TRAFFIC FUEL POTENTIAL OF WASTE BASED BIOGAS IN INDUSTRIAL COUNTRIES – THE CASE OF FINLAND

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Introduction

A common feature of the most influential technology policy studies concerning reductions of environmental impacts of traffic is to completely ignore biogas alternative (Table 1). The same can be observed in the most influential general energy and climate studies, such as the UN World Energy Assessment and the IPCC Third Assessment Report, despite they have biogas option included in non-traffic energy use. Usually traffic biofuel studies and policies have strong focus on ethanol and biodiesel that currently are the highest volume traffic biofuels. However, both environmental and resource considerations would support a significant role for biogas as well.

Table 1. Major technology policy studies on reducing environmental impacts of traffic, that neglect biogas fuel option.

United Nations	Air Pollution from Ground Transportation: An Assessment of Causes, Strategies and Tactics, and Proposed Actions for the International Community, UN & World Bank, 2002, 158p
OECD	Can Cars Come Clean? Strategies for Low Emission Vehicles, 2004, 207p
International Energy Agency	• Bus Systems for the Future: Achieving Sustainable Transport in the Future, 2002, 188p • Saving Oil and Reducing CO_2 Emissions in Transport: Options & Strategies, 2001, 194p • The Road from Kyoto: Current CO_2 and Transport Policies in the IEA, 2000, 176p • Automotive Fuels for the Future: The Search for Alternatives, 1999, 92p
European Conference of Ministers of Transport	• Implementing Sustainable Urban Travel Policies: National Reviews, 2003, 270p • Vehicle Emission Reductions, 2001, 132p
European Union	• Well-to-Wheel Analysis of Future Automotive Fuels and Powertrains in the European Context, 290p (JRC 2004) • European Energy and Transport: Trends to 2030, EC, 2003, 220p
USA	• Fuel-Cycle Emissions for Conventional and Alternative Fuel Vehicles: An Assessment of Air Toxics, 71p (ANL 2000) • Describing Current and Potential Markets for Alternative-Fuel Vehicles, DoE/EIA, 1996, 160p

Environmental impacts of biogas use

When waste based biogas is included in the options it can be shown to have the lowest lifecycle greenhouse gas (GHG) emissions among all fuels and fuel pathways with the exception of hydrogen electrolysis with on-site wind power and fuel cell vehicles (LBST 2002). That study, a broadest traffic fuel LCA study to date, analysed 88 different fuel pathways and found waste based biogas also having the lowest lifecycle energy consumption of all studied biomass based traffic fuel pathways, including ethanol, methanol, synfuel (FT and HTU/HDO process), syn-H2 and biodiesel.

Furthermore, although the conventional traffic biofuel, i.e. bioethanol and biodiesel, pathways can offer significant GHG and other emission reductions compared to fossil fuels they perform poorly compared to most other renewable energy pathways (LBST 2002, JRC 2004, ANL 2000).

Biogas emissions are similar to natural gas except that CO_2 emissions are eliminated due to the use of net calculation method of renewable fuels. Even the most advanced natural gas to hydrogen and fuel cell pathways can offer only less than 30% GHG emission reductions compared to present diesel vehicle technology (LBST 2002). But biogas lifecycle GHG emissions using ordinary current bi-fuel (without increased compression ratio) Otto engine are 75% lower than the most advanced natural gas to hydrogen and fuel cell use pathway can offer (LBST 2002). Tailpipe emission reductions obtainable when replacing gasoline or diesel vehicles by biogas vehicles use are given in Table 2.

Table 2. Emission reductions of biogas vehicles compared to conventional vehicles based on the inner city part of the European driving cycle (Guideline 93/116). Values have been calculated based on Nigge (2000) and CO_2 net calculation method. Diesel buses fulfil the EURO4 emission norm coming into force in 2005.

Pollutant	Bus: diesel to biogas	Car: diesel to biogas	Car: gasoline to biogas
Greenhouse gases (CO_2, CH_4 and N_2O	-96%	-95%	-96%
Small particles PM 2.5	-94%	-100%	-67%
SO_2	-100%	-100%	-100%
NOx	-39%	-88%	-57%
NMVOC	-70%	-33%	-79%

While there are no significant means to further improve the natural gas pathway, there are plenty of options to improve the biogas pathway. Engine technological means include utilizing the high octane number of methane, over 120, and increase the compression ratio of Otto engine from conventional 9 up to 15 with significant efficiency increase. This can not be done in bi-fuel engines because they must be able to use ordinary gasoline with octane number under 100, but it is the usual practise with heavy vehicle engines. Further increase in efficiency is available using dual-fuel Diesel engines or gas turbines. Fuel cells offer the ultimate opportunities, either with onboard reformer or with a future direct methane fuel cell.

But even higher improvements are available by using biogas in the whole fuel production and transport cycle and thus generating a truly CO_2 free fuel also for the whole lifecycle. The unburned CH_4 in exhaust gases will then remain the only GHG emission, with impacts shown in Table 2. This is technically easy to implement in waste management and agricultural applications. Furthermore, the fertilizing value of the putrescible waste, i.e. the only material value of such waste, is not lost during digestion but, on the contrary, improved. In addition, biogas process does not compromise food use of biomass, like is the case in ethanol and biodiesel processes. And compared to incineration of municipal solid waste the biogas process yields almost 20% more energy and the energy comes in the especially valuable form of methane, whereas the incineration pathway wastes all traffic fuel potential (EEA 2002a).

Czech Republic, France, The Netherlands, New Zealand, Sweden, Switzerland and USA had biogas upgrading units for vehicle use standards operational in 2000 (IEA 2000) and later at least Italy, Iceland and Finland have joined the group. There are globally over 3 million methane vehicles capable of using upgraded biogas (IANGV 2004). Sweden is currently the world leading vehicle biogas user with over 4000 vehicles utilizing fully or partly biogas.

Resource potential for traffic biogas production

One of the reasons why biogas is not included in the biofuel options (Table 1) despite its obvious merits and existing experiences is the lack of information on biogas production potential comparable to other biofuels. General waste statistics in EU or other OECD countries do not yet give enough information for reliable calculation of the biogas production potential. Thus, more detailed Finnish statistics, so called VAHTI database of environmental administration, and studies were used to obtain an estimate of technical potential for one country as an example. The results are given in Table 3 as number of cars that could be powered by putrescible waste based biomethane. The total of 490,000 cars and 35 PJ of primary energy corresponds to 20% of all traffic energy consumption in Finland – or 1900 car-km per capita. Although the utilization of the full resource is impossible the EU target of 5.75% share of biofuels in 2010 could be fulfilled by utilizing 28% of the potential.

Energy crops could substantially increase the potential. For example canary reed could produce in Southern Finland 30 MWh of methane energy per hectare and the existing set-aside agricultural land of 211,000 hectares could produce 6.3 TWh of energy, enough for over 300,000 cars. And in the long term many times that amount of land could be made available in Finland.

Table 3. Waste based traffic biogas potential in Finland (population 5.2 million) measured as number of cars that could be powered by biomethane assuming 20 MWh average annual energy consumption per car and optimal use of the waste streams.

Source of biogas	Amount of cars
Putrescible solid waste	50 500
Sewage sludge	15 100
Landfill gas (present production only)	11 800
Agriculture: Manure of domestic animals	167 000
Agriculture: Plant waste	214 000
Agriculture: Slaughter waste	13 200
Fish cultivation and professional fishing	1 600
Watercourse management	7 300
Industrial waste	9 500
TOTAL	490 000

EEA (2002a-b) gives statistics of biodegradable municipal solid waste (BMW) and sewage sludge (SS) production in EU countries. With average methane energy yield of 1 MWh/t for BMW (EEA 2002a) and 2 MWh/t for SS and 20 MWh average annual energy consumption per car the biogas traffic fuel potential can be given as number of cars as in Table 4. Total of 6 million cars could by powered by these two waste sources in the EU. In the case of Finland these statistics overestimate the potential. Due to the lack of harmonization of waste categories and the lack of information on putrescibility the statistics for other countries may be shifted in either direction. For example the statistics of Austria and Belgium show obvious discrepancies in comparison. On the other hand, non-putrescible BMW may become a useful resource for new biomethanation technologies in the future.

Table 4. Traffic fuel biogas potential for the European Union countries from biodegradable municipal solid waste (BMW, year 1995) and sewage sludge (SS, year 2000) given as thousands of cars assuming 20 MWh of annual average energy consumption per car. Total is 6 million cars. Based on (EEA 2002a-b).

	A	B	D	DK	E	F	FI	GB	GR	I	IRL	L	NL	P	S
BMW	75	220	1400	91	580	790	83	820	130	460	50	8	240	170	130
SS	20	13	270	20	110	98	15	140	10	-	7	1	40	35	24

Agricultural wastes form the largest waste based biogas potential. In Finland total of 7900 GWh is available consisting of 42% from animal manure, 54% from plant waste and 3% from animal carcasses. This is 1.5 MWh per capita that is here used as a coarse estimate for the EU as a whole due to similar food self-sufficiency and eating habits. Table 5 collects BMW, SS and agricultural waste potential in the EU as thousands of cars. The total is 34 million cars which is 20% of cars in the EU.

Table 5. Amount of cars that could be powered by biogas from BMW, SS and agricultural waste in the EU.

Source of biogas	Amount of cars
Biodegradable municipal solid waste	5.2 million
Sewage sludge	0.8 million
Agricultural waste	28 million
TOTAL	34 million

Industrial waste production and quality is highly country dependent. Available statistics do not allow for making estimate on its biogas potential.

Conclusions

There is a substantial biogas traffic fuel potential available from putrescible waste streams with the benefits of non-interfering with food production, not requiring additional land use and not losing the fertilizing value of the waste. In Finland the EU target of 5.75% of biofuels in total traffic energy consumption could be fulfilled by utilizing 28% of available putrescible waste resource. Since the quantity of produced putrescible waste per capita does not differ much in other industrial countries they also have a significant and mostly untapped biogas traffic fuel potential. And energy crops may add substantially to the potential in many countries.

The biogas fuel production can be truly CO_2 free and all the tailpipe emissions are very low compared to conventional fossil and conventional biofuels. Thus, this technology might have a significant contribution to make in climate and health policies in addition to waste, traffic and agriculture policies, making missing it in the relevant policy studies hard to substantiate on factual grounds.

Unfortunately, the current waste statistics in the EU and Finland do not give enough of information for accurate assessment of biogas energy potential. It would be necessary to add information on putrescibility, share of volatile solids and methane yields.

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