Gas grid scales and their impact on biogas production and utilization – a modeling analysis

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District heating (DH) systems (In Sweden)

- Large share of urban and municipality heating markets
- Major change of fuel/heat supply
  - from oil
  - to biomass, municipal solid waste and industrial waste heat
- Still rather small but increasing CHP share
- Thus, potential for improvement

Based on this we have already done a number of studies assessing bioenergy technologies in a DH system context
Biogas

- Biogas from anaerobic digestion can be a contributor to a more environmentally benign energy system:
  - Potential feedstock consists to high degree of waste products with few alternative areas of use.
  - High carbon mitigation efficiency
- Potentials based on available feedstock are about 10 times higher than current use.
- Today biogas is used mainly for heating and as transport fuel (while in the rest of Europe for CHP)
- Several problem areas have been highlighted:
  - Limited and fragmented markets
  - Lack of profitability for producers
  - Lack of infrastructure

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Heated debate

- Natural gas infrastructures or not
  - synergistic effects between natural gas and biogas, vs.
  - a natural gas grid expansion may be to the disadvantage of renewable energy (in particular bioenergy), and
  - local markets are large enough for the existing biogas potential.

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Purpose

• Main questions of investigation:

—What policy support levels are required to overcome the techno-economic barriers of increased biogas utilisation?

—How do different biogas distribution strategies affect the techno-economic potential of biogas?

Methodological approach:
A case study taking geographical aspects into account

• Studied region: Västra Götaland

• Potential biogas substrate supply, production, and use specified on a municipality level.

• Different inter-municipal biogas distribution options are contrasted.

—Performance depends on transport distances, amount of biogas distributed, geographical gas grid coverage
Gas grid scale options (strategic choices modeled)

• Local biogas scale (“Local”)
  — Biogas is utilised locally, within the municipality in which it is produced.

• Grid-based regional biogas scale (“Regional”)
  — Biogas grids can be built within the same local government federation area, i.e. Skaraborg, Sjuhärad, Fyrbodal, GBG region.

• Truck-based distribution biogas scale (“Truck”)
  — Compressed biogas can be transported anywhere within the Västra Götaland region.

• National natural gas grid scale (“NG Grid+”)
  — Large (exogenous) expansion of the natural gas grid is assumed. Biogas can be injected in the grid and co-distributed with natural gas.
Energy systems modelling approach using a

- Techno-economic, bottom-up, partial equilibrium, cost-minimising, optimisation model built in the MARKAL framework

- MIP – mixed integer programming

- System boundaries
  - Geographical: Region of Västra Götaland with individual representation of 48 municipalities.
  - Time: 2004-2029 (5 model years, 3 seasons/year)
  - Energy systems: district heating systems, biogas systems
    - demand for district heat, markets for electricity and transport fuels

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Local biogas system

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Energy market assumptions (Base)

• Transport fuel market:
  — Biogas as vehicle gas can be sold at 80% of the petrol price (incl. CO₂)
  — A maximum of 10% of the total transport fuel use in 2019 and 20% in 2029 is allowed to be biogas (in each local market/municipality)

• Price-setting marginal electricity technology:
  — Either coal condensing or natural gas condensing power plants depending on which has the lowest variable production cost at the time (season, model year)

• Fuel and CO₂ prices 2009→2029: *based on WEO 2010
  — Crude oil*: 27→40 EUR2004/MWh (60→90 USD2009/barrel)
  — NG*: 19→28 EUR2004/MWh
  — CO₂*: 20→80 EUR2004/ton
  — Biomass: 20→27 EUR2004/MWh

Modeling

• An optimisation model applied with a simulating approach
• Each gas distribution scenario is run multiple times with different biogas subsidy levels
  — Biogas subsidy range: 0-60 EUR/MWh
  — Subsidy is given to biogas utilisation regardless of sector
**Biogas utilisation**

– in a cost-minimised system for different biogas subsidy levels and gas distribution strategies

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**Biogas utilisation**

**Regional biogas grids**

**at a subsidy of 60 EUR/MWh**
Findings

- While large shares of the technical biogas potential could be reached with comparably low subsidies (e.g., 60-85% at 30 EUR/MWh), utilisation levels close to full technical potential are linked to substantial governmental subsidy expenditures.

- Better conditions for biogas distribution leads to some extent to higher cost-effective total biogas utilisation levels, but, in particular, to a shift from biogas used in CHP to biogas as vehicle gas.

- The base assumptions show that an expanded natural gas grid could imply higher cost-effective biogas utilisation levels than other biogas distribution strategies, but...
  - ...there is also a risk of the opposite development with lower utilisation of biogas as well as of bioenergy in general.

  → Biogas distribution based on trucks and biogas grids constitute more robust strategies.

Change in fuel use and electricity generation in DH sector

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System costs and subsidies

Average subsidies per abatement of CO$_2$ (a) and of regional oil/natural gas use (b)
Sensitivity analysis - Risks with NG grid expansion

- If NG is a competitor to transport biogas: less biogas
  - If electricity price is high: less bioenergy in DH

Conclusions

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- The base assumptions show that an expanded natural gas grid could imply higher cost-effective biogas utilisation levels than other biogas distribution strategies, but...
  - there is also a risk of the opposite development with lower utilisation of biogas as well as of bioenergy in general.
  - Biogas distribution based on trucks and biogas grids constitute more robust strategies.