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ASFE Position Paper

Emissions from Synthetic Fuels

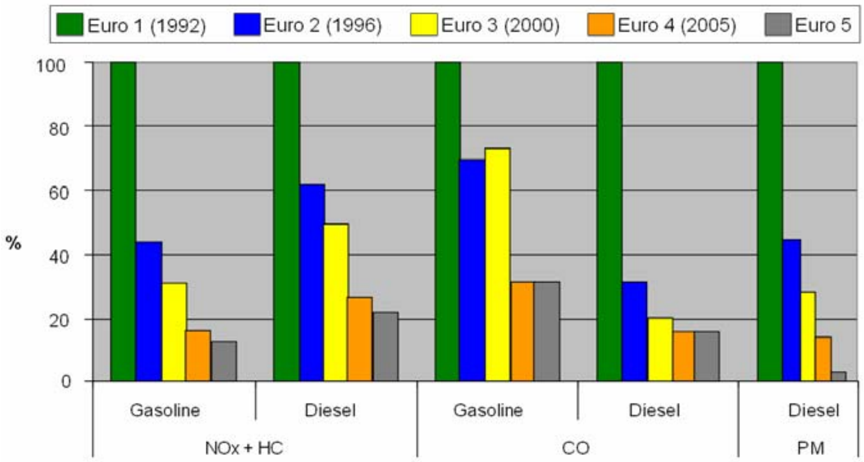
Introduction

Synthetic fuels can be produced from a range of feedstocks; biomass, coal and natural gas. Of the three synthetic fuel production pathways, Gas to Liquids (GTL) process is at the most advanced stage of commercial development. By 2010 synthetic fuels production via GTL process is expected to approach 100,000 barrels per day, well over current biodiesel production worldwide. It is estimated that as many as ten large-scale GTL plants will be in operation by 2020, producing over 1 million barrels per day of GTL products. With the global development of both Coal to Liquids (CTL) and Biomass to Liquids (BTL), a combination of three technologies will be supplying increasing volumes of low local emissions fuels to the transport market.

1. European Emission standards

Over the past decades, engine and fuel technologies developments have dramatically reduced pollutant emissions and improved air quality in Europe. Following very substantial developments on both petrol and diesel engines through catalysts and associated engine management systems, the focus has recently been shifted to diesel engines. In the EU the improvements have been significant, for example with the development of cleaner combustion (e.g. through pump-injector element or common rail technology for diesel engines or direct injection for petrol engines), and with cleaner fuels (e.g. removal of lead in gasoline and much of the sulphur in all automotive fuels). Through these combined innovations of car producers and fuel suppliers' modern vehicles were able to meet ever more stringent exhaust emission regulations (Figure 1).

Figure 1: evolution of EU emissions standards for passenger cars (Euro 5: proposal of EU Commission)



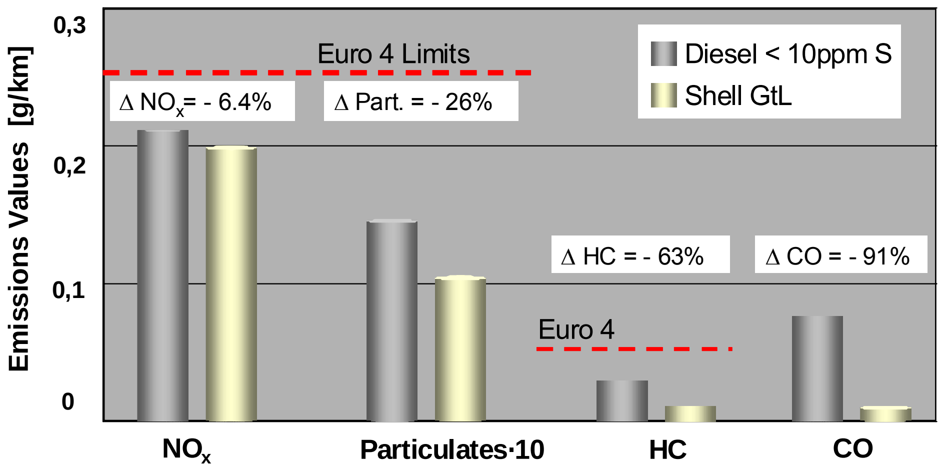
The application of successive Euro-standards applies to new vehicles only which takes time to replace existing vehicles throughout the vehicle fleet, so that improvements of air quality are considerably delayed. In contrast, the introduction of synthetic fuels will have an immediate positive impact on the local emissions from the existing vehicle fleet. These benefits could be delivered through the wider use of synthetic fuels (GTL, BTL, CTL) in diesel engines. When diesel engines are optimized to run on synthetic fuels further reductions of regulated emissions can be obtained.

2. Local emissions from diesel passenger cars

The diesel share of new passenger car sales in the EU increased from approximately 15% at the beginning of the 1990s to almost 50% in 2005. In large part this is due to the lower fuel consumption and powerful performance of diesel engines, although in some countries, fuel and/or new car incentives have encouraged uptake. As diesel engines are some 20-40% more efficient, their CO2 emissions are significantly lower (some 20%) than their equivalent petrol counterparts.
Road trials of synthetic fuels in several European capitals and elsewhere have demonstrated significant reductions in tailpipe emissions (particulate matter, nitrogen oxides, carbon monoxide and hydrocarbons), leading to improvements in local air quality.

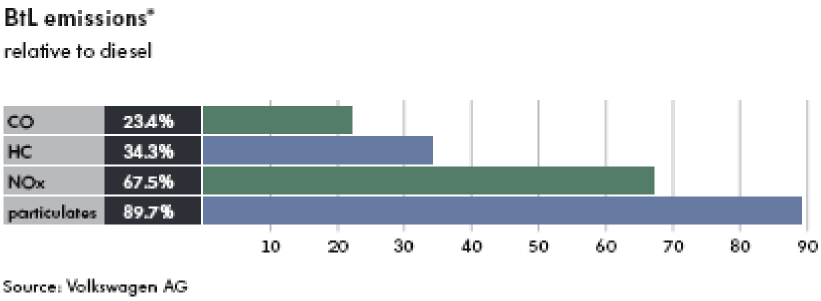
Specific improvements are highly dependent on the vehicle, the engine design and the management system, and are also influenced by the test cycle chosen and the control diesel used for comparison (figure 2).

Figure 2: PM, NOx, HC and CO benefits of 100% GTL fuel for a trial with 25 Volkswagen Golf cars in Berlin in 2003



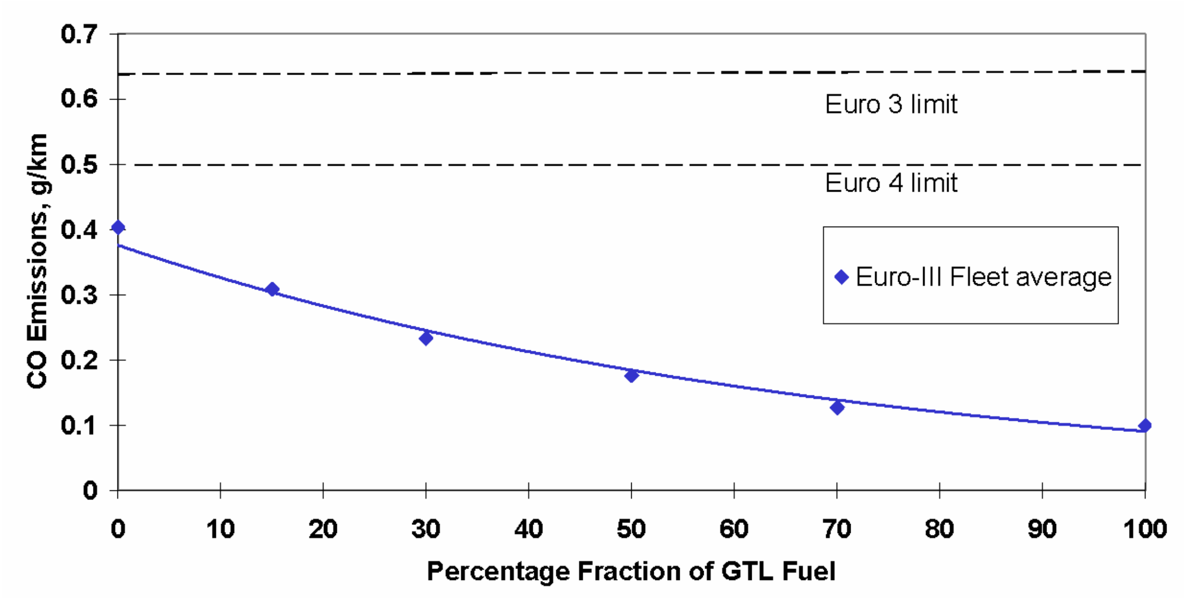
Whatever the feedstock, all synthetic fuels have the same properties and deliver the same pollutant emission results. As an example, in a standard engine, emissions of nitrous oxides (NOx) have been reduced by some 5% compared to crude oil-derived diesel fuel. By tuning the engine to maximise NOx reduction, then even larger NOx benefits are achieved, but often at the expense of PM emissions benefits (figure 3). This might provide interesting potential for vehicles equipped with particulate filters.

Figure 3: Comparison of exhaust emission levels of refinery diesel and BTL fuel (Golf TDI 103 kW, New European Driving Cycle (NEDC)); Engine control unit tuned for maximum reduction of NOx



GTL blends with standard diesel also show emission benefits. The impact of blend concentration is non-linear, giving greater emissions benefits than expected for HC, CO and PM at low concentrations of GTL fuel. Figure 4 illustrates such results for CO emissions. Tests have shown that a blends of GTL fuel provide better than linear emissions benefits for three of the key emissions [PM, HC and NOx]. This is an important factor given the limited volumes of GTL fuel.

Figure 4: Impact of GTL blend concentration on CO emissions



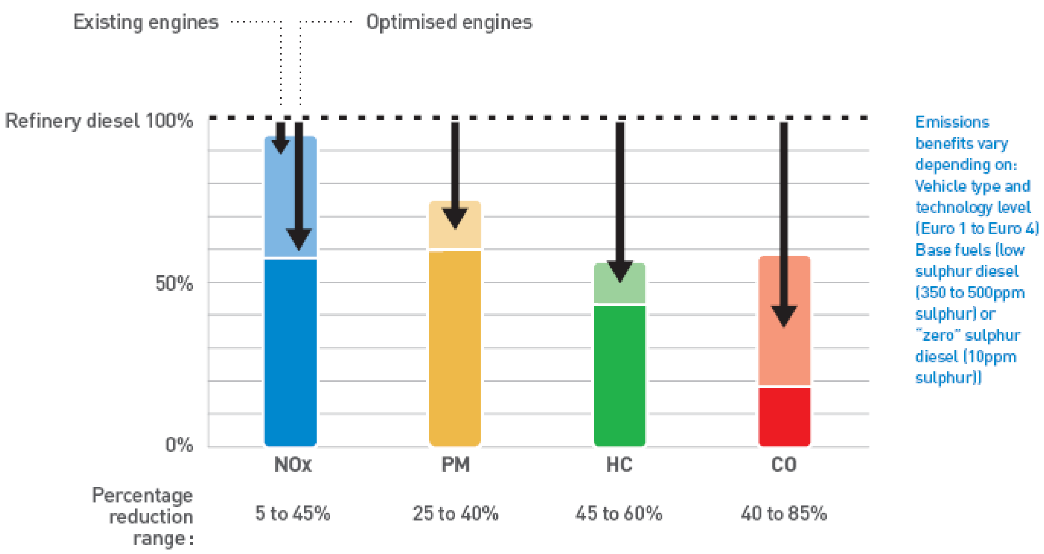
In summary the emissions from light duty vehicles are typically in the range of those shown in Table 1

Benefit (% reduction)	Light-Duty			
	Euro 1	Euro 2	Euro 3	Euro 4*
PM	42	39	41	33
NOx	10	5	0-5	3
HC	45	63	62	64
CO	40	3	75	86

* limited number of tests

Different vehicles give different emission reductions, and depend on the various test cycles. It is important to note that synthetic fuel enables significant emission reductions even when compared with so-called 'sulphur free' diesel.

Figure 5: Summary of exhaust emission ranges in light duty vehicles from neat synthetic fuels



3. *Local emissions from commercial diesel vehicles*

Emissions from heavy duty engines in trucks and buses powered by diesel are often seen as a major source of poor air quality, particularly in densely populated areas. Synthetic fuels can significantly reduce pollutant emissions from such vehicles – without the need for expensive modifications to refuelling infrastructure and engines. This makes them a far more cost-effective option for reducing pollutant emissions than fuels such as CNG and LPG.

Trials have been carried out in UK, US, Japan and elsewhere to demonstrate the emissions benefits that synthetic fuels offer using existing heavy duty engines. In all cases the trials have been in collaboration with engine and vehicle manufacturers, and have typically shown significant reductions in NOx and particulates emissions.
For example, a London bus was operated on GTL fuel in 2003 in collaboration with DaimlerChrysler. In California, a trial with Yosemite Waters – a bottled water distributor- was held in conjunction with 'International Navistar' engines as well as the local air quality regulator - SCAQMD. Measured emissions benefits for a range of engine technologies are given in Table 2, (from these one can estimate a composite fleet average, which would give a reduction in PM of 18%, NOx 15%, HC 10%, and CO by 10%.

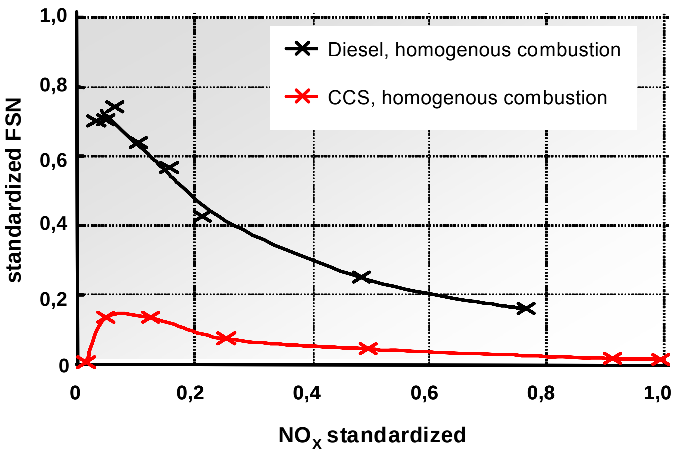
Table 2: Measured emissions benefits for a range of engine technologies

Benefit (%)	**Heavy-Duty**		
	Euro I	Euro II	Euro III
PM	18	18	34↔10
NOx	16	15	5↔19
HC	13	23	<9
CO	22	5	16

4. Emissions from optimised engines

Development work is taking place between engine manufacturers and synthetic fuel suppliers to optimise engines around synthetic fuels and make use of the unique properties. For example the cetane number of synthetic fuels is some 75-80 compared to 45-55 in standard diesel. This enables engine software calibration changes to be made, in addition to hardware changes to reduce compression ratio and to adapt the injection system. These changes increase the efficiency of the engine and further reduce engine emissions. Figure 8 below shows the relationship between the PM and NOx emissions for different engine settings in a prototype HD engine tested by Volkswagen. At all engine conditions GTL has superior PM and NOx emissions compared with the other fuels. This gives an engine designer the possibility of designing low emission, high efficiency engines optimised on GTL fuel.

Figure 6: NOx trade-off in a combined combustion engine with conventional diesel and a tailored synthetic fuel (CCS).



The development of the combustion engines itself will be accompanied by the development of more intelligent powertrain systems, leading to a more comfortable solution with better fuel efficiency.

Synthetic fuels could also prolong the life of advance exhaust filters, where these are necessary to meet emission standards. This is mainly because synthetic fuels have near zero aromatics and sulphur and intrinsically low PM emissions.

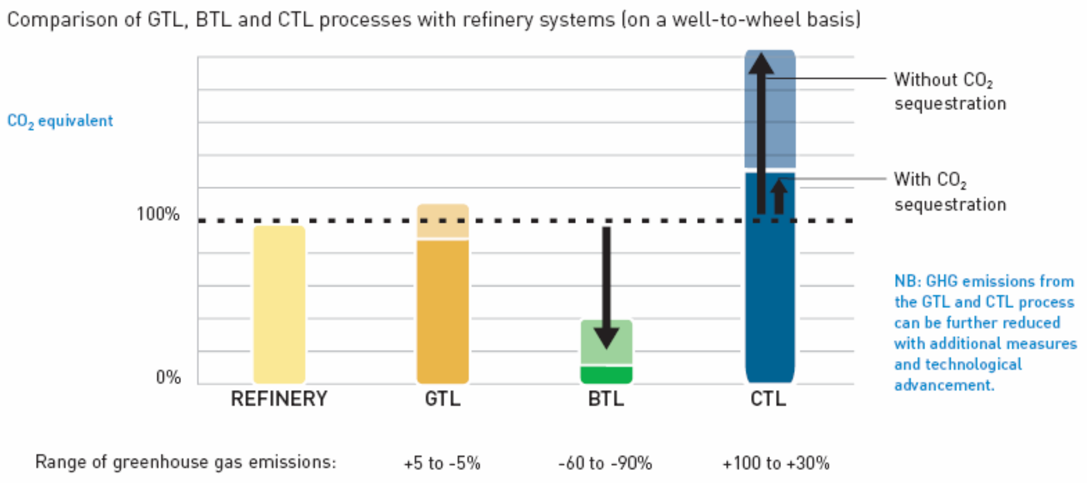
5. Greenhouse gas emissions (GHG) emissions from GTL, BTL and CTL

The environmental attributes of the conventional and synthetic fuel technologies are assessed by measuring the impact caused through production, transportation and fuel usage, the so-called well to wheel basis or life cycle assessment. Industry studies show that greenhouse gas emissions (GHG) of the "GTL system" are comparable to a refinery system (+/- 5%). The well to tank CO2 emissions from a GTL production plant are slightly higher than those from a conventional refinery, but are offset by the tank to wheels CO2 emissions which are up to 4-5% lower. As diesel engines are some 20-30% more efficient, their CO2 emissions are significantly lower (some 20%) than their equivalent petrol counterparts.

Relative to a refinery system, BTL offers clear life-cycle greenhouse gas benefits in the range of 60 to 90% improvement. The BTL process is able to use waste biomass such as woodchips, which has already taken up CO2 from the atmosphere during its growth. Burning the BTL fuel in an engine, simply returns the captured CO2 to the atmosphere.

CTL process has a carbon penalty compared to refinery system, due to the high carbon-to-hydrogen (C:H) ratio of coal, the starting feedstock. However, this could be reduced through CO_2 sequestration and other means.

Figure 7: GHG emissions from GTL, BTL and CTL on a life cycle basis.



Further improvements in synthetic fuels GHG emissions can be expected from optimized engines (5-10%) and process improvements from focused R&D. Hence GTL could reach a 5-10% GHG emission benefit if compared to refinery diesel and CTL plus sequestration could reach a neutral CO2 balance in comparison to today's petroleum based fuels.

6. Summary

In summary, the introduction of synthetic fuels either in neat or blended form can significantly reduce local emissions. The ranges vary between engines and whether they are optimized.

In addition to the improvement of local air quality, synthetic fuels offer the opportunity to shift to alternative energy carriers and open up the way towards sustainable fuel production pathways.
On a life cycle basis, GHG emissions from a GTL system are comparable to those from a conventional crude oil refinery. Synthetic fuel made from biomass (BTL) offers a 90% improvement in CO2 emissions compared to a refinery and enables the possibility of renewable fuel for transport.

Sources:

Shell (Richard Clark) Esslingen 2001 and Esslingen 2005 papers
Daimler Chrysler/Sasol Vienna Motor Symposium 2006 paper
Shell data
Volkswagen (Wolfgang Steiger): Vienna Motor Symposium 2006 paper
Volkswagen Sunfuel Brochure
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