
FlexSNG

# Development of a bubbling circulating fluidized-bed reactor for biomass and waste gasification

**IConBM2022, International Conference on BIOMASS 5-8 June 2022, Naples, Italy**

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This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 101022432 and the Government of Canada's New Frontiers in Research Fund (NFRF) and the Fonds de recherche du Québec (FRQ).


# VTT Technical Research Centre of Finland

**244 M€**
turnover and other operating income

**2,129**
employees

**45%**
of the net turnover from abroad

**32.5%**
a doctorate or a licentiate's degree

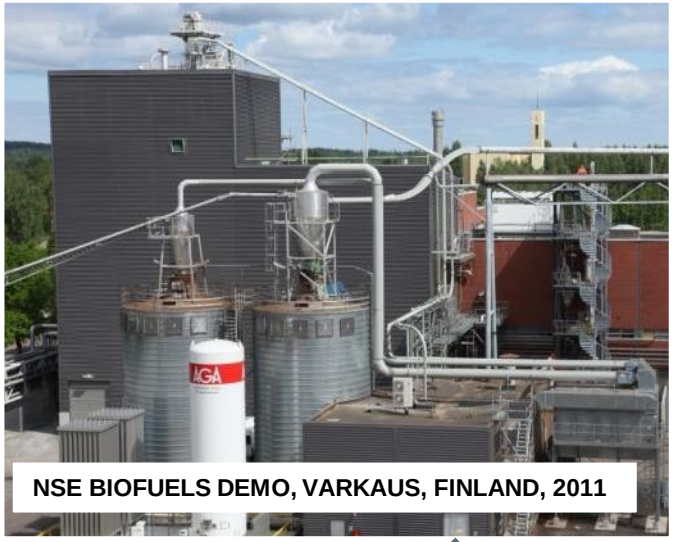
Established in
**1942**

Owned by Ministry of Economic Affairs and Employment

# Biomass gasification for biofuels and bio-chemicals

## Long experience of medium-to-large scale synthesis gas technologies

PEAT AMMONIA PLANT
OULU, FINLAND, 1991



NSE BIOFUELS DEMO, VARKAUS, FINLAND, 2011

**Hybrid process** integrating biomass gasification and electrolysis – operating the same plant with biomass alone and boosted with electrolysis $H_2$ http://www.flexchx.eu/

**Co-production of Bio-char and synthesis gas** at a plant that can be operated in a maximized gas yield mode or in co-production mode https://www.flexsng.eu/

1985 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030

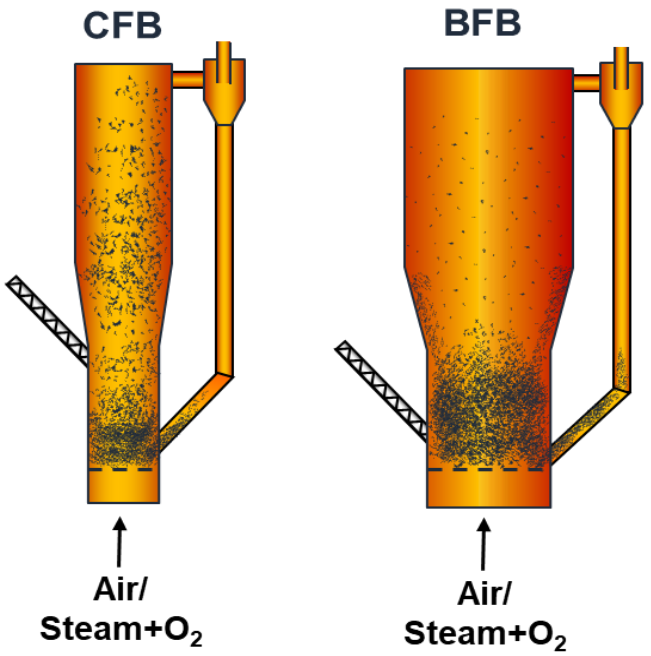
COAL GASIFIER APPLIED FOR PEAT AND WOOD

LARGE-SCALE GASIFICATION SPECIALLY DEVELOPED FOR WOOD FEEDSTOCKS

PROCESS DEVELOPMENT FOR LOWER CAPEX, WASTES AND FLEXIBLE OPERATION

# Basic Fluidized-bed reactor types

Circulating FB Bubbling FB



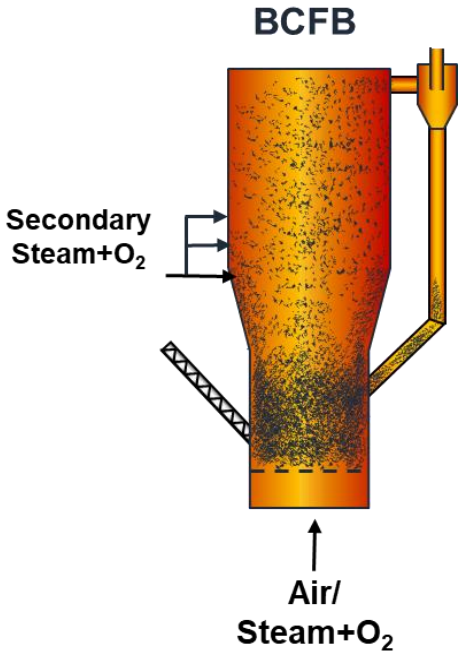

## CFB gasifier

- High carbon conversion because recycling charcoal meets oxygen at the bottom of the bed
- Ash and bed additive calcium are crushed into fine particles which pass through the cyclone
  → less sensitive to ash sintering and fouling
- Highly reliable and stable process
- Residence time is short resulting in higher tar content

## BFB gasifier

- Longer residence time and better contact with the bed material = lower tar contents
- More sensitive to feedstock particle size and ash composition (alkalis retained in the bed)
- Cyclone recycling line gets easily blocked by fine low-bulk density biomass char
- Lower carbon conversion and oxygen reacts with volatile matter instead of recycling char

# Fluidized-bed reactor types - BCFB




BBCFB = Bubbling Circulating Fluidized Bed

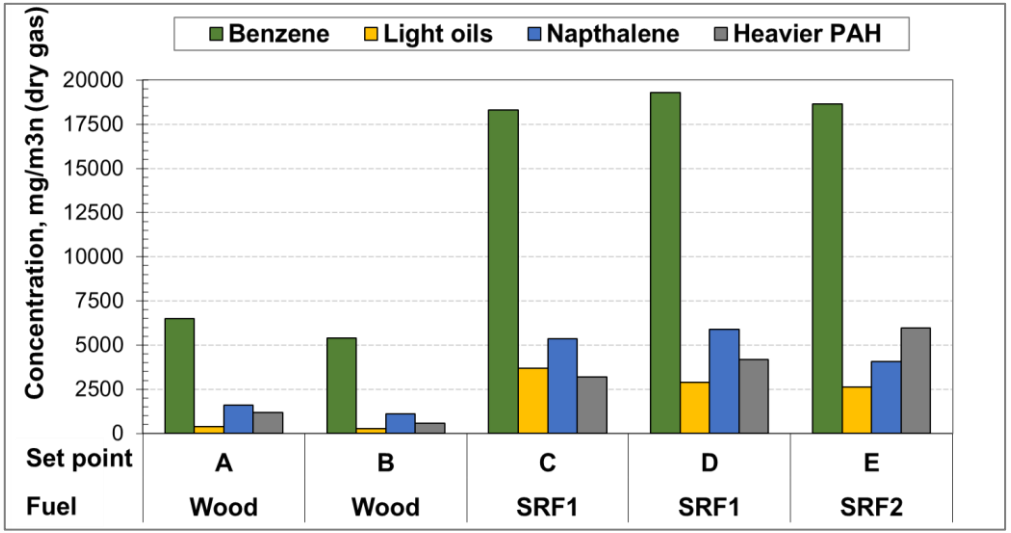
- A combination of a bubbling fluidized-bed (BFB) bottom and a circulating fluidized-bed (CFB) top
- Solves the problem of recycle line blockages typical to BFBs
- Makes it possible to operate the bed at lower temperature and freeboard at higher

BCFB operation achieved by

- Cyclone recycle connected to the upper part of the dense bed of the BFB reactor
- Mixture of coarse and fine bed material is used
- Fuel is fed into the lower part of the dense bed

# Waste gasification tests at 1 MW BCFB pilot

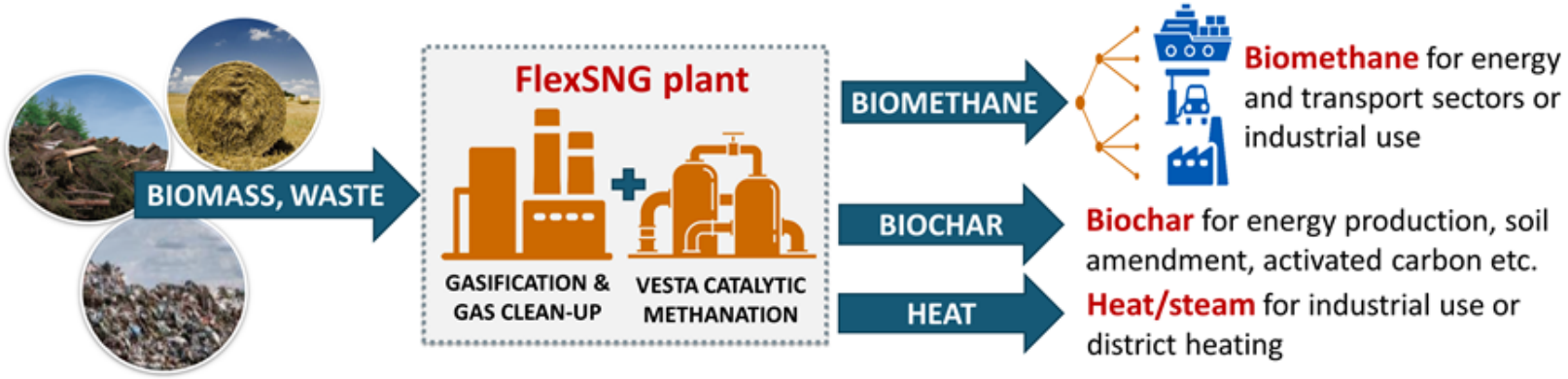
- Tests carried out with demolition wood and different types of Solid Recovered fuels (SRF) representing household and industrial waste streams
- Results presented in the paper published in the CET journal




Gasification of plastic-containing wastes yields significantly more tars and hydrocarbon gases than wood gasification.

# FlexSNG project

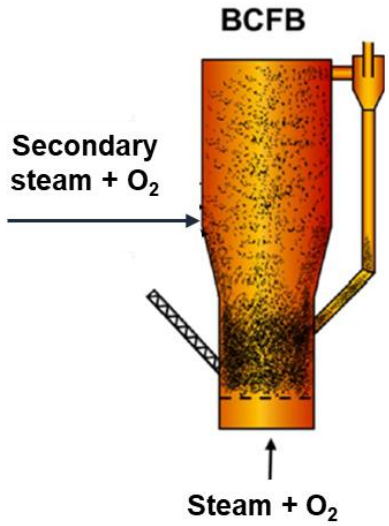
Our vision is to develop and validate (TRL5) a **flexible and cost-effective gasification-based process** for the production of **pipeline-quality biomethane**, **high-value biochar** and **renewable heat** from a wide variety of **low-quality biomass residues and biogenic waste feedstocks**.




- EU-H2020 RIA project: **"Flexible Production of Synthetic Natural Gas and Biochar via Gasification of Biomass and Waste Feedstocks"**
- Duration: 36 months (1 June 2021 – 31 May 2024)
- EU funding: ~ 4.5 M€

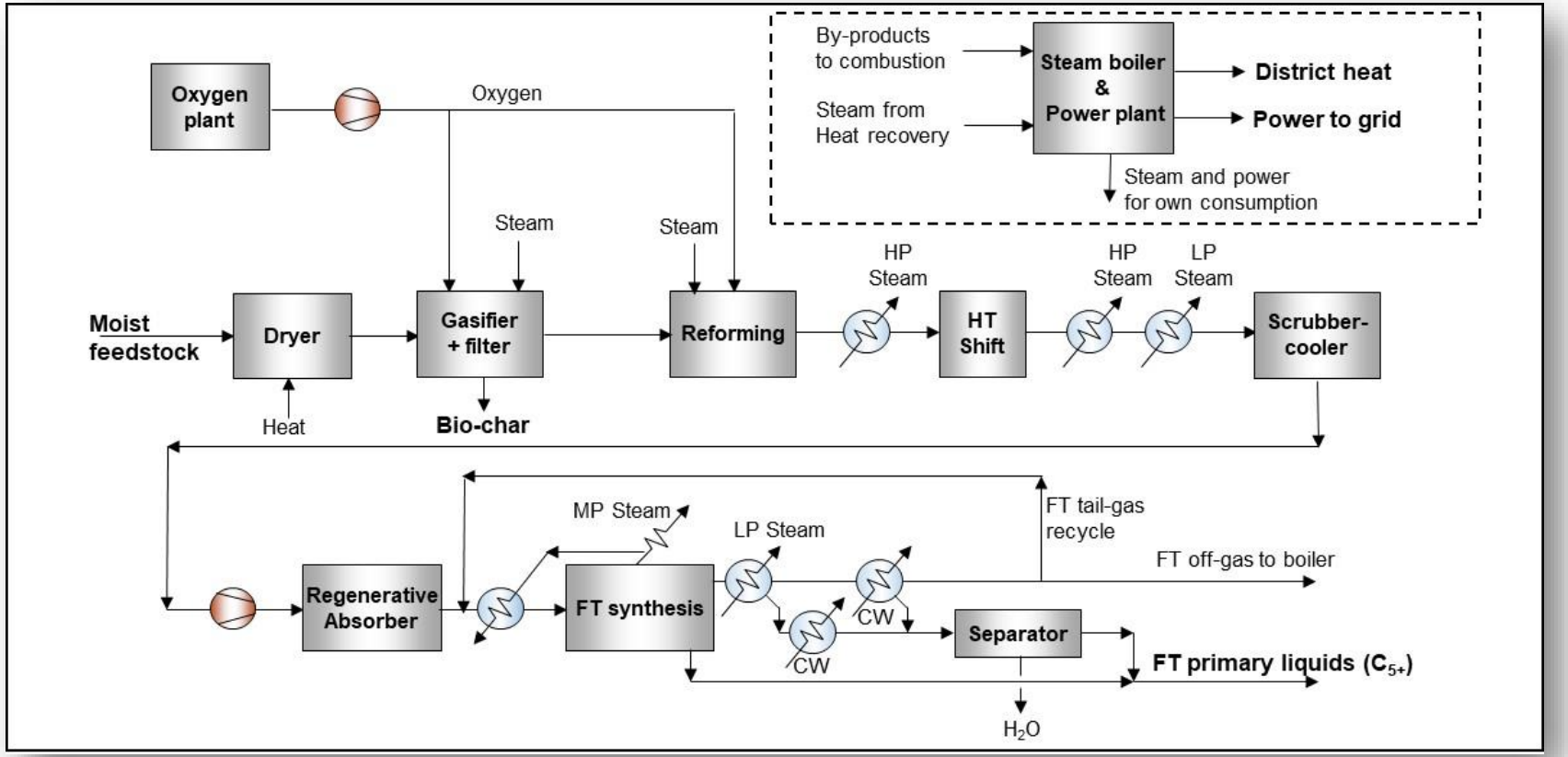
# Bubbling Circulating Fluidised-Bed (BCFB) gasifier

- A combination of a bubbling fluidized-bed (BFB) bottom and a circulating fluidized-bed (CFB) top
- Developed already in the early 2000's for lower grade feedstocks and tested back then in fuel gas applications with waste fuels – now adapted for co-production of syngas and biochar
- **<u>Co-production of biomethane and biochar:</u>**
  - Lower bed section acts as the carbonization zone - operated below 800 °C
  - Partial decomposition of tars in the upper part of the gasifier – temperature elevated to 820-900 °C through secondary oxygen + steam injection
  - ~20% of biomass carbon converted to biochar
- **<u>Maximised production of biomethane:</u>**
  - Operation similar to a traditional CFB gasifier (operated at 850-900 °C) - more uniform temperature profile in the gasifier
  - > 99% carbon conversion achieved in gasification
  - Biochar can be used as co-feed to "upgrade" more challenging feedstocks (e.g. wastes, industrial sludges) as suitable feeds for gasification

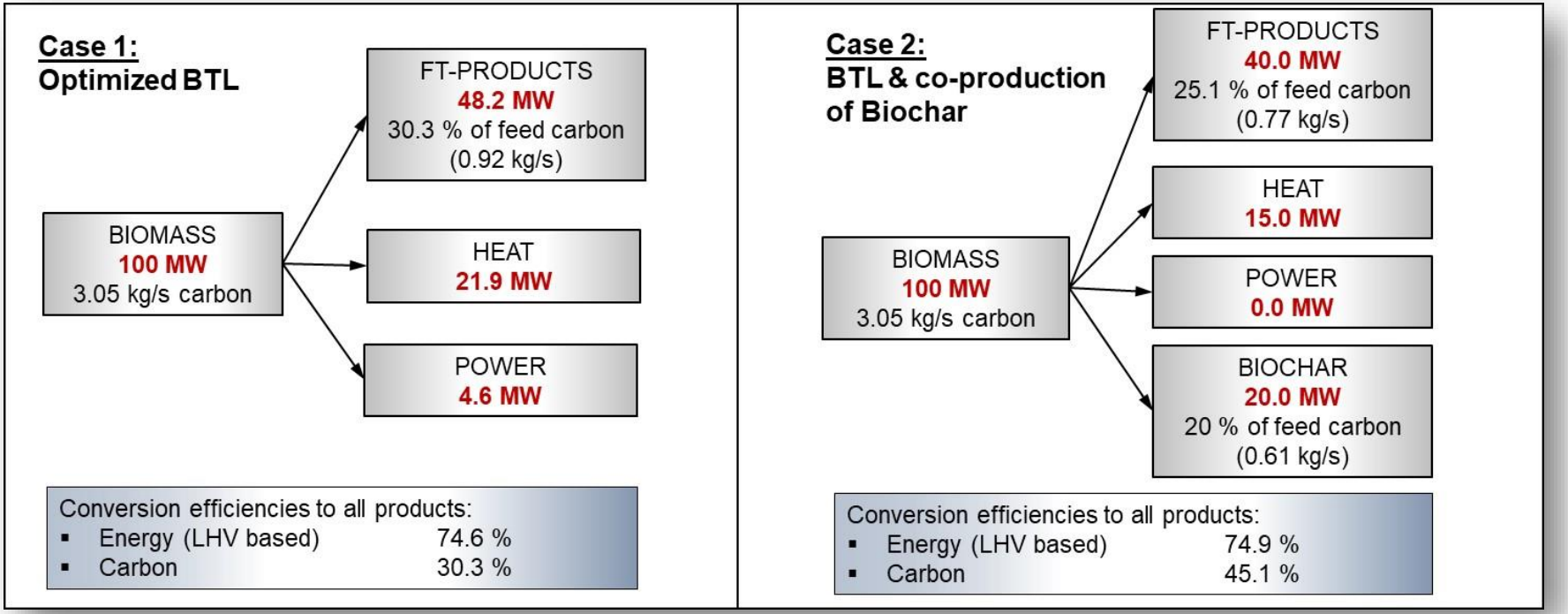


# Preliminary studies for a co-production plant

- Prepared based on previous VTT studies focused on FT synthesis
- In the FlexSNG-project studies on Synthetic Natural Gas production will be carried out



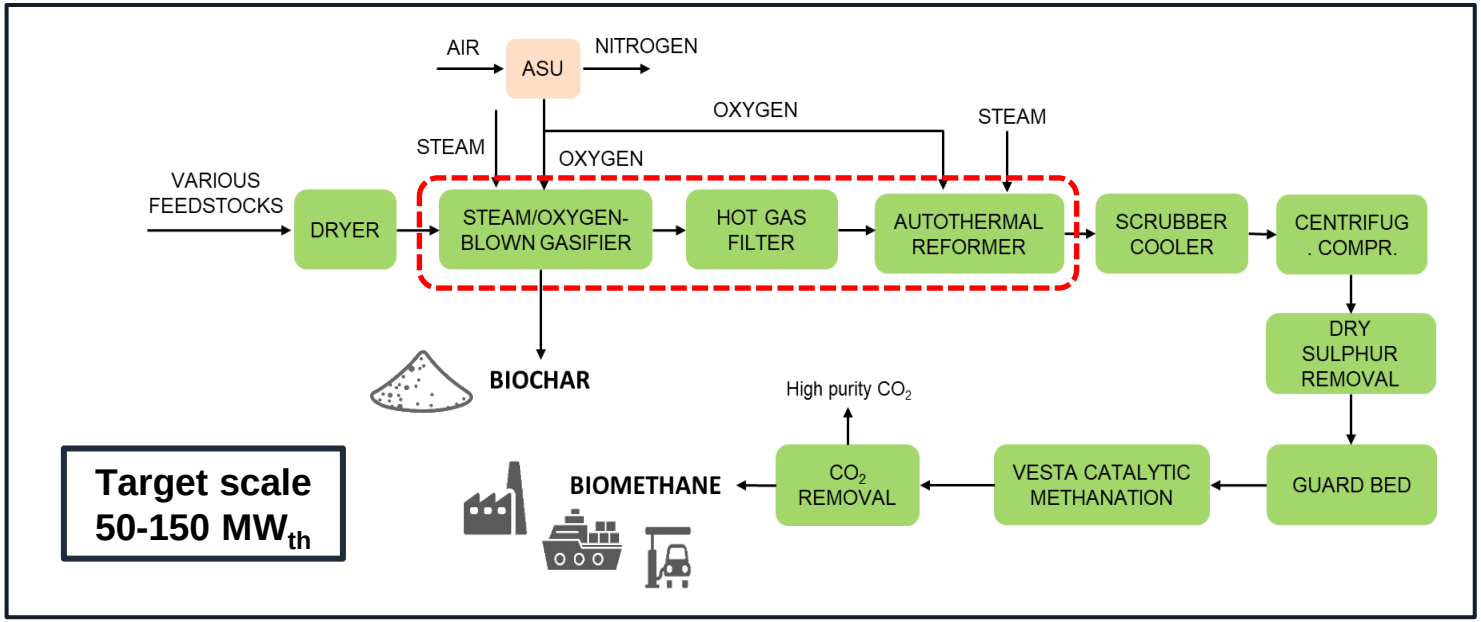
# Estimated mass and energy balances of the plant operated under maximed BtL and Co-production modes



# FlexSNG concept for flexible production of SNG and biochar

One plant, **two operation modes**:

1. **Co-production of biomethane, biochar and heat:** 45% conversion to biomethane, 25% to biochar and 10% to usable heat.
2. **Maximised production of biomethane and heat:** 70% conversion to biomethane and 15 % to heat.



# Biochar compositions
## Test campaign in January 2022 (BCFB 22/04)

| Sample | Biochar: sieved from bottom ash Jan. 2022 | Filter dust Jan. 2022 |
|---|---|---|
| Set point | BCFB 22/04D2 | BCFB 22/04D2 |
| LHV, MJ/kg (d.b.) | 27.1 | nd |
| PAH, mg/kg | 0.77 | 26 |
| Dry matter analysis, wt % | | |
| C | 68.1 | 78.3 |
| H | 1.4 | 1.0 |
| N | 0.3 | 0.4 |
| S | 0.03 | 0.06 |
| O (as difference) | 7.4 | 4.1 |
| Ash | 22.6 | 16.1 |
| Cl | <0.025 | < 0.03 |

Biochar – sieved from bottom ash

Filter dust

Samples are from gasification test campaign carried out in Jan. 2022 within the FlexSNG project.

# Conclusions

- BCFB gasifier is combination of a bubbling fluidized-bed (BFB) bottom and a circulating fluidized-bed (CFB) top – this design has been validated by pilot tests at VTT
- Flexible synthesis gas production concepts are being developed at VTT
- Firstly, flexibility is targeted by combining the use of biomass gasification and electrolysis operated with renewable electricity
- Secondly, clean syngas can be utilised to produced a wide variety of end products, including transport fuels and chemicals
- Finally, a concept for co-producing  Biochar and renewable methane is being developed in an EU-Canada collaboration project FlexSNG

# Thank you!

FlexSNG

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https://www.linkedin.com/company/flexsng-project-h2020/

https://twitter.com/flexSNG

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