Fast Pyrolysis Bio-Oil:
Roll out of pyrolysis technology
Bio4Products webinar

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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

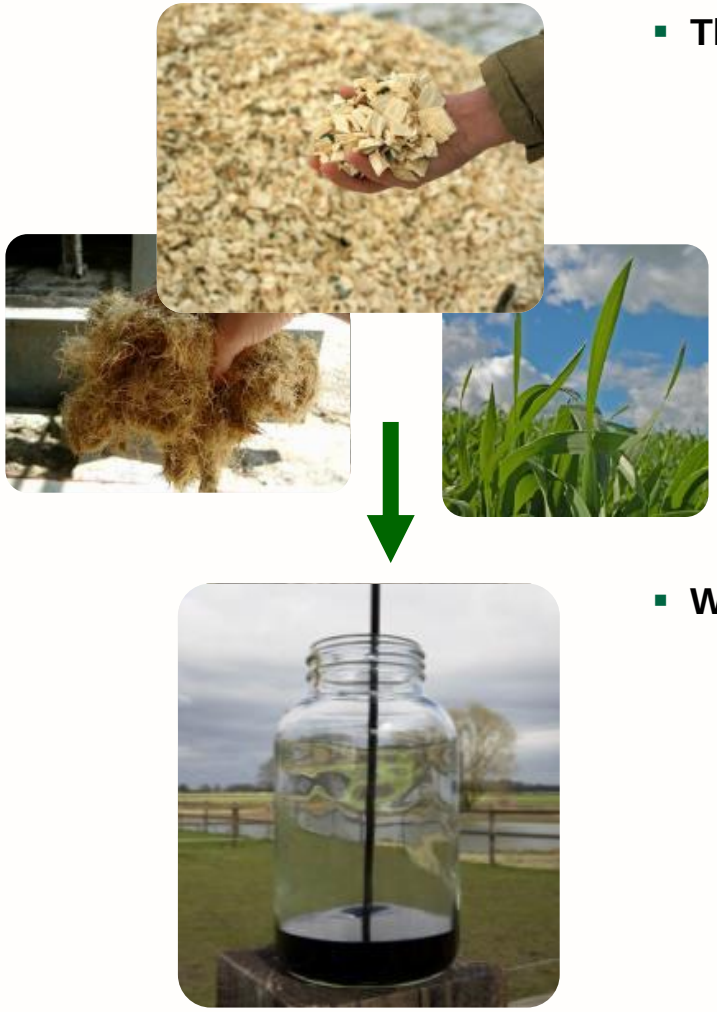
2019	*Roll-out*	Empyro sold to Twence; GreenFuelNordic; Pyrocell
2015		Start-up Empyro plant & Boiler at FrieslandCampina
2014	*development*	Start construction 120 t/d Empyro plant
2013		Long-term FPBO supply contract signed
2009		Establishment of Empyro BV to demonstrate FP technology
2007		Establishment 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 University of Twente (UT)
1987		

Pyrolysis oil, the sustainable alternative

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

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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

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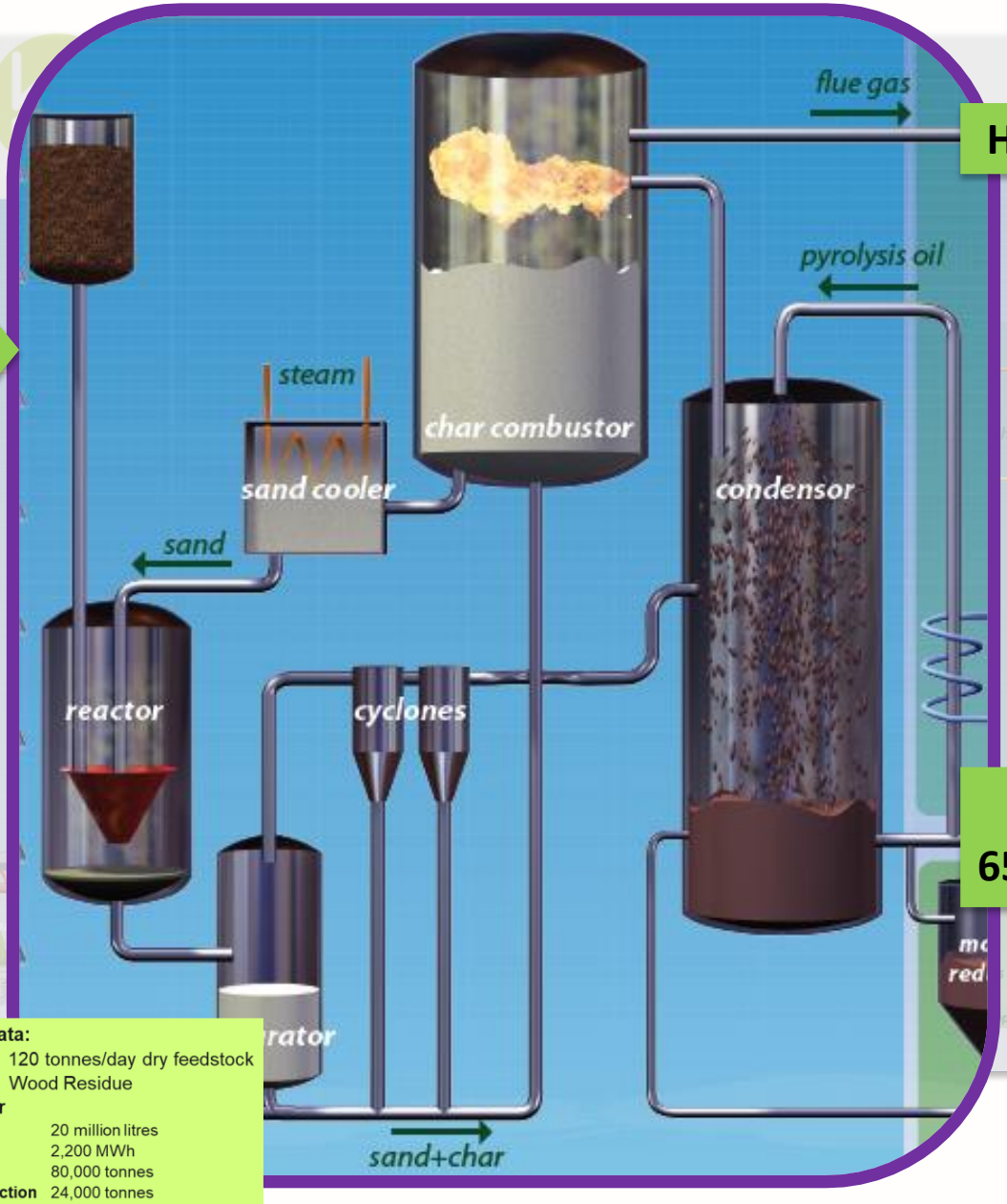
The fast pyrolysis process

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

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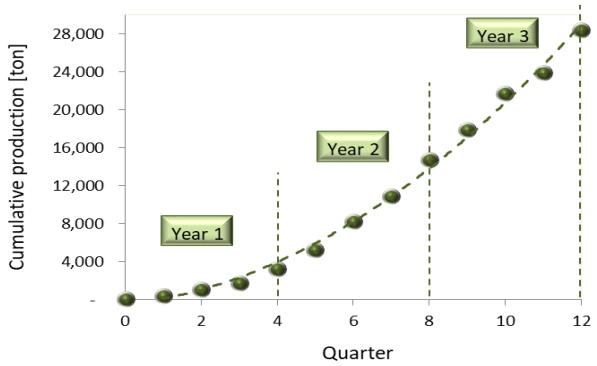
Empyro: commercial FPBO production

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)

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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)

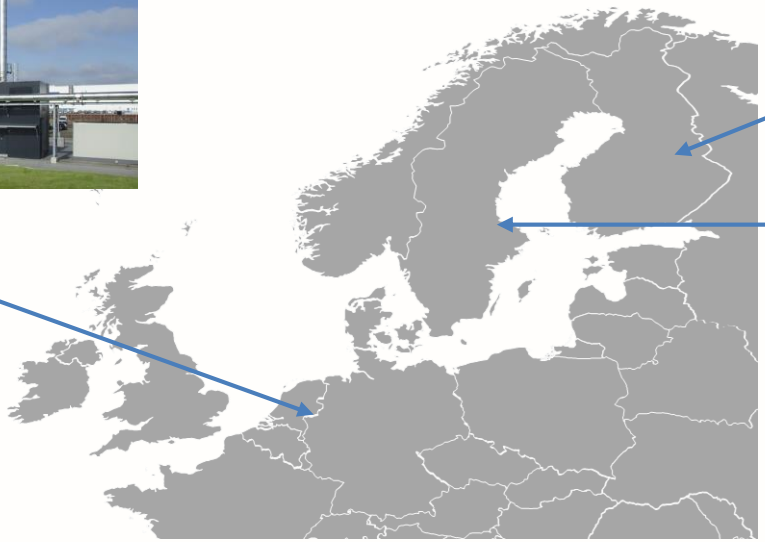
FPBO application (by FrieslandCampina)

- 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

Empyro Twence, Hengelo
The Netherlands



Green Fuel Nordic, Lieksa
Finland

Pyrocell Setra, Gävle
Sweden

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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, ...)

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Fast Pyrolysis Bio Oil Applications

Pyrolysis oil, the sustainable alternative

Fast Pyrolysis Bio-Oil Applications

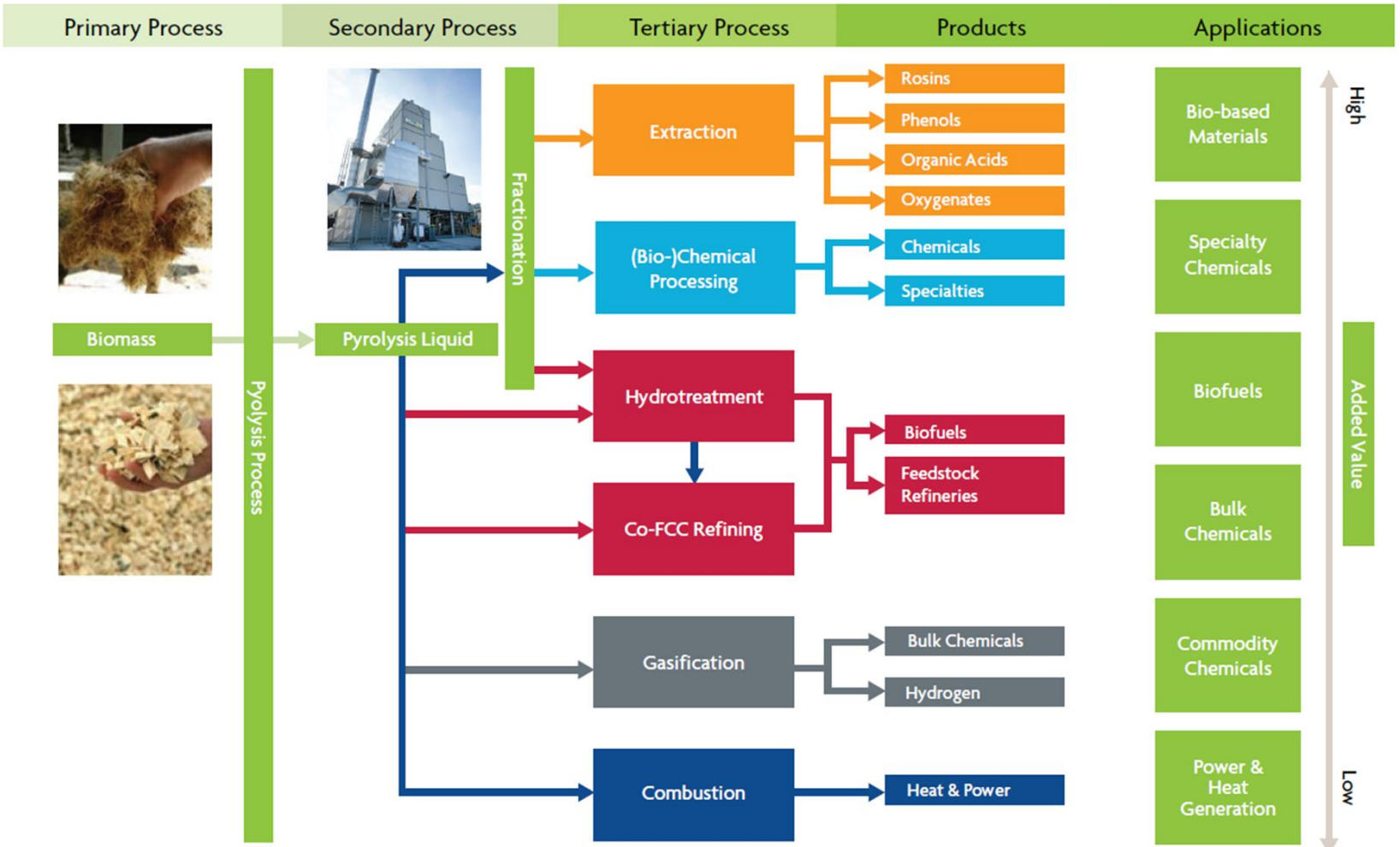

Figure based on BTG Biomass Technology Group B.V. intellectual property

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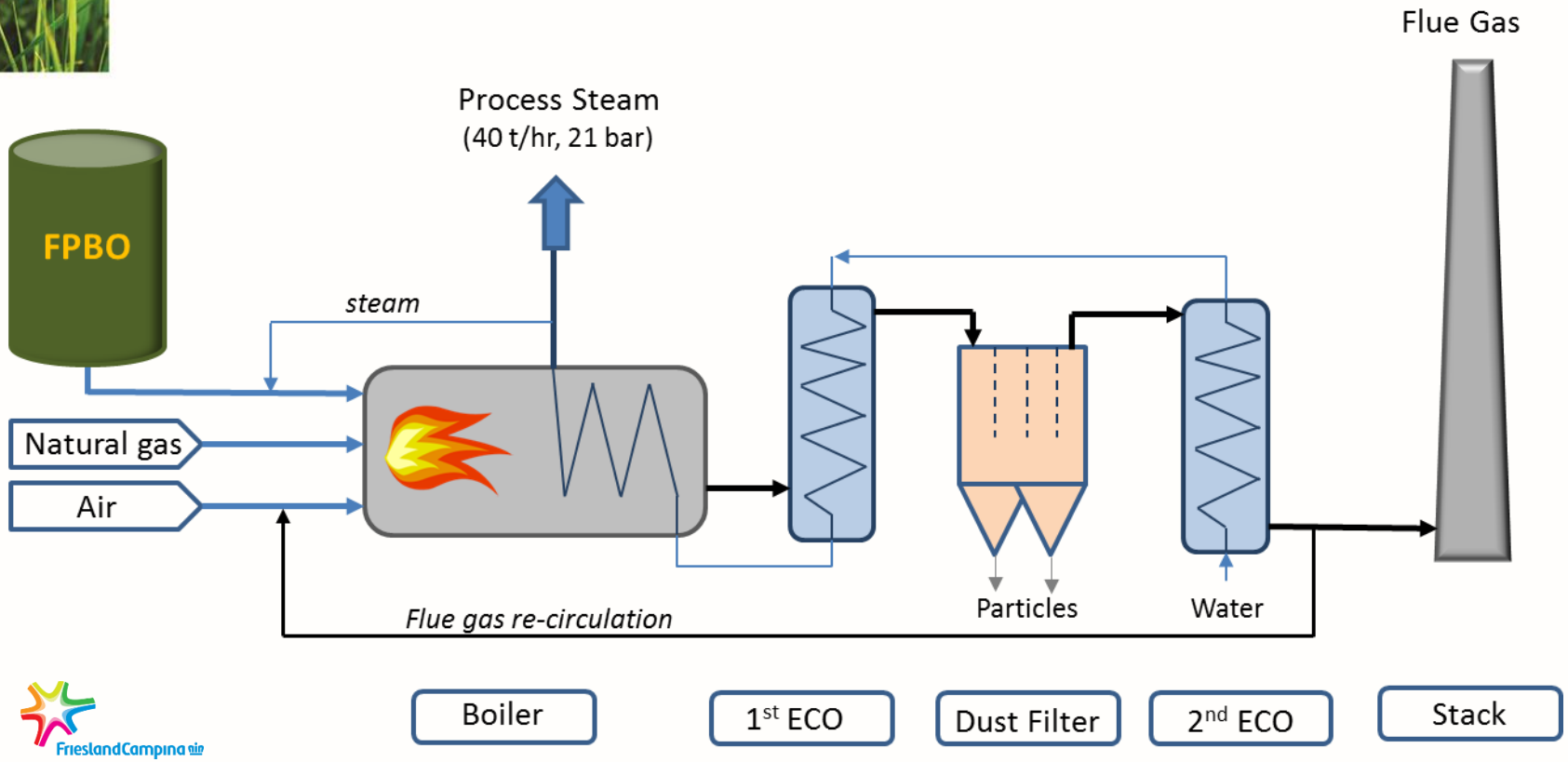
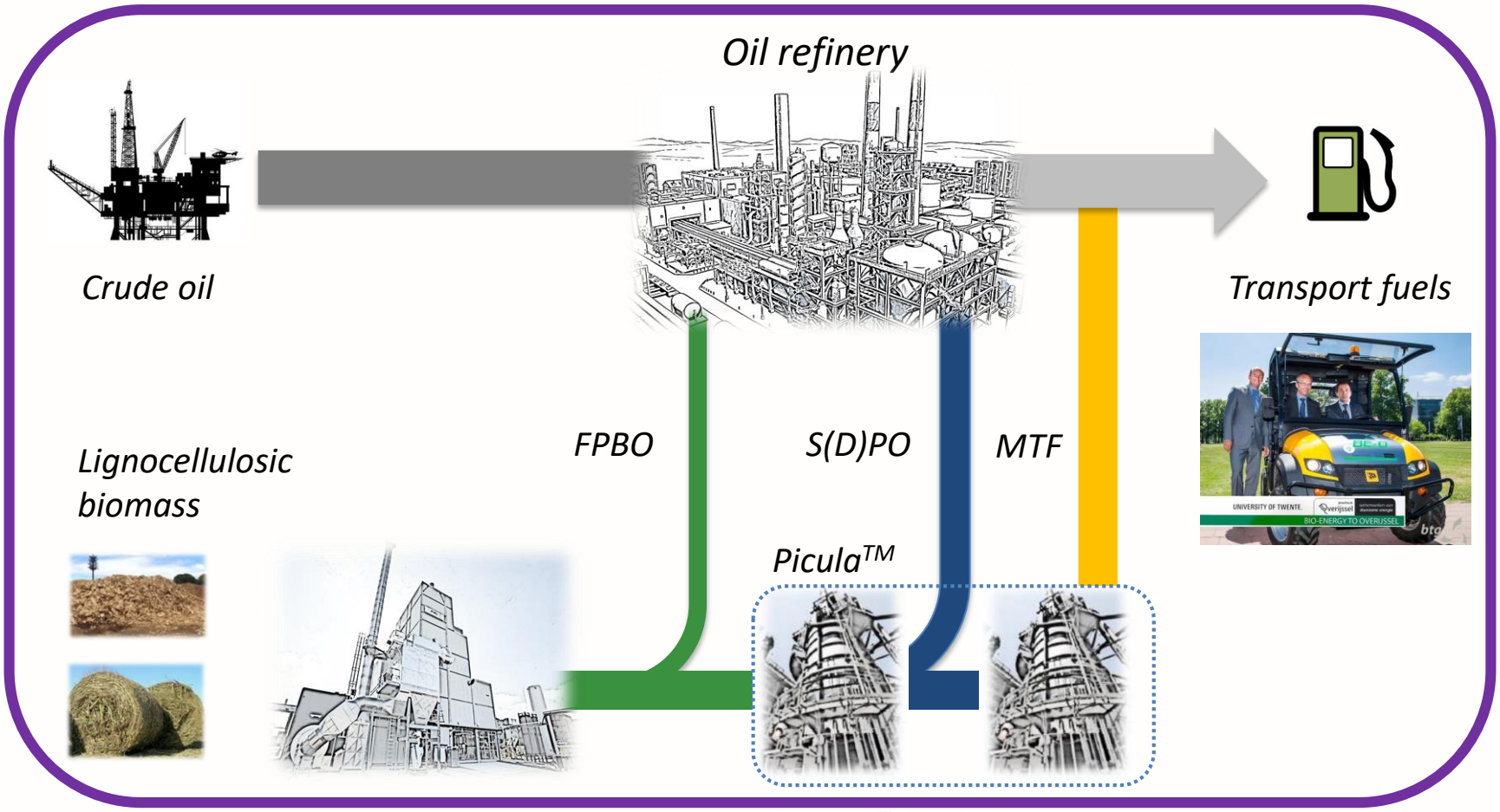
Pyrolysis Oil Application

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

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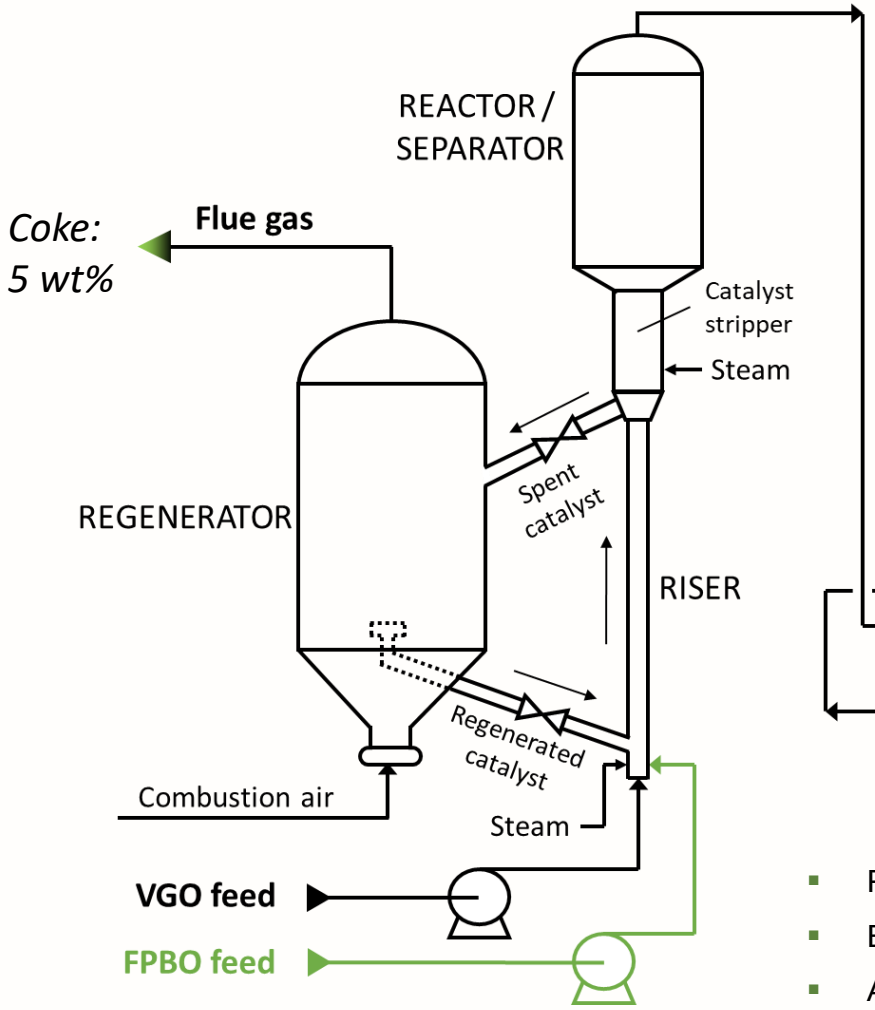
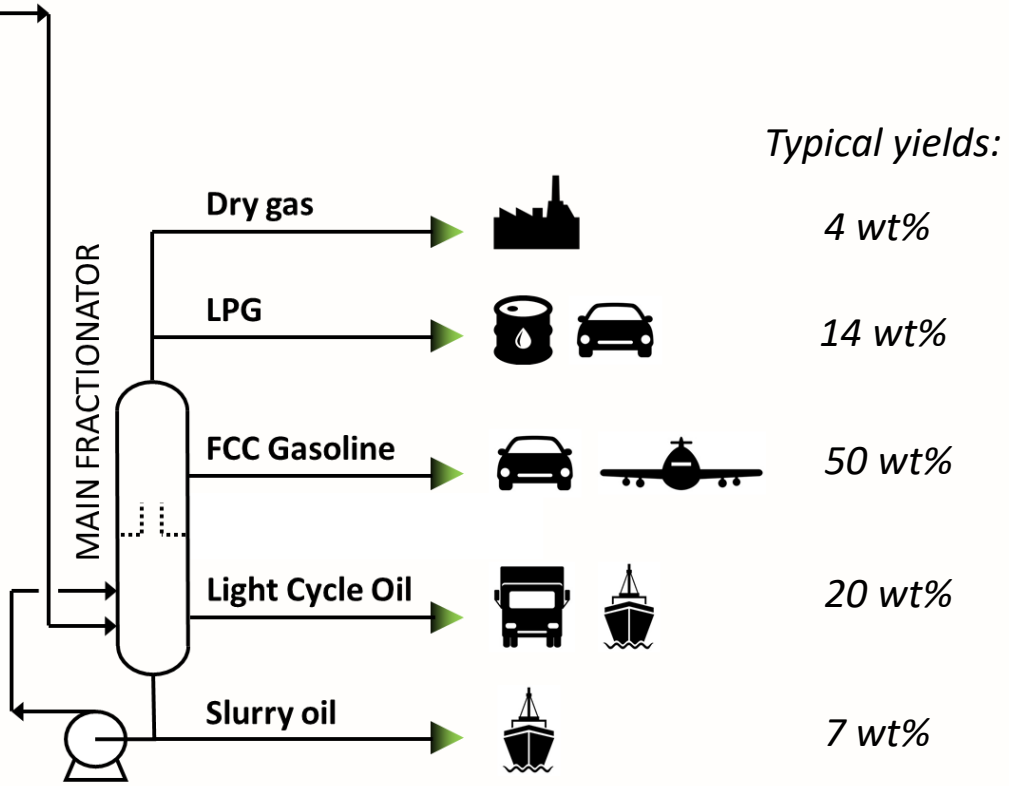
Co-FCC of FPBO: how does it work?





- 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

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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

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