An integrated gas grid model for upgraded biogas in future renewable energy system

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Feasibility study on utilizing natural gas grid for upgraded biogas

- Are there any bottlenecks due to flow capacities of the gas grid?
- Can the low pressure distribution grid be used only for raw biogas and medium pressure grid for upgraded gas only?
- To what extent can these grids balance the supply and demand?
- How much raw & upgraded biogas contribute to the electricity, heat and transport demands?
- How much gas would be exported/ imported? And under what operating conditions?
The Funen Case

- Adequate system size for analyses
- Developed natural gas network
- Could be replaced entirely by biomethane
- Availability of feedstock

Modelling approach:
An integrated grid model in “SIFRE” tool
Balancing supply and demand for electricity, DH, Industrial process heat & transport sector

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Bio-Methane Potential for Fyn

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Biogas production (mio Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>2 PJ</td>
</tr>
<tr>
<td>With Straw</td>
<td>5,7 PJ</td>
</tr>
</tbody>
</table>

| No. of plants   | 10                          |
| Estimated size of plant | 28 mio Nm³/y               |

Supply

- DH Networks
- 80 bar pipeline
- 17 bar pipeline
- 4 bar pipeline
Funen gas demand

Data from NGF Nature Energy

- Funen gas demand: 5,62 PJ
- Industrial demand: 2,84 PJ
- % of total: 51%
- Convertibility to el.: 50-75%

Color graduation: light to dark for % of total energy

- 80 bar pipeline
- 17 bar pipeline
- 4 bar pipeline
## Compressed Biomethane Refilling stations

<table>
<thead>
<tr>
<th>Area</th>
<th>CNG stations</th>
<th>Annual Demand (PJ)</th>
<th>Peak Load (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Fyn</td>
<td>2</td>
<td>0.38</td>
<td>36</td>
</tr>
<tr>
<td>North Fyn</td>
<td>1</td>
<td>0.19</td>
<td>18</td>
</tr>
<tr>
<td>Central Fyn</td>
<td>3</td>
<td>0.58</td>
<td>55</td>
</tr>
<tr>
<td>East Fyn</td>
<td>2</td>
<td>0.38</td>
<td>36</td>
</tr>
<tr>
<td>Southwest Fyn</td>
<td>3</td>
<td>0.58</td>
<td>55</td>
</tr>
<tr>
<td>Southeast Fyn</td>
<td>2</td>
<td>0.38</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>2.5</strong></td>
<td><strong>158</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LNG Terminal</th>
<th></th>
<th></th>
<th></th>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>2.5</strong></td>
<td><strong>158</strong></td>
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</tbody>
</table>

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Localized gas grid grid of Funen

- Total 6 units of supply and Demand
- Each unit mainly consisting of 17 & 4 bar gas grid
- All units connected to 80 bar transmission line
- Different supply and demand characteristics
Decentralized CHPs mode with H2 assisted upgrading
Local biogas CHPs and 1 Central CHP plant

West Fyn
18 MW_{gas}  →  15 MW_{gas}
7 MW_{e}
31 MW_{gas} (@1 bar)
2x18 MW_{gas}
Southwest Fyn
18 MW_{gas}  →  15 MW_{gas}
7 MW_{e}
31 MW_{gas} (@1 bar)
2x18 MW_{gas}

North Fyn
18 MW_{gas}  →  12 MW_{gas}
7 MW_{e}
31 MW_{gas} (@1 bar)
18 MW_{gas}
Central Fyn
2x18 MW_{gas}  →  2x7 MW_{e}
2x31 MW_{gas} (@1 bar)
9 MW_{gas}

East Fyn
2x18 MW_{gas}  →  2x7 MW_{e}
2x31 MW_{gas} (@1 bar)
31 MW_{gas} (@1 bar)
2x18 MW_{gas}
Southeast Fyn
2x18 MW_{gas}  →  2x7 MW_{e}
2x31 MW_{gas} (@1 bar)
31 MW_{gas} (@1 bar)
2x18 MW_{gas}

Supply units
Demand units
Compressor
High pressure pipeline ~ 80 bar
Medium pressure grid ~ 17 bar
Low pressure grid ~ 4 bar

West Fyn: 18 MW_{gas}, 7 MW_{e}, 31 MW_{gas} (@1 bar), 2x18 MW_{gas}
North Fyn: 18 MW_{gas}, 7 MW_{e}, 31 MW_{gas} (@1 bar), 18 MW_{gas}
East Fyn: 2x18 MW_{gas}, 2x7 MW_{e}, 2x31 MW_{gas} (@1 bar), 9 MW_{gas}
Southwest Fyn: 18 MW_{gas}, 7 MW_{e}, 31 MW_{gas} (@1 bar), 2x18 MW_{gas}
Central Fyn: 2x18 MW_{gas}, 2x7 MW_{e}, 2x31 MW_{gas} (@1 bar), 9 MW_{gas}
Southeast Fyn: 2x18 MW_{gas}, 2x7 MW_{e}, 2x31 MW_{gas} (@1 bar), 27 MW_{gas}

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60% biogas upgraded

CH4 upgrading

Share of upgraded gas
• Medium pressure grid in stress during Centralized CHP production

- CH4 flows within areas
  - Decentralized
  - Central CHP

- High consumption in MP grid ~ upgraded gas volume
- Different compression levels depending on the upgrading technology

- Electricity consumption of compressors
  - Compression for HP injection: 29%
  - Compression for MP injection: 46%
  - Compression for LP injection: 24%
Maximum Biogas Capacity in low-pressure grid

Pipeline characteristics
- Material: PE Plastic
- Diameter: 107 mm
- Friction factor: 0.01
- Length: 1 km

Minimum Biomethane pressures

Pipeline characteristics
- Material: Steel
- Diameter: 312 mm
- Friction factor: 0.015
- Length: 20 km

Gas demand (MW)

Minimum  Pipeline   Pressure (bar)
Gas demand (MW)
Junction Pressure (P1) Bar
Pressure at outlet (P2) Bar
Total pressure loss (DP) %

Total pressure loss

Pipeline characteristics
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Energy in different sectors

- Biomethane grid fully catering to Transport sector

- Though gas import is 15% in volume, import actually occurs 38% of time

Primary Energy Supply

- Biogas: 52%
- Electricity: 30%
- Compression: 15%
- Imported Gas: 3%

Production vs Demand
Concluding remarks

- The system is capable of balancing the supply & demand majority of the time
- 60% of biogas is upgraded to biomethane
- More strain is observed on MP biomethane grid
- Improvements through:
  - Optimization of the storages to increase flexibility of upgrading
    &
  - Operational strategies for compressors to minimize gas imports
Thank you