B, C, G, XtL - what else?
Lurgi’s Routes to Transportation Fuels

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Lurgi’s Gasification Technologies

**Fixed Bed Grate Gasifier**
- Coal; Solid wastes, sewage sludge etc.
- **Lock hopper**
- **Wash cooler**
- **Gas-offtake**
- **Water jacket**
- **Oxidant** (O₂, Steam)
- **Ash lock hopper**
- **Ash**

**BGL Gasifier**
- Coal; Solid wastes, sewage sludge etc.
- **Lock hopper**
- **Wash cooler**
- **Gas-offtake**
- **Oxidant** (O₂, Steam)
- **Tuyeres**
- **Slag quench vessel**
- **Slag lock hopper**
- **Slag**

**Multi Purpose Gasifier**
- Residues Coal/Oil Tars Slurries
- **Burner**
- **Oxidant** (O₂, Air) Steam
- **Water Quench**
- **Gas-offtake**
- **Soot Slurry**
- **Slag**
Lurgi - References for Coal Gasification

- Lurgi FBDB gasifiers around the world
  - 97 units, Mark IV / V, Sasol, South Africa
  - 14 units, Mark IV, U.S.A.
  - 24 units, Mark IV, SVZ, Germany
  - 5 units, Mark IV, Tianjin, PR China
  - 2 units, Mark IV, Yima, PR China

- Total 144 Gasifiers
  producing more than 110 Mio Nm3/d Syngas
Reference plant for Lurgi FBDB Coal Gasification

80 Lurgi Fixed Bed Dry Bottom Gasifiers

Sasol Secunda South Africa October 1980
B, C, X to Liquids Routes

Suitable Gasification

Fischer Tropsch Synthesis

Upgrading

Biomass
Coal
Waste

Megamonia®

Mega-Methanol®

MTC
MtSynfuels®
MTP®
MTO
MegaDME
MTH

Fuel Gas
LPG
Naphtha
Diesel
Waxes
Ammonia
Fuel Cells

Chemicals (MTBE, Acetic Acid, Formaldehyde, ...)
Diesel, transport. fuels
Propylene/Polypropylene
Acrylic Acid/Acrylates
Ethylene/Propylene
Fuel/DME(Diesel)
Hydrogen
Lurgi’s FT Experience I

- Commercialisation of ARGE-synthesis in 1952
  - location: Sasolburg / South Africa
  - start up: 1955
  - no. of reactors: 5 x 500 bpd

- All original reactors still in operation today
  extension of capacity in 1987 1 x 700 bpd

Modern FT Reactor Technology:
- Slurry phase reactor (by far preferred)
- tubular reactor
- fluidised bed reactor

Lurgi has commercial experience in all these reactor technologies
Lurgi designed the syngas production units of all FT-plants currently in commercial operation

- Sasol/Secunda (coal gasification)
- Mossgas (combined reforming of NG)
- SMDS/Bintulu (partial oxidation of NG)

Today, Lurgi MegaSyn® is available for FT Syntheses as well as for MtSynfuels®, Lurgi’s route through methanol to transportation fuels.

Lurgi also is active again in the FT-field – as JV partner in the company GTL.F1 which is developing/commercialising a modern FT-technology.
The Lurgi MegaMethanol® Process
coal / biomass - based

Coal/Biomass Gasification → POX / Raw Gas Shift → Syngas Purification → Methanol Synthesis → Methanol Distillation

- Purge gas Recycle
- Oxygen
- Air Separation

Pure Methanol
Lurgi’s MtSynfuels® Route

Methanol 19,200 t/d

Olefin Production

Water recycle

Process water, 10,115 t/d, can replace raw water

Olefin Oligomerisation

Hydrocarbon Recycle

Product separation + MD Hydrogenation

H₂, 70 t/d, from Methanol synthesis

Kero/Diesel 6,961 t/d

Gasoline 877 t/d

LPG 741 t/d

maximum diesel case 64,000 bpd total products

Methanol 19,200 t/d

Hydrocarbon Recycle

Product separation + MD Hydrogenation

H₂, 70 t/d, from Methanol synthesis

Kero/Diesel 6,961 t/d

Gasoline 877 t/d

LPG 741 t/d

maximum diesel case 64,000 bpd total products
Typical GTL Synfuel Product Slates\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Lurgi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha [wt.%]</td>
<td>30</td>
<td>14</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Gasoline [wt.%]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>(51)</td>
</tr>
<tr>
<td>Kerojet [wt.%]</td>
<td>20</td>
<td>18</td>
<td>25</td>
<td>15</td>
<td>30</td>
<td>49 (29)</td>
</tr>
<tr>
<td>Diesel [wt.%]</td>
<td>50</td>
<td>68</td>
<td>60</td>
<td>65</td>
<td>50</td>
<td>40 (20)</td>
</tr>
</tbody>
</table>

Gasoline: Kero+Diesel 1:8 (1:1)*
Naphtha: Kero+Diesel 1:2,3 1:5,4 1:5 1:4 1:4

1\(^1\) Chem Systems, 2001
Lu = Lurgi MtSynfuels\(^\circ\) added for comparison

* High diesel case versus (high gasoline case)
## Comparison Lurgi MtSynfuels® - FT Synthesis

### Product Slate and Properties

<table>
<thead>
<tr>
<th>Product Slate</th>
<th>Lurgi Route</th>
<th>FT Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha : Diesel (max.)</td>
<td>1 : 7.9</td>
<td>1 : 2.3 – 1 : 6</td>
</tr>
</tbody>
</table>

### Product Properties

<table>
<thead>
<tr>
<th>Spec (Europe from 2005)</th>
<th>Lurgi Route</th>
<th>FT Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gasoline</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Aromatics</td>
<td>vol.%</td>
<td>max.</td>
</tr>
<tr>
<td></td>
<td>vol.%</td>
<td>max.</td>
</tr>
<tr>
<td>-Benzene</td>
<td>wppm</td>
<td>max.</td>
</tr>
<tr>
<td>-Sulphur</td>
<td>vol.%</td>
<td>max.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>max.</td>
</tr>
<tr>
<td>-Olefins</td>
<td></td>
<td>max.</td>
</tr>
<tr>
<td>-RON 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-MON 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diesel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Polyaromatics</td>
<td>vol.%</td>
<td>max.</td>
</tr>
<tr>
<td>-Sulphur</td>
<td>wppm</td>
<td>max.</td>
</tr>
<tr>
<td>-Cetane No.</td>
<td>min.</td>
<td></td>
</tr>
</tbody>
</table>

1) Diesel with 10 wppm sulphur has to be available on the market
2) RON / MON for Regular Gasoline / Euro-Super / Super-Plus
3) Properties before naphtha upgrading
### Comparative Economics

**Cost of Production Estimate**

<table>
<thead>
<tr>
<th>GTL Technology</th>
<th>MtSynfuels®</th>
<th>modern FT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Capital Investment</strong></td>
<td>1.797 G€</td>
<td>1.809 G€</td>
</tr>
<tr>
<td><strong>Specific Total Plant Capital</strong></td>
<td>23,490 €/bpd</td>
<td>23,650 €/bpd</td>
</tr>
<tr>
<td><strong>NG to process (LHV)</strong></td>
<td>5.18 €/bbl</td>
<td>6.25 €/bbl</td>
</tr>
<tr>
<td><strong>NG to utilities (LHV)</strong></td>
<td>1.06 €/bbl</td>
<td>0.3 €/bbl</td>
</tr>
<tr>
<td><strong>Cat. &amp; Chemicals</strong></td>
<td>2.63 €/bbl</td>
<td>2.3 €/bbl</td>
</tr>
<tr>
<td><strong>Cost of Production + ROI 16%</strong></td>
<td>28.2 €/bbl</td>
<td>28.1 €/bbl</td>
</tr>
<tr>
<td><strong>Cost of Production + ROI 25%</strong></td>
<td>35.9 €/bbl</td>
<td>35.8 €/bbl</td>
</tr>
<tr>
<td><strong>Market Prices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gasoline</td>
<td>[€/bbl]</td>
<td>W. Europe</td>
</tr>
<tr>
<td>- Diesel</td>
<td>[€/bbl]</td>
<td>43.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37.2</td>
</tr>
</tbody>
</table>

1) natural gas @ 0.54 €/MMBtu

2) corresponding crude oil price: about 42 $/bbl
Study: Coal-based MtSynfuels\textsuperscript{®} complex
Basic Process Flow Diagram

Coal 7.7 Mt/a

Coal Preparation

Coal Gasification

Partial Oxidation

Gas Cooling

Raw Gas Shift Conversion

Gas Purification (Rectisol)

O_{2}

Sulphur Recovery

O_{2}

O_{2}

Sulphur

ASU

Methanol Synthesis & Distillation

DME step

Olefin Synthesis

Olefin Oligomerisation

Product Separation & MD Hydrogenation

Final Products

2.92 Mt/a

Light Ends (LPG)

Kero/Diesel

Gasoline

Possible intermediate products:

DME 4.6 Mt/a

or

Methanol 6.53 Mt/a
Study: Coal-based MtSynfuels® complex
Estimate for 64,000 bpd project

- **Production:**
  - Diesel, Mt/a: 1.065 max., 0.533 min.
  - Kerojet, Mt/a: 1.302 max., 0.774 min.
  - Gasoline, Mt/a: 0.3 max., 1.36 min.
  - Light Ends (LPG), Mt/a: 0.25 max., 0.25 min.

- **Consumption:**
  - Coal, Mt/a: ~7.7 max.
  - (m.a.f., excl. power production)

- **Investment:**
  - 2.5-3 G€ based on European conditions (rough estimate excl. power plant, incl. utilities and offsites)

- **Conclusion:**
  - Coal (Biomass) gasification-based projects are even more capital intensive than gas-based ones. They will be justified mostly on (geo-) strategic grounds like scarcity of other resources or CO₂-“avoidance” in case of biomass.
Conclusion

- Gas-based Synfuels projects are profitable at current gas and crude oil prices
- MtSynfuels is an attractive supplement to FT
- CtL projects are feasible under certain strategic conditions
- All necessary technologies are available
- “Profitability” may be improved by additional products – considering also DME and methanol as transportation fuels
Thank You!

Questions?

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