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 bio fuel which means that it does not compete with the food chain.

Pyrolysis oil, the sustainable alternative

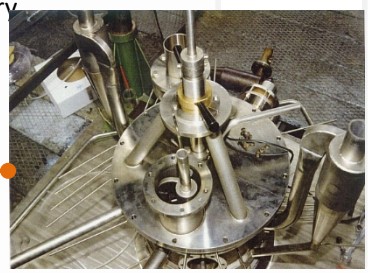

Fast Pyrolysis – development timeline BTG



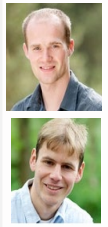



2019	Roll-out	Empyro sold to Twence; GreenFuelNordic; Pyrocell
2015		Start-up Empyro plant & Boiler at FrieslandCampina
2014	development	Start construction 120 t/d Empyro plant
2013		Long-term FPBO supply contract signed
2009		Establishment of Empyro BV to demonstrate FP technology
2007		Establishment of BTG Bioliquids BV to commercialize BTG Fast Pyrolysis technology
2005		Delivery of 50 t/d FP-plant to Malaysia
2004		Large-scale co-firing test at Harculo Power Plant
1998	research	Start-up of 200 kg/hr FP pilot plant in BTG Laboratory
1994		Delivery semi-continous test unit (50 kg/hr) to Shenyang (China)
1993		Knowledge transferred from UT to BTG
1989		Rotating cone reactor ‘invented’ at
1987		University of Twente (UT)










Pyrolysis oil, the sustainable alternative

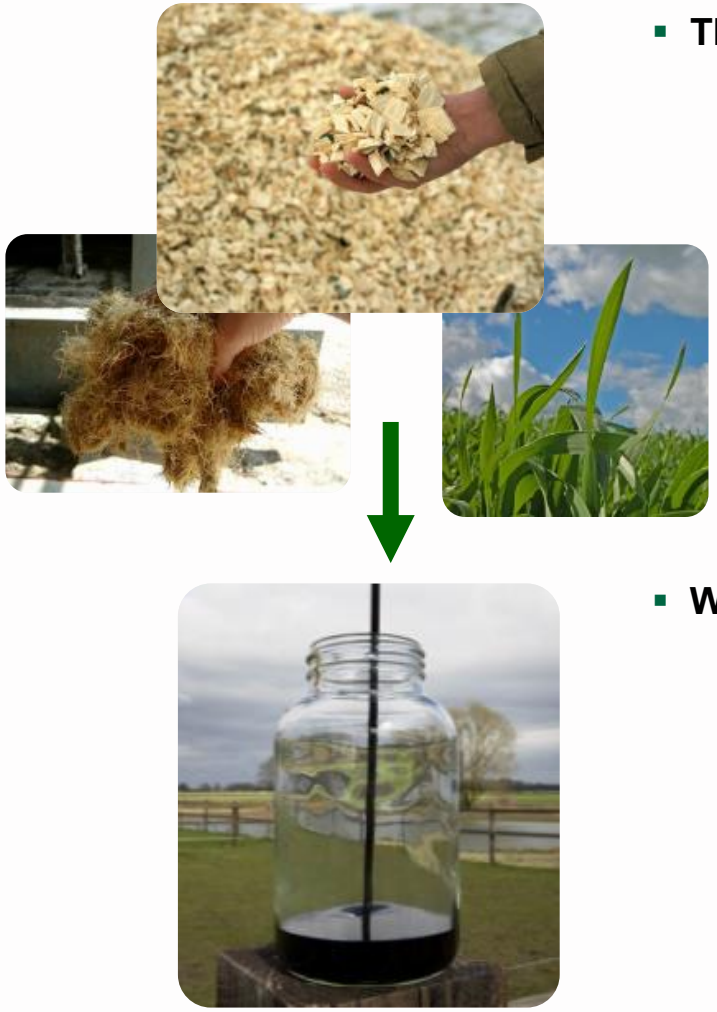
Observations

- 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 °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:

Composition	"$C_2H_5O_2$" *(average)*
Density	1100 - 1200 kg/m^3
Heating value	17 - 20 GJ/m^3
Water content	20 - 30 wt.%
Ash	< 0.1 wt.%
Acidity (pH)	2.5 - 3

Pyrolysis oil, the sustainable alternative

The fast pyrolysis process

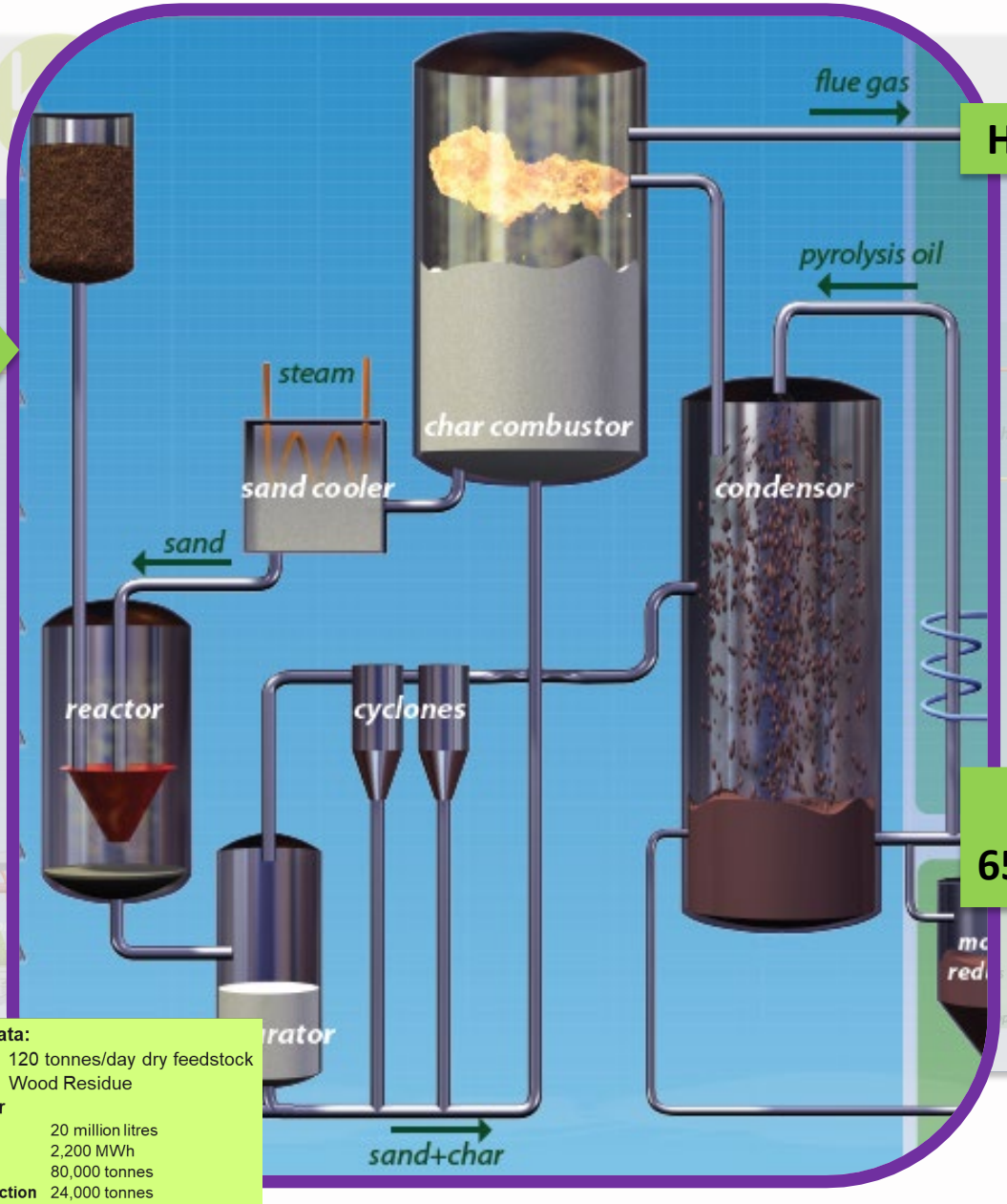
EMPYRO
energy & materials from pyrolysis

process steam to biomass dryer
process steam to customer
flue gas
boiler
high pressure steam
steam turbine
power to grid
power to pyrolysis plant
dry biomass
pyrolysis oil
steam
char combustor
sand cooler
condensor
sand
minerals
wet biomass
air
moist air
reactor
cyclones
cooling water
pyrolysis oil
biomass dryer
separator
moisture reduction*
particle reduction*
water
solids
air
sand+char
*optional

Pyrolysis oil, the sustainable alternative

The fast pyrolysis process

Wood residue (5 dry t/h)



Heat + P (32 E%)

FPBO 65 wt% / 56 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

TechnipFMC btg-btl biomass-to-liquid

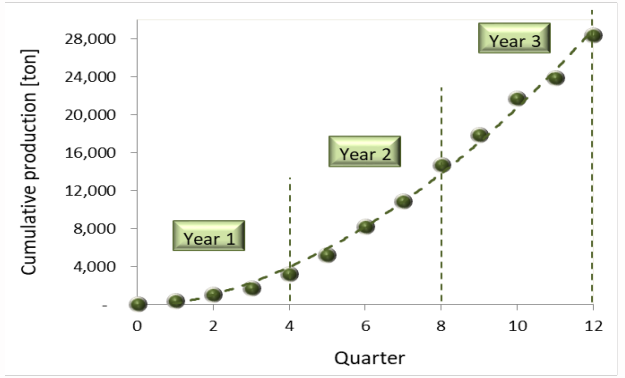
Empyro: commercial FPBO production

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

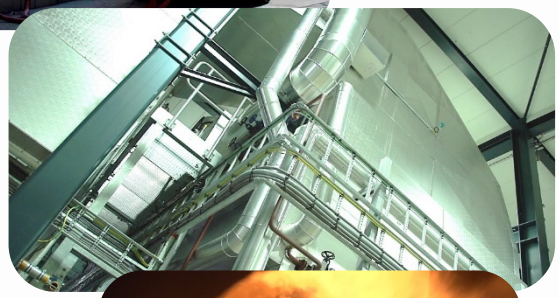


Production

- 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)

Pyrolysis oil, the sustainable alternative

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)

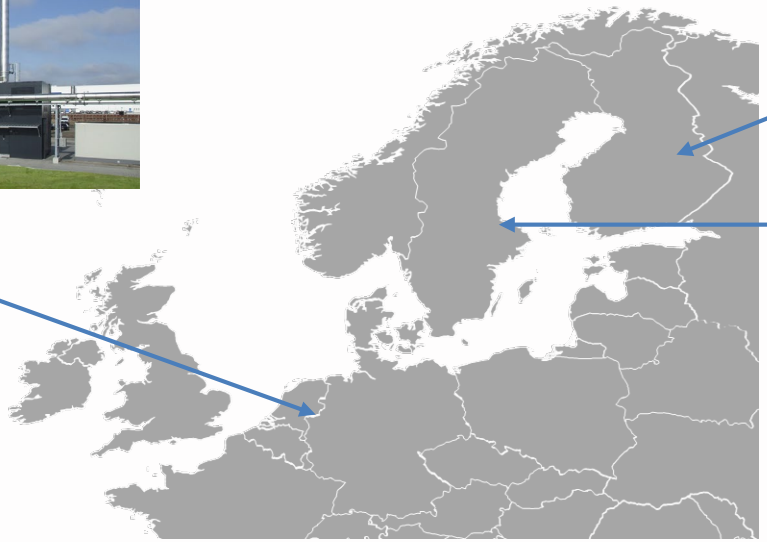
- FPBO is used to replace 10 million m^3 natural gas
- Sustainable heat is used for producing dairy products
- Switch from gas to FPBO gives 93% GHG reduction*
- Boiler runs without problems, processed all Empyro oil
- Borculo site reduced overall CO_2 footprint by 15%

**Source: 2017 audit of Empyro*

Commercial roll out

Green Fuel Nordic, Lieksa
Finland

Empyro Twence, Hengelo
The Netherlands



Pyrocell Setra, Gävle
Sweden

Pyrolysis oil, the sustainable alternative

TechnipFMC
btg-btl
biomass-to-liquid

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

Since 2016 we integrated the unique expertises of BTL & TechnipFMC

btg-btl biomass-to-liquid

- 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

TechnipFMC

- 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, ...)

TechnipFMC btg-btl biomass-to-liquid

Pyrolysis oil, the sustainable alternative

Fast Pyrolysis Bio Oil Applications

Pyrolysis oil, the sustainable alternative

Fast Pyrolysis Bio-Oil Applications

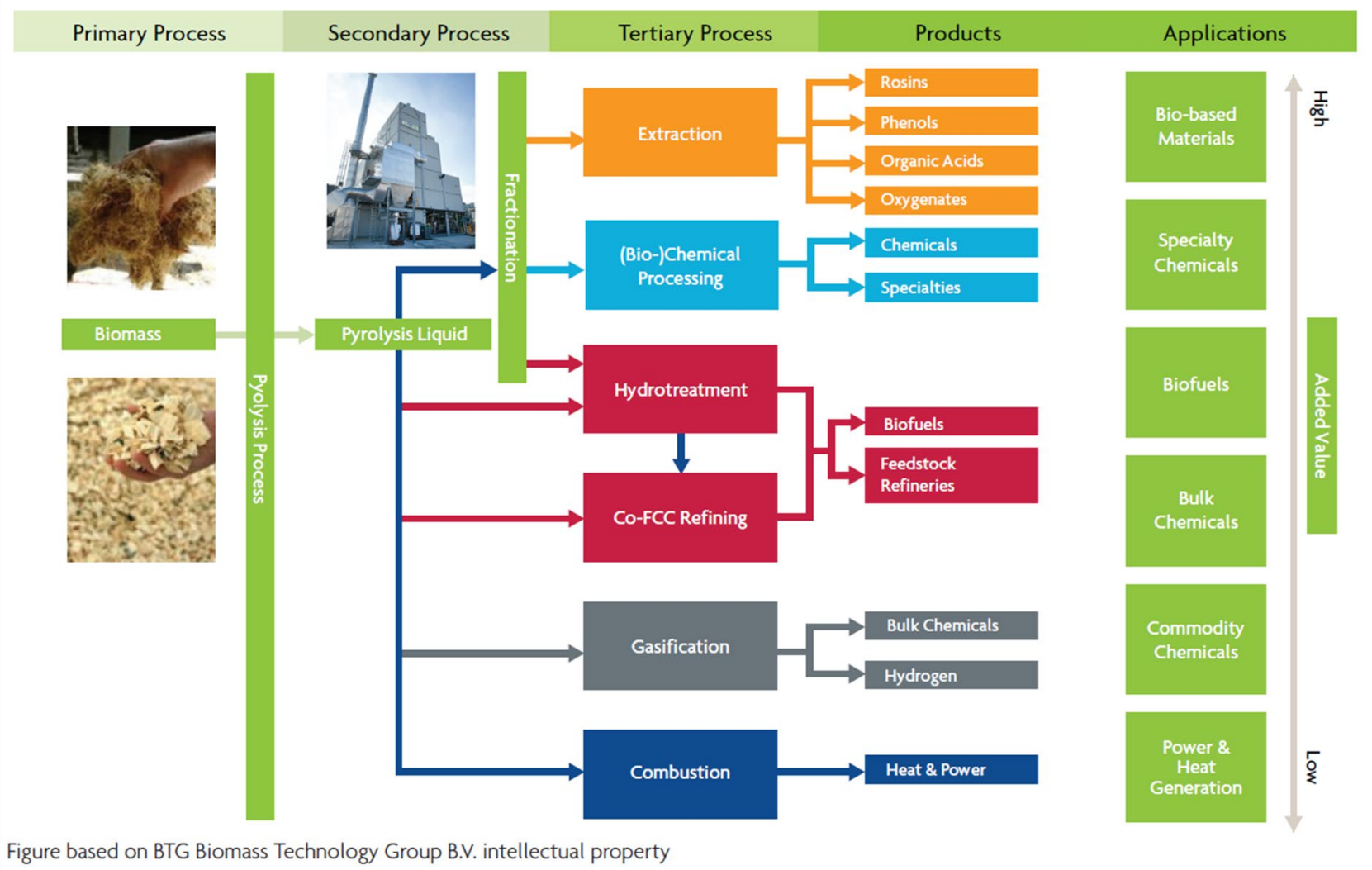


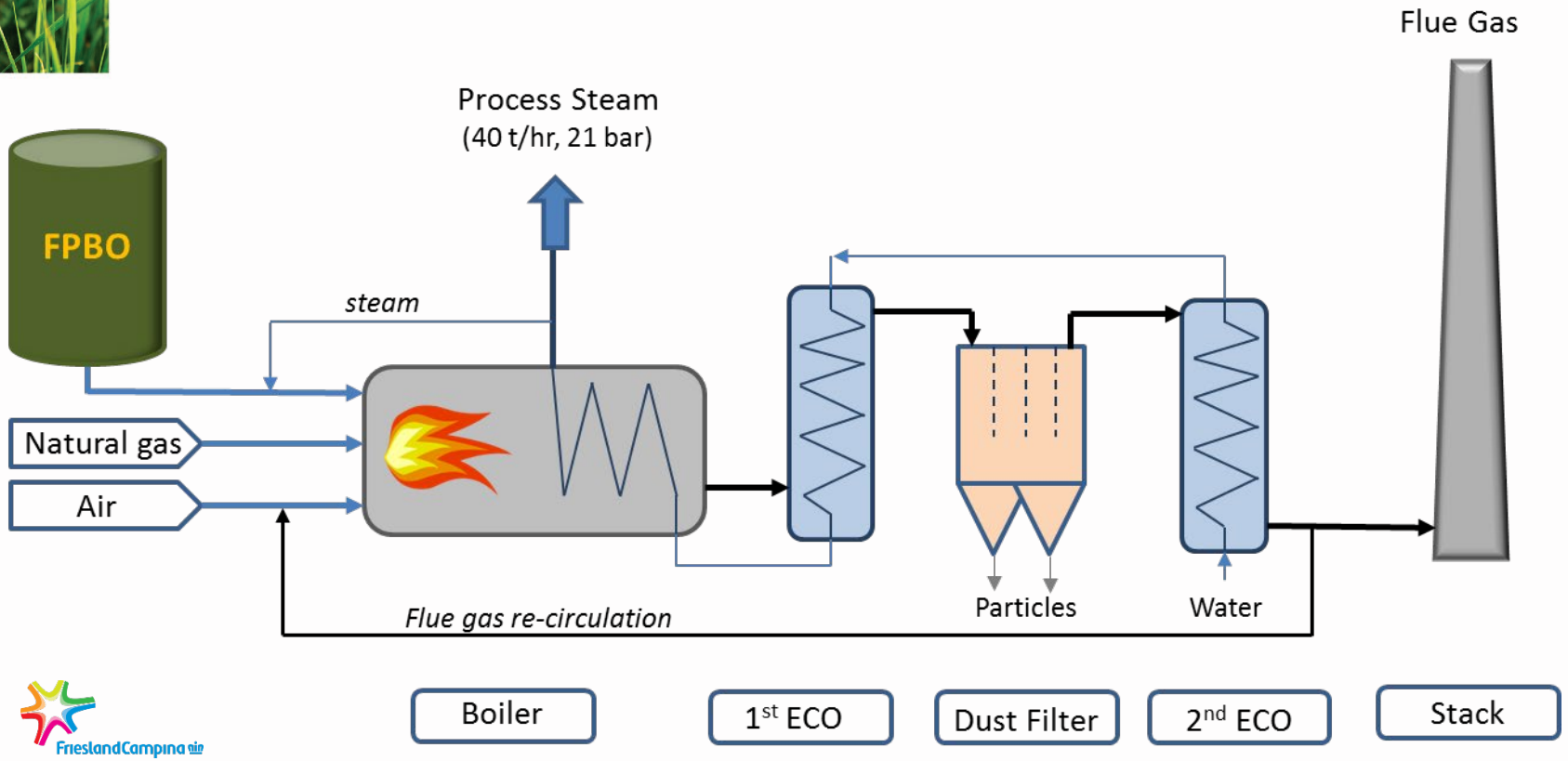
Figure based on BTG Biomass Technology Group B.V. intellectual property

Pyrolysis oil, the sustainable alternative



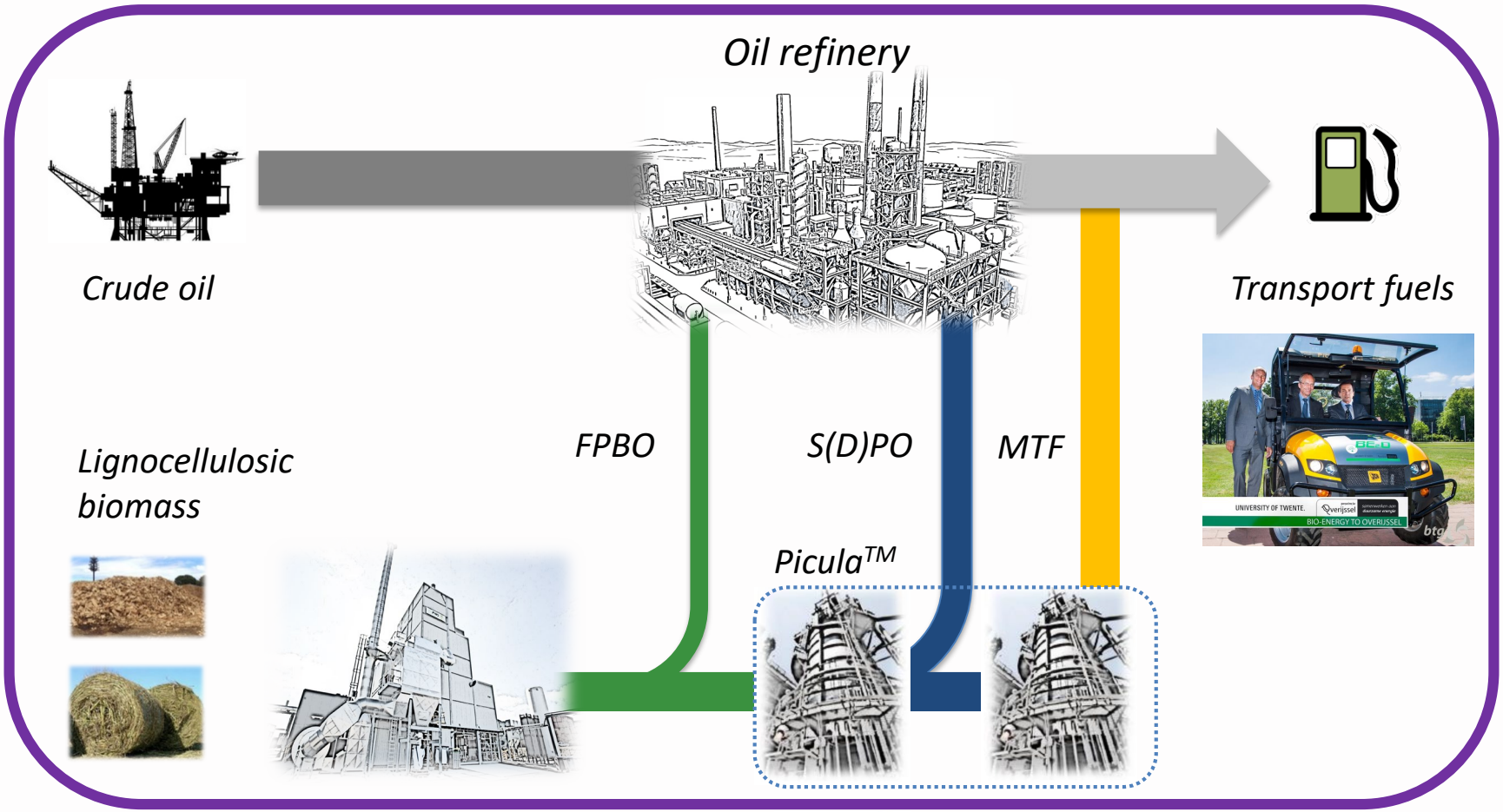
Pyrolysis Oil Application

Industrial Steam Generation at FrieslandCampina



Schematic drawing of Process Steam Boiler at FrieslandCampina

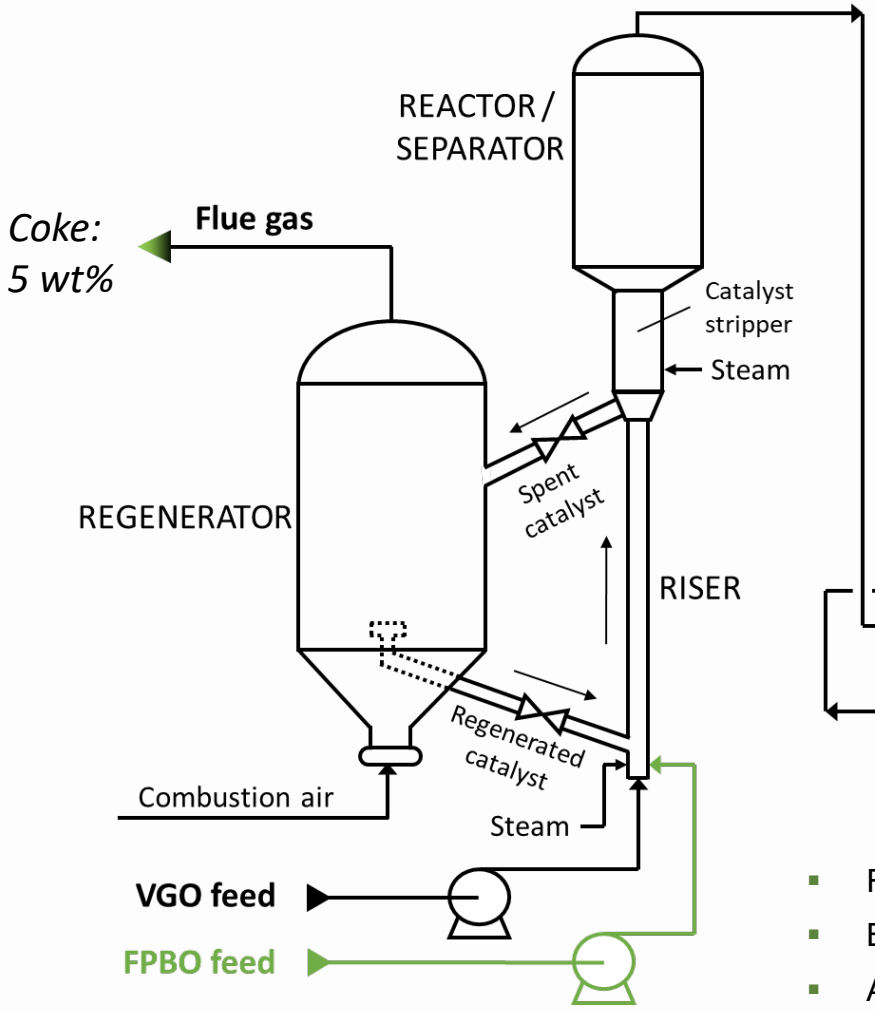
Fast pyrolysis developments: advanced biofuels

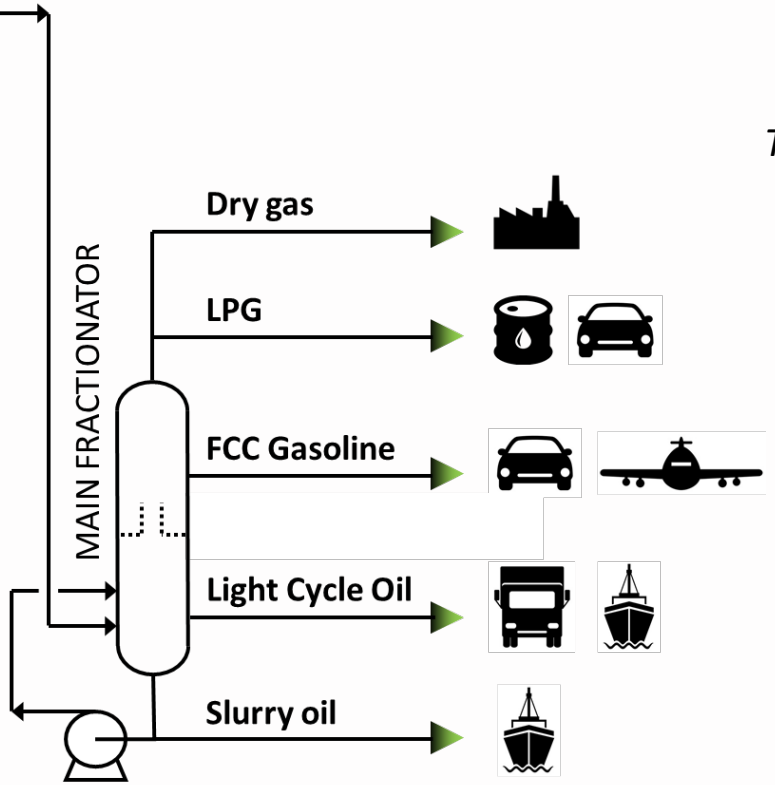


FPBO: crude fast pyrolysis bio-oil
SPO: stabilised pyrolysis oil
MTF: mixed transportation fuels

Pyrolysis oil, the sustainable alternative

Co-FCC of FPBO: how does it work?





Typical yields:

Dry gas	*4 wt%*
LPG	*14 wt%*
FCC Gasoline	*50 wt%*
Light Cycle Oil	*20 wt%*
Slurry oil	*7 wt%*

- 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

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

btg-btl
biomass-to-liquid

Visiting adress
Josink Esweg 34,
7545 PN, Enschede
The Netherlands

Contact
T +31 (0)53 486 1186
F +31 (0)53 486 1180
E office@btg-btl.com

Follow us:
btg-btl.com
youtube.com/BTGBioliquids
twitter.com/BTG_BTL