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Position Paper: Dual Fuel

The best fuel in the most efficient engine

A Position Paper of NGVA Europe prepared by:
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Foreword

This NGVA Europe Position Paper gives a general overview of the ecological and economic advantages of the Dual Fuel technology (diesel and natural gas) and shall be taken as a reference document identifying main technical features, but also pointing out required technical and legislative measures creating better market conditions for Duel Fuel powered vehicles. This Position Paper will be used a basis, in order to develop it further within the NGVA Europe expert Working Groups.

Introduction

In the global warming debate the reduction of CO_2 is the main issue. With regard to vehicle technology two approaches are generally considered: improving the engine technology to reduce fuel consumption and using a better, less CO_2 emitting fuel.

Among fossil fuels natural gas is the option that has the best CO_2 reduction potential. Engines that run on natural gas are emitting significant less CO_2 in the combustion process than petrol engines. CO_2 emissions can be reduced further to almost zero when using biomethane. As natural gas and biomethane are chemically comparable, both fuels are fully compatible when used in gas engines.

These engines are basically spark plug engines that are less efficient than Diesel engines. Diesel engines, however, can not run on pure natural gas. DUAL FUEL ENGINES (diesel and natural gas) combine the efficiency and torque characteristics of diesel engines with the reduced emissions of gas engines.

The base engine is a diesel engine where diesel and natural gas are burned simultaneously. Natural gas is fed into the cylinder; the amount of diesel injection is reduced accordingly. As dual fuel systems allow retrofitting of diesel engines, CO_2 plus other tail pipe emission reductions like PM, NOx, CO and HC can be reduced even for existing vehicles. So the ecological benefit can penetrate the market faster. At the same time replacing diesel by natural gas helps to reduce the dependency on oil imports.

System Description

Basically the dual fuel engine remains a diesel engine. Unlike a dedicated gas engine it has no spark plugs. In the dual fuel engine the gas is fed into the intake air or cylinder, the self-ignition of diesel serves as an indirect spark plug to ignite the gas-air-diesel mixture (see Fig. 1). Typically up to 80-90 % of the diesel can be substituted by gas.

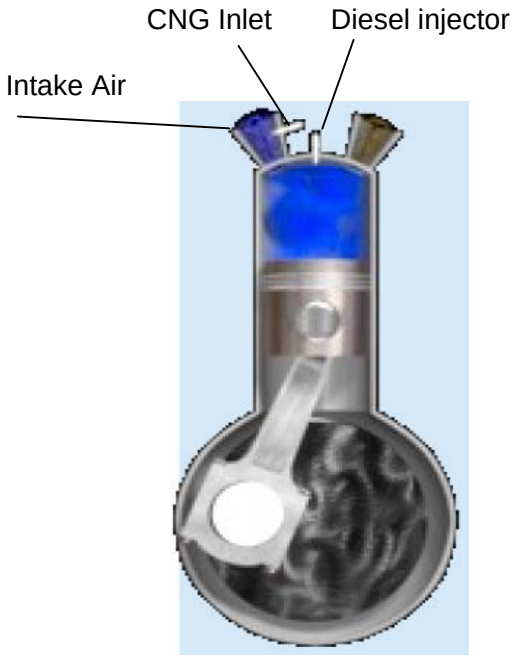

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Fig. 1: Dual fuel principle

Additional components are required for dual fuel operation: CNG high pressure cylinders, a pressure regulator, temperature and pressure sensors, gas injectors, an electronic control unit, filters and, depending on Euro emission levels, other components like an oxy-catalyst.

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As the engine remains a diesel engine, efficiency and torque of dual fuel engines are comparable to the diesel engine. The diesel is the most efficient combustion engine, which means fuel consumption is lower than that of a spark plug engine. The use of duel fuel combustion technology retains the power, torque and fuel consumption, but with the benefit of a lower carbon fuel.

Emissions

Natural gas in combustion engines is a very clean fuel. It is free of particulate matters (PM) and produces less CO_2 than petrol fuel. The emissions of dual fuel engines therefore show less PM and CO_2, the amount of reduction is depending on the share of CNG added, the type of the basic diesel engine and the engine control management.

Typically assuming a 50 % content of CNG, the reduction of CO_2 is between 10-15%, PM reduction is up to 60 %.

Fig. 2 indicates the range of reduction as given by measurements of the Technical University of Kaiserslautern, published test results by SBS, Bosch and Clean Air Power.

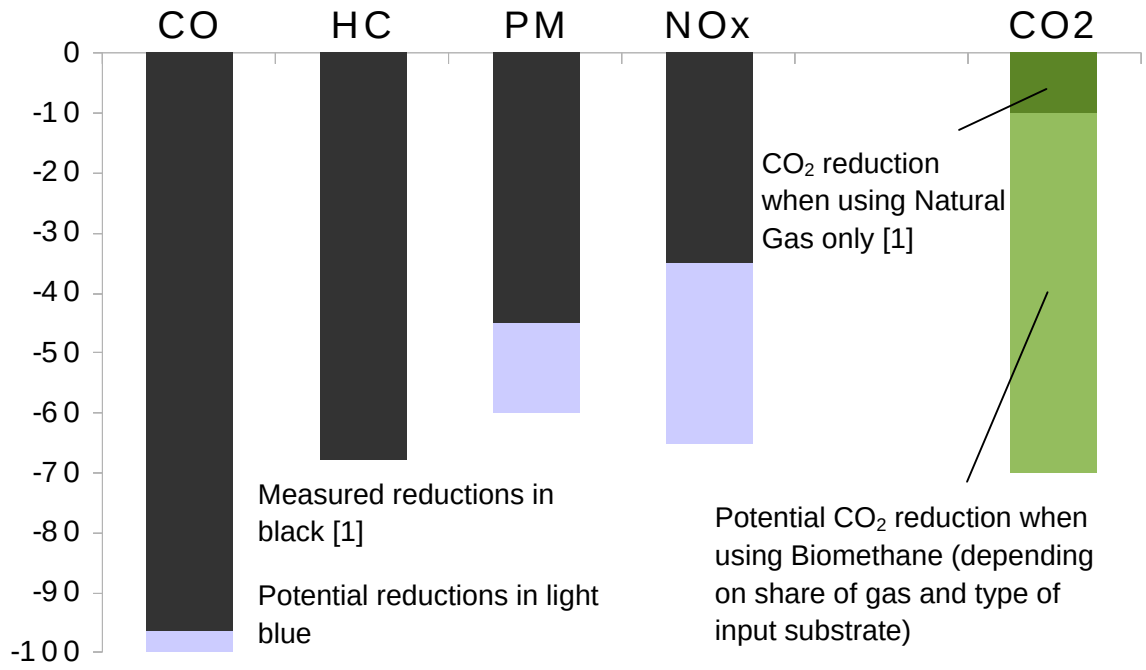

Fig. 2: Reduction of emissions (%)

The potential to reduce emissions also depends on the basic diesel engine. Modern common rail engines have a higher potential due to the variety of parameters that are controlled by the electronic engine management. However this requires a profound knowledge of the OEM´s engine control, an obstacle for retrofit applications. With the availability of today's new systems that can work without interfering the OEM control unit, this problem may be overcome. Older engines are easier in this respect, unfortunately they have a lower potential in reducing emissions and the share of gas which can be added is limited.

There is the technological potential to "upgrade" a diesel vehicle, i.e. the level Euro 3 of a diesel vehicle could be improved to Euro 4 when adding a dual fuel retrofit kit. This would be particularly interesting to keep access to restricted urban areas especially in Germany ("Feinstaubzonen"). This may require some effort (and thus cost) and may not be applicable to all engines. How to homologate such an upgraded engine is not defined yet – one of the issues in the current discussions on the European level.

A very significant advantage of dual fuel systems is the reduction of CO_2 when using biomethane (see Fig. 1 and [5]). At 50% operation with biomethane, CO_2 reduction could be approximately 50% (depending on the way biomethane is produced). The best small diesel passenger vehicles with an emission of 80-90 g/km CO_2 could be reduced in CO_2 further down to 40-50 g/km when using biomethane in dual fuel operation. This would be best in class among existing technologies including electric vehicles in a well-to-wheel consideration.

Economic Benefits

Normally natural gas is a cheaper fuel compared to diesel. Cost savings of dual fuel vehicles will depend on the share of gas added. The more gas is added, the higher the savings of fuel cost. On the other hand, the higher the gas share the more complex the required hard and software of the system will be. Also, durability concerns may occur when operating at high gas to diesel ratios. Engine experts say that typically the diesel engine is not affected by durability concerns when the gas share is limited to 50-60 %.

The on-cost for dual fuel systems is driven by the cost for the gas cylinders, exhaust systems, component cost for additional sensors, injectors etc. and the electronic control unit. The on-cost for components is less than compared to dedicated gas vehicles because the main cost drivers are the CNG cylinders which can be reduced in volume as the range is guaranteed by diesel fuel as well.

The higher the emission level of the basic diesel engine is, the higher the effort concerning engine control has to be, leading to higher cost in development and sensor/component technology.

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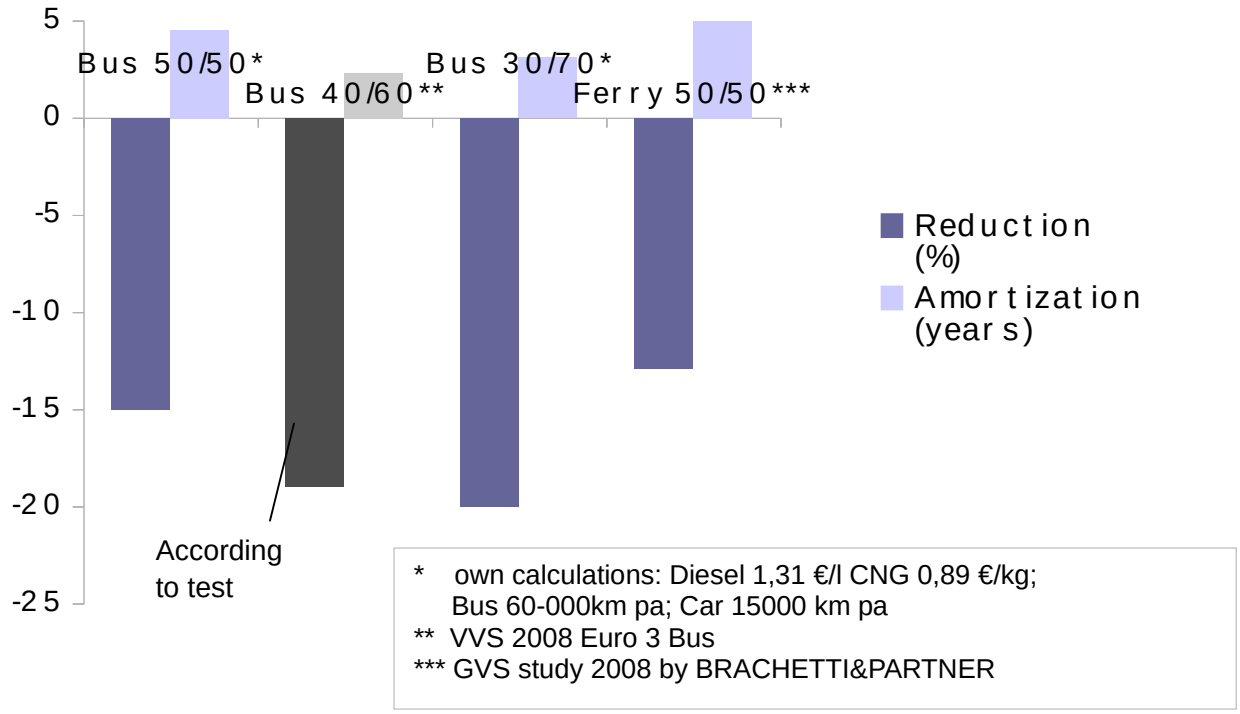

Fig. 3: Fuel cost reduction (%) and amortization (years)

Fuel cost reductions (Fig. 3) based on German CNG and Diesel pricing are about 15 to 20 %. Amortization for the busses is less than 3 years, assuming system costs of about 15.000 € with the vehicle 8 to 10 years in operation, see [1]. For the ferries amortization is about 5 years while the vessel is in operation for 15 years, details see [2]. Both cases show that dual fuel operation is giving an impressive commercial benefit especially to fleet operators, when having a high annual mileage and highly powered engines.

If required, dual fuel vehicles can be operated in single fuel (diesel) mode as well, as the basic diesel engine remains unchanged. Vehicles can operate in areas without CNG or LNG supply.

Market Segments

In principal dual fuel systems can be applied to all diesel vehicles:

- Passenger cars
- Trucks, busses

- Off-highway vehicles
- Trains
- Ships, ferries, boats

Dual fuel systems in vehicles of high fuel consumption and high mileage are the preferred option from an economic point of view.

Retrofit options could provide solutions to reduce cost and emissions for existing vehicles of high operation cycles like busses, trucks, ships and trains.

Passenger cars are more likely to be supported by OEM solutions due to the packaging situation and the complexity of the vehicle architecture.

Legislation

On the European level a homologation of dual fuel vehicles is NOT possible due to the latest amendment of ECE R115 which removed test procedures for dual fuel engines. Also, dual fuel passenger cars and light duty vehicles are not covered by ECE R115. National regulations exist in the Netherlands, the UK, Italy and Sweden.

A proposal to overcome the road block is being prepared and will be submitted to the UN ECE authorities in the first quarter of 2010. This proposal does not comprise passenger cars and light duty vehicles.

Conclusions

Emissions

A significant reduction of CO_2 emissions of diesel engines in dual fuel operation is possible. Example: 50% CNG content reduces CO_2 by 10-15 % which is very difficult to achieve with conventional efforts. By using biomethane a 40-50% reduction should be possible and which is not achievable by others means.

Dual fuel operation reduces particulate matters significantly.

Cost

Compared to dedicated CNG vehicles the system cost of dual fuel systems is lower as the main cost driver, CNG cylinders, can be reduced in volume to achieve sufficient range.

Based on German fuel prices fuel costs are reduced by appr. 15-20 %. See [1, 2].

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Strategy

The diesel engine is the most efficient engine and natural gas is the cleanest fuel. When using biomethane the CO_2 emission problem in the well-to-wheel consideration is minimized. As it is based on internal combustion engines the on-cost is much lower than for any electric based vehicle, at least within the next 10 to 15 years. Natural gas reduces the dependency on oil imports; the production of biomethane is possible within Europe.

For the future the road to hydrogen is open as dual fuel operation also allows Hythane (blend of hydrogen and natural gas) and pure hydrogen to be used with diesel.

Action plan for Europe

Dual fuel technology combines economic benefit to the user with significant potential to reduce CO_2 even for existing vehicles. To support the market penetration in the short term several actions should be taken:

- Homologation on European level including vehicle classes M1 and N1
- Best level certification: dual fuel allows both, single diesel operation and diesel/gas operation. The Euro level certification should follow the better emissions (dual fuel operation) analog to the petrol/gas regulation (Annex II), thus allowing the “upgrading” in EURO emission level for retrofit vehicles.
- Taxation: When using biomethane as a fuel, taxation should reflect its CO_2 advantages in the well-to-wheel process. Currently no other technology can offer such a potential to reduce CO_2, in the short term even applicable to existing vehicles.
- EU should provide support for retrofitting diesel vehicles with dual fuel technology, especially as a means to reduce particulate matters in urban areas.

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Bibliography

1. **Stadtbahn Saar - Press release** *Diesel-Erdgasverfahren entwickelt, Innovation aus dem Saarland senkt Emissionswerte und Kraftstoffkosten*, *12. November 2008*.

2. **BRACHETTI & PARTNER** im Auftrag der **GVS**, *Konzeptstudie zur Einführung von Diesel-Erdgas-Mischbetrieb bei Bodenseefähren.* Düsseldorf, June 2008.

3. **Peter Boisen**. *Dual Fuel technology reduces CO_2 emissions*. NGVA Technical Communication, 2008.

4. **Dr. Stefan Behrning.** *Dual Fuel Technology in Europe.* Köln, 16. December 2009.

5. **Clean Air Power.** *Low-carbon heavy goods transport with dual fuel and biomethane.* Malmö, January 2010.