Reducing Carbon Emissions from Road Transport

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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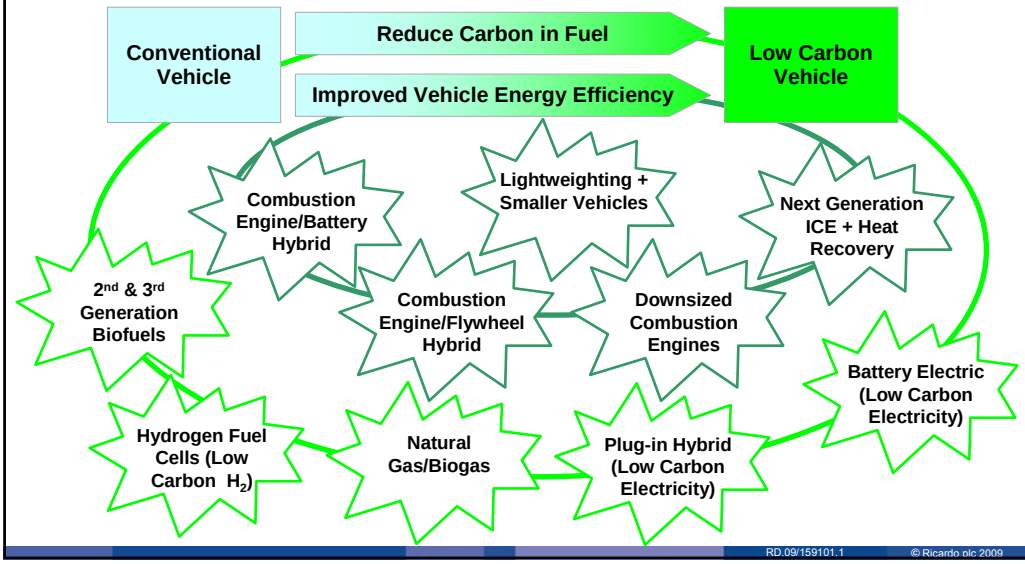
There are many technical options to reduce vehicle CO2 emissions - All have challenges & there are no clear winners – All are likely to be required to win the battle

- Low carbon vehicles achieved through improved efficiency and/or low carbon fuels:



The route to low CO_2 transport is too complex for a "single" solution - We should be wary of jumping from one favourite to the next..

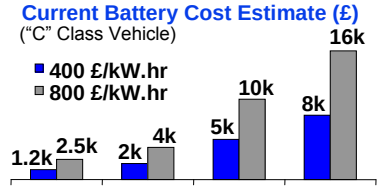
- Technology & "Fashion"

1980	Synthetic Fuels (Oil Crisis)
1985	"Adiabatic" Insulated Engines
1990	Methanol
1995	Electricity (CARB & EV1?)
2000	Hydrogen & Fuel Cells
2005	HCCI & "Alternative" Combustion
2007	Biofuels & Ethanol
2009	Plug-in Hybrids & EV's
2011	What's next?

- Policy makers frequently do not possess a Science/Technology background
- Auto Industry very bad at promoting high visibility "Green" techs for PR rather than substance/real mass market solutions

- Politicians need headlines & high profile policies:
  - "Put the right tax incentives in place & we will achieve a Hydrogen economy in <10 years"
  - "We have tried the technology neutral approach and it has not worked"
  - "The solution is... "
- Senior politicians often reliant on "policy units" and "think tanks"
  - "No-nothing twenty-something non-elected advisors trying to be radical"
- Big political initiatives:
  - "Hydrogen Highway" in California
  - Electrification of Transport
- Political enthusiasm too far ahead of technical & commercial capability

Electric and Plug-in Electric vehicles remain very expensive due to Battery Pack – "Lease" arrangement could be more competitive

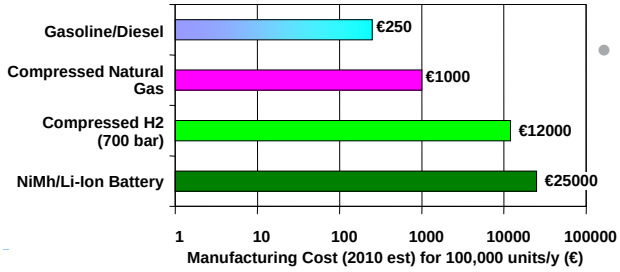


Note: battery cost is a contentious subject, driven by differing views on materials costs, rate of technical improvement, permissible depth of discharge (DOD), range, etc.

- Indicative Electric Vehicle Prices:
  - Aixam £14k
  - BYD £14k
  - G-Wiz £16k (Li-Ion)
  - MyCar £10k
  - Th!nk £12k (Zebra) $20k (Li-Ion) including $7500 tax credit?
  - i-MiEV £750 / month (ie £9kpa)
  - Tesla £80k-100k
  - Mini E ($850 / month in US, ie $10k pa)
  - Smart E ($30k in Switzerland)
  - Chevy Volt ($40k in US target price)
- Price dominated by battery pack
- Alternative is for battery "lease" arrangement
  - Removes Life/Replacement issue
  - Total Cost of Ownership closer to conventional vehicle
  - Highly dependent on price of Gasoline/Diesel

Alternative energy storage not competitive with liquid hydrocarbons Li-Ion batteries cannot compete on cost with conventional fuels

Onboard Fuel Tank System Cost (300 mile range)



- Current gasoline/diesel fuel tank filling rate approaches 40 megawatts!
- 300 mile range Li-ion battery (60 kW.hr) for "C" class vehicle €25000+ & 1000+ kg
  - Assuming €500/kW.hr & 80% DoD
  - Full range electric vehicle unlikely in short-medium term
  - Niche market for city vehicles

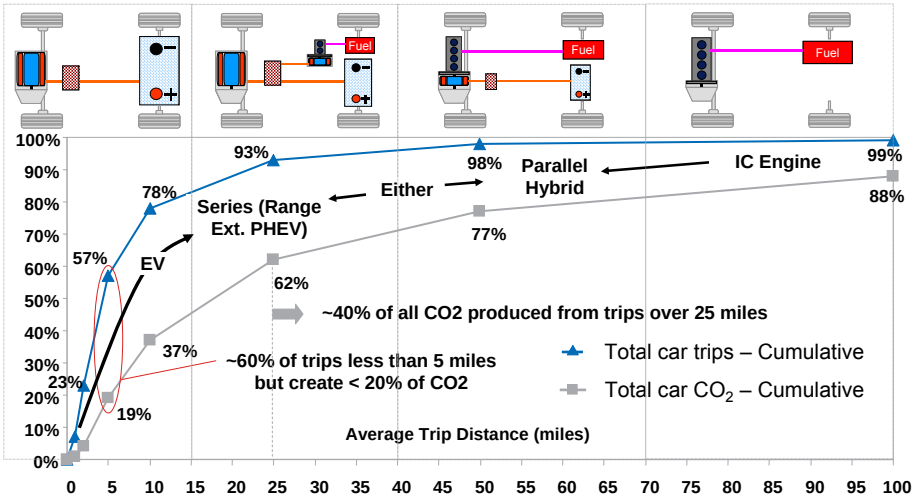
with	Vehicle Price without Battery	Vehicle Range	Annual Mileage	Battery Cost (£)	Annual Fuel Bill (£)	Assumptions:
Typical 1.0 litre City Car	£10k	Unlimited	8,000		550	4.3 litres/100km & £1/litre
City Electric Vehicle	£10k	80	8,000	9600	1100	Li-Ion £800/kW.hr & 10 Year Life

- 50 kW PM Electric Motor+Power Electronics+Electric HVAC cost ≈ 50 kW Gasoline Engine
- Battery cost must be reduced to ~ £400/kW.hr for Short Range City EV to be Competitive
  - Possible in time but price requires interim subsidy
- Plug-in Hybrid could provide more cost competitive product by minimising size of battery…

Electric Vehicle Challenges

Electric vehicles limited to city use due to battery size/cost - Range anxiety addressed by Series PHEV – IC/Parallel hybrid for highway

- Most efficient powertrain configuration is a function of application

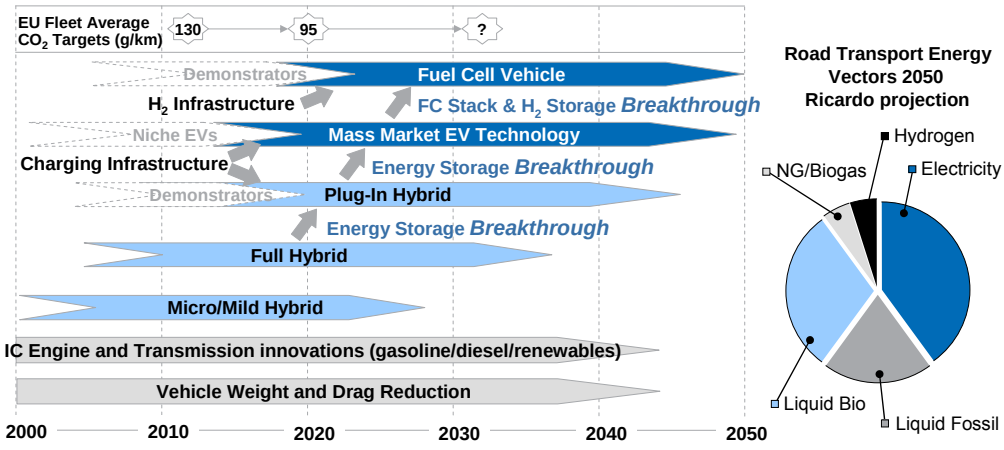


- EV likely to be more efficient for city use but series electric range extender less efficient than parallel hybrid for highway/motorway travel

GB, 2002/2006 average. Source: DfT analysis; Ricardo roadmaps

Long Term Vision & Roadmap

The *long term* will require a mass market shift to new energy vectors driving the need for "mainstream alternative" powertrain technology



Regulated by Tailpipe CO_2 or Vehicle fuel efficiency → Regulated by Well to Wheels CO_2 & efficiency → Regulated by Life Cycle Analysis

Source: Ultra Low Carbon Vehicles in the UK – BERR/DfT; Ricardo roadmaps and technology planning; Shell Energy Scenarios to 2050 (2008)

Low Carbon products must be mass produced to make an impact; There is very little original R&D in the UK but new initiatives to co-ordinate & focus investment provide real opportunities for progress

Challenges

- Automotive is a capital intensive industry – A new mass market product can cost over £1 billion to launch and up to 10 years before a net return on investment
- Niche products have no effect on fleet CO_2
  - but can drive demand for mass market
- Selling higher cost low CO_2 vehicles to early adopters & affluent lifestylers is easy
  - Mobilising the mass market is difficult
- There is very little advanced automotive R&D carried out in the UK – Largely offshore
  - The UK automotive supply network finds it difficult to engage in R&D with vehicle OEM's
- The UK automotive community has very little experience in working together
  - Loss of IP or competitive position?

Opportunities

- Formation of the New Automotive Innovation Growth Team has stimulated UK Auto industry co-operation
- UK Research Council focus on Economic Impact and co-ordination with Technology Strategy Board
- Public Procurement of Low CO_2 Vehicles
- Emerging common consensus on future Automotive Technology roadmap
- The UK automotive supply chain is highly responsive to change with best practice engineering and manufacturing
- UK's leading position in motorsport could be used to stimulate automotive skills development especially in engineering
- The Japanese Auto Manufacturers now operating in the UK have developed much more cohesive supply networks

Source: Vision for the UK Automotive Industry in 2020 – B McGinty & S Parker

Industry/Government consensus for sustainable low CO_2 transport – Collaboration/Co-operation & Long Term Planning will speed delivery

- **Auto Industry should be more Constructive**
  - Spend less effort resisting & work together to provide a long term plan based on Industry/Government co-operation –> NAIGT "Automotive Council"
- **Economics Rules OK**
  - Lower carbon vehicles cost more money to make than deliver savings in fuel bills
  - Assume long term **not** short term fiscal and/or policy support to be viable
- **UK strategy should be to lead** in key areas, not be mediocre in many
  - Develop Technology "pipeline" via co-ordinated University Research; Pre-competitive research; Industry R&D
  - Develop & support vertically integrated OEM/supplier R&D collaborations and networks
  - Use long term Government procurement policy to create low carbon markets
  - Develop/support leading UK suppliers

UK Opportunities

- Next generation Clean Diesel
- Intelligent Transport Systems
- Next generation Battery Chemistries – "Leapfrog"
- Lightweight Structures/Composites
- Design/Engineering Services
- KERS for road cars