

BTG-next
Advanced Biofuels from Pyrolysis Oil



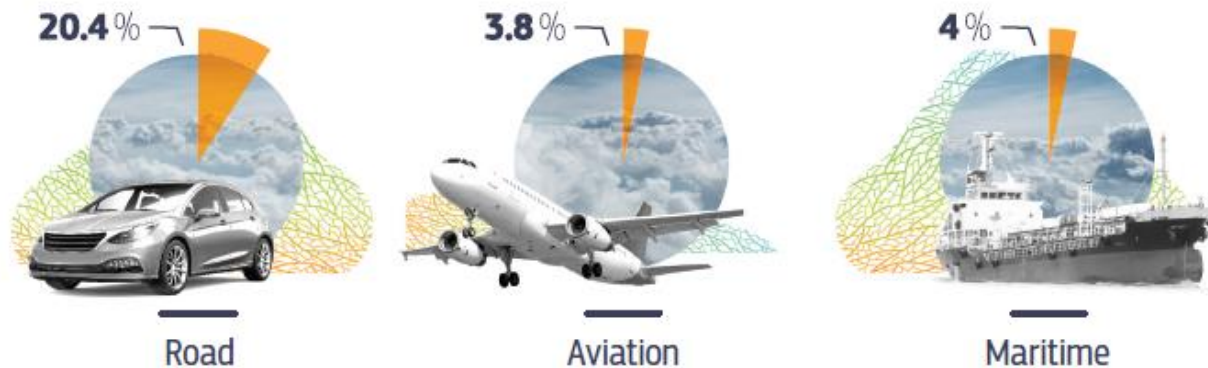
European
Commission

Make Transport Greener

A successful green transport transition will provide significant economic, social and environmental benefits: cutting climate-warming greenhouse gas emissions, reducing air and noise pollution and their negative impacts on our health, and driving innovation.

TRANSPORT NEEDS TO CUT EMISSIONS BY 90% BY 2050

Share of total EU Greenhouse Gas (GHG) emissions, per mode



Content...

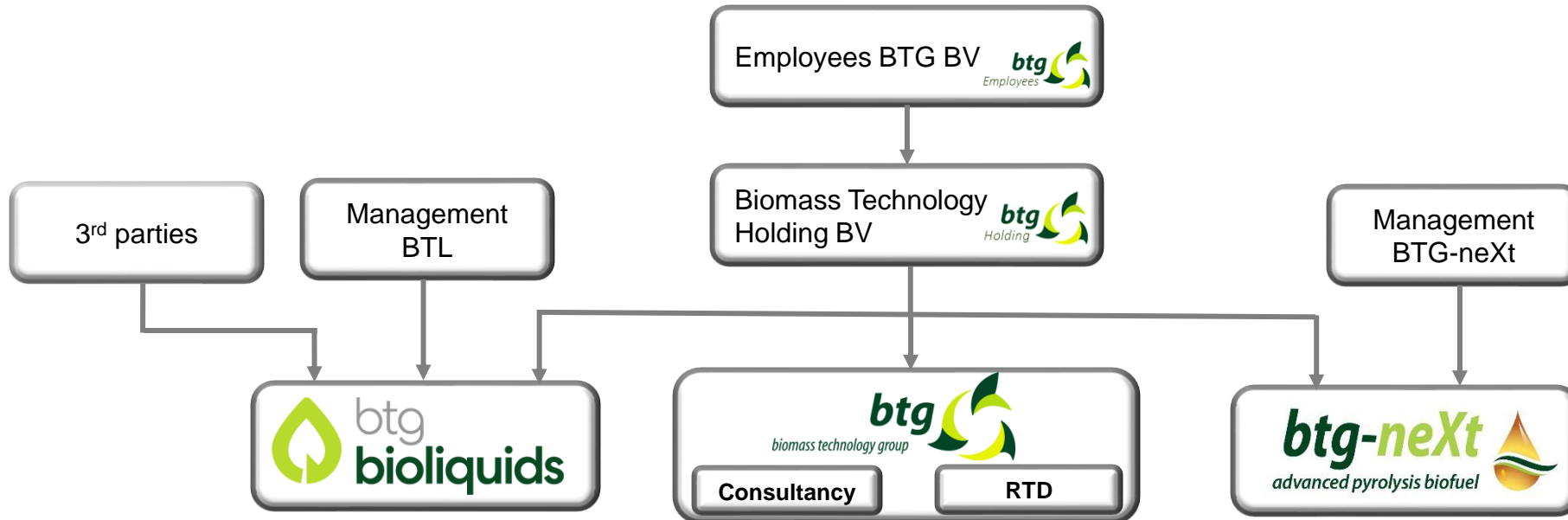
- 🔥 Company
- 🔥 Fast Pyrolysis of sustainable biomass
- 🔥 Advanced biofuels from pyrolysis oil
- 🔥 Summary



The Company...

BTG Biomass Technology Group BV is a SME

- 🔥 established in 1987 as spin-off company of University of Twente;
- 🔥 fully owned by its employees since 2003;
- 🔥 specialized in all aspects of biomass thermal conversion into energy, fuels and chemicals;



Dutch Award 2016
“entrepreneurial vision, perseverance and persuasion on bioenergy”

EUBIA Award 2019
“outstanding contribution to the development of advanced technologies for biomass conversion into fuels and energy”

Nomination King Willem-I Award 2020
“pyrolysis technology of BTG is a game changer for the petrochemical industry”

The Company...

FPBO = Fast Pyrolysis Bio-Oil



- Process & product development on thermochemical/catalytic/electrochemical biomass conversion to energy, fuels, chemicals and biobased products
- Contract research in the field of chemical process technology
- Supply of products (FPBO, upgraded FPBO, fractions (lignin, sugars))
- Value chain assessments (techno-economic, sustainability (LCA, LCC), market, logistics)
- Policies, legislation and regulation
- Project development



- Commercialization & implementation of FPBO *production* technology based on RCR;
- Owner of Patents on process and reactor;
- Acts as technology provider and supplies skid-mounted, key components of the FP-process
- Sales of FPBO (webshop)



- Established in 2019
- Commercialization of FPBO *upgrading* based on Picula™ catalyst;
- Owner of Patents on upgrading catalyst & process;



- Operation of fast pyrolysis production plant (operational since 2015)
- Former daughter-company of BTG Bioliquids
- Owned by Twence since 2019

Twence®

Fast Pyrolysis

- 🔥 Thermal cracking of organic material in absence of oxygen
- 🔥 Main product: liquid bio-oil (FPBO)
- 🔥 Other products: gas and char
- 🔥 Minerals recovered at low temperature
- 🔥 Fast heating required to maximize liquid yield

- 🔥 Typical Process conditions
 - $T = 400 - 600 \text{ }^\circ\text{C}$
 - $P = \text{atmospheric}$
 - $\tau_{\text{gas}} \sim \text{seconds}$

- 🔥 '*Liquid Composition*': carboxylic acids, ketones, aldehydes, alcohols, carbohydrates, depolymerized lignin, extractives, water,...

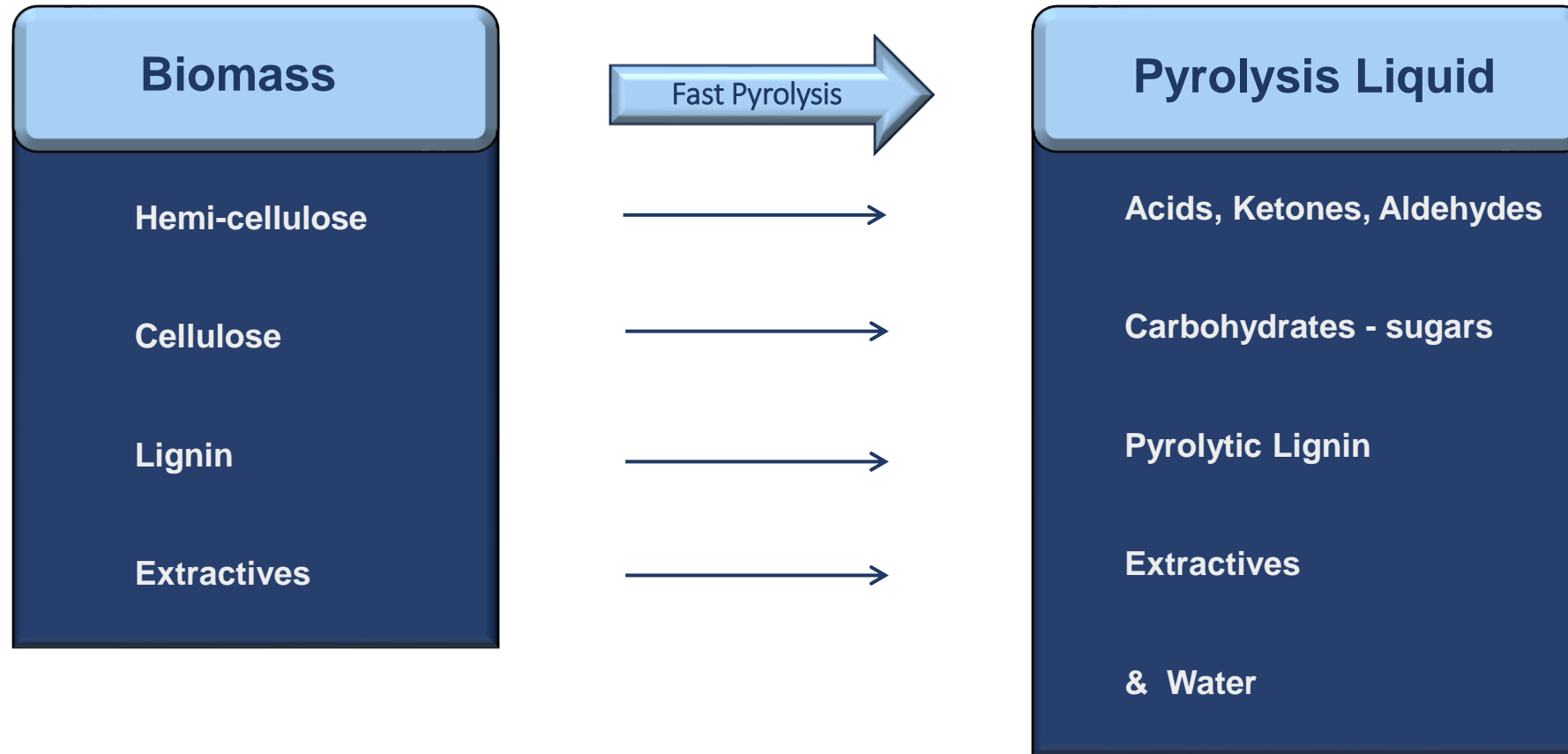
Water content	25	wt%
Density	1,170	kg/m ³
LHV	16	MJ/kg
Acid Number	70	mg _{KOH} /g
Sulfur	< 0.05	wt%
FlashPoint	?	°C
Cetane Number	< 20	-
MCRT	> 15	wt%



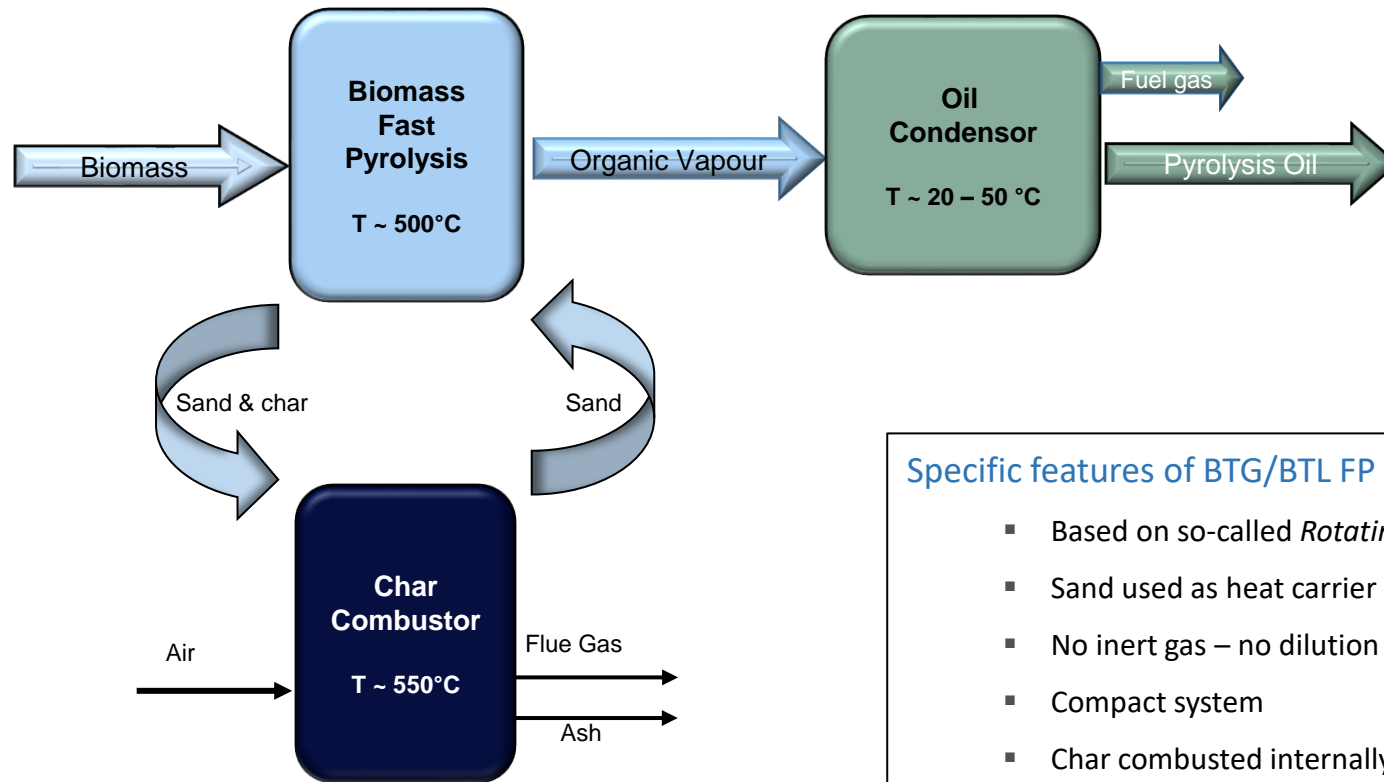
Crude Pyrolysis Oil

Fast pyrolysis oil components

Fast pyrolysis of lignocellulosic biomass:



Fast Pyrolysis Process



Specific features of BTG/BTL FP process:

- Based on so-called *Rotating Cone Reactor (RCR) Technology*;
- Sand used as heat carrier
- No inert gas – no dilution of vapor stream
- Compact system
- Char combusted internally to provide heat

Patents on pyrolysis reactor, sand circulation and FPBO water control granted

(a.o. United States , Indonesia, South Africa, China, Europe, Malaysia, Canada, Russia, Brazil).

Simplified representation of BTG's pyrolysis process



- Operation started in 2015
- Capacity: 5 t/h woody biomass
- Empyro was set-up as daughter-company of BTG Bioliquids
- Since 2019 Empyro is owned by Twence
- FPBO replaces natural gas (FrieslandCampina, Borculo)

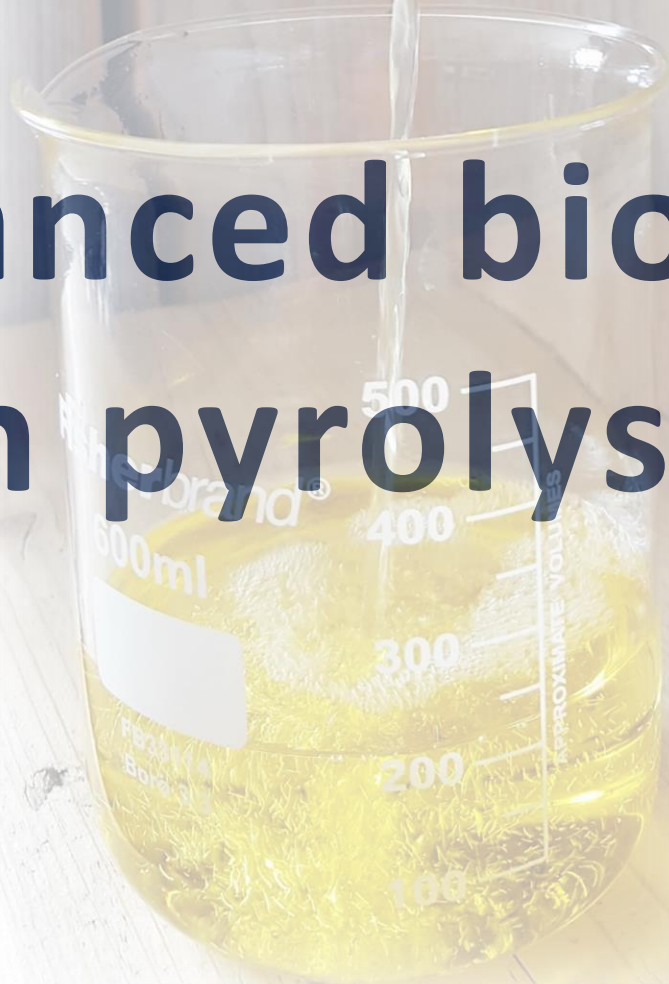


- Green Fuel Nordic is a Finnish company
- First unit operational in Lieksa since December 2020.
- Ambition to have multiple units at the same site.
- FPBO used as heating fuel (seasonal) and/or refinery co-feed



- Pyrocell is a joint venture of Swedish wood company Setra and Oil company Preem.
- First unit in Gävle operational since September 2021
- FPBO to be used as co-feed for the FCC-unit at the Preem refinery in Lysekil (Sweden) to produce advanced biofuels (start spring 2022)

Advanced biofuels from pyrolysis oil



Fast pyrolysis oil vs Marine distillate fuel

Water content	25	wt%
Density	1,170	kg/m ³
LHV	16	MJ/kg
Acid Number	70	mg _{KOH} /g
Sulfur	< 0.05	wt%
FlashPoint	?	°C
Cetane Number	< 20	-
MCRT	> 15	wt%



Crude Pyrolysis Oil



Pyrolysis Oil = Fuel

Pyrolysis Oil ≠ Oil

Water content	-	wt%
Density	< 890	kg/m ³
LHV	42	MJ/kg
Acid Number	< 0.5	mg _{KOH} /g
Sulfur	< 0.1	wt%
FlashPoint	> 60	°C
Cetane Number	> 40	-
MCRT	<< 1	wt%



Marine Distillate Fuel (DMA)

Advanced biofuels from pyrolysis oil

Options to produce a drop-in fuel

1. Co-feed of FPBO with VGO in existing FCC unit

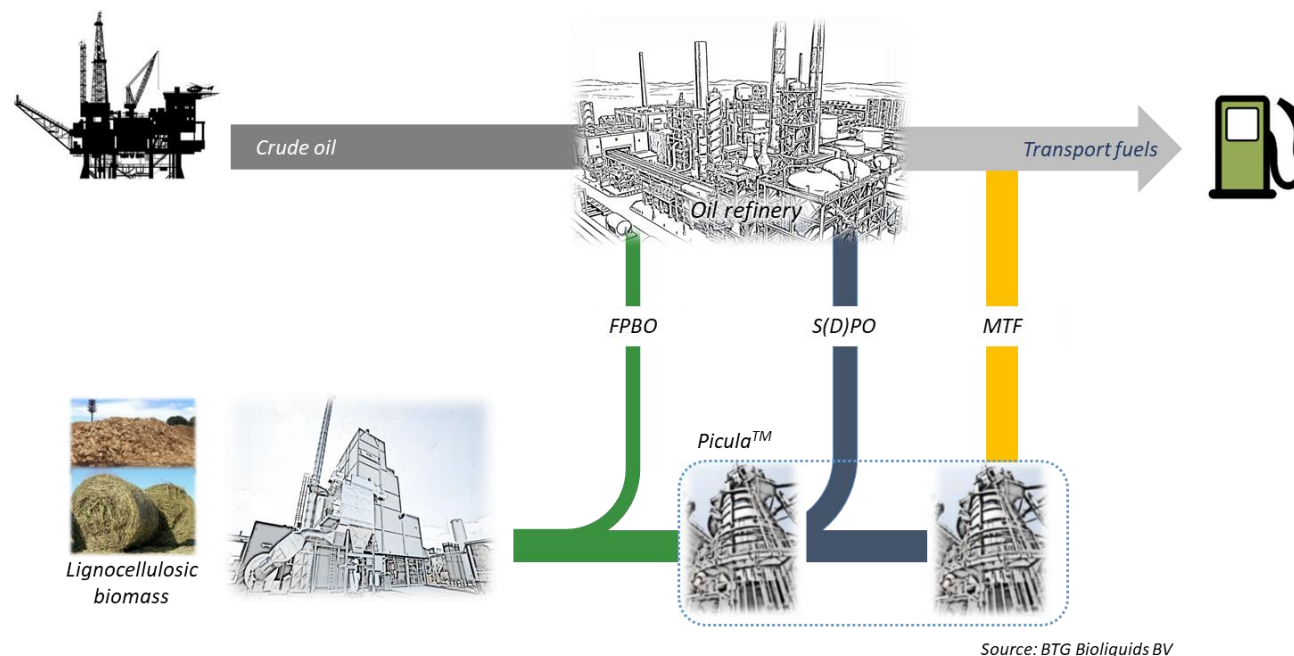
- 🔥 Extensive testing by Petrobras
- 🔥 Successful test by UOP-Preem on refinery implementation (Sept '21)
- 🔥 To be demonstrated full-scale by Preem (2022)
- 🔥 Max co-feed around 5-10 wt%

2. Co-feed of SPO with VGO in existing FCC unit

- 🔥 Lab- and pilot testing
- 🔥 Higher co-feed ratio's possible (20-30 wt%)
- 🔥 Less impact on product slate compared to crude FPBO

3. Stand-alone upgrading of FPBO to drop-in (HPO)

- 🔥 Lab- and pilot testing
- 🔥 Multi-step hydrotreating process
- 🔥 Product (HPO) is fully miscible with fossil fuels



FPBO = Fast Pyrolysis Bio-Oil
S(D)PO = Stabilized (Deoxygenated) Pyrolysis Oil
HPO = Hydroprocessed Pyrolysis Oil

Stand-alone FPBO Upgrading - Approach

FPBO



H₂



Step 1 = stabilization

- 🔥 Dedicated catalyst: PICULA™
- 🔥 Elevated pressure: 200 bar
- 🔥 Temperature ramping: 100 – 300 °C
- 🔥 Space Velocity: 0.2 – 0.5 kg_{FPBO}/kg_{cat} h
- 🔥 Product = SPO



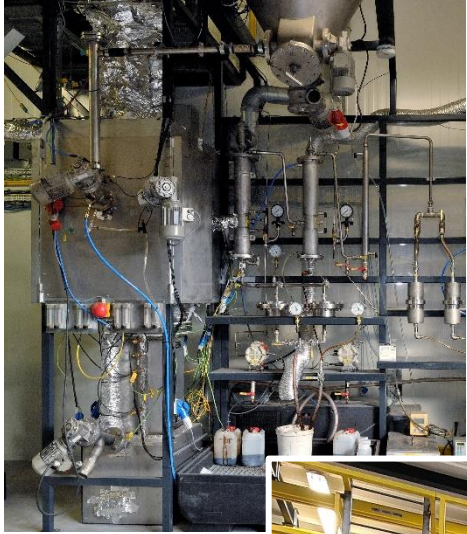
Step 2 = hydrotreatment SPO

- 🔥 Standard catalyst: sulphided NiMo/CoMo
- 🔥 Elevated pressure: 100 - 140 bar
- 🔥 Temperature ramping: 250 – 450 °C
- 🔥 Space Velocity: 0.5 – 1 kg_{SPO}/kg_{cat} h

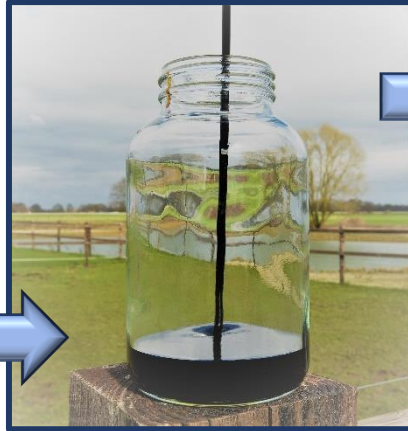


- 🔥 Overall hydrogen consumption ~ 0.05 kg_{H2}/kg_{FPBO}
- 🔥 **Product** = Hydroprocessed Pyrolysis Oil (HPO)

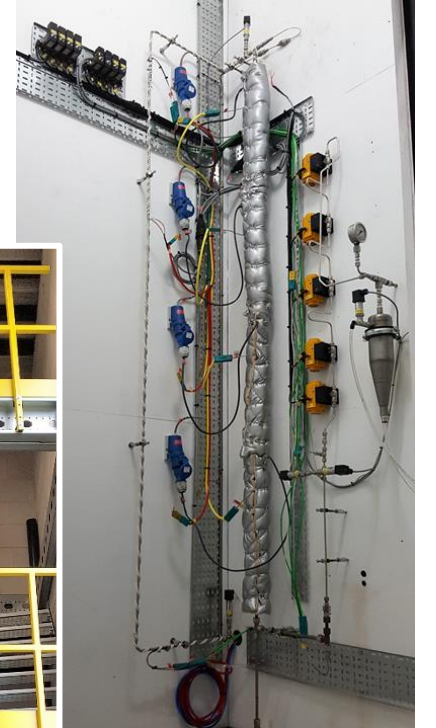
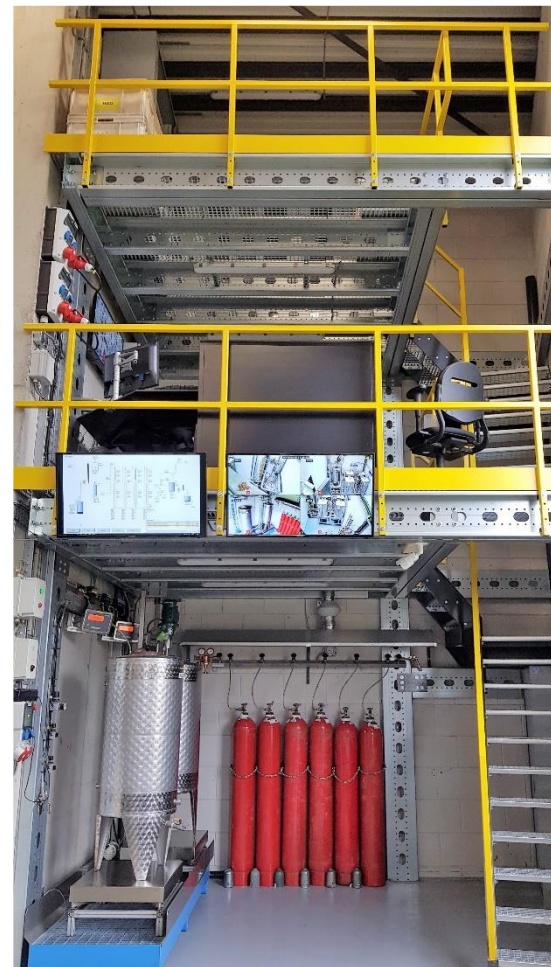
Test facilities...



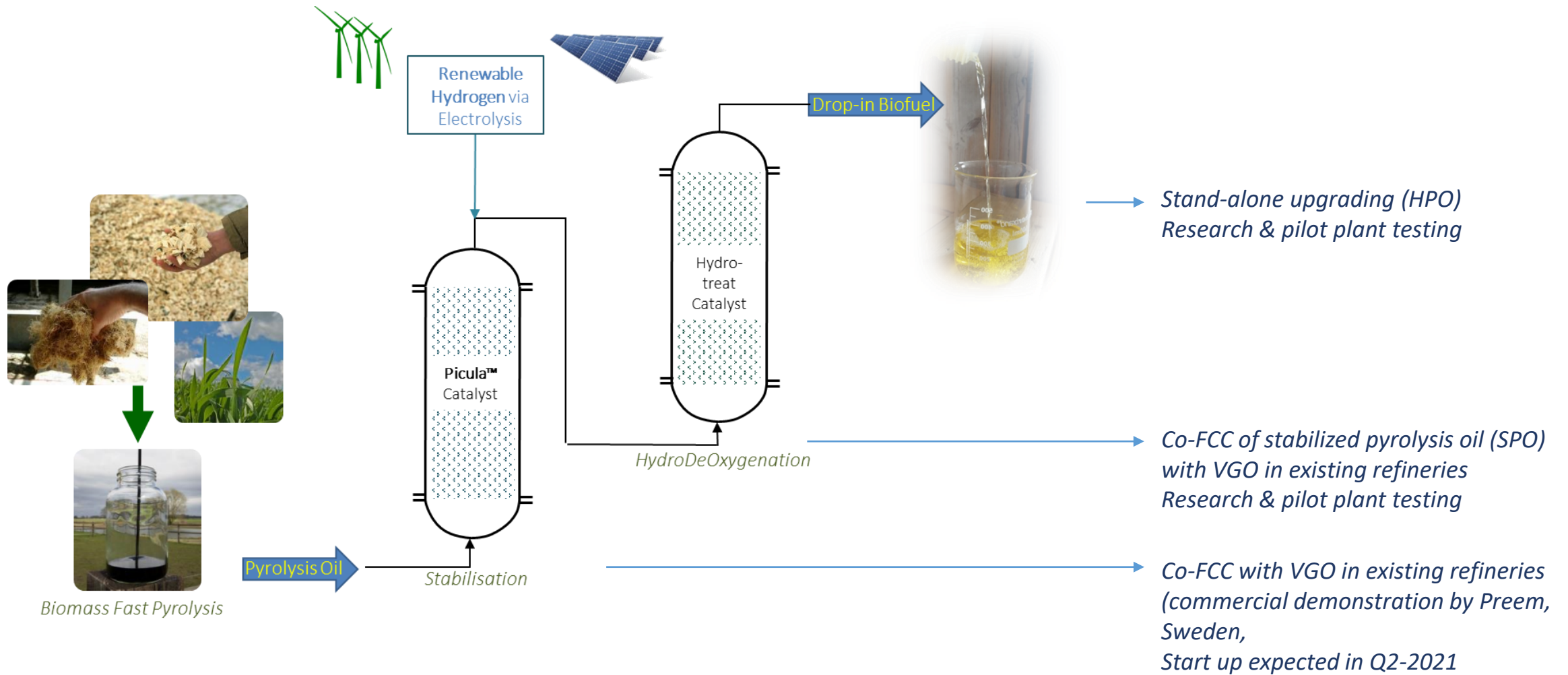
Bench- & pilot scale fast pyrolysis test facilities



Bench- & pilot scale hydrotreating facilities



Fast pyrolysis Upgrading - process

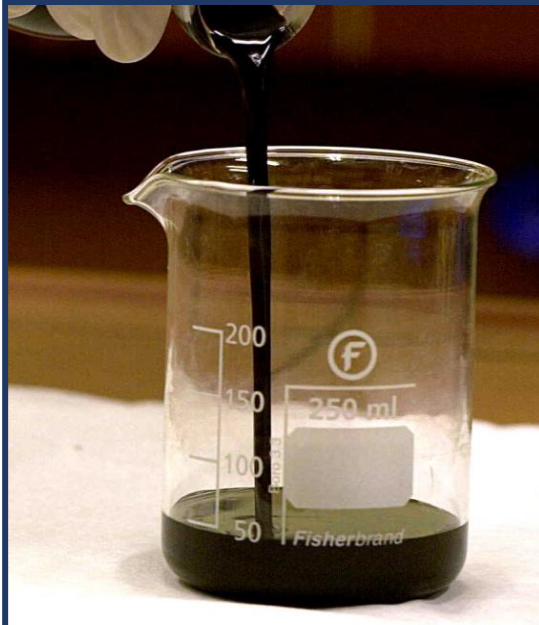


NeXt-fuel value chain for pyrolysis oil upgrading

confidential

Fuel Properties

Water content	25	wt%
Density	1,170	kg/m ³
LHV	16	MJ/kg
Acid Number	70	mg _{KOH} /g
Sulfur	< 0.05	wt%
FlashPoint	?	°C
Cetane Number	< 20	-
MCRT	> 15	wt%



Crude Pyrolysis Oil

Water content	< 0.1	wt%
Density	870	kg/m ³
LHV	> 40	MJ/kg
Acid Number	< 0.15	mg _{KOH} /g
Sulfur	< 0.05	wt%
FlashPoint	25	°C
Cetane Number	?	-
MCRT	<< 1	wt%



Biofuel from pyrolysis Oil (HPO)

Water content	-	wt%
Density	< 890	kg/m ³
LHV	42	MJ/kg
Acid Number	< 0.5	mg _{KOH} /g
Sulfur	< 0.1	wt%
FlashPoint	> 60	°C
Cetane Number	> 40	-
MCRT	<< 1	wt%



Marine Distillate Fuel (DMA)

Summary “Advanced biofuels from pyrolysis oil”

- 🔥 Fast pyrolysis bio-oil production is maturing, and commercial plants are realized in Europe (the Netherlands, Sweden and Finland)
- 🔥 Fast pyrolysis bio-oil can be upgraded to an advanced drop-in, liquid biofuel;
- 🔥 The upgrading process is based on 2-step hydrotreating process; the 1st step needs a dedicated catalyst;
- 🔥 Initial target market is the shipping sector; in particular blending the biofuel with marine distillate fuels;
- 🔥 BTG-neXt ambition is to demonstrate the FPBO upgrading on a pre-commercial scale of a few barrels/day by 2023.

