Update on Technology and Projects
Presented by Dirk Volkmann

• **Historical background**
• **Feedstocks and Applications**
• **New Projects**
• **New Development / R&D**
• **New Alliances**
Gasification Technology Experience

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed-bed gasification</th>
<th>Entrained-flow gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>24 gasifiers constructed in the Gas Combine „Schwarze Pumpe“</td>
<td>DBI</td>
</tr>
<tr>
<td>1978</td>
<td>Lignite</td>
<td>DBI</td>
</tr>
<tr>
<td>1979</td>
<td>Saliferous lignite</td>
<td>DBI</td>
</tr>
<tr>
<td>1980</td>
<td>42 lignite varieties</td>
<td>Lignite</td>
</tr>
<tr>
<td>1981</td>
<td>15 hard coal varieties</td>
<td>Saliferous lignite</td>
</tr>
<tr>
<td>1982</td>
<td>(international) Pulverized hard coal and lignite</td>
<td>Natural gas</td>
</tr>
<tr>
<td>1983</td>
<td>Petrol coke, fly ash</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td></td>
<td></td>
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<tr>
<td>1985</td>
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<td>1986</td>
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<td>1987</td>
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<td>1988</td>
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<td></td>
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<tr>
<td>1989</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>15 municipal and industrial sewage sludges, MSW, waste oil, wood, straw</td>
<td>Waste oil, tar oil</td>
</tr>
<tr>
<td>1991</td>
<td>Slurry, fly ash</td>
<td>Slurry</td>
</tr>
<tr>
<td>1992</td>
<td>Industrial waste and residues</td>
<td>Tar oil / solids sludges</td>
</tr>
<tr>
<td>1993</td>
<td>Chlorinated organic feeds</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>Nitrogen waste organics</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>Black liquor</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td></td>
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<td>1997</td>
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<td>2001</td>
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<tr>
<td>2002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>Babcock</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>FUTURE ENERGY</td>
<td></td>
</tr>
</tbody>
</table>
## Gasification Facilities of FUTURE ENERGY GmbH in Freiberg

<table>
<thead>
<tr>
<th>Facility</th>
<th>Capacity</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage sludge drier</td>
<td>500 kg/h</td>
<td></td>
</tr>
<tr>
<td>Pyrolysis unit</td>
<td>500 kg/h</td>
<td></td>
</tr>
<tr>
<td>Inert gas plant</td>
<td>1000 Nm³/h</td>
<td>80 bar</td>
</tr>
<tr>
<td>Oxygen plant</td>
<td>max. 300 Nm³/h</td>
<td>80 bar</td>
</tr>
<tr>
<td>Pulverized fuel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry feeding</td>
<td>300 kg/h</td>
<td></td>
</tr>
<tr>
<td>Gasifier</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactor with cooling screen</td>
<td>3-5 MW, max. 30 bar</td>
<td></td>
</tr>
<tr>
<td>COS hydrolysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCN hydrolysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SulFerox desulfurization unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste water treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasifier VV100</td>
<td>2-3 MW</td>
<td></td>
</tr>
<tr>
<td>Reactor with cooling wall</td>
<td>max. 30 bar</td>
<td></td>
</tr>
</tbody>
</table>
### Proprietary Gasification Technologies

<table>
<thead>
<tr>
<th>Recoverable fuel</th>
<th>Chemical wastes</th>
<th>Conventional fuels</th>
<th>Residual and waste materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Liquor</td>
<td>Residual oils + tail gases</td>
<td>Oil</td>
<td>Tar</td>
</tr>
<tr>
<td>high-salt</td>
<td>Synthesis residues</td>
<td>Natural gas</td>
<td>Heavy oil</td>
</tr>
<tr>
<td></td>
<td>- Chlor. org. materials</td>
<td>Biogas</td>
<td>Oil sludge</td>
</tr>
<tr>
<td></td>
<td>- Nénogen organic waste</td>
<td>Biogas</td>
<td>Sewage sludge</td>
</tr>
<tr>
<td></td>
<td>low-ash</td>
<td>ash-free</td>
<td>ash-containing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ash-containing</td>
<td>ash-containing</td>
</tr>
</tbody>
</table>

#### Reactor with cooling screen and quench
- **FE Entrained-Flow Gasification**
- **Oxygen Fuel**
- **Cooling screen**
- **Pressur. water inlet**
- **Pressur. water outlet**
- **Quench water**
- **Cooling jacket**

#### Reactor with cooling wall
- **FE Entrained-Flow Gasification**
- **Oxygen Fuel**
- **Cooling screen**
- **Smelt outlet**
- **Gas outlet**
- **Cooling water**

#### Reactor with cooling screen
- **FE Entrained-Flow Gasification**
- **Oxygen Fuel**
- **Cooling screen**
- **Gas outlet**
- **Refractory liner**
- **Coat**
- **Partial quench system**
- **Cooling water**

#### Pyrolysis plus gasification
- **Noell Conversion Process**
- **Pyrolysis**
- **Entrained-flow gasification**

#### Raw syngas
- **Syngas**
  - Methanol
  - Hydrogen
  - Fertilizers
  - Oxoalcohols
- **Gas to energetic use**
  - Power
  - Heat
  - Fuel gas

#### Recovered resources
- **Hydrochlorid acid**
- **Clean salts**
- **Granulated slag**
- **Green liquor**
• Historical background
• Feedstocks and Applications
• New Projects
• New Development / R&D
• New Alliances
Potential feeds:
- (Natural gas)
- Refinery gas
- Residual oil
- Petroleum coke
- Sewage sludge
- Waste oil
- Biomass (wood)
- Black liquor
- Municipal waste
- Chemical residues
- Coal

Gasifier island with ASU and gas cleaning

Combined cycle

Chemical production

Fischer-Tropsch synthesis

Slag to building industries or metals recovery

Potential products:
- Reduction gas (iron ore, steel)
- Oxygen
- Nitrogen
- Argon
- Carbon dioxide
- Sulfur/sulfuric acid
- Steam

Electrical energy

- Hydrogen
- Carbon monoxide
- Fertilizers
- Chemicals
- Methanol
- Acetic acid
- Motor fuels
- Chemicals
Market Strategy

• Europe
  – Gasification of chemical residues
  – Biomass to Liquids (BTL)

• The Americas
  – Coal to power and chemicals
  – Gasification of chemical residues and waste

• Asia
  – Coal to power and chemicals
  – Biomass to Liquids (BTL)

• Australia / NZ
  – Coal to power and chemicals
• Historical background
• Feedstocks and Applications

• **New Projects**
• New Development / R&D
• New Alliances
Autothermal Oil Conversion Plant
Sokolovská Uhelná, a.s., Vřesová (1)

- Feed stock: 15 to/h generator tars and
  3 to/h secondary fuel
- Reactor conditions: 28 bar at 1.400 °C
- Reaction-Volume: 15 m³
- Gas utilization: 440 MW Combined Cycle
  Power Plant
- Syngas production: 50.000 Nm³/hdry = 140 MWth
- Reactor: Ø 3.4 m, h with quench 11.8 m,
  refractory lined
- Effluents: waste water 4-8 m³, soot 100 – 240 kg/h,
  vents ~ 500 Nm³ /h
Autothermal Oil Conversion Plant
Sokolovská Uhelná, a.s., Vřesová (2)

- **Input:**
  - O₂ 17,500 Nm³/h dry, steam 7.2 t/h,
  - N₂ 400 Nm³/h dry

- **FE BE scope:**
  - product feeding / media supply systems / gas cleaning / gasifier system incl. cooling,
  - monitoring purging / special burner design / soot water treatment plant / slag discharge

- **Supplies:**
  - Gasifier/Quench, refractories, burners

- **Project status:**
  - under construction
  - (start-up 2005)
Vresóva Plant

24 fixed-bed gasifiers 28 bar

Condensation

Rectisol plant

GuD combined-cycle plant

Steam

Entrained-flow gasification 28 bar

Oxygen

Hard brown coal

Oxygen

Steam

Tar

Waste water

Electricity 440 MW

Raw gas
Fischer-Tropsch Demonstration Plant
FUTURE ENERGY site Freiberg, Germany (1)

• Location: FE test facility in Freiberg
• Input: Tar/coke slurry 500 kg/h
          Oxygen 450 Nm³/h
• Output: Synthesis gas (H₂/CO = 2:1) 1010 Nm³/h
          Diesel 125 kg/h
• Reaction conditions: pressure 25 bar
          temperature 1,400 °C
          volume 276 l
Fischer-Tropsch Demonstration Plant
FUTURE ENERGY site Freiberg, Germany (2)

• Equipment added to existing plant: slurry feeding & preparation, CO-shift-conversion, WWT, gas synthesis (F-T) product upgrading, hydro-cracking, fractioning

• Project Status: selection of F-T technology
  start of BE in 2004
  (start-up 2006)
• Historical background
• Feedstocks and Applications
• New Projects
• **New Development / R&D**
• New Alliances
Generation of Hydrogen from Biomass

(Straw*; hay*; wood; paper/cardboard; waste plastics)

delivery, storage

Educt preparation
chopping, pre-drying

Chaff

Fast pyrolysis
1 bar, ~500 °C, t few s

Heat transfer
medium loop

Oil/char slurry

Rail transport of slurry
from 20 to 40 pyrolysis plants
to a large-size centralized
syngas generation + utilization plant

Entrained-flow gasification
~1300 °C, >60 bar, t 2-3 s

Tarfree raw syngas

Gas cleaning
Gas conditioning

Residual gas

Technical hydrogen

Electrical energy

* critical biofuels having high ash, K and Cl contents
PROPERTIES OF SLURRIES
FROM BIOMASS PYROLYSIS OIL AND CHAR

- critical particle volume fraction $\phi_{\text{crit}}$
depends on shape (aspect ratio) and size spectrum:
  $\sim 0.6$ spherical, $\sim 0.45$ regular crystals

- viscosity $\eta$ (slurry) = $\eta$ (liquid) $(1 + \frac{5}{2}\phi + 6.2\phi^2)$;
  / one order reduction from 20 to 80 °C

- density: oil $\sim 1200$ kg/m³, char (true) $\sim 1500$ kg/m³
  slurry $\sim 1300$ kg/m³, char (bulk) $\sim 200 - 400$ kg/m³
30 % char/raw tar slurry
New Development / R&D

- New reactor size (upscaling)
- New reactor design at 85 bar (dry and slurry feed)
- New recovery boiler development
- New concepts for the gasification of MSW/RDF
- New approach for black liquor gasification
Comparison of size of FE-Entrained Flow Gasifiers (25 bara)

130 MW
50,000 m /h$_N^3$

400 MW
160,000 m /h$_N^3$

800 MW
320,000 m /h$_N^3$
• Historical background
• Feedstocks and Applications
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New Alliances

• Forschungszentrum Karlsruhe
  – Development of a reliable, large scale process chain for the production of BTL (flash pyrolysis, gasification, F-T)

• Close cooperation (exclusively ?) with a technology based Engineering Company
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