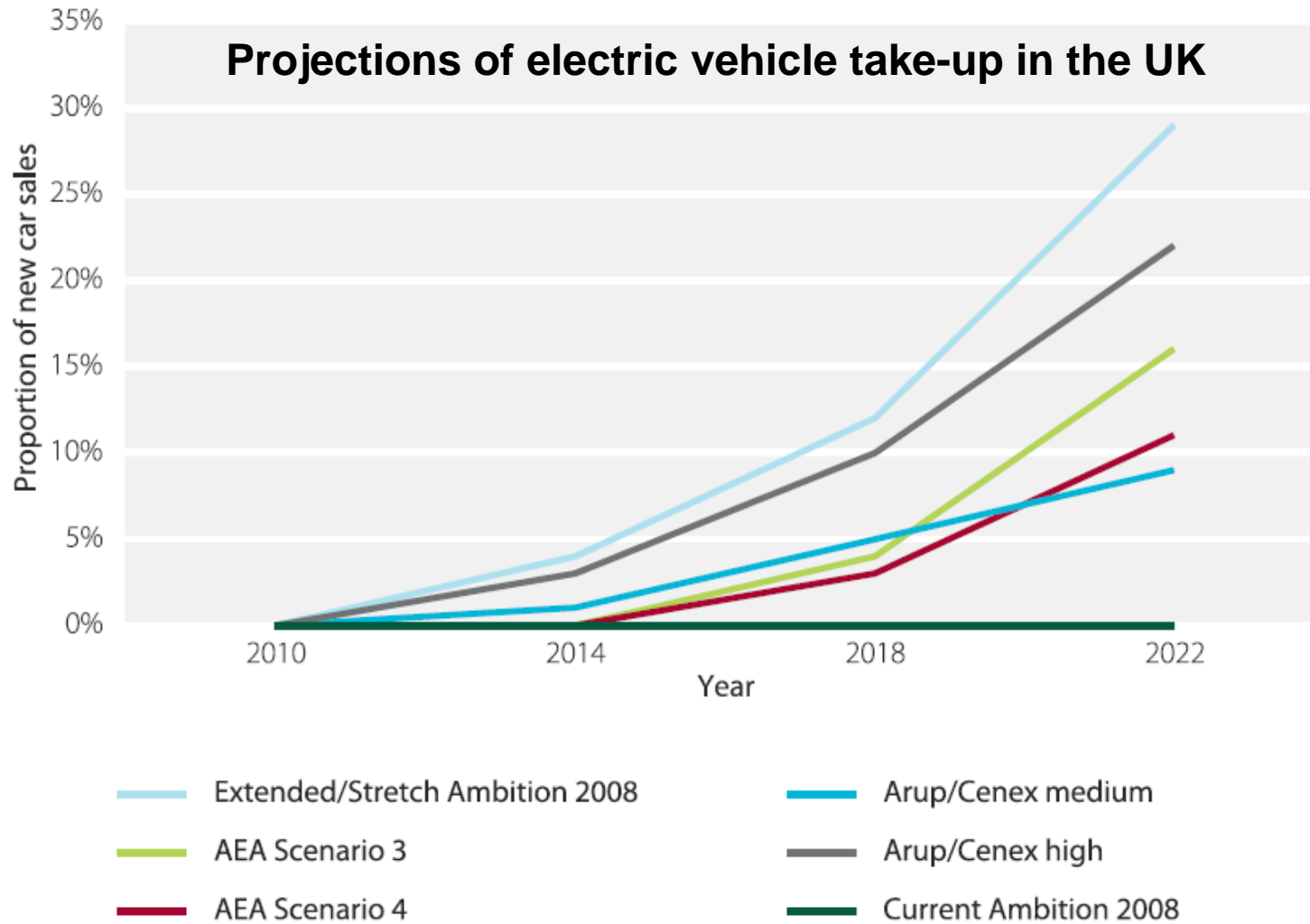


Its not just Carbon Dioxide!

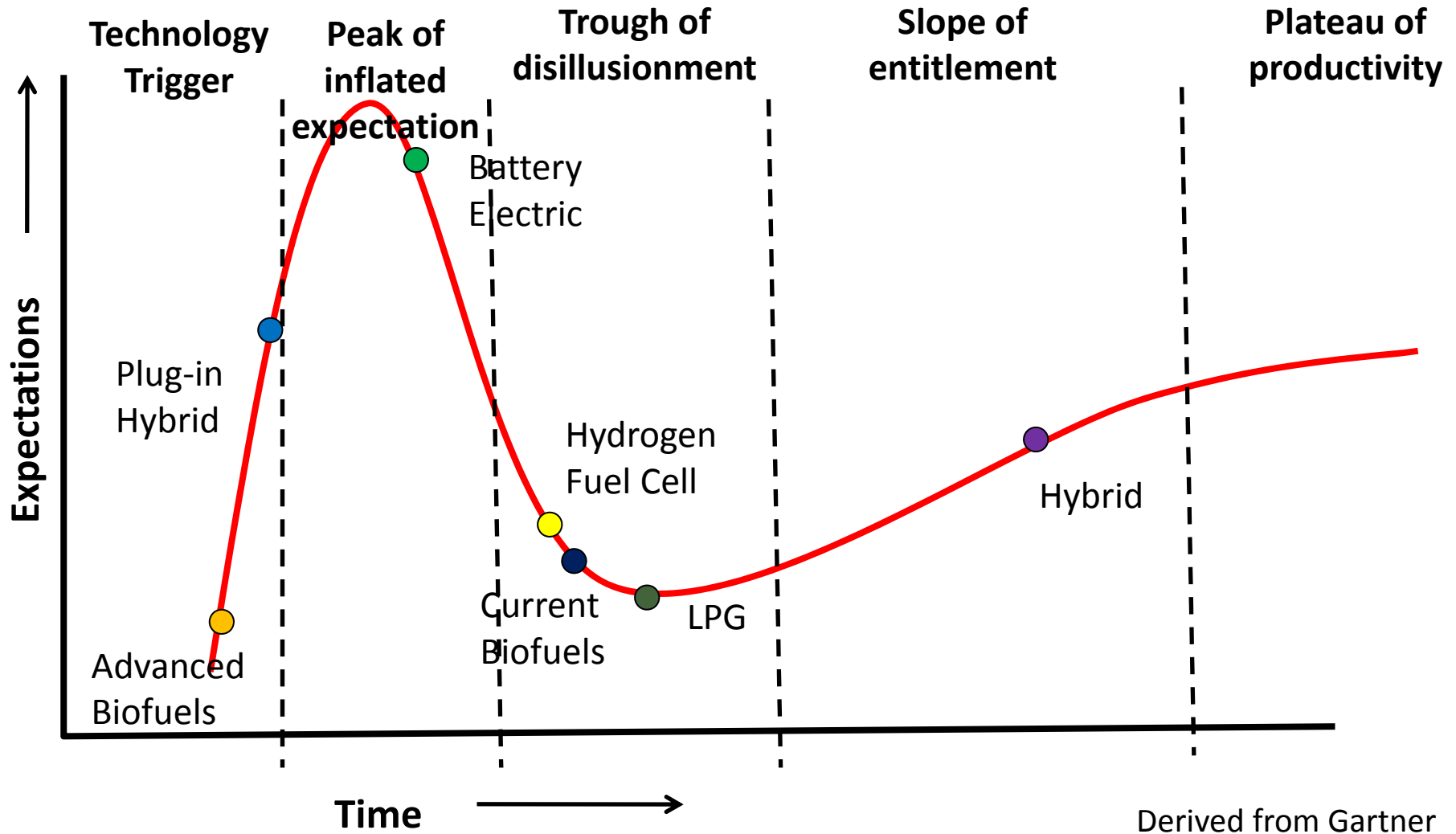
Source: Climate Change 1995, The Science of Climate Change: Summary for Policymakers and Technical Summary of the Working Group I Report, page 22.

| Species | Chemical formula | Lifetime (years) | Global Warming Potential (Time Horizon) | | |
|-----------------|---|------------------|---|-----------|-----------|
| | | | 20 years | 100 years | 500 years |
| CO ₂ | CO ₂ | variable § | 1 | 1 | 1 |
| Methane * | CH ₄ | 12±3 | 56 | 21 | 6.5 |
| Nitrous oxide | N ₂ O | 120 | 280 | 310 | 170 |
| | | | | | |
| HFC-23 | CHF ₃ | 264 | 9100 | 11700 | 9800 |
| HFC-32 | CH ₂ F ₂ | 5.6 | 2100 | 650 | 200 |
| HFC-41 | CH ₃ F | 3.7 | 490 | 150 | 45 |
| HFC-43-10mee | C ₅ H ₂ F ₁₀ | 17.1 | 3000 | 1300 | 400 |
| HFC-125 | C ₂ H ₂ F ₅ | 32.6 | 4600 | 2800 | 920 |
| HFC-134 | C ₂ H ₂ F ₄ | 10.6 | 2900 | 1000 | 310 |
| HFC-134a | CH ₂ FCF ₃ | 14.6 | 3400 | 1300 | 420 |
| HFC-152a | C ₂ H ₄ F ₂ | 1.5 | 460 | 140 | 42 |
| HFC-143 | C ₂ H ₃ F ₃ | 3.8 | 1000 | 300 | 94 |
| HFC-143a | C ₂ H ₃ F ₃ | 48.3 | 5000 | 3800 | 1400 |

Market uptake is highly uncertain – depending upon public acceptability, battery costs / subsidies



The adoption of new technologies is likely to be incremental and does not follow the hype cycle



The views expressed in this slide are illustrative and do not represent LowCVP position

Getting the buyers to change uses a range of tools

Consumer purchasing behaviours vary widely

A portfolio of taxation gives the greatest shift

Registration Tax based on CO2

Ownership Tax Based on CO2

Fuel Duty

Progressive CO2 taxation of Company Cars has been very powerful in UK

These currently also significantly support Ultra low emissions vehicle (eg EV and PHEV) uptake.

Grants in place for cleanest vehicles

Low Emission Zones

CO2 based Congestion charges

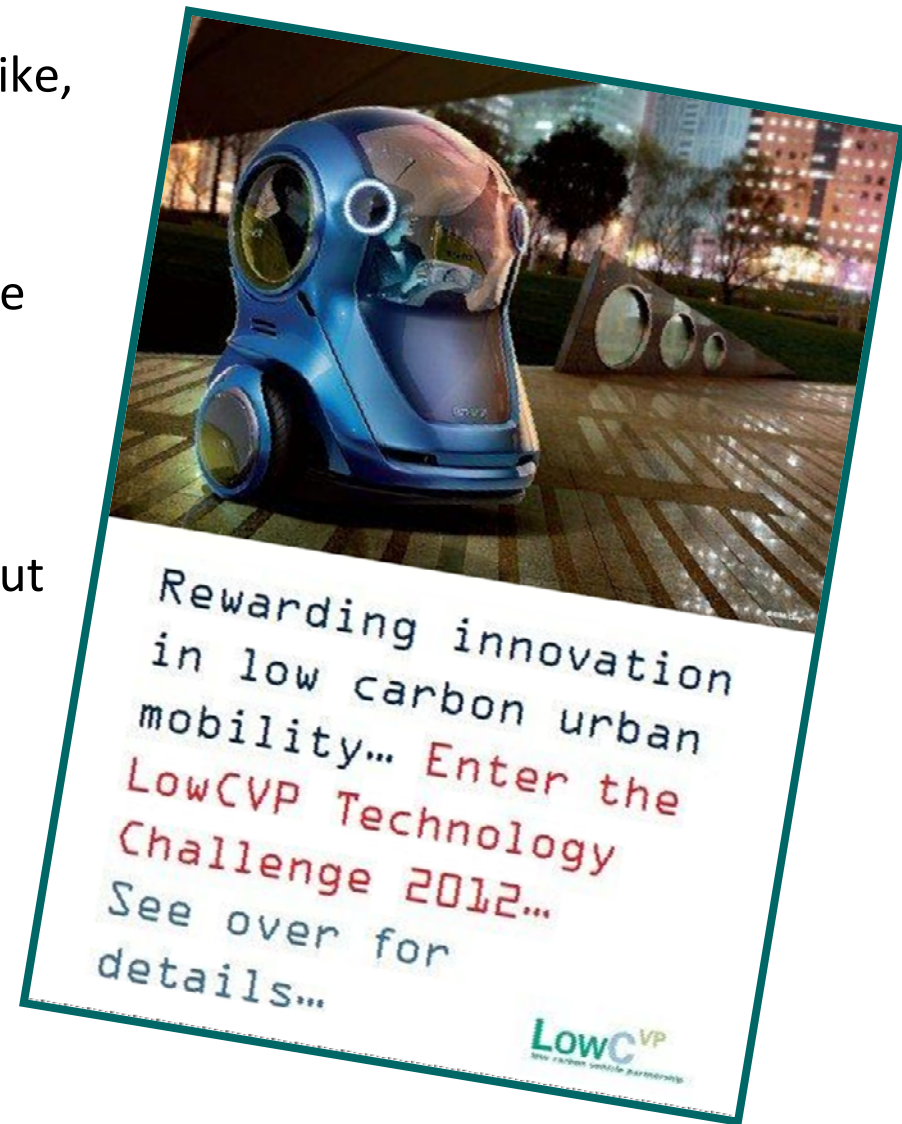
| Fuel Economy | | VED band and CO ₂ |
|--|-----------------------|---|
| CO ₂ emission figure (g/km) | | |
| <=100 | A | B g/km |
| 101-110 | B | |
| 111-120 | C | |
| 121-130 | D | |
| 131-140 | E | |
| 141-150 | F | |
| 151-160 | G | |
| 161-170 | H | |
| 171-180 | I | |
| 181-190 | J | |
| 191-200 | K | |
| 201-210 | L | |
| 211-220 | M | |
| 221-230 | N | |
| 231-240 | O | |
| 241-250 | P | |
| 251+ | Q | |
| Fuel cost (estimated) for 12,000 miles <small>A fuel cost figure indicates to the consumer a guide fuel price for comparison purposes. This figure is calculated by using the combined drive cycle (urban, extra-urban and average) fuel price. Representative average. For current and per litre as at March 2008 in an inland, petrol 95p, diesel 105p and LPG 81p (VCA March 2008).</small> | | |
| VED for 12 months <small>Vehicle excise duty (VED) or road tax varies according to the CO₂ emissions and fuel type of the vehicle.</small> | | |
| Environmental Information <small>A guide on fuel economy and CO₂ emissions which contains data for all new passenger car models is available at any point of sale free of charge. In addition to the fuel efficiency of a car, driving behaviour as well as other non-technical factors play a role in determining a car's fuel consumption and CO₂ emissions. CO₂ is the main greenhouse gas responsible for global warming.</small> | | |
| Make/Model: | Engine Capacity (cc): | |
| Fuel Type: | Transmission: | |
| Fuel Consumption: | | |
| Drive cycle | Litres/100km | Mpg |
| Urban | | |
| Extra-urban | | |
| Combined | | |
| <small>Carbon dioxide emissions (g/km): Important note: Some specifications of this make/model may have lower CO₂ emissions than this. Check with your dealer.</small> | | |
| <small>Department for Transport</small> | | <small>To compare fuel costs and CO₂ emissions of new cars, visit www.vcacarfueldata.org.uk</small> |



Future mobility technology challenge

- What will our future vehicles look like, how will they be owned
- What will fuel them
- How will they be integrated into the system

- LowCVP among others. regularly challenge the industry to think about these questions and encourage innovation in every area



Technology challenge

Technology development for Cars, Vans, Public Transport Commercial vehicles is part of a very complex mobility and Energy system

It must comply with a range of needs/wants:

- Be compatible with the current and future energy pathways
 - Meet the worldwide regulation /incentive/taxation frameworks
 - Be saleable for high volume applications
 - Deliver lower carbon on the tests and in the real world
 - Ultimately be efficient on a life cycle basis
 - Be compatible with the energy and infrastructure network
 - Not rely on long term government support
 - Support the changing face of mobility
-
- **Be what the customer wants to buy and use!!**

The Low Carbon Vehicle Partnership

Connect | Collaborate | Influence – www.lowcvp.org.uk

- ❑ **Connect:** With privileged access to information, you'll gain insight into low carbon vehicle policy development and be introduced to key stakeholders.
- ❑ **Collaborate:** You'll benefit from many opportunities to work – and network - with key UK and EU government, industry, NGO and other stakeholders
- ❑ **Influence:** You'll be able to initiate proposals and help to shape future low carbon vehicle policy, programmes and regulations



LowCVP is a partnership organisation with over 170 members with a stake in the low carbon road transport agenda.