Economic Evaluation of a Synthetic Natural Gas Production Plant using Indirect Gasification of Lignocellulosic Biomass

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VETAANI Task 5 Business evaluations
9.4.2014
The Objective

- 100 MW woody biomass gasifier
- Produces Synthetic Natural Gas (bio-SNG)
- Indirect gasification
- Three plant configurations
- Located in Finland or in Sweden
  - Finland: Replacing natural gas in energy production
  - Sweden: Transport fuel
- Studied N\textsuperscript{th} plant operational in 2020
  - To eliminate additional costs of implementing new technology
- Plant lifetime 20 years

• Is it viable?
Contents – main topics

1. The Scenarios
   – Scenario storylines and Energy prices

2. Energy and climate policy framework
   – EU and National level

3. Techno-economic analysis
   – Technology, Plant configurations, Capital and Production costs

4. Business plan of a bio-SNG plant
   – SWOT analysis, Markets and Industry, Financial calculations, Indirect benefits, and Plant ownership

5. Discussion and conclusions
1 The Scenarios

• We have used IEA scenarios as reference scenarios
• Scenarios have been adjusted to fit local conditions

1. New Policies Scenario
   – Most optimistic

2. Baseline Scenario
   – Baseline Scenario assumes continued RES and CO$_2$ policies, but less ambitious than New Policies Scenario
   – Most probable - used in more detailed profitability calculations

3. Restrained Policies Scenario
   – Worst case scenario
## Energy Prices

- **Energy prices today and in 2020**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Natural gas €/MWh</th>
<th>Biomass €/MWh</th>
<th>Heat €/MWh</th>
<th>Electricity €/MWh</th>
<th>CO2 €/tCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Today</td>
<td>35.00</td>
<td>17.00</td>
<td>25.00</td>
<td>45.00</td>
<td>5.00</td>
</tr>
<tr>
<td>New Policies Scenario</td>
<td>42.00</td>
<td>18.70</td>
<td>27.50</td>
<td>51.75</td>
<td>30.00</td>
</tr>
<tr>
<td>Baseline Scenario</td>
<td>44.10</td>
<td>17.00</td>
<td>25.00</td>
<td>51.75</td>
<td>20.00</td>
</tr>
<tr>
<td>Restrained Policies Scenario</td>
<td>33.25</td>
<td>16.15</td>
<td>23.75</td>
<td>49.50</td>
<td>15.00</td>
</tr>
<tr>
<td>Sweden today</td>
<td>63.00</td>
<td>23.00</td>
<td>30.00</td>
<td>45.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

- **Energy prices in 2020-2040 in the Baseline Scenario (used in NPV analysis):**

<table>
<thead>
<tr>
<th>Baseline Scenario</th>
<th>Natural gas €/MWh</th>
<th>Biomass €/MWh</th>
<th>Heat €/MWh</th>
<th>Electricity €/MWh</th>
<th>CO2 €/tCO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>44.10</td>
<td>17.00</td>
<td>25.00</td>
<td>51.75</td>
<td>20.00</td>
</tr>
<tr>
<td>2030</td>
<td>48.84</td>
<td>25.00</td>
<td>30.00</td>
<td>55.00</td>
<td>30.00</td>
</tr>
<tr>
<td>2040</td>
<td>51.05</td>
<td>30.00</td>
<td>35.00</td>
<td>60.00</td>
<td>40.00</td>
</tr>
</tbody>
</table>
2 Energy and climate policy framework

1. EU level
   – EU energy and climate targets 2020
   – EU ETS
   – RES directive

2. National level
   – Finland
     • National energy and climate strategy
     • RES support policies
     • Energy taxation
   – Sweden
     • Gas car policies and legislation
     • Biogas policies
   – German biogas policies
3 Techno-economic analysis

1. SNG technology
2. Plant configurations 1-3
   1. Condensing steam cycle, CO$_2$ vented (COND-VENT)
   2. CHP steam cycle, CO$_2$ vented (DH-VENT)
   3. CHP steam cycle, CO$_2$ captured (DH-CCS)
      – Each configuration: Fuel in 100 MW, SNG out 71 MW
3. Process simulation results
   – Energy and mass flows of all the plant configurations
4. Cost analysis
   – Capital costs (Total) Conf. 1 & 2: **120.8 M€**, Conf. 3: **123.1 M€**
   – Production costs
   – 10 % Required Rate of Return as base assumption
3 Techno-economic analysis

**Production costs**

- Calculations based on Energy and mass flows, Scenario energy prices, Annual capital costs
- Converted to cash flows
- Simplified calculations precision example (Conf. 2 DH-VENT)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual capital costs</td>
<td>12 % CCF</td>
</tr>
<tr>
<td>Annual O&amp;M costs</td>
<td>4 % of investment</td>
</tr>
<tr>
<td>Biomass in</td>
<td>-100.00 MW</td>
</tr>
<tr>
<td>SNG out</td>
<td>71.80 MW</td>
</tr>
<tr>
<td>Electricity in(-)/out(+)</td>
<td>-1.30 MW</td>
</tr>
<tr>
<td>Heat out</td>
<td>17.50 MW</td>
</tr>
<tr>
<td>Comp CO2 out</td>
<td>- tpd</td>
</tr>
<tr>
<td>CO2 transportation cost</td>
<td>-</td>
</tr>
<tr>
<td>Avoided CO2 emissions</td>
<td>111,188.91 tCO2/a</td>
</tr>
</tbody>
</table>
Income and cost structure

- Plant conf. 2 (DH-VENT)
- Baseline Scenario

- Maximum heat sales
- The price of CO₂ is 20 €/tonne

Income:
- SNG 81%
- Heat 11%
- CO₂ 8%
- Support 0%

Costs:
- Annual capital cost 44%
- Biomass 40%
- O&M 14%
- Electricity 2%

Avoided CO₂ emissions:
- SNG 9%
- Heat 21%

Support:
- 0%
4 Business plan

1. Project objectives
2. SWOT analysis
3. Market and industry analysis
4. Financial calculations
   – Simplified calculations
   – Sensitivity analysis for plant configuration 2 (DH-VENT)
   – NPV analysis for plant configuration 2 in Baseline Scenario
5. Indirect benefits
6. Ownership
4 Business plan

SWOT analysis (1/2)

- **Strengths**
  - Deep emission cuts
  - Wide feedstock base
  - Regional development
  - Fulfills EU targets
  - Employment growth
  - Energy security and independence
  - High biomass to transport fuel conversion efficiency
  - SNG is a versatile fuel
  - SNG can be used in existing power plants and applications
  - Wide client base via gas pipe connection
  - Technological expertise

- **Weaknesses**
  - Capital intensive compared to energy production from less processed biomass
  - Current natural gas and biomass price ratio
  - Infrastructure requirements
  - Limited potential plant locations
  - Technology partly in demonstration phase
Opportunities
- Increasing demand for gas
- Increasing supply of wood for energy production
- Structural reform of the EU ETS or otherwise increasing EUA prices
- Favorable EU 2030 climate and energy targets

Threats
- Falling natural gas prices
- Biomass CO$_2$ factor changes
- Increasing biomass demand
- Biomass sustainability criteria changes
Simplified profitability analysis

- All Scenario, Plant configuration and Heat sales combinations in 2020, 10 % RRR
- No support mechanisms

No support mechanisms

Case Sweden
4 Business plan

Possible support mechanisms

- **Investment support**
  - 30% – 40%

- **Feed-in tariff (FiT) / guarantee price**
  - 83.50 €/MWh\textsubscript{el} equals to 14.29 €/MWh\textsubscript{SNG} (2020, Baseline S.)

- **Heat premium**
  - 50 €/MWh\textsubscript{el} equals to 22.50 €/MWh\textsubscript{SNG}

- **Tax benefit**
  - Biogas is exempt from excise tax
  - In CHP production heat component is taxed, electricity is not
  - Bio-SNG plant benefits the amount of heat tax component, which equals to 4.13 €/MWh\textsubscript{SNG}
## Sensitivity analysis

(conf. 2 in 2020, balance €/a)

### Base level

<table>
<thead>
<tr>
<th></th>
<th>Heat sales 7660 h/a, High</th>
<th>Heat sales 7660 h/a</th>
<th>Heat sales 2500 h/a</th>
<th>Heat sales 0 h/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Policies</td>
<td>-1 583 594</td>
<td>-3 506 113</td>
<td>-5 989 363</td>
<td>-7 192 488</td>
</tr>
<tr>
<td>Baseline</td>
<td>-748 208</td>
<td>-2 495 952</td>
<td>-4 753 452</td>
<td>-5 847 202</td>
</tr>
<tr>
<td>Restrained Policies</td>
<td>-6 852 967</td>
<td>-8 513 323</td>
<td>-10 657 948</td>
<td>-11 697 011</td>
</tr>
</tbody>
</table>

### Feed-in tariff / guarantee price for electricity 83,50 €/MWh

<table>
<thead>
<tr>
<th></th>
<th>New Policies</th>
<th>Baseline</th>
<th>Restrained Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed-in tariff</td>
<td>6 274 358</td>
<td>7 109 744</td>
<td>1 561 849</td>
</tr>
<tr>
<td>Guarantee price</td>
<td>4 351 840</td>
<td>5 362 001</td>
<td>-98 507</td>
</tr>
<tr>
<td>Electricity</td>
<td>1 868 590</td>
<td>3 104 501</td>
<td>-2 243 132</td>
</tr>
<tr>
<td>Balance</td>
<td>665 465</td>
<td>2 010 751</td>
<td>-3 282 194</td>
</tr>
</tbody>
</table>

### Feed-in tariff & Heat premium 50 €/MWh

<table>
<thead>
<tr>
<th></th>
<th>New Policies</th>
<th>Baseline</th>
<th>Restrained Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed-in tariff</td>
<td>18 649 088</td>
<td>19 484 474</td>
<td>13 936 579</td>
</tr>
<tr>
<td>Heat premium</td>
<td>16 726 570</td>
<td>17 736 731</td>
<td>12 276 222</td>
</tr>
<tr>
<td>Premium</td>
<td>14 243 320</td>
<td>15 479 231</td>
<td>10 131 597</td>
</tr>
<tr>
<td>Balance</td>
<td>13 040 195</td>
<td>14 385 481</td>
<td>9 092 535</td>
</tr>
</tbody>
</table>

### Feed-in tariff & 120 % investment cost

<table>
<thead>
<tr>
<th></th>
<th>New Policies</th>
<th>Baseline</th>
<th>Restrained Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed-in tariff</td>
<td>2 516 733</td>
<td>3 352 119</td>
<td>-2 195 775</td>
</tr>
<tr>
<td>Investment cost</td>
<td>594 215</td>
<td>1 604 376</td>
<td>-3 856 132</td>
</tr>
<tr>
<td>Investment cost</td>
<td>-1 889 034</td>
<td>-653 123</td>
<td>-6 000 757</td>
</tr>
<tr>
<td>Balance</td>
<td>-3 092 159</td>
<td>-1 746 873</td>
<td>-7 039 819</td>
</tr>
</tbody>
</table>

### 30 % investment support

<table>
<thead>
<tr>
<th></th>
<th>New Policies</th>
<th>Baseline</th>
<th>Restrained Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed-in tariff</td>
<td>2 672 842</td>
<td>3 508 228</td>
<td>-2 596 529</td>
</tr>
<tr>
<td>Investment support</td>
<td>750 324</td>
<td>1 760 484</td>
<td>-4 256 886</td>
</tr>
<tr>
<td>Investment support</td>
<td>-1 732 925</td>
<td>-497 015</td>
<td>-6 401 511</td>
</tr>
<tr>
<td>Balance</td>
<td>-2 936 050</td>
<td>-1 590 765</td>
<td>-7 440 573</td>
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</tbody>
</table>

### Tax benefit

<table>
<thead>
<tr>
<th></th>
<th>New Policies</th>
<th>Baseline</th>
<th>Restrained Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tax benefit</td>
<td>688 182</td>
<td>1 523 569</td>
<td>-4 581 189</td>
</tr>
<tr>
<td></td>
<td>-1 234 335</td>
<td>-2 244 174</td>
<td>-6 241 546</td>
</tr>
<tr>
<td></td>
<td>-3 717 585</td>
<td>-2 481 674</td>
<td>-8 386 171</td>
</tr>
<tr>
<td></td>
<td>-4 920 710</td>
<td>-3 575 424</td>
<td>-9 425 233</td>
</tr>
</tbody>
</table>
NPV analysis (1/2)

10 % RRR (Conf. 2, Baseline Scenario, Plant lifetime 20 years)

NPV = 0 when
- Investment support 39.5 % or 45.4 M€
- FiT 80.16 €/MWh\textsubscript{el}
- Investment support 30 % with FiT 59.70 €/MWh\textsubscript{el}
NPV analysis (2/2)
8 % RRR, (Conf. 2, Baseline Scenario, Plant lifetime 20 years)
5 Discussion and Conclusions (1/3)

- Feasible technology for Finland (with support mechanisms or optimistic heat sales) and Sweden in 2020
- In energy production, bio-SNG is a rational alternative in situations where the biomass can not be transported to the plant site
5 Discussion and Conclusions (2/3)

- Financial points
  - In certain scenarios the plant is close to profitable even without support mechanisms (RRR 10 % and 8 %)
  - No support mechanisms for bio-SNG at the moment. We have studied mechanisms for comparable technologies in the report
  - The profitability is highly dependent also on the future energy prices and plant construction costs
  - Plant heat sales affect the plant profitability
  - More economical to use the biomass on site if possible
5 Discussion and Conclusions (3/3)

• Technical points
  – Wide feedstock base – good fuel availability and pricing
  – Can utilize existing natural gas infrastructure

• Indirect and other benefits
  – Helps to meet the energy and climate targets
  – Several local and nation wide benefits

• Recent development
  – Russian energy uncertainty
  – Dropping binding RES targets 2030

• Future Bio-SNG production plants for reference
  – Joutseno 200 MW biorefinery
Thank you!