Attractive Process Routes for the Production of Secondary Energy Carriers out of Lignite

Bruno Sailer - RWE Power AG, Hans van de Ruit & Michael Ettenger - Fluor
Agenda

- Background / motivation and objectives of RWE’s study
- Investigated routes
- Basic study parameters and resulting capacities
- Results and space requirements
- Capital cost estimate and economic analysis
- Conclusions
Background / motivation and objectives

Production of (petro-)chemicals out of lignite (or hard coal) for developing new markets

- Future shortage of mineral oil and natural gas
- High impact of renewables on power market
- Coal-to-Gas (CtG) and Coal-to-Liquids (CtL) are key technologies for a sustainable energy supply → Lignite products can partly substitute imports → Increasing security of supply
- Chemicals easier to handle and to store in comparison to electricity
- Lower direct CO₂ emissions compared to power generation due to fixed carbon within the product

→ Identification of attractive products with their CtG / CtL routes as full plant
→ Establishing of techno-economical data of the different routes
→ FLUOR contracted for the study

Source: Bundesverband Braunkohle; 12/2010
Investigated routes

- 8 products * 2 feedstocks * 2 variants (w and w/o CO₂ compression) = 32 routes
- Additionally 2 routes based on natural gas feedstock for benchmarking
- Pre-defined syngas generation technologies matching feedstocks (HTW for lignite, EFG for hard coal, SMR / POx for natural gas)
Basic study parameters and resulting capacities

- Assumption: grass roots plants in GER with grid E-power and natural gas to balance energy demand.
- Feedstock rate of all routes was set by FT routes with capacity of 30,000 bpd FT products.
- Process technologies were screened and a good typical selected; for each process unit at least two trains of maximum available capacity necessary; additional “typical” number of spare trains
  - Economies of scale maximized (unit train capacities were pushed to max)
  - Consistent basis across cases gives comparability of all routes

<table>
<thead>
<tr>
<th>Capacity [k t/d]</th>
<th>Hard coal – EFG (HC)</th>
<th>Lignite – HTW (L)</th>
<th>Natural gas (NG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedstock</td>
<td>11.7</td>
<td>32.8 (raw lignite)</td>
<td>8.0</td>
</tr>
<tr>
<td>Hydrogen (H₂)</td>
<td>1.9</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Methanol (MeOH)</td>
<td>10.1</td>
<td>6.3</td>
<td>-</td>
</tr>
<tr>
<td>SNG</td>
<td>4.5</td>
<td>4.7</td>
<td>-</td>
</tr>
<tr>
<td>FT Diesel</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Urea</td>
<td>18.7</td>
<td>14.4</td>
<td>-</td>
</tr>
<tr>
<td>Gasoline via MeOH (MtG)</td>
<td>3.8</td>
<td>2.4</td>
<td>-</td>
</tr>
<tr>
<td>Gasoline from Syngas</td>
<td>3.7</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>DME 1)</td>
<td>7.4</td>
<td>5.8</td>
<td>-</td>
</tr>
</tbody>
</table>

→ Technical and economical performance data generated on block basis; Simulation based on Fluor in-house data for all processing units and utility systems.

→ For some products (e. g. H₂, MeOH) the plant capacity is of significant size compared to European market volume; change of capacity for future development reasonable

1) Capacity in Methanol routes depending on recycle of non-converted syngas → to be validated/optimized in future
Results

Capacity

- Lignite and hard coal routes show different product yield due to different syngas production rates and methane content of HTW raw gas
  - Lower capacity for lignite in methanol routes, H₂ and urea due to purge gas losses
  - Higher capacity for lignite in SNG route because methane is target product
  - No disadvantage for lignite in FT route due to off gas reforming

Efficiency

- Overall efficiency dominated by chemical energy flows (not E-power)
- Hard coal routes show higher overall efficiency compared to lignite routes due to higher yield of CO + H₂; overall efficiency of natural gas routes comparable to coal routes
- H₂ route and SNG route with higher overall efficiency than fuel production

Utilities

- Lower demand of natural gas and imported power for most of the lignite routes due to off gas and char combustion; export of E-power in natural gas routes

Emissions

- Lignite routes have higher CO₂ emissions (in line with efficiency)
- H₂ / Urea route with highest / lowest CO₂ emissions relative to product mass flow
- CO₂ sequestration in coal routes is an effective way to reduce emissions
- Treatment of by-products and waste water to be considered
Space requirement
Example; indicative for space only

<table>
<thead>
<tr>
<th>Space required [ha]</th>
<th>HC</th>
<th>L</th>
<th>NG</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>30</td>
<td>31</td>
<td>8</td>
</tr>
<tr>
<td>MeOH</td>
<td>36</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>SNG</td>
<td>31</td>
<td>33</td>
<td>-</td>
</tr>
<tr>
<td>FT Diesel</td>
<td>33</td>
<td>36</td>
<td>20</td>
</tr>
<tr>
<td>Urea</td>
<td>55</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>MtG</td>
<td>38</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>Gasoline</td>
<td>35</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>DME</td>
<td>42</td>
<td>32</td>
<td>-</td>
</tr>
</tbody>
</table>

→ Space required for CtG / CtL routes approx. 30 – 40 ha
→ Urea shows even higher demand due to high complexity and seasonal product storage
→ Routes based on lignite show highest (coal yard) and on natural gas show lowest (lower plant complexity) space requirement
Capital cost estimate

- Total investment costs of CtG / CtL plant approx. 4 – 5 bn € \(^1\) (without CO\(_2\) compression); for urea routes even higher; investment costs for CO\(_2\) compression: approx. 100 m €
- Lignite routes show slightly higher costs compared to hard coal routes; natural gas routes show lowest costs due to lower complexity compared to CtG / CtL
- Recently upward trend in investment costs for downstream industry

\(^1\) Class 5 per AACEI; Based on process unit capacity factored approach supported by Fluor in-house information; Railway and harbour system, bio pond style water treatment, demolition of underground obstacles and client costs not included
Economic analysis
Lignite routes without CO₂ compression

- Discounted cash flow method; done in-house by RWE Power based on FLUOR input data from simulation
- Not included: Product quality effects (CtG / CtL vs. conventional), market impacts, ...

→ Synthetic Fuels have big market volume and attractive price forecast due to increasing world demand and declining crude oil quality, but not economically viable at present
→ Perspective of low-volume-market products (urea, H₂) looking better; actual attractiveness uncertain due to challenging market structures (volume, entry, ...)
Conclusions

- CtG / CtL is in the focus of RWE and can become more and more important in future to substitute mineral oil and gas.
- In Germany lignite is to be preferred as feedstock for CtG / CtL due to price trend of imported energy carriers (hard coal).
- All CtG / CtL routes have about the same high space requirement.
- Production costs strongly influenced by investment and CO₂ costs (w/o CCS; evaluation of CCS not possible due to uncertain implementation)
- Production costs of all CtG / CtL routes exceed today’s market price.
- Viability of CtG / CtL strongly depending on crude oil price; in case upward price trend continues, CtG / CtL might become viable in the near future.

- Various products with interesting perspective → further investigation / optimization
- Base route “syngas production” keeps all options open and is also attractive in future.
- Implementation of CtG / CtL can improve Germany’s security of energy supply; political promotion and public acceptance are needed.
Thanks for your attention! Any Questions?

Bruno.Sailer@rwe.com
Hans.van.de.Ruit@fluor.com
Michael.Ettenger@fluor.com