Fuel cells and hydrogen: the future

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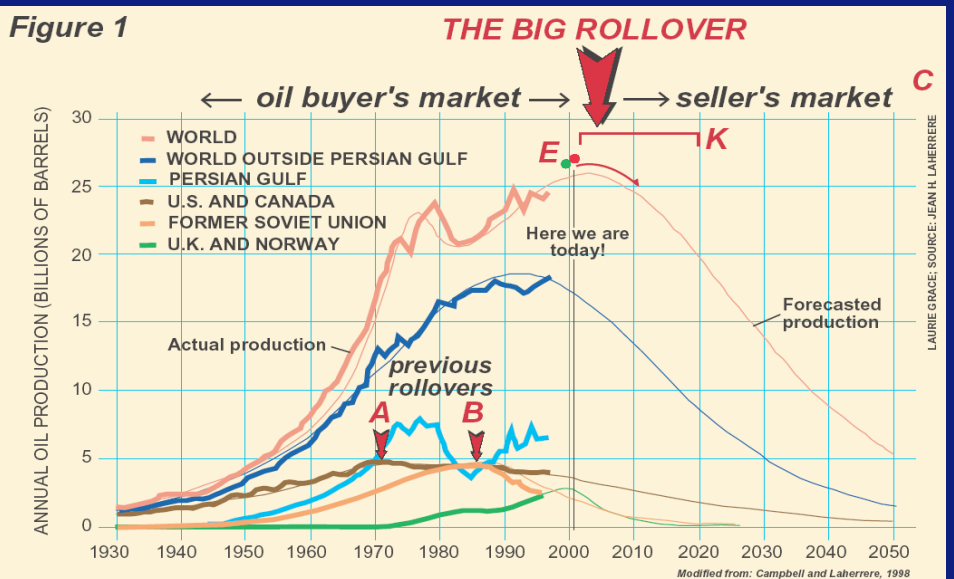
Presentation outline

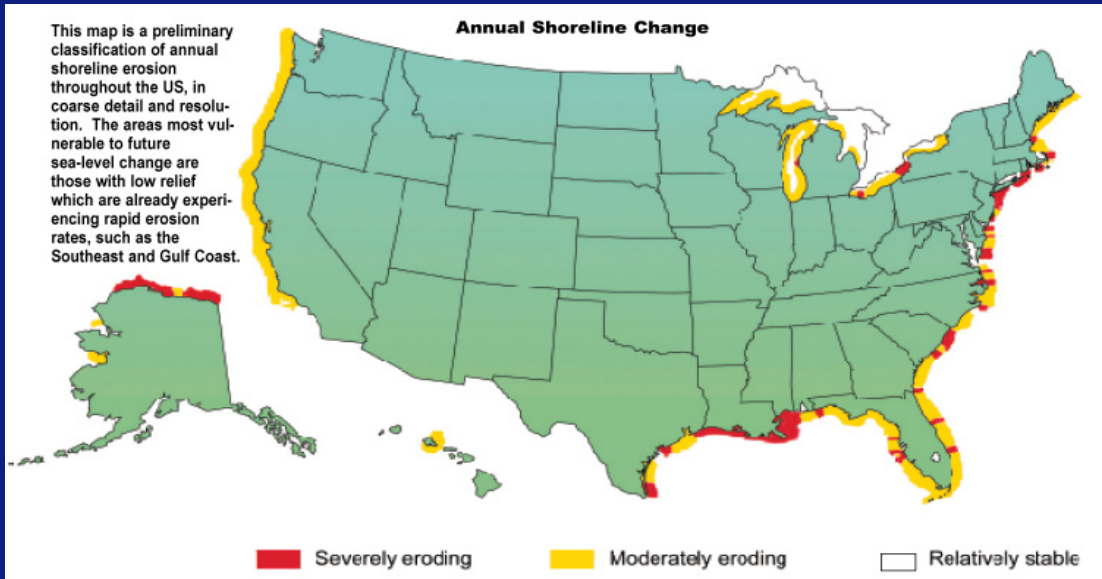
- Facing up to the problem
- Possible solutions
- So why fuel cells and hydrogen?
- Are they real?
- What next?

Massive growth in transport is causing tensions around energy use

- Air quality is dropping
- Greenhouse gas emissions rising
- Raw materials extraction is unsustainable
- Supply is increasingly concentrated

The devil…or the deep blue sea?





We can either drastically reduce transport demand, or use ‘technology fix’

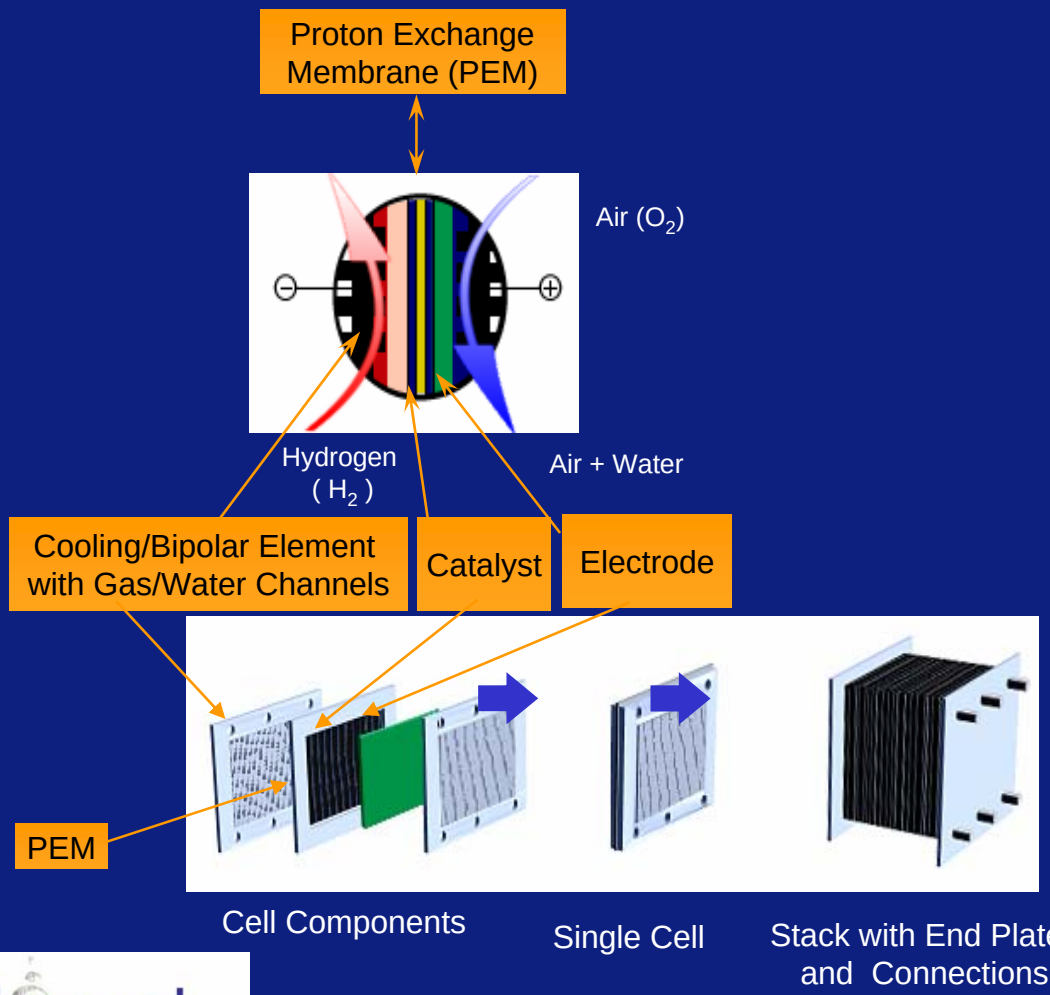
- Reductions are not about hair shirts:
  - More efficient vehicles
  - More people per vehicle
  - More, better, public transport
  - Etc…
- Or we can try to fix the system
  - End-of-pipe solutions
  - Clean technologies using renewable fuels
- Demand reduction attacks all problems at once…technology fix may need to be done at every point

We must choose from a myriad technologies and different fuels

- Better engines, lighter cars, hybrids
  - Reductions in polluting emissions and CO_2
- Natural gas, LPG, electricity as fuels
  - Possible reductions in polluting emissions and CO_2
- But transport growth nullifies much of this
- Many biofuels are good, but resources may be a problem
- But we may have a magic bullet:
  - Hydrogen can help with all of this
  - Fuel cells make hydrogen better

So…what *is* a fuel cell?

Proton Exchange Membrane Fuel Cell Schematic



- Fuel cells can be more efficient, cleaner and quieter than conventional engines
- Fuel is converted directly to electrical power

And hydrogen?

Hydrogen is the lightest, most abundant element on earth

Hydrogen is an energy carrier (like electricity) not a primary energy source (like oil) as it has to be produced

Hydrogen can be produced from many sources: e.g. splitting of hydrocarbons such as gas and oil, or electrolysis of water

Hydrogen can be stored as a liquid, compressed gas, hydride or more esoteric forms

Hydrogen can be used as a store for renewable energy to make it continuously available

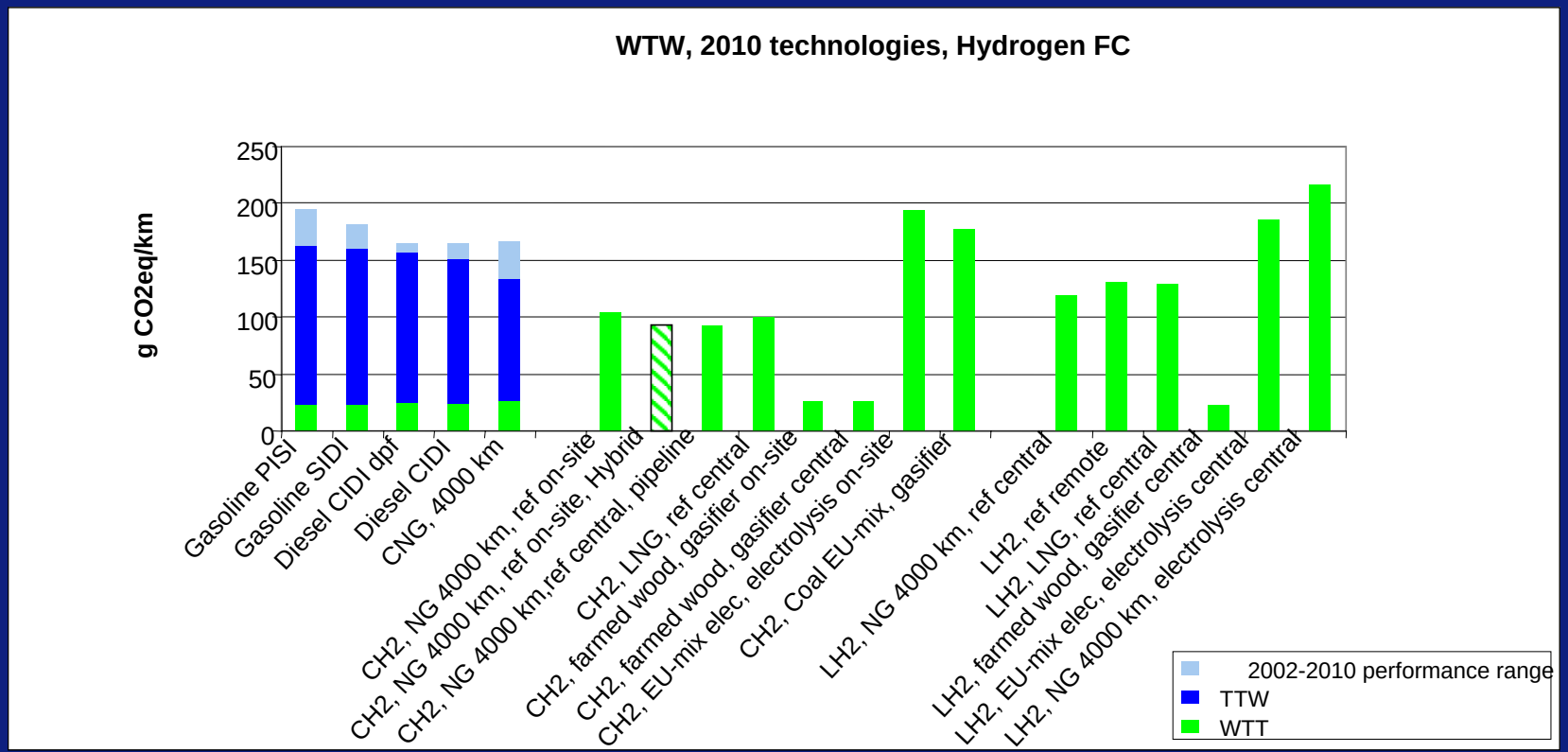
Hydrogen can be burned in an internal combustion engine or gas turbine or used in a fuel cell. By-products are water and heat

So far we have no clear lead to hydrogen…

- Each of our key policy objectives can be met by other means in the short term:
  - Energy efficiency – no diversification
  - Emissions clean-up – CO_2 increases
  - Diversification of sources – no emissions benefits
- But other aspects are not considered here:
  - Economics, inertia, corporate returns, the public
- And these means may conflict

Why are fuel cells and hydrogen an answer?

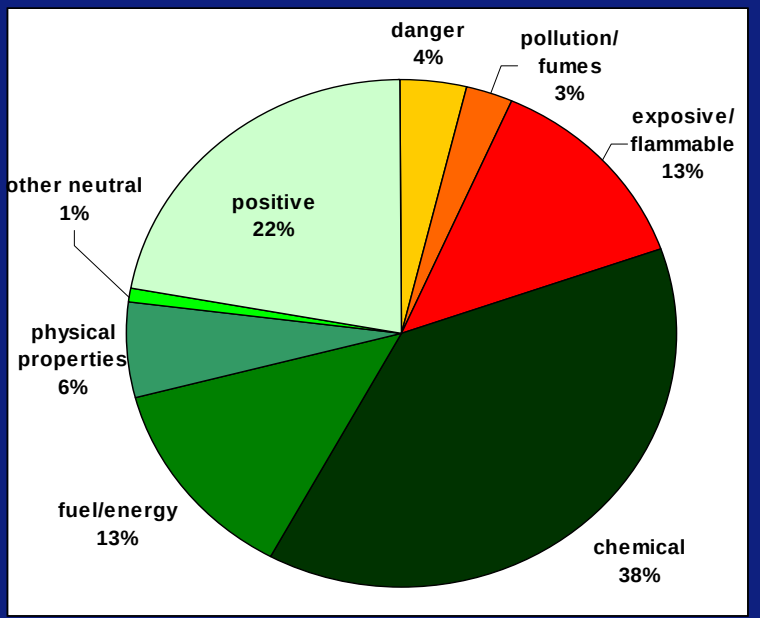
- They offer the *possibility* of pollution-free, renewable, diverse transport



Are there problems? Absolutely!

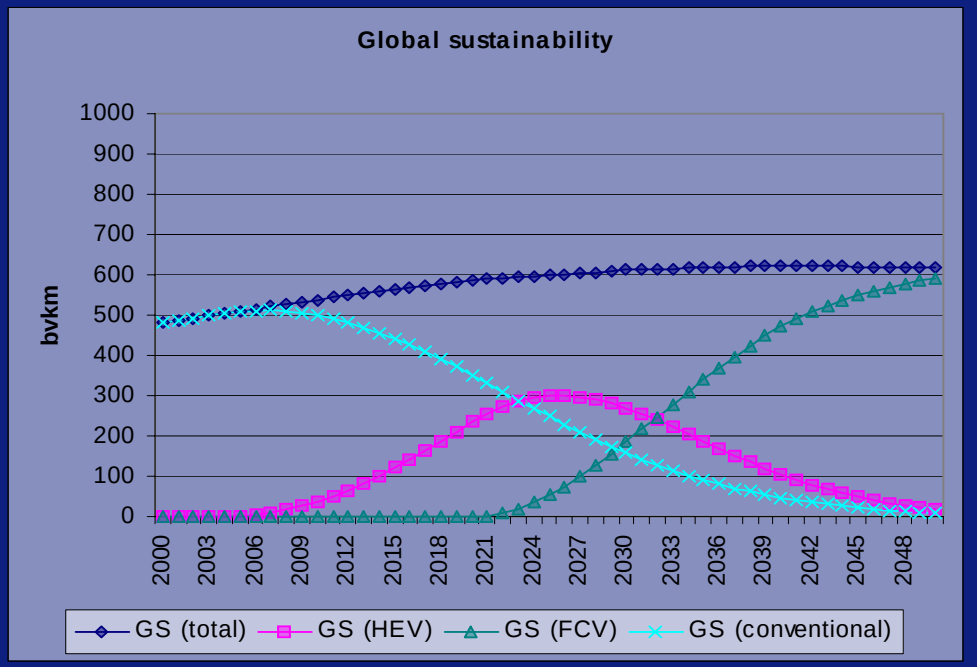
- Costs are high, lifetimes and performance low
- Very few vehicles are available
- Switching *systems* is very difficult
  - it's not 'just' fuel, or 'just' engines
- Some energy chains make things worse
- Policy drivers are not yet big enough
- Public awareness is low

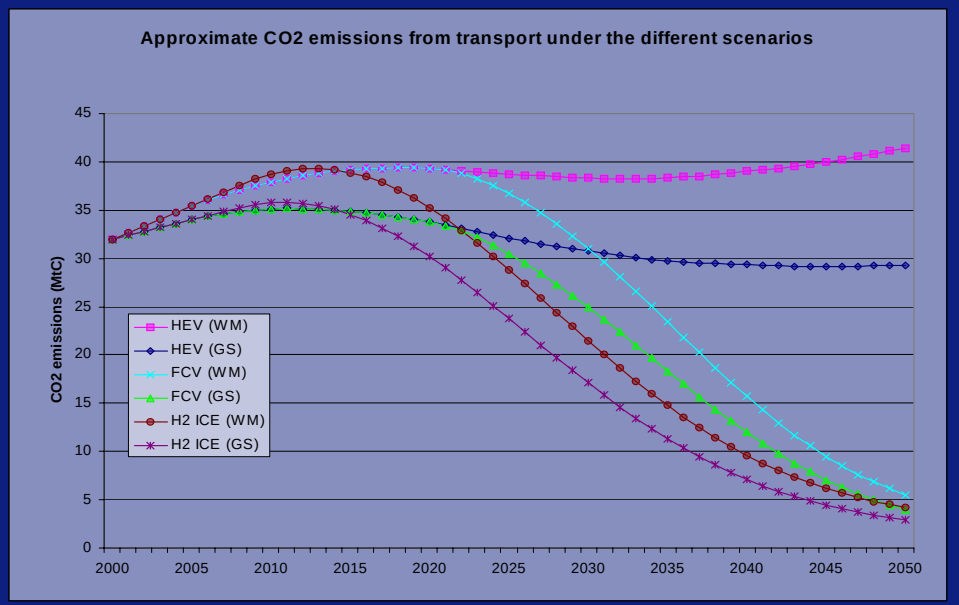
"What are the first words that come to mind when you hear the word 'hydrogen'?"



Can it happen fast?

- No – even at 100% replacement it takes decades
- So…lots of other things need to be done
- But we need to do hydrogen and fuel cell things too – because every year's wait pushes out that uptake curve, and we don't yet know enough





Can we see the future? Let's work back from the long term

- We need to meet the energy needs of the population…including our children
- We can *only* do this sustainably
- We must use the resources we have in the best way
- Most other options offer partial solutions, but may come sooner
- Transitions take time (partial solutions may help)
- We need to be changing now
- Hydrogen and probably fuel cells *are* the future, but we don't know when the future starts or how best to get there