Hythane®
for city bus operation

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How to reach sustainability?

1. Natural gas
2. Biogas
3. Hythane
4. Hydrogen

Hydrogen – From many different sources

- Production from fossil fuels
  - Natural gas, coal, crudes
- Production from biomass
  - Gasification, fermentation
- Biological hydrogen production
  - Photosynthesis, fermentation
- Electrolysis

Hythane – A first step towards hydrogen

- Reduction of pollutants (NO_x, CO and HC)
- Reduction of greenhouse gas emissions through renewable fuel
- Reduced greenhouse gas emissions through reduced fuel consumption (higher engine efficiency)

Hythane - The history

- 1992 - Patent on hydrogen introduction for NO_x-reduction
- 1995 - Demonstration of buses in Montreal. Significant NO_x-reductions observed
- 2001 - 3 buses in California, USA
- 2003 - 2 buses in Malmö, Sweden
- 2006 - Two cities in France ?
- 2008 - 10 000 buses in Beijing ?

The Malmö Hythane® project

Development and demonstration of the use of natural gas/hydrogen-mixtures as fuel in natural gas buses

Project Partners:

SGC, E.on, Lunds Universitet, Raufoss Fuel Systems, Energimyndigheten, Skåne, Carl Bro Intelligent Solutions

Targets

- Increase the efficiency of the engine by 5 - 7%
- Decrease emissions of NO_x and CO by >10%.
- Decrease the emission of greenhouse gases by 10 - 20%

7 work packages

Photo: Volvo

- Bench test with Volvo engine
- System study vehicle
- System study and system adjustment - refuelling
- Conversion of bus
- Test and follow up of bus in city traffic
- Emission testing
- Reporting and dissemination

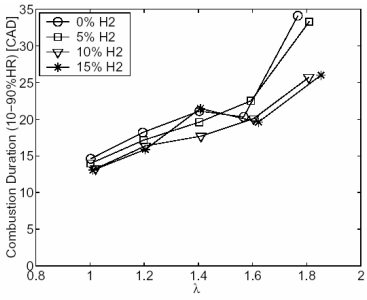
Hydrogen from renewable electricity

- Capacity: 36 Nm^3H_2/tim
- Total energy efficiency : 5,3 kWh/Nm^3H_2 (η=56%)
- Water consumption: 36 l/tim
- Installed power supply: 210 kW

Hydrogen filling station in Malmö

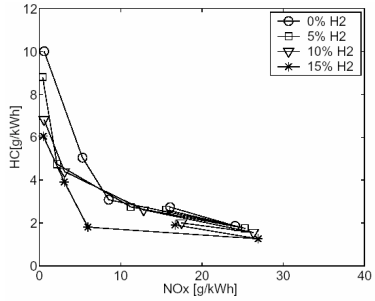
Photo: Owe Jönsson, SGC, 2003

Results - Single cylinder tests



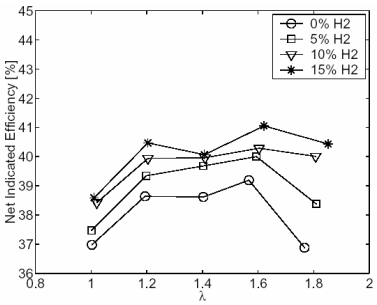
Combustion duration shorter with hydrogen addition, especially close to the lean limit

Results - Single cylinder tests



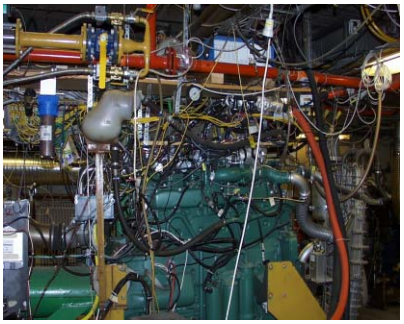
Hydrogen addition significantly reduces hydrocarbon emissions at any NO_x-level

Results - Single cylinder tests



Faster combustion and higher combustion efficiency with hydrogen => Higher efficiency

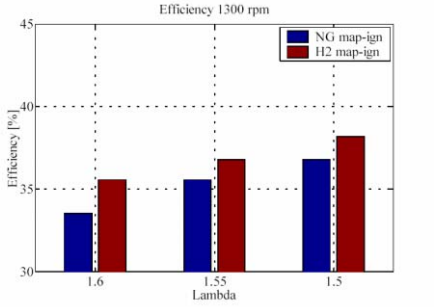
The six cylinder engine



Volvo TG 103 /G10A

Efficiency - six cylinder engine

8% Hydrogen



Emissions - six cylinder engine

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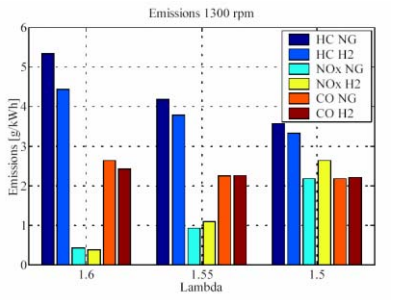
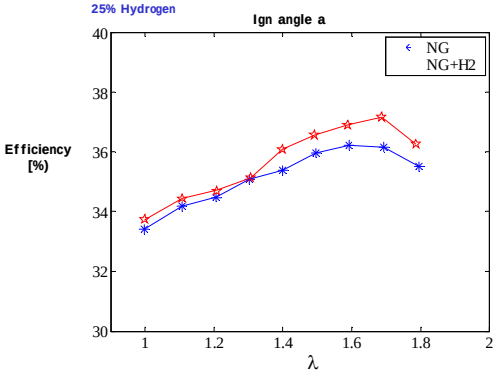


Efficiency - six cylinder engine

25% Hydrogen



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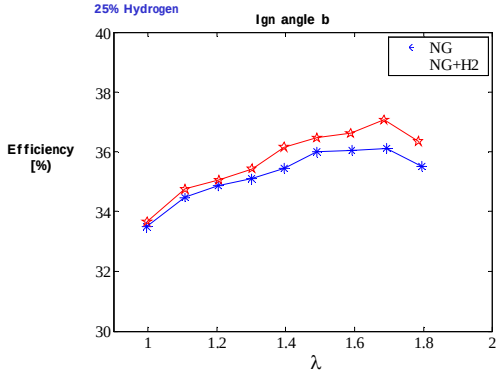

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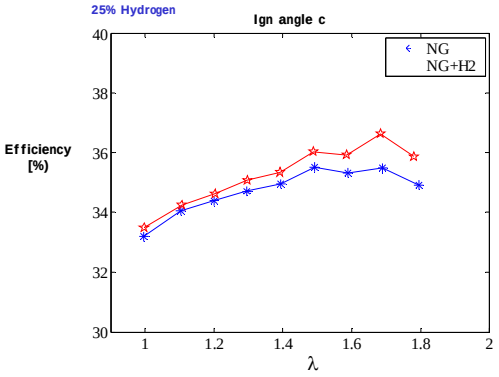

Emissions - six cylinder engine

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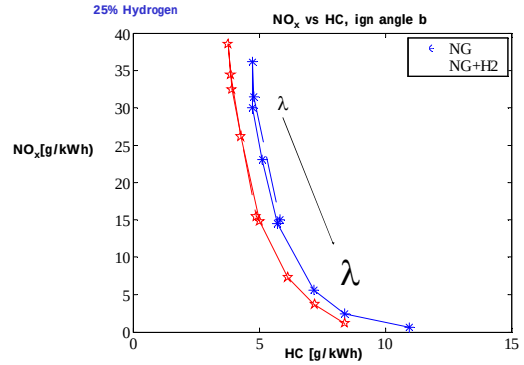

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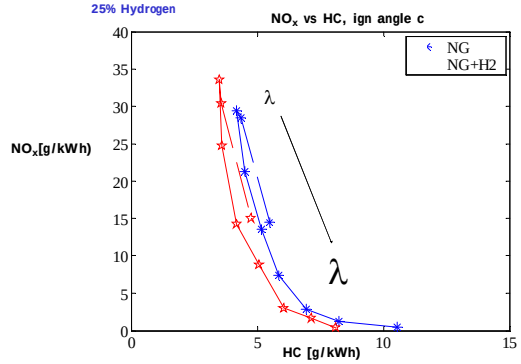

Emissions - six cylinder engine

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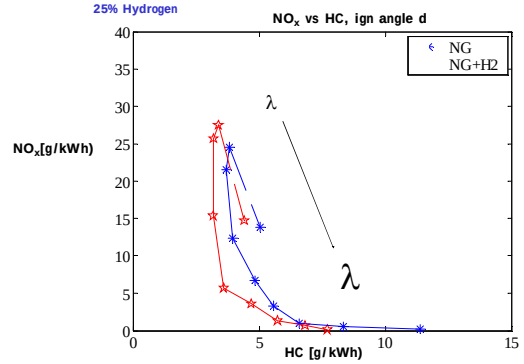

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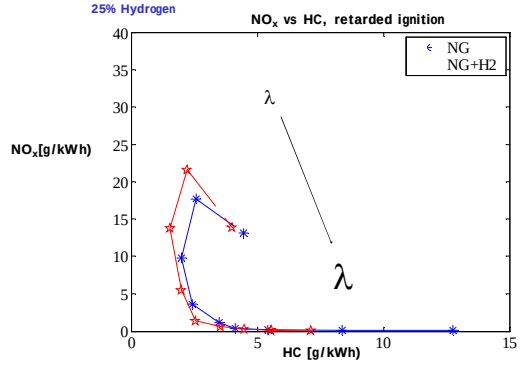

Emissions - six cylinder engine

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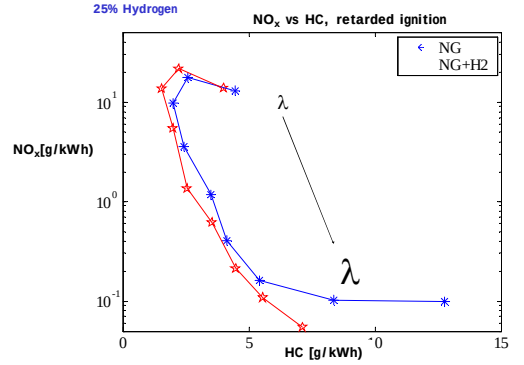


Conclusions – laboratory tests

6 cylinder engine, 25% hydrogen

- 28% reduction of CO_2-emissions with Hythane®
- Significantly better HC/NO_x trade off => "0-emissions" of NO_x possible
- Slightly improved efficiency with 25% hydrogen compared to CNG and 8%
- 25% hydrogen requires retarded ignition and increased fuel supply

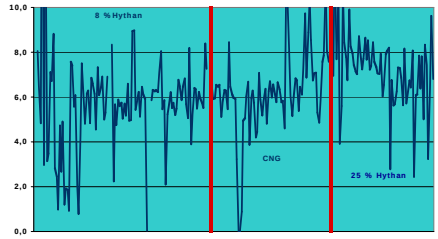
System study - vehicle

- >95% components in fuel system were hydrogen compatible
- Cylinder head incompatible but hydrogen concentration was deemed to be low
- Hoses specifically monitored
- Re-inspection at end of project

Safety recommendations

- Training program for maintenance staff
- Regular leak detection
- Visual inspection of degradation
- No refuelling with 100% hydrogen !
- Identification of Hythane® buses by stickers and signs
- Log book
- "Invisible flame" detector

Fuel consumption

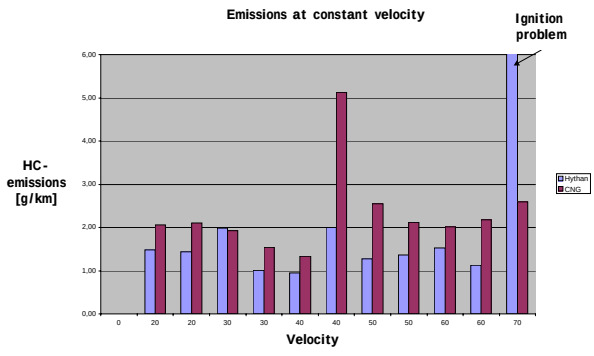


- Difficult to get accurate statistics
- 14% fuel reduction with 8% hydrogen (2,3% H_2 on energy basis)
- 4% fuel reduction with 25% hydrogen (7% H_2 on energy basis)

"On road" emissions test

- Test during full load and constant load
- 20-30% reduction in HC-emissions
- Higher power with Hythane®
- Transients give 50% less HC and CO but 50% more NO_x
- Improved operation with Hythane®

"On road" emissions test



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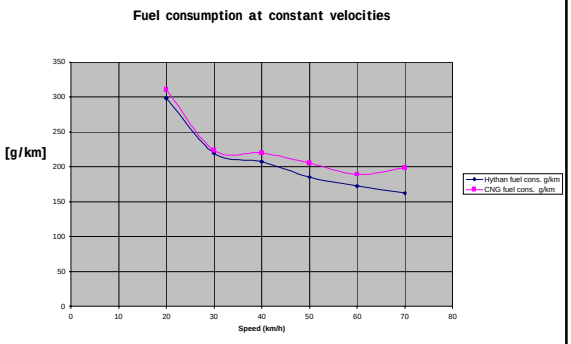

Summary of results

- Laboratory values difficult to achieve in practice
- Small hydrogen addition yields relatively big results (10 – 15% reduction in GHG emissions)
- Settings of 25% bus not optimal for emission reduction
- Considerably improved operability of bus with hydrogen addition
- Conversion to Hythane®8 requires no adjustment to bus
- Conversion from CNG to Hythane®25 very simple but must be optimized
- No hazards with Hythane® have been observed
- Positive reactions from drivers

Conclusions

- Fuel cell vehicles are currently not yet a commercial alternative
- Hythane® is possible to distribute in the NG grid
- Hythane® gives lower fuel consumption and lower CO and HC-emissions from HD NGV´s
- Conversion from NG to Hythane® is simple
- Hythane® significantly reduces GHG-emissions
- Hythane® is a first step towards a hydrogen society