EU Transport GHG: Routes to 2050?

Alternative energy carriers for transport

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Partners

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Introduction

- Based on:
  - Paper 2 – Alternative Energy carriers and Powertrains to reduce GHG emissions from transport (Nik Hill, et al)

- Presentation is based on draft findings set out in this paper

- Aim of subsequent discussion is to:
  - Agree what we know and do not know
  - Identify any omissions in our information/sources
  - Review the conclusions that are emerging

What alternative energy carriers and fuels are we considering?

- **CNG/LNG**: Natural Gas (NG) can be used in **C**ompressed or **L**iquefied form
- **LPG**: Mixture of mainly propane and butane
- **Electricity**, including plug-in hybrids
- **Hydrogen (H2),** as an energy carrier, and **fuel cells**:
  - H2 produced by reformation of NG, electrolysis of water, other methods in longer-term
  - H2 used in fuel cells to generate electricity
- **Solar** and **wind**
- **Nuclear?**

CNG/LNG/LPG – Cars

- **GHG benefits:**
  - **NG cars: Limited GHG emissions** benefits - ~25% lower GHG emissions than gasoline, similar to diesel, < EVs, FCVs
  - **Bi-fuel (with LPG)** cars have lifetime GHG emissions < gasoline, > diesel

- Big benefit is significantly **lower air quality emissions** than gasoline or diesel. NG compared to gasoline:
  - 90% to 97% lower CO
  - 35% to 60% lower NOx
  - Potentially 50% to 75% lower HC
  - Little or no PM

- **NG and LPG already established:**
  - Across Europe there already almost a **million NGVs on the road**
  - **LPG also already established** – 33,000 LPG tank stations in Europe

CNG/LNG – Cars

- **Costs**
  - Infrastructure costs for CNG and LNG are high
    - CNG fuel pump: 375,000 Euro to 750,000 Euro
    - LNG fuel pump: 150,000 Euro to 450,000 Euro
- **Barriers**
  - Technical:
    - Durability of some components (natural gas regulators and on-board LNG tanks)
  - Infrastructure
    - Shell estimate that 20,000 refuelling sites costing US$7billion needed to meet potential demand
  - Storage
    - Most NGVs are dual fuelled. Some consumers dislike reduced gasoline range.

CNG/LNG – HGVs

- NG engines **are 5% to 25% less fuel efficient** than diesel (INFRAS, 2007) but NG is less carbon intensive so **GHG emissions are similar**
  - **Strong air quality** benefits
  - Already NG trucks on the road e.g. UPS has 800 worldwide
  - NG HGVs are typically **more expensive to purchase** (~25%), **cheaper to run**
  - NG is less energy dense than diesel so NG HGVs have a lower range
  - Lack of widespread refuelling infrastructure is a barrier
- **Dual fuelling** has more potential
  - It can still run as a diesel truck, which negates infrastructure issue
  - Manufacturer claims it reduces operating cost by up to £24,000 assuming 200,000km
  - Manufacturer claims CO2 emissions reduced by 20% per year based on 90% diesel substitution
  - Existing vehicles can be retrofitted

CNG/LNG/LPG in buses and trains

Buses:

- **Similar GHG emissions to diesel**
- Buses are **more expensive to purchase** (~25%)
- But **cheaper to run**
- Lower range than diesel bus
- Lack of widespread refuelling infrastructure is a barrier

Rail:

- **Similar GHG emissions to diesel**
- Main benefit: Lower air pollutant emissions (CO, NO, HC, PM) vs diesel
- Barriers (CNG/LNG):
  - Medium to large engines only available for stationary applications
  - Low energy density and hence reduced range
  - Would require expensive new refuelling infrastructure
- Barriers (LPG):
  - No engines available and diesel engine conversion would be complex

Gases in aviation and water transport

Aviation:

- Not suitable as too low energy density

Marine:

- **LNG - potential future fuel** for ships (payback dependent on fuel prices):
  - 15% reduction potential (taking into account extra methane) (Einang and Per Mange, 2007)
  - Reduction in other emissions as well
  - Barriers: Requires three times the space on ships of equivalent (by energy content) diesel
  - Availability of LPG in ports a challenge that would need to be solved
  - More relevant for new ships, as significant modification required for existing ships
- **LPG is not considered a viable** option for shipping

Inland Waterways:

- LNG and CNG (payback dependent on fuel prices):
  - LNG: 15% reduction potential
  - CNG being trialled on a ferry in Norway: 20% CO_2 reduction achieved (Skjolsvik, 2005)
  - Generally still under development for inland waterway use

Light duty electric vehicles and hybrids

- EVs have the **greatest potential** for carbon savings
  - WWF study
    - Petrol = 1,619g CO_2 per kWh of motive energy
    - Diesel = 1,300g CO_2 per kWh of motive energy
    - Electric = 619g CO_2 per kWh of motive energy (current EU grid mix)
  - Will lock in carbon savings as grid is decarbonised

- **Lithium-ion batteries** have provided step change in energy density
- By 2050, we will have better batteries?

- However, **no significant uptake until early 2020s**
  - Volume manufactured EVs will continue to become available in small numbers over the next couple of years

- **Plug-in hybrid vehicles:**
  - No range issues
  - Lower battery cost

Light duty electric vehicles and hybrids - Costs

- **High marginal capital cost**
  - £6,500 to £20,000 for small EVs
  - £8,500 to £14,000 for medium PHEVs
  - Although often a v.tenuous link between cost and price
    - Loss leaders…

- **But, cheaper to run**
  - Fuel savings heavily discounted by consumers
  - Lower maintenance costs

Light duty electric vehicles and hybrids – Various significant barriers

- **High lithium-ion battery** costs
  - Hard to find good estimates, Arup/Cenex:$800/kWh to 1,000$/kWh
  - $250/kWh to $300/kWh once reach production volumes of 100,00 per annum
  - Different li-ion chemistries may help reduce cost

- **Reduced range for EVs**
  - Battery swapping?
  - Project Better Place

- Lack of charging infrastructure
- Charging time for slow charging
- Behavioural change needed – new habits
- Competition from advanced diesels which will be cheaper

- **Impact on grid**
  - Not thought to be significant until sizeable uptake (15% to 20%) of vehicles
  - Smart Grids

Electric HGVs?

- **Electric traction**
  - Potentially the least carbon intensive option
  - Smith Electric Vehicles have developed a 12tonne EV truck (price is £74k to £80k)
  - In the medium term applicability is limited to electric HGVs only **being able to travel modest distances** due to:
    - Requirement for a large, expensive battery pack
    - Limited range
    - Lack of widespread charging infrastructure

- **Hybrid traction**
  - **Greater medium term potential** for hybrid HGVs than electric HGVs
    - Fuel savings from regenerative braking and stop-start functions (up to 20% in urban areas, Infras 2007)
    - Much smaller (and hence cheaper) batteries than a pure electric HGV
  - Volvo hybrid trucks already being trialled
    - E.g. Veolia is leasing 4 hybrid rubbish collection trucks in the UK and France
  - Marginal capital cost is 153Euro/tonne of CO2 abated, Infras 2007

Electric and hybrid buses

- Electric traction:
  - **Battery cost is a key barrier**
  - Not currently able to meet **operational requirements** (18 hours per day) (Transport for London)
  - Recharging is less of an issue since most buses **are captive fleets** so only require one set of infrastructure
  - A **long term option** once battery technology improves

- Hybrid traction:
  - **Well suited** to the stop-start bus drive cycle
  - Many hybrid buses **already in service** (e.g. 60 in London, Vienna) but not yet mass production
  - 40% price premium (Volvo)
  - 20% – 30% **reduction in fuel consumption** and hence GHG emissions (Volvo)
  - Payback of 4 to 7 years

Electrification - rail

- **Various benefits** to electric traction:
  - Quieter
  - Cheaper to lease/buy and maintain
  - Greater number of seats
  - Reduced air quality emissions at stations
  - Improved energy security
- However, **80% of traffic** already carried by electric traction
  - But only **51% of tracks electrified**…approaching limit of cost effectiveness?
- Greatest GHG reduction (in UK) opportunity even with current energy mix:
  - 20% to 40%, Railway Forum
  - 20% to 30%, Network Rail
- Cost
  - £550k to £650k per track km, Railway Forum
- Barriers
  - Capital costs – Government support likely to be required

Electric planes, ships and barges?

- Not considered to be an option for **aircraft**
- Electric storage for **ship** and **barge** powertrains not seen as viable option

Hydrogen and fuel cells - LDVs

- Potential role post 2020:
  - US administration: “will not play a role in next 10 – 15 years”
  - European Transport Ministers: “may play a role in the long term”
- Research: being undertaken by manufacturers and funded by the EU
- Less energy efficient than EVs and hence lower C savings
  - WWF: FCV pathway has energy efficiency of 28% compared to PHEVs 34% (on grid electricity) and 69% (on renewables)
  - Ease of energy storage is only advantage over EVs
- May play a role post 2030 but by no means guaranteed
- Cost
  - IEA: Fuel cell costs need to reduce 10-50 times to become competitive
  - Infrastructure is expensive – worldwide infrastructure US$2.5trillion (IEA)

Hydrogen fuels cells for HGVs and buses?

- **HGVs:**
  - **Unlikely to see commercial applications** for forseeable future
    - Cost, durability and power density are all issues with fuel cells
    - Hydrogen is less energy dense than diesel therefore lower range
    - Would require a new refuelling infrastructure
    - *Perceived* safety risk (although less flammable the gasoline and would float away if leaked)
  - Potential use for **HDV accessories??**
- **Buses:**
  - H2 fuel cell buses trialled in Europe during 3 year CUTE project (end: 12/05)
    - Buses operationally available 90% of the time
  - Transport authorities are purchasing hydrogen buses in small numbers
    - Transport for London plan to buy 10
    - AC Transit in US is buying 12 for $28million (I.e. $2.33million per bus vs ~$350k to $400k for a diesel bus)
  - Longer (trolley) buses with fuel cells cheaper than trams?
  - Benefits of buses being a captive fleet
  - The marginal capital cost means they will be a long term option
  - *Perceived* safety risk

Fuel cells and hydrogen - railways

- Benefits
  - Improved energy security
  - Combination of lower GHG emissions than diesel and ease of storage
- Fuel cell powered rail vehicles are being tested
  - East Japan Rail Company, railcar
  - Denmark (2010), railcar
  - BNSF in the US, shunting loco
- Cost and GHG savings for a class 66 locomotive, RSSB 2005
  - Fuel cell power train = £344k (vs ~£250k for a diesel power train)
  - Hydrogen storage = £1million in 2005, reduced to £200k by 2010?
  - 2% switch from diesel to hydrogen would save 4,500 tonnes CO2 in the UK
- Barriers
  - Additional capital cost
  - Operational lifetime of fuel cells not sufficient
  - Inherently less energy efficient than pure electric traction
  - New infrastructure required – diesel/electric infrastructure well understood and in place

Hydrogen fuel cells in the air and water?

Aviation:
- Some interest (e.g. by NASA)
- Possible means of propulsion for small planes?
- … but many barriers, including:
  - Need for large storage tanks (due to low density of H2)
  - Need for a heavier power system
  - Stringent safety requirements to satisfy
  - Supply of H2

Marine (very long payback):
- Not considered to be viable before 2050 (AEA et al, 2008)
- Research being undertaken
  - E.g. Oceanjet concept (Southampton University)
  - Hydrogen-equipped whale watching boat (to provide lighting) in Iceland
  - Zemships project developing a 100 passenger capacity fuel cell ship
- Potential use in ports as limited number of facilities, so refuelling easier?
- Barriers: High current costs, reliability, weight/volume, safety of onboard storage and handling of fuels

Inland waterways: Not actively being considered?

The sun and the wind?

Marine - potentially longer-term:

- **Sails for propulsion** (unknown payback):
  - 5 to 7/8% for tankers/bulk carriers at 15 knots (Tech Uni Berlin, 2008); more at lower speeds
- **Towing kites** for propulsion (long payback):
  - Producer estimates: 10 to 35%; works best on ships travelling < 16 knots
  - Costs: $0.5 million to $3.5 million; installation costs – extra 5-10%; operational – extra 5 to 15%
  - Barriers: Complexity of necessary launch, recovery and control systems
- **Solar** (to cover auxiliary power) (long payback):
  - 3.5% for tankers (Wartsila, 2008), varies by ship type
  - Efficiencies of solar cells expected to double
  - Could be used in conjunction with sails, etc
  - Back-up power is needed; not an option on all types of vessel; currently expensive
  - Also potential for support of auxiliary power on **barges**

The nuclear option?

- **Not covered in Paper 2, but mentioned in an earlier meeting…**
- **Used in submarines**
- **Has been trialled in ships, although perhaps not recently**
- **Limited potential application in most modes**
- **Time for a comeback?**
- **Barriers:**
  - Public concerns about safety of such vessels
  - Costs?
  - Local laws banning access to nuclear vessels?
  - Waste products and need for disposal infrastructure

Summary – CNG/LNG/LPG

- Already relatively well established for **road transport**
- GHG benefits **comparable to diesel** fuelled vehicles
- Co-benefits in terms of air pollution
- Vehicles more expensive, but lower running costs
- Reduced range due to larger fuel storage needs
- Bi-fuelled vehicles can be used to **address some range** issues
- For all modes, distribution of/need for refuelling infrastructure a barrier
- Potential long-term option for **marine vessels**
- No potential application for **aviation** and being researched for **inland waterways**

Summary – electricity and hybrids

- High **potential for GHG** savings
- **Higher capital costs** (especially batteries), but **cheaper to operate**
- Unlikely to be significant numbers until **early 2020s**
- **Range limited** (not the case with PHEVs)
- **Batteries** are improving and will contribute to do so
- Barrier is the lack of **charging infrastructure**
- **Hybrids more appropriate** (than pure electric) for HDVs and buses
- Rail already **largely electrified** – potential on remaining lines?
- Electric propulsion not relevant for **aircraft** and **water vessels**

Summary – Other energy carriers/fuels

H2 and fuel cells:

- **Being researched for LDVs** – possible role post 2030?
- Not likely to be used to power HDVs – **potential use for accessories**
- Being trialled in buses – benefits of captive fleet
- Being tested in trains, but cost, technical and energy efficiency barriers
- Unlikely to be used widely in aircraft and water vessels by 2050

Wind and sun:

- Wind potential long-term option for marine vessels
- Solar has potential for accessories on marine vessels

Nuclear:

- Not likely/acceptable as a widespread transport fuel?

2050 vision??

- A more diverse set of specialised vehicles using a range of different low carbon fuels that better suit their purpose
- **CNG/LNG/LPG:** Limited role by 2050 having been used more extensively in road transport between 2020 and 2030? Relatively well used in marine applications?
- **Electricity:** Rail virtually 100% electrified; road transport also a significant user of electricity?
- **Fuel cells:** Some use in rail and on roads in specialised applications, e.g. buses and advanced passenger transport?
- **Wind:** Some specialised marine applications?
- **Solar**: Used to power accessories on various types of vehicle?
- **Aviation**: New plane concepts using biofuels and conventional kerosene?
- **Inland waterways**??

Discussion points

- Do you agree with the short- and long-term potential?
- Do you agree that there are currently significant barriers? How might these be overcome?
- Do you agree with the findings by mode?
- What is your 2050 vision for alternative energy carriers and fuels?