Validation tests of flexible fluidised-bed gasification process for co-production of synthesis gas and biochar

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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

PILOT PLANT AT VTT BIORUUKKI, ESPOO, 2022

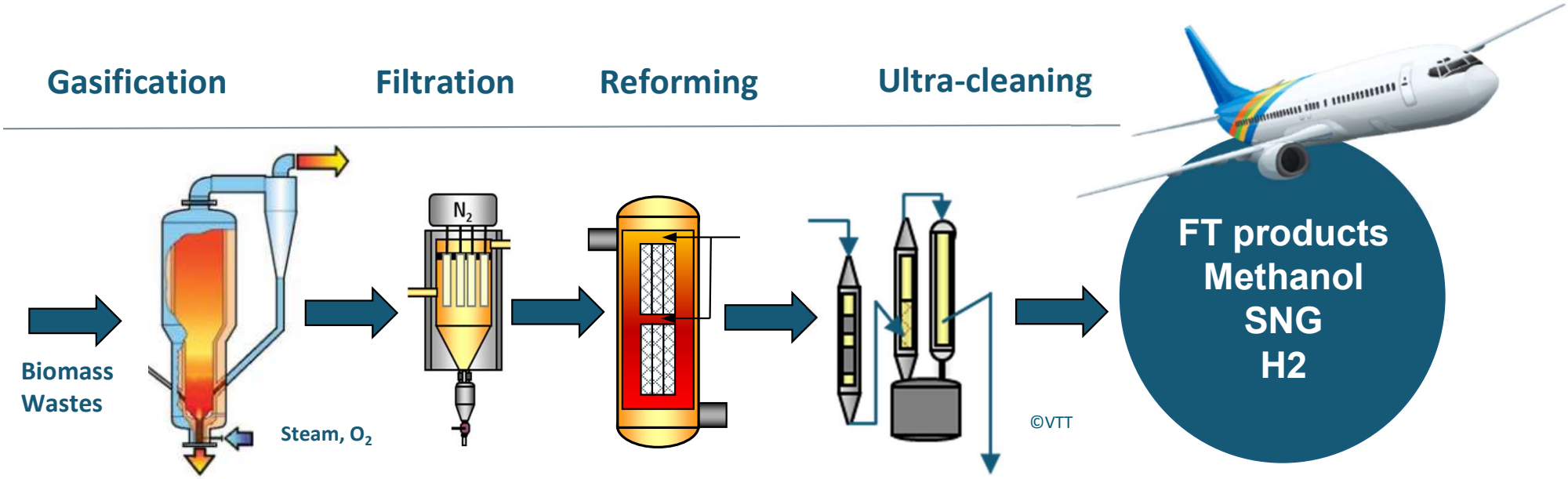
1985 | 1995 | 2000 | 2005 | 2010 | 2015 | 2020 | 2025 | 2030

COAL GASIFIER APPLIED FOR PEAT AND WOOD

LARGE-SCALE GASIFICATION SPECIALLY DEVELOPED FOR WOOD FEEDSTOCKS

PROCESS DEVELOPMENT FOR LOWER CAPEX, HIGHER CARBON UTILIZATION AND WASTES

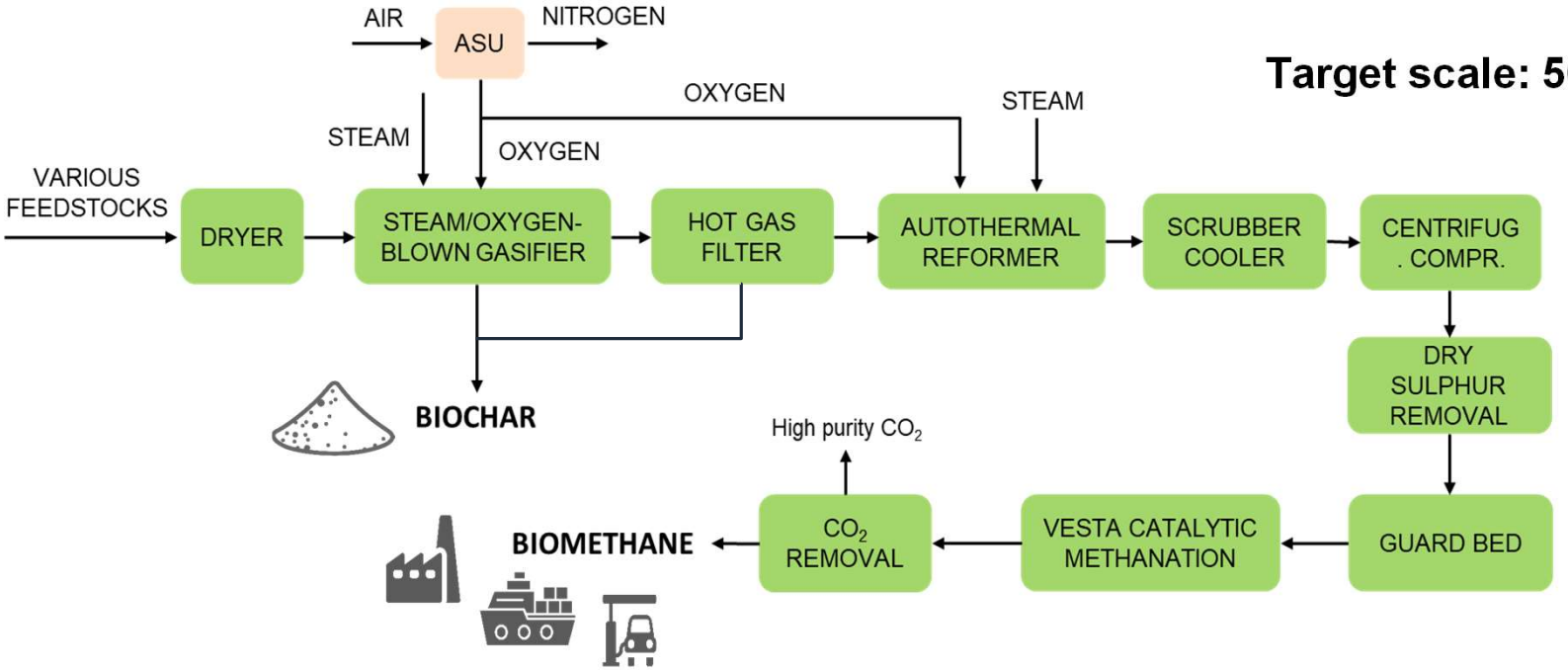
Key steps in the gasification-synfuels process of VTT



Technological basis – TRL7

- Air-blown CFB gasifier commercial, **steam/O_2-blown demonstrated at 12 MW**
- Filtration demonstrated at 5 MW scale, commercial in air-blown gasification
- **Reforming demonstrated at 5 MW scale**
- Final gas cleaning commercial (similar to coal gasification)

FlexSNG concept for flexible production of SNG and biochar

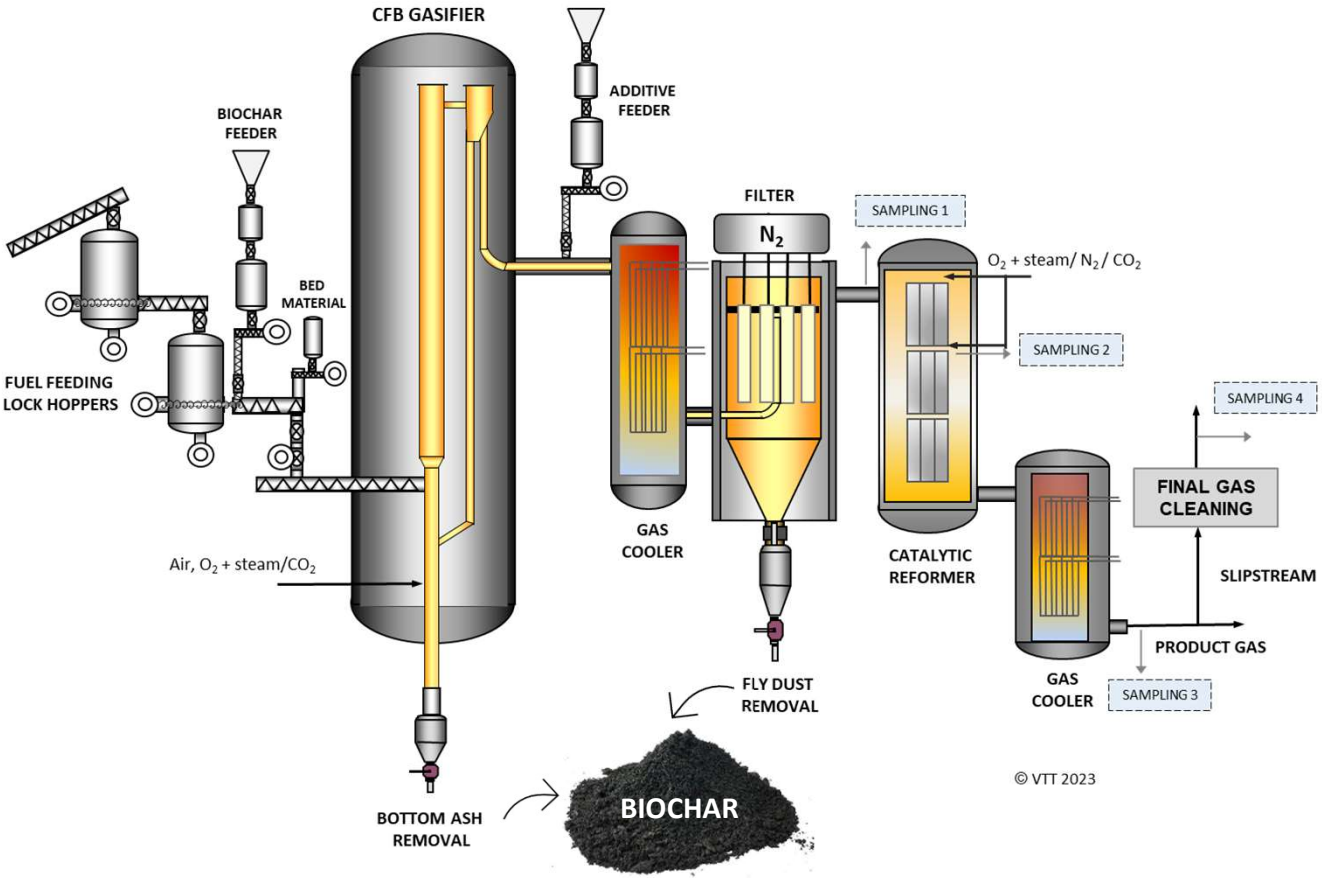


Target scale: 50-150 MW_{th}

One plant, **two operation modes**:

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

VTT's pressurized O_2/steam-blown CFB gasification pilot plant at Bioruukki



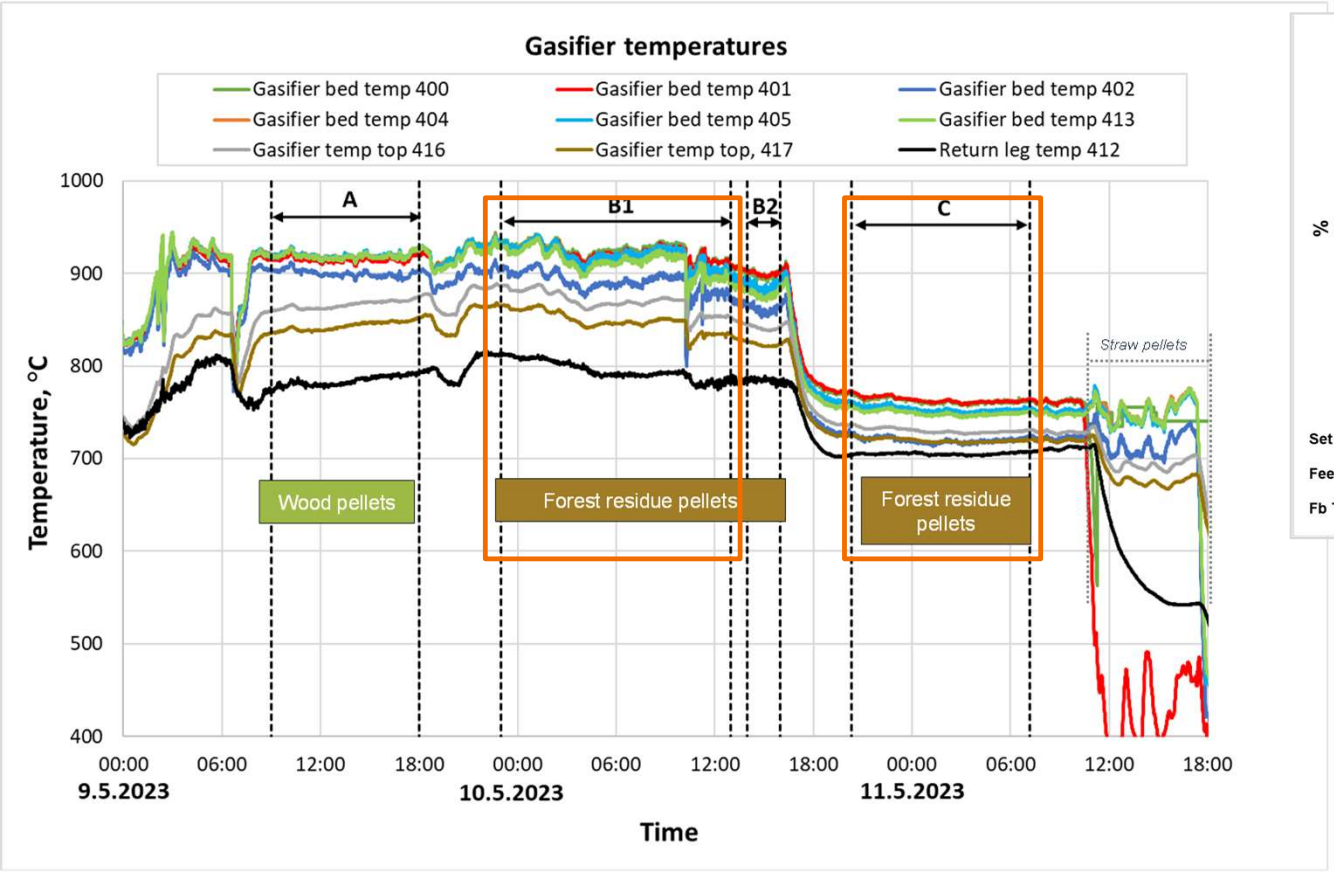
Operation in biochar co-production and maximized syngas production modes

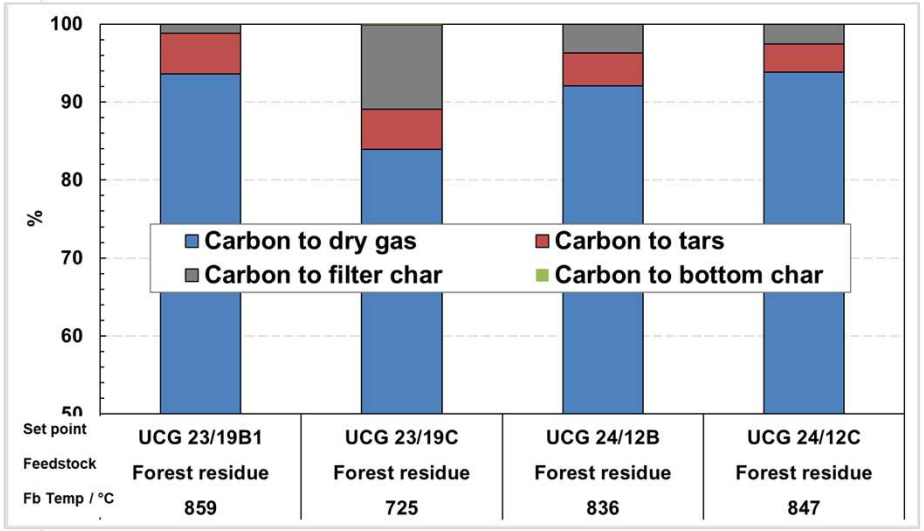
CFB gasifier "UCG2021"	
Plant capacity, MW	0.2-0.5
Operation pressure, bar	1 - 8
Temperature range, °C	750 - 920
Gasification agents	Air, O_2 + Steam/CO_2
Feedstocks	Biomass residues, wastes
Feed rate, kg/h	max. 100 kg/h
Gas velocities, m/s Fluidizing velocity at the bottom of bed Gas velocity at the top of reactor	 1 - 3 1.5 - 3
Reactor (i.d.), mm Lower part Upper part	 150 225
Reactor height, m Total height	 7.5

Feedstocks in validation tests

Test campaign	23/19 23/44 24/12	23/19 24/12	23/19	23/44	23/44	23/44
Feedstock (pellets)	Wood	Forest residue	Straw	Waste wood	Biochar	SRF
LHV, MJ/kg (d.b.)	18.9	19.3	17.6	18.9	32.2	21.4
Moisture, wt-%	7.5	11.7	10.2	7.5	~2-3**	3.4
Volatile matter, wt-%	78.0	75.0	76.1	79.4	7.4	74.2
Fixed carbon, wt-%	21.7	20.7	19.3	19.1	91.1	7.3
Dry matter analysis, wt-%						
C	50.2	49.8	44.8	50.2	91.4	50.0
H	6.5	5.7	6.2	5.9	1.7	6.4
N	<0.1	0.5	0.7	0.5	0.6	1.0
O (as difference)	42.9	39.6	43.5	41.8	4.7	21.8
Ash	0.3	4.4	4.6	1.5	1.5	18.6
S	0.01	0.049	0.10	<0.1	<0.1	0.60
Cl	0.002	0.022	0.15	0.019	nd	1.67

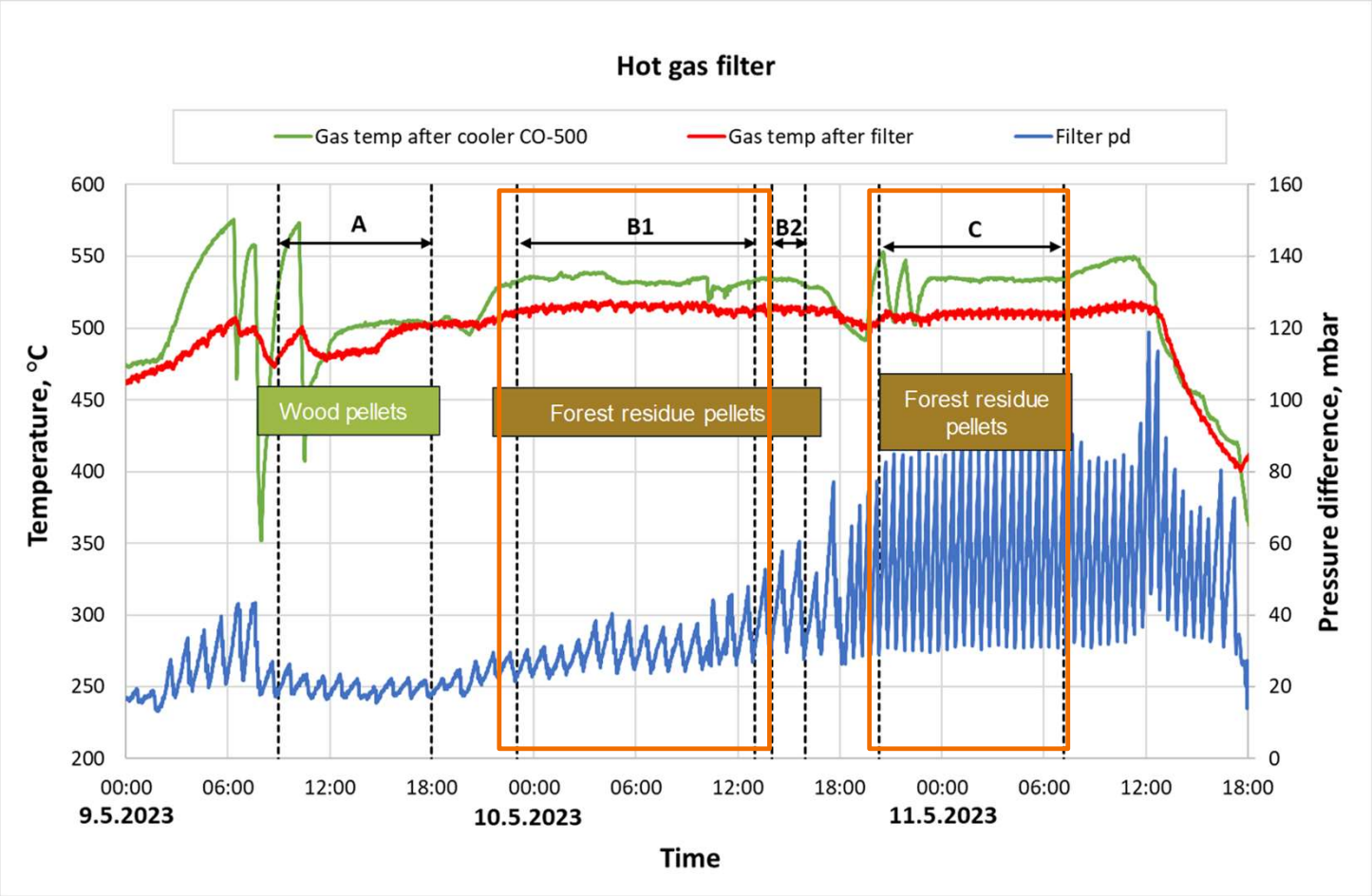
Gasifier operation in co-production of biochar and maximized syngas production modes





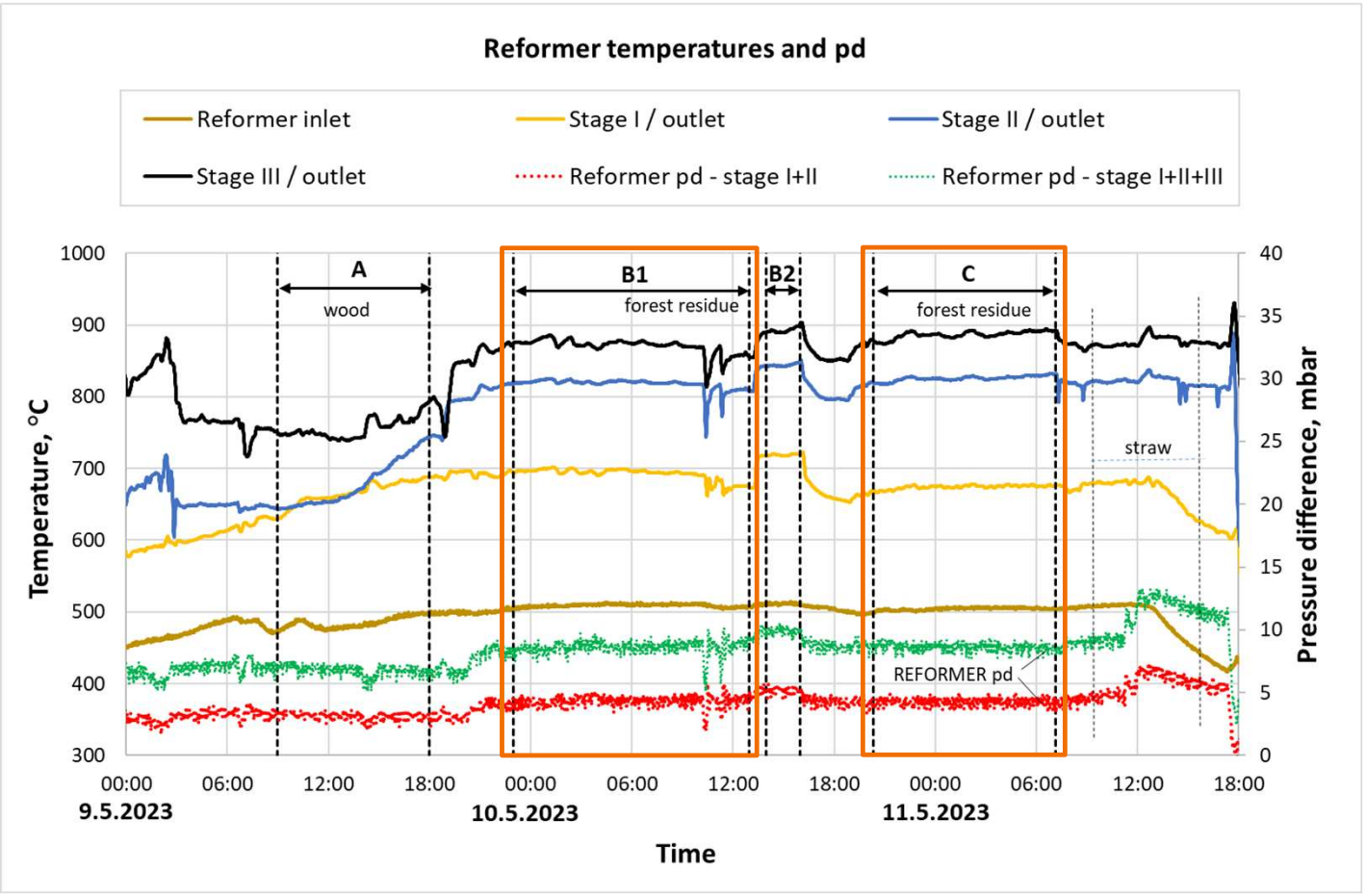
- CFB gasifier at 850-900 °C operation temperature carbon conversions of the order of 97-98 % are reached.
- With forest residues the biochar yield could be raised to ca. 11 % by reducing the gasification temperature from 860 to 725 °C.

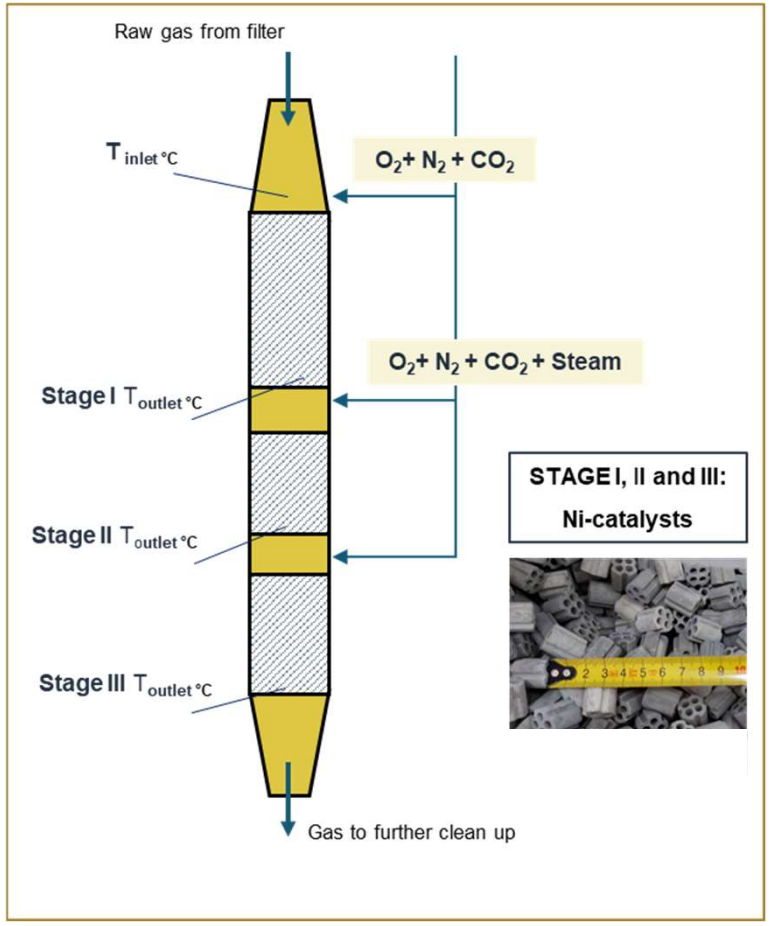
Hot gas filter performance



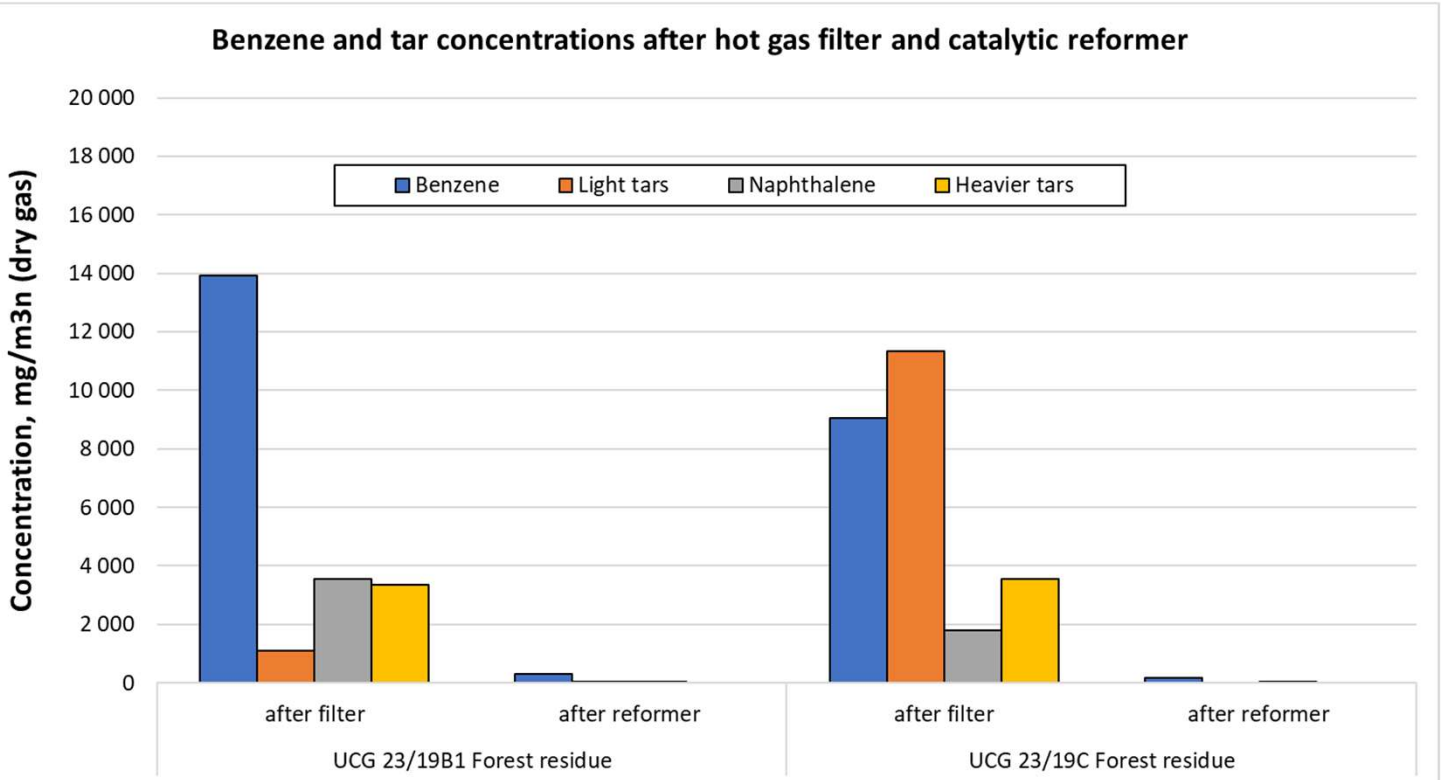
- Filter temperature: 497…524 °C
- No signs of filter blinding in set points
- No filter breakages or leakages during testing

Catalytic reformer performance





Gas composition after hot gas filter and after catalytic reformer



Set point	UCG 23/19B1	UCG 23/19C
Reformer conversions		
Tars, %	100	100
benzene, %	99	98
methane %	81	73
ethene %	100	100
NH3, %	54	60

Set point	UCG 23/19B1	UCG 23/19C
Dry gas after filter, vol-%		
CO	22,6	14,1
CO2	34,7	38,3
H2	30,3	34,8
N2 (calc. as difference)	3,3	3,1
CH4	7,9	7,8
C2H2	0,1	0,0
C2H4	1,0	1,2
C2H6	0,2	0,7
C3-C5Hy	0,0	0,0
H2S (ppm)	400	400
COS	nm	nm
Ar (O2+Ar)	0,0	0,0
Benzene, g/m3n (dry gas)	13,9	9,1
Tars, g/m3n (dry gas)	7,6	14,5
Ammonia, mg/m3n (dry gas)	3860	4377
Dry gas analysis after reformer, vol-%		
CO	21,2	15,7
CO2	32,6	35,4
H2	36,1	35,9
N2 (calc. as difference)	8,9	11,3
CH4	1,2	1,7
C2H2	0,0	0,0
C2H4	0,0	0,0
C2H6	0,0	0,0
C3-C5Hy	0,0	0,0
H2S (ppm)	400	400
COS	nm	nm
Benzene, mg/m3n (dry gas)	64,4	175,3
Tars, mg/m3n (dry gas)	6,5	4,6
Ammonia, mg/m3n (dry gas)	1378	1358
H2/CO	1,7	2,3

Conclusions

- The CFB gasifier can be operated flexibly with woody residues under both modes of the FlexSNG process: maximizing syngas and co-producing biochar and syngas. Shifting between operational modes is simple and can be achieved by adjusting the operating temperature and the oxygen-to-biomass feed ratio.
- The hot filter and catalytic reformer operated without any problems during the test campaign. The pressure drops remained constant, and the reformer achieved high conversions.
- After 190 hours of pilot-scale gasification, it was confirmed that the key enabling technologies of the FlexSNG gasification process were validated under both operation modes, reaching TRL5.

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beyond the obvious

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