Fast Pyrolysis Bio-Oil: Commercial Production & Applications
TC Biomass Chicago 2019
Gerhard Muggen, BTG Bioliquids B.V.

October 7, 2019
BTG Bioliquids company introduction

As a technology provider and product leader we are committed to the commercial deployment of our fast pyrolysis technology.

Explicitly made from biomass residues which is known as second generation (2G) or advanced biofuel which means that it does not compete with the food chain.

Pyrolysis oil, the sustainable alternative
Fast Pyrolysis – development timeline

BTG

1987
Knowledge transferred from UT to BTG
Rotating cone reactor ‘invented’ at University of Twente (UT)

1993
Start-up of 200 kg/hr FP pilot plant in BTG Laboratory

1994
Delivery semi-continuous test unit (50 kg/hr) to Shenyang (China)

1998
Start-up of 200 kg/hr FP pilot plant in BTG Laboratory

2004
Large-scale co-firing test at Harculo Power Plant

2005
Delivery of 50 t/d FP-plant to Malaysia

2007
Establishment of BTG Bioliquids BV to commercialize BTG Fast Pyrolysis technology

2009
Establishment of Empyro BV to demonstrate FP technology

2013
Research development Roll-out

2014
Start construction 120 t/d Empyro plant
Long-term FPBO supply contract signed

2015
Start-up of Empyro plant & Boiler at FrieslandCampina

2019
Empyro sold to Twence; GreenFuelNordic; Pyrocell

© 2019

Pyrolysis oil, the sustainable alternative
Observations

- Time (step by step) and timing is important
- Do not under estimate the character of the biomass itself
- It is all about the people (technical, financial, operational and commercial) and the right balance.
- Find the right balance between thinking and acting. Be an entrepreneur, but do not overpromise
About Fast Pyrolysis

Pyrolysis oil, the sustainable alternative
What is fast pyrolysis?

- Thermal cracking of organic material in the absence of oxygen
  - Main Product: Liquid Bio-oil
  - Process conditions:
    - $T = 400 - 600 \, ^\circ C$
    - $P = \text{atmospheric}$
  - By products:
    - Heat (Steam)
    - Power (Electricity)
- Works with most lignocellulosic (non-edible) feedstocks
  - Wood chips, sugar cane bagasse, straw, sunflower husk, etc.
  - Qualify as feedstocks for “REDII” advanced biofuels

**Typical Pyrolysis Oil Characteristics:**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>“( \text{C}_2\text{H}_5\text{O}_2 ) \text{ (average)}&quot;</td>
</tr>
<tr>
<td>Density</td>
<td>1100 - 1200 kg/m(^3)</td>
</tr>
<tr>
<td>Heating value</td>
<td>17 - 20 GJ/m(^3)</td>
</tr>
<tr>
<td>Water content</td>
<td>20 - 30 wt.%</td>
</tr>
<tr>
<td>Ash</td>
<td>&lt; 0.1 wt.%</td>
</tr>
<tr>
<td>Acidity (pH)</td>
<td>2.5 - 3</td>
</tr>
</tbody>
</table>

Pyrolysis oil, the sustainable alternative
The fast pyrolysis process

Pyrolysis oil, the sustainable alternative
The fast pyrolysis process

Wood residue (5 dry t/h)

FPBO 65 wt% / 56 E%

Heat + P (32 E%)

Empyro Plant Data:
- Capacity: 120 tonnes/day dry feedstock
- Feedstock: Wood Residue
- Output per year:
  - Oil: 20 million litres
  - Electricity: 2.200 MWh
  - Steam: 80,000 tonnes
  - CO2- eq. reduction: 24,000 tonnes
Empyro: commercial FPBO production

**Commissioning**
- March 2015: First litres of oil; delivery of steam to AkzoNobel
- August 2015: Delivery of FPBO to FrieslandCampina
- October 2016: Steam turbine commissioned
- October 2017: Empyro reaches nameplate capacity
- January 2019: Empyro acquired by Twence

**Economics**
- Overall investment within original budget
- Actual oil production costs in line with predictions

**Production**
- Scale up of RCR very successful
- Team of 7 operators; 1 operator can run the plant
- ~25 million litres FPBO was produced after 3 years
- Oil yield around design value 65 wt%; quality excellent from start
- 3.3 tons of oil per hour + 7.4 MW\textsubscript{th} steam; 650 kW\textsubscript{e} Electricity (near 90% heat efficiency)
Fast Pyrolysis: state of the art

FPBO production
- Mar 2015: start-up of Empyro
- Plant now runs steadily, 24/7, at design capacity
- Biomass is certified for its sustainable origin
- Jan 2019: Empyro was acquired by Twence
- Apr 2019: new FPBO plant sold to GFN (Finland)
- Sept 2019: new FPBO plant sold to Pyrocell (Sweden)

FPBO application (by FrieslandCampina)
- FPBO is used to replace 10 million m³ natural gas
- Sustainable heat is used for producing dairy products
- Switch from gas to FPBO gives 93% GHG reduction*
- Boiler runs without problems, processed all Empyro oil
- Borculo site reduced overall CO₂ footprint by 15%

*Source: 2017 audit of Empyro

Pyrolysis oil, the sustainable alternative
Commercial roll out

Green Fuel Nordic, Lieksa, Finland

Pyrocell Setra, Gävle, Sweden

Empyro Twence, Hengelo, The Netherlands

Pyrolysis oil, the sustainable alternative
Since 2016 we integrated the unique expertises of BTL & TechnipFMC

- Decades of experience with biomass and fast pyrolysis
- Proprietary Fast Pyrolysis technology (rotating cone reactor)
- Realized Empyro, the first commercial FPBO plant operating 24/7
- One of the world's largest Engineering & Construction companies
- Extensive track record in successful delivery of turnkey contracts
- Provides all services from basic engineering up to commissioning
- 60 years experience in refinery technologies (e.g. FCC, hydrogen, ...)

BTL & TechnipFMC: realizing FPBO together

Together we deliver turnkey Fast Pyrolysis Bio-Oil production plants

- We support our customers from the first basic design up to and including the operation of their commercial FPBO plant
- We have the skills to support refiners in (co-)processing FPBO for the production of advanced biofuels

Pyrolysis oil, the sustainable alternative
Fast Pyrolysis Bio Oil Applications
Fast Pyrolysis Bio-Oil Applications

Figure based on BTG Biomass Technology Group B.V. intellectual property

Pyrolysis oil, the sustainable alternative
Pyrolysis Oil Application

Industrial Steam Generation at FrieslandCampina

Schematic drawing of Process Steam Boiler at FrieslandCampina

Pyrolysis oil, the sustainable alternative
Fast pyrolysis developments: advanced biofuels

- Crude oil
- Lignocellulosic biomass
- FPBO: crude fast pyrolysis bio-oil
- S(D)PO: stabilised pyrolysis oil
- MTF: mixed transportation fuels
- Picula™

Pyrolysis oil, the sustainable alternative
Co-FCC of FPBO: how does it work?

FPBO is injected via separate nozzles into the FCC riser
- Biomolecules are cracked together with the regular FCC feed
- Acidity disappears instantly upon contact with the hot catalyst
- Green carbon is distributed across the different products

Typical yields:
- Coke: 5 wt%
- Dry gas: 4 wt%
- LPG: 14 wt%
- FCC Gasoline: 50 wt%
- Light Cycle Oil: 20 wt%
- Slurry oil: 7 wt%

Pyrolysis oil, the sustainable alternative
Summary & perspectives

- Fast pyrolysis is proven at commercial scale, worldwide capacity is expanding.
- Current FPBO application is as renewable heating oil (replacing e.g. natural gas).
- Government mandate for advanced biofuels requires refiners to look at alternatives for fossil or edible vegetable oils. Preem (Sweden) is the first refiner that openly declared they will use FPBO to make advanced biofuels.
- Co-processing crude Fast Pyrolysis Bio-Oil in FCC units is a low-capex option that is proven at demo scale as a viable way to meet renewable fuel requirements, with little to no impact on refinery operations when co-processing 5 wt-% or less.
- Co-processing higher FPBO shares to get more bio-C in the products can be achieved with a mild FPBO hydrotreatment step.*
- Hydrotreatment can make other applications (e.g. steam cracker feed) possible. A green premium is probably required for the business case.
- FPBO fractionation for biomaterial applications is being scaled up as well. Lignin fraction of FPBO could also be an interesting cracker feedstock.

* Venderbosch et al. 2018