The Results: 2010 Future Car Challenge

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Final comments
\[ \text{CO}_2 = D \times E \times F \]

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- VEHICLE KILOMETRES
- ENERGY PER KILOMETRE
- CO2 PER UNIT ENERGY
\[ \text{CO}_2 = D \times E \times F \]

ROAD TRANSPORT \rightarrow VEHICLE KILOMETRES \rightarrow ENERGY PER KILOMETRE \rightarrow CO2 PER UNIT ENERGY

- decrease demand
- shift to cleaner modes
- increase occupancy
\[ \text{CO}_2 = D \times E \times F \]

ROAD TRANSPORT

- Rolling resistance
- Aerodynamics
- Weight
- Energy conversion unit

VEHICLE KILOMETRES

ENERGY PER KILOMETRE

CO\text{2} PER UNIT ENERGY
\[ \text{CO}_2 = D \times E \times F \]

ROAD TRANSPORT

vehicle kilometres

energy per kilometre

CO2 per unit energy

biofuel

synthetic fuel

electricity

... low/zero carbon please!
Road transport technology and climate change mitigation

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

Executive summary

Cumulative global carbon dioxide (CO₂) emissions between now and 2050 will strongly influence the extent of climate change by the end of this century. Transport alone was responsible for around 23% of global energy-related CO₂ emissions in 2007. Transport emissions could become as much as 50% of all GHG emissions in 2050 if current policies are not implemented. The UK has committed to an 80% reduction in greenhouse gas (GHG) emissions in 2050, therefore need as a matter of urgency to decarbonise transport.

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Transport and energy sources and new powertrain systems 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 to developing economies, and the dependence of low-carbon vehicles on the still-evolving decarbonised energy supply and associated infrastructure.

How can we reduce transport emissions to meet the challenge of global climate change?
The Results from the 2010 BLFCC
### Vehicle type entries

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

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>mpg</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>147</td>
</tr>
<tr>
<td>HEV</td>
<td>83</td>
</tr>
<tr>
<td>Petrol ICE</td>
<td>95</td>
</tr>
<tr>
<td>HFEV</td>
<td>71</td>
</tr>
<tr>
<td>Diesel ICE</td>
<td>65</td>
</tr>
</tbody>
</table>
Driver impact on energy consumption?
Driver impact on energy consumption?
Do we need an “energy index” for performance?
## CO₂ emissions conversion factors

<table>
<thead>
<tr>
<th></th>
<th>CO₂ emissions (g/MJ)</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>74.7</td>
<td>Calorific value of 30.8 MJ/litre and CO₂ emissions 2.302 kgCO₂/litre (DEFRA, 2010)</td>
</tr>
<tr>
<td>Diesel</td>
<td>70.2</td>
<td>Calorific value of 37.6 MJ/litre and CO₂ emissions 2.641 kgCO₂/litre (DEFRA, 2010)</td>
</tr>
<tr>
<td>Electricity</td>
<td>151</td>
<td>UK grid rolling average CO₂ emissions [542 \text{ g/kWh}] including transmission and distribution losses (DEFRA, 2010)</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>91.7</td>
<td>Produced from steam reformed natural gas according to assumptions in (Offer, 2010)</td>
</tr>
</tbody>
</table>

Note: Upstream inefficiencies beyond the petrol pump or power station were not considered.
CO2 results impact results
Average Emissions Factor (AEF) 542 gCO2/kWh

Marginal Emissions Factor (MEF) 690 gCO2/kWh
This value 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 gCO2/kWh
-best case scenario-

Worst case scenario vs Best case
690 gCO2/kWh vs 470 gCO2/kWh
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).

CO₂

Hybrids gave the lowest CO₂ emissions, with around half of the vehicles emitting less than 70 gCO₂/km.

The most efficient diesel combustion engine vehicles emitted about 80 gCO₂/km but the majority exceeded 110 gCO₂/km.

The majority of electric vehicles emitted 70-110 gCO₂/km assuming a UK grid average emissions factor of 542 gCO₂/kWh.

There is a stark contrast between these CO₂ figures and the ‘official’ figures published for the vehicles. 9 out of 14 ICE vehicles which claimed to emit less than 110 gCO₂/km exceeded this threshold, some by as much as 50%.
ISSUES:

Life cycle CO2 emissions
Cost of power train
Demand reduction and fuel
Parallel decarbonisation of electricity system will give CO₂ emission reductions, but this is a long-term strategic process – need to look at big picture

Renewable transport targets by electricity or biofuels get equitable incentives – scope for negative emissions with biomass-to-electricity plus CCS recognised

Growing standardisation

Focus charging support on early movers

Demand-side management to exploit synergies with whole electricity system

Growing standardisation

On-going electricity system trajectory

Charging network trajectory

Renewable transport targets by electricity or biofuels get equitable incentives – scope for negative emissions with biomass-to-electricity plus CCS recognised

Growing standardisation

Focus charging support on early movers

Demand-side management to exploit synergies with whole electricity system

Growing standardisation

Private garages & office car parks

Charging posts (city centres)

Charging posts (residential areas)

Rapid charging

Battery swapping

V2G?

Smart metering

Grid reinforcement

New power generation

Super grids?
CO2 Versus Cost for Powertrain Technologies – D Class Car

- Suitable for all vehicle classes upwards of B class
- Suits gasoline engines but can also be applied to diesel engines
- Can be applied to other vehicles such as vans etc