Flexible Bioenergy via Fast Pyrolysis

Bert van de Beld

Workshop Flexible Bioenergy –

24 January 2020 – Graz - Austria

btg biomass technology group

Your partner in bioenergy

Content

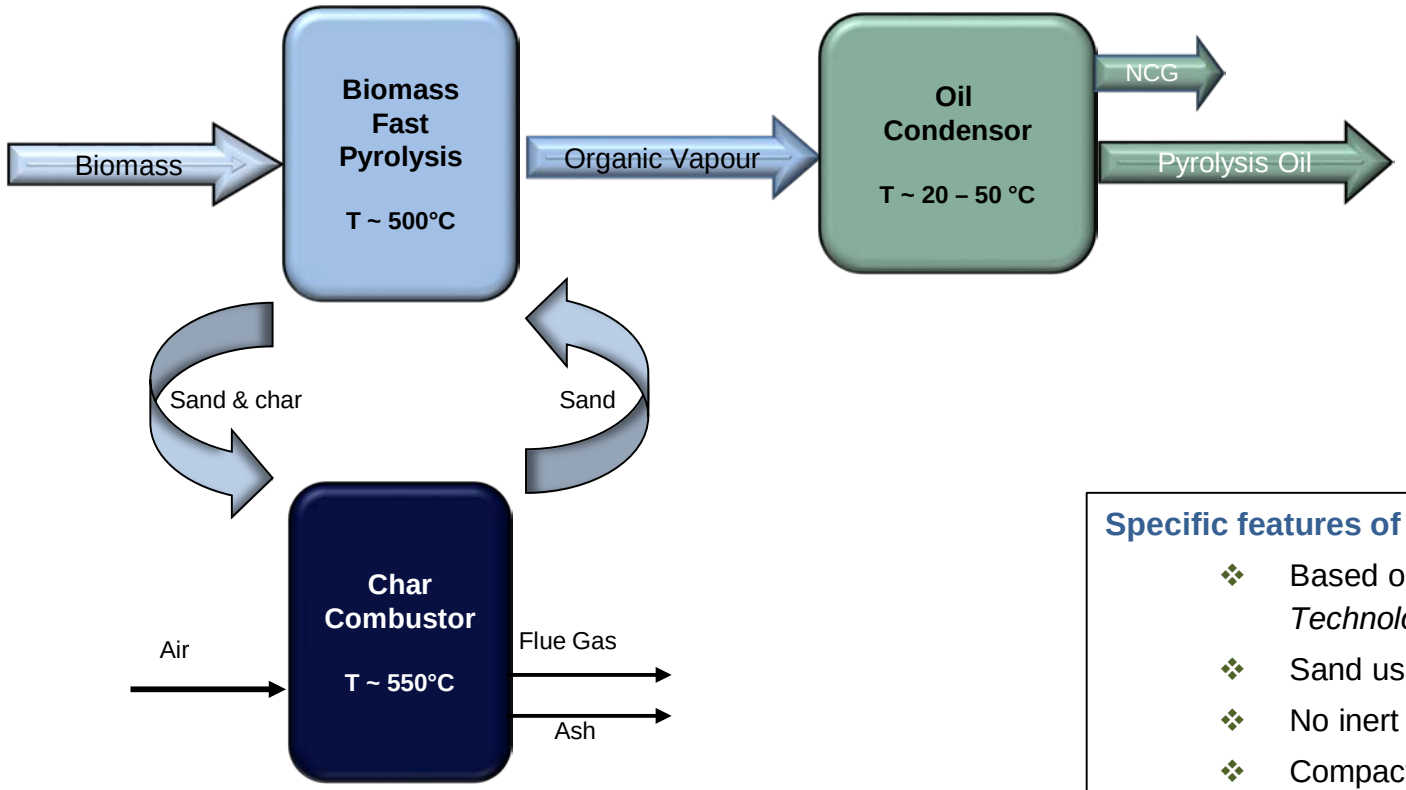
- Introduction on fast pyrolysis
- Flexibility in the fast pyrolysis process
- Flexibility on the use of fast pyrolysis oil
- Future options for flexibility
- Summary

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 °C
  - P = atmospheric

Property	Value	Unit
Water content	25	wt%
Solids content	0.02	wt%
Density	1,170	kg/m^3
LHV	16	MJ/kg
	19	MJ/L
pH	2.8	-
MCRT	17	wt%
Viscosity (40 °C))	30	cSt

Fast Pyrolysis Process



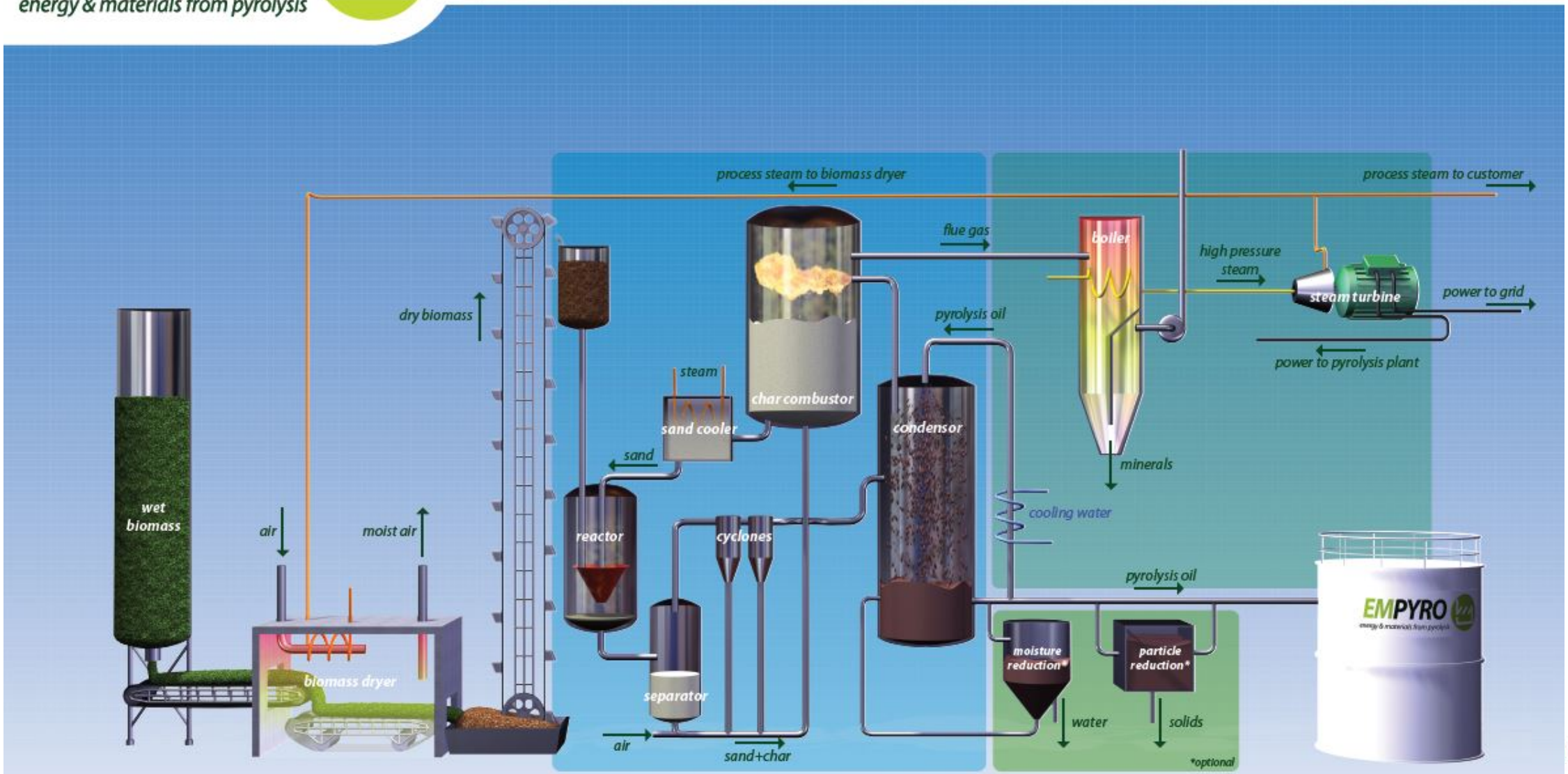
Specific features of BTG/BTL FP process:

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

Simplified representation of BTG's pyrolysis process

Fast Pyrolysis Process - *polygeneration*

EMPYRO
energy & materials from pyrolysis

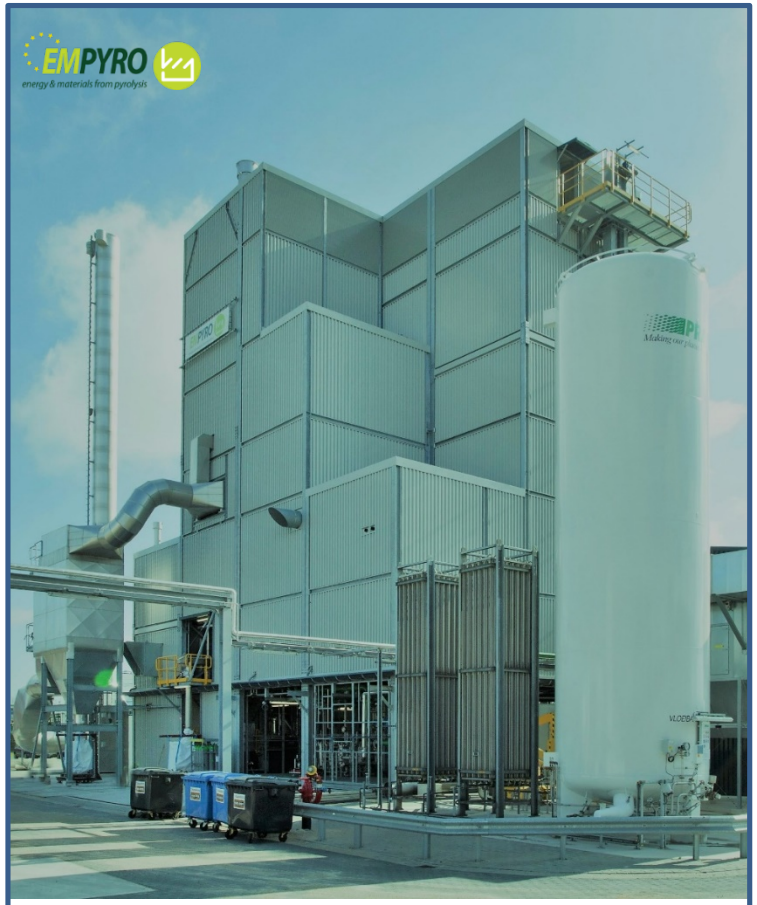


EMPYRO -Fast Pyrolysis Production Plant

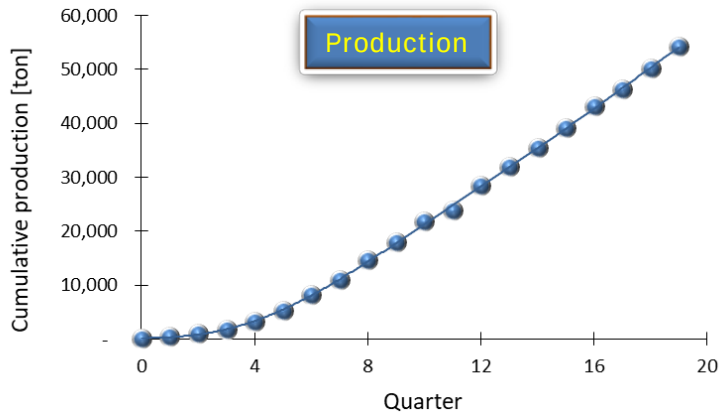
KEY FIGURES

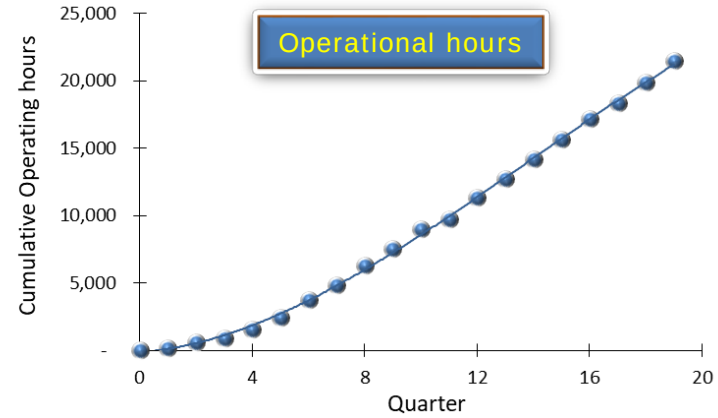
- Feedstock: clean woody biomass
- Capacity: 5 ton feed/hr (~ 25 MW_{th})
- Output:
  - 3.2 t/hr FPBO
  - 7.4 MW_{th} steam
  - 650 kW_e Electricity

- > 20,000 hrs operation
- > 45 million litre FPBO produced
- FPBO used as fuel in natural gas fired steam boiler



EMPYRO: Commercial Fast Pyrolysis demonstration plant Hengelo, the Netherlands





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Flexibility in the fast pyrolysis process ?

- (Current) Fast pyrolysis process produces simultaneously **Fuel oil**, **Process steam** & **Electricity**;

- Constant & stable operation preferred for the primary biomass conversion: avoid changes in feeding capacity & process conditions;

- Steam – electricity production directly linked to oil production; limited options to change ratio between products without affecting oil properties.

Current fast pyrolysis process offers limited options for creating Bioenergy Flexibility

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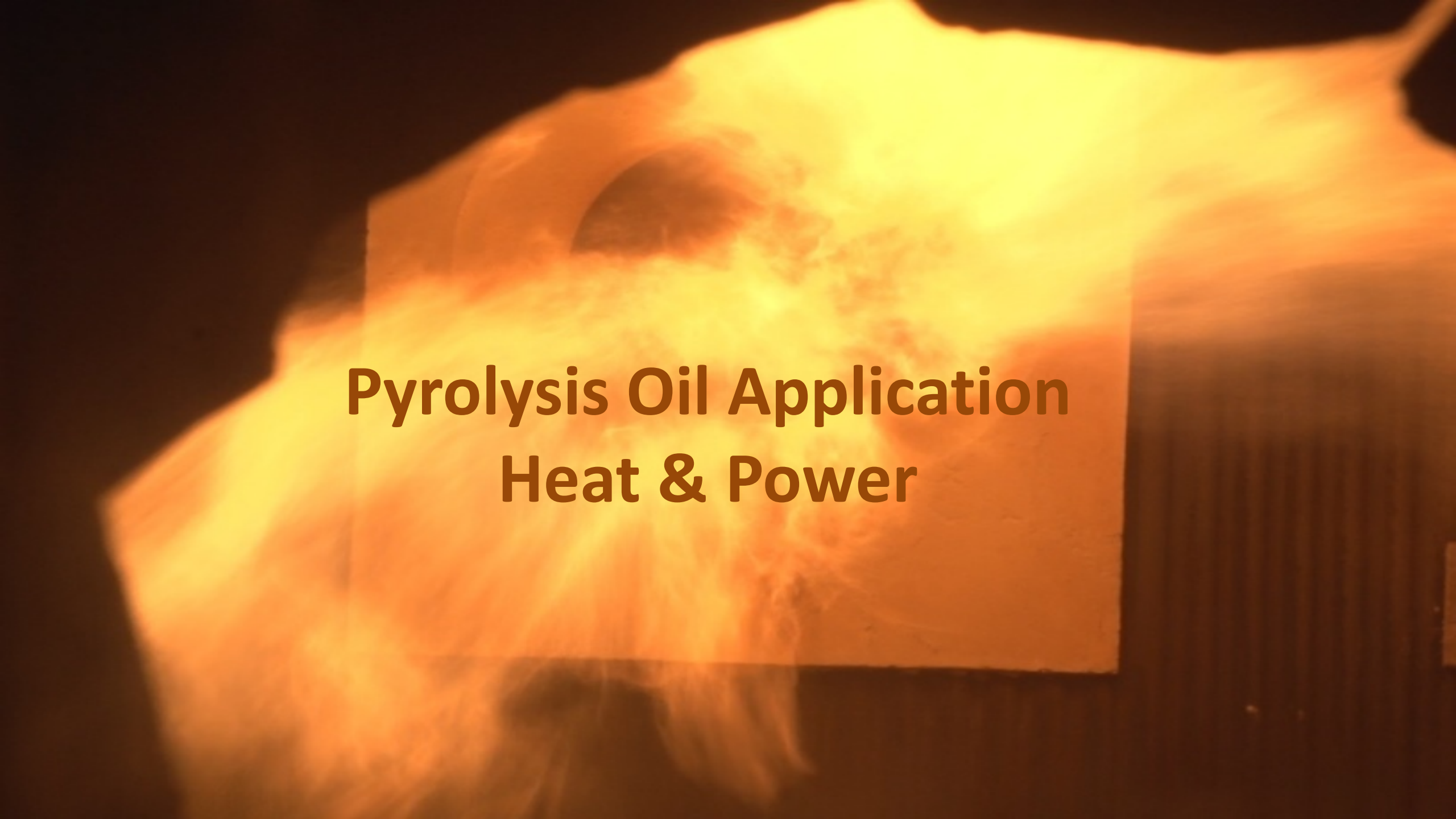

Pyrolysis Oil Application
Heat & Power

FPBO as peak or auxiliary fuel

- *Seasonal storage* as demonstrated by Fortum Joensuu. “Fortum Otso bio-oil can replace heavy or light fuel oil e.g. at heat plants and in industrial steam production. Bio-oil is ideal for applications where the steam or thermal loads fluctuate”.
- *Auxiliary fuel:* Pyrolysis oil could be used to substitute the fuel oil that is used for firing up and down coal boilers or other existing assets. (typical power plant boiler could use 1,000 and 20,000 m^3 per year) (Ref. IEA-Report: Bioenergy's role in balancing the electricity grid and providing storage options – an EU perspective)
- *Co-firing* with natural gas: demonstrated by FrieslandCampina (direct use, only intermediate storage, i.e. couple of days…); Pyrolysis oil is transported by tank truck to site. Flexibility in co-firing ratio;

Issues?

- *Long-term storage & stability:* good quality FPBO can be stored for 6 – 12 months without major complications in its use in large combustors;
- *Mismatch in cash-flow:* significant financial resources required to overcome mismatch in Costs (=FPBO production) and Income (=FPBO application/sales);

FPBO storage at Fortum (5,000 m^3)

FPBO storage at Empyro (250 m^3)

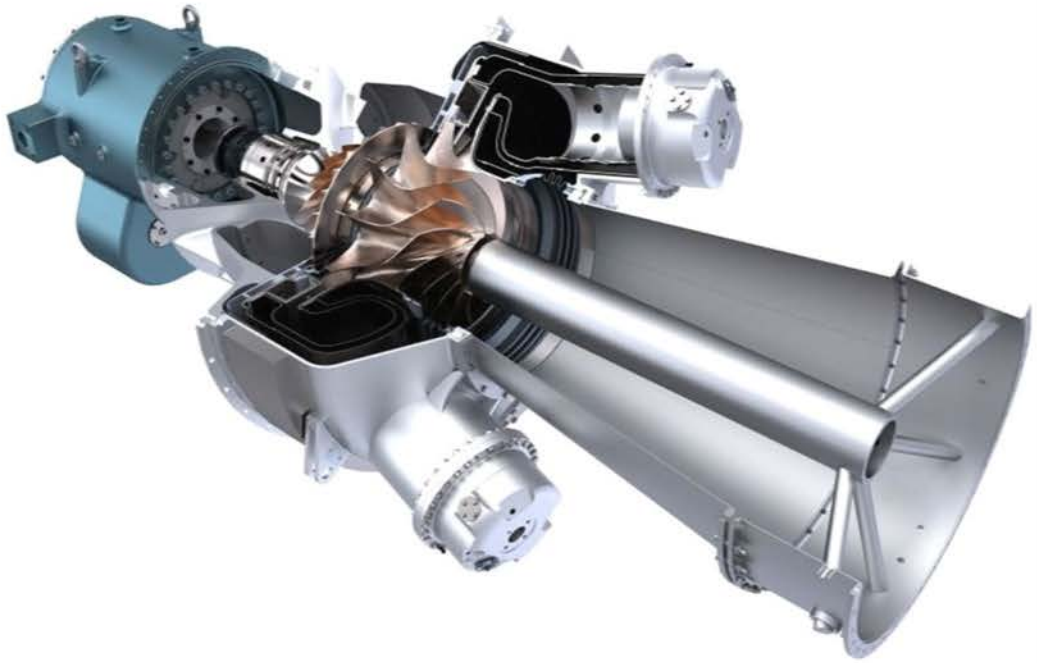
FPBO storage at FrieslandCampina (100 m^3)

Flexible power production

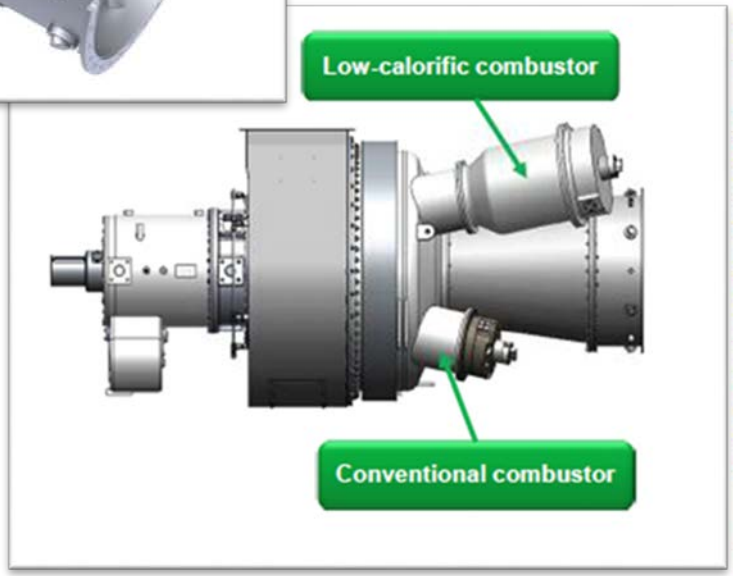
WHY IT'S UNIQUE

The OP16 Gas Turbine enables...

- ✓ High exhaust gas temperature (570 °C) to produce steam or direct drying
- ✓ High heat-to-power ratio 3:1
- ✓ Clean exhaust gas free from lube oil contamination
- ✓ Quick installation without big changes to your process
- ✓ Independent energy (heat & power) source on-site
- ✓ Low maintenance, high availability

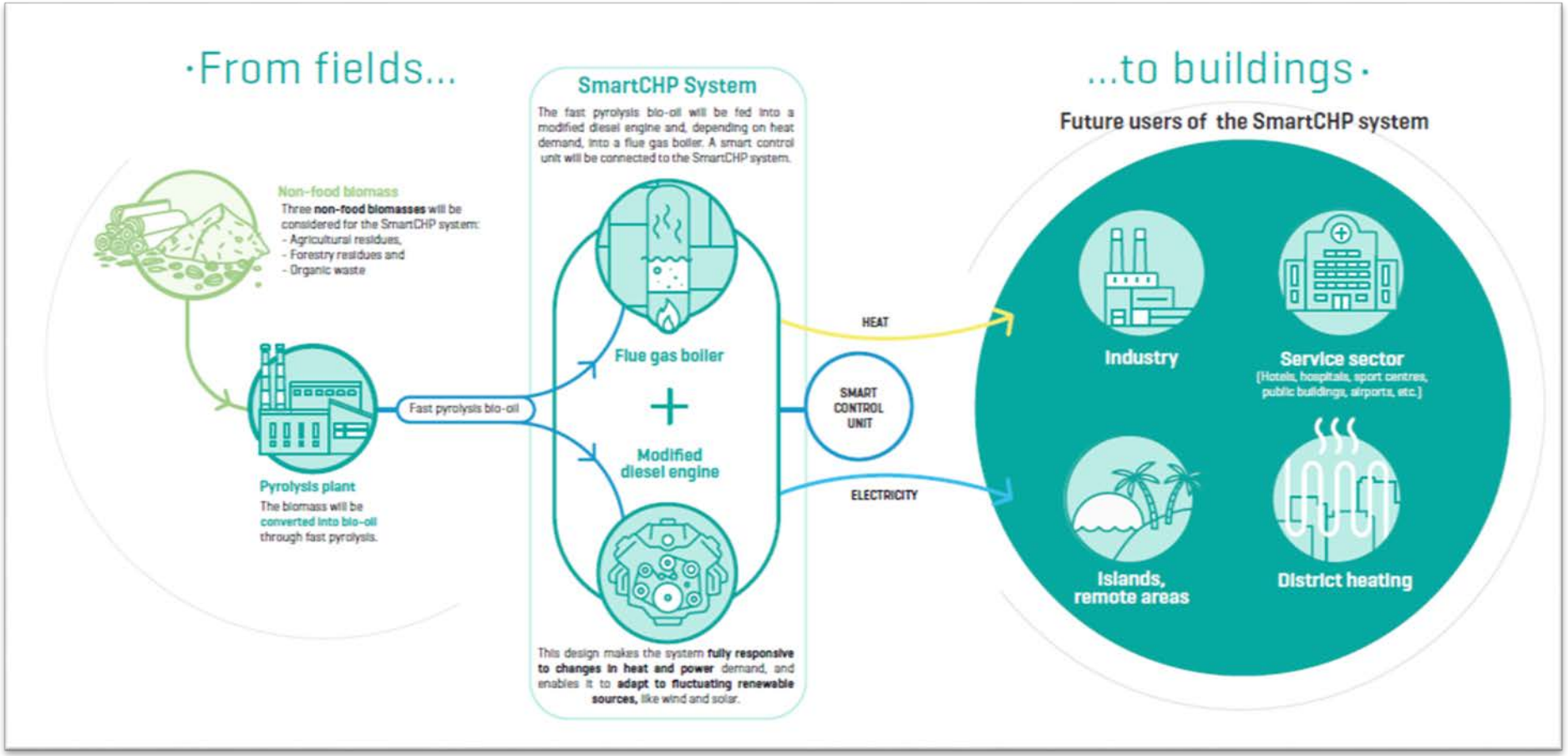


- Power production on basis of a modified gas turbine
- OPRA has developed a combustor to burn pyrolysis oil and other low-calorific fuels;
- Low heating value fuels require more time for proper burning;
- Full scale combustion chamber has been tested by Opra Turbine with pyrolysis oil;
- OPRA ready to deliver 1.8 MW_e units commercially;



Flexible power production

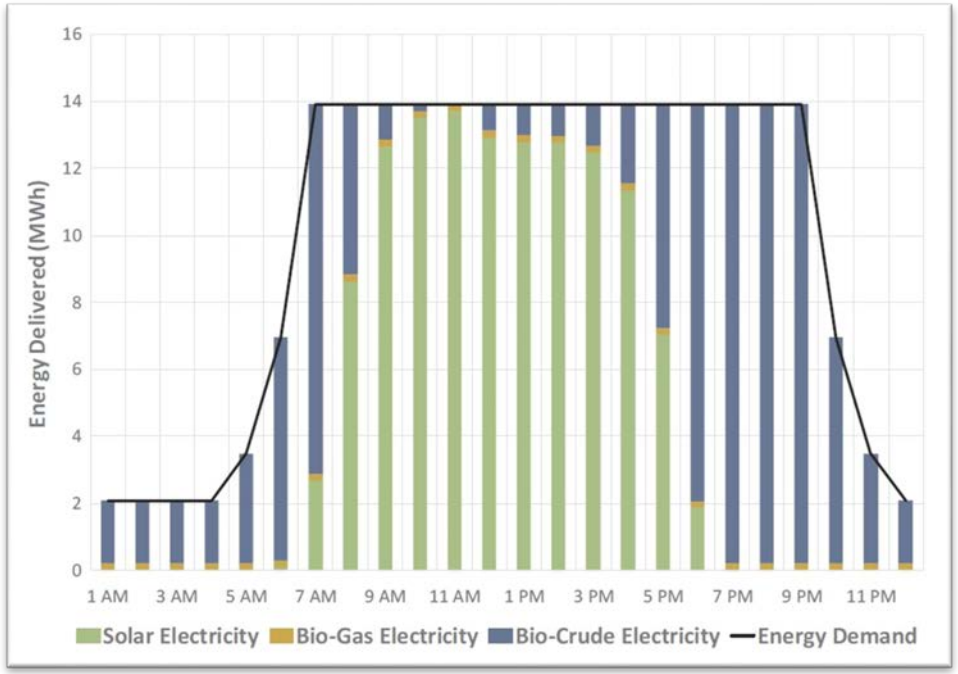
- Modified diesel engine running on FPBO;
- FPBO use decoupled from its production;
- Small-scale CHP (100 kW_e – 1 MW_e);
- Smart control to adapt to actual heat and power demand;

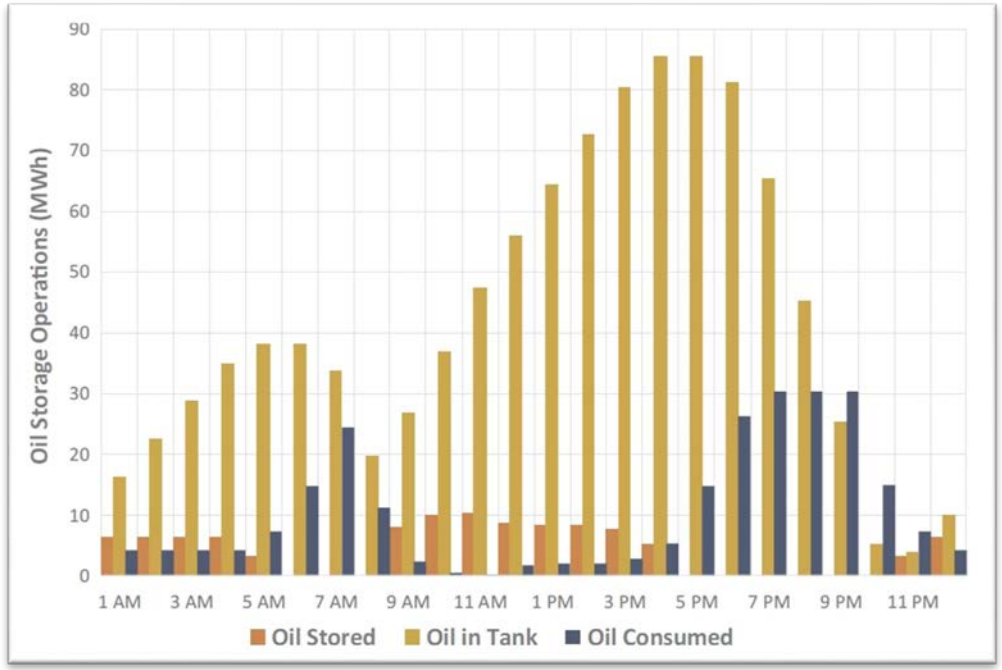


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 815259.

Example Perkins *et al*: Medium scale diesel engine

- Techno-economic assessment comparing *solar electricity + batteries* vs *solar electricity + FPBO combustion in diesel engine*
- Engine placed on site of pyrolysis plant; size match the full FPBO production
- “daily balancing”
- FPBO production constant; consumption adapted to match actual demand (- solar electricity production)
- Perkins conclusion is that this approach can be competitive with batteries





Techno-economic comparison of the levelised cost of electricity generation from solar PV and battery storage with solar PV and combustion of bio-crude using fast pyrolysis of biomass, Greg Perkins, Ventura Energy, Brisbane 4001, Australia, *Energy Conversion and Management* **171** (2018) 1573–1588


Future Flexibility ?
Electrochemistry
& Fast Pyrolysis

Add-on: Electricity storage in FPBO via Electrochemistry

Excess Electricity

Pyrolysis Oil

EC2FUEL:
Electrochemical Stabilisation & Upgrading

- Mild process conditions
- Improved Oil quality:
  - Reduced reactivity
  - Improved storage stability
  - Increased energy density

Stabilized Pyrolysis Oil

EC2FUEL – concept (Dutch TKI-project)

Low-Temperature Electrochemical Upgrading of Bio-oils Using Polymer Electrolyte Membranes, Tedd E. Lister et al, Energy Fuels 2018, 32, 5, 5944-5950

Add-on: Electrochemical conversion of NCG into fuels & chemicals

Excess Electricity

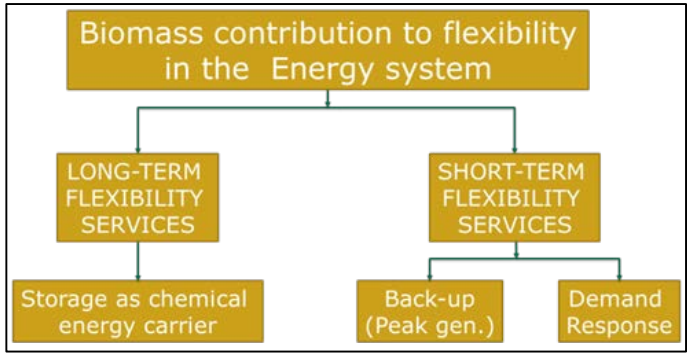
CO/CO2/CH4

Electrochemical conversion of **N**on-**C**ondensable **G**ases into fuels & chemicals

- NCG consists primarily of CO and CO_2 (undiluted)
- Potential: 1 ton CO_2 / 3 ton FPBO
- Capturing should be competitive;
- Electrochemical conversion of CO2 (and CO) into e.g. alcohols

Fuels & Chemicals

Flexibility by FPBO ?



From Task 44 – Flexibility from bioenergy

Fast pyrolysis contribution to flexibility in the energy system

Long-term flexibility services

- Energy carrier as such
- Excess Electricity storage in FPBO by ECH
- PtX by using CO_2 rich stream and excess electricity

Short-term flexibility services

- Use of FPBO as Peak fuel
- Diesel engine based CHP units
- Turbine based CHP units

Contact information

Visiting address
Josink Esweg 34
7545 PN, Enschede
The Netherlands

+31 (0)53 486 1186
+31 (0)53 786 1180

Postal address
P.O. Box 835
7500 AV, Enschede
The Netherlands

www.btgworld.com
office@btgworld.com

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