ENGVA – for sustainable mobility

Challenges and opportunities for NG and biomethane used as a vehicle fuel

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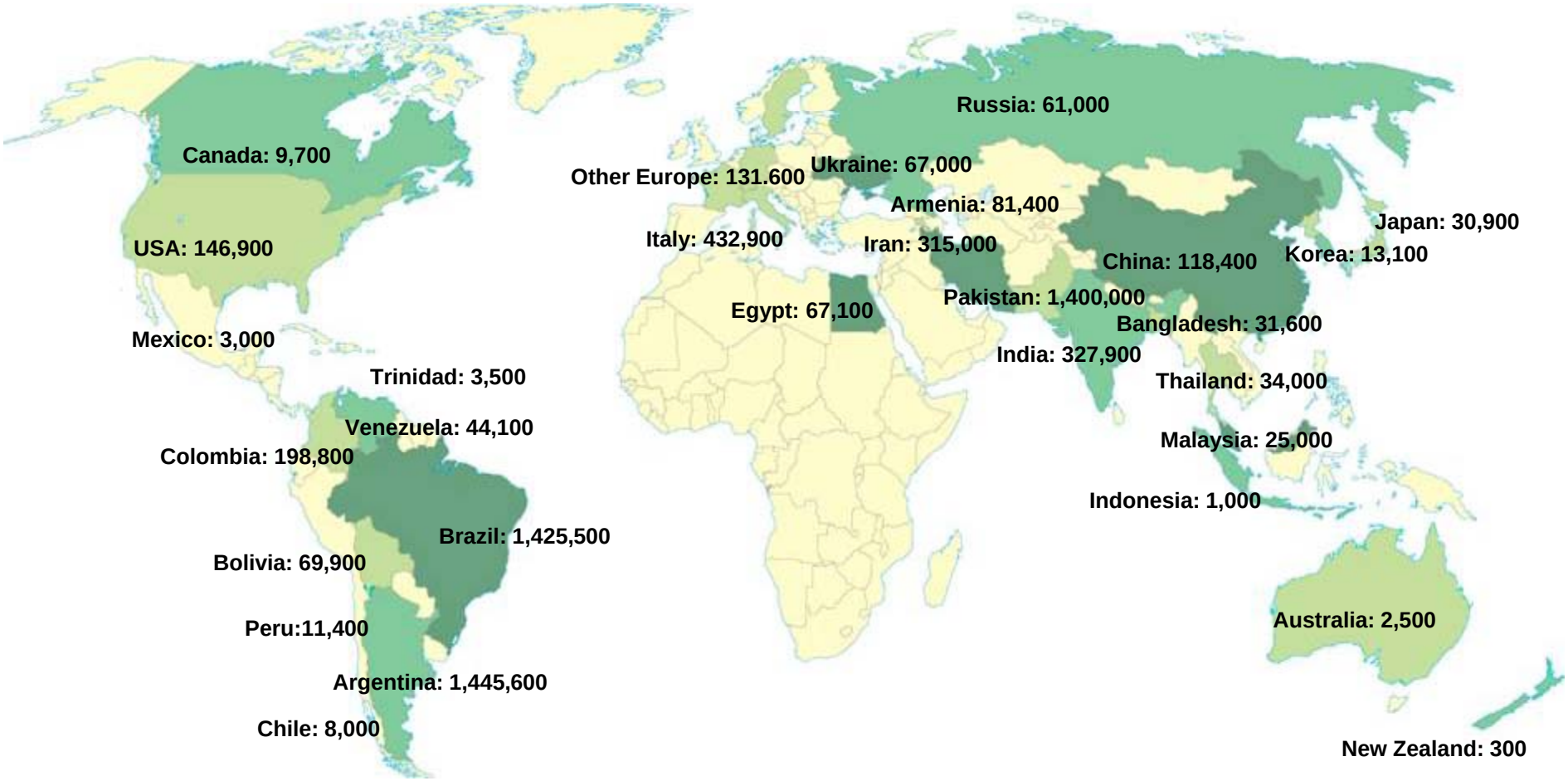
DEFINITIONS

- **Biogas: Raw gas produced in anaerobic digestion (AD) plants, which, in its untreated form, apart from methane also includes a 30-40 % biologically derived carbon dioxide**

- **Biomethane : Almost pure methane gas produced via upgrading of landfill gas, or raw biogas. Also produced synthetically via gasification of forest industry waste.**

- **Biomethane is chemically more or less identical with high grade natural gas, and fully interchangeable with natural gas, thus no need for special vehicle, or equipment standards**

6.6 MILLION NGVs WORLDWIDE



162,000 buses, 129,000 trucks, and 6,300,000 cars now running on natural gas and biomethane

APPROXIMATE PRESENT WORLDWIDE USE OF METHANE AS A VEHICLE FUEL

	Billion Nm3	TWh	PJ	Mtoe
Total	20.6	206	743	17,8
Cars	13,6	136	489	11,7
Buses	5.8	58	210	5,0
Trucks	1,2	12	45	1,1

Grammes of CO2 emissions per 10 kWh LHV (lower heating value) energy content

• Methane	1980
• Propane	2368
• DME	2460
• Methanol	2538
• Diesel	2675
• Gasoline	2723
• Ethanol	2755

One litre of diesel, or one Nm3 of methane, both contain 10 kWh
One litre of diesel generates 2.7 kg of CO2
One Nm3 of methane generates 2.0 kg of CO2
The use of gaseous, instead of liquid, fuels offers large CO2 savings
Methane outperforms all other hydrocarbon fuels concerning CO2

FUEL USE IN DIFFERENT VEHICLES

A city bus on average consumes as much fuel as 15 passenger cars (or 15 one family houses)

A large 44 ton truck might in a year typically consume as much fuel as 50 passenger cars (in extreme cases twice as much)

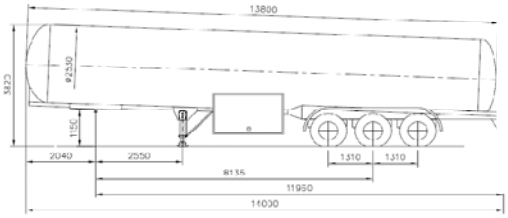
Dual fuel trucks fitted with LNG tanks on the tractor unit, CNG tanks on the trailer, are now in focus. At least 80 % diesel substitution, and the same energy efficiency as a normal diesel engine. Thus 20 % CO2 reduction driving on NG, 80 % when using biomethane.

Transportation costs – CNG vs LNG

Costs included:

CNG swap body, or LNG trailer investments

Running costs for tractor unit, including fuel, driver, loading and unloading



One way distance	**CNG** 1.8 ton swapbody [€/Nm^3]	**LNG** 21 ton trailer [€/Nm3]
100 km	**0.14**	**0.02**
200 km	**0.26**	**0.04**
400 km	**0.52**	**0.06**

Cost level expected to be substantially lower in Asia, but the relations would be the same. Swap body transports only economically viable over very short distances.

Technology for cryogenic upgrading of biogas

Cryostar/Prometheus technology available for flows in excess of 500 Nm3/hour

Capacity 1000 Nm^3/hour raw biogas	Only LNG sales [€/Nm^3 LNG]	Also CO2 sales [€/Nm^3 LNG]
Investment costs	**0.08**	**0.08**
Operational costs	**0.10**	**0.10**
Maintenance costs	**0.05**	**0.05**
CO2 income	**-**	**- 0.12**
Total net cost	**0.23**	**0.11**

As a comparison European costs of conventional upgrading is around € 0.15/Nm3 for plants with an annual production of 3-5 million Nm3 (most likely somewhat lower in Asia)

BENEFITS WITH LNG DUAL FUEL TRUCKS

LNG gives 500 km range on gas (another 500 km if CNG tanks are fitted on the trailer)

Full cargo capacity

Reduced total operating costs

Environmental benefits

Reduced crude oil dependence

Flexibility – can drive on diesel in areas without LNG supply

The Early Vehicles

HARDSTAFF CATERPILLAR DUAL FUEL

ISSUES

- An urgent demand to replace petroleum fuels
- New fuels, and new or modified vehicle systems need time to reach maturity. Some ‘child sicknesses’ are unavoidable.
- Local variations in fuel quality and varying climate conditions may cause unforeseen problems
- Initial poor refuelling infrastructure limits market potential
- Low sales volumes give high development costs per unit
- Customer risks must be minimized
- Government needs to ‘stimulate’ the automotive industry

- The following slides focus on some regulatory issues which directly or indirectly affect the market potential for vehicles using NG/biomethane

ECE R115

- **Aftermarket conversions of light duty vehicles may result in accelerated engine wear unless components like valves and valve seats are exchanged. R115 does not include any demands regarding testing of life length of converted engine.**
- **OEM engine warranties and normal product liability responsibility void unless conversion made with OEM approval**
- **Retrofit system supplier becomes responsible for warranty and product liability.**
- **Installer is responsible only for failures caused by an incorrect installation.**
- **Buyers of LD conversion kits may expose themselves to a considerable financial risk. In high value cars this risk may be unacceptably high.**

LNG

- The use of onboard LNG fuel systems offers far higher operating ranges than CNG systems.
- LNG supply not limited to imports via seaboard terminals. Also possible to locally transform high pressure pipeline gas into LNG at very low costs. LNG may also be produced via cryogenic purification of biogas or landfill gas.
- Supply of LNG may in a number of locations be simpler and cheaper to arrange than supply of CNG.
- For commercial vehicles used on a daily basis all year round LNG boil-off does not present a problem (tank contents will not vent for a period of up to two weeks).
- LNG is not a good option for privately used passenger cars which now and then may stay unused for weeks.
- The European use of LNG solutions in commercial vehicles is hampered by the lack of accepted standards and regulation codes.

DUAL FUEL

- **Fuel efficiency on par with diesel combustion. CO2 emissions and fuelling costs very substantially reduced. Noise and regulated emissions also reduced.**
- **Engine or vehicle type approval rules lacking. Power output, regulated emissions, and CO2 emissions easy to establish. The tricky issue is to define the fuel consumption, of diesel and NG respectively. We need to combine the CO2 method with actual fuel consumption measurements.**
- **Enormous potential to reduce crude oil demand. Helps to cure European oil refinery output imbalance (too much petrol, too little diesel).**
- **Present focus is on HD, but would also function in LD cars. New dual fuel projects are underway in several countries, but we urgently need certification rules concerning fuel consumption.**

L-CNG FILLING STATIONS

- **CNG refuelling structure at locations far away from the existing NG grid is a problem. Truck transports of CNG economically only feasible over very short distances (say below 100 km), for LNG distances of up to 1000 km are acceptable.**
- **L-CNG station investment costs are on par with conventional CNG stations, but cost less to operate and maintain. Have added advantage of also being able to supply LNG, thus enabling market expansion for HD dual fuel LNG long haulage vehicles.**
- **The challenge - to quickly arrange standards and regulations for road transports of LNG, and for L-CNG filling stations.**

HYTHANE ™

- A small percentage of hydrogen added into natural gas/biomethane may have positive effects both on regulated emissions and engine fuel efficiency. Range reduction is a possible trade-off.
- Forecourt reforming of NG into hydrogen, and local blending of hythane, would help to create a base supply of hydrogen
- Stumbling blocks - the present R110 rules limit the hydrogen content carried in some CNG steel tanks to max 2 % by volume. Could the use of 'hythane' be handled within R110?
- What steps would be required to arrange certification of engine power, CO2, regulated emissions and fuel consumption? The CO2 method alone does not give correct fuel consumption data.

ECE R110

- **Has one basic flaw – the choice of two different ranges of operating temperatures – COLD (down to -40^0 C), or MODERATE down to – 20^0 C. Regardless of approval alternative the vehicles are allowed for use all across Europe. Very marginal cost savings via the MODERATE choice may endanger safety and functionality when a vehicle is used under really cold conditions.**
- **Fortunately no difference in demands for cylinders, PRD valves, and manual valves**
- **These dual standards are not in line with European internal market demands.**

NEW DEMANDS FOLLOWING FROM WIDER CHOICE OF FUELS AND FUEL BLENDS

- **Fuel consumption expressed in volumetric units no longer enough. It would be easy to also express the certified consumption in LHV energy units (e.g. kWh or MJ/100km).**
- **To avoid confusion, regulatory texts should, concerning NG/biomethane gas volumes, always state Sm3 or Nm3.**
- **For BEVs and plug in hybrids - a convention for converting power use to average LHV energy units required to supply this electric power. How can one otherwise compare the fuel economy in these vehicles with conventionally powered vehicles?**
- **A similar approach might also be relevant concerning air pollution and CO^2 emissions.**
- **Similar issues will come up in connection with the use of hydrogen.**

THE WAY AHEAD

Oil production has already peaked in many oil producing countries, but the world demand just keeps growing. According to the laws of supply and demand the oil prices are skyrocketing. Natural gas production will also peak, but most likely twenty years later. These twenty years could be used to start a gradual replacement of natural gas with biomethane.

Biomethane produced from waste offers a more favourable greenhouse gas balance than any other fuel - including hydrogen produced with renewable power. Gas produced from manure is not only CO2 neutral, but actually reducing the overall GHG impact due to avoided natural leakages of methane, ammonium and laughing gas. The residuals from the gas production can be used as fertilizer, thus further reducing CO2 emissions, and avoiding eutrophication problems.

Methane, whether natural gas or biomethane, is the cleanest of all hydrocarbon fuels, and thus helping to combat air pollution.

Finally, even if we found a lot more oil, we cannot continue to increase the global greenhouse gas emissions. Wind, waves, tides, photovoltaics, geothermal energy etc can be used to provide electric power and heating, but the biomass resources should, to the extent possible, be conserved for use in the transportation sector. No other biofuel can compete with biomethane concerning fuel yield per ton of waste, or per hectare of arable land.

Thanks for your attention!