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Hydrogen a future transport fuel?

For

SHIFT conference

19th September 2007

contents

- Why hydrogen for transport
- Technical progress
- Global hydrogen support
- UK activities
- Some conclusions

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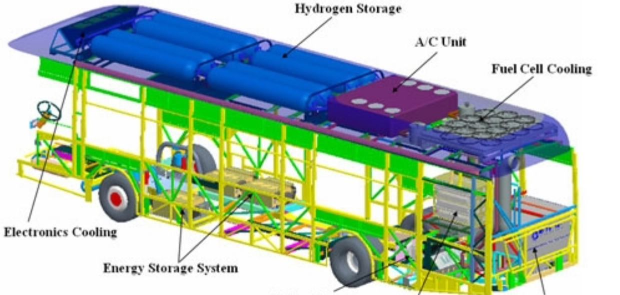
Hydrogen for transport offers.....

- CO_2 free transport
- Access to a diversity of energy sources - avoiding dependence on a single energy supply (e.g. Middle East)
- Virtually noiseless cars
- An equivalent or better driving experience to gasoline based cars
- And emissions so clean you can drink them.



Hydrogen in an ultra low CO_2 economy

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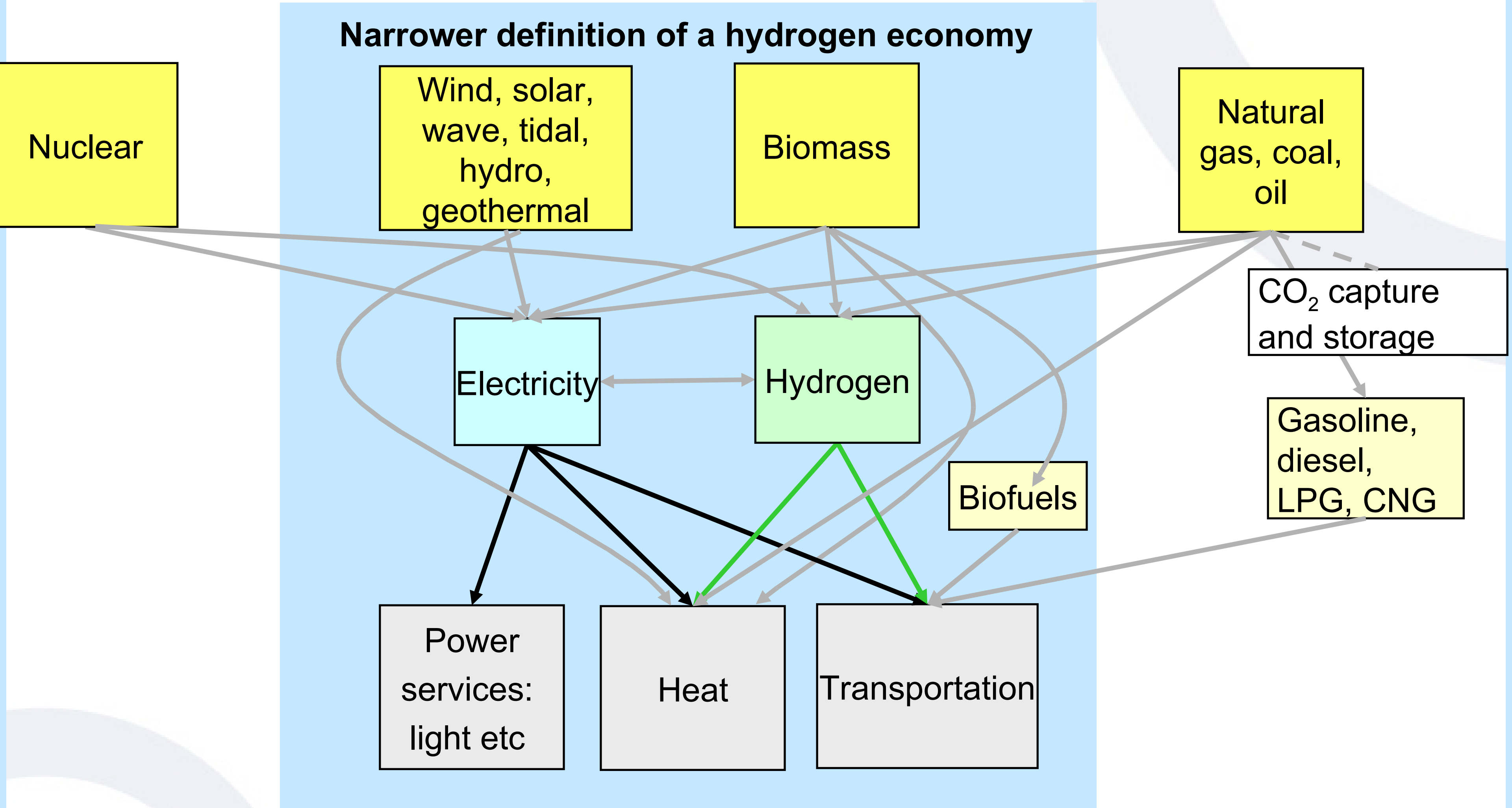

From DTI's strategic framework on a hydrogen economy – E4Tech, Element Energy and Eoin Lees Energy

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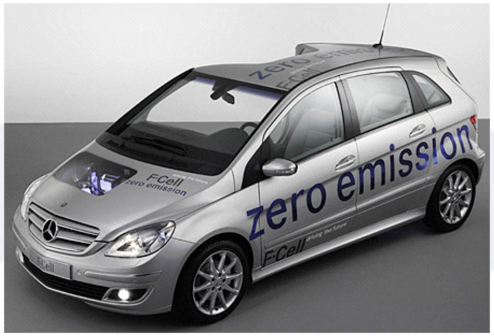
And all car companies have major development programs….but when will they be commercial?

Honda



Daimler Chrysler

GM (Opel/Vauxhall)

DC Citaro (operating in London)

ENV bike

Toyota fork lift

BMW

Van Hool

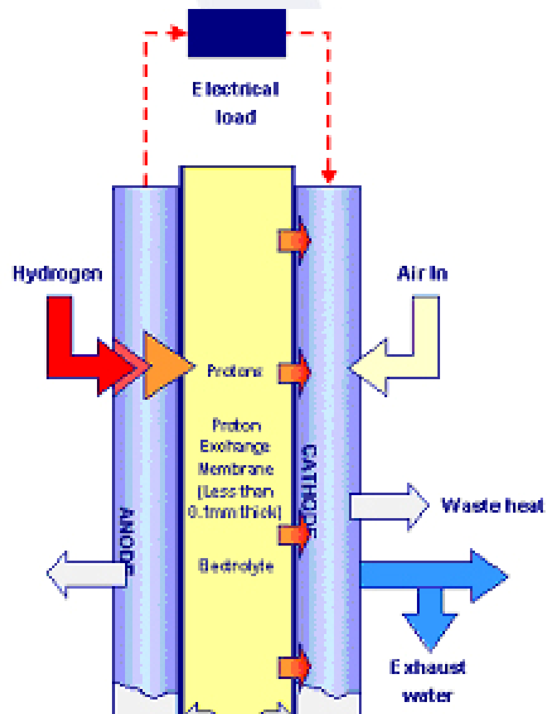
Toyota

Fuel cells are the main focus

Most excitement around hydrogen transport centres on fuel cell, powered vehicles.

In a fuel cell, an electrochemical reaction generates electricity and emits only water.

The process is significantly more efficient than combustion in conventional engines.



IC engines can be modified for H_2

It is also possible to modify an existing gasoline engine to use hydrogen.

This may offers a lower cost route to hydrogen vehicles, using today's technology.

However, efficiency is lower than for fuel cells.

The hydrogen BMW uses a hydrogen internal combustion engine.

The lower efficiency means they have used liquid hydrogen for on board storage to provide sufficient range.

If plausible technology development assumptions are made, hydrogen can play a major role in zero carbon transport

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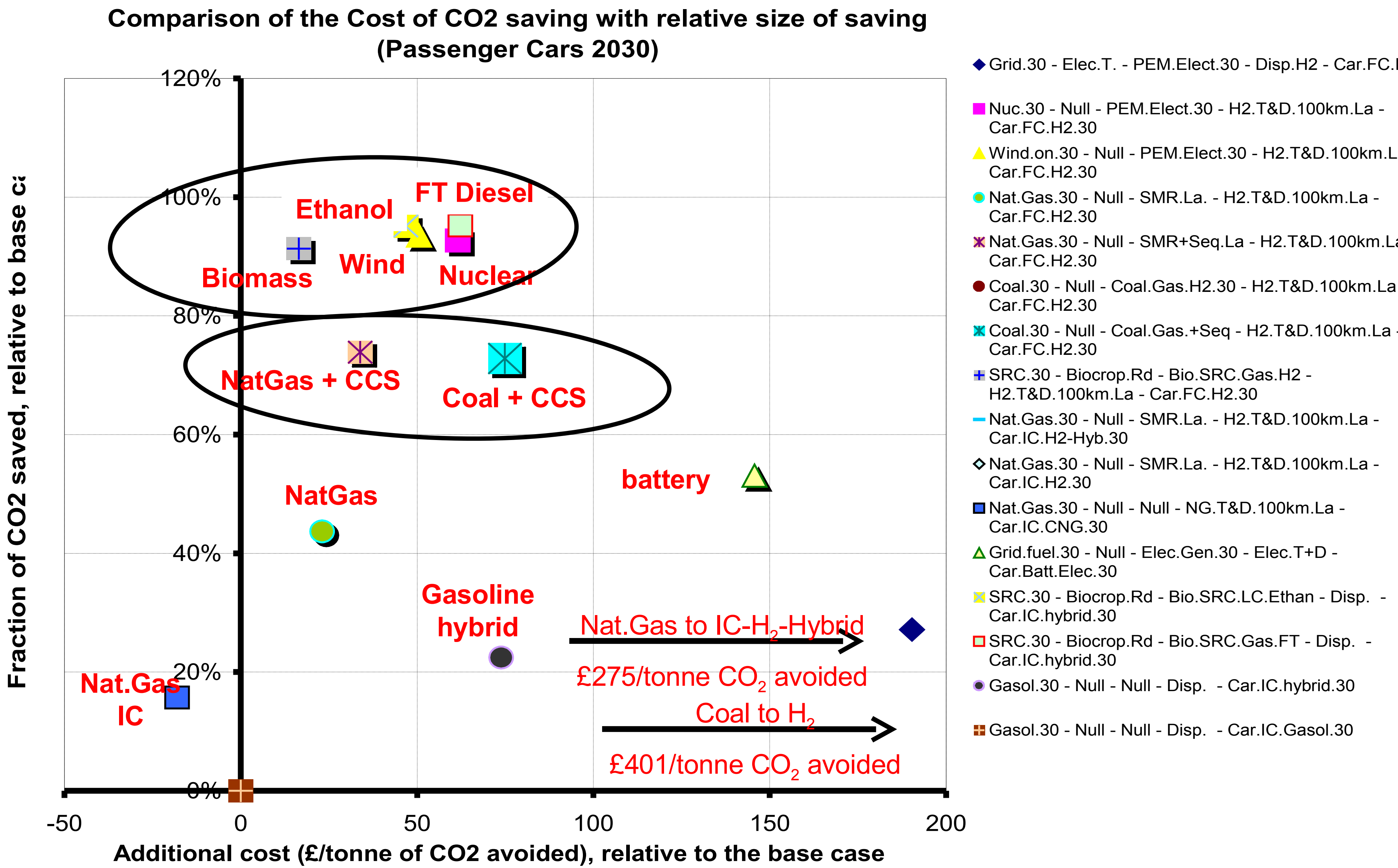
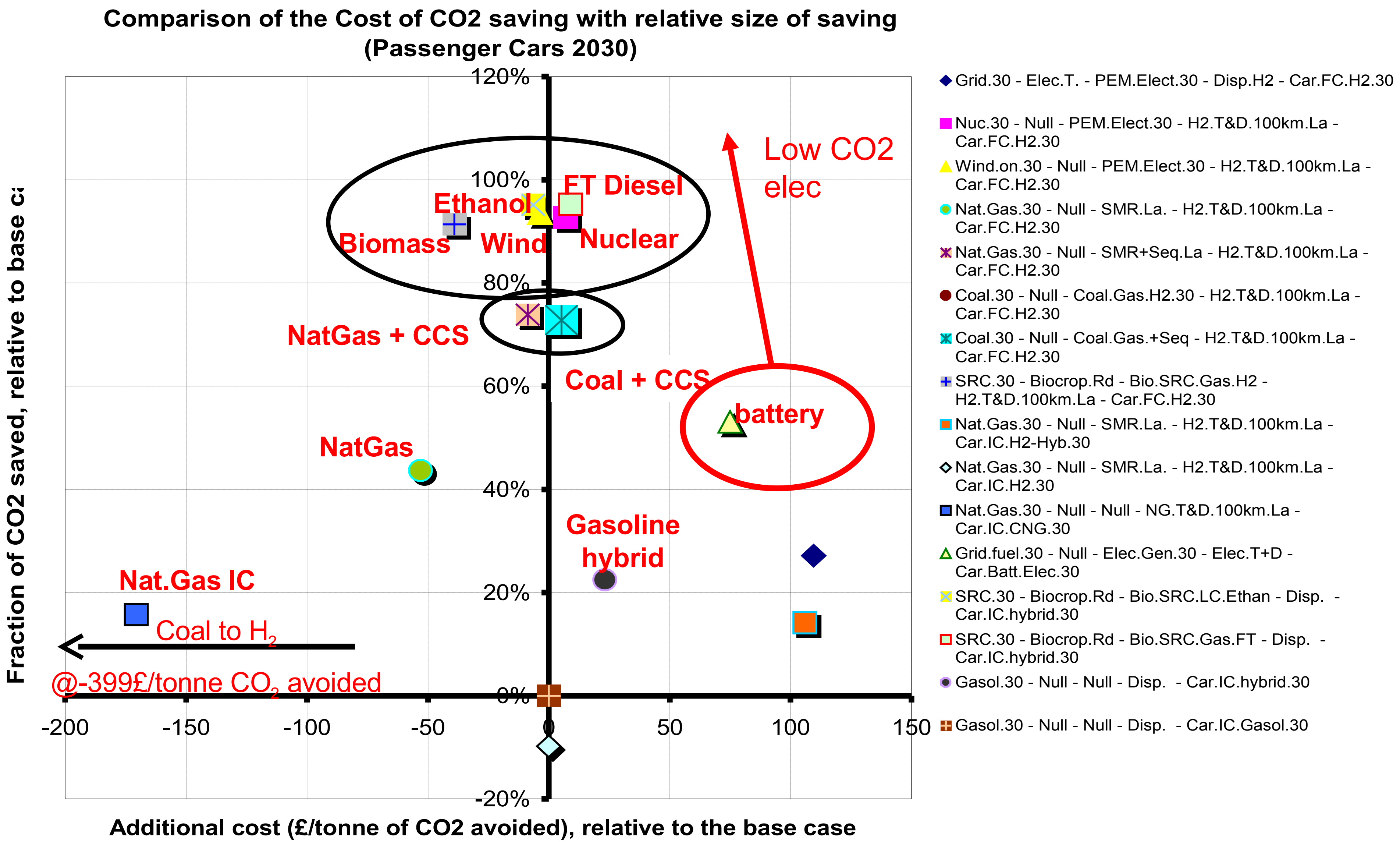


The arguments are only strengthened by a rising oil price (below assumes $50 per barrel)



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6 zero CO_2 routes to transport

Our analysis suggests that by 2030, hydrogen could offer up to six affordable routes to ultra low CO_2 transport.

- Wind, PV or other renewable electrolysis
- Nuclear hydrogen generation (thermochemical or electrolytic)
- Coal (with sequestration of CO2)
- Natural gas (preferably with sequestration)
- Biomass gasification
- New technologies, including photo-electrochemical, biological fermentation and photosynthetic processes

This diversity of choices has benefits for security of supply as well as the obvious CO_2 benefits

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The key 'assumptions'

Despite the potential, substantial improvements are required in:

- **Cost of vehicles** – H_2 Vehicles are currently an order of magnitude too expensive. This needs to be reduced through technology improvements and volume manufacture.
- **Hydrogen storage** - storing a gas at sufficient density to provide adequate range. Current vehicles give up to 300 miles (@700 bar H_2)! Storage costs also affect transport of H_2.
- **Refuelling infrastructure** - needs to be deployed alongside rollout of vehicles
- **Component lifetime** - especially fuel cell life

Progress on the 'assumptions'

These projects give some perspective :

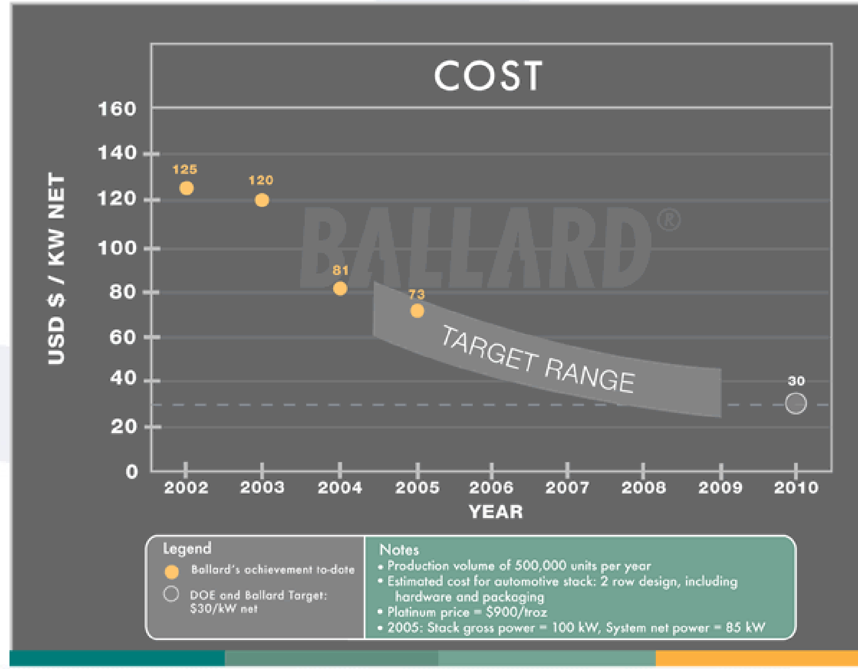
- **Cost** - still a challenge - acceptable in niches (warehousing), but mass markets will require volume manufacture.
- **Storage** - at 700 bar, acceptable range can be achieved. 350 bar is acceptable for London buses. Storage is more of an issue for infrastructure.
- **Lifetimes** - improving as understanding of the core chemistry improves. Lifetimes over 3,000 hours already available
- **Infrastructure** - no significant investment to date. Significant uncertainty about the best methods of achieving low CO_2 hydrogen.

Key to commercialisation is marrying infrastructure with an OEM commitment to mass manufacture

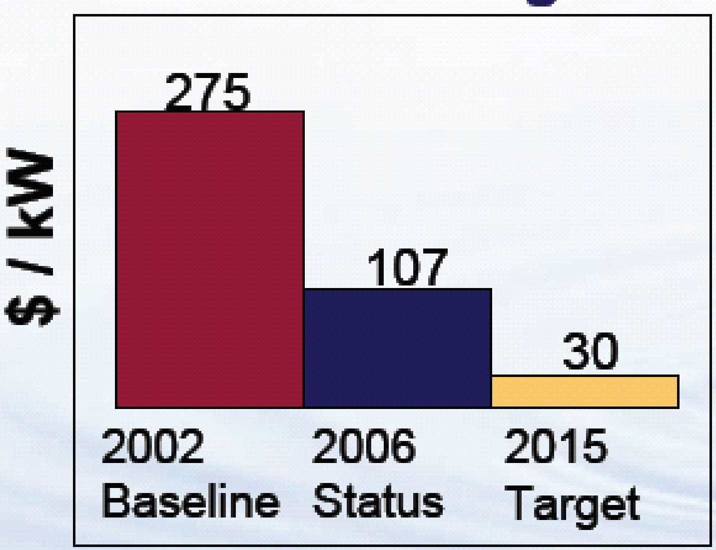
There has been substantial progress on cost reduction and durability.

Data shown is from Ballard and the DoE hydrogen program.

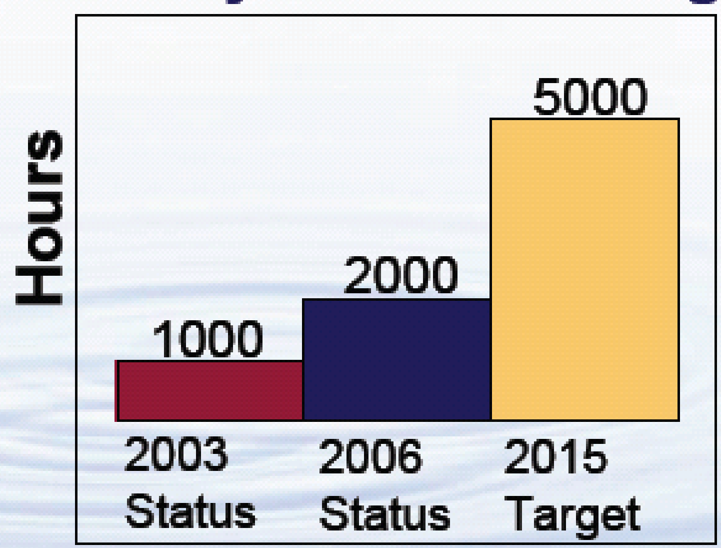
Evidence suggests that warranties ell over 3,000 hours are currently offered on FC products



Fuel Cell System Costs Status vs. Targets

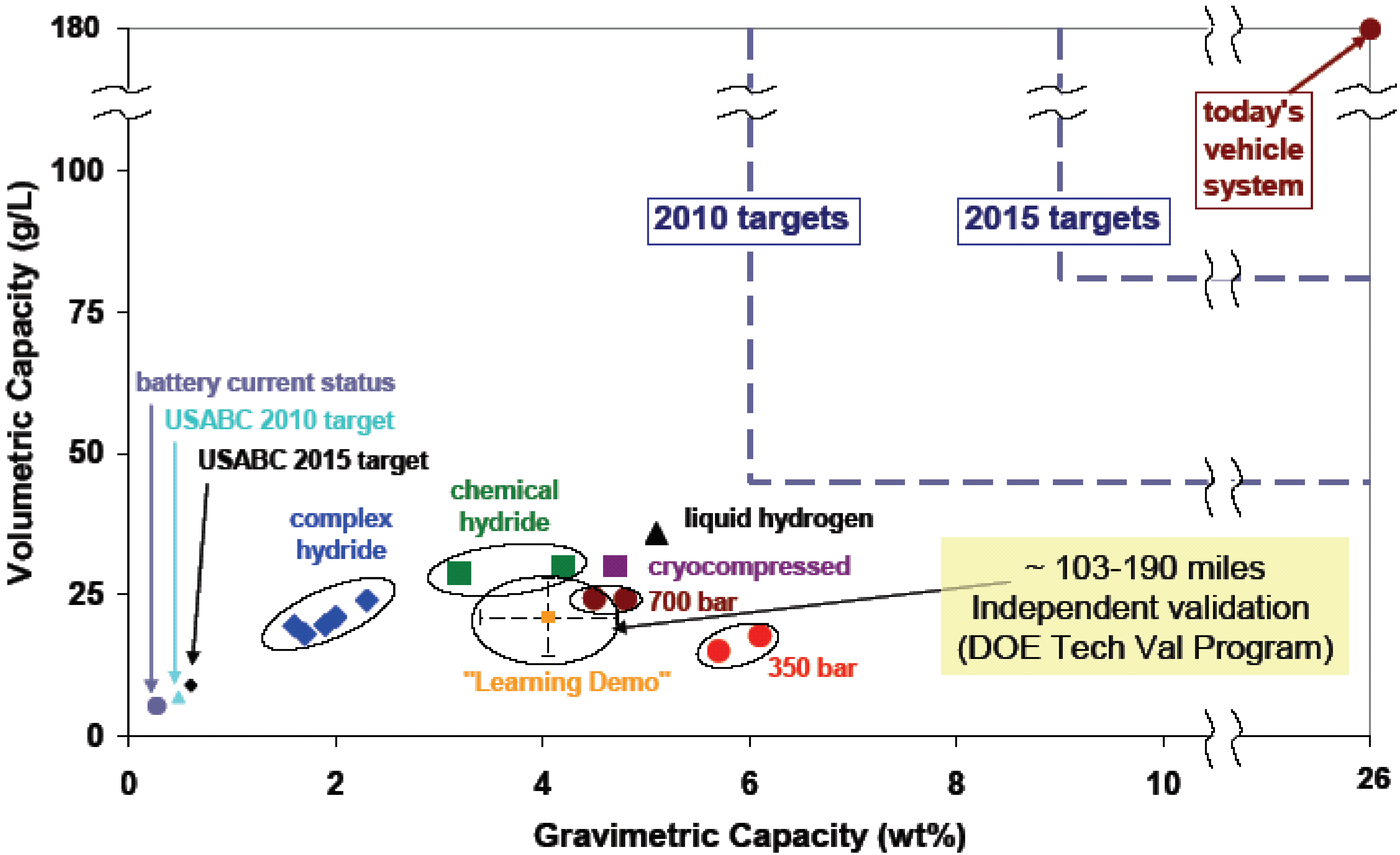


Fuel Cell System Durability Status vs. Targets

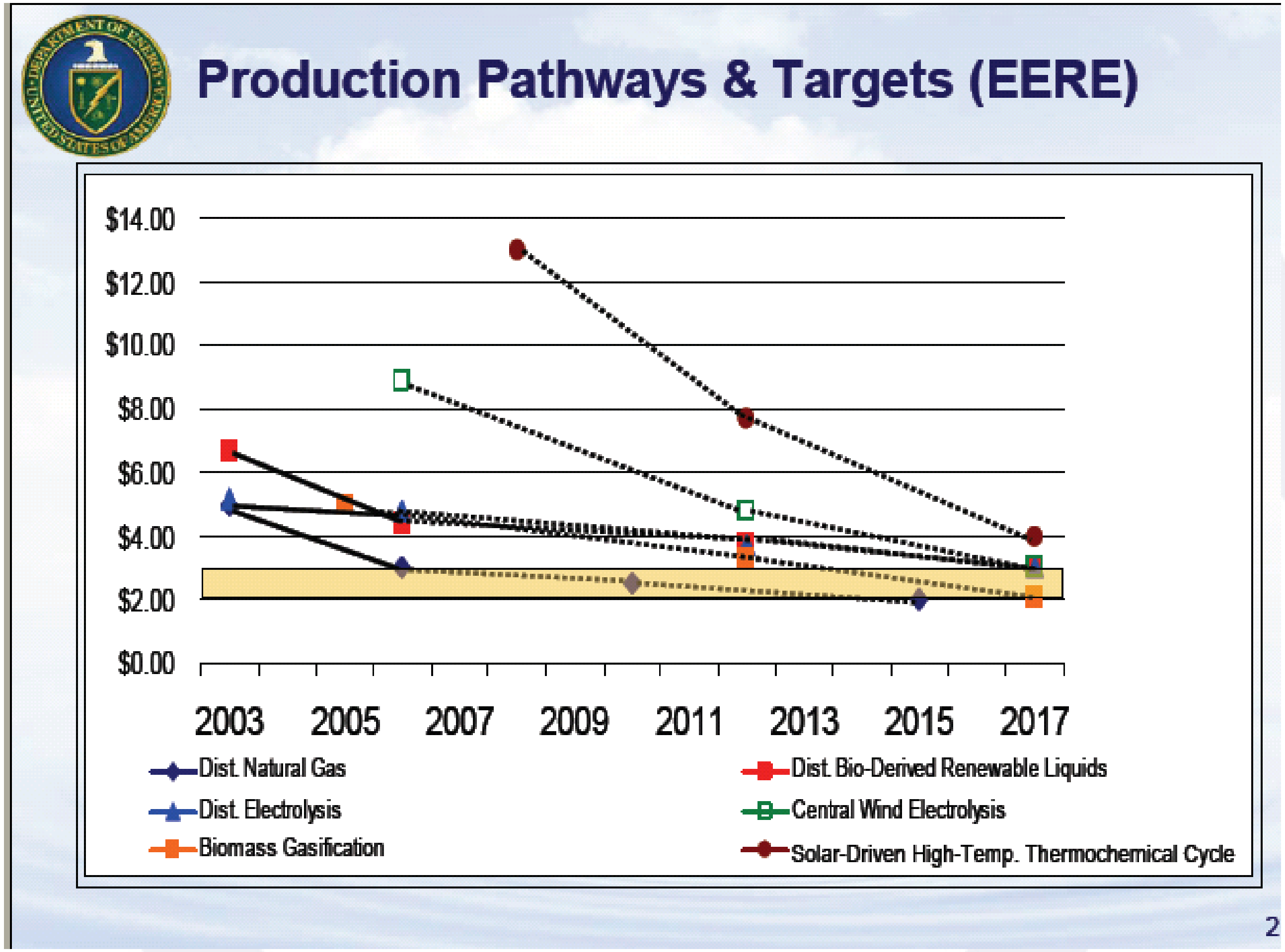


H2 storage is the subject of considerable research, but no 'magic' solution has been found

No technology meets targets- results include data from vehicle validation



Estimates from developers & analysis results; periodically updated by DOE. "Learning Demo" data is for 63 vehicles.



US DoE targets suggest affordable hydrogen technologies will become available and an affordable cost

However, very large capital infrastructure investment will be required to deliver hydrogen to the > 25% of filling stations require for vehicle rolllout.

Options other than hydrogen?

There appear to be only three options for completely taking CO_2 out of the transport system.

Each option is subject to considerable uncertainty

- **Bio-fuels** – currently favoured, but significant concerns over the overall resource and hence effect on agriculture, also concerns over energy use in production.
- **Batteries** – battery only vehicles, fed by renewables appear attractive, but there is no chemistry which offers practical range and refuelling time.
- **Hydrogen** – currently held back by cost and status of tech development.

At present, all options remain open

Worldwide there is substantial support

Hydrogen is being pursued by each of the major developed economies:

The US is targeting 2015 for commercialisation of hydrogen transport, based on a detailed hydrogen plan (>$2 billion).

“I believe that today’s children will one day take their driver’s test in a hydrogen-powered, pollution-free car. It’s a big goal, but it’s an attainable goal,”

Japan has a structured program with a target of 5 million vehicles on the road by 2020.

China is also taking hydrogen seriously…….

Europe is ‘building consensus’

The EC has developed an ‘implementation plan’ which envisages a major public private partnership to deliver:

- R&D in infrastructure and hydrogen vehicles sufficient to kick start commercialisation from 2015 or earlier
- Commercially acceptable lifetime (5,000 hours), efficiency (>40%) and range by 2015
- Affordable cost vehicle components by 2015.
- 1-5 million vehicles on EC roads by 2020
- 0.4 to 1.8 million H_2 vehicles sold annually from 2020

Total transport related investment will be **2.6 billion euro**

When will it happen? – some guesses

Hydrogen for vehicles will develop in niche applications first.

- The first commercial niche appears to be in lifting equipment for warehousing (relevant from 2007)
- Zero emission buses may be the next opportunity (commercial 2015, major trials now)
- Also, niche vehicles (e.g. urban delivery) could have an early role (from 2010)
- Major car manufacturers are aiming between at 2015 for their first commercial hydrogen vehicles

UK Hydrogen initiatives tend to be regional

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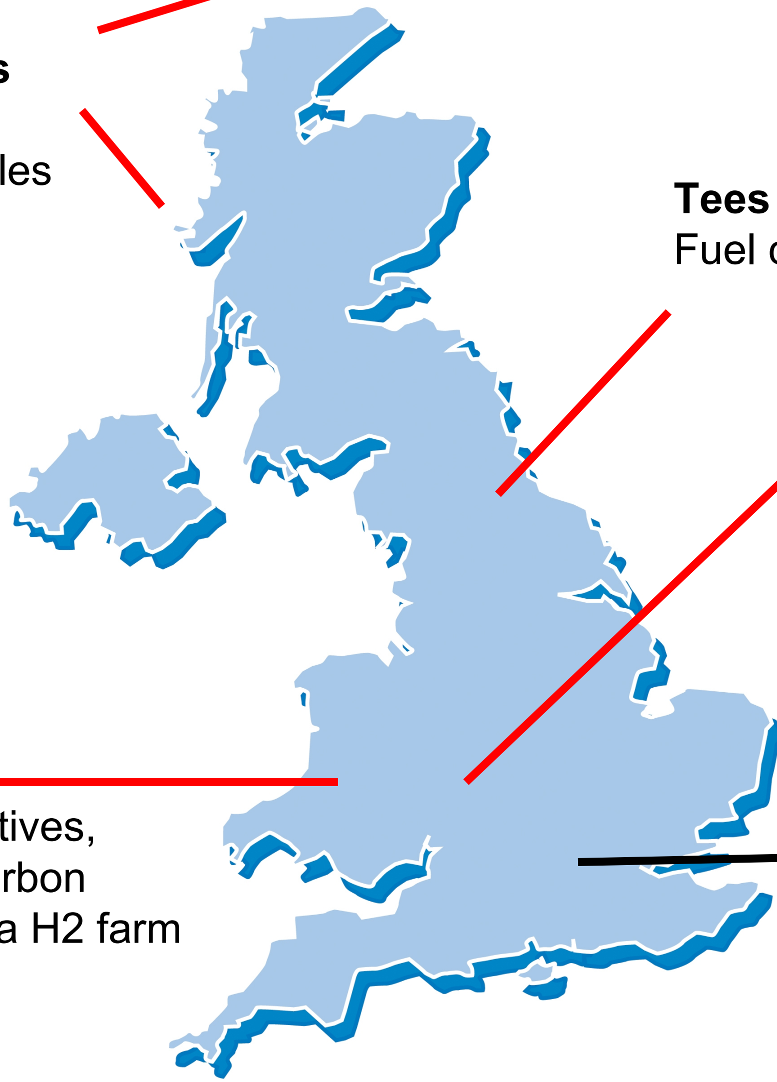
Scottish islands
SFCC
Excess renewables

Tees Valley
Fuel cells applications facility



West Midlands
Strong manufacturing base for both automotive applications and fuel cell manufacture

Wales
H2 Wales
Numerous initiatives, including low carbon production and a H2 farm

London
CUTE
London Hydrogen Partnership
Mayors deployment program for 70 vehicle by 2010
Support for numerous stationary applications

UK government is now engaging

The DTI has announced a £15 million, three year program for hydrogen demonstration activities!

The fund will support near commercial technologies in buildings and transport – mainly in large projects.

This funding is in addition to an annual fund for hydrogen and fuel cell R&D and substantial regional investments.

In addition, the government now has a clear position on hydrogen and is supporting the European activities.

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London Hydrogen Transport Programme (LHTP)

TfL are currently delivering the London Hydrogen Transport Programme, backed by the Mayor and developed by the LHP.

70 vehicles will be deployed, including 10 buses on a complete bus route.

Three new filling stations will be deployed, one based at a bus depot (currently largest in Europe).

The project is aimed at making London a global player in H_2.

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conclusions

Hydrogen clearly offers zero carbon transport.

IF technology develops as expected, the cost of the technology could be manageable.

Initial trials have been technically encouraging, but there is much work to do.

The current challenge is linking the deployment of infrastructure with mass manufacture of vehicles

Between 2010 and 2020 niche transport technologies will become competitive, but the passenger car is an unknown

The UK has a lot of catching up to do to remain competitive.