Biomethane as a sustainable bus and truck fuel

Global experiences

Jonas Strömberg
Director Sustainable Solutions
Today’s Agenda

- Mega trends and sustainable transport
  - Challenges for the transport sector
- Solutions - the green toolbox
  - Biomethane solutions
- Good examples
- Questions and discussion
Global warming
IPCC’s new synthesis report

- Unmitigated climate change jeopardizes living conditions for everyone on the planet and threatens economic growth.
- We can still affect the outcome, but…
- ...the window for action is rapidly closing
- Any further investment in fossil energy infrastructure will cause devastating lock-in effects
Weather related natural disasters increase

“Any further investment in fossil energy infrastructure will cause devastating lock-in effects” (IPCC)
TOWARDS A CITY DOMINATED WORLD

- Cities will account for 86% of global GDP in 2025
- Cities will represent 80% of energy use and CO₂ emissions
- Major growth is in rising middle-sized cities (250 000 – 10 Million)
- Urban mobility (people/goods) will triple 2010-2050
- Cities will drive the green transport demands/development
- Sustainable city mobility for people and goods → key for cities (and for Scania) to stay attractive and competitive.
1,3 million deaths in traffic accidents/year
3,1 million deaths from particle emissions/year
1 out 8 deaths related to poor air quality
HD diesel → over 50% of particle emissions
Congestion and air quality problems threaten many cities’ economical growth
Drivers for sustainable transport
Transportation’s double challenge:
Reduce GHG emissions AND cure the oil addiction

Virtually all of the projected net increase in oil demand comes from transportation
The last battle...

**CO₂-reduction**

- **Transport**
- **Heating**
- **Housing and offices**
- **Industry**
- **Electricity production**

**Source:** Elforsk, rapport 12:68, 2013

**CO₂ from transport is the major remaining challenge!**
Diesel shortage → high costs for net oil importers. Diesel substitutes essential!

Fuel security
Climate Change and CO$_2$

Air Quality & Congestion

Are you part of the problem?
Or part of the solution?

Oil use in OECD

Transport sector

Other sectors

>73 %

1970: Index 100

Source of data: EM-DAT: The OFDA/CRED International Disaster Database.
http://www.em-dat.net, UCL - Brussels, Belgium
Solutions for sustainable transport
No silver bullets - a broad, green toolbox

1. Save energy – all kinds
2. Smarter transport – for people and goods
3. Replace fossil energy with renewable energy
- Driver training saves on average 11% of fuel. Ecolution by Scania.

- Hybrids and electrification are important for the future - but no silver bullet - only one part of the future transport puzzle

- Scania hybrid tests since 1980s. Energy storage (batteries) still a bottleneck (this is not a car!)…

- Scania Euro 6 hybrids for diesel and biodiesel available.

- Scania test projects with inductive power transfer (Bombardier) and electric trucks with pantograph (Siemens) ongoing...

- ...to be cost efficient and commercially viable, electrification has to be part of a large scale industrial modular system!

1. Save energy

Driver training/Electrification/hybrids
Solutions for sustainable transport
No silver bullets - a broad, green toolbox

1. Save energy – all kinds
2. Smarter transport – for people and goods
3. Replace fossil energy with renewable energy
- Dedicated bus lanes
- High frequency
- Attractive and efficient stations
- Bus priority
- High quality customer info
- Modal integration at stations
- Flexible traffic management
- Greatly improved road safety
- High capacity at low cost - and quick implementation

- BRT Bogota: 45 000 pass/hour - $ 5 M/km
- Metro Mexico City: 39 000 pass/hour - $ 41 M/km

2. Smarter transport
Bus systems by Scania
- A bus system improves city structure and city image as much as a tram...

- A bus system could have the same capacity as a metro...

- ...only quicker and to a much lower cost!

**Bus Systems by Scania**
Solutions for sustainable transport

No silver bullets - a broad, green toolbox

1. Save energy – all kinds
2. Smarter transport – for people and goods
3. Replace fossil energy with renewable energy
Alternative fuels...

- ...clean up the air and saves lives. Poor air quality responsible for 1 out 8 deaths...
- ...create up to 100 times more local jobs than oil...
- Replaces costly diesel and oil imports and creates independent local energy security...
- ...cuts CO₂ emissions with up to 90%...
- ...helps fight poverty and improves local rural economies...
- ...turn waste into clean local fuels!
Biofuels Worldwide (IEA)

- Biofuels quadrupled (4x) during 2000-2010
- Continued growth -2050

Rapid growth of biofuel use
Bioethanol/ED95
World’s No. 1 biofuel
Diesel engine & efficiency
Up to 90 %
CO₂ reduction
Buses, coaches
waste collectors,
distribution trucks.

Biodiesel & HVO
Low blends to B100
Diesel engine
Up to 60 %
CO₂ reduction
All types of
applications, including
hybrids, long-haulage and
coaches.

Biogas/Natural gas
Compressed or liquid
Otto engine
Up to 90 %
CO₂ reduction
City/Intercity buses,
waste collectors,
distribution trucks.

Products for the three major alt. fuels
Our motto:
If you can't out-compete diesel - never mind...

**World's No. 1 biofuel**
- Diesel engine & efficiency
- Up to 90% CO₂ reduction
- Buses, coaches, waste collectors, distribution trucks.

**Bioethanol/ED95**
- Biogas/Natural gas
- Biodiesel & HVO
- Low blends to B100
- Diesel engine
- Up to 60% CO₂ reduction
- All types of applications, including hybrids, long-haulage and coaches.

**Biogas/Natural gas**
- Compressed or liquid
- Otto engine
- Up to 90% CO₂ reduction
- City/Intercity buses, waste collectors, distribution trucks.

*Products for the three major alt. fuels*
Package solutions for bus systems, vehicles, biofuels, energy savings and infrastructure are available – here and now!

Bus systems by Scania

Distribution & waste

Driver training

Biofuel, infrastructure & service

Scania
Swedish greentech experience
Buses, trucks, biofuel production and cleantech

Scania and partners = Turn-key solutions
From waste/sludge to clean biogas fleets

- A low carbon fuel
- A clean fuel
- Solving local waste and sludge problems
- Sweden is a biogas pioneer, with biogas expertise - from waste to vehicle!
More than 5,000 gas buses, trucks and engines sold

Australia  Norway
Chile  Peru
Colombia  South Africa
Estonia  Spain
Indonesia  Sweden
Island  UK
Iran  USA

Scania gas vehicles
Stockholm → 100% biofuels in city transport

- All buses on biofuels in Stockholm
- Ethanol (500), Biogas (300) and Biodiesel (900)
- Also introduced for waste collect & trucks
- Big effect on both air quality and CO₂
- Cost efficient emission and CO₂ reduction
- Long term policy & key actors co-op
BIOMETHANE FOR SUSTAINABLE URBAN MOBILITY IN BRAZIL

BIOMETHANE
PARANÁ
ITAIPU
CHICKEN MANURE
Local Renewable Fuels for India

Local Waste → Local Fuel → Local Transport

Local Waste → Local Fuel → Local Transport
Nagpur local clean fuel project

- 1) Nagpur city sewage treatment plant: Upgrading of biogas to vehicle fuel.

- 2) Purti Nagpur ethanol plant: Ethanol for vehicle fuel + the organic waste from production turned into biogas of fuel quality.

- → 105 ethanol buses and 100 biogas buses in phase 1. Lower cost than natural gas!

- Co-op NMC (City of Nagpur), Purti, Swedfund, IVL (Swedish Environmental Research Institute), Business Sweden, Spectrum and Scania.
Biomethane for fuel: Strong trend in the UK

- Single deck available now, double deck coming 2016
- In operation in Reading, Sunderland and Bristol.
- Local Biogas production increasing rapidly and feed the gas grid – green certificates makes the biogas available for everyone.
### Operating costs

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Euro rating</th>
<th>Pence per mile</th>
<th>Avg miles between breakdowns (normalised)</th>
<th>Servicing interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG single deck</td>
<td>Euro V</td>
<td>13</td>
<td>220</td>
<td>8 wks</td>
</tr>
<tr>
<td>Lightweight diesel midibus</td>
<td>Euro V</td>
<td>14</td>
<td>190</td>
<td>8 wks</td>
</tr>
<tr>
<td>Series hybrid double deck</td>
<td>Euro V</td>
<td>24</td>
<td>140</td>
<td>12 wks</td>
</tr>
<tr>
<td>Diesel single deck</td>
<td>Euro IV</td>
<td>26</td>
<td>144</td>
<td>8 wks</td>
</tr>
<tr>
<td>Diesel double deck</td>
<td>Euro IV &amp; V</td>
<td>28 - 32</td>
<td>100 - 132</td>
<td>8 wks</td>
</tr>
</tbody>
</table>

- £1m to install station, depreciated over 15 years.
- Supported by DfT funding, Green Bus Fund 4.
Biogas from ~1000 citizens powers a bus for a year!


Local fuel by local people
Great Britain survey on gas buses

- “Smoother”
- “More comfortable”
- “Quieter”
- ”Greener”

92% of passengers prefer gas buses to standard diesel buses!
The UK’s first dedicated Euro 6 gas-powered Scania tractor unit has been delivered to leading UK digital retailer Argos.

Scania (Great Britain) Limited
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March 2014
- Finland: Biogas and bioethanol from beer waste.
- Scania + St1 = turn-key solution.
- Norge: Quick increase in biogas buses. From CNG to CBG.
- First 10 gas buses underway (Jan 2016)
  - Free State area, Virginia
  - Megabus/Unitrans
  - First Eu6 buses in Africa

- Biogas feasibility study ongoing in Western Cape area.

- Market value of biogas:
  - Heat: 3 ZAR
  - Electricity: 4.5 ZAR
  - Fuel: 9 ZAR
Gas – nothing new
Scania Euro 6 gas engines
The most energy efficient way to use your gas

Otto engine with outstanding efficiency
Gas 40% thermal peak efficiency
Diesel 43% thermal peak efficiency

Scania modular system – Scania quality
Less than 40 parts differ from diesel engine
Excellent service and spare part availability

All city and regional purposes
280 hp (Bus, Truck, 1350 Nm)
320 hp (Bus, 1500 Nm)
340 hp (Truck, 1600 Nm)
Diesel torque levels

Other features
Less sensitive to gas quality
100% operability on 2 000 m+
Operates on both CNG and LNG
No complex after-treatment systems necessary
Only 3-way catalyst necessary to reach Euro 6
Up to 90% CO₂ cuts with biogas (~10-20% with CNG)

Setting a new standard
Power and torque performance CNG/Biogas
280hp diesel vs 280hp gas (Euro 6)

Biomethane operation also for 15 m/18 m articulated and intercity buses – and for demanding topographies.
Ultra-clean emissions - lower than Euro 6

- Euro 6 demand
- Scania Euro 6 Gas

![Graph showing emissions levels for Euro 6 demand and Scania Euro 6 Gas, with lower emissions for Scania Euro 6 Gas across all measured parameters: NOx, NH3, PM, CH4, CO, NMHC.](image-url)
Fuel quality requirements

Both CNG and LNG contains methane but also varying amounts of carbon dioxide, nitrogen, ethane, propane and butane. Energy content and combustion properties depend on the concentration of these compounds.

Biogas/Biomethane

- Must fulfill Swedish Standard SS 15 54 38 (1999) with methane content 97±2 volume%.
- Additional requirement: Siloxanes max 0.1 ppm (calculated as Si)

Natural Gas

- Natural gas according to ISO 15403-1, (H- and L-group according to Annex B and Wobbe index 38 – 56 MJ/m³)
- Additional requirements: Methane number min 70.
  Sulphur content max 20 ppm

Refuelling and gas tanks

- CNG tanks 1 200 L and 1 500 L available (~250-350 l/diesel eq.)
- Fast and slow fill available – or both (NGV1/NGV2)
City, Intercity & BRT

Euro 6 gas buses for all applications
Certified for quiet deliveries

- Scania’s gas engines have been certified according to the Piek-Keur Quiet TRUCK standard.

The certification has been adopted by several European cities as a prerequisite for night time distribution.
## Emissions of fossil CO₂
Comparison between diesel, gas and ethanol, hybrid and electric

### Average number of passengers

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20,00</strong></td>
<td>(Input average number of passengers here)</td>
</tr>
</tbody>
</table>

### Fuel consumption

(Input actual fuel consumption for corresponding diesel operation here)

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Biodiesel</th>
<th>Biomethane</th>
<th>CNG</th>
<th>Ethanol ED95</th>
<th>Diesel Hybrid</th>
<th>Full electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>(litre/10 km)</td>
<td>5,00</td>
<td>5,25</td>
<td>6,40</td>
<td>5,69</td>
<td>8,46</td>
<td>3,00</td>
<td>n/a</td>
</tr>
<tr>
<td>(kWh/10 km)</td>
<td>49,62</td>
<td>49,00</td>
<td>62,57</td>
<td>55,58</td>
<td>49,62</td>
<td>29,77</td>
<td>14,89</td>
</tr>
</tbody>
</table>

### Fuel consumption (Ideal Case)

(40% reduction)

<table>
<thead>
<tr>
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<th>Biomethane</th>
<th>CNG</th>
<th>Ethanol ED95</th>
<th>Diesel Hybrid</th>
<th>Full electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>(litre/10 km)</td>
<td>3,00</td>
<td>3,15</td>
<td>3,84</td>
<td>3,41</td>
<td>5,08</td>
<td>1,80</td>
<td>n/a</td>
</tr>
<tr>
<td>(kWh/10 km)</td>
<td>29,77</td>
<td>29,55</td>
<td>37,55</td>
<td>33,33</td>
<td>29,77</td>
<td>9,90</td>
<td>5,69</td>
</tr>
</tbody>
</table>

### Total amount of fossil CO₂-emission per 10 km (kg)

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Biodiesel</th>
<th>Biomethane</th>
<th>CNG</th>
<th>Ethanol ED95</th>
<th>Diesel Hybrid</th>
<th>Full electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>14,9</td>
<td>9,2</td>
<td>4,0</td>
<td>13,8</td>
<td>4,6</td>
<td>8,9</td>
<td>7,8</td>
</tr>
</tbody>
</table>

### Fossil CO₂-emission per passenger-km (grams/person-km)

<table>
<thead>
<tr>
<th></th>
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<th>Biomethane</th>
<th>CNG</th>
<th>Ethanol ED95</th>
<th>Diesel Hybrid</th>
<th>Full electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>grams</td>
<td>0,075</td>
<td>0,046</td>
<td>0,020</td>
<td>0,069</td>
<td>0,023</td>
<td>0,045</td>
<td>0,039</td>
</tr>
</tbody>
</table>

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Biogas → high CO₂ efficiency

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- Biogas operation brings high CO₂ cuts in a commercial way.

<table>
<thead>
<tr>
<th>Powertrain</th>
<th>CO₂ reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>0 %</td>
</tr>
<tr>
<td>CNG</td>
<td>~10 %</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>~38 %</td>
</tr>
<tr>
<td>Diesel hybrid</td>
<td>~40 %</td>
</tr>
<tr>
<td>Full electric</td>
<td>~47 %</td>
</tr>
<tr>
<td>Ethanol ED95</td>
<td>~69 %</td>
</tr>
<tr>
<td>Biogas</td>
<td>~73 %</td>
</tr>
</tbody>
</table>

Biogas → most CO₂ cuts per € spent
How to get started

- Long term policies and regulations vital (city and national)
- Heavy fleets represent a large proportion of emissions (~50%)
- Depot based traffic – infrastructure costs kept low
- Possibilities to quickly replace vehicles, build volumes and reach scale advantages

Start with heavy fleets
Biofuel + Bus Systems = Sustainable Transport

- Car: g CO₂/pkm
- Diesel bus
- Biogas bus
- Cleaner than Euro 6
- 90% less CO$_2$
- Quiet
- Local fuel & local jobs
- Biogas for fuel is the strongest business case
- Highly popular with passengers
- A city package with buses, trucks, waste collectors, refuelling infrastructure and fuel

Conclusions

Commercially competitive with diesel!
Sustainable transport is not difficult...

...it is here and now!

Thank you for your attention!
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Director Sustainable Solutions
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Job creation

Biofuel production create up to...

...a 100 times more jobs

per unit of energy produced, than the traditional oil industry!
Air quality

Alternative Fuels...

clean up the air and save lives

Heavy trucks and buses cause over 50% of particle emissions.

Leapfrog from poor diesel qualities straight to Euro 5 and Euro 6
Energy security

Alternative Fuels...

...creates an independent fuel supply

Strong oil dependency in the region makes local economies vulnerable for fluctuations and political pressure.
Both food and fuel

Alternative Fuels...

..helps fight poverty

Majority of World’s poor are small scale farmers that benefit from growing both food and fuel crops.

By-products (fertilizer, animal feed) helps local economy.

“We need to move from a food vs fuel debate to a food and fuel debate”

(FAO Director General da Silva)
From waste to clean biofuel fleets

Alternative Fuels..

..helps eliminate waste

Waste water, organic waste and food waste could commercially be turned into clean biogas and ethanol fuels.

Scania and partners can supply the whole turnkey solution.
Carbon footprint

Alternative fuels...

...cuts CO₂ emissions with up to 90%

Scania work with sustainability verified biofuel supply partners
“Cities walk, while nations talk”

Alternative fuels...
...do your Mayor a favour!

Energy security, transport, waste, air quality and climate change mitigation are on all cities top priority lists.
Dual fuel vs dedicated gas engines?

Dual Fuel question marks..?

- No legal emission certificates. Not possible to certify such an engine according to Euro regulations → unregulated vehicles in city operation?
- Risk of high emissions, both regulated and unregulated ones, especially in city type operation.
- Technological compromise between two systems → non-optimised operation and high overall fuel consumption for dual-fuel.
- City type operation with dual-fuel leads to low gas utilization, shows results in Stockholm’s Clean Truck EU project. Less than 20% gas use.
- Retrofits? Warranties, long term part supply and quality issues?
- Two fuel tanks – weight, cost and capacity issues?
- Two fuel injection systems → high service costs? Scania gas engine service is equal to diesel operation...
Risk aversion
...and where is the sense of urgency?

- 66 % risk that global warming until 2100 will be between 1,4 to 3,1 °C
- 7,1 % risk → 4 °C
- 1,8 % risk → 6 °C
Fuel CO₂

“Regular” specification

Ecolution spec

Maintenance+

Driver training and coaching

Save energy

Optimized spec’s and maintenance, Driver
Scania’s own Transports

Buses Stockholm – Södertälje and KTH - Kista

Long haulage, SE - NL

Distribution, SE
Big CO₂ reduction potential - here and now

- Scania’s vision for the transport sector: Halving of CO₂ per tonne-km by 2020
- Results from Scania’s own hauling company operating internal transport:
  
  Halving of CO₂ per tonne-km between 2008-2013!

- 10% more cost efficient
- Holistic perspective – driver, logistics, vehicle, service, driver support, biofuels...
Potential of renewable energy sources

If all available renewable energy was used, it would cover 2,000 times today's energy use.

KÄLLA: IRENA, Deutsches Zentrum für Luft- und Raumfahrt
GRAFIK: CAROLINE PETTERSSON
A complete system with trunk lines and feeder lines, “park-and-ride”...

- Dedicated bus lanes
- Priority for buses
- Longer distance between stops: 0.4-0.65 miles
- Fast ticketing system
- System identity and high quality passenger information
- High quality stations and traffic management

Bus System Components
Tailored depending on local conditions and needs
Inductive power transfer
Test in Södertälje

- Scania, KTH, ITRL; Södertälje kommun, SLL, Tom Tits Muséeum
- June 2016
- Charging station by a bus stop
- 6-7 min charging → power for the full trip
- City bus with hybridized powertrain
- [http://www.youtube.com/watch?v=eNjdZchOHVE](http://www.youtube.com/watch?v=eNjdZchOHVE)
Three most important sustainability challenges for heavy duty transportation

1. Local emissions (particles, NOx, noise...)
2. Energy efficiency
3. Emissions of fossil CO₂
1. Local emissions and noise
   Driven by legislation

NO\textsubscript{X} reduction 94 %

PM (partiklar) (g/kWh)

Euro 1 1992
Euro 2 1996
Euro 3 2001
Euro 4 2006
Euro 5 2009
Euro 6 2014

NO\textsubscript{X} (g/kWh)

Particle reduction 98 %
2. Energy Efficiency
100 % Market driven

- Market driven
- The no 1 competition factor
- All commercial measures automatically applied
- Rising fuel prices
3. But what about the big challenge?
No real incentives for reductions of fossil CO$_2$ from the transport sector

Data from TREMOVE
### Biofuels and hybrids – short term

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Introduction Euro 6</th>
<th>Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (Biogas, CNG, LNG)</td>
<td>Introduced</td>
<td>280 hp (9 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus and Truck</td>
</tr>
<tr>
<td>Gas (Biogas, CNG, LNG)</td>
<td>Introduced</td>
<td>320 hp (9 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus</td>
</tr>
<tr>
<td>Gas (Biogas, CNG, LNG)</td>
<td>Introduced</td>
<td>340 hp (9 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Truck</td>
</tr>
<tr>
<td>Ethanol ED95</td>
<td>2016</td>
<td>280 hp (9 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bus and Truck</td>
</tr>
<tr>
<td>Biodiesel/HVO</td>
<td>Introduced</td>
<td>320, 360 hp (9 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>450, 490 hp (13 l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>580 (16 l)</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Diesel, Biodiesel and HVO Selected markets Low Entry</td>
<td>250, 280 hp (9 l) (Bus)</td>
</tr>
</tbody>
</table>
Euro 6 biofuel buses for all applications
Local emissions
Go directly to Euro 6 with clean biofuels

NO\textsubscript{x} reduction 94 %

PM (partiklar) (g/kWh)

Euro 1 1992

Euro 2 1996

Euro 3 2001

Euro 4 2006

Euro 5 2009

Euro 6 2014

Particle reduction 98 %

Scania sustainable transport
Biogas versus natural gas

**Biogas**
- CO$_2$: Part of the natural carbon cycle
- DO not contribute to a net increase of CO$_2$ in the atmosphere

**Natural gas**
- CO$_2$: Release carbon from fossil deposits
- Increase CO$_2$ levels in the atmosphere