BioTfueL
Biomass+X to Liquid Synfuels Plant
and Alternative Syngas Applications at thyssenkrupp

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thyssenkrupp Industrial Solutions

engineering.tomorrow.together.
## thyssenkrupp – Brief Overview

Key indicators – fiscal 2014/2015

<table>
<thead>
<tr>
<th>Components Technology</th>
<th>Elevator Technology</th>
<th>Industrial Solutions</th>
<th>Materials Services</th>
<th>Steel Americas</th>
<th>Steel Europe</th>
</tr>
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<tbody>
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</table>

<table>
<thead>
<tr>
<th>Sales [million €]</th>
<th>EBIT [million €]</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,753</td>
<td>313</td>
<td>29,627</td>
</tr>
<tr>
<td>7,208</td>
<td>794</td>
<td>51,335</td>
</tr>
<tr>
<td>6,256</td>
<td>424</td>
<td>19,388</td>
</tr>
<tr>
<td>14,254</td>
<td>206</td>
<td>20,226</td>
</tr>
<tr>
<td>1,773</td>
<td>(138)</td>
<td>3,725</td>
</tr>
<tr>
<td>8,697</td>
<td>492</td>
<td>27,601</td>
</tr>
</tbody>
</table>

## thyssenkrupp AG

Sales: 42,778 [million €]  |  EBIT adj.: 1,676 [million €]  |  Employees: 154,906

over 100 gasifiers designed, built and put into successful operation
thyssenkrupp Industrial Solutions: Proprietary Syngas Technologies

PRENFLO®
Entrained-Flow Gasification

HTW
Fluidized Bed Gasification

SMR
Steam Methane Reforming

ATR
Autothermal Reforming
PRENFLO is a slagging gasifier that operates above the ash melting point → high carbon conversion, high efficiency

➢ for coal and petcoke
➢ for biomass, if pre-treated

Largest Reference: Elcogas IGCC, Puertollano/Spain

40 years of experience
Fluidized-Bed Gasification: HTW Gasification

- HTW especially suited for biomass, wastes and low-rank, high-ash coals with high ash melting points
- HTW has strong reference basis through full commercialisation over 3 decades
- New HTW Pilot Plant at University Darmstadt commissioned in 2015
- Current main focus on China, India
The BioTfueL Project - a multinational cooperation of topic leaders

**R&D**
- From R&D to market
- From field to wheel

**Technology Providers**
- Axens
- thyssenkrupp
- IFP Group Technologies
- CEA

**Fuel Producers**
- Avril
- TOTAL

**BioTfueL Plant**

10 years partnership to realize a complete B-XTL process chain
(total invest: US$ 200 million)
3 Process Steps for the Production of 2nd Generation Synthetic Biofuels

1. Pretreatment
   - Wood
   - Straw, etc.
   - Coal
   - Petcoke

2. Gasification and Syngas Treatment
   - Torrefaction
   - Milling
   - PRENFLO PDQ

3. Synthesis
   - CO-Shift
   - AGR Purification
   - Gasel Fischer-Tropsch Synthesis
   - Hydrocracking
   - Hydroisomerization

BioTfueL: „multifeedability“

Bio-Jetfuel
Bio-Diesel
BioTfueL: Step 1

Biomass Pretreatment
BioTfueL: Which kiln type would be most suitable?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Multiple Hearth Furnace (MHF)</th>
<th>Rotary Dryer / Rotary Kiln</th>
<th>Fluidized Bed Reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled drying</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ +</td>
</tr>
<tr>
<td>Combined drying and roasting in one unit</td>
<td>+ + +</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controlled roasting</td>
<td>+ + +</td>
<td>+ (direct)</td>
<td>+</td>
</tr>
<tr>
<td>Homogenous temperature distribution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control of temperature profile range</td>
<td>+ + +</td>
<td>+ (indirect)</td>
<td>+</td>
</tr>
<tr>
<td>(250 - 300°C)</td>
<td></td>
<td>(direct)</td>
<td></td>
</tr>
<tr>
<td>Mixing</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Suitable for high moisture</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Suitable for wide range of biomass qualities (size, heat value, composition)</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Variation of retention time</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Possibilities for upgrading</td>
<td>+ +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Availability and reliability</td>
<td>+ + +</td>
<td>+ +</td>
<td>+ + +</td>
</tr>
<tr>
<td>Easy maintenance</td>
<td>+ + +</td>
<td>+ + (indirect)</td>
<td>+ + +</td>
</tr>
<tr>
<td>Product quality</td>
<td>+ + +</td>
<td>+ (direct)</td>
<td>+ + +</td>
</tr>
</tbody>
</table>

MHF = Best Solution for controlled torrefaction!
Biomass Torrefaction – what does it mean?

Temperature

Materials
- second generation biomass – wide range of properties
- soft and hard wood
- straw, miscanthus, switch grass
- biomass waste: corn and rice husk etc.,
- non-food crops

Torrefaction Conditions and Requirements
- Temperature: key to optimum torrefaction, homogenous temperature distribution
- Reaction: endothermal
- Pressure: atmospheric
Torrefaction: POLTORM Technology Characteristics

Process
- Easy operation and high energy recovery
- Smooth thermal treatment with definite control of temperature profile
- Optimized heat exchange under smooth and safe conditions in inert atmospheres

Material
- Optimum product quality for a wide range of feed properties (moisture, grain size, composition)
- High product quality regarding grindability and energy densification
- Maximum mass loss, minimum energy loss

Experience
- Highest availability and service life
- Low wear & spare part requirements, low maintenance costs
- Long term experience with industrial MHF-furnaces
Biomass Torrefaction – but how?

Diagram showing the process of biomass torrefaction with labeled parts such as Material Feed, Center Shaft, Rabble Arms, Material path, Off-Gas stack, Heat exchanger, Rabble Teeth, Hearth, Product Outlet, Filter, Air Preheater, Offgas Fan, Bag Filter, Heat Exchanger, Drying, Torrefaction, Gas Loop, Drying Gas Loop, Torrefaction Gas Loop, Nat. Gas, Prim. Air, Post-Combustion Chamber, Feed, Offgas, Product, Surplus Gas.
POLTORR technology: Material Transport and Hot Gas Injection

- Hot gas injection at 4 ports and 2 stages in each zone

- Concurrent in Dryer
- Counter-current in Torrefier
Product Characteristics of Torrefied Wood Chips

<table>
<thead>
<tr>
<th>wood</th>
<th>calorific value [MJ/kg]</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>C</td>
<td>m-% dry</td>
</tr>
<tr>
<td>H</td>
<td>m-% dry</td>
</tr>
<tr>
<td>O</td>
<td>m-% dry</td>
</tr>
<tr>
<td>N</td>
<td>m-% dry</td>
</tr>
<tr>
<td>Cl</td>
<td>m-% dry</td>
</tr>
<tr>
<td>S</td>
<td>m-% dry</td>
</tr>
</tbody>
</table>

Atomic H:C Ratio

Atomic O:C Ratio
Hardgrove Index
> 50
\(\rightarrow\) typical for hardcoal
easy grinding
BioTfueL: Torrefaction plant, Venette Site

TORREFACTION SECTION

RAW BIOMASS STORAGE and PELLETISATION SECTION

TORREFIED BIOMASS STORAGE
BioTfueL: Torrefaction plant at Venette Site (Status 06/2016)
BioTfueL: Step 2

Gasification (PRENFLO PDQ)

BioTfueL Dunkirk

2 demo plants located in France for torrefaction and gasification/FT:
- to generate scale-up data
- to validate various schemes/configurations
BioTfueL: PRENFLO PDQ Gasification

**Features**

- dry powder feed (coal/biomass)
- 4 horizontal co-annular burners
- membrane wall
- direct water quench
- operation pressure flexible to requirements (25 - 42 bar)
- raw gas temperature outlet of quench (200 - 250 °C)
- compact gasification system with low plant investment
BioTfueL - Overall Dunkirk Site View (Gasification, AGR, FT)

- Stack
- Acid gas treatment
- Fine purification
- Gasification tower
- Utility storage
- Storage coal/biomass
- Syngas combustion
- Grinding and storage pulverized material
BioTfueL Plant Dunkirk – Installation of PRENFLO PDQ Gasifier, Feed Bin and Incinerator

> Package U200 & I&RU (TK-IS)
BioTfueL: PRENFLO PDQ Gasification

Dunkerk Site
Gasification Plant
BioTfueL: Step 3

FT Synthesis & upgrading

Gasel™ Technology Suite
- Axens catalyst, process design, process integration and licensing
- Validated with representative feedstock from FT pilot plan

Syngas \( \text{H}_2/\text{CO} \approx 2 \)

Fischer-Tropsch

Hydrocracking

high cetane diesel + jet fuel
BioTfueL: FT Synthesis & upgrading

Fischer-Tropsch Demo Plant
Eni’s Sannazzaro Refinery, Italy

• Start-up in 2001

Main areas tested and validated
• Catalyst Performance
  (activity, selectivity)

• Liquid/Solid separation
  (4 systems tested)

• Slurry handling
  (mixed waxes + solid catalyst)

• Operating experience:
  20,000 hours-on-stream
  since 2001
BioTfueL: FT Synthesis & upgrading

- Development and scale-up by Eni & IFP Energies nouvelles since 1996
- Process design, integration and licensing by Axens
- LT-FT in Slurry Bubble Column
- Axens Hydrocracking technology for Upgrading
- Tailored Cobalt FT and Upgrading catalysts
BioTfueL: Summary

- The BioTfueL objectives are to develop, demonstrate and commercialize a full B-XTL chain.
- One key objective is a multi-feedstock ability in one single PDQ gasification reactor.
- The BioTfueL project combines the expertise of 6 companies.
- The BioTfueL project allows to give full performance guarantees for the complete chain from biomass to jet fuel and diesel.
- Gasification and Fischer-Tropsch are proven technologies and allow maximum feedstock flexibility.
- First industrial B-XTL plants will have a capacity of 5,000 bbl/day in one single train.
Thank You for Your Attention!