Decarbonising The Automotive Industry

Biomethane Fuelled Vehicles -The Carbon Neutral Option

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Decarbonising the Automotive Industry: Emissions Compliance and the Pursuit of Greener Vehicles

Biomethane fuelled vehicles – the carbon neutral option

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Agenda

• CNG Services Ltd
• Aims for the presentation
• Biomethane fuelled vehicle developments
  – Featuring the Passat TSI
• Biomethane resource in UK
• Making biomethane
• Eco-leadership projects using biomethane
• “It’s the vehicles, stupid’”
CNG Services Ltd

- Owns the UK’s highest capacity CNG filling station and is developing a number of innovative low carbon transport and electricity generation projects including:
  - Trialling home-fill CNG device with the VW Eco-fuel Caddy (CNG)
  - Cleaning bio-gas and injecting biomethane into the gas grid
  - Cleaning bio-gas and using it to fuel vehicles
  - Generation of electricity from gas pressure energy
  - Consultants in relation to LNG imports to UK

1 LNG tanker holds around 65,000 tonnes of gas.....enough to fuel 65,000 CNG Caddy’s each doing 20,000 km per annum!
Aims for the presentation

• Reminder that diesel CO2 emissions are rising
• Show what the VW and Opel engineers are doing
• Show that biomethane CNG can be a transformational low carbon, low emission fuel
• Show the biomethane resource available in the UK and the way it can easily be converted into a pure, high quality vehicle fuel
  – No impact on food or rain-forests or gorillas
  – Very low energy consumption in making the vehicle fuel
  – Made in the UK
• “It’s the vehicles stupid”
Diesel

- Diesel vehicles are excellent
- Diesel is a very good fuel
- Exhaust emissions are much lower with Euro 5
- However, ‘easy oil’ is running out and new oil has a large CO2 penalty associated with it:

Abandon oil sands, urges big investor

GTL, oil shale, oil sands – all are very bad in terms of CO2. CO2 emissions from making fossil diesel are on an upwards path.

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Heather Connor, Investment editor
The Observer, Sunday September 14 2008

One of Britain's biggest investors will launch a campaign this week to persuade Shell and BP to drop their plans for heavy investment in oil sands and shale projects in North America.

Co-operative Asset Management is concerned that the huge environmental costs of producing crude from oil sands or shale could change the economics of these so-called 'unconventional' fuel sources, putting the oil companies and their investors at risk of a huge wasted investment.

Paul Monaghan, head of sustainability and social goals at the Co-op, points to research showing that extracting oil from shale creates eight times as many emissions as conventional oil production, while oil sands produce three times as much. While these sources are economic at current oil prices, a fall in crude or a rise in the price of carbon under the trading system could make them much more expensive.
Biomethane fuelled vehicles – these are the key to market transformation
Vehicles that can run on biomethane – the journey so far

Performance

Environmental performance

2000

2005

2010

GOLDEN AGE FOR NGVs BIOMETHANE FUEL

These vehicles were not that good!

Based on petrol, Simple conversion

Bi-fuel

Converted petrol engine

Some improvement, but still basically a converted petrol engine

Unbeatable alone; Unbeatable in all respects!!

Designed for biomethane

We are here

We are here

Designed for biomethane

Unbeatable in all respects!!

Unbeatable alone; Unbeatable in all respects!!

Designed for biomethane

We are here

These vehicles were not that good!
Passat 1.4 TSI EcoFuel

Manufacture on the production line
In Germany from November 2009
Passat TSI EcoFuel

- **engine**: 1.4 TSI CNG already fulfills Euro-5
- **operating mode**: bivalent
- **performance**: 110 kW / 150 PS
- **torque**: 220 Nm (1,500 – 4,000 U/min)
- **maximum speed**: 210 km/h
- **fuel consumption**: 5.1 kg / 100 km
- **CO2-emissions**: 129 g/km
- **Features instrument panel with level gauge for gas /gasoline und operating range**
- **operating range**
  - biomethane 420 km
  - 3-underfloor gas tanks, steel
  - 135 Liter (22 kg)
  - gasoline 400 km, 31 Liter
- **820 km total operating range**
Combination of the advantages of mechanical and exhaust gas turbocharging

- Spontaneous response through mechanical charging ($i = 1:5$)
- Moderate exhaust back pressure because of large turbine
Comparison of torque

<table>
<thead>
<tr>
<th>Speed [rpm]</th>
<th>CNG with Monoturbo</th>
<th>TSI with Twincharger gasoline</th>
<th>TSI-CNG with Twincharger</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>140</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>2.000</td>
<td>160</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>3.000</td>
<td>180</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>4.000</td>
<td>200</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>5.000</td>
<td>220</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>6.000</td>
<td>240</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>7.000</td>
<td>240</td>
<td>220</td>
<td>220</td>
</tr>
</tbody>
</table>
Advantages TSI plus CNG

- The twincharger-technology of Volkswagen is the starting position to deliver an alternative fuel power train with very low fuel consumption and very low emissions, but very good driving performance.

- The turbo lag, which is normally present in a CNG-Turbo-engine, is compensated by the mechanical compressor.

- The performance of the CNG-TSI is very similar to a big bore natural aspirated engine, nevertheless the consumption and emission are very low.

- In combination with the dual clutch DSG gearbox, VW achieve additional fuel consumption reductions and very good driver experience.
1.4 TSI CNG - bivalent

Developments for biomethane:

- hardened annular valve seat
- armour-plated valves
- camshaft timing matched
- forged piston
- enlarged oil nozzles
- matched piston rings
- turbocharger with smaller compressor wheel
CO2 emissions
VW Passat - different engine/fuel options

Leistung [kW]

CO2 - Emissionen [g/km] (NEFZ)

- B6 TDI 1.9 Bluemotion
- B6 TDI 2.0 DPF
- B6 TDI 2.0 DPF DSG6
- B6 TSI 1.8 DSG7 (Prognose)
- B6 TSI-CNG 1.4 DSG7

On biomethane = carbon neutral

Quelle: K-EFUP
### Air quality

**VW Passat - different engine/fuel options**

<table>
<thead>
<tr>
<th></th>
<th>Ethen-Äquiv. [ kg ]</th>
<th>CO₂-Äquiv. [ t ]</th>
<th>SO₂-Äquiv. [ kg ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8 TSI DSG7*</td>
<td>19</td>
<td>38</td>
<td>67</td>
</tr>
<tr>
<td>2.0 TDI DSG6</td>
<td>14</td>
<td>37</td>
<td>77</td>
</tr>
<tr>
<td>2.0 TDI DPF</td>
<td>13</td>
<td>33</td>
<td>75</td>
</tr>
<tr>
<td>1.4 TSI CNG DSG7*</td>
<td>16</td>
<td>-18%</td>
<td>53</td>
</tr>
</tbody>
</table>

*b Prognose

(berechnet mit einer angenommenen Laufleistung von 150.000 km);

Quelle: K-EFUP

For NOX and particulates, the TSI CNG is best. It is also best for CO2 even on fossil natural gas. On biomethane it cannot be beaten.
Opel Adds New Turbo CNG Unit To Pro-Environmental Engine Range

Higher output and torque with lower consumption and emissions

In 2009, Opel will introduce one new 1.6-liter turbo CNG engine (Compressed Natural Gas) with around 110 kW/150 hp and 210 Nm of torque. Developed by GM Powertrain in Turin, the new unit joins Opel's current aspirated CNG engine, which has the same displacement and an output of 69 kW/94 hp.

"Environmental awareness and driving fun are no longer mutually exclusive," says Alain Visser, Chief Marketing Officer, GM Europe. "With this newly developed turbocharged CNG engine, we continue pursuing our strategy of turbocharging engines to increase efficiency – meaning lower consumption and emissions – without making any concessions in performance."

Key features of the new CNG engine include a turbocharger integrated into the exhaust manifold, an intake manifold with gasoline and CNG fuel pipes, an oil cooler and piston cooling. By virtue of their propulsion units, natural gas-powered Opel vehicles produce 80 percent less nitrogen oxide than a diesel, and almost 20 percent less CO2 than a gasoline model (nearly 10 percent less CO2 than diesel). Furthermore, the exhaust gases contain almost no soot particles.
VW Caddy Eco-fuel

- Best selling CNG van in Germany, launched mid 2006
  - Built to run on CNG rather than a petrol conversion
  - Right hand drive is type approved for sale in UK
- UK trial underway:
  - With “Phill” home-fill device
  - Range 350km on bio-methane + 150 km on petrol
**MB Sprinter NGT**

- **Mercedes Benz**
  - Sprinter CNG in UK in Q2 2009
  - First time MB have designed a CNG Sprinter from ‘first principles’ (rather than petrol conversion):
    - Very low emissions
    - 25% less CO2 than petrol on grid gas
    - Carbon neutral on bio-methane
  - Also has petrol tank
    - Total range of 1100 km
    - Ideal for supermarket home delivery, quiet, clean, long range, fast refuelling

In Germany, it is expected that this vehicle will become the vehicle of choice for Utilities and delivery companies looking both at their CO2 footprint, their emissions performance and at their bottom line…
Iveco Daily

Iveco presents new Daily CNG

At the European Road Transport Show 2007, Iveco will be exhibiting the new Daily CNG which was recently introduced in Italy. This van makes Iveco one of the few commercial vehicle manufacturers to sell a heavy van with a natural gas driven engine straight from the factory.

All Iveco Daily CNG versions are equipped with the 3.0 litre F1C CNG engine. This four-cylinder, 18 valve, turbo-charged engine provides 136 hp (100 kW) and 350 Nm of torque. The standard version comes with a manual, six-speed gearbox. As of early 2008, an automatic Agile gearbox will also be available.

Five tanks
The Daily CNG comes equipped with five tanks with a total capacity of 220 litres. An optional sixth tank can be installed to provide a total capacity of 250 litres. Iveco has not yet issued fuel consumption figures for a range.

Ecologically responsible vehicle
The Daily CNG’s emission values are well under the limit prescribed by the Euro 4 and Euro 5 standards. The CNG engine equipped Daily is therefore regarded as an ecologically sound vehicle which qualifies for the EEV (Enhanced Environmental Vehicle) classification according to European environmental legislation. All the natural gas versions bear the CNG logo and the hummingbird symbol.

Being trialled by Veolia running on biomethane
Very low emissions of NOX/particulates
Carbon neutral on bio-methane
MB Econic - rigid

- 20% lower CO2
- Very low emissions, EEV
- No congestion charge
- 50% of noise of diesel and expected to be approved for night running (avoiding traffic and congestion charge)

Decreasing CO2 impact

Diesel

CNG

biomethane
MB Econic - tractor

• Distribution logistics
  – This vehicle is a CNG Econic tractor, operating in Germany
  – Gross combination weight rating 40 tonne
  – EEV emissions and 20% lower CO2 than diesel
  – On bio-methane, carbon neutral

• MB bringing to UK in right hand drive form
  – Storage tanks vertically arranged behind the cab to give long range
  – In UK in Q2 2009
Biomethane fuelled refuse trucks

• Refuse Trucks
  – MB Econic (see below in Malmo, running on bio-methane)
  – Iveco (right) – all 560 refuse trucks on methane in Madrid

• UK Waste
  – Best Practice for Waste is separation of green material at source and then anaerobic digestion
  – Best use for biogas is to clean up for vehicles due to very low efficiency of electricity generation from reciprocating engines
Biomethane Resource

UK Govt says:

The potential for biogas

7.6.3 The UK produces over 100 million tonnes of organic material per year that could be used to produce biogas. This breaks down as follows:

- 12-20 million tonnes of food waste (approximately half of which is municipal waste collected by Local Authorities, with the rest being hotel or food manufacturing waste);
- 90 million tonnes of agricultural material such as manure and slurry;
- 1.73 million tonnes of sewage sludge.

Biogas can also be produced from energy crops such as maize or grass leys.

7.6.4 Each has a different calorific value when fed through an anaerobic digestion plant – with, for example, food waste usually producing more useful biogas than sewage sludge. The water industry already has a system of anaerobic digestion plants to maximise output of sewage sludge and there are incentives to exploit anaerobic digestion for agricultural material and food waste for on-site generation.

7.6.5 Our initial analysis suggests that the anaerobic digestion of food waste, livestock slurries, sewage sludge and energy crops to produce biogas could contribute approximately 10-20 TWh by 2020. Achieving this potential by 2020 would depend upon the collection and separation of organic waste as well as the development of a network of anaerobic digestion plants. 10-20 TWh is equivalent equal to 5.5 to 11 million barrels of oil equivalent = 12 – 25% of road fuel demand.

Table 2.10: Output and intensity factors affecting changes in transport energy use between 1990 and 2006

| Energy consumption | Million tonnes of oil equivalent | Of which change due to:
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Road passenger transport</td>
<td>26.9</td>
<td>27.2</td>
</tr>
<tr>
<td>Road goods transport</td>
<td>12.0</td>
<td>13.8</td>
</tr>
<tr>
<td>Rail</td>
<td>1.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Air</td>
<td>7.3</td>
<td>12.0</td>
</tr>
<tr>
<td>Water</td>
<td>1.4</td>
<td>1.0</td>
</tr>
<tr>
<td>All transport sectors</td>
<td>48.6</td>
<td>55.5</td>
</tr>
</tbody>
</table>

Sources: BERR
Department for Transport
Biomethane as vehicle fuel – why not make electricity instead and have electric vehicles?

Question:
I attended an SMMT Commercial Vehicles Section meeting in London last week where the subject of alternative fuels briefly came up.

xxxxxx indicated that it was a non-sense to fuel road vehicles with gas and that it made more sense to burn gas to generate the electricity to power electric vehicles.

How would you respond to such a challenge?

Answer
1. Efficiency:
   Burning the biogas to make electricity will be at around 30-35% efficient which is not that good! 65 - 70% of energy wasted. We cannot afford to waste that much energy, those days have gone. If you burn gas in a central CCGT you get 88% which is not so bad. But to get biogas into the gas grid you clean it up and then inject it into grid…at same time, you can run vehicles on this gas, perfect!

2. Electric cars:
   1. What range on an electric Passat would you have? Is 820 km possible? How does drive-ability compare to TSI/petrol? How long to re-charge? Can you see Passat drivers in an electric version, when?
   2. Are there any electric buses and refuse trucks?
   3. What range would an electric Sprinter have? How much weight hit? How long to fill up? Can you envisage Tesco home shopping using electric vehicles?

To quote the German guy in VW who developed the Passat:
I personally believe that CNG/biomethane (long range) and electricity (short range) are the fuels for the future in transportation

Ask xxxx for a list of white vans, trucks, buses, refuse trucks. Passat size vehicles that run on electricity. If none, ask for a list of such vehicles being developed. The Passat TSI biomethane took 5 years, the OEMs must be working now on such vehicles for 2013?

3. Interaction with Wind
   By 2020, when it is windy, UK will get its electricity from nuclear and wind...all the gas fired power plants and coal will be off, on hot standby. When wind falls (or is too strong) they will start up. If you make biogas you have to generate electricity ALL the time, even when its windy (as biogas gas is made all the time), this means a lot of the time you will be making it but you may not want it...If you make it into vehicle fuel you can always use it....

Regards
John
Bio-gas to biomethane

Or can go direct to compressor and vehicles from here

Lots of ways to clean biogas to biomethane for vehicles or grid injection – No technology issues, costs falling due to Larger productio volumes and containerisation
## Eco-leadership Projects

<table>
<thead>
<tr>
<th>Customer</th>
<th>Source of gas</th>
<th>Vehicles</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Company</td>
<td>Sewage treatment works – 40,000 m³/day of gas available</td>
<td>Vehicles on site plus injection into gas grid (could be used to fuel Passat with home-fill device)</td>
<td>1 Passat doing 20,000 km needs 1000 kg of gas. All this gas would fuel 5,700 Passats from this sewage works</td>
</tr>
<tr>
<td>Water Company</td>
<td>New AD using food waste</td>
<td>Caddy, Sprinter plus exported via trailers</td>
<td>On site electricity generation would be &lt;35% efficient</td>
</tr>
<tr>
<td>Local authority</td>
<td>Organic waste (garden and kitchen)</td>
<td>Refuse trucks, Sprinters, buses</td>
<td>AD avoids use of landfill</td>
</tr>
<tr>
<td>Grower</td>
<td>Waste from growing fruit and vegetables</td>
<td>Sprinter</td>
<td>CO2 separated from biogas to be used to increase growth rate of crops</td>
</tr>
<tr>
<td>Waste Management Company</td>
<td>Domestic organic waste + abattoir waste</td>
<td>Inject into gas grid</td>
<td>On site electricity generation would be &lt;35% efficient</td>
</tr>
</tbody>
</table>

"It’s the vehicles, stupid’"
Summary

“It’s the vehicles, stupid’

- Top quality biomethane vehicles becoming available
  - UK benefiting from CNG vehicles developed for German market
  - It really is the vehicles, stupid!
- CO2 and greenhouse gas reductions is the major driver
  - Very efficient means of delivering 2nd Generation bio-fuel benefit early, with no ‘food crop’/gorilla/rainforest issues
  - Biomethane earns RTFO certificates
  - EU Renewable Fuel Directive says that biomethane should earn 2 X ROCs
- UK has a huge potential resource
  - Can stop wasteful use of biogas for non CHP electricity
  - Transportation is the most CO2 efficient use on a Well to Wheel basis because it reduces the production of ‘marginal diesel’and has a very simple supply chain – make the fuel were it is used