Future Fuels and Vehicle Technology – The Greenhouse Gas Challenge

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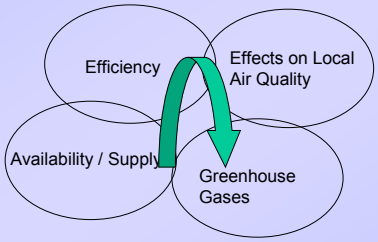
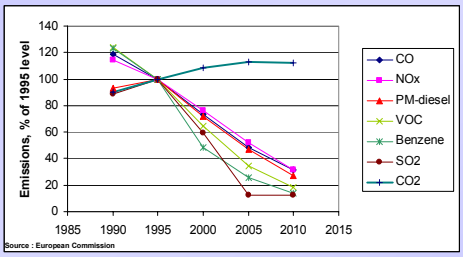
Over the past 30 years, it has been recognised that the use of oil and the internal combustion engine to meet the demand for mobility generates significant sustainability challenges.



Significant progress has been made in reducing local emissions and the focus is now shifting to Greenhouse Gases



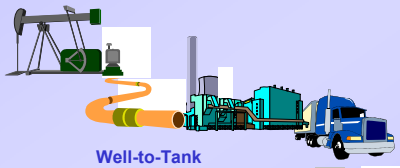
Future challenge: Reduce CO_2 while maintaining low regulated emissions

Changes to transport fuels and vehicles are required to meet sustainability challenges

- **Need to balance the requirements of affordable mobility while reducing local and global environmental impacts**
  - Cleaner Hydrocarbon Fuels used in more fuel efficient/low emission engine technology.
  - Renewable Biofuels - e.g. ethanol and vegetable oil esters
  - Radical new technologies - e.g. Fuel cells & Hydrogen
- **Alternatives need to meet economic and social sustainability criteria as well as contributing to environmental objectives.**
- **Need to understand the challenge of consumer acceptance.**

Evaluation of GHG impact of different fuel/powertrains requires a Well-to-Wheel Analysis

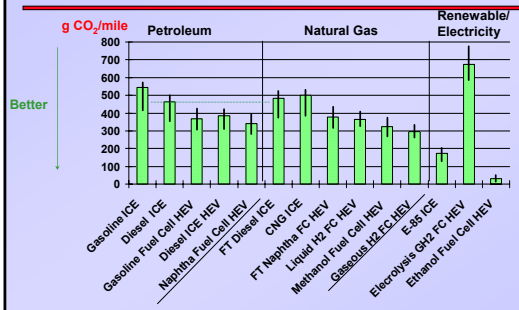
- Systems Approach
- Assessment of energy consumption and greenhouse gas emissions



Well-to-Tank

Tank-to-Wheel

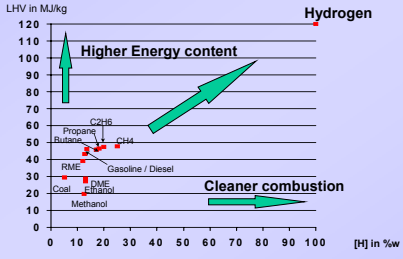
Well-to-Wheel Greenhouse Gases - US Study



Shell's Interpretation of existing Well-to-Wheel Studies

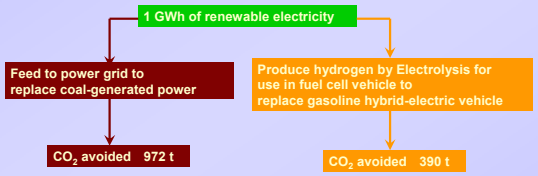
- Dieselisation is a near term opportunity for GHG reduction.
- ICE hybrids can deliver significant further benefits (benefit bigger for gasoline).
- Fuel cell vehicles have potential for further gains but dependent on how Hydrogen produced.
- Some Bio-fuels pathways offer significantly lower greenhouse gas emissions
- CNG may have a very limited GHG benefit vs. conventional fuels for internal combustion engine (ICE) vehicles (depending on gas source assumed).
- No clear benefit for H2 in ICE.
- GTL broadly comparable with conventional diesel on a full systems basis (plus potential from fully optimised engine technologies).
- There are some potential trade offs between GHG and criteria pollutants.
- Need to overlay the cost of different options – WTW methodology provides input data but not the answer for cost effectiveness evaluation.

In the long run, hydrogen has the potential to be the ultimate fuel, but significant technology and infrastructure hurdles must be overcome



RENEWABLE ELECTRICITY TO HYDROGEN ?

- **Renewable electricity is a limited resource**
  - Can be used in different ways



- **Producing hydrogen for fuel cell vehicles does not necessarily maximise the overall GHG benefit, until renewables represent a significant percentage of primary energy**

Bio-fuels are increasingly on the agenda….

- Current options are Ethanol, ETBE (gasoline) and Esters (diesel).
- Future options will include Ligno-cellulosic ethanol and BTL.
- Historically seen as a way of providing local alternatives to imported oil and a use of agricultural surpluses
- Significant GHG reduction potential on a well to wheels basis
- Can use existing distribution infrastructure

But

- costs are typically 2-4 times conventional fuels
- Practical limits to availability
- CO2 impact depends on how the biofuel is produced

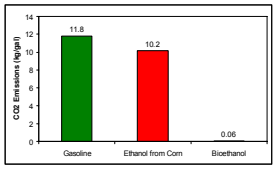
Shell view is that "advanced" biofuels have significant potential, versus limited benefit and high costs of conventional biofuel pathways.

Shell has invested in ligno-cellulosic ethanol technology as this offers significant potential for CO2 reduction….

IOGEN

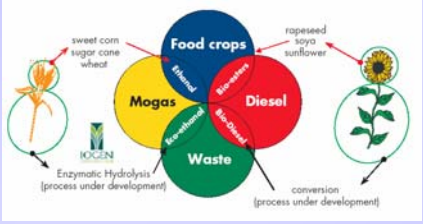
Ethanol, when made from biomass (bioethanol) virtually eliminates net CO_2 emissions

Figure 2.9: Comparative Full Life Cycle CO_2 Emissions



* Source: "Scenarios for U.S. Carbon Reductions" USDOE 1997

Shell is committed to developing advanced bio-fuels that meet the needs of all stakeholders

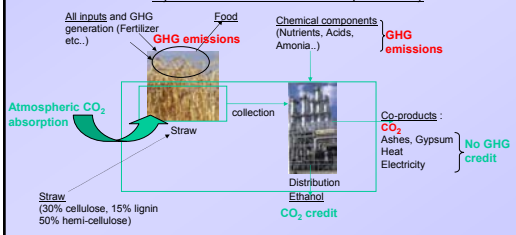


Addressing the sustainability challenge for bio-fuels:
- Economics - Ultimately must be competitive with hydrocarbons
- Social - Cannot use food crops as a feedstock
- Environmental – Lowest impact

Environmental benefits of ligno-cellulosic ethanol; Greenhouse Gas Well To Tank (WTT) balance – the process

Extract from the GM-LBST study, September 2002 (US-NREL data on the conversion of Ligno-cellulosic material to ethanol) – feedstock : straw.
(Also studied in the US GM-Argonne WTW study , September 2001)

System boundaries in the European study

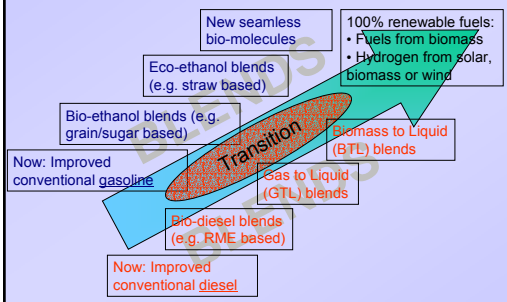


Energy security drivers mean there is a growing interest in producing transport fuels from Coal and gas

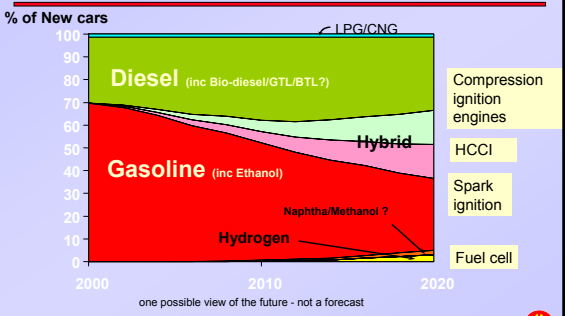
- US and China looking for options to utilise indigenous coal reserves.
- DME and Methanol options are a theoretical possibility but with severe practical limitations.
- CTL would avoid infrastructure and consumer acceptance barriers (and could form part of a GTL/BTL fuel family).
- Carbon management and economics will be determining factors

Large scale CO_2 sequestration a potential gamechanger?

A stairway to Renewable Transport Fuels; evolution not revolution.



For the next 20 years, we expect dieselisation, hybridisation and use of new blending components to impact more than hydrogen



one possible view of the future - not a forecast

Sustainable Mobility is not just about Vehicle Technology and Fuels……but they will play a key role

The **WBCSD Sustainable Mobility Project** is developing a vision of mobility in 2030

Current findings on fuels and vehicle options align broadly with the Shell vision

Views differ on the rate at which FCVs/Hydrogen can be commercialised and ultimate potential for advanced biofuels.

No single technology option is a feasible "fix" in a 30-50 year timescale – multiple measures required.

Shell's Long Term Energy Scenarios to 2050 are one way of thinking about different pathways to a more sustainable future