

Automotive World

## Decarbonising the Automotive Industry:

### Emissions Compliance and the Pursuit of Greener Vehicles

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#### Biomethane fuelled vehicles – the carbon neutral option

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Year 2008 may well be recognised as a turning point in the journey away from fossil fuels and this has major implications for the waste management industry. The increase in oil price to \$140/bbl is the market signaling that, to use the words of Shell CEO van der Veer, 'easy oil' is running out. The large oil fields that have supplied the world with oil are starting to decline and new resources, such as oil sands in Canada, have much higher levels of CO<sub>2</sub> emissions associated with their extraction.

At the same time, countries like Nigeria are capturing and liquefying the natural gas (to make LNG) that is a by product of oil production. Nigeria is forecasting LNG production of around 60 million tones per annum by 2012, bringing in around \$60 billion of income - not a bad return for what was flared off as a waste product until 1999. High natural gas prices in the US are also bringing forward huge resources of 'tight' natural gas that are now economic to produce. Such gas needs more wells than normal gas and so requires the higher gas prices we have now – historically low natural gas prices in the US have acted to leave the 'tight gas' in the ground but it is now economic to bring it to market.

In addition, Europe is promoting wind generation, with the UK, the windiest country in Europe, aiming for 35% of its electricity to come from wind by 2020. The UK also has

new regulations from 2016 that will not allow new houses to have natural gas and so heating must be provided by renewable sources such as wood or from electricity produced by wind or solar power. High energy prices, wind generation and initiatives to reduce fossil fuel demand are squeezing the demand for natural gas at a time when supplies of both LNG and tight gas is growing dramatically.

These factors have caused some of the major car makers to look at natural gas vehicles as an attractive new opportunity. Whilst there are now around 8 million NGVs in the world, with Brazil, Argentina and Pakistan the volume leaders, it is developments in Q1 2009 in Germany that are potentially transformational and offer a compelling vision to the waste management industry.

### **New biomethane fueled vehicles**

In 2004 a group of VW engineers set out a vision for a large car that could be fueled by natural gas (fossil or renewable) to deliver high performance, long range, low CO<sub>2</sub>/km and no loss of boot space. That vehicle is about to come off the production line in Germany as the Passat TSI Eco fuel. The combination of twin superchargers and a turbocharger provide exceptional performance, with 150 bhp and 0 to 60 Mph in 9.7 seconds. Its range on biomethane is 420km with a further 400 km on petrol. Whilst it is carbon neutral on biomethane, even on fossil natural gas it has class leading low CO<sub>2</sub> of 129 g/km. Finally, by putting the CNG tanks under the floor, VW have engineered a carbon neutral vehicle with no loss of boot space. With 800 filling stations in Germany for the Passat TSI, VW are expecting a breakthrough in terms of sales with 25,000 per annum a reasonable target. With fuel at half the cost of petrol and this performance it can be expected to achieve high level of sales. The illustration and photo below show the new Passat Ecofuel.



The basic engine is the modern and very popular 1.4 TSI-engine with twin-charge technology. The bivalent CNG-concept already fulfills the Euro 5 emission regulation. The Passat has a maximum performance of 110 kW / 150 HP. It delivers a maximum torque of 220 Nm between 1500rpm and 4000 rpm – which is diesel-like. The CO<sub>2</sub>-emission is very low. The Passat EcoFuel consumes only 5.1 kg/100 km meaning the CO<sub>2</sub> emission is below 130 g/km.

The Passat has 3 under-floor gas bottles with total volume of 135 liters (22kg), with that amount it can drive 420 km. The car has an additional 31 l. gasoline tank with a total range for both CNG and petrol of 820 km.

### 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
- CO<sub>2</sub>-emissions: 129 g/km
- features: instrument panel with level gauge for gas /gasoline und operating range
- operating range: CNG 420 km  
3-underfloor gas tanks, steel  
135 Liter (22 kg)  
gasoline 400 km, 31 Liter



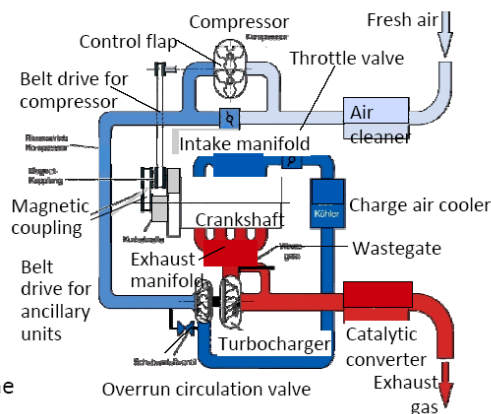
820 km total operating range

The VW twincharger combines the advantages of the mechanical and exhaust gas turbocharging. The mechanical charger is geared up 1 to 5 and delivers instantaneous torque response in low rotational speed. The large turbine provides moderate exhaust back pressure as shown below:

### TSI turbocharging with mechanical auxiliary charging

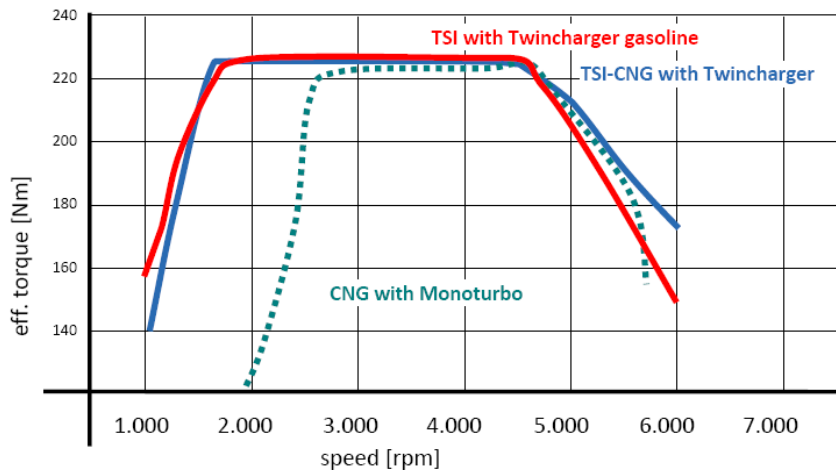
combination of the advantages of mechanical and exhaust gas turbocharging

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



Below is shown the torque characteristic of various Charging concepts. The first curve shows the gasoline TSI Twincharger . The second curve shows how a CNG-Monoturbo would work with a large turbo lag in the bottom range. The twincharger closes this lag and gives the excellent performance.

### Comparison of torque

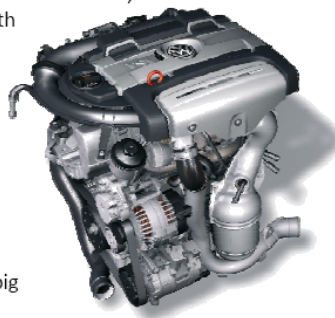


The twincharger technology of the Volkswagen Passat is a unique starting position to realize an alternative power train with very low fuel consumption and very low emissions, but very good driving behaviors.

### Advantages TSI plus CNG

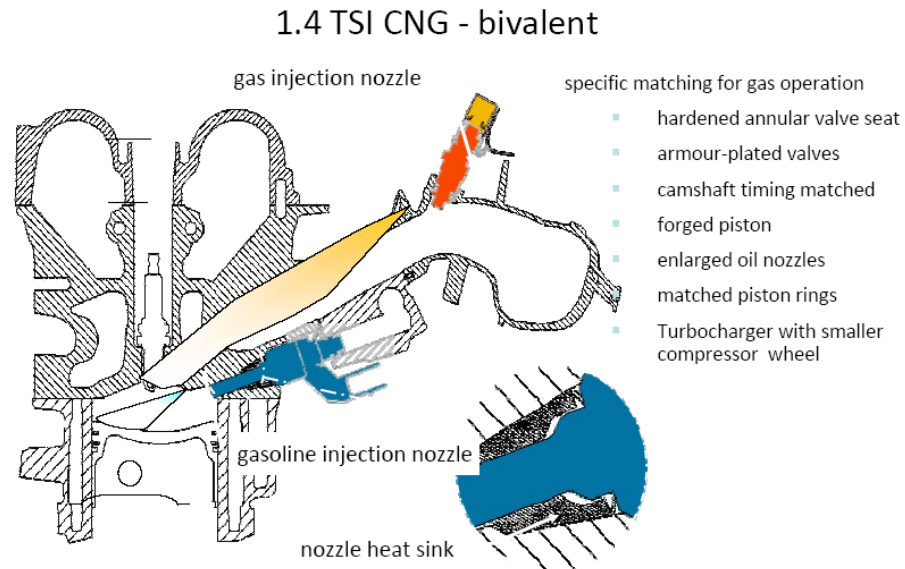
- the twincharger-technology of Volkswagen is the unique starting position to realize a alternative power train with very low fuel consumption and very low emissions, but very good driving behaviors.
- the turbo lag, which is normally immanent for a CNG-Turbo-engine, is effectively compensated by the mechanical compressor.
- the driving behavior 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 our dual clutch DSG gearbox we achieve additional fuel consumption reductions but simultaneously better shifting comfort

TSI ° 1,4l - 110 kW CNG

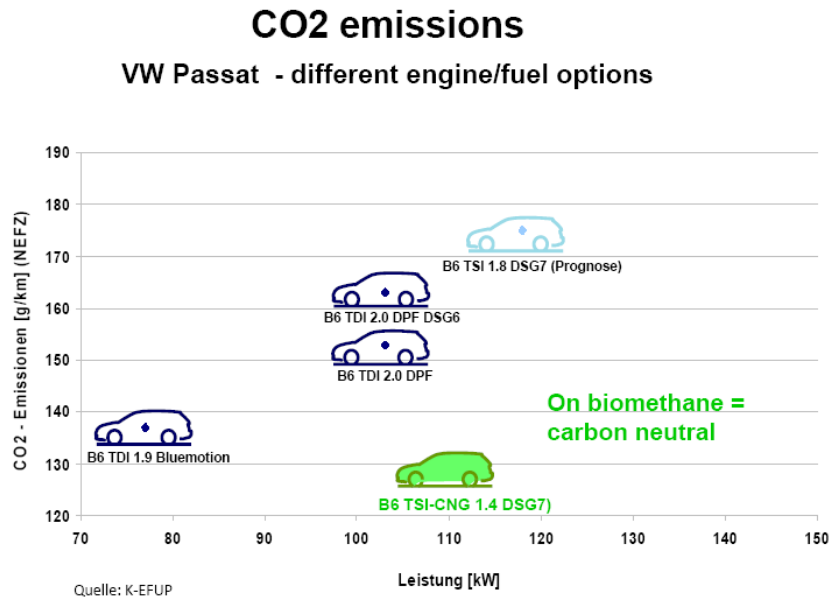


DSG ° gearbox

This picture below shows a cut through the cylinderhead. The gas injection nozzle blows the gas into the suction tube.



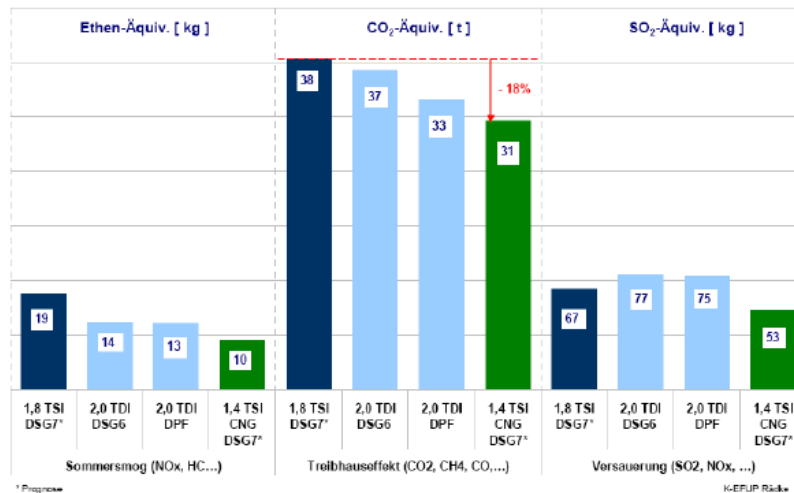
The graph below shows that the TSI CNG vehicle has significantly lower CO<sub>2</sub> emissions for equivalent performance vehicles. On biomethane, the vehicle represents a carbon neutral option for customers.



In addition to CO<sub>2</sub>, the emission of NO<sub>x</sub> and particulates are also lower from the TSI CNG vehicle which fairly reinforces its eco-leadership position.

## Air quality

### VW Passat - different engine/fuel options



(berechnet mit einer angenommenen Laufleistung von 150.000 km);

Quelle: K-EFUP

**For NO<sub>x</sub> and particulates, the TSI CNG is best. It is also best for CO<sub>2</sub> even on fossil natural gas. On biomethane it cannot be beaten**

The VW Passat is being joined by the General Motors Zafira Turbo, which also offers great performance and low CO<sub>2</sub>. Then there are a suite of vehicles from Mercedes Benz – the B Class, the Sprinter van and the Econic truck. Together, with other vehicles from cars to buses and trucks, we now have a family of vehicles that are unbeatable in environmental performance when fueled on compressed biomethane.

Below are shown the new VW Caddy and MB Sprinter which are the vehicles that UK water companies are introducing to allow their transport requirements to be provided by carbon neutral biomethane rather than diesel.



The photo below shows an MB Econic tractor fueled by methane and being used in Germany to haul waste.



The photo below shows biomethane fueled Econic refuse trucks in Malmo



The new biomethane fueled vehicles also have exceptionally low emissions, the Econic, for example, meets the EEV standard which will not be matched by diesel trucks until around 2015.

Each m3 of biomethane used to fuel a Passat or Econic displaces a litre of diesel and means some 'hard to extract and high CO2 to produce' oil is left in the ground. Natural gas was made from dinosaur poo 150 million years ago.....we can make renewable natural gas, biogas, from organic waste in around 20 days using

anaerobic digesters. It is straightforward and low cost these days to remove water, H<sub>2</sub>S and CO<sub>2</sub> from this biogas and we then have biomethane, a perfect vehicle fuel which, combined with these new vehicles provides a carbon neutral motoring opportunity for 'eco-leadership' companies.

"Second Generation" biofuels are defined as those which are made from organic waste not food crops. Biomethane is now clearly established as the leading such fuel used for vehicle fleets in most EU countries. Sweden has around 15,000 NGVs with 55% of the fuel from biomethane and 15 Swedish cities having biomethane powered bus fleets, such as Stockholm (photo below) which is replacing bioethanol fueled buses to move to 100% biomethane fueled from 2009:



### **Injection of biomethane into the gas grid**

Whilst the production of biomethane is well established, transporting this gas to consumers via the existing gas grids in Europe is an innovation being promoted by the EU in its new Renewable Energy Directive.

In the UK, there is already an extensive AD industry but the biogas produced has only been used to generate electricity. High energy prices mean that the overall efficiency of such schemes (less than 40% due to limited use for waste heat) is causing a re-think as to the appropriate use of the biogas. The high quality of the new biomethane fueled vehicles and the relatively poor CO<sub>2</sub> performance of on-site electricity generation means that injection of biomethane into the gas grid and its use as a vehicle fuel is now attractive as shown in the following table:

	<b>Co2 saving/ annum in tonnes</b>
<b>Summary - from 100 m<sup>3</sup>/hr of biogas production</b>	
<b>On site electricity generation with no use for waste heat</b>	<b>1,393</b>
<b>Biomethane injected into gas grid and used to generate electricity at combined cycle gas turbine plants</b>	<b>2,294</b>
<b>Road transport use displacing 'marginal' diesel</b>	<b>2,335</b>

There are no regulatory barriers to injecting renewable methane into the gas grid. In fact, whilst it does not happen yet, the UK pipeline system welcomes it with open arms, not even charging a fee to accept it at the lower pressures that local gas pipelines operate at. The raw biogas has to be dried, cleaned, enriched and odorised, but this is straightforward with a range of technologies widely used in Europe. The reason it does not happen is that, under a legal technicality, biomethane

loses all its green benefits when it enters the mains. The UK Government has recognized that this is bad for the environment and is consulting in relation to this with the aim of encouraging 'renewable' gas in the same way it encourages renewable electricity.

### European experience

Injection of biomethane into gas grids is now happening across Europe in a market growing at more than 25% annually. In Sweden, Switzerland, Austria, Germany and the Netherlands, the production of renewable methane from domestic waste offers a solution to the problems of waste recycling, reduction in global warming and reduction in natural gas imports. It is a compelling vision - gas suppliers who already offer 'green' electricity tariffs could also offer 'green' gas tariffs. Supermarkets could recycle their green waste, turning it back into methane and running all their vehicles on carbon neutral biomethane and tapping into the premiums available for renewable biofuels. The residual digestate from the AD also has value as a fertilizer.

Fixing fuel prices for the life of the AD plant is also attractive – as long as organic waste is produced, the fuel will be available. The experience in Lille where 330 buses are fueled on biomethane from domestic waste is that the direct link between waste and bus fuel is something that leads to very high rates of organic waste recycling from consumers as well as lower local council taxes.

### UK biomethane for vehicle projects

The table below gives an indication of the projects being supported by CNG Services Ltd:

Customer	Source of gas	Vehicles	Comments
Water Company	Sewage treatment works – 4,000 m <sup>3</sup> /hr of gas available	Vehicles on site plus injection into gas grid (could be used to fuel Passat with home-fill device)	1 Passat doing 20,000 km needs 1000 kg of gas. Likely to have 100,000 kg injected into grid so could fuel 1000 Passats.
Water Company	New AD using food waste	Caddy, Sprinter plus exported via trailers	
Local authority	Organic waste (garden and kitchen)	Refuse trucks, Sprinters, buses	AD avoids use of landfill
Grower	Waste from growing fruit and vegetables	Sprinter	CO <sub>2</sub> separated from biogas to be used to increase growth rate of crops
Waste Management Company	Domestic organic waste + abattoir waste	Inject into gas grid	

**Biogas fact file**

Biogas, or renewable natural gas, is the name given to the mixture of methane and carbon dioxide (CO<sub>2</sub>) gases that is formed whenever organic materials decompose in the absence of air. This process is known as anaerobic digestion and, when it occurs in nature, the gases escape to atmosphere. However, this natural process can be managed in an industrial plant. To make it more efficient, the industrial process requires warmth, air to be excluded, and the organic material is usually prepared before being fed into tanks which allow the gases to be captured and used. Modern industrial processes can make renewable natural gas in a matter of days rather than the thousands of years that were taken to produce natural gas.

Renewable natural gas is by far the most environmentally friendly fuel in the world when compared with other fuels currently available. Capturing the methane which would otherwise be emitted from decomposing organic materials, and preventing this from becoming a greenhouse gas that is 21 times worse than CO<sub>2</sub> in terms of climate change, is actually improving the environment rather than just being 'less bad' by merely replacing fossil fuels with renewable fuels.

Nearly all countries now have a mission to work out schedules for sustainable development, and powering vehicles from fuel made from wastes is a very obvious and direct example.

**Manufacturing process**

Biogas can be manufactured from just about any organic material. Historically, it has been produced from sewage sludge and animal slurries, but more recently the focus has been on producing gas from energy crops such as grass or maize, and wastes such as those that arise from food manufacturing, brewing, and household rubbish. On average, some 60% of the contents of a household dustbin are organic and can be used to make gas.

The biogas produced by natural processes contains about 65% methane, 35% CO<sub>2</sub> and some trace gases including hydrogen sulphide (HS). This raw biogas is mainly used in stationary engines that generate electricity. At sewage works it is used to power the machinery on site, and at landfill sites it is fed into the national electricity grid.

**Biogas as a vehicle fuel**

To use biogas as a vehicle fuel the CO<sub>2</sub> needs to be removed so that the methane content is similar to that in natural gas. If the CO<sub>2</sub> is allowed to remain in the biogas mixture the operating range of the vehicle is compromised as CO<sub>2</sub> does not burn. Hydrogen sulphide also needs to be removed as this is corrosive. Treated biogas for automotive applications is referred to as biomethane.

**Environmental option**

In a report from the Swedish Committee of Alternative Fuel, biogas was acknowledged as the best alternative fuel available today with regards to climate, environment and health – due to its low emissions and no net contribution to the greenhouse effect.