Lurgi’s Gas To Chemicals (GTC®):
Advanced technologies for natural gas monetisation

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Harald Kömpel, Waldemar Liebner, Matthias Wagner
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• Lurgi’s MegaMethanol®-Technology
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• Near future: “gas-based petrochemistry”
• Conclusion
Gas To Chemicals (GTC®)

Flared Natural Gas

Middle East 13.7%
North America 15.7%
Africa 43.3%
E. Europe & FSU 6.3%
West. Europe 2.2%
C&S America 11.6%
Far East & Oceania 7.2%

Source: Cedigaz, 2003

total amount flared world-wide: $81 \times 10^9$ m³ per year

better use:
make 102 Mt/a of methanol!
build 60 MegaMethanol (and MTP) plants!
Gas To Chemicals (GTC®)

Gas to Chemicals Processing Routes

- Fischer Tropsch Synthesis
  - Upgrading
  - Megamonia®
  - MegaSyn®
  - Lurgi proprietary process
  - MTC
  - MtSynfuels®
  - MTP®
  - MTO
  - MtPower
  - MTH

Natural Gas / Associated Gas

- Fuel Gas
  - LPG
  - Naphtha
  - Diesel
  - Waxes
  - Ammonia
  - Fuel Cells
  - Chemicals (MTBE, Acetic Acid, Formaldehyde, ...)
  - Diesel, transport. fuels
  - Propylene/Polypropylene
  - Acrylic Acid/Acrylates
  - Ethylene/Propylene
  - Power/Fuel/DME (Diesel)
  - Hydrogen

DrLb / GTC_Gastech05_pres / 25.02.05
The basis for even more value from natural gas:

- **MegaMethanol®:**
  - > 1.7 million t/a methanol single train capacity

- **Technical Features:**
  - Oxygen-blown synthesis gas production
  - Two-step methanol synthesis
  - Hydrogen Recovery
Gas To Chemicals (GTC®)

Simplified Diagram of Lurgi’s MegaMethanol® Technology

- Optimised reforming: high flexibility in stoichiometric number
- high energy efficiency for MeOH synthesis
- low investment costs
- large single-train capacity

methanol production cost: 65 $/t
### Gas To Chemicals (GTC®)

**Latest Lurgi-Methanol Project References**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Capacity (mtpd)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHANEX, USA</td>
<td>1700</td>
<td>1992</td>
</tr>
<tr>
<td>STATOIL, Norway</td>
<td>2400</td>
<td>1992</td>
</tr>
<tr>
<td>SINOPEC, China</td>
<td>340</td>
<td>1993</td>
</tr>
<tr>
<td>KMI, Indonesia</td>
<td>2000</td>
<td>1994</td>
</tr>
<tr>
<td>NPC, Iran</td>
<td>2000</td>
<td>1995</td>
</tr>
<tr>
<td>SASTECH, RSA</td>
<td>400</td>
<td>1996</td>
</tr>
<tr>
<td>TITAN, Trinidad</td>
<td>2500</td>
<td>1997</td>
</tr>
<tr>
<td>YPF, Argentina</td>
<td>1200</td>
<td>1999</td>
</tr>
<tr>
<td>ATLAS, Trinidad</td>
<td>5000</td>
<td>2000</td>
</tr>
<tr>
<td>NPC, 4th Methanol, Iran</td>
<td>5000</td>
<td>2000</td>
</tr>
<tr>
<td>METHANEX, Chile 4</td>
<td>2400</td>
<td>2002</td>
</tr>
<tr>
<td>NPC, 5th Methanol, Iran</td>
<td>5000</td>
<td>2004</td>
</tr>
<tr>
<td>Hainan, China</td>
<td>2000</td>
<td>2004</td>
</tr>
<tr>
<td>Qafac, Qatar</td>
<td>6750</td>
<td>2004</td>
</tr>
<tr>
<td>IAC Acetex (+730 t/d CO)</td>
<td>5400</td>
<td>2004</td>
</tr>
</tbody>
</table>
Dimethyl Ether (DME) - Alternative to Conventional Diesel Fuel

- Excellent transportation fuel (“better diesel”)
- Very low emission levels
- Clean and efficient power generation
- Similar properties as LPG (storage, transport)

DME: Energy Carrier of the Future!
(see www.aboutdme.org)
Gas To Chemicals (GTC®)

Lurgi MegaDME
Dimethyl Ether Production by Methanol Dehydration
MegaMethanol® & Dehydration Plant = MegaDME

- Single-train production capacities: 5000 t/d (1.7 Mt/a) and more
- Available “on order”
- Incremental investment cost increase on MegaMethanol® plant: < 10%
- Delivered cost (“trans-ocean”): same as for methanol (on energy basis)
Lurgi will build several large DME plants, however …

<table>
<thead>
<tr>
<th>Plant location</th>
<th>production DME, kt/a</th>
<th>Status</th>
<th>exp. s-u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>269</td>
<td>contract signed</td>
<td>2008</td>
</tr>
<tr>
<td>Latin America</td>
<td>690</td>
<td>LOI, financing</td>
<td>2008</td>
</tr>
<tr>
<td>Middle East</td>
<td>1180</td>
<td>contract (pre-)BE</td>
<td>2009</td>
</tr>
<tr>
<td>Middle East</td>
<td>1180</td>
<td>LOI, financing</td>
<td>2009</td>
</tr>
</tbody>
</table>
Gas To Chemicals (GTC®)
MTP: Simplified Process Flow Diagram with production figures

- **Methanol, Grade AA**
  - $1.667 \times 10^6$ t/a = 5000 t/d

- **DME Pre-Reactor**

- **MTP Reactors**
  - (2 operating + 1 reg.)

- **Olefin Recycle**

- **Water Recycle**

- **Fuel Gas 15,000 t/a**
  - internal use

- **Product Conditioning**

- **Product Fractionation**

- **Propylene 519,000 t/a**

- **LPG 54,000 t/a**

- **Gasoline 143,000 t/a**

- **Process Water 936,000 t/a**
  - for internal use and/or irrigation
Gas To Chemicals (GTC®)
Block Flow Diagram - PP Complex

3.8 Mio Nm³/d
Natural Gas

12.3 Mio Nm³/d
Syngas

1,700,000 t/a
Methanol

520,000 t/a
Propylene

Syngas Plant

Methanol Plant

MTP® Plant

Polypropylene Plant

900,000 t/a Water

140,000 t/a Gasoline

520,000 t/a Polypropylene

1,700,000 t/a Methanol

520,000 t/a Propylene

900,000 t/a Water

140,000 t/a Gasoline

520,000 t/a Polypropylene

DrLb / GTC_Gastechnology_pres / 25.02.05
Gas To Chemicals (GTC®)
Block Flow Diagram - PP Complex

3.8 Mio Nm³/d
Natural Gas

GTP Plant

0.52 Mt/a Propylene

Poly-propylene Plant

0.9 Mt/a Water

0.14 Mt/a Gasoline

0.52 Mt/a Polypropylene
WORLD POLYPROPYLENE PRICE COMPARISON
Current Dollars

Source: CMAI
## GTP® Economics

### ROI - Case B: low propylene / high gasoline

Integrated GTP / PP Complex

<table>
<thead>
<tr>
<th>Description</th>
<th>GTP - PP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment Cost EPC</strong></td>
<td>Mio $/€  730</td>
</tr>
<tr>
<td><strong>Owner’s Cost incl. Capitalised Interest</strong></td>
<td>Mio $/€  146</td>
</tr>
<tr>
<td><strong>Feed Stock Cost</strong></td>
<td>US$</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$0.5/MMBtu</td>
</tr>
<tr>
<td><strong>Production Cost</strong></td>
<td>Mio $/€  150.7</td>
</tr>
<tr>
<td>- Raw Materials</td>
<td>Mio $/€  46.6</td>
</tr>
<tr>
<td>- Utilities</td>
<td>Mio $/€  8.6</td>
</tr>
<tr>
<td>- Operation &amp; Maintenance</td>
<td>Mio $/€  19.9</td>
</tr>
<tr>
<td>- Plant OVHD &amp; Insurance</td>
<td>Mio $/€  21.2</td>
</tr>
<tr>
<td>- Depreciation</td>
<td>Mio $/€  54.4</td>
</tr>
<tr>
<td><strong>Revenues</strong></td>
<td>Mio $/€  317.2</td>
</tr>
<tr>
<td>- Gasoline (130 €$/t)</td>
<td>Mio $/€  31.6</td>
</tr>
<tr>
<td>- Polypropylene (650 €$/t)</td>
<td>Mio $/€  285.6</td>
</tr>
</tbody>
</table>

**Return on Investment**

ROI % 19

**Internal Rate of Return (before Tax)**

IRR\(^2\) % 20.6

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1) ROI estimate based on Chem Systems Methodology  
2) IRR estimate based on COMFAR
MTP® Technology Status

**PROCESS**
- >9000 operating hours of pilot plant
- demo unit has logged >11,000 hours (March 04)
- proof of polymer grade propylene
- process design for commercial plant completed

**CATALYST**
- catalyst development completed by supplier
- catalyst is commercially manufactured

In short:
The technology is on the market ...
... at fully commercial terms
MTP projects – gas-based

<table>
<thead>
<tr>
<th>Plant location</th>
<th>production PP, kt/a</th>
<th>Status</th>
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<td>LOI, financing</td>
<td>2009</td>
</tr>
</tbody>
</table>
Gas To Chemicals (GTC®)
Gas-based Refinery via Methanol: Lurgis MtSynfuels®

Methanol 15,000 t/d

Olefin Production

Olefin Oligomerisation

Product separation + MD Hydrogenation

H₂, 55 t/d, from Methanol synthesis

Hydrocarbon Recycle

Kero/Diesel 5,438 t/d

Gasoline 685 t/d

LPG 579 t/d

Water recycle

Process water, 7,902 t/d, can replace raw water

Product separation + MD Hydrogenation

Hydrocarbon Recycle

Hydrocarbon Recycle

Water recycle
Gas To Chemicals (GTC®)
Synfuels, Mossel Bay, RSA
Lurgi’s FT Experience

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

- All original reactors still in operation today;
  extension of capacity in 1987 (+ 1 reactor)

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.
### 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 : Kero+Diesel (max.)</td>
<td></td>
<td>1 : 2.3 – 1 : 6</td>
</tr>
<tr>
<td>Gasoline : Kero+Diesel</td>
<td>1 : 8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Properties</th>
<th>Lurgi Route</th>
<th>FT Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gasoline</strong></td>
<td>Spec (Europe from 2005)</td>
<td></td>
</tr>
<tr>
<td>-Aromatics</td>
<td>vol.% max.</td>
<td>35</td>
</tr>
<tr>
<td>-Benzene</td>
<td>vol.% max.</td>
<td>1</td>
</tr>
<tr>
<td>-Sulphur</td>
<td>wppm max.</td>
<td>50/10 1)</td>
</tr>
<tr>
<td>-Olefins</td>
<td>vol.% max.</td>
<td>18</td>
</tr>
<tr>
<td>-RON 2)</td>
<td></td>
<td>91/95/98</td>
</tr>
<tr>
<td>-MON 2)</td>
<td></td>
<td>82.5/85/88</td>
</tr>
<tr>
<td><strong>Diesel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Polyaromatics</td>
<td>vol.% max.</td>
<td>11</td>
</tr>
<tr>
<td>-Sulphur</td>
<td>wppm max.</td>
<td>50/10 1)</td>
</tr>
<tr>
<td>-Cetane No.</td>
<td>min.</td>
<td>51</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 of FT-naphtha
## Comparative Economics\(^1\) - Cost of Production Estimate

<table>
<thead>
<tr>
<th>GTL Technology</th>
<th>MtSynfuels(^\circ)</th>
<th>existing FT(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Capital Investment</td>
<td>1,181 MM $(€)</td>
<td>1,671 MM $</td>
</tr>
<tr>
<td>Total Plant Capital</td>
<td>19,680 $(€)/bpd</td>
<td>27,856 $/bpd</td>
</tr>
<tr>
<td>NG to Process (LHV)</td>
<td>3.82 $(€)/bbl</td>
<td>4.22 $/bbl</td>
</tr>
<tr>
<td></td>
<td>7.64 MMBtu/bbl</td>
<td>8.44</td>
</tr>
<tr>
<td>Cat. &amp; Chemicals</td>
<td>2.19 $(€)/bbl</td>
<td>MMBtu/bbl</td>
</tr>
<tr>
<td>Utilities</td>
<td>0.28 $(€)/bbl</td>
<td>1.53 $/bbl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.8 $/bbl</td>
</tr>
<tr>
<td>Cost of Production + ROI</td>
<td>22.47 $(€)/bbl</td>
<td>28.68 $/bbl</td>
</tr>
</tbody>
</table>

- **Market Prices**\(^2\)
  - **Gasoline**\([$/bbl]\) W.Europe: 56.9, US Nymex: 51.5
  - **Diesel**\([$/bbl]\) W.Europe: 48.3, US Nymex: 53.6

\(^1\) ChemSystems 2001

\(^2\) Corresponding Crude Oil Price: about 42 $/bbl
Gas To Chemicals (GTC®)
Gas-based Petrochemistry

Feedstock
- OIL
  - conventional route
- Natural Gas
  - Associated Gas
    - “Stranded Gas”
      - emerging route
- COAL/Biomass
  - future route?

Intermediates
- Cracker
  - Syngas
    - Methanol
- MTO
  - Lurgi’s MegaSyn
- Lurgi’s MTP®
- Lurgi’s MTC

Aromatics
- Benzene
- Toluene
- Xylenes

Olefins
- Ethylene
- Propylene

“Oxigenates“
- Alcohols
- Ethers
- Esters
- Acids
- Aldehydes

Petrochemical Products
- Polyolefins
  - PE, PP
- Acrylates
- Polycondensates
  - PC, PET, PBT
- Solvents
- Fuels
- Fuel additives
Gas To Chemicals (GTC®)
Valuable Products (Petrochemicals) from Natural Gas

Natural Gas “Methane” → Syngas CO + H₂ → MeOH-Plant → Methanol → MTP-Plant → Propylene → PP-Plant → Polypropylene

- Oxoalcohol-Plant
- 2-EHOH Acryl. Plant
- 2-EHAC: 2-Ethylhexylacrylate
- Acrylic Acid Plant
- Acrylic Acid
- Bu-Acryl. Plant
- BuAc: Butylacrylate
Lurgi’s MegaSyn® and MegaMethanol® open new routes of gas monetisation:

- Dimethyl ether (DME) can be produced at attractive costs to become an economical fuel

- Propylene is a high-demand, high value product. It can be produced cheaper than by conventional processes

- The economics of MtSynfuels® are comparable to FT routes

- A “gas-based petrochemistry” is developed by Lurgi
Thank You!

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