Vehicle investigation on Hydrogen/Compressed Natural Gas mixtures (HCNG, 2 Vol.% H_2)

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Project description

The energy turnaround will produce huge amount of fluctuating renewable excess electricity. Wasting of this renewable energy has to be avoided, therefore chemical storage of excess electricity and utilization for mobility is well suited with a high potential for the substitution of fossil fuels. HCNG is the cheapest technology (fuel and vehicle) for using fluctuating renewable excess electricity in mobility.

Current CNG vehicles are approved for natural gas with a hydrogen content of maximum 2 Vol.%. For higher blending ratios an adaption of the vehicle is necessary. Since pure natural gas in Switzerland contains almost no hydrogen, up to 2 Vol.% of hydrogen, produced with renewable energy, can be admixed without negative impacts on the gas grid and the vehicle infrastructure.

Three vehicles (Fiat Ducato) of the fleet operator company Mobility Solutions AG were selected as field testing vehicles and were equipped with data loggers to record various engine parameters. The vehicles were in use about 3 months in normal operating with CNG. After this phase, the vehicles were successively switched to HCNG operation and measured again on the dyno after some run in time to investigate the effects of small blending ratios.

Field testing

The CNG vehicles with 2 Vol.% hydrogen blending are mainly used in the parcel distribution service and therefore have a high number of engine starts per day. The data from the field test shows an average of over 30 starts a day. Currently 7'600 engine starts with CNG and 10'500 engine starts with HCNG have been evaluated. On average, 95% of the engine starts are carried out at an engine coolant temperature higher than 80°C.

The evaluation also included an analysis of engine start times. One of the results of this analysis was the time delay from the first turn of the engine starter and the first firing of the first cylinder (CTFF) derived from engine speed measurements during startup. Four different delays were distinguished:

- *Very short*
  CTFF smaller than 100ms
- *Short*
  CTFF between 100ms and 200ms
- *Normal*
  CTFF between 200ms and 400ms
- *Long*
  CTFF bigger than 400ms

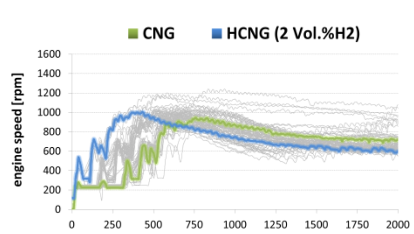


Figure 1: *Various engine start speed traces with examples for CNG and HCNG*

HCNG compared to CNG operation shows a shift to shorter crank to first fire times (Figure 2). This can be explained with the higher ignition quality caused by the hydrogen in the HCNG blend. Even small amounts of hydrogen seem to have a measurable impact on the engine start quality.

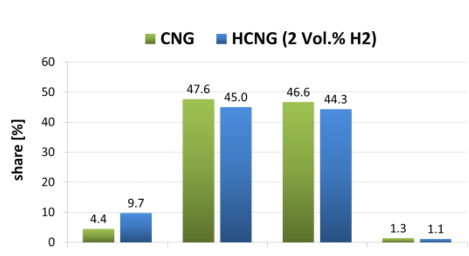


Figure 2: *Start time distribution for CNG and HCNG (average of three vehicles and a total of 18'100 engine starts)*

Chassis dyno measurements

With each vehicle base measurements were carried out on the chassis dynamometer with CNG and also with HCNG (2 Vol.% H_2) as fuel. As driving cycle for these measurements, the CADC cycle from the Artemis program has been used. This cycle corresponds to a real world driving cycle with three phases (urban, rural, highway) (Figure 3).

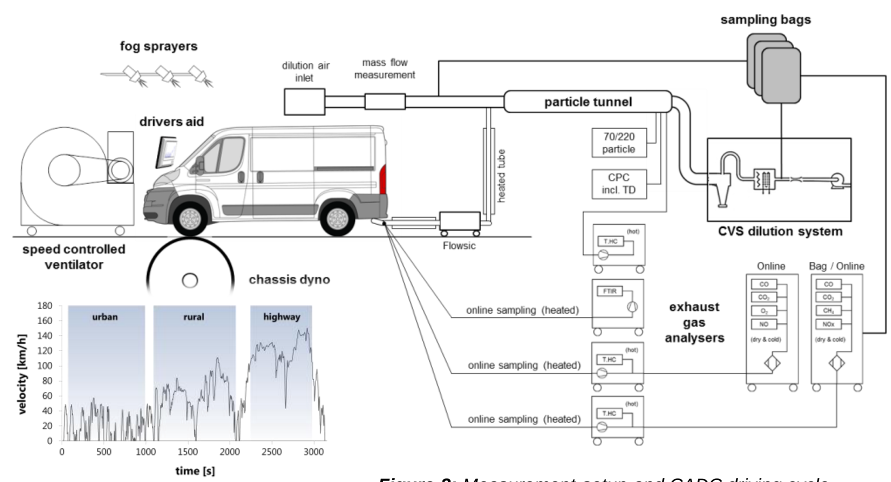


Figure 3: *Measurement setup and CADC driving cycle*

The emission values for carbon monoxide (CO), nitrogen oxides (NOx) and unburned hydrocarbons (T.HC) show no significant differences between the two types of fuel. However, the 2 Vol.% H_2 blending shows a slight reduction of CO_2 emissions of 1 - 1.5% (Figure 4), which can be explained by the reduced C-content of the fuel as well as a slight improvement of engine efficiency (Figure 5).

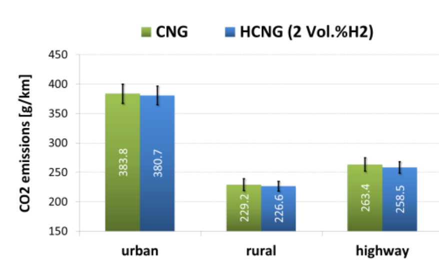


Figure 4: *Average CO_2 emissions , CADC (error bars represent the standard deviation)*

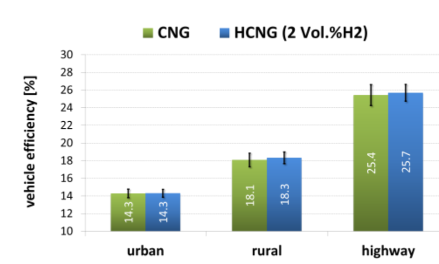
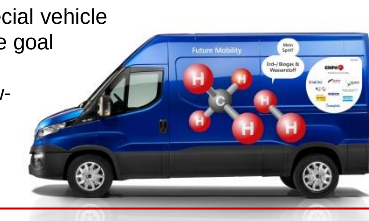


Figure 5: *Vehicle efficiency (tank to wheel, error bars represent the standard deviation)*

The slight efficiency increase can be explained by the improved ignition phase. Such effects have already been observed at Empa in other HCNG projects. In the current case, however, they are very faint due to the low blending of hydrogen.

Outlook (HCNG, 25 Vol.% H_2)

To investigate the effect of higher blending ratios a special vehicle is in preparation (up to 25 Vol.% hydrogen content). The goal is to show that with minor changes in the fuel system, current CNG vehicles are capable of running with renewable fuel produced with fluctuating excess electricity with lower CO2 emissions and higher efficiency.



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