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

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… 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

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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

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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

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- **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

The intercity bus sector is also under "gasification" in Sweden

*Sandén, B., Jonasson, K. Variety Creation, Growth and Selection Dynamics in the Early Phases of a Technological Transition: The Development of Alternative Transport Fuels in Sweden 1974-2004. pp. 76, 2005.

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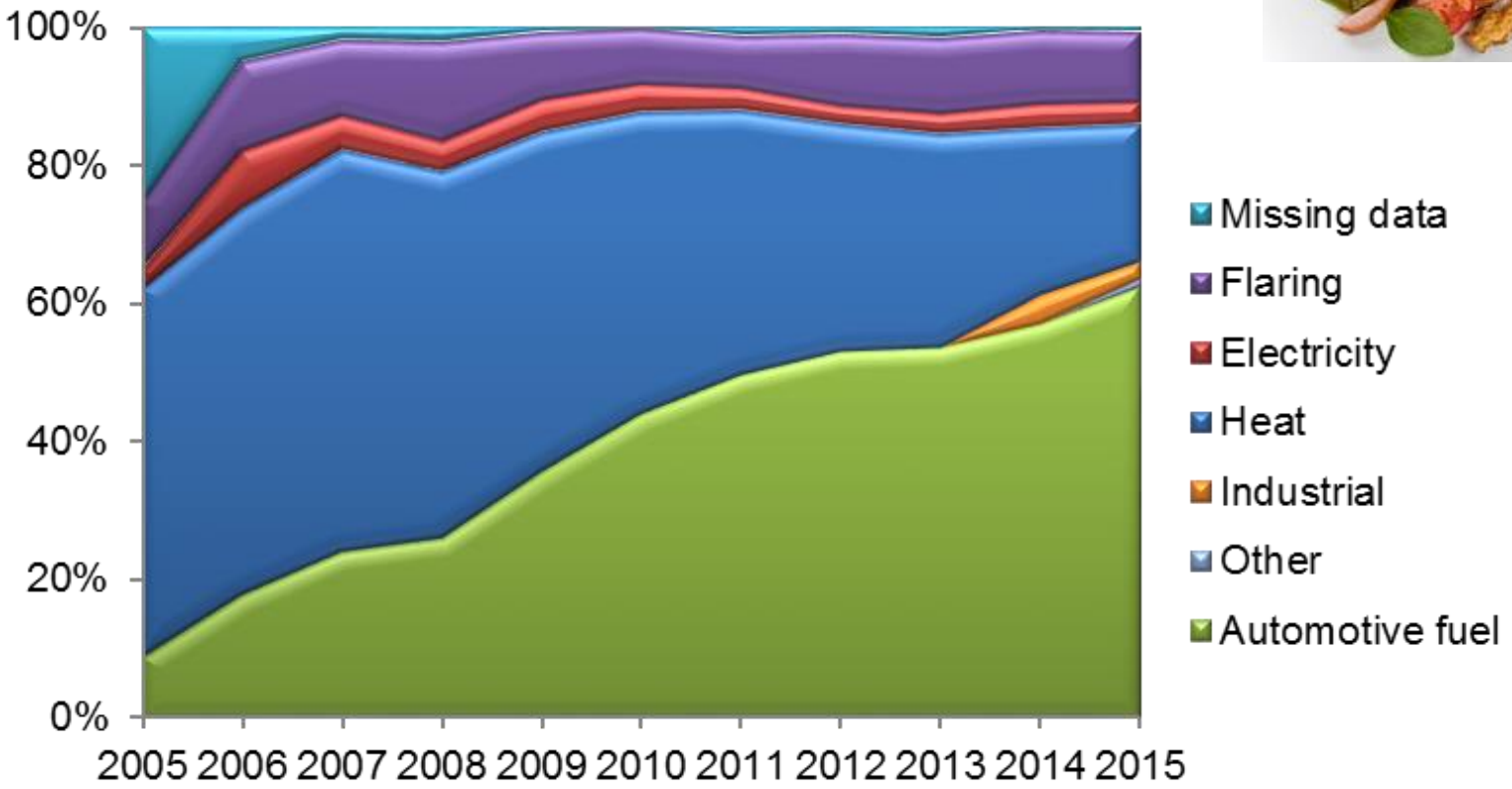
Biogas utilisation 2005-2013

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)



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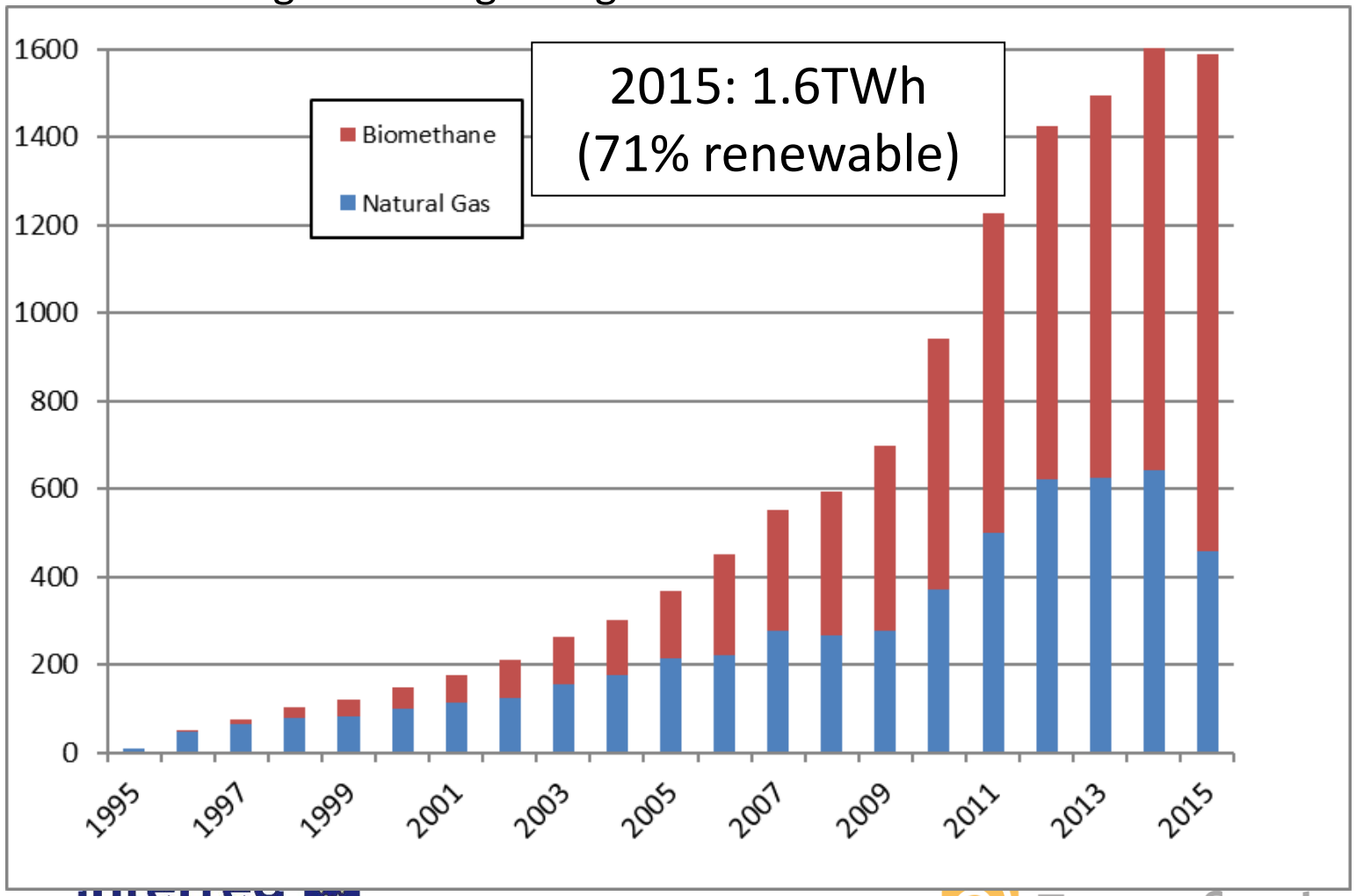
Volumes of CNG/biomethane in Sweden

Evidence of a fruitful interplay between the use of natural gas and biomethane

Market growth stagnating for the first time



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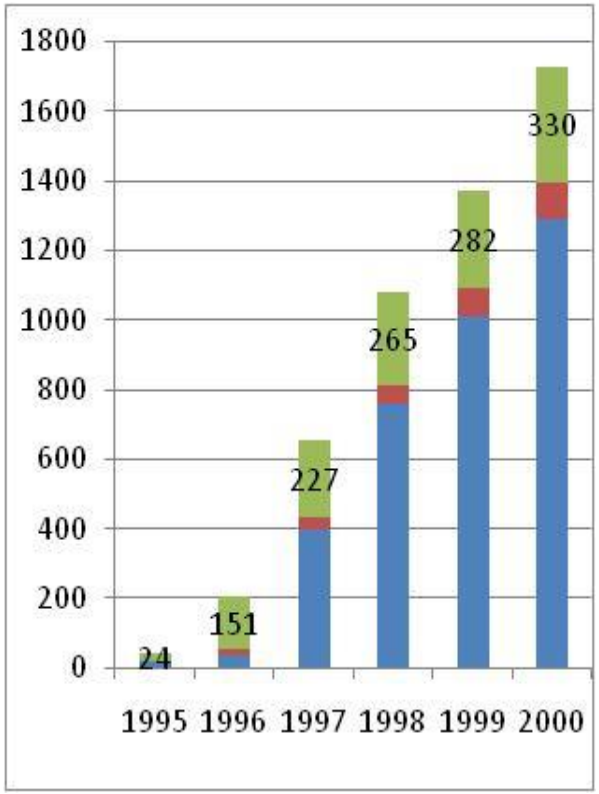
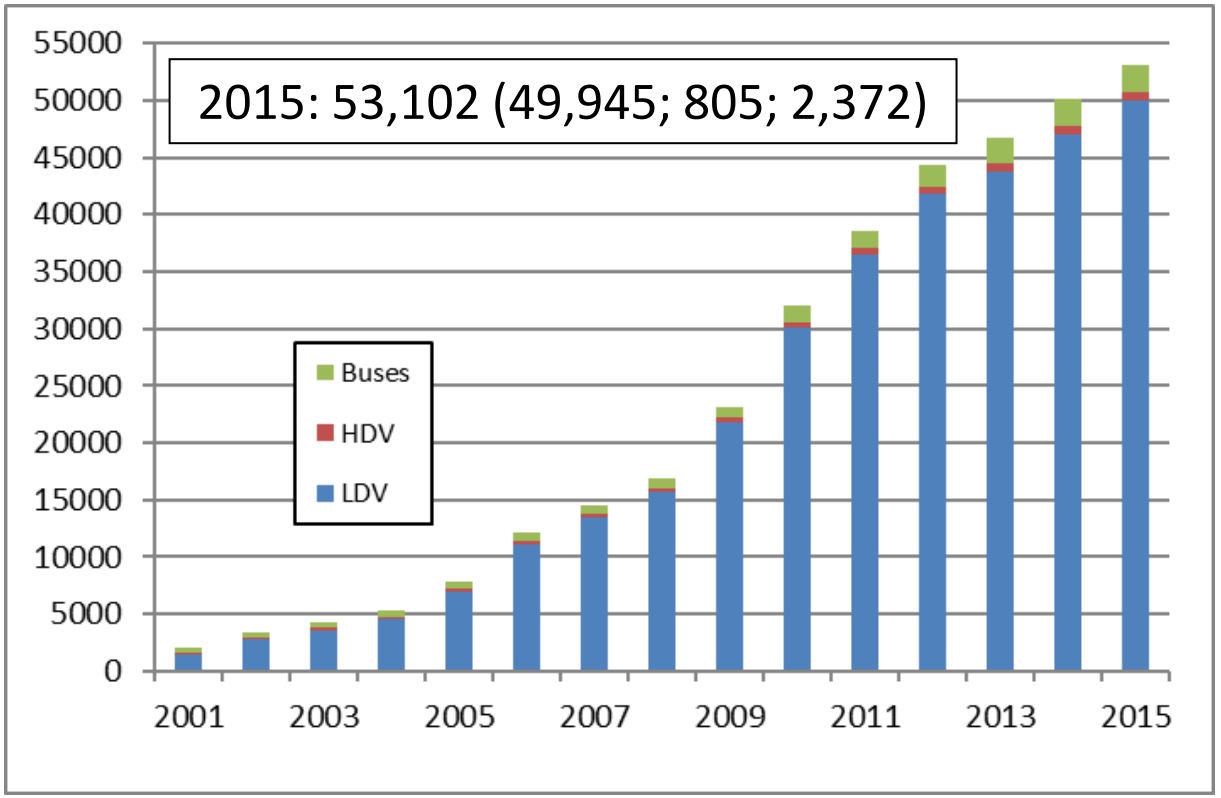
No. of NGV's in Sweden

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





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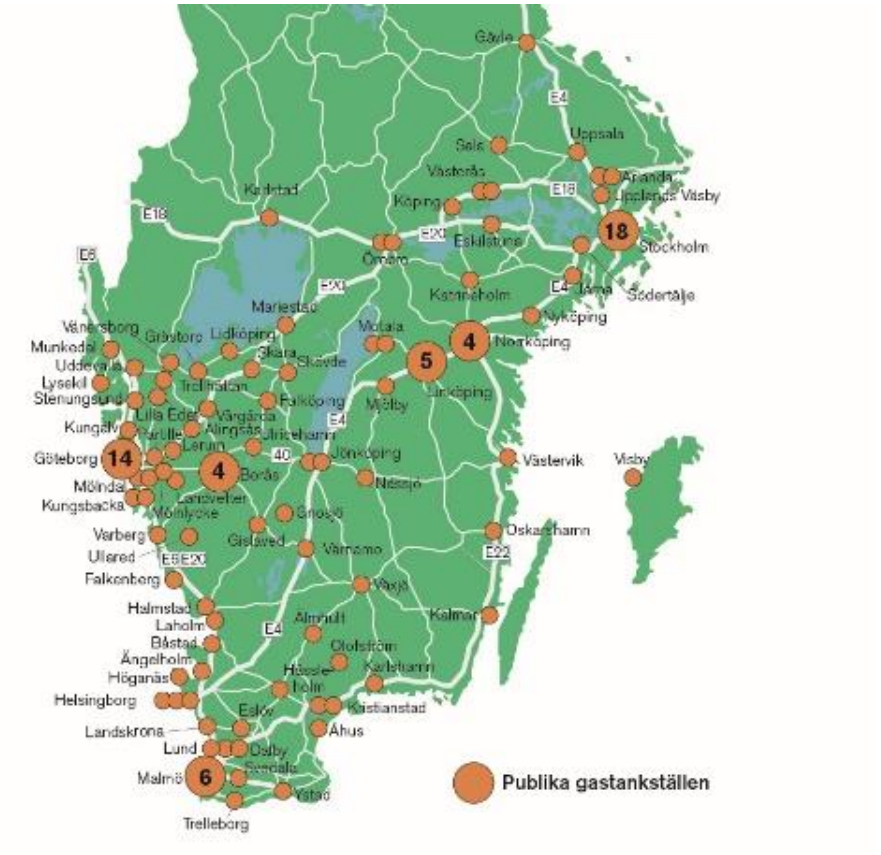
161 public refuelling stations

In total 221, and 6 supplying LNG/LBG



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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

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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!

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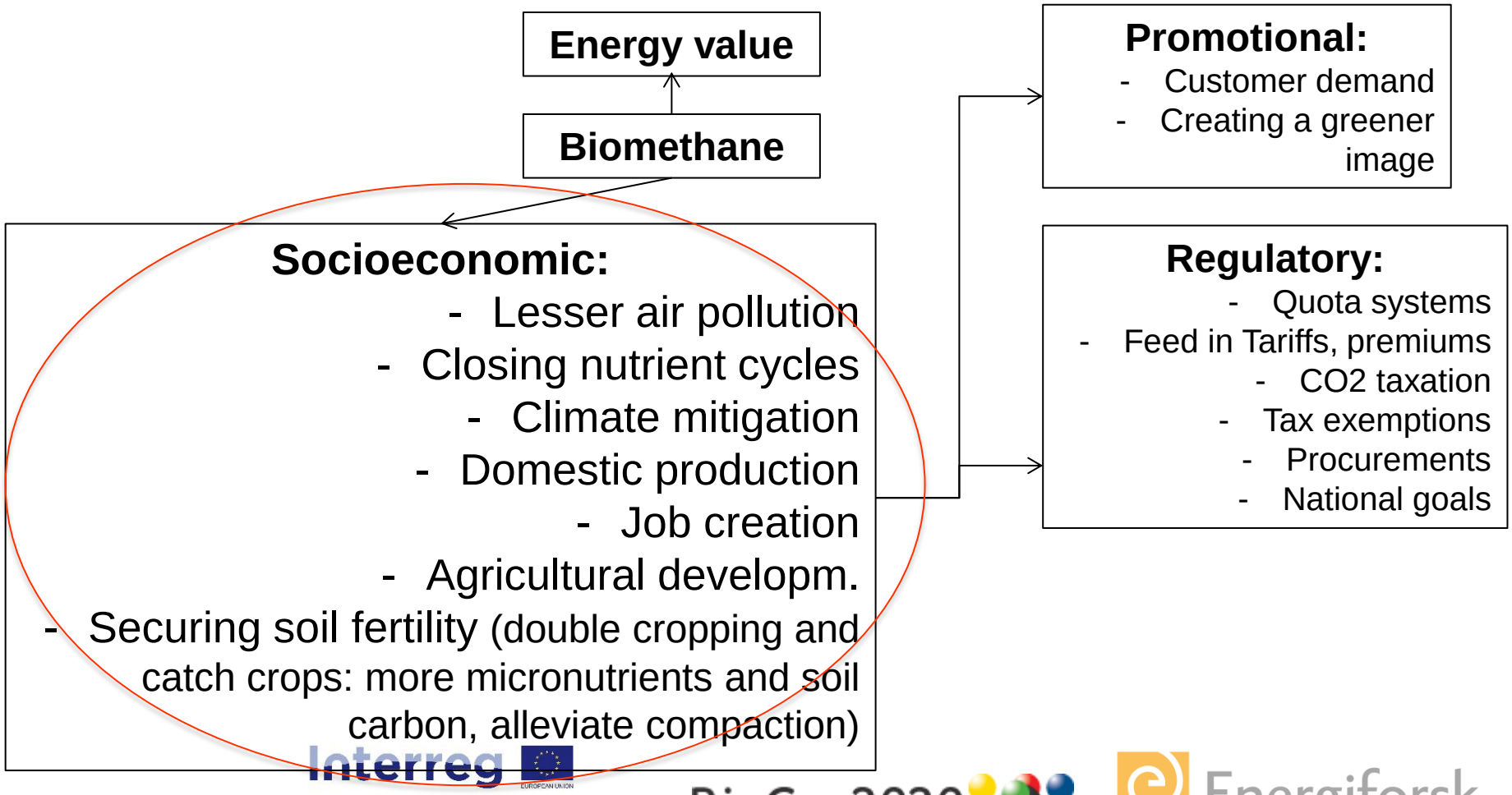
Wider picture important: Biomethane positive externalities



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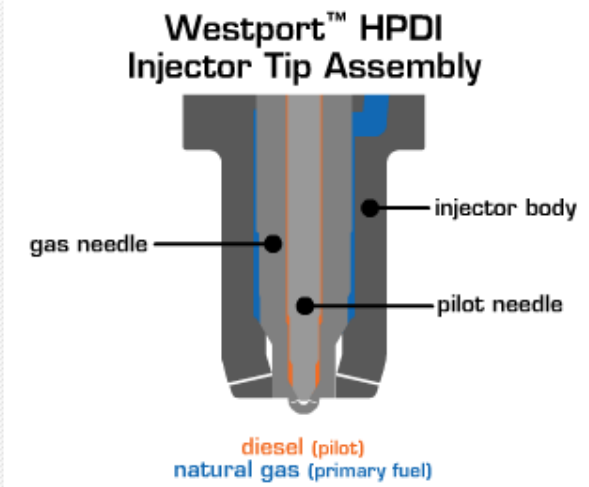
The future gas engine with diesel-like performance

- 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



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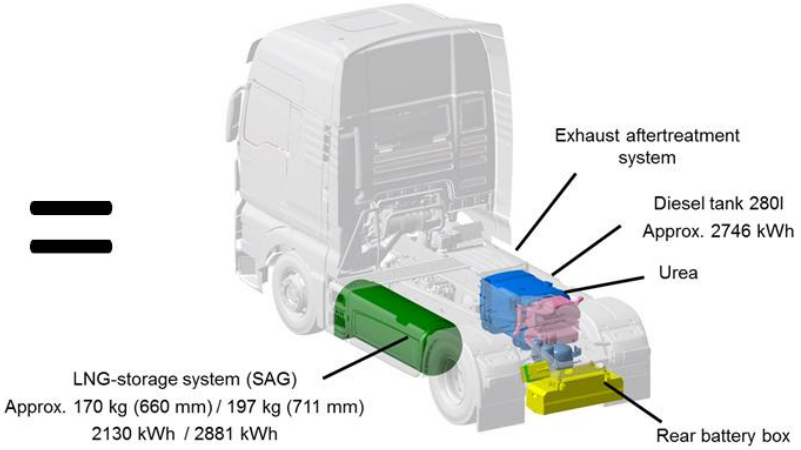
HDGAS – MAN, IVECO and Volvo working together on more efficient methane HDVs



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

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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)

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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

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Challenges/opportunities future biomethane powered automotive market

Thank you for the opportunity!

Questions?

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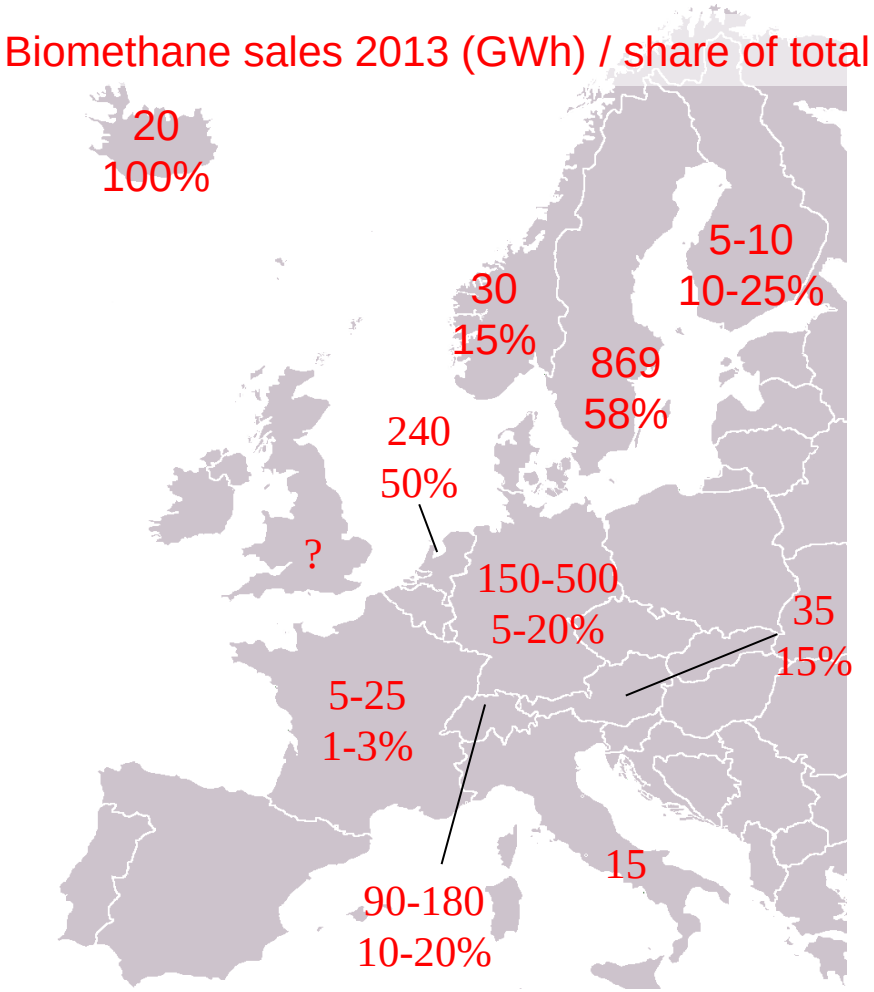
Biomethane powered transport in Europe



Sources: European Biogas Assoc., NGVA Europe, newsletters

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

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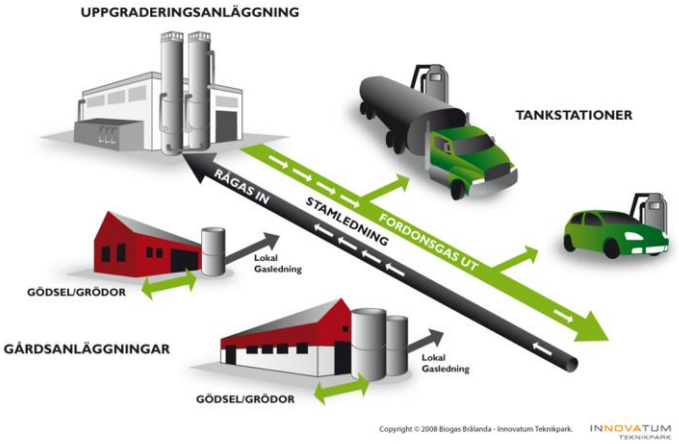
Sweden is world leading in transporting gas off-grid

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

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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

	Sweden	California
Annual Traditional NG Use (BCF)	2,174,403,982	8,401,702,738
Annual RNG Use (BCF)	3,244,879,788	7,976,973,875
Total Annual NGV Use (BCF)	5,419,283,770	16,378,676,613
Percent Traditional NG Use	40.1%	51.3%
Percent RNG Use	59.9%	48.7%
Source Data (tack till Erik Neandross för dataframtagningen)		
http://www.arb.ca.gov/fuels/lcfs/media_request_092215.xlsx		
https://www.energimyndigheten.se/globalassets/nyheter/2015/transportsektorns-energianvandning-2014.pdf		

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_2 but also particles and SO_x and NO_x

Vehicle type	Present fuel	Liquid bio fuels	Electric	Hybrids	Biogas
Cars	Petrol/Diesel	Yes (%)	Yes	Yes	Yes (CBG)
Delievery trucks	Diesel	Yes (%)	No	Yes	Yes (CBG)
Urban busses	Diesel	Yes (%)	Yes (wired)	Yes	Yes (CBG)
Heavy trucks	Diesel	Yes (%)	No	No	Yes (LBG)
Train	Diesel/Electric	Yes (%)	Yes (wired)	No	Yes (LBG)
Ships	Diesel	Yes (%)	No	No	Yes (LBG)

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