The Results: 2010 Future Car Challenge

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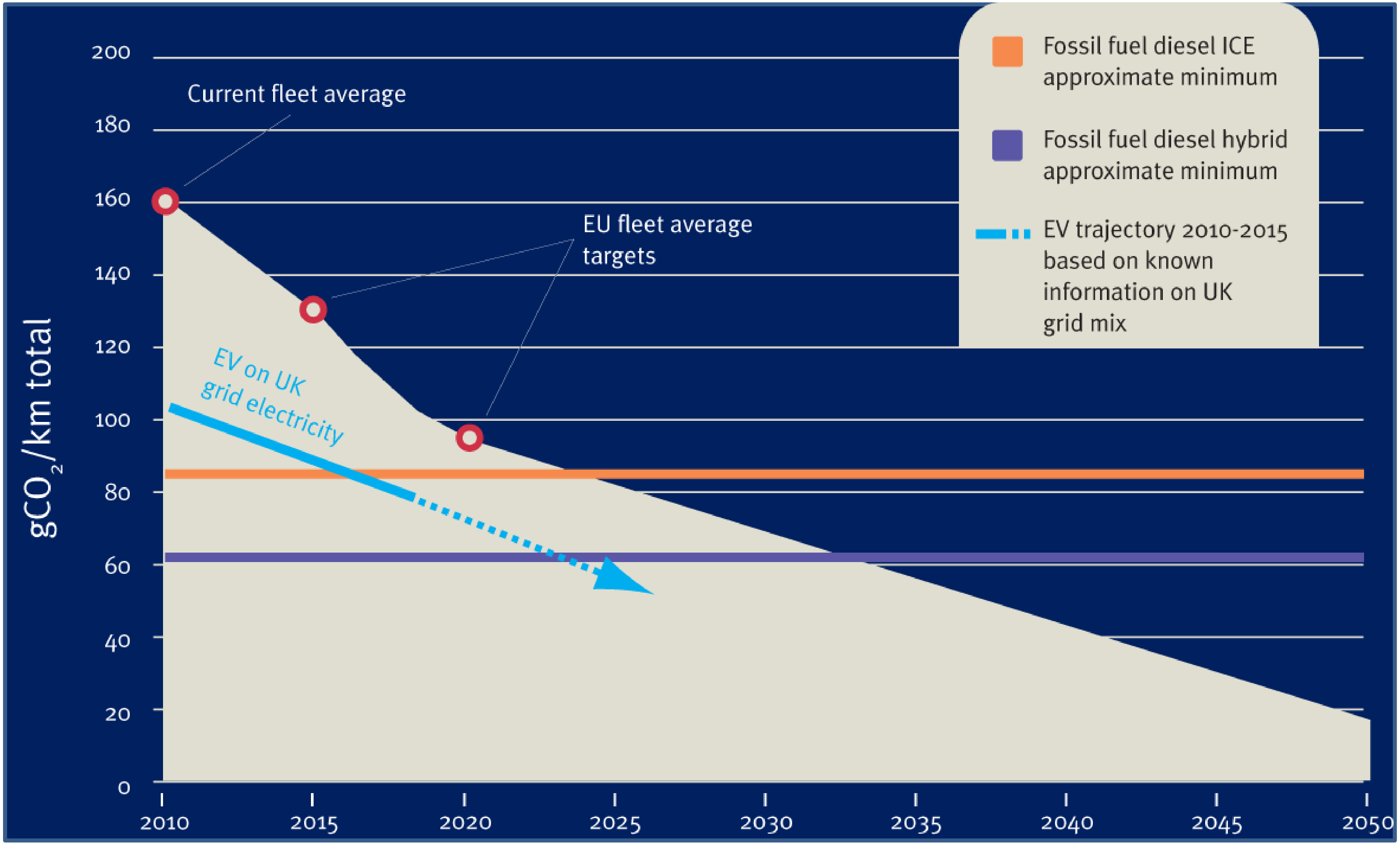
CO_2 projection



$$CO_2 = D \times E \times F$$

ROAD TRANSPORT	VEHICLE KILOMETRES	ENERGY PER KILOMETRE	CO2 PER UNIT ENERGY

$$CO_2 = D \times E \times F$$

ROAD TRANSPORT	↓ VEHICLE KILOMETRES	ENERGY PER KILOMETRE	CO2 PER UNIT ENERGY

- decrease demand
- shift to cleaner modes
- increase occupancy

$$CO_2 = D \times E \times F$$

ROAD TRANSPORT

VEHICLE KILOMETRES

↓ ENERGY PER KILOMETRE

CO2 PER UNIT ENERGY

- Rolling resistance
- Aerodynamics
- Weight
- Energy conversion unit

$$CO_2 = D \times E \times F$$

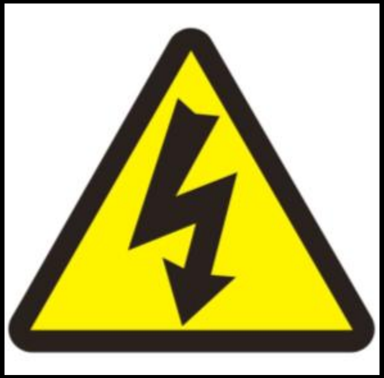
ROAD TRANSPORT

VEHICLE KILOMETRES

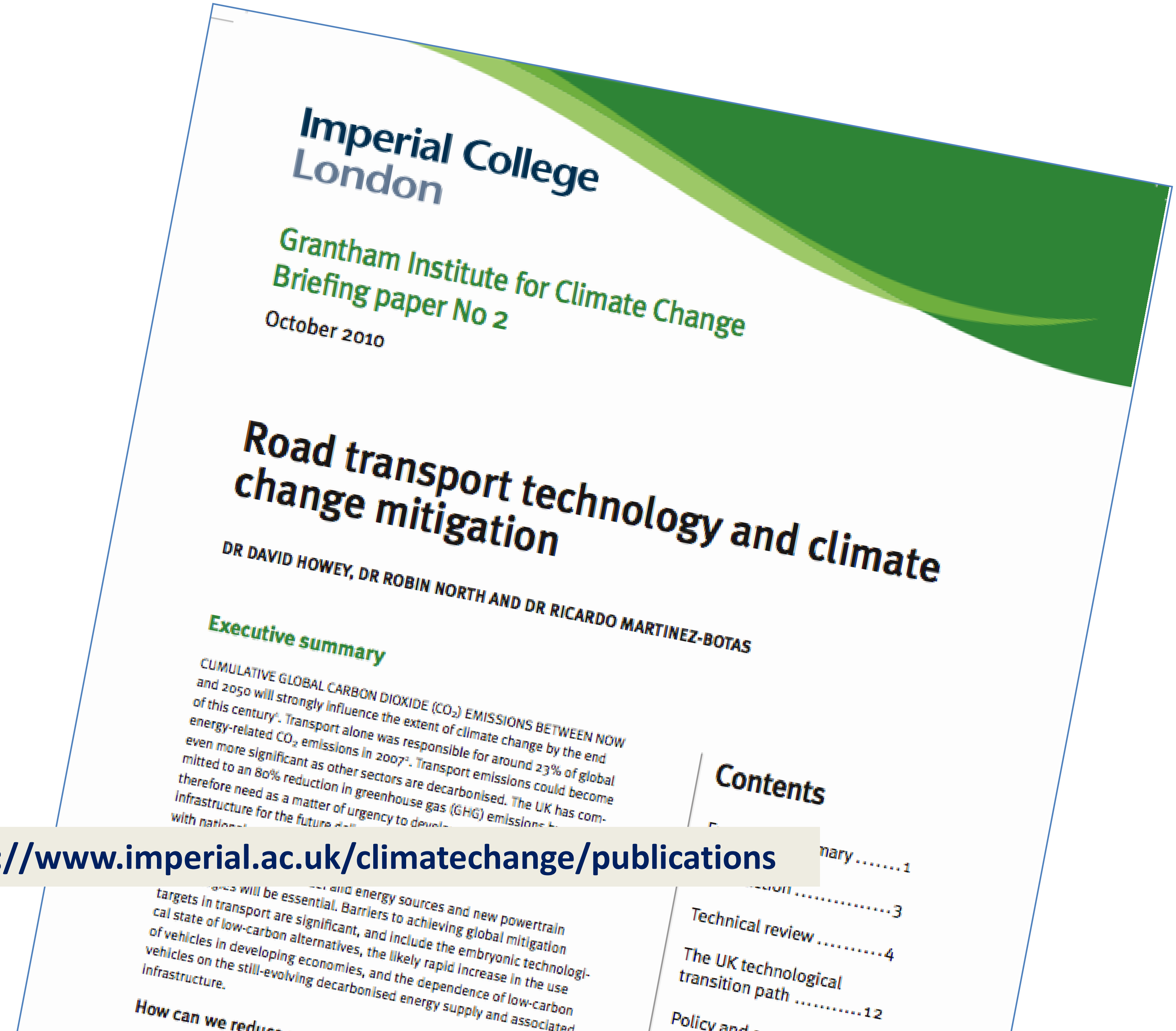
ENERGY PER KILOMETRE

CO2 PER UNIT ENERGY

biofuel | synthetic fuel | electricity



... low/zero carbon please!



Imperial College London

Grantham Institute for Climate Change
Briefing paper No 2
October 2010

Road transport technology and climate change mitigation

DR DAVID HOWEY, DR ROBIN NORTH AND DR RICARDO MARTINEZ-BOTAS

Executive summary

CUMULATIVE GLOBAL CARBON DIOXIDE (CO_2) EMISSIONS BETWEEN NOW and 2050 will strongly influence the extent of climate change by the end of this century[1]. Transport alone was responsible for around 23% of global energy-related CO_2 emissions in 2007[2]. Transport emissions could become even more significant as other sectors are decarbonised. The UK has committed to an 80% reduction in greenhouse gas (GHG) emissions b... therefore need as a matter of urgency to devel... infrastructure for the future deli... with nation...

...will be essential. Barriers to achieving global mitigation targets in transport are significant, and include the embryonic technological state of low-carbon alternatives, the likely rapid increase in the use of vehicles in developing economies, and the dependence of low-carbon vehicles on the still-evolving decarbonised energy supply and associated infrastructure.

How can we redu...

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http://www.imperial.ac.uk/climatechange/publications

The Results from the 2010 BLFCC

Vehicle type entries

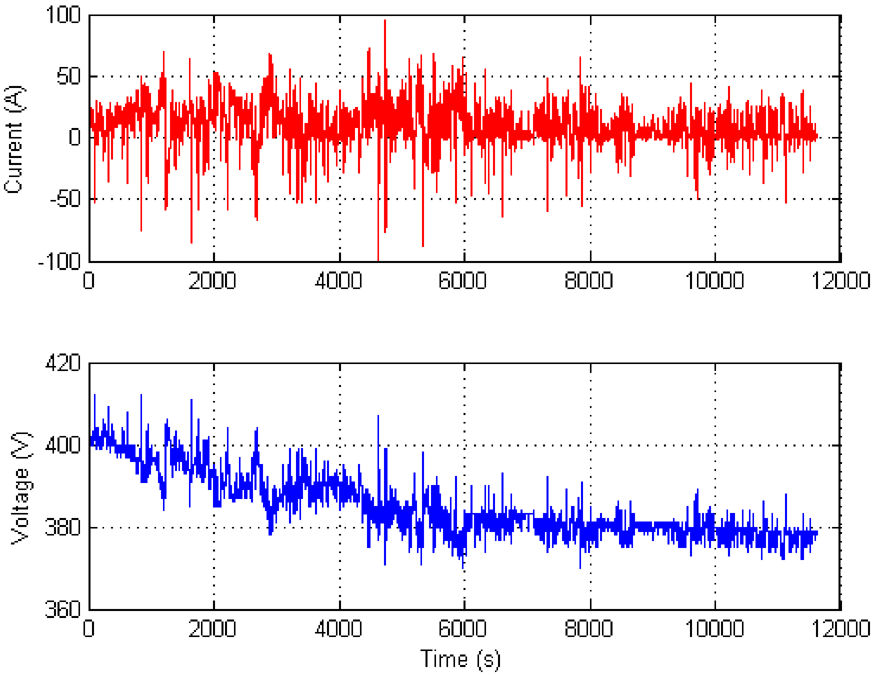
Powertrain types	Vehicle sizes/ types
Internal Combustion Engine (ICE)	Small passenger vehicle (small)
Electric Vehicle (EV)	Regular passenger vehicle (regular)
Hybrid Electric Vehicle (HEV)	Sports vehicle (sports)
Plug-in Hybrid Electric Vehicle (PHEV)	Multi-purpose passenger vehicle (MPV)
Hydrogen Fuel-cell Electric Vehicle (HFEV)	Light commercial vehicle (LCV)
Extended-Range Electric Vehicle (E-REV)	

Measurement

Fuel energy consumed was measured by filling up to 100% at start and finish and measuring the fuel required to achieve this at the finish.

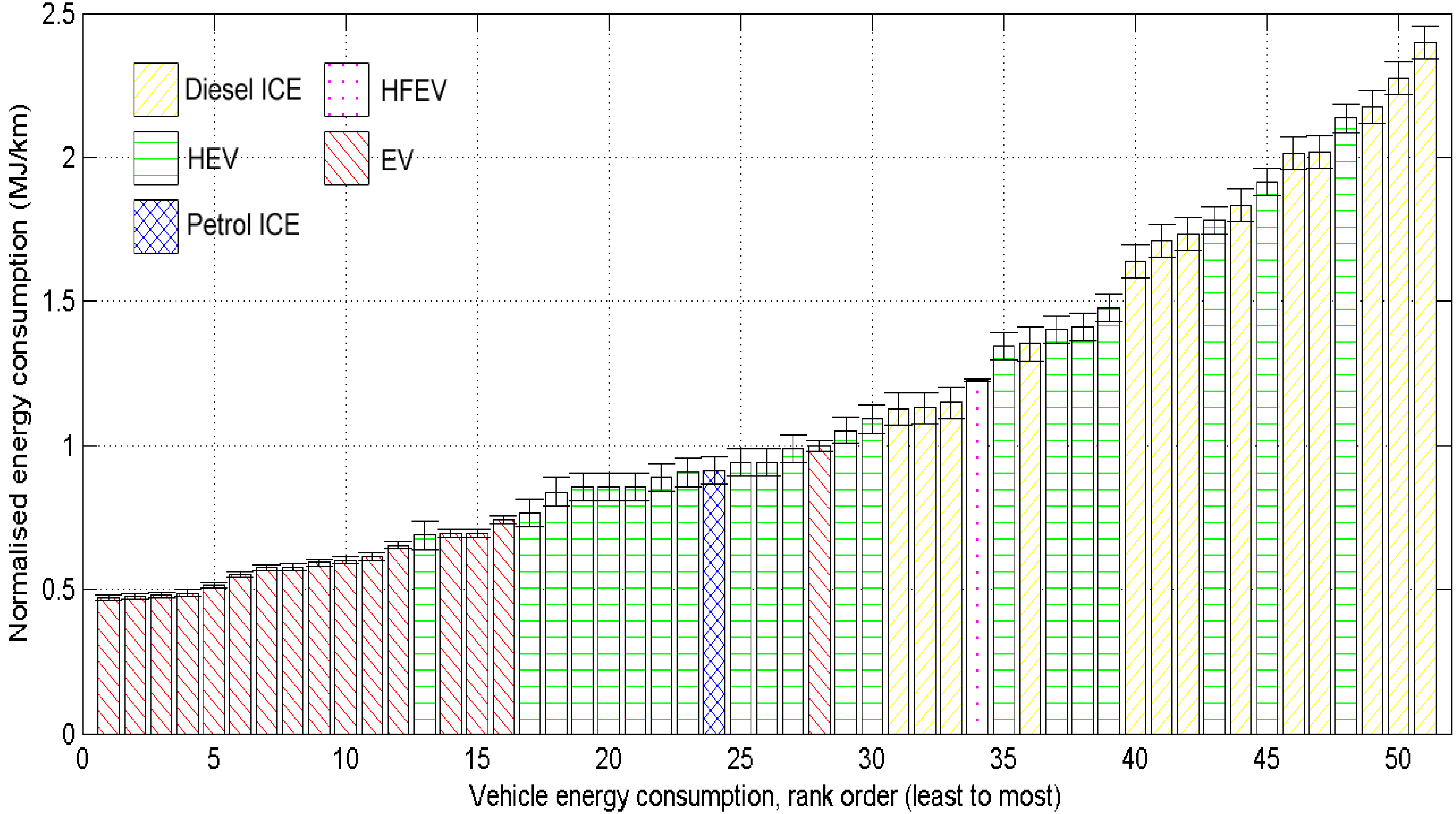
Electrical energy consumed was measured using data loggers fitted directly to the electric vehicles' high voltage systems.

An efficiency factor of 92% for AC-DC battery charging and 99% for battery charge/discharge was included.

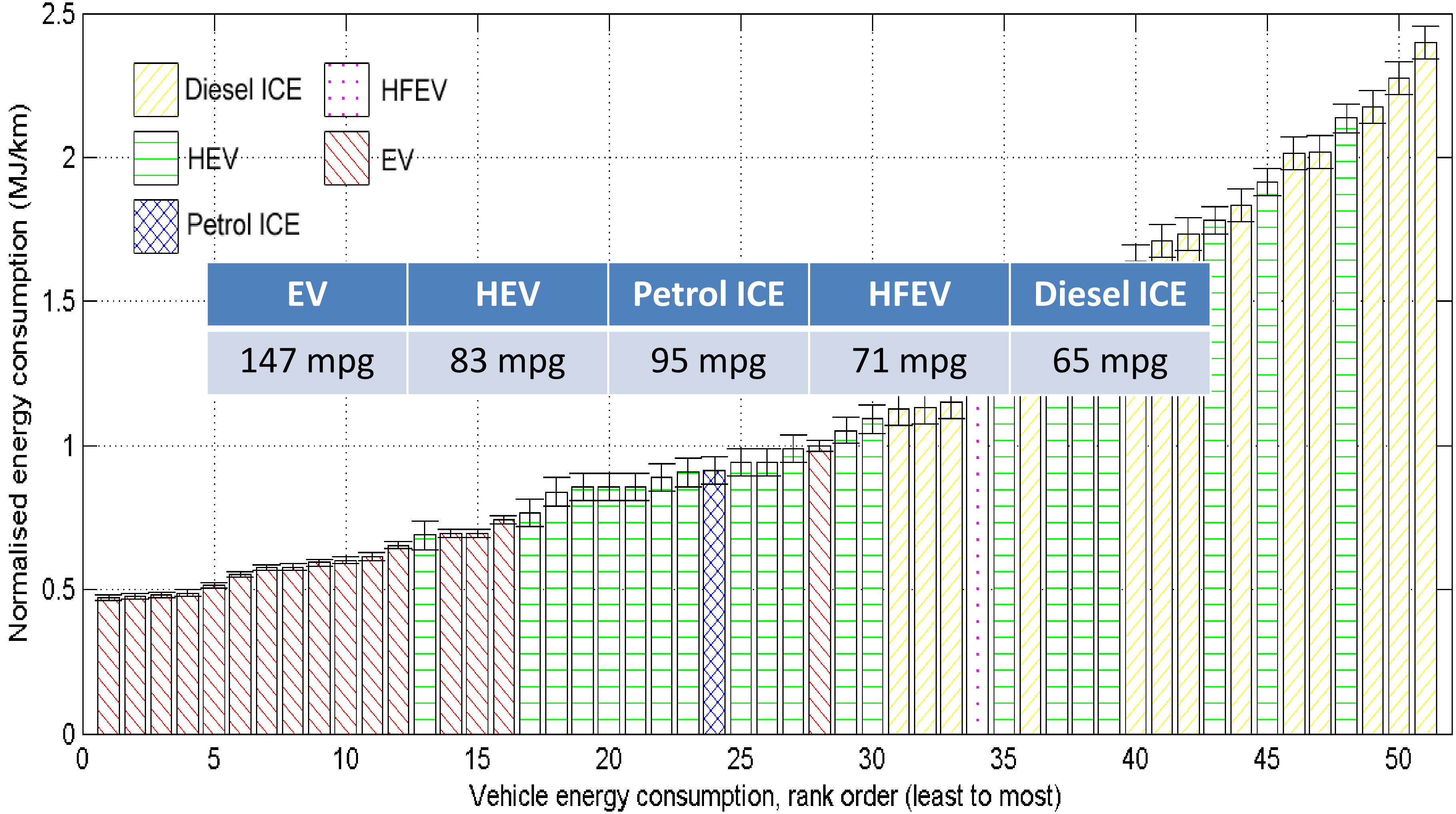


Energy consumption results

(including uncertainty margins)

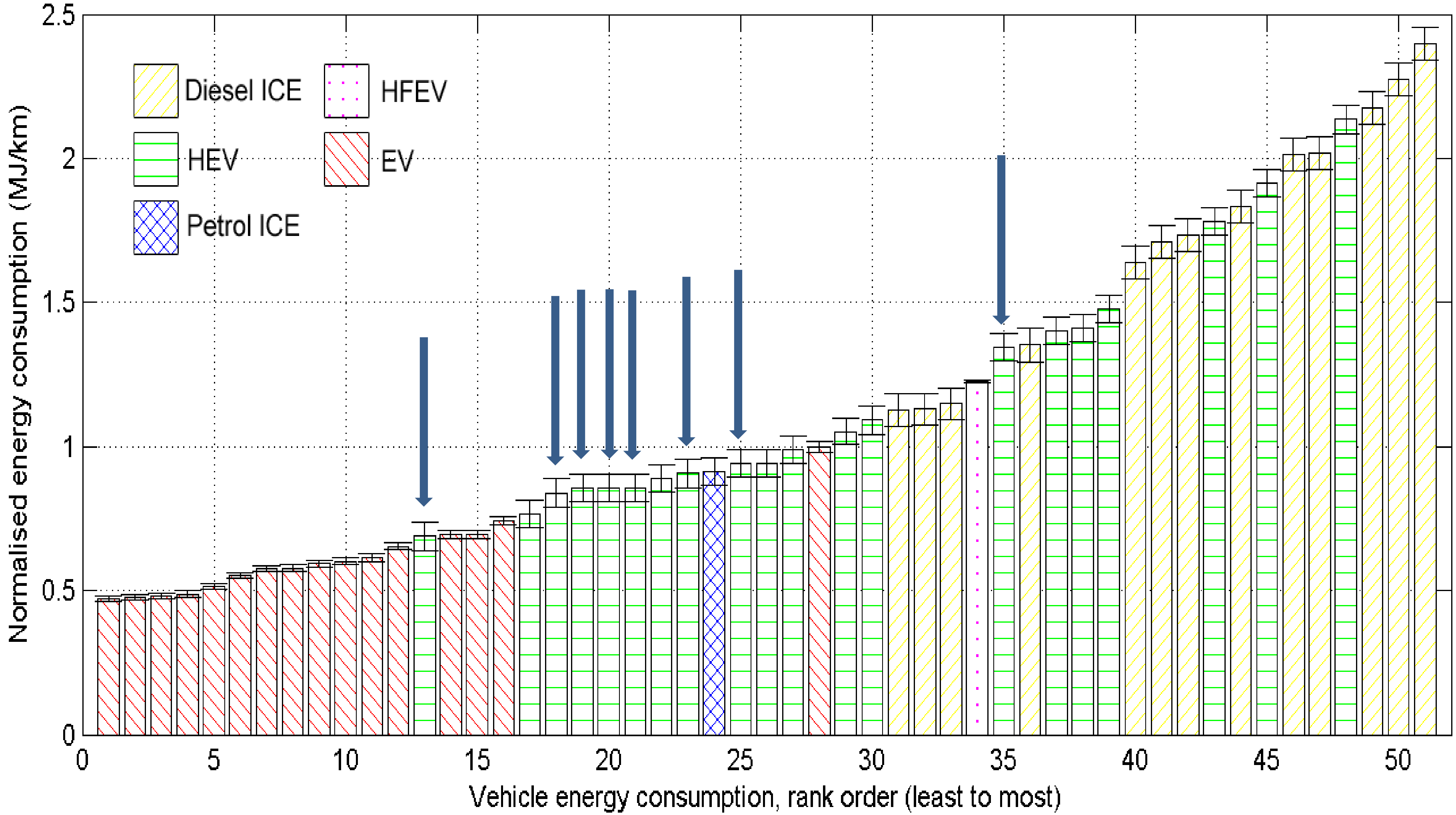


Performance on mpg equivalent

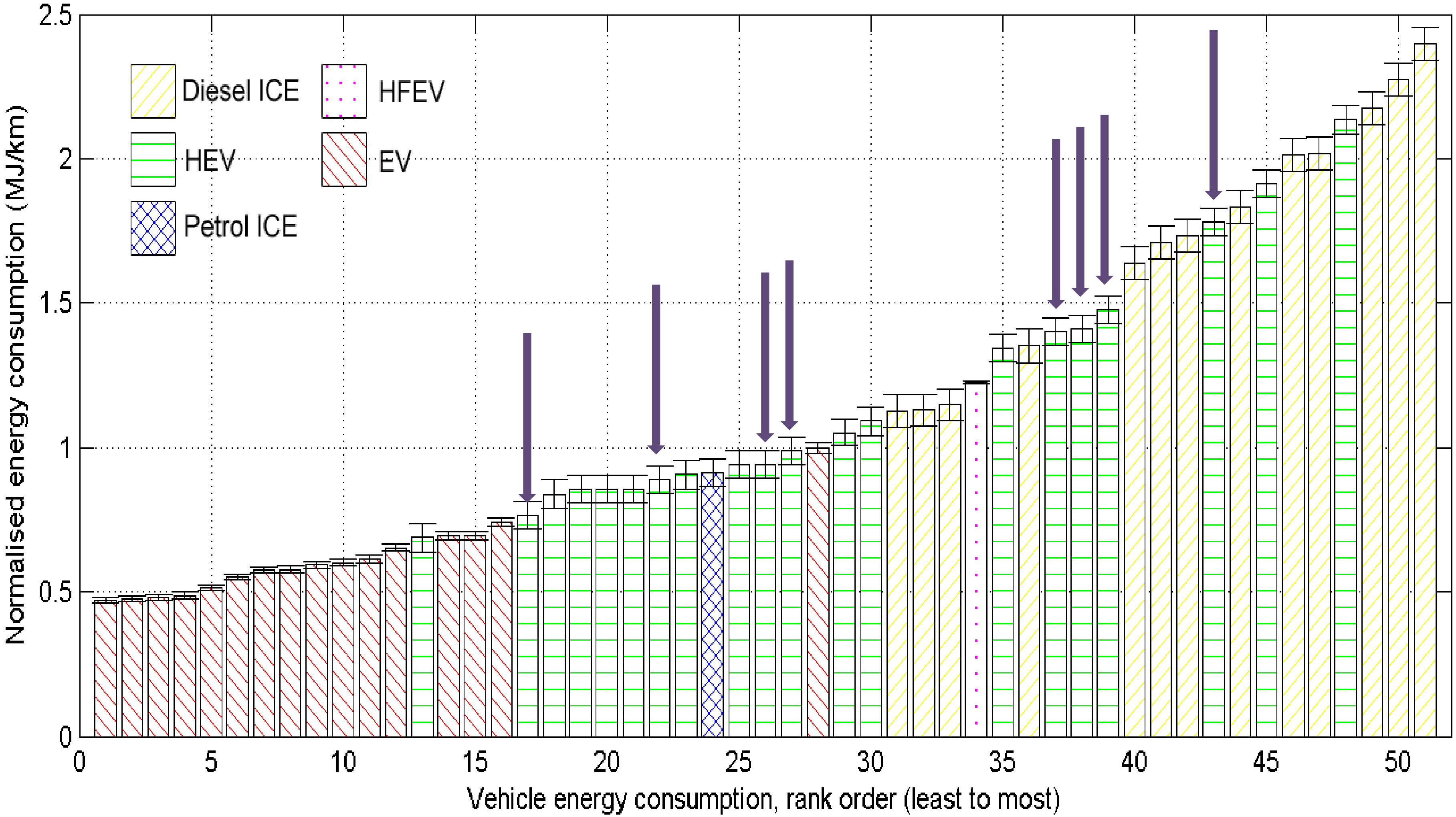


EV	HEV	Petrol ICE	HFEV	Diesel ICE
147 mpg	83 mpg	95 mpg	71 mpg	65 mpg

Driver impact on energy consumption?



Driver impact on energy consumption?



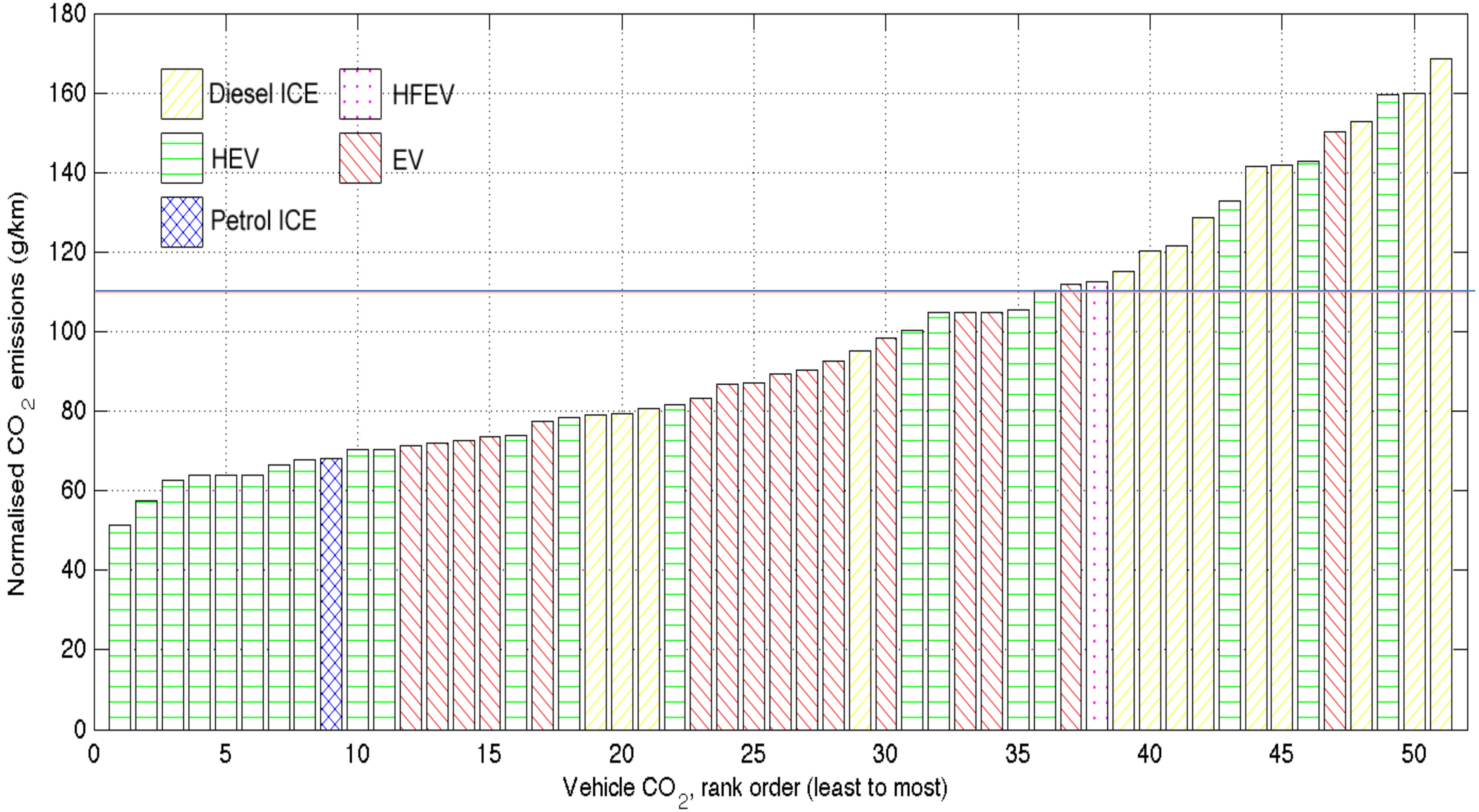
Do we need an "energy index" for performance?

CO_2 emissions conversion factors

	CO_2 emissions (g/MJ)	Assumption
Petrol	**74.7**	**Calorific value of 30.8 MJ/litre and CO_2 emissions 2.302 kgCO2/litre (DEFRA, 2010)**
Diesel	**70.2**	**Calorific value of 37.6 MJ/litre and CO_2 emissions 2.641 kgCO2/litre (DEFRA, 2010)**
Electricity	**151**	**UK grid rolling average CO_2 emissions 542 g/kWh including transmission and distribution losses (DEFRA, 2010)**
Hydrogen	**91.7**	**Produced from steam reformed natural gas according to assumptions in (Offer, 2010)**

Note: Upstream inefficiencies beyond the petrol pump or power station were not considered.

CO2 results impact results



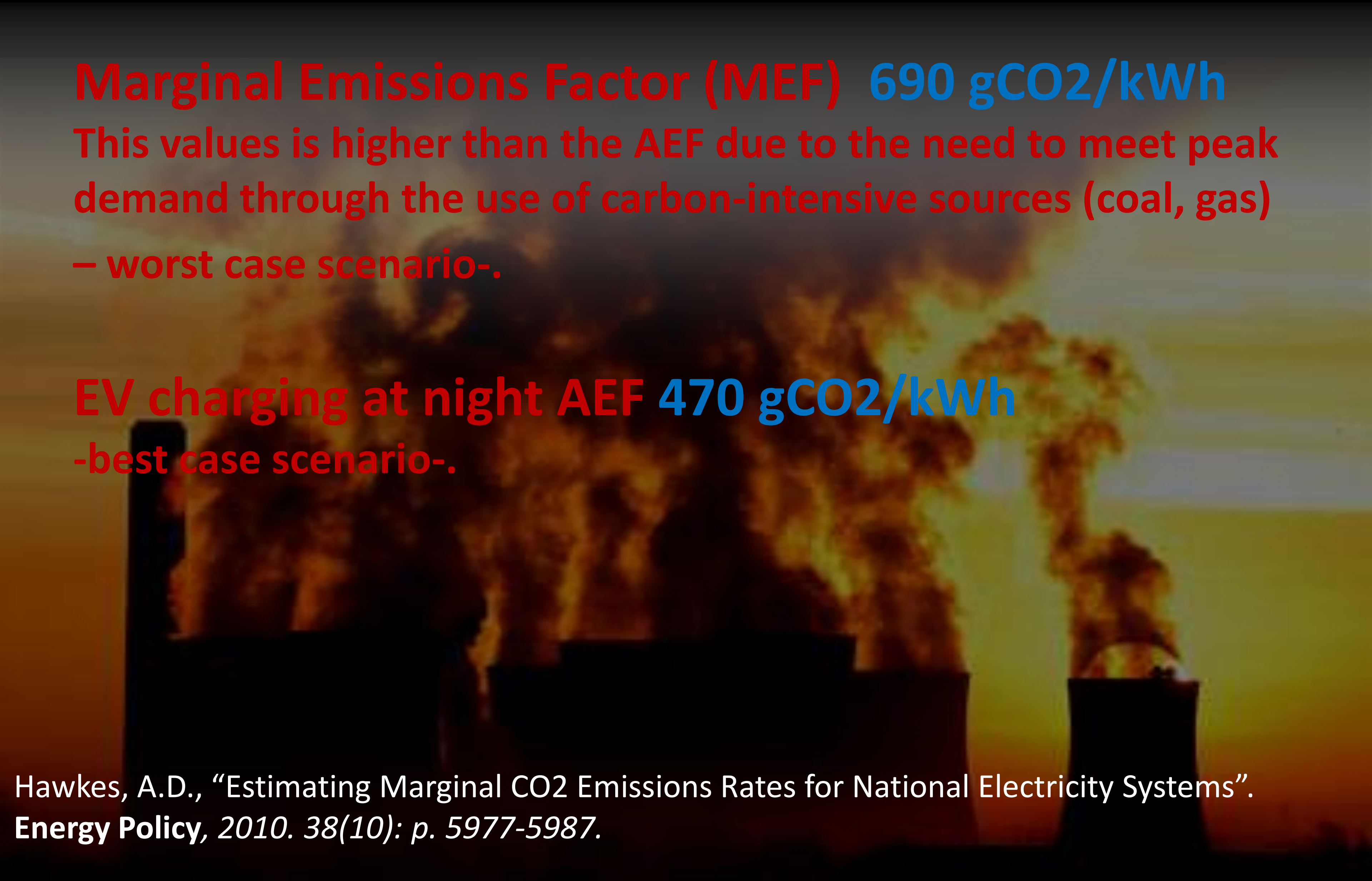
Average Emissions Factor (AEF) 542 gCO_2/kWh

Marginal Emissions Factor (MEF) 690 gCO_2/kWh

This values is higher than the AEF due to the need to meet peak demand through the use of carbon-intensive sources (coal, gas) – worst case scenario-.

EV charging at night AEF 470 gCO_2/kWh

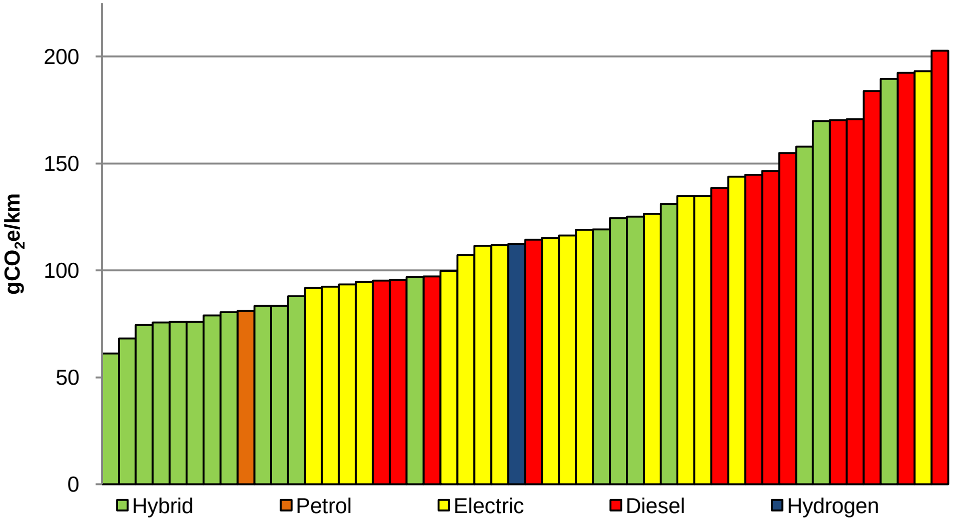
-best case scenario-.



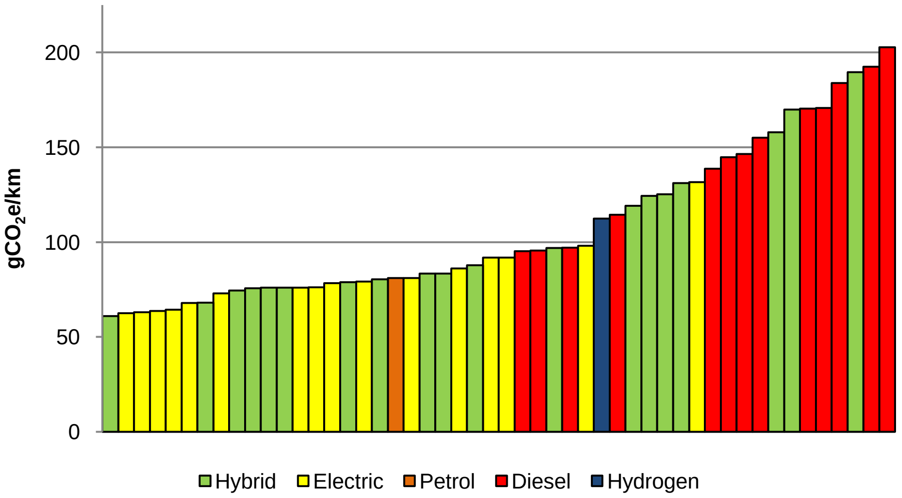
Hawkes, A.D., “Estimating Marginal CO2 Emissions Rates for National Electricity Systems”. **Energy Policy**, *2010. 38(10): p. 5977-5987.*

Worst case scenario vs Best case

690 gCO2/kWh



470 gCO2/kWh



Summary

ENERGY

16 competing electric vehicles used the least amount of energy (average 0.62 MJ/km).

This was followed by the 20 hybrid vehicles (average 1.14 MJ/km), and the 14 internal combustion engine vehicles (average 1.68 MJ/km).

CO_2

Hybrids gave the lowest CO_2 emissions, with around half of the vehicles emitting less than 70 gCO_2/km.

The most efficient diesel combustion engine vehicles emitted about 80 gCO_2/km but the majority exceeded 110 gCO_2/km.

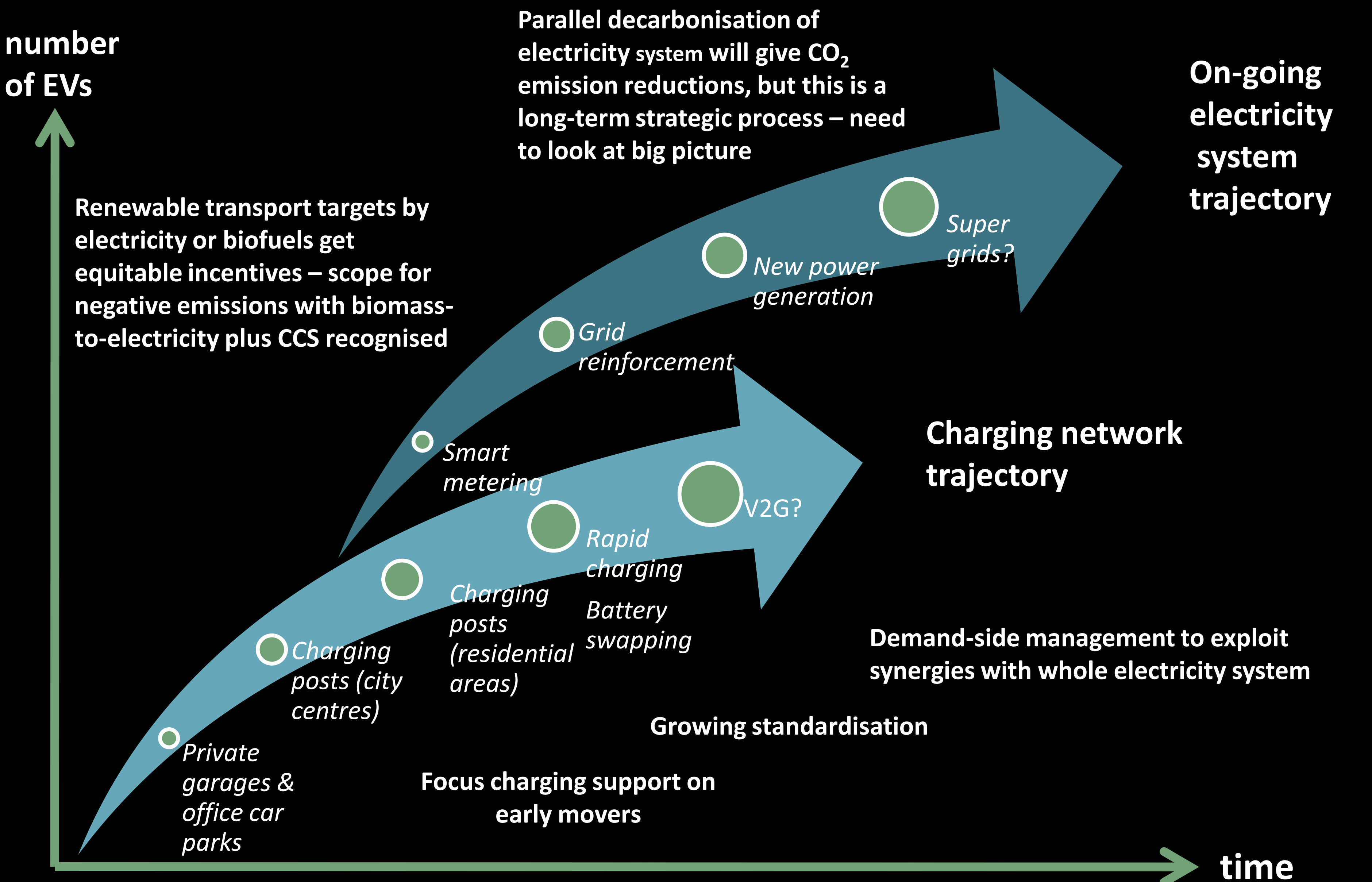
The majority of electric vehicles emitted 70-110 gCO_2/km assuming a UK grid average emissions factor of 542 gCO_2/kWh.

There is a stark contrast between these CO_2 figures and the 'official' figures published for the vehicles. 9 out of 14 ICE vehicles which claimed to emit less than 110 gCO_2/km exceeded this threshold, some by as much as 50%.

ISSUES:

Life cycle CO_2 emissions
Cost of power train
Demand reduction and fuel

EV infrastructure development pathways



Source: Alex Beaudet

CO_2 Versus Cost for Powertrain Technologies – D Class Car