Coal Gasification Renewed –
technology options to exploit Europe‘s coal reserves

Brussels, November 13, 2013
ThyssenKrupp

Why coal gasification (gasification of solids)?

TK Uhde’s experience and expertise in gasification

Summary and Outlook
Leading engineering expertise supports global sustainable progress

Drivers
- Demography
  - More consumer and capital goods
- Urbanization
  - More infrastructure and buildings
- Globalization
  - More resource and energy use

Business opportunities
- Leading engineering expertise
  in
  Material Mechanical Plant

Demand (“more”)
- Reduced CO₂ emissions, renewable energies
- Efficient resource and energy use, alternative energies

Restrictions
- Climate change
- Finite resources
- Political framework

Drivers
- Demography
  - More consumer and capital goods
- Urbanization
  - More infrastructure and buildings
- Globalization
  - More resource and energy use

Business opportunities
- Leading engineering expertise
  in
  Material Mechanical Plant

Demand (“better”)
- Reduced CO₂ emissions, renewable energies
- Efficient resource and energy use, alternative energies

Restrictions
- Climate change
- Finite resources
- Political framework

Leading engineering expertise supports global sustainable progress

Coal Gasification Renewed
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Diversified industrial group: Our business areas

Key indicators – fiscal 2011/2012*

<table>
<thead>
<tr>
<th>Business Area</th>
<th>Sales (€ million)</th>
<th>EBIT*** (€ million)</th>
<th>Employees</th>
</tr>
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<tbody>
<tr>
<td>Components Technology</td>
<td>7,011</td>
<td>453</td>
<td>28,011</td>
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<tr>
<td>Elevator Technology</td>
<td>5,705</td>
<td>587</td>
<td>47,561</td>
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<td>Industrial Solutions**</td>
<td>5,257</td>
<td>689</td>
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<td>Materials Services</td>
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<td>311</td>
<td>27,595</td>
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<td>Steel Europe</td>
<td>10,992</td>
<td>247</td>
<td>27,761</td>
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* Continuing operations (excluding Inoxum and Steel Americas)
** Created effective January 01, 2013 through the combination of the Plant Technology and Marine Systems business areas; Figures on a pro forma basis
*** Adjusted
More than **2,000** plants built by **TK Uhde** on all continents

<table>
<thead>
<tr>
<th>Category</th>
<th>Plants</th>
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<tbody>
<tr>
<td>Fertilisers</td>
<td>130</td>
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<tr>
<td>Nitric acid</td>
<td>185</td>
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<tr>
<td>Refineries</td>
<td>380</td>
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<tr>
<td>Aromatics</td>
<td>75</td>
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<tr>
<td>Hydrogen, ammonia, methanol</td>
<td>120</td>
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<tr>
<td>Org. Chemicals/petrochemicals</td>
<td>375</td>
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<tr>
<td>Plastics, synthetic fibres</td>
<td>115</td>
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<tr>
<td>Polyester / polyamides</td>
<td>400</td>
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<tr>
<td>Electrolysis</td>
<td>150</td>
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<td>Coke Plant Technologies</td>
<td>500</td>
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<tr>
<td>Tank storage facilities</td>
<td>105</td>
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<tr>
<td>Industrial plants</td>
<td>150</td>
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</table>
Presentation Outline

- ThyssenKrupp
- Why coal gasification (gasification of solids)?
- TK Uhde’s experience and expertise in gasification
- Summary and Outlook
Why Coal Gasification (gasification of solids)?

TK Uhde’s Solid-Gasification Reference Plants & Projects
Why Coal Gasification (gasification of solids)?
From Feedstock to Products

- **Feedstock**
  - Gas, Naphtha
  - Oil/Residues
  - Petroleum Coke
  - Hard Coal
  - Biomass
  - Brown Coal
  - Waste

- **Gasification**
  - Steam Reformer/ATR
  - Oil Gasification
  - PRENFLO * Gasification
  - HTW * Gasification

- **Syngas**
  - CO + H2

- **Further processing**
  - Methanol
  - Ammonia
  - FischerTropsch Synthesis
  - CO-Conversion
  - Methanation
  - Power Plant (IGCC)

- **Product**
  - Diesel
  - Petrol + LPG
  - Fertilizer
  - Diesel, Naphtha
  - Lubricants
  - Hydrogen
  - Synthetic Natural Gas
  - Electricity

*) TK Uhde proprietary gasification technology
## Why Coal Gasification (gasification of solids) ?

### Market Drivers

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Technology</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>fossil fuel prices</td>
<td>proven technology</td>
<td>polygeneration</td>
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<tr>
<td>fossil fuel availability</td>
<td>clean technology</td>
<td>CCS</td>
</tr>
<tr>
<td>fossil fuel flexibility</td>
<td>ideal for low rank fuel</td>
<td>sellable by-products</td>
</tr>
</tbody>
</table>
Why Coal Gasification (gasification of solids)?

Proven Gasification Processes

- **Fixed Bed**
  - Temperature: 550 °C
  - Feedstock: 3 - 30 mm
  - Oxidising Agents
  - Ash / Slag

- **Fluidised Bed**
  - Temperature: 800 – 1100 °C
  - Feedstock: 1-5 mm
  - Oxidising Agents
  - Ash

- **Entrained Flow**
  - Temperature: 1350 – 1600 °C
  - Feedstock: 0.1 mm
  - Oxidising Agents
  - Slag
Presentation Outline

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Various Materials require various Gasification Technologies

TK Uhde’s Gasification Portfolio

- HTW™ Fluidised-Bed Gasification
- PRENFLO® Entrained-Flow Gasification

Wastes, Wood, Peat, Brown Coal, Lignite, Hard Coal, Pet coke, Residues
Various Materials require various Gasification Technologies

TK Uhde’s Gasifiers

<table>
<thead>
<tr>
<th>PSG</th>
<th>PDQ</th>
<th>HTW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Entrained-flow gasification</strong></td>
<td><strong>Fluidized bed gasification</strong></td>
<td></td>
</tr>
</tbody>
</table>

Coal Gasification Renewed
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From Koppers-Totzek to PRENFLO

- **Koppers-Totzek**
  - Start of development 1941

- **PRENFLO burner test rig**
  - 6 t/d (450 m³/n syngas)
  - Start Up: 1984

- **PRENFLO Fürstenhausen**
  - 48 t/d (3,500 m³/n syngas)
  - Start Up: 1985
  - Scale Up Factor: 8

- **PRENFLO Puertollano**
  - 2,400 t/d (180,000 m³/n syngas)
  - Start Up: 1998
  - Scale Up Factor: 50

Developments over 57 years:
- Koppers-Totzek to PRENFLO
Koppers-Totzek gasification plant in Modderfontein, S. Africa
(Design capacity: 1,000 t/d of ammonia)
Koppers-Totzek gasification plant in India
(Capacity: 900 t/d of ammonia)
Dry-fed, single train IGCC with CCS Pilot Plant at Elcogas, Spain
300 MW net based on petcoke / coal feedstock
Developments
The HTW Process

HTW Laboratory Plant
RWTH-Aachen
12 t/d Coal, Atm.
Start Up: 1974

Atmospheric Winkler generators
1956 – 1964 260 t/d Lignite

HTW-Pilot Plant
Rheinbraun Wachtberg
40 t/d Lignite, 10 bar
Start Up: 1988

HTW-Pilot Plant (WVW)
Rheinbraun Wesseling
185 t/d Lignite, 25 bar
Start Up: 1989

KoBra IGCC
RWE, Hürth
3700 t/d Lignite 27 bar
Engineering: 1994

HTW-Demonstration Plant
Rheinbraun Berrenrath
720 t/d Lignite, 10 bar
Start Up: 1986

Scale Up Factor:
5

Scale Up Factor:
18

>20 Years
HTW Pilot Plant
RWE-Plant-Wachtberg
Frechen / Germany
1,6 t/h
1978 - 1985
HTW Plant
WVV- UK-Wesseling
Wesseling / Germany
7,7 t/h Lignite
10 – 25 bar
1988 - 1990
HTW Syngas Plant
Kemira Oy
Oulu / Finnland
30 t/h Peat
≈ 300 t/d NH3
1988 - 1991
HTW Commercial Scale Demo Plant
Berrenrath/Germany

25 t/h dried lignite – 140 MWth
34,000 m³/h of syngas
≈ 300 t/d Methanol
67,000 total operating hours
84 % availability (last 10 years)
1986 - 1997
HTW-Precon-Gasification
Niihama / Japan
48 t/d Municipal Waste
1999 - 2002

Sumitomo Heavy Industries Ltd.
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Coal-to-Gasoline (CTG) plant

* Photo Courtesy TransgasDevelopment

#1 coal preparation
#2 coal gasification
#3 CO-shift reactor
#4 acid gas removal
#5 methanol synthesis
#6 methanol-to-gasoline
#7 gasoline storage

PREFLO PDQ gasifiers
ICM’s 18,000 bbl/d CTL Plant in Mongolia
Minister Battulga at ThyssenKrupp’s Reference Plant

Elcogas, Puertollano, Spain, April 08, 2013
JAM Project in China – Commissioning in 2009

Converting Coal into Gasoline
BioTfueL – integrated process chain
PRENFLO with FT based on solid and liquid feedstock

**Feedstock**
- Wood
- Straw etc.
- Coal
- Pet coke
- Liquid Residues

**Pretreatment**
- Torrefaction
- Milling

**Gasification**

**Gas Treatment**
- CO-Shift
- AGR

**Synthesis**
- Gasel™ Fischer-Tropsch Synthesis and Product Upgrading
  - Biodiesel; Bio-kerosene

**Target**
Development and commercialisation of integrated process chain for production of 2nd generation biofuels
Biomass-to-Methanol Plant, Hagfors / Värmland / Sweden

Artist View

Photo courtesy VärmlandsMetanol AB

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Presentation Outline

- ThyssenKrupp
- Why coal gasification (gasification of solids)?
- TK Uhde’s experience and expertise in gasification
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Gasification is a proven process, a vast number of gasifiers are operating since decades successfully on commercial basis.

Gasification allows flexibility in feedstock (coal, petcoke, biomass, waste, meaningful combinations).

Gasification allows conversion of carbonaceous feedstocks into high valuable products (chemicals, hydrogen, SNG, synthetic fuels, polygeneration).

Gasification produces sellable by-products (sulfur, fly-ash, slag).

Gasification allows CO$_2$ capture based on existing technologies.

Gasification decreases dependency from oil and/or gas imports.
Opportunities for gasification of solids in Europe:

- **Northern Europe:** Biomass (e.g. forest residues, peat)
- **Southern Europe / Mediterranean Area:** Biomass (agricultural waste), Coal (high ash/low rank coal)
- **Central/Eastern Europe:** Lignite / low rank coal
- **Europe in general:** Imported coal and/or waste

TK Uhde acts as technology provider. Demand and regulatory environment are driver of its utilisation.
Thank you for your attention