The future role of biomethane as a vehicle fuel

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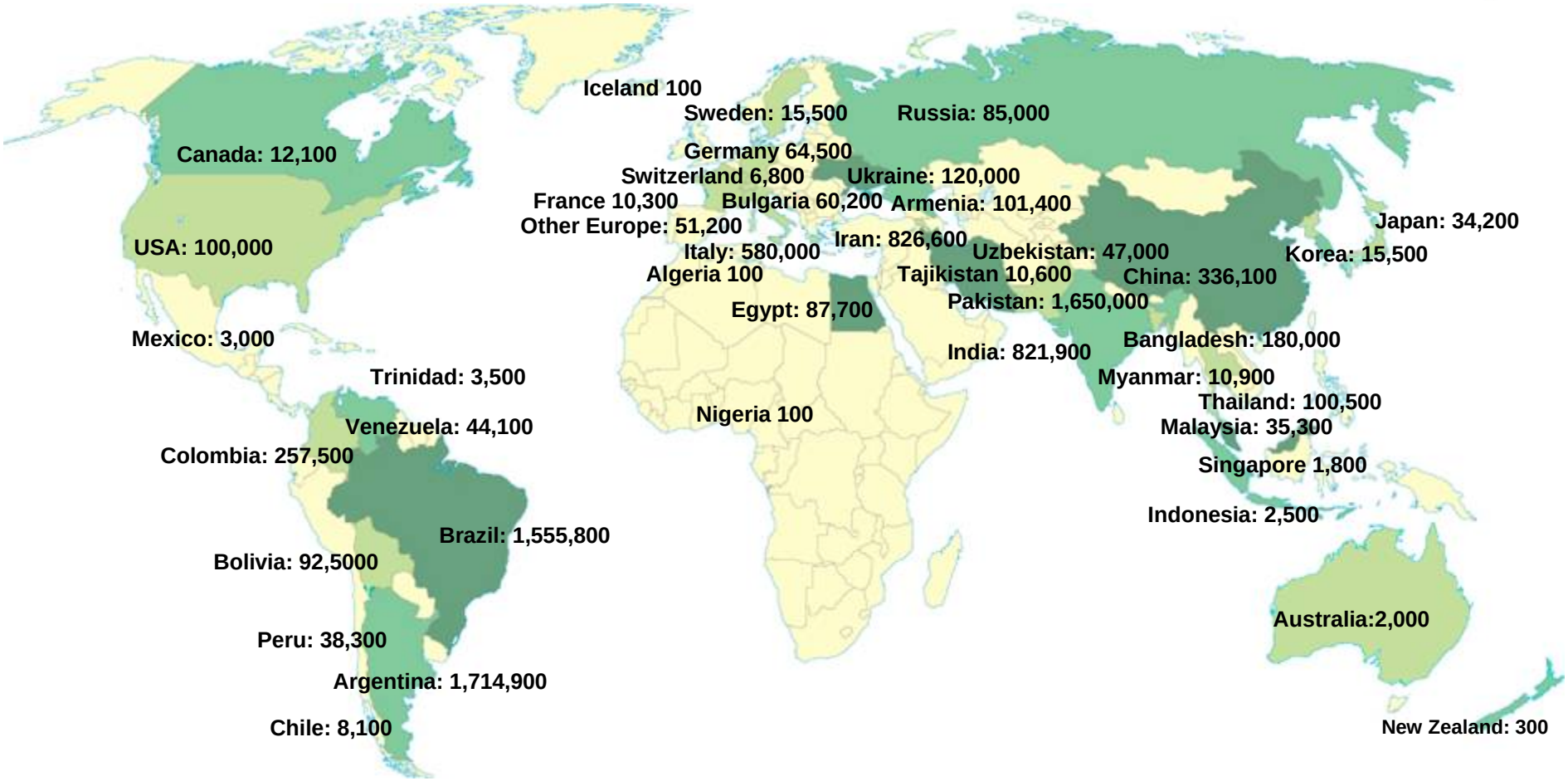
9.1 MILLION NGVs WORLDWIDE IN OCT, 2008
(4 million at the end of 2004)



Source: The GVR, Sept 2008, adjusted

7,707,000 cars, 180,000 buses, 143,000 trucks, and 1,029,000 other vehicles now running on natural gas and biomethane, using 25,4 billion Nm3 of methane annually (21.9 Mtoe). A total of 13,000 filling stations worldwide.

NGVs as % of all cars, trucks, and buses

- **Iran 75.0 %** **(no NGVs five years ago!)**
- **Pakistan 58.7 %**
- **Armenia 30.4 %**
- **Argentina 22.5 %**
- **Bolivia 19.4 %**
- **Bangladesh 19.3 %**
- **Colombia 16.1 %**
- **Malaysia 9.3 % (?)**
- **Tajikistan 6.5 %**
- **Brazil 4.4 %**
- **Peru 3.2 %**
- **Myanmar 3.1 %**
- **Kyrgyzstan 2.9 %**
- **Bulgaria 2.9 %**
- **Egypt 2.8 %**
- **Uzbekistan 2.8 %**
- **India 2.3 %**
- **Moldova 2.1 %**
- **Venezuela 1.56 %**
- **Italy 1.48 %**
- **Ukraine 1.35 %**
- **Trinidad & Tobago 1.22 %**
- **Georgia 0.60 %**
- **Belarus 0.44 %**
- **Thailand 0.40 % (?)**
- **China 0.39 %**
- **Chile 0.35 %**
- **Sweden 0.33 %**
- **Singapore 0.28 %**
- **Lichtenstein 0.20 %**
- **Russia 0.19 %**
- **Switzerland 0.15 %**
- **Korea 0.14 %**
- **Germany 0.13 %**

Please note that the fuel market share is often larger than the vehicle market share
NGVs can no longer be dismissed as niche vehicles only

HD potential in all of Europe

- Totally some 800 million people
- About 1200 HD buses per million people -> total fleet around 1 million, meaning up to 100,000 new buses every year (10 year life time)
- About 6000 HD trucks per million people -> total fleet around 5 million, up to 600,000 new trucks every year (8 year life time)
- Present HD NGV fleet about 60,000 buses and 90,000 trucks
- About one million buses and five million trucks annually use up to 250 million tonnes of diesel oil, corresponding with close to 800 million tonnes of CO2 emissions.
- Dual fuel vehicles using natural gas could save some 160 million tonnes of CO2 emissions – or more than 600 million tonnes if instead using biomethane.

Rumours that all future new models from Volkswagen,Seat, Skoda and Aud will have a basic design allowing the introduction of NG/biomethane versions

Tuesday, December 18, 2007

VW Will Offer Turbo CNG Passat

By Brendan Moore

12.18.2007

Quick, what's the most popular fleet car in Germany?

You are very smart to guess the Volkswagen Passat. And according to an article in *Automotive News Europe*, Volkswagen is being very smart by planning to offer a version of the Passat that will run on either gasoline or compressed natural gas (CNG). CNG is currently selling at .90 euro a liter while gasoline is priced at 1.35 euro a liter.

The Passat will offer the world's first turbocharged engine that will run on either gasoline or CNG. The engine is reputed to be a version of VW's 1.4 liter turbocharged engine and is expected to produce a minimum of 150 hp.

Fiat, Opel and Peugeot are reportedly all working on similar powerplants.

Combi as well as sedan, manuals and automatics, less than 130 g/km CO2, 420 km range on gas

Germany will have 1000 CNG filling stations by 2009…..this vehicle can be expected to sell in very large numbers.

Germany and Austria committed to the 2020 target 20 % biomethane share in all methane used for transports.

Do you remember how turbo diesel sales took off in the mid 80s?

Confirmed Fiat policy October 2008

All new car models from now on developed by Fiat will have a basic design allowing the introduction of NG versions

NGV product news
light duty passenger cars and vans

- **Fiat Panda Aria concept car, 2-cyl turbo, start/stop micro-hybrid, 0.9 litre, 80 hp, 69 g/km CO2 on a blend of 70 % NG and 30 % hydrogen**
- **Hyndai i10 Blue CNG concept car, 3-cyl turbo, start/stop micro-hybrid, 0.8 litre, 97 hp, 65 g/km CO2**
- **Audi 2.0 litre TSFI engine (with power ratings between 170 and 220 hp) may be offered with soft hybrid solution including start/stop and also recovery of braking energy, and also available in NG version. This engine is also conisdered for a NG version with an underfloor CNG cylinder installation..**
- **IFP study of Smart NG version reaching CO2 emissions of 80 g/km**
- **Opel Corsa and Skoda Octavia NG concept cars have been shown**
- **Peugeot has launched plans to build two new engine factories for 3-cylinder tirbo engines (which would be ideal for NG applications)**
- **MagnaSteyer has shown concept offroad (all wheel drive with 45 % climbing power) hybrid NG concept car Mila Alpin with CO2 emissions below 100 g/km**
- **Brazilian Obvio trifuel (NG/E85/gasline) plug-in hybrid concept car with CVT transmission and 1.6 litre engine with 200 hp**
- **Rumours that all future Volkswagen, Skoda, Seat, and Audi models will be engineered to allow underfloor CNG cylinder installations, more firm rumours that also the Touran from early 2009 will be available with the NG compressor/turbo engine soon available in Volkswagen Passat**
- **New MB B-class 170 NGT already on the market**
- **Fiat Punto Grande, Opel Zafira turbo, and Volkswagen Passat (both sedan and wagon) with compressor/turbo charged engines soon on the market**

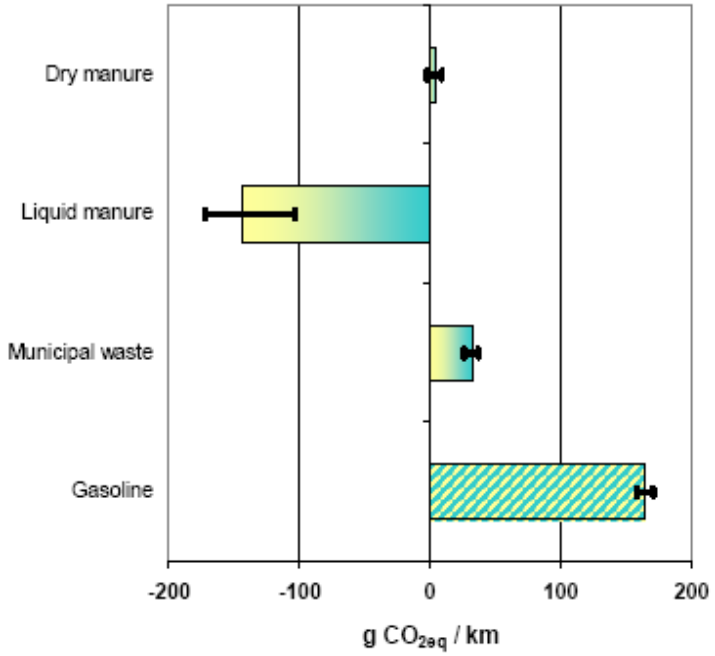
2009 likely to become a year with a fast expansion of the fleets of European NG passenger cars – higher performance engines, improved range, further reduced CO2 emissions, and a real potential for fast substitution of oil based fuels. Price surcharge, compared to standard petrol powered cars, about the same as for diesel powered cars.

A modern gas car (MB B-class 170 NGT), a modern filling station, a modern fuel - biomethane

picture supplied by Fordonsgas Sverige AB) – photography Nils-Olof Sjödén

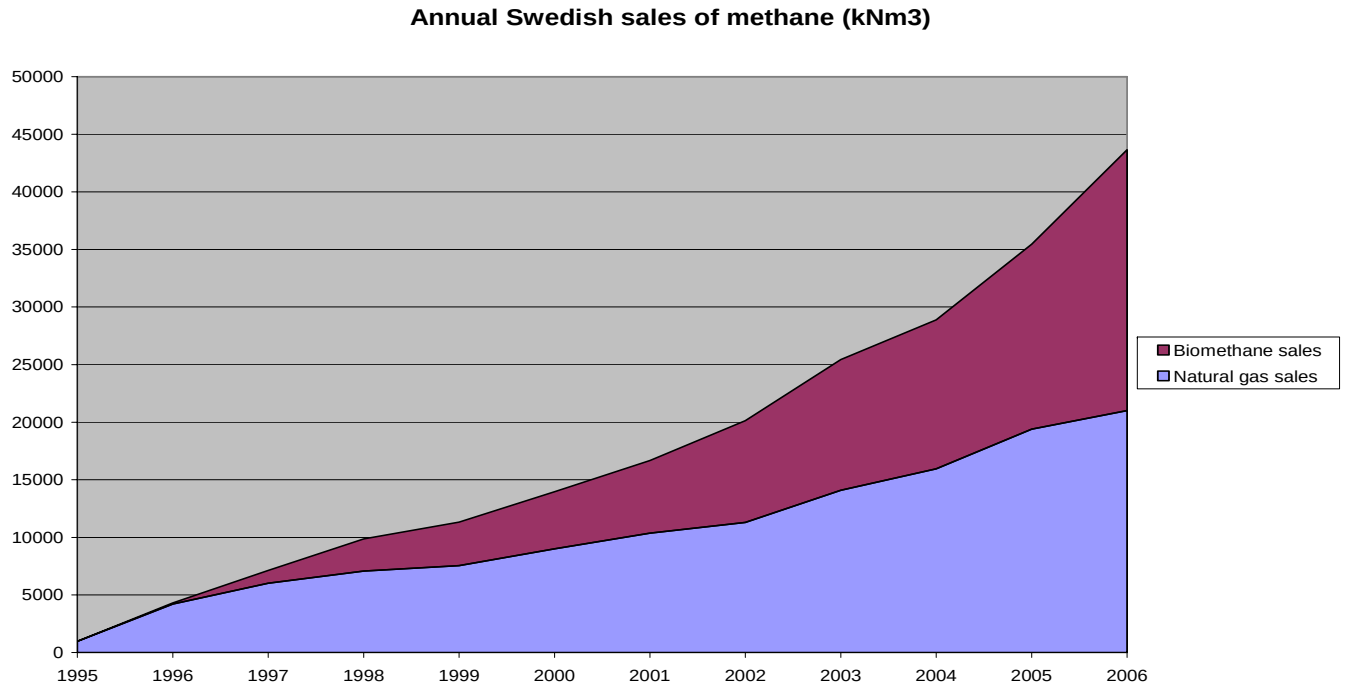
Lidköping

Biomethane GHG performance



Data from Concawe/Eucar/JRC study

BIOMETHANE MARKET GROWTH IN SWEDEN (kNm3)



Methane now accounts for 0,50 % of the Swedish road fuels. With an annual growth of 35 % the market share will reach 2 % by 2010. Biomethane already accounts for more than 50 % of all methane sold in Sweden (18 % in Switzerland).

Commercial vehicles

- Dedicated HD spark ignited NG engines continue to offer the largest reductions of air pollution in urban areas. First examples of hybrid technology in HD NG vehicles now coming onto the market.

- Dual fuel engines a very attractive choice in long haulage goods traffic. Offers the same fuel efficiency as diesel engines, meaning 20 % reductions of CO2 emissions, and very low fuelling costs. Some concepts offer capability to run on diesel only (in areas without access to natural gas), other concepts can only run in dual fuel mode.

- CO2 savings when running on biomethane around 80 %.

- Use of onboard LNG fuel storage offers opportunities for increased operating range.

PROPOSED SWEDISH L-CMG INFRASTRUCTURE

(2- 300 km between stations)

Infrastructure for 200,000 ton annual diesel substitution (3 % of Sweden's transportation fuel requirements)

LMG production*	€ 12 million
20 LMG trailers	€ 6 million
24 L-CMG stations	€ 10 million
Total investment	€ 28 million

Specific investment costs € 0,01/Nm^3

*Both liquefied biomethane and liquefied NG

From a study made by Vattenfall Power Consultants

Biomethane potentials

Waste based fuels

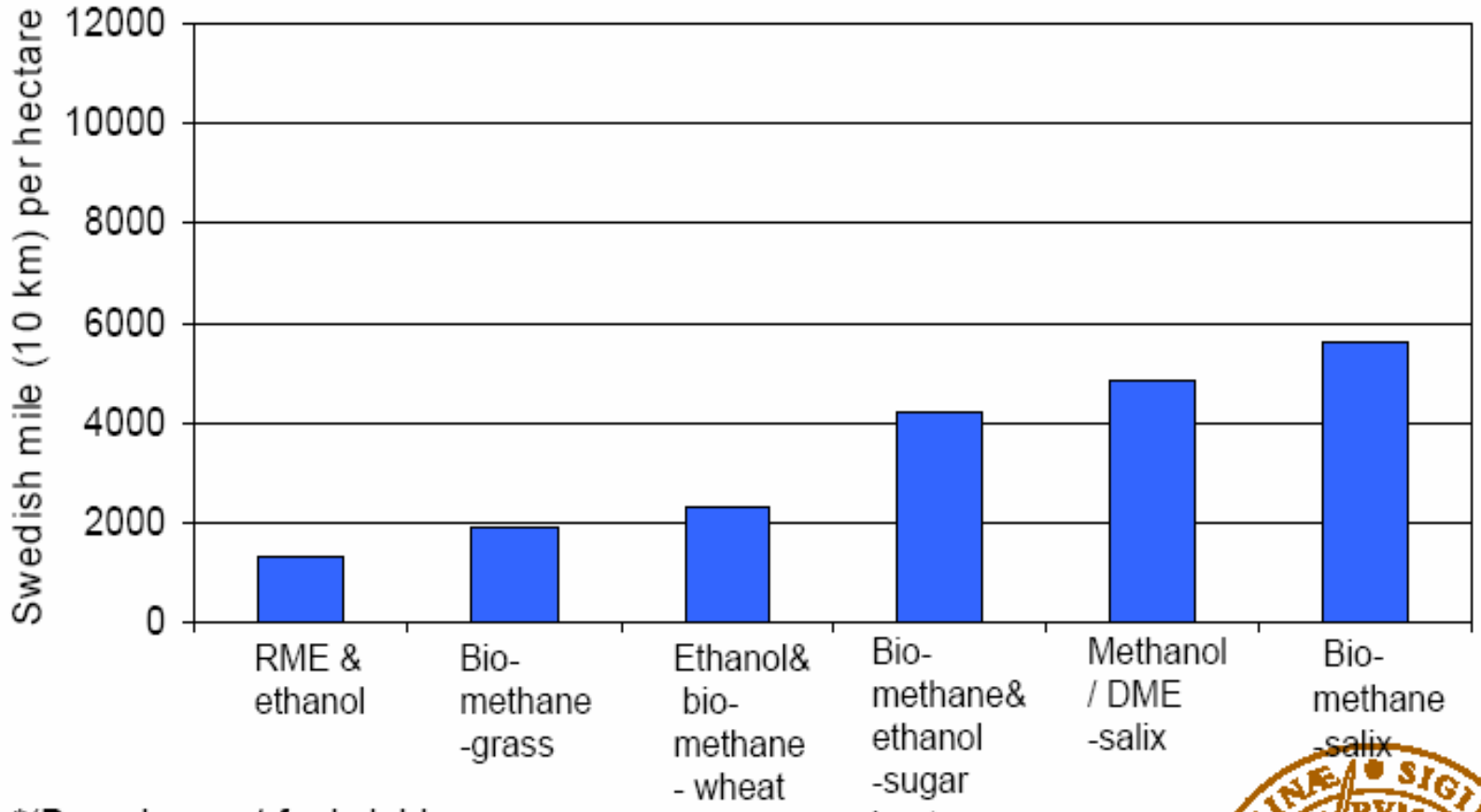
- Some 15 % of the European fuel needs in the transportation sector could be covered by biomethane derived from *anerobic digestion* of all kinds of biodegradable waste

- In countries with an established forest industry the residuals and waste products can be processed via *gasification* to produce biomethane. The potential, of course, varies from one country to another.In Sweden a recent estimate states a potential corresponding with not less than 75-105 % of the present total Swedish demand of fuels for road transports.

Crop based fuels

- To the extent that crops will be used for production of agrofuels, biomethane offers much higher fuel yields per hectare of land than other alternatives.

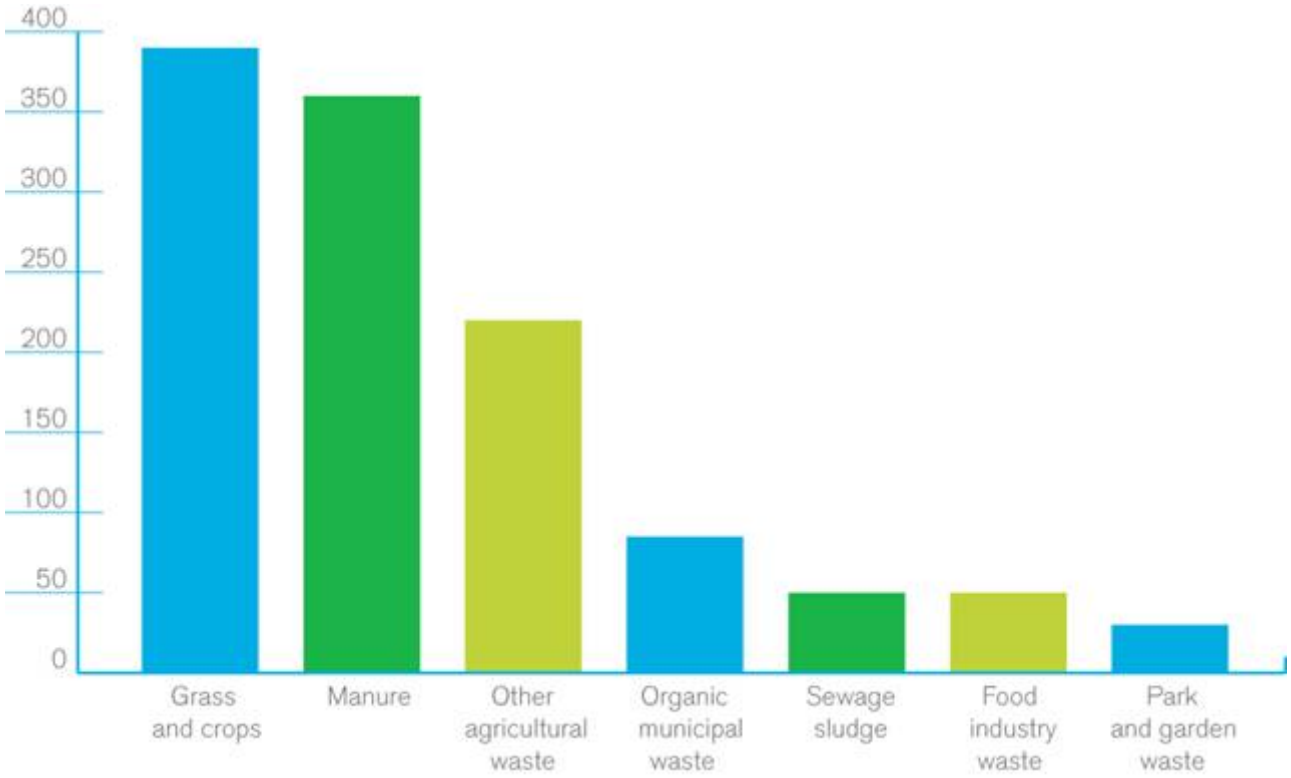
Transport work per hectare of arable land*



*(Based on net fuel yields;
southern Sweden & good arable land)

Pål Börjesson, Environmental and energy systems studies, Lund's Technical University

EU-15 ***THEORETICAL*** BIOGAS POTENTIAL 1200 TWH
(THE TOTAL USE OF ROAD FUELS IS ABOUT 3200 TWH OR 275 MTOE)



The German Wuppertal institute in January 2006 released an estimate that up to 20 % of all road fuels could be replaced by biomethane

Synthetic fuel potentials

- Using forest industry waste to make biomethane net energy conversion yields of 56-65 % have been demonstrated, and above 70 % targeted

- For various competing wood based options like DME, methanol, or FT diesel net yields of 55 % are targeted, for ethanol perhaps only 40 %. Why settle for 40 or 55 %, if you could get 70%?

Countries with ongoing commercial projects for supply of biomethane as a vehicle fuel

- Korea
- China
- India
- Pakistan
- Spain
- France
- Switzerland
- Austria
- Germany
- The UK
- The Netherlands
- Sweden
- Norway
- Iceland
- Brazil
- The USA

The EP on March 12, 2008, voted in favour of a proposal by Cscaba Sándor Tabajdi (610 in favour, 23 against, and 13 abstentions) concerning the adoption of a directive on biogas. The EC was asked to prepare a proposal supporting injection of biomethane into the NG grid, and suggested that 'green gas' should enjoy similar benefits as those applicable for 'green electricity'. The EP also stressed the need for R & D funding, and highligthed that biomethane could be used not only for heat and power generation, but also as a fuel for use in the transport sector.

Biomethane from waste – potentials

- One million people will directly or indirectly generate enough organic waste to annually produce at least 100 million Nm3 of methane gas, and simultaneously large volumes of good fertilizer.
- 100 million cubic metres would cover the fuel needs in 100,000 cars. The required investment would, excluding facilities for waste handling and pre-treatment, be around € 100 million.
- Each AD plant would typically produce between 2 and 5 million cubic metres annually - say 30 plants for every 1 million human population. The capital costs would be in the order of € 0.1 per Nm3 delivered pure methane gas, and total costs on average around € 0.6 per Nm3.
- Gas from old landfills could be purified with cryogenic technology to produce pure LMG which can be transported using tank trucks. This gas could be supplied at a cost below today's natural gas price.

Liquified biomethane

- Cryogenic technology used for up-grading and purification of biogas or landfill gas
- Two products, liquified biomethane (-160^{o}C) and liquified CO2 (-78^{o} C)
- Cost and energy efficiency in transportation of liquified methane
- Refueling stations with both compressed and liquid methane, and 2/3 saving on maintenance and operational costs.

Sweden is not the only country in the world without an NG pipeline network reaching all parts of the country

Three words of warning

1. Since the late 90s the efforts to promote the use of NGVs have been met by promises of future much more efficient H2/FC vehicles. Ten years later these vehicles are equally far from a commercial reality. Promises offer no help today.

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2. The gradual realization that liquid biofuels made from crops may, in fact, not at all, or only marginally, contribute to GHG avoidance, now leads to the promotion of "2nd generation liquid biofuels" made from ligno-cellulosic biomass. That these fuels are less efficient than biomethane made from the same resource is a fact ignored by the defenders of the status quo. Vehicles should, in their opinion, use liquid fuels. Well, use LNG, if you like.

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3. The third defense against really changing vehicles and refuelling infrastructure is the promise of "plug-in hybrids". A plug-in passenger car, however, needs some 2 kg of batteries per/km range. "Refuelling" takes hours, not minutes. If we assume that a minimum range of at least 150 kms is required to meet a broad consumer demand, this means a vehicle with 300 kgs of battery weight. Please show me the true energy balance for this vehicle, and for a comparable vehicle fuelled by NG/biomethane!

Conclusion

We cannot always find a new excuse not to take action.

In countries with limited financial resources, and with huge pollution problems, the solution has already been found – in the short to mid term natural gas, but at the same time a gradually increasing share of biomethane.

NGVs will very substantially reduce GHG emissions

Also, there is no conflict between the use of methane, and the use of hybrid technology.

No vehicle will benefit more than an NGV from the use of this technology.

Recovered electric energy should be used to power the vehicle at low engine loads when a spark ignited NG engine is not as efficient as a diesel engine.

Fuel savings will also reduce the required need for comparatively costly gas cylinders.

The future

A WWF report in April 2007 introduced the discussion of sustainable and non sustainable biofuels. The same report recommended increased use of NG as a vehicle fuel in a short and mid term perspective – for a more sustainable future.

The EP review of the draft EU directive (Jan 23, 2008) on renewable energy and biofuels now highlights three resources – all kinds of organic waste, aqua cultures (algae), and grass or crops only from 'degraded' agricultural land

Even if it would be possible to maintain crude oils supplies, meeting the world demand at a reasonable price, we cannot continue to increase the CO2 emissions.

Sunshine, wind, and water can be used to generate electric power, but not fuels. Let us prioritize the use of available biomass resources for use as fuels, and let us choose the biofuel alternatives that will maximize oil substitution.

No other biofuel can compete with biomethane in terms of fuel per tonne of waste, or per hectare of cultivated land.

GNV2009
madrid, españa

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June 17-19, 2009
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