Fast Pyrolysis Bio-Oil: Commercial Production & Applications
Nieuwe energiedag Oost Nederland

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 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 bio fuel 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
1994
1998
2005
2009
2014
2015
2019

Delivery semi-continuous test unit (50 kg/hr) to Shenyang (China)
Start-up of FP pilot plant in BTG Laboratory
Start construction 120 t/d Empyro plant
Long-term FPBO supply contract signed

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

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-up Empyro plant & Boiler at FrieslandCampina

2015 Delivery of 50 t/d FP-plant to Malaysia

2019 Empyro sold to Twence; GreenFuelNordic; Pyrocell
Start-up Empyro plant & Boiler at FrieslandCampina

Pyrolysis oil, the sustainable alternative
About Fast Pyrolysis
What is fast pyrolysis?

- **Thermal cracking of organic material in the absence of oxygen**
  - Main Product: Liquid Bio-oil
  - Process conditions:
    - T = 400 - 600 °C
    - P = 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>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>“C_2H_5O_2” (average)</td>
</tr>
<tr>
<td>Density</td>
<td>1100 - 1200 kg/m³</td>
</tr>
<tr>
<td>Heating value</td>
<td>17 - 20 GJ/m³</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
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 29 million litres
- Electricity 3,200 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_{th} steam; 650 kW_{e} Electricity (near 90% heat efficiency)
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
Commercial roll out

Empyro Twence, Hengelo, The Netherlands

Green Fuel Nordic, Lieksa, Finland

Pyrocell Setra, Gävle, Sweden

Pyrolysis oil, the sustainable alternative
BTL & TechnipFMC: realizing FPBO together

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, ...)

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

![Diagram of pyrolysis processes and applications](image-url)

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

FPBO: crude fast pyrolysis bio-oil
SPO: stabilised pyrolysis oil
MTF: mixed transportation fuels
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%
- 4 wt%
- 14 wt%
- 50 wt%
- 20 wt%
- 7 wt%
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