The bioCRACK Process

– a refinery integrated biomass-to-liquid concept to produce diesel from biogenic feedstock

Edgar AHN, CSO
BDI - BioEnergy International AG
Outline

- BDI at a glance
- Motivation
- bioCRACK Concept
- Pilot Plant
- Experimental Results
- Outlook / Summary
BDI at a glance

- Austrian based, highly professional plant engineering and construction company
- Tailor-made turn-key solutions
- Own biodiesel & biogas technologies “from waste to value“
- More than 40 reference plants on 4 continents, since 1991
- Strong in-house r & d (5 – 10% of annual revenue)
Global Player

bioCRACK Pilot Plant
OMV Refinery/Vienna
bioCRACK - Motivation

IEA projected global biofuels demand

Huge projected global demand on biofuels especially on advanced (Bio)Diesel

**EU RED:**
10% renewable energy in transport (2020), Lignocellulosic-biofuels preferred (double counting)

**US Renewable Fuel Standard (RFS2):**
36 billion gallons renewable fuels, of which 21 bgal advanced biofuels (2022)

Source: IEA Technology Roadmap - Biofuels for Transport 2011  1 exajoule ~ 23-24 Mio t Oil
bioCRACK - Motivation

Europe oil product balances

Deficit of Diesel fuel in Europe up to 60 Mio t p.a. projected

Source (by OMV): Refining Capacity Study, EUROPIA Strategy Council
bioCRACK - Motivation

- Continuous development of **Benchmark-Technologies for Biofuel production**

- Technically simple process for the production of **Next Generation Biofuel**

- Conversion of **biogenic waste & residues** from „non-food“ areas into high-quality Biofuel
bioCRACK - Project Goals

- Compliance of current quality standards in final fuel product
- Useable side-products, no waste streams
- Integrable in conventional process of mineral oil refining
- Liquid phase pyrolysis (liquefaction of solid biomass)
- Co-processing of intermediate product in refinery (heavy ends) and solid Biomass
bioCRACK History

- **2007**: Start basic research of liquid phase pyrolysis
- **2008/9**: Start-up of test plant (6kg/h); Test trials
- **2010/11/12**: Start Coop. with OMV, Engineering pilot plant Construction & start-up
- **2013/14**: Continuous test runs (24h/5d)
bioCRACK Partners

BDI – BioEnergy International AG

OMV Refining and Marketing GmbH

Institute of Chemical Engineering and Environmental Technology
Prof. Dr. M. Siebenhofer

Austrian Climate & Energy Fund
“New Energies 2020”
bioCRACK - Concept

Typical pathways from lignocellullosis to biofuel

Source: Chem.Rev.2006,106,4044ff
bioCRACK - Concept

In liquid phase pyrolysis (LPP) a hot liquid is used as heat carrier

**Pro:**
- Moderate process conditions (ambient pressure, temperature <450°C)
- Compared to other technologies simple concept
- Heat recovery possible
- Usage of standard industrial equipment
- Time to market short
- Direct conversion from solid biomass to liquid hydrocarbon

**Contra:**
- Limitation in maximum temperature
- Limited conversion from solid to fuel
- Challenging separation task solid/liquid
- Utilisation of by-products necessary
- Cracking of the heat carrier oil

To succeed with LPP one need to use a heat carrier oil where cracking is desired!
bioCRACK - Process Scheme

**Biomass**

**Carrier oil**

**pre-treatment**

**Conditioning**

**bioCRACK converter**

liquid phase pyrolysis (LPP)

**separation**

**Gas**

**Pyrolysis oil**

**Raw fuel**

**Diesel with renewable content**

**Biochar**
bioCRACK - Pilot Plant

Biomass → Pre-treatment

Carrier oil → Conditioning

bioCRACK Converter

liquid phase pyrolysis
bioCRACK - Pilot Plant

Vorbehandlung

BioCRACK

Konditionierung

Konverter

Flüssigphasenpyrolyse

Separation

Separation

BioGas

Liquid phase

Crude diesel

Diesel with biogenic share

Biocoal

Biomasse

Trägeröl

BioCRACK

BDI BioDiesel

BDI BioGas

BDI RetroFit
bioCRACK - Pilot Plant

- Biomass
- Pre-treatment
- Carrier oil
- Conditioning

bioCRACK Converter
- liquid phase pyrolysis

Separation

BioGas
- Liquid phase
- Crude diesel
- Diesel with biogenic share

Biocoal
bioCRACK - Refinery Integration

- Crude oil processing:
  - Heavy oil fraction
  - Biomass

- Utilities:
  - Steam
  - Power
  - Cooling water
  - Nitrogen

- BioCRACK process:
  - Gas
  - Heavy oil fraction
  - Reaction water
  - Raw fuel
  - Pyrolysis oil
  - Biochar

- CHP:
  - Steam, power

- FCC:
  - Gasoline, lower HC

- WWT

- Hydrogenation:
  - Diesel
bioCRACK Pilot Plant

Facts and figures

- Project duration: April 2010 - 2014
- Project cost: € 7 Mio (Grand by Austrian Climate and Energy Fund: € 2,0 Mio.)
- Dimensions: basis: 7,5x7m, height: 21,5m
- Steelwork: 60 tons
- Pipes: >2.000 m
- I/O: > 700
- Engineering demand: ~ 17.000 hours
- Feed capacity: 100 kg/h biomass and 1000 kg/h heavy oil
- Pressure: atmospheric
- Temperature: up to 400°C
bioCRACK Pilot Plant

Integrated pilot plant at the OMV refinery Schwechat/Austria*

*Dismantled End 2015
Ideal biomass for bioCRACK is renewable lignocelluloses

- Low water content
- Low nitrogen, chlorine, toxics
- Fine particle size (<5mm) possible

Examples:
- Wood chips (soft and hard wood)
- Forestry residues
- Chopped straw/agricultural residue
- …..

Biomass contains up to 50% oxygen in complex molecular structure. Oxygen is an unwanted element in liquid fuel and has to be removed to reach requested fuel quality!
bioCRACK - detailed C14 Balance

Bio-carbon transfer in streams (H06, 375°C)

H06.2
375°C, 60kg/h, direct

Results from bioCRACK pilot plant Schwechat
Feedstock: spruce
bioCRACK - Diesel Fuel

Upgrading of raw diesel to EN590 quality is possible

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Untreated raw diesel</th>
<th>After hydro treatment</th>
<th>EN 590</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (15°C)</td>
<td>868 kg/m³</td>
<td>833 kg/m³</td>
<td>820 - 845 kg/m³</td>
</tr>
<tr>
<td>Viscosity (40°C)</td>
<td>2.53 mm²/s</td>
<td>n.a.</td>
<td>2 - 4.5 mm²/s</td>
</tr>
<tr>
<td>Cetan</td>
<td>44</td>
<td>53</td>
<td>&gt; 51</td>
</tr>
<tr>
<td>C/H/O</td>
<td>85/13/2 wt.%</td>
<td>86/14/0 wt.%</td>
<td>n.a.</td>
</tr>
<tr>
<td>Volatile &lt;350°C</td>
<td>83 wt.%</td>
<td>86 wt.%</td>
<td>&gt; 85 % (v/v)</td>
</tr>
<tr>
<td>Sulfur</td>
<td>177 mg/kg</td>
<td>3 mg/kg</td>
<td>&lt; 10 mg/kg</td>
</tr>
</tbody>
</table>

Results from bioCRACK pilot plant and hydrogenation at OMV/Schwechat
Feedstock: spruce
bioCRACK - Biochar

Analysis of biomass (spruce) and biochar

<table>
<thead>
<tr>
<th>Element</th>
<th>Biomass (spruce) [wt.%]</th>
<th>Biochar [wt.%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>50</td>
<td>81</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>6.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Rest (Oxygen + Ash)</td>
<td>44.2</td>
<td>13.4</td>
</tr>
</tbody>
</table>

**Utilisation:**
- ✓ Renewable solid fuel for combustion
- ✓ Additive in steel industry, construction material,....
- ✓ Fertilizer and carbon sink
- ✓ Further upgrading to transportation fuel
Dehydration of bioCRACK pyrolysis oil is possible

<table>
<thead>
<tr>
<th></th>
<th>Pyrolysis Oil</th>
<th>Pyrolysis Oil dehydrated</th>
<th>Crude Oil$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content</td>
<td>[wt.%]</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>Lower Calorific Value</td>
<td>[kJ/kg]</td>
<td>8700</td>
<td>29000</td>
</tr>
<tr>
<td>Carbon</td>
<td>[wt.%]</td>
<td>22</td>
<td>72</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>[wt.%]</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Oxygen</td>
<td>[wt.%]</td>
<td>68</td>
<td>19</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>[wt.%]</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Utilisation: ✓ Renewable liquid fuel for combustion
✓ Source for chemicals
✓ Further upgrading to transportation fuel

$^1$Mortensen et al., Applied Catalysis A: General, 407 (2011)
GHG Calculation according to EU-Directive

\[ E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee} \text{ [g CO}_2\text{-eq/MJ biofuel]} \]

\[ E = (E_{fossil} - E_{biofuel}) / E_{fossil} \text{ [%]} \]

E > 35% (2017: > 50%; 2018*): > 60%  

*) new biofuel plants

E = total emissions from the use of the biofuel;

\( e_{ec} \) = emissions from the extraction or cultivation of raw materials;

\( e_l \) = annualized emissions from carbon stock changes caused by land-use change;

\( e_p \) = emissions from processing;

\( e_{td} \) = emissions from transport and distribution;

\( e_u \) = emissions from the fuel in use;

\( e_{sca} \) = emission saving from soil carbon accumulation via improved agricult. management;

\( e_{ccs} \) = emission saving from carbon capture and geological storage;

\( e_{ccr} \) = emission saving from carbon capture and replacement; and

\( e_{ee} \) = emission saving from excess electricity from cogeneration.

Emissions from the manufacture of machinery and equipment shall not be taken into account

Comparison to Other Biofuels in Austria

- biofuels from bioCRACK (wood) - 84%
- FT-biofuels (wood) - 75%
- bioethanol (wood) **) - 80%
- bioethanol (straw) **) - 75%
- bioethanol (black liquor) **) - 50%
- biodiesel (70% vegetable oil, 10% animal fat & 20% waste cooking oil) - 58%
- bioethanol (45% wheat & 55% maize) *) - 70%

*) without CO₂ use: 50%
**) without CO₂ use

bioCRACK Industrial Scale - Layout

- **Capacity:**
  400,000 to/y BM
  ➔ 60,000 to/y biofuels
- **Total Area:** 235,000m²
- **Area I:**
  Multi-Feedstock biomass feedstock preparation,
- **Area II:**
  bioCrack Refining 1-4, Product treatment (BCO, FCO, PYO), TOL Conditioning
- **Area III:**
  Energy central station, bioChar treatment
**bioCRACK – Added Value**

Estimated added Value of the conversion products from wood:

<table>
<thead>
<tr>
<th>Stream</th>
<th>Annual Demand t</th>
<th>Price per t</th>
<th>Cost/Revenue p.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>360.000</td>
<td>€ 100</td>
<td>€ 36.000.000</td>
</tr>
<tr>
<td>bio Naptha</td>
<td>19.000</td>
<td>€ 850</td>
<td>€ 16.150.000</td>
</tr>
<tr>
<td>bio Gasoil</td>
<td>44.000</td>
<td>€ 1.100</td>
<td>€ 48.400.000</td>
</tr>
<tr>
<td>bio Char</td>
<td>100.000</td>
<td>€ 60</td>
<td>€ 6.000.000</td>
</tr>
<tr>
<td>Pyrolysis Oil raw</td>
<td>137.000</td>
<td>€ 90</td>
<td>€ 12.330.000</td>
</tr>
<tr>
<td>Gases</td>
<td>60.000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Added Value p.a.</strong></td>
<td></td>
<td></td>
<td><strong>€ 46.880.000</strong></td>
</tr>
</tbody>
</table>

**Example integration bioCRACK in OMV refinery concept:**
- general increase of fuel production from VGO by + 5%
- Shift in fuel distribution from petrol (-11%) to diesel (+25%) and kerosene (+15%)

**Estimated Capex 400.000 t p.a. biomass: 200 - 300 Mio €**

Preliminary estimated data in cooperation OMV and Joanneum Research
Ongoing Research & Development
bioCRACK Outlook

- Completion of r&d project: 2015
- After successful completion:
  - Up-scaling to demonstration plant ➔ financing (VC, EU-NER300, ?)
  - GHG-saving potential
  - Profitable implementation in refineries
  - Licensing
- Extension project „bioBOOST“:
  value-adding utilization of side-product streams