CHALMERS
UNIVERSITY OF TECHNOLOGY

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

*Martin Börjesson & Erik O. Ahlgren*
Division of Energy Technology
Department of Energy and Environment
Chalmers Univ of Technology
Göteborg, Sweden

ETSAP Nov 9, 2011

CHALMERS
UNIVERSITY OF TECHNOLOGY

## 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

CHALMERS
UNIVERSITY OF TECHNOLOGY

# 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*



CHALMERS
UNIVERSITY OF TECHNOLOGY

# 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.

CHALMERS
UNIVERSITY OF TECHNOLOGY

# 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?



CHALMERS
UNIVERSITY OF TECHNOLOGY

# 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

Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

# 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.



CHALMERS
UNIVERSITY OF TECHNOLOGY

## Regional


## NG Grid+

Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

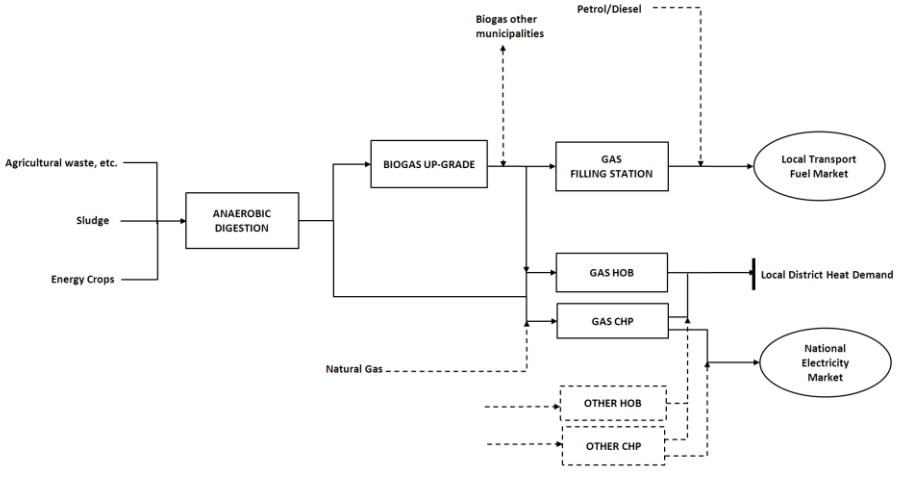
# Energy systems modelling approach using a

- 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



CHALMERS
UNIVERSITY OF TECHNOLOGY

# Local biogas system




Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

# Energy market assumptions (Base)

- Transport fuel market:
  - Biogas as vehicle gas can be sold at 80% of the petrol price (incl. $CO_2$)
  - 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



CHALMERS
UNIVERSITY OF TECHNOLOGY

# Modeling

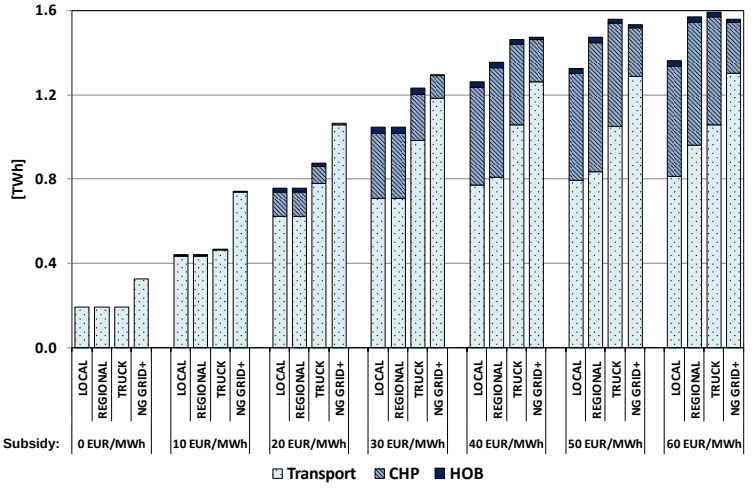
- An optimisation model applied with a simulating approach
- Each gas distribution scenario is run multiple times with different **biogas subsidy** levels
  - Biogas subsidy range: 0-60 EUR/MWh
  - Subsidy is given to biogas utilisation regardless of sector

Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

## Biogas utilisation

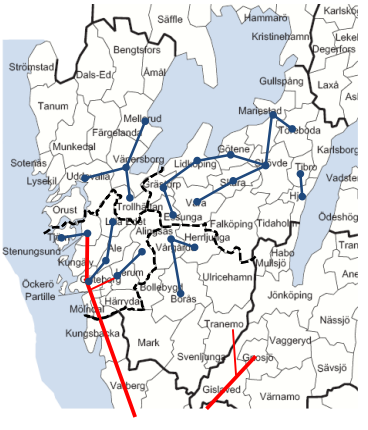
– in a cost-minimised system for different biogas subsidy levels and gas distribution strategies






CHALMERS
UNIVERSITY OF TECHNOLOGY

## Regional biogas grids at a subsidy of 60 EUR/MWh




Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

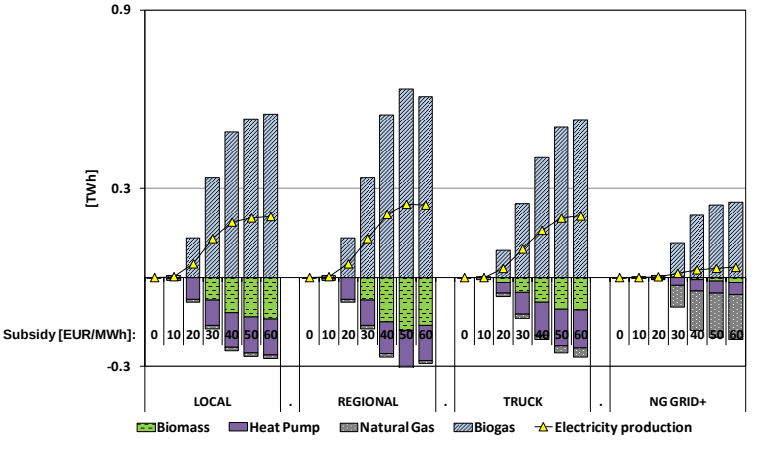
# Findings

- 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



CHALMERS
UNIVERSITY OF TECHNOLOGY

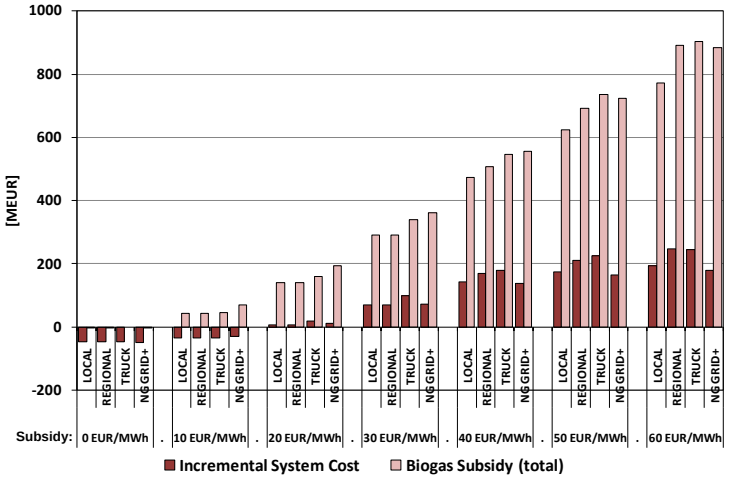
# Change in fuel use and electricity generation in DH sector




Background Purpose Method Results Conclusions

CHALMERS
UNIVERSITY OF TECHNOLOGY

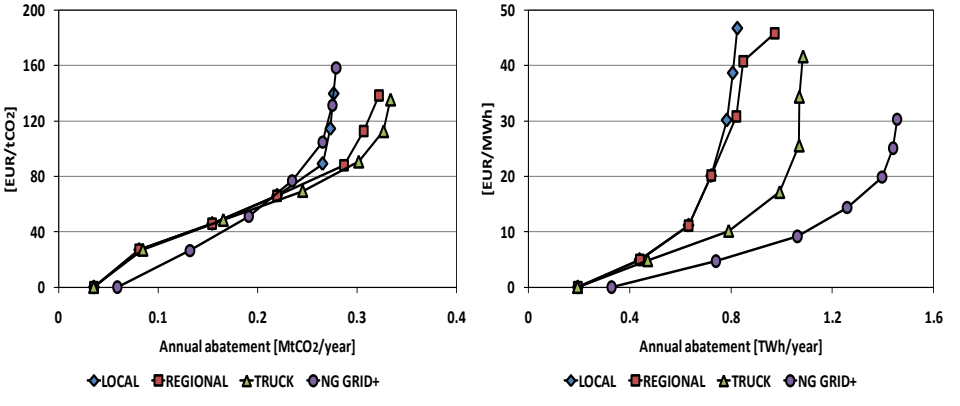
# System costs and subsidies






CHALMERS
UNIVERSITY OF TECHNOLOGY

# Average subsidies per abatement of $CO_2$ (a) and of regional oil/natural gas use (b)



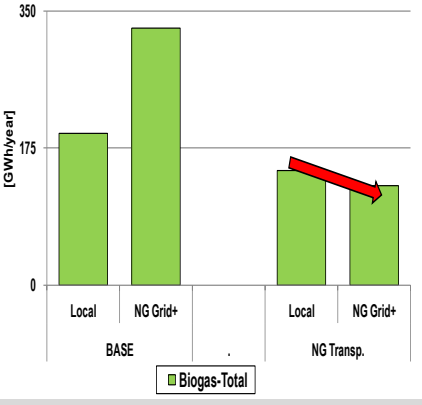

(a) CO2

(b) oil/natural gas

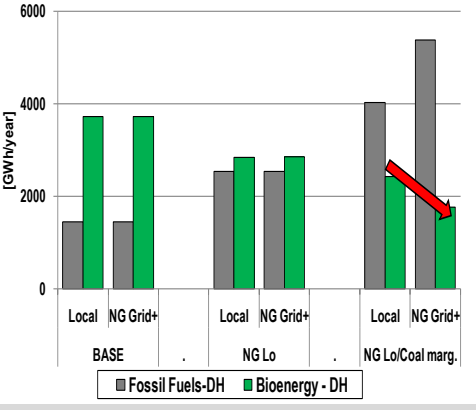
CHALMERS
UNIVERSITY OF TECHNOLOGY

## 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






CHALMERS
UNIVERSITY OF TECHNOLOGY

# Conclusions

- 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.
- To some extent, better conditions for biogas distribution leads 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