EUBCE

29th European Biomass Conference & Exhibition

Horizon 2020 European Union Funding for Research & Innovation

MID TERM RESULTS OF THE H2020-LC-SC3-RES-11 BLAZE PROJECT: BIOMASS LOW COST ADVANCED ZERO EMISSION SMALL-TO-MEDIUM SCALE INTEGRATED GASIFIER FUEL CELL COMBINED HEAT AND POWER PLANT

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29° European Biomass Conference & Exhibition EUBCE

ONLINE 26-29 April

http://www.blazeproject.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 815284

OUTLINE

The project started in March 2019. In the first 24 months the consortium performed:

1. biomass feedstock analysis, by screening 10 samples and 5 mixtures of representative biomass wastes, and then by more deeply testing two of the most relevant performance evaluations;
2. gasification tests without and with primary sorbents to reduce sulphur and chlorine bearing compounds;
3. literature review to select bio-syngas representative organic and inorganic contaminants for button cell and short-stack SOFC tests and so tar catalyst tests in order to select the catalysts to be applied within the filter candles and the secondary tar reformer and sorbents tests in order to select the material to be applied in the secondary sulphur and chlorine reactors;
4. button cells at ENEA and short stacks at EPFL tests in order to understand SOFC performance (e.g. syngas behaviour and tar, sulfur and chlorine tolerance)
5. performed overall plant simulations and final pilot plant design;
6. pilot plant realization achieving pilot plant gasification with hydrogen stable over 30%/v

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BLAZE SCHEME

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Flexible electricity supply and heat integration with agro, industrial or buildings

ELECTRICITY

HEAT

Recirculated anode off-gas

Secondary hot gas conditioning

400-700°C

Heat driven blower

SOFC 700-800°C

ANODE

ELECTROLYTE

CATHODE

Burner

Air

Exhaust gas

Raw syngas

800-900°C

BFB gasifier integrating sorbents & catalysts (for primary gas conditioning)

steam 400 °C

Hot air

Hot air depleted

Steam

Water

Air

Cooled depleted air

Air

Low cost woody e.g. pruning waste

Industry waste (timber/food/distillation)

OFMSW

Digestate

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BIOMASS

Feedstock	CATEGORY	Humidity (%-wt, as received)	LHV MJ/kg	Ash %wt, dry basis	S %wt, dry basis	Cl %wt, dry basis	Ash melting T (DT) (°C)
Subcoal	Municipal waste	3,20	21,68	15,60	0,10	1,00	1250,00
Olive pomace pitted	Secondary residues of industry utilising agricultural products	36,30	19,79	5,95	0,06	0,08	1290,00
Sawmill waste	Primary residues from forest	11,20	18,89	0,41	<0.01	<0.01	1300,00
Multi-essence wood chips	Waste from wood	24,50	17,88	1,45	0,02	<0,01	1370,00
Olive Prunings	Secondary residues from wood industries	14,90	17,76	1,55	<0.01	<0.01	1380,00
Almond shells	Secondary residues of industry utilising agricultural products	10,00	17,68	1,31	<0.01	<0.01	1000,00
Swarf and sawdust	Secondary residues from wood industries	6,60	17,14	0,43	<0.01	<0.01	>1385
Wood chips	Primary residues from forest	8,90	16,74	0,54	<0.01	<0.01	>1385
Corn cobs	Agricultural residues	9,00	16,62	3,04	0,03	0,44	645,00
Arundo Donax	Agricultural residues	10,10	16,25	3,43	0,11	0,29	1185,00
1- Wheat Straw (pellets 10 mm)	Agricultural residues	7,60	15,98	9,22	0,05	0,12	1065,00
2- Wheat Straw (pellets 6 mm)	Agricultural residues	7,60	15,40	13,29	0,08	0,21	1135,00
Rice husks	Secondary residues of industry utilising agricultural products	5,20	15,19	14,70	0,02	0,03	990,00
Digestate	Digestate from biogas production	71,20	12,69	25,81	0,97	0,10	1245,00
Black Liquor	Secondary residues from wood industries	20,60	11,20	48,28	0,74	0,12	680,00
Municipal solid waste	Municipal waste	23,00	10,22	47,01	0,20	0,40	1220,00

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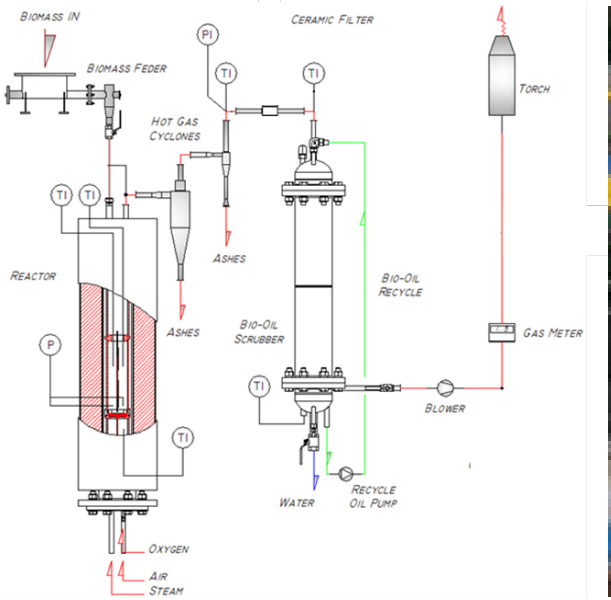
Gasification and Primary Sorbents



Reference steam gasification composition fixed: 40% H2, 22% CO, 15% CO2, 5% CH4, 18% H2O

Representative contaminants levels fixed: 2 organic (toluene between 250 and 750 mg/Nm3, and naphthalene between 25 and 75 mg/Nm3, i.e. 5 and 15 ppm) and 2 inorganic (H2S between 1 and 3 ppm, KCl between 50 and 200 ppm)

The bed of olivine and calcined dolomite, 70:30 by weight, provided reduction (from 23% to 76%) in the contents of both Tar and inorganic contaminants.

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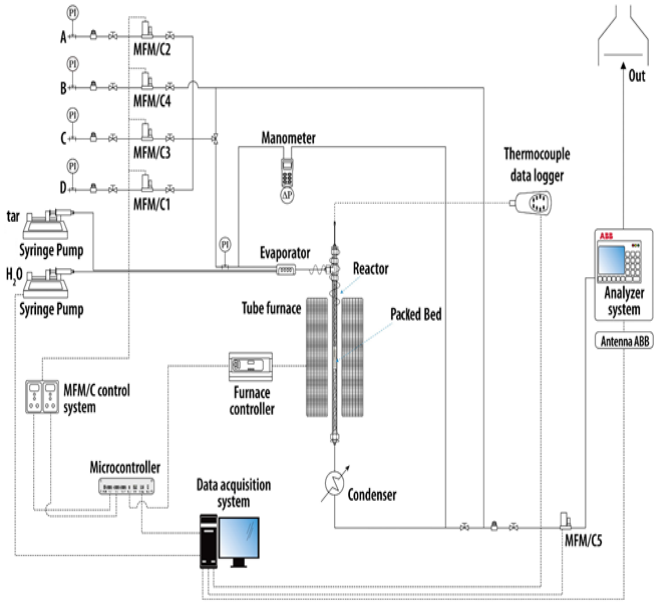
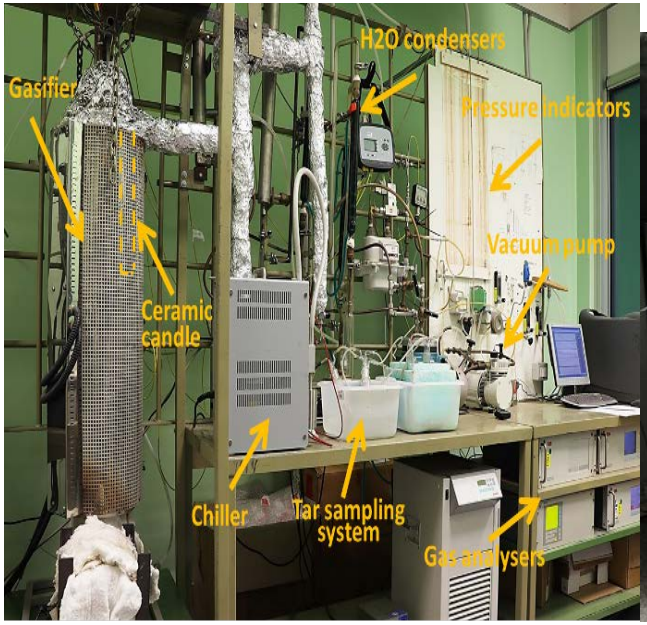
TAR and Contaminants





Test with GHSV from 5000 to 15000 showed from 100% to 90% tarry carbon to COx

Lowering the temperature from 800 to 700 °C or adding sulphur (H2S) decreased the conversion

Similarly a relaese of H2S was observed from ZnO sorbents when the temperature was increase from 450 to 650 °C or water added.

Best configuration of catalyst within ceramic candles is only in the peripheral part

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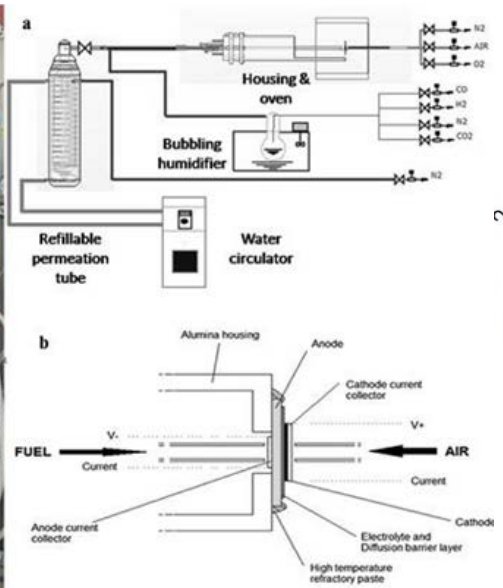
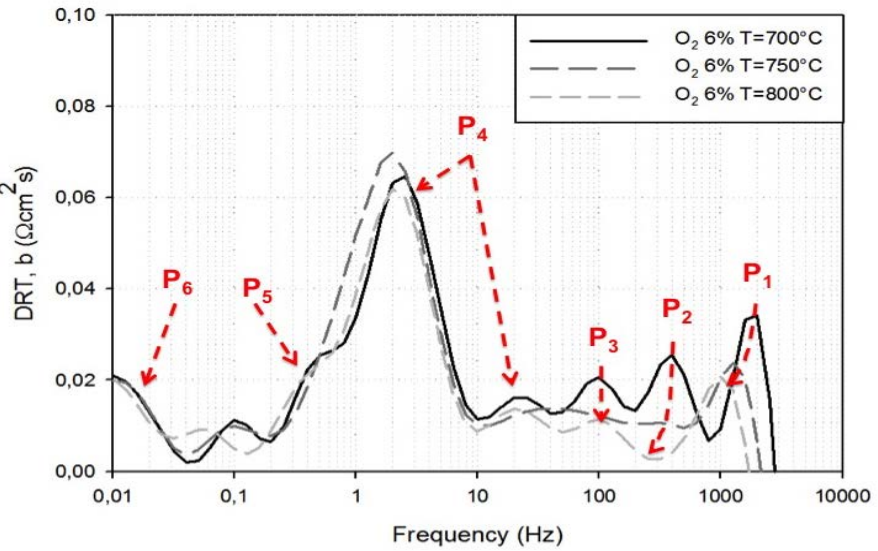
Button SOFC tests





SP manufactured 30 button cells to ENEA and 4 stacks to EPFL. Button investigated to perform mechanistic studies on conversion and poisoning effects of contaminants while stacks to investigate the operational window of the SOFC stack.

ENEA tested by H2-N2, H2-H2O and CO-CO2 identifying up to six different processes from the DRT plots (P1 and P2 fuel electrochemical oxidation anode side, P2 charge transfer mechanism O2 to O2- cathode side, P4, P5 and P6 mass transport, gas conversion impedance and diffusion of the cathodic gas in the porous structure

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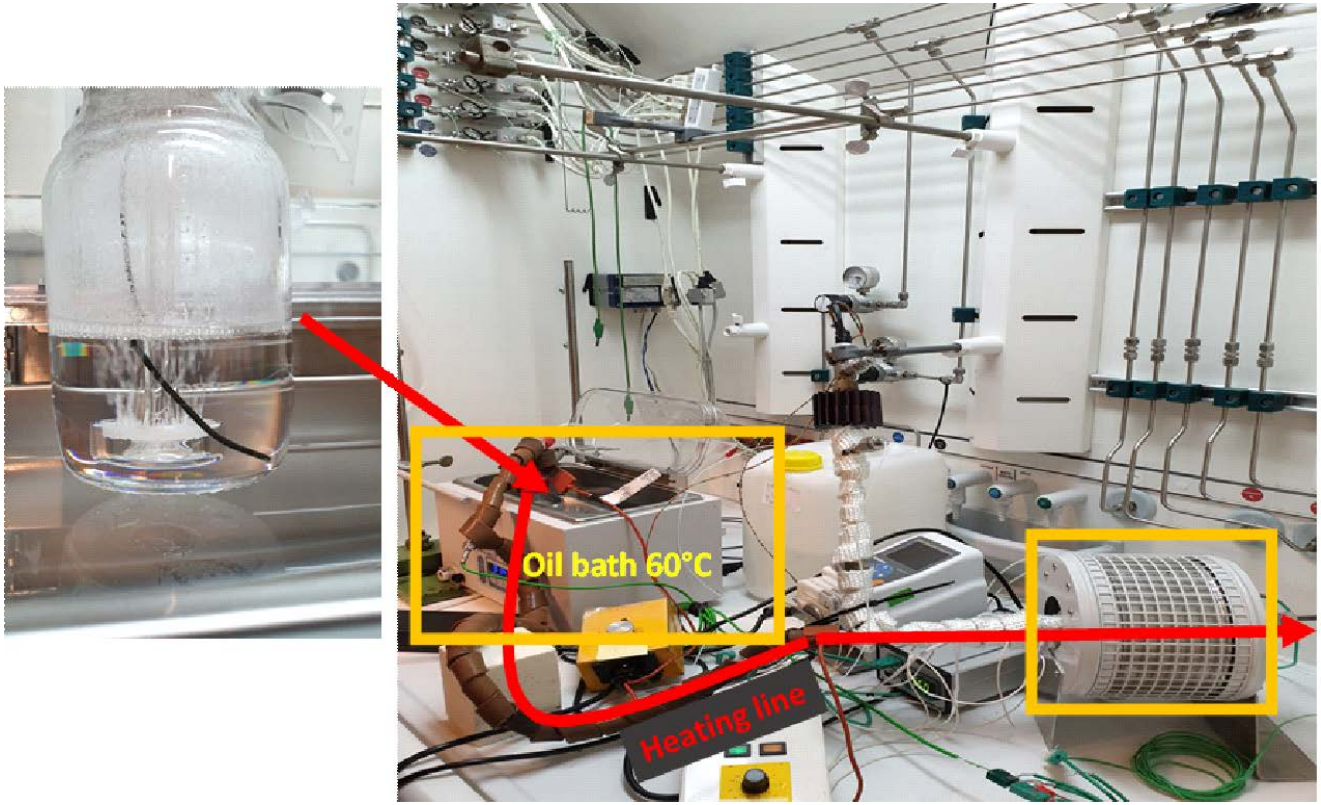
Stack SOFC tests



EPFL completed the adaptation of the test bench to host the new stack design as showed in figure below. The initial IV curves measured in H2/N2 gas conditions showed good homogeneity of the different repeating units.

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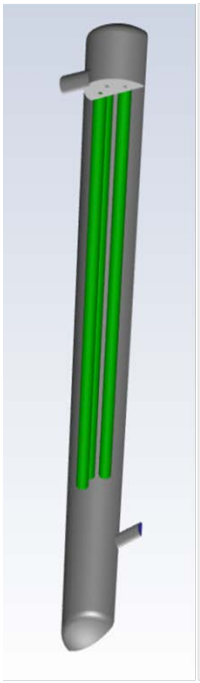
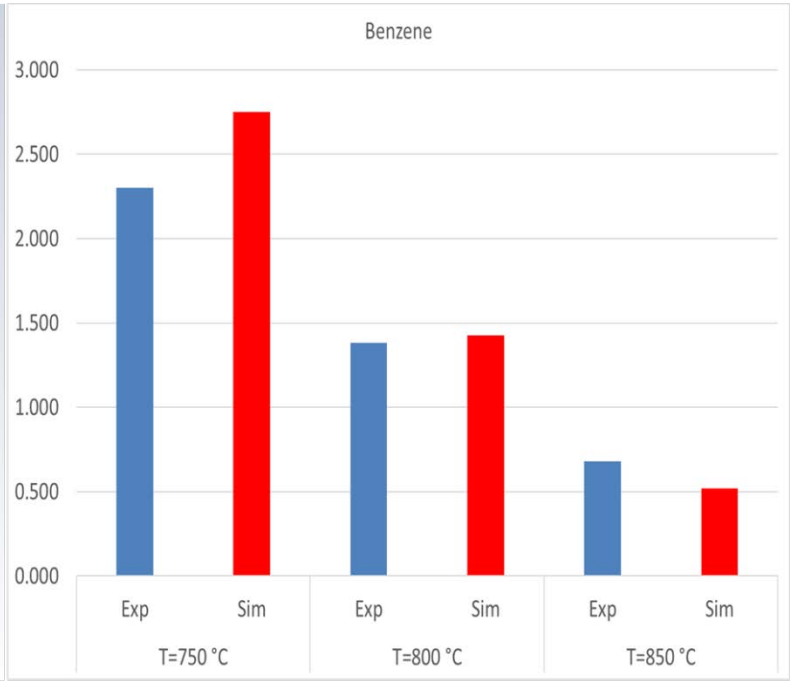
CFD SIMULATIONS





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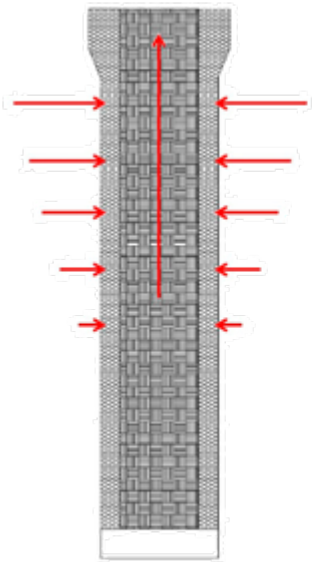

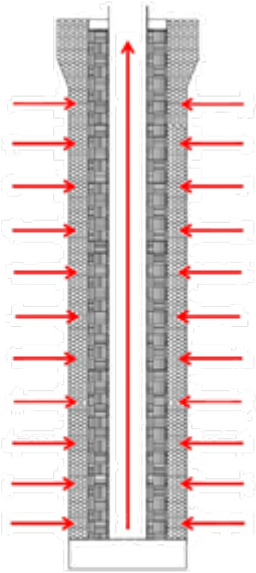

CFD Simulations of a 3D Vessel with catalytic candles for validation of the 2D model with experimental data from the bench scale gasifier in order to identify the best layout considering various freedoms of system configurations, e.g., different options of: gas cleaning units, anode off-gas recirculation, heat exchangers, pressurised gasifier/combustor or different fan/blowers.

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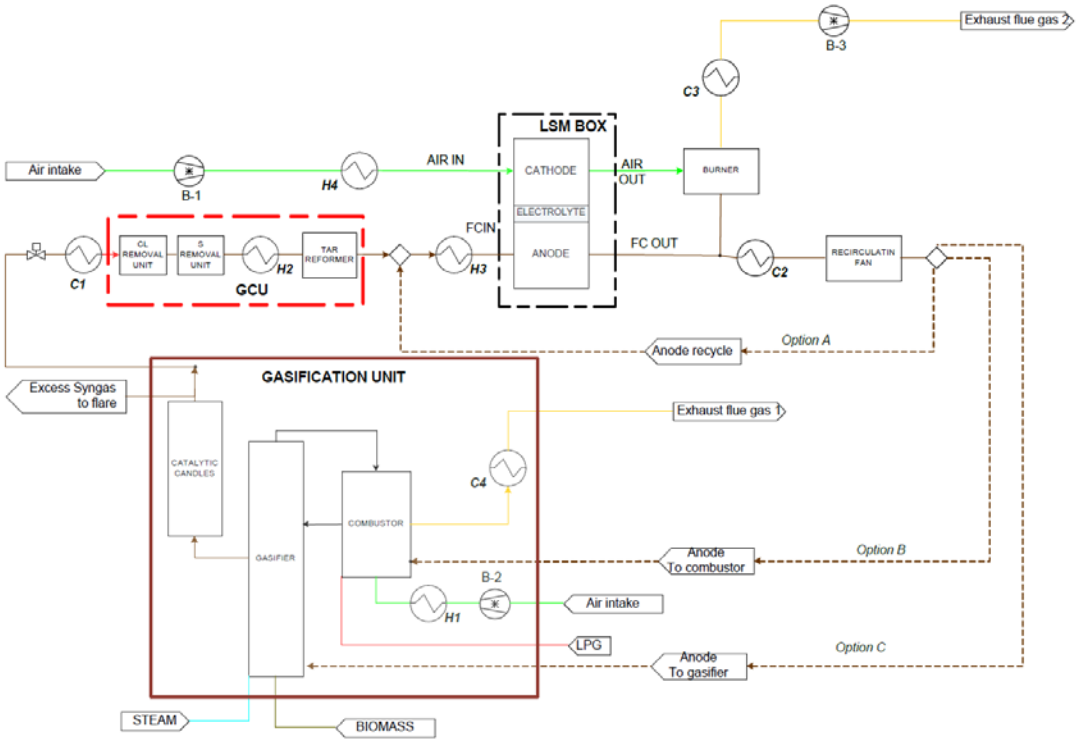
PILOT PLANT DESIGN



Name	Description
Case B	Pressurized gasifier. AOG sent to the SOFC LSM inlet stream (RR=0.5) and the rest to the gasifier combustor. The turbo-fan is used in the AOG to LSM stream. FU global = 0.75.
Case D	Pressurized gasifier. AOG sent to the gasifier combustor (without turbo-fan). Case D1 (FU = 0.6) and D2 (FU = 0.75).
Case F	Analogous to B, without a pressurized gasifier but with a suction blower after the tar reformer. FU global = 0.75.

EPFL has simulated potential BLAZE plants by means of the modelling software Aspen Plus, consisting in the allothermal gasifier, gas purification units, SOFC unit, recirculator and auxiliaries. The cases B, D and F, showed in the table below, were specifically modeled, see related deliverable www.blazeproject.eu/resources .

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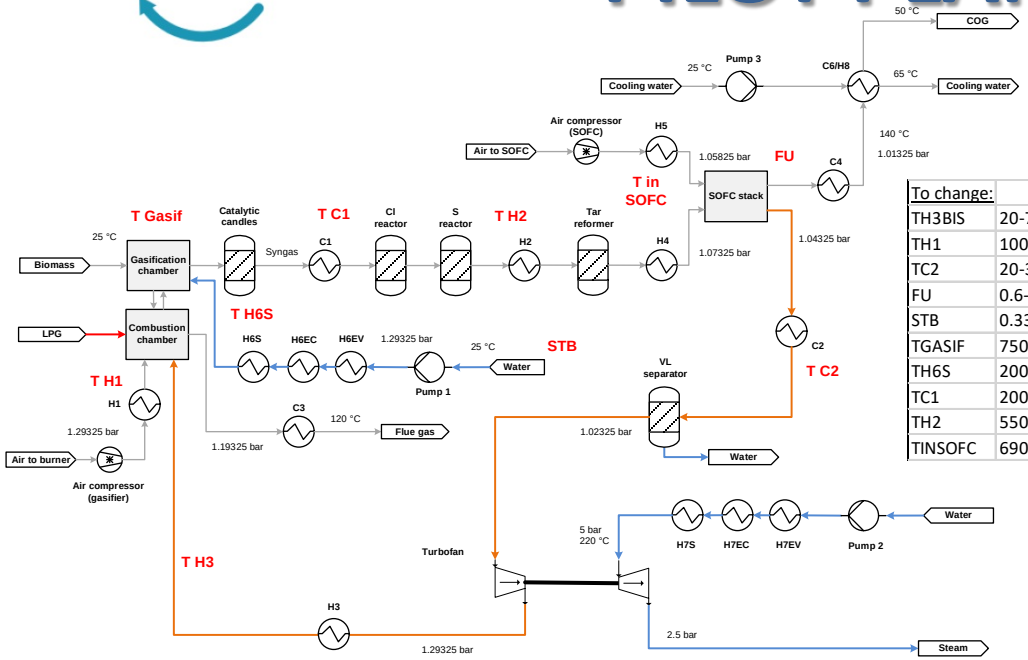
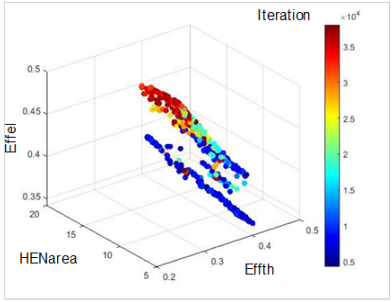
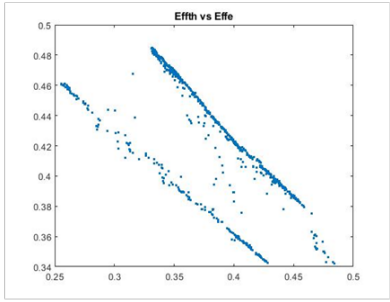
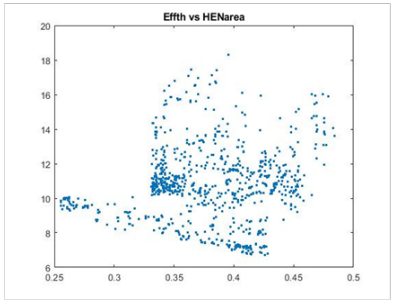
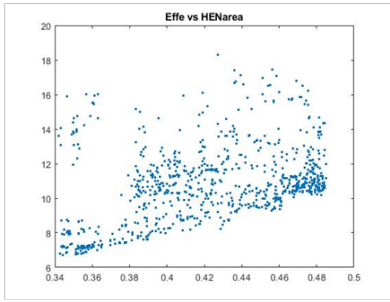


To change:	
TH3BIS	20-760
TH1	100-760
TC2	20-300
FU	0.6-0.8
STB	0.33-0.98
TGASIF	750-850
TH6S	200-400
TC1	200-450
TH2	550-700
TINSOFC	690-750









Results	Case B	Case D1	Case D2	Case F
Power SOFC (kW)	27	22.4	27	27
Wnet (kW)	25.4	20.7	25	25.2
Syngas LHV (ar) (MJ/kg)	12.47	12.47	12.47	12.47
Syngas flow (kg/h)	15.9	15.9	15.9	15.9
Inlet biomass (kW)	58.6	58.6	58.6	58.6
CGE	0.67	0.65	0.63	0.65
Eff_SOFC	0.49	0.41	0.5	0.49
Eff_elec	0.36	0.32	0.33	0.34
Eff_total	0.7	0.63	0.63	0.66
Steam to sell	25.5 kg/h	20.1 kg/h	22.7 kg/h	27.2 kg/h

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PILOT PLANT REALIZATION

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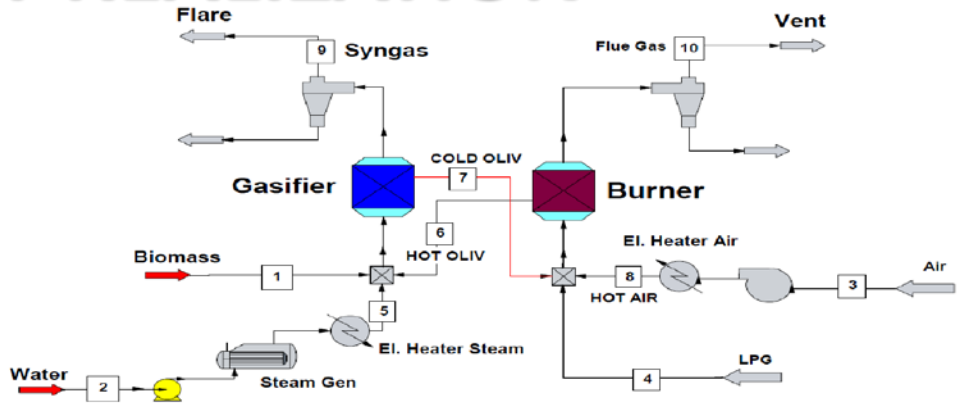

	Test #1	Test #2	Test #3
Biomass	Hazelnut shells		
Biomass feed rate a.r. (kg/h)	10	15	15
Olivine $d_{3,2}$ diameter (µm)	557		
Steam (to gasifier) (kg/h)	~11.5	~11.5	~11.5
S/B	~1	~0.75	~0.75
Air (to combustor) (kg/h)	43		
Air injection (l/min)	-	-	80
LPG (to combustor) (l/min)	16		
T gasifier (°C)	810	830	860
T upper freeboard (°C)	615	680	750
T combustor (°C)	910	930	960
Steam Inlet T (°C)	300		
Air inlet T (°C)	25		
Length of tests (min)		60	
H2 (%vol dry)	36.30	34.34	32.70
CO (%vol dry)	19.03	21.40	19.16
CO2 (%vol dry)	29.08	33.36	33.58
CH4 (%vol dry)	10.25	10.90	7.04
LHV (MJ/Nm3)	9.99	10.31	8.68
Tar (g/Nm3)	8.05	10.57	3.30

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