Challenges and opportunities for the future biomethane powered automotive market

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Lots of opportunities for growth!

• Large biomethane potential, AD + gasification
• Commercially mature market
  – Biogas production, lots of vehicle offers in all different segments, expanding refuelling network
• Dieselgate + The promise of future gas powertrains
  – Real emissions are lower (NO2) and less unhealthy (particles)
  – Future dedicated gas engines on par with diesel, 2nd gen dual fuel (methane diesel)
• Key technology of the circular economy and the future sustainable agricultural sector
... but also challenges

- Production capital intensive with low profit margins
- Electric powertrain preferences, e.g. city bus segment
- Market actor inadequacies
  - Complex and heterogenous value chain
  - Marginal segment for both gas industry and vehicle manufacturers
  - Lack of commercial competence
- Public perception and acceptance
- Bioenergy credibility is suffering (energy crops, forestry)
- The need for long-term policy environments
Why biomethane in transports?
Only fully oil dependent sector in Sweden! (92 %)*

- **Full utilization of energy with solutions available now**
  - Inevitable heat losses in CHP utilization, wind & sun better alternatives
  - Commercially available solutions for oil dependent transports of all types (LDV, MDV, HDV, short, medium and long-distant), with performance on par with diesel soon to come!
  - Natural gas and biomethane: freely intermixed and interchangeable
  - Evident co-distribution and backup synergies (backup for market fluctuations, process failure) allow for 100 % utilization of your biomethane and earlier market buildup

- **Promotional value compensates for added costs**
  - Steadily increasing the renewable share gives true greening

* Industry – 25 % fossil fuels (oil, coal, natural gas)
Households – 10 % fossil fuels (oil)
Source: Energiläget 2014, Swedish Energy Agency
Biomethane potential
Waste, residual products and energy crops

Cities (urban)
- Sewage sludge
- Household organic waste
- Industrial organic waste
- Landfill gas

Agriculture
- Manure
- Residual products
- Energy crops

Forestry
- Residual products from forests and industry

The natural scavenger in all biorefinery schemes; dedicated biogas production show high substrate flexibility, and excellent conversion and area efficiency
NGV market dynamics of Sweden
Local pollution problems + no grid access = biomethane buses

- Converting to NG buses to solve local pollution problems
  - Grid connected cities of Malmö and Gothenburg
  - NG companies searching for a new market segment

The future: 24 m biomethane powered hybrid bus in Malmö from 140601 – most frequent commuter line, BRT concept
NGV market dynamics of Sweden
Local pollution problems + no grid access = biomethane buses

- **Environmental state funding to municipals decisive (1998-2010)**
  - Non-grid cities upgraded to biomethane to fuel their buses – grid cities followed
  - Captive bus fleets shown* providing the essential niche of the emerging NGV market in Sweden

Biogas utilisation 2005-2013

282 biogas plants ➔ 1.94 TWh biogas (2015)

Food waste collection in 212 of Sweden's 290 municipalities
30,000 ton 2005 ➔ 337,000 ton 2014 (1/3 of potential)
Volumes of CNG/biomethane in Sweden
Evidence of a fruitful interplay between the use of natural gas and biomethane

Market growth stagnating for the first time

2015: 1.6TWh (71% renewable)
No. of NGV’s in Sweden

The NGV market base: Captive bus fleets (1 bus ≈ 20-30 LDV’s)

2015: 53,102 (49,945; 805; 2,372)
161 public refuelling stations
In total 221, and 6 supplying LNG/LBG
Biomethane in Sweden today

Capital intensive business with still small profit margins need additional drivers and good framework conditions

- **Tax exemption + high fossil fuel taxes most important driver**
  - Retail at approx. 1.35 SEK/kWh (7.5SEK/AUD)
  - Fringe benefit tax reduction on company cars 40%

- **Long-term high-volume contracts securing the market**
  - Waste management + procurement of public transport

- **Challenges ahead**
  - Missing: Extension of existing policies, no new ones to facilitate production growth (tax exemption ruled unlawful by the EU, 2021 → ?? certificate system, continued exemption for biomethane only?)
  - Competition in the bus segment (HVO, electrification, diesel hybrids)
  - Low oil prices
Sustainability of bioenergy questioned

- ILUC – Indirect land use change, the reason behind the 7% cap food based biofuels in EU
- The “carbon debt” issue (gasification!)
  - Long pay-back time for forest-based bioenergy
  - But: Intensified forest management show that BOTH forest growth and increased gross fellings are possible, inclusive of solid biofuels outtake
- Current state of mind:
  - Policies disappearing
  - Lack of trust – is this really the solution for the future?
- Crucial to turn this around in time for post 2020 regulations of biofuels and renewable energy!
Wider picture important: Biomethane positive externalities

Energy value

Biomethane

Socioeconomic:
- Lesser air pollution
- Closing nutrient cycles
- Climate mitigation
- Domestic production
- Job creation
- Agricultural development
- Securing soil fertility (double cropping and catch crops: more micronutrients and soil carbon, alleviate compaction)

Promotional:
- Customer demand
- Creating a greener image

Regulatory:
- Quota systems
- Feed in Tariffs, premiums
- CO2 taxation
- Tax exemptions
- Procurements
- National goals

Interreg

BioGas2020

Energiforsk
The future gas engine with diesel-like performance

• Current commercial trends:
  – Scania Euro VI dedicated otto gas engine 340 hp: Sweet spot 40% efficiency, only 7% fuel penalty mixed driving. Rumours about >400hp version!
  – Westport HPDI 2.0: dual-fuel direct injection with diesel-like performance, Volvo launch predicted to late 2017
HDGAS – MAN, IVECO and Volvo working together on more efficient methane HDVs

Three HDGAS engine concepts:
**Volvo** - A high pressure gas direct injection diesel engine
**Iveco** - A low pressure direct injection spark ignited engine
**MAN** - A low pressure port injected dual fuel engine

**LNG tank**

**LNG DualFuel demo truck**
TRL Level 6/7

Source: www.hdgas.eu
Diesel-like gas engines feasible?

- Current gas engines in essence non-optimized conversions of conventional engines – research shows potential!
  - Improved low load performance and increased max. power close to the dilution limit through high turbulence pistons, EGR, turbocharging, higher compression and model based control (M Kaiadi 2011)
  - Increasing dilution limit further: Fuelled prechamber tech delivered 47.5% efficiency at 10 bar IMEPg with low NOx (no optimization) – results not dependent on engine scale! Lack of funding for further studies! (A. Shah 2015)
  - Stratified lean burn DI (18 bar) 28 % more efficient compared to stoichiometric, mixing limitations creates soot and need further work on hardware optimization (M. Melaika 2016)

- But: It all hinges upon the gas quality delivered!
Gas quality challenge when considering CNG/biomethane powered transport

• A growing but still emerging market situation where peripheral market segments of two major business actors (grid owners and OEM’s) interact
  – Challenge: Reach low emissions and high fuel efficiency in heavy duty gas engines without risking the gas core business
  – Cost optimisation across two businesses: trust and cooperation needed, despite complexity
  – New conditions: Euro VI Certification on real market fuels with durability testing included (after 700,000 km or 7 years on the road)
Final remarks

• The complex research showing the environmental and socioeconomic sustainability benefits of bioenergy need to be disseminated AND demonstrated!

• Public-private partnerships and long-term policies are key in building a biomethane powered NGV market!
  – Cost adaptive but long-term policy environment, preferrably % market size!
  – The whole value-chain need to be involved from the beginning!
  – Future efficient gas powertrains calls for cooperation between gas industry and vehicle manufacturers!

• More commercial competence building needed!

• Customer oriented approach, making gas powered transport more “sexy”

• In the background: Reduction of OPEX and CAPEX through continued technology improvement and increased understanding of the AD biology regarding the technology of the process
Challenges/opportunities future biomethane powered automotive market

Thank you for the opportunity!
Questions?

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Biomethane powered transport in Europe

- At the most 1% market share
- 2015: Sweden forerunner (1,124 GWh) followed by Germany (580 GWh)
- ...but USA is now no.1 (at least double compared to Sweden, and 2-digit annual growth)

Sources: European Biogas Assoc., NGVA Europe, newsletters
Sweden is world leading in transporting gas off-grid

Read more in case story from IEA Bioenergy Task 37: Non-grid biomethane transportation in Sweden

Vision: Regional grids. The idea is to connect production units, refuelling stations and customers to an LNG terminal
Biomethane: USA now no. 1

- Reliable stats only for California, but according to source roughly 90% of available biomethane finds its end-use here because of better frame conditions
- Stats from 2014, The Swedish total gas volume corresponds to 159 million m³
- So more than double the consumption in California

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<tr>
<th></th>
<th>Sweden</th>
<th>California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Traditional NG Use (BCF)</td>
<td>2,174,403,982</td>
<td>8,401,702,738</td>
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<tr>
<td>Annual RNG Use (BCF)</td>
<td>3,244,879,788</td>
<td>7,976,973,875</td>
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<td>Total Annual NGV Use (BCF)</td>
<td>5,419,283,770</td>
<td>16,378,676,613</td>
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<td>Percent Traditional NG Use</td>
<td>40.1%</td>
<td>51.3%</td>
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<tr>
<td>Percent RNG Use</td>
<td>59.9%</td>
<td>48.7%</td>
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Source Data (tack till Erik Neandross för dataframtagningen)
http://www.arb.ca.gov/fuels/lcfs/media_request_092215.xlsx
Examples US incentives for biomethane

- **Renewable Fuel Standard (FS2 – federal)**
  - Conventional fuel suppliers need to purchase RINs (Renewable Identification Numbers) to fulfil their RVO (Renewable Volume Obligations)*
  - RVO target 2013: 16.55 billion gallons, total 9.63%, including special quotas for cellulosic, advanced and biomass based diesel (conventional share = 6.9%); 2022 goal: 36 billion gallons
  - Blend wall (10% EtOH) effects, cellulosic biofuels waiver credits
  - Biogas from landfill, WWTP or manure digesters = advanced; landfill eligible to fulfil cellulosic advanced biofuel obligation! 3-12 USD/mmBTU (2014)

- **Low Carbon Fuel Standard (LCFS, California)**
  - Similar market based cap and trade system used in California
  - Demands reduction of carbon intensity, from 0.25% (2011) to 10% (2020), also natural gas and electricity eligible
  - 20-80 USD/ton CO2 (Source: Harrison Clay, CERF, 2014)

- **Late 2015:** 6-13 USD/mmBTU for RINs, 2-4 USD/mmBTU for LCFS → 0.25-0.5 SEK/kWh .... (293kWh/mmBTU, 8.50 SEK/USD)

* "RINs and RVOs are used to implement the Renewable Fuel Standard” http://www.eia.gov/todayinenergy/detail.cfm?id=11511
Biomethane as a transport fuel

Not only lower emissions of CO\textsubscript{2} but also particles and SO\textsubscript{x} and NO\textsubscript{x}.

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Present fuel</th>
<th>Liquid bio fuels</th>
<th>Electric</th>
<th>Hybrids</th>
<th>Biogas</th>
</tr>
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<tbody>
<tr>
<td>Cars</td>
<td>Petrol/Diesel</td>
<td>Yes (%)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes (CBG)</td>
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<tr>
<td>Delievery trucks</td>
<td>Diesel</td>
<td>Yes (%)</td>
<td>No</td>
<td>Yes</td>
<td>Yes (CBG)</td>
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<tr>
<td>Urban busses</td>
<td>Diesel</td>
<td>Yes (%)</td>
<td>Yes (wired)</td>
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<td>Heavy trucks</td>
<td>Diesel</td>
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<td>Yes (LBG)</td>
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<tr>
<td>Train</td>
<td>Diesel/Electric</td>
<td>Yes (%)</td>
<td>Yes (wired)</td>
<td>No</td>
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<td>Ships</td>
<td>Diesel</td>
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