First results of BLAZE: Biomass Low cost Advanced Zero Emission small-to-medium scale integrated gasifier fuel cell combined heat and power plant

H2020 RIA, 4 M€, 3/2019-2/2022, GA 815284

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European Fuel Cell
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CHP IN EU-28 (Eurostat)

- 120 GWe (ST 50%, CC 25%, ICE 13%, GT 10%): 362 TWh -> ≈3000 AEh (≈ 11% of electricity demand).
- 300 GW_{th}: 775 TWh -> ≈ 2500 AEh
- space heating ≈ 50% process heating (Germany, Italy, Poland and the Netherlands largest capacity)
- Natural gas ≈ 50%, solid fossil fuels and peat ≈ 20% , oil and oil products 5%, biomass (timber by-products, black liquor, wood, straw, animal waste, OFMSW) attained 20% but there is difficulty in converting different biomass feedstocks in a Reliable and Economic (Efficient and Clean) way
- Zero Energy Buildings (ZEB&ZED) from 31st December 2020 (public buildings from 31st December 2018)

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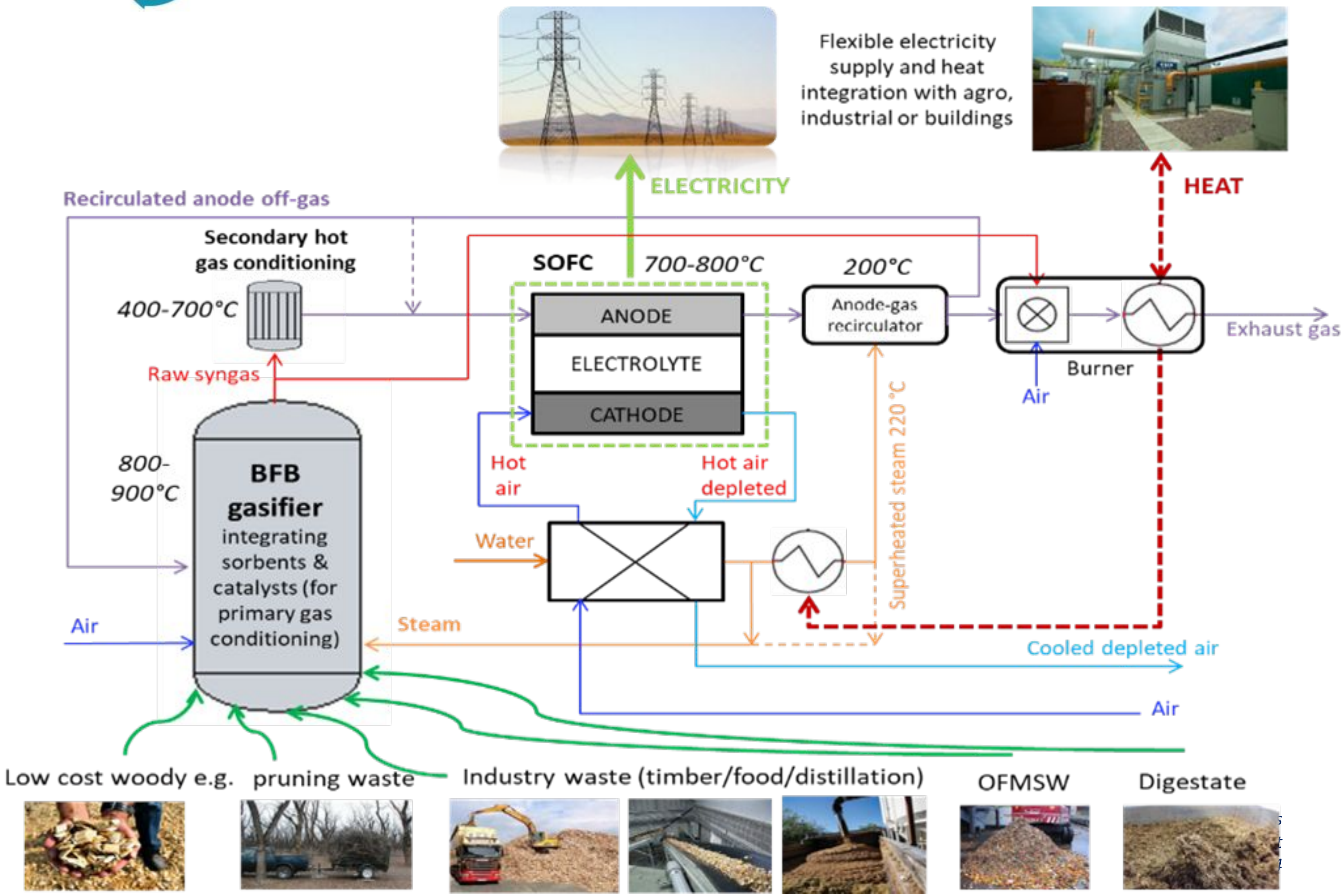

BLAZE OBJECTIVES

- overall 90% (versus 65%, target SET-PLAN 75%)
- electrical 50% (versus 25%, target SET-PLAN >30%)
- near-zero gaseous and PM emissions
- CAPEX below 4,000 €/kWe (actual 10,000 €/kWe)
- OPEX of ≈ 0.05 €/kWhe (actual 0.10 €/kWhe)
- electricity production cost 0.10 €/kWh (actual 0.22 €/kWh, SET-PLAN target of 20% cost reduction by 2020, and 50% by 2030).

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COSTS COMPARISON

Below 1 MWe systems mainly applied :

1. Biomass combustor coupled to organic rankine cycle (ORC)
2. Biomass fixed bed gasifier coupled to internal combustion engine (ICE)

BLAZE 100 (100 kWth biomass DBFBG integrated with 50 kWe SOFC) is compared to a 100 kWth biomass combustor coupled to a 15 kWe ORC and a 100 kWth biomass fixed bed gasifier coupled to a 25 kWe ICE

Cost of a gas boiler with burner, flue tubes and accessories is added to the CHP plants cost. To this item, heating civil works, piping, pump, expansion vessel and regulation system have been added.

Buildings heat price: 0.06 €/kWht (AEh: 3000 electrical and 2500 thermal)

Industrial heat price: 0.04 €/kWht (AEH: 7500 electrical and thermal).

Biomass price: 60 €/ton (similar to the price of high humidity wood chips for BLAZE) 100 €/ton (similar to the price of low humidity wood chips for ORC and ICE systems).

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CAPEX

CAPEX	BLAZE	ICE	ORC
Input kWth	100	100	100
Biomass storage and feeding (spider, hopper, screw) cost €	6,000	6,000	6,000
Gasification (BLAZE or ICE/GT) or Combustion (ORC) cost €	90,000	90,000	70,000
€/kWth	960	960	760
Power generator size kWe	50	25	15
Power generator size kWth	40	50	65
SOFC-ICE/mGT–ORC cost €	100,000	37,500	30,000
€/kWe	2,000	1,500	2,000
System cost €	196,000	127,500	100,000
€/kWe (considering all CAPEX to only electric power)	3,920	5,100	6,667
100 kWth gas boiler with tubes and accessories €	50,000	50,000	50,000
Electric system cost €	170,000	110,000	82,000
€/kWe	3,400	4,400	5,467
Thermal system cost €	76,000	67,500	68,000
€/kWth	1,900	1,350	1,046

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OPEX

Because of this small size (i.e. a production from 45 to 150 MWhe) the CAPEXs are generally higher but the electricity price is also higher. In BLAZE the CAPEX per kWe produced is less than in the conventional solid biomass cases because, even if the gasification and SOFC CAPEX are higher, the electrical efficiency is double.

	€/year		
OPEX cost item	BLAZE	ICE	ORC
Personnel (automated operation - 50 h/yr)	1,000	1,000	1,000
Gasifier/Combustor, Gas Cleaning system, Boiler	1,300	1,300	1,000
Power generation (SOFC or ICE)	1,300	1,300	600
Biomass Cost	4,000	7,000	7,000
Ash disposal cost	500	500	500
Other Costs (e.g. insurance, aux. consumptions)	1,000	1,000	1,000
Total OPEX	9,100	12,100	11,100

As expected the higher OPEX costs for traditional CHP with respect to BLAZE are mainly due to the higher biomass cost.

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LCOE

$$LCOE = \frac{C_i + \sum_{i=1}^{20} CO_i(1+r)^{-i} + \sum_{i=1}^{20} CC_i(1+r)^{-i}}{\sum_{i=1}^{20} EE_i(1+r)^{-i}}$$

r interest rate;
C_i the investment cost incurred (CAPEX)
CO_i the cost of operating and maintenance incurred during the i-th year
EE_i electricity (or thermal energy) produced in the i-th year
CC_i fuel cost incurred in the i-th year
The OPEX are the sum of CO and CC. The interest rates is assumed equal to 3.00% owing to the around 0% of ECB, European Central Bank and 3% of spread.

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BIOMASS CHP COST PER ELECTRIC KWh

	BLAZE		ICE		ORC	
Equivalent annual hours	3000	2500	3000	2500	3000	2500
OPEX €/kWh	0.06	0.03	0.16	0.04	0.20	0.04
CAPEX €/kWh	0.08	0.03	0.11	0.02	0.13	0.02
Tot CAPEX+OPEX €/kWh	0.14	0.06	0.27	0.06	0.33	0.06
Equivalent annual hours	7500	7500	7500	7500	7500	7500
OPEX €/kWh	0.04	0.02	0.12	0.03	0.14	0.03
CAPEX €/kWh	0.06	0.02	0.07	0.01	0.06	0.01
Tot CAPEX+OPEX €/kWh	0.10	0.04	0.19	0.04	0.20	0.04

The table shows that BLAZE is the only system that, in case of lower annual equivalent hours, has a competitive electricity generation cost, and that BLAZE, in case of high annual equivalent hours, can reach electricity generation cost below 0.10 €/kWh.

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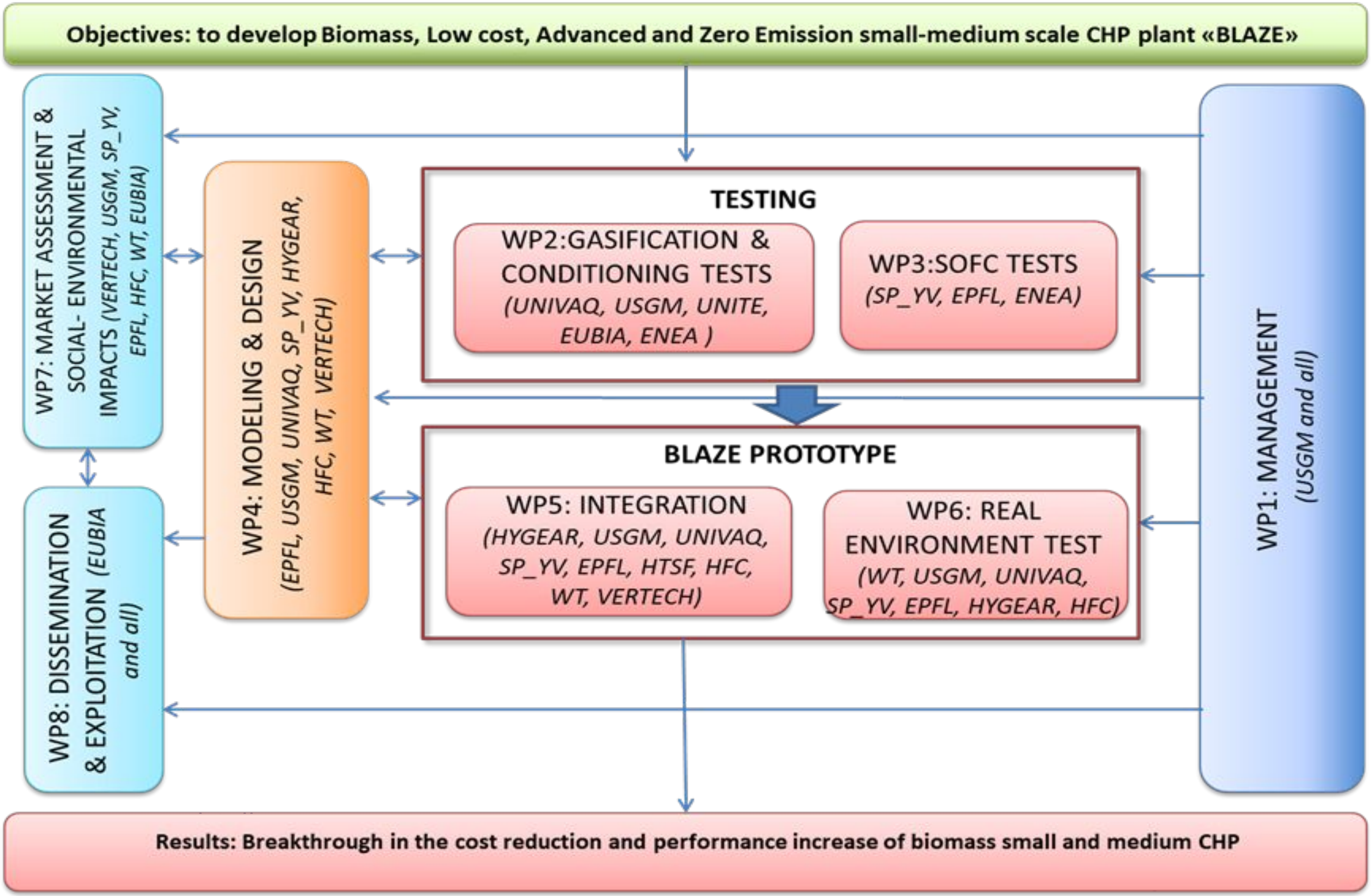
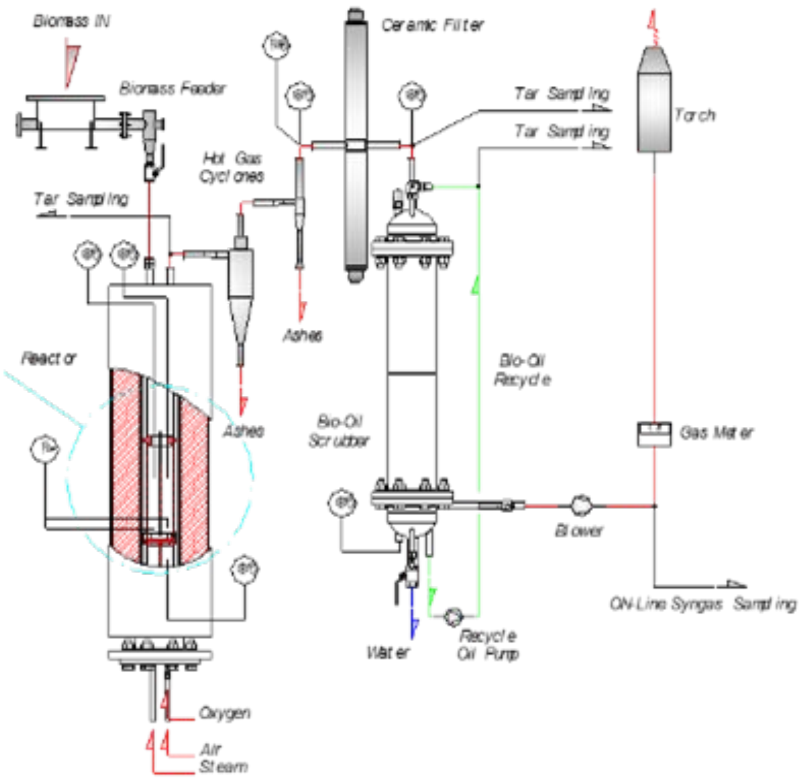


WP2: BIOMASS ASSESSMENT, GASIFICATION AND CONDITIONING

A wide spectrum of biomass feedstock available in Europe is assessed and tested for bio-syngas production and compatibility with solid oxide fuel cells, tar removal, and hot gas cleaning and conditioning.



scheme of the 3 kWth BFB plant

photo of the whole facility

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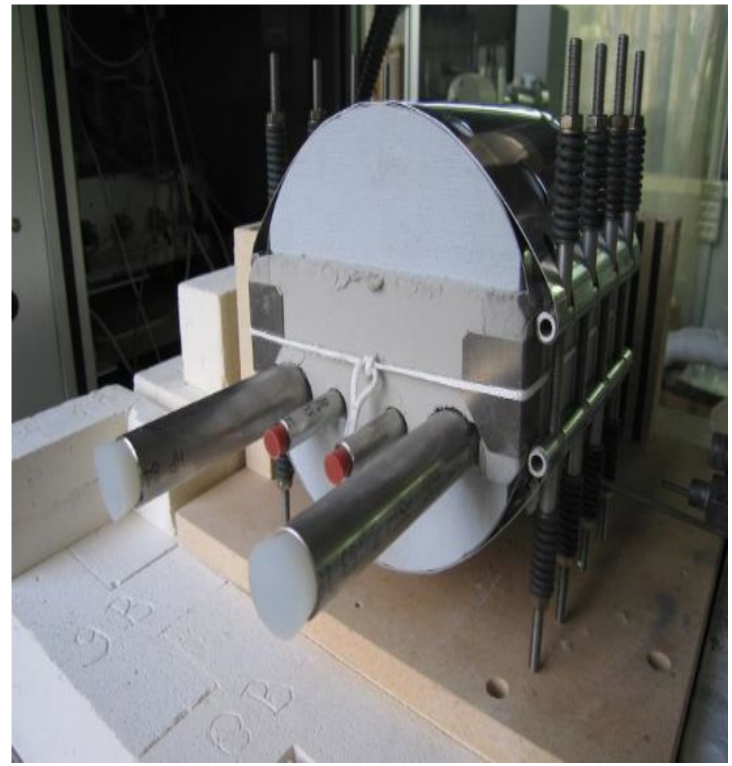
WP3: SOLID OXIDE FUEL CELLS (SOFC) TESTS

The benchmarking of kinetics, performance, and durability of SOFC cells is carried out in order to optimize the cell's response to the characteristics of the bio-syngas obtained from different types of biomass.

SOFC single cell test rig - gas and contaminants mixing stations (ENEA)



SOFC short stack tests

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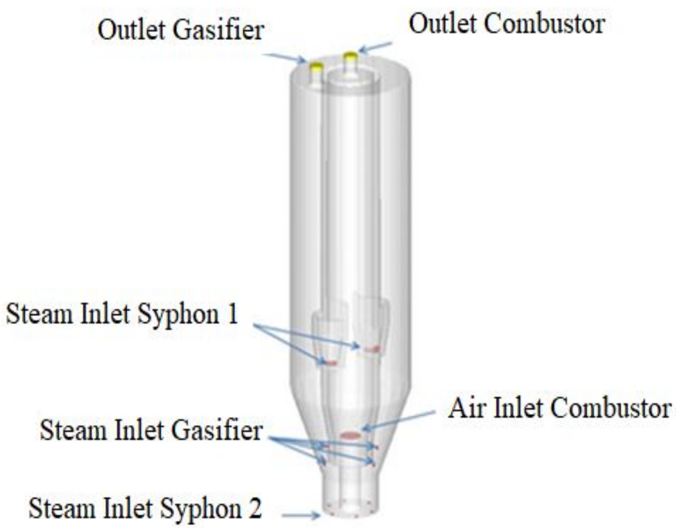
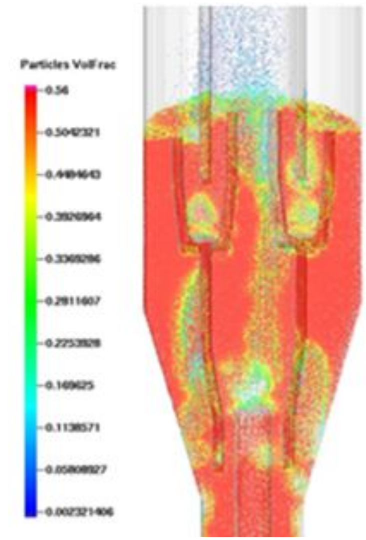
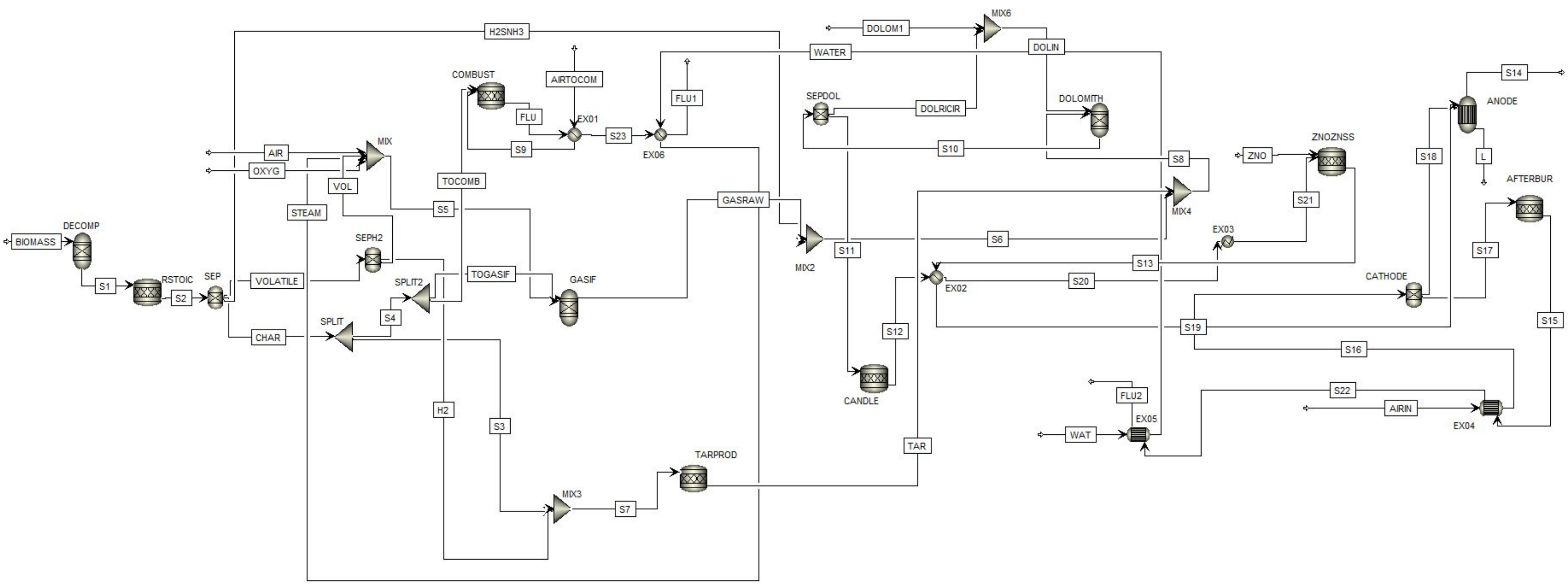
WP4: MODELING AND PILOT DESIGN



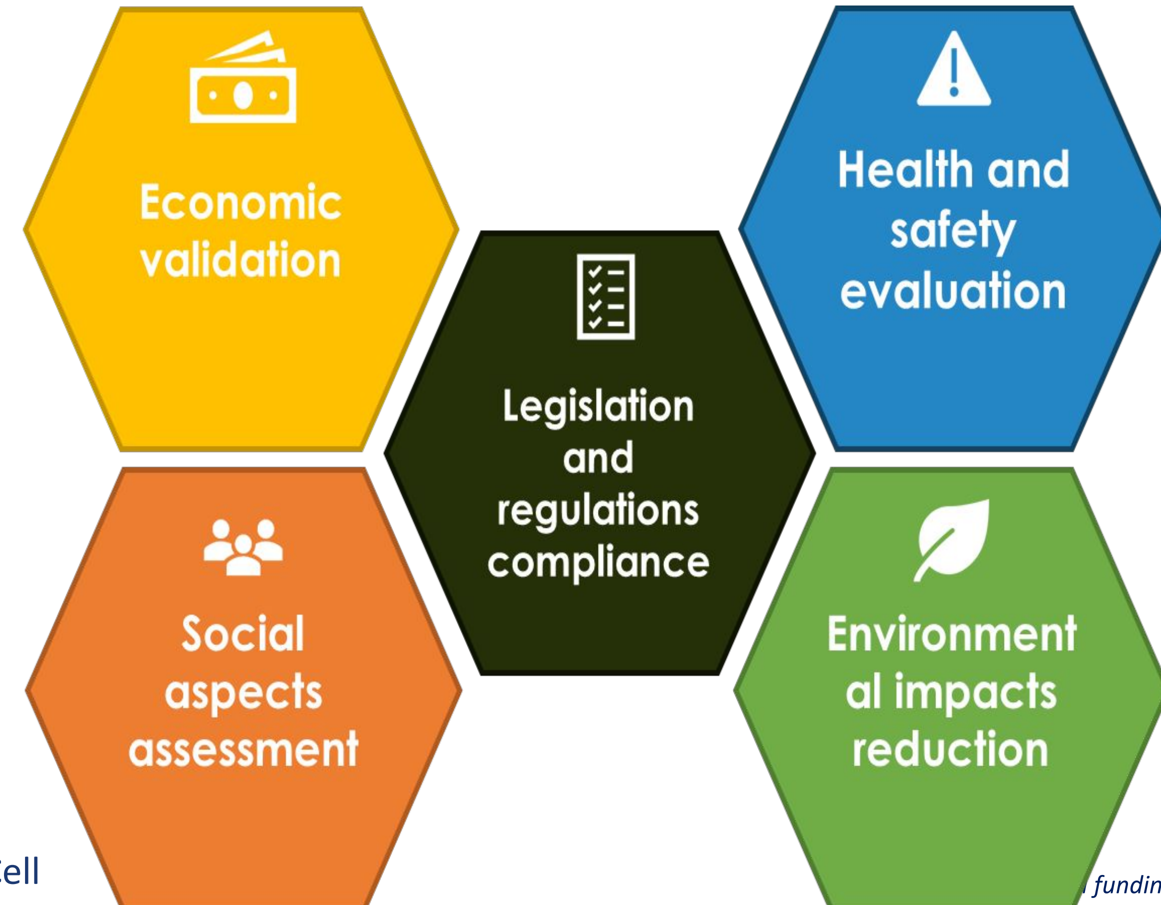
The design and implementation of the modifications on gasification and conditioning are performed at pilot scale.





WP7: TECHNO-ECONOMIC, SOCIAL AND ENVIRONMENTAL ASSESSMENT

Feasibility studies are developed to quantify the impacts and to deploy the best alternatives for cost-efficient small and medium-scale biomass CHP, with increased resource efficiency and positive socio-economic impact.



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WP8:DISSEMINATION COMMUNICATION AND EXPLOITATION OF RESULTS

A detailed market assessment and efficient business strategies for the successful implementation and replication of the BLAZE CHP system is carried out, as well as a plan to promote knowledge-sharing among the most relevant stakeholders, media and citizens.

Techno-economic evaluation
- Feasibility assessment of BLAZE technology.

Sustainability assessment
- Environmental.
- Economic.
- Social.

Legal and non-legal limitations and barriers
- Health and safety study.
- Legal limitations identification.
- Barriers of application identification.

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BLAZE FIRST ACTIVITIES

The project started the first of March 2019. In the first 6 months the consortium:

1. undertake a preliminary cost analysis, showed in the section before,
2. chose 10 samples and 5 mixtures of representative biomass wastes to be tested in the gasification labs,
3. chose bio-syngas representative tar and contaminants to be tested in the SOFC lab scale facilities,
4. set up the experimental gasification, conditioning and SOFC labs that will undertake a comprehensive lab activities in the next 12 months

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tar and contaminants

- literature overview (www.blazeproject.eu/resources) analyzing 83 papers (mostly experimental).
- representative syngas composition: 45% H_2, 24% CO, 11% CO_2, 2% CH_4, 18% H_2O
- 2 organic (toluene and naphthalene to represent so-called slow and fast tars)
- 3 inorganic (H_2S, KCl; HCl) representative contaminants
- 25 mg/Nm3 (5 ppm) and 75 mg/Nm3 (15 ppm) naphthalene
- 250 mg/Nm3 (to be expected from clean biomass such as almond shells) and 750 mg/Nm3 (feedstock emitting high toluene concentrations)
- H_2S (sulfur compounds) have to be reduced to 1-3 ppm
- KCl represent both halogens and alkalis: 50-200 ppm KCl

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BLAZE ACTIVITIES

Fig. 2. UNITE gasification and UNIVAQ catalyst and sorbent test rig

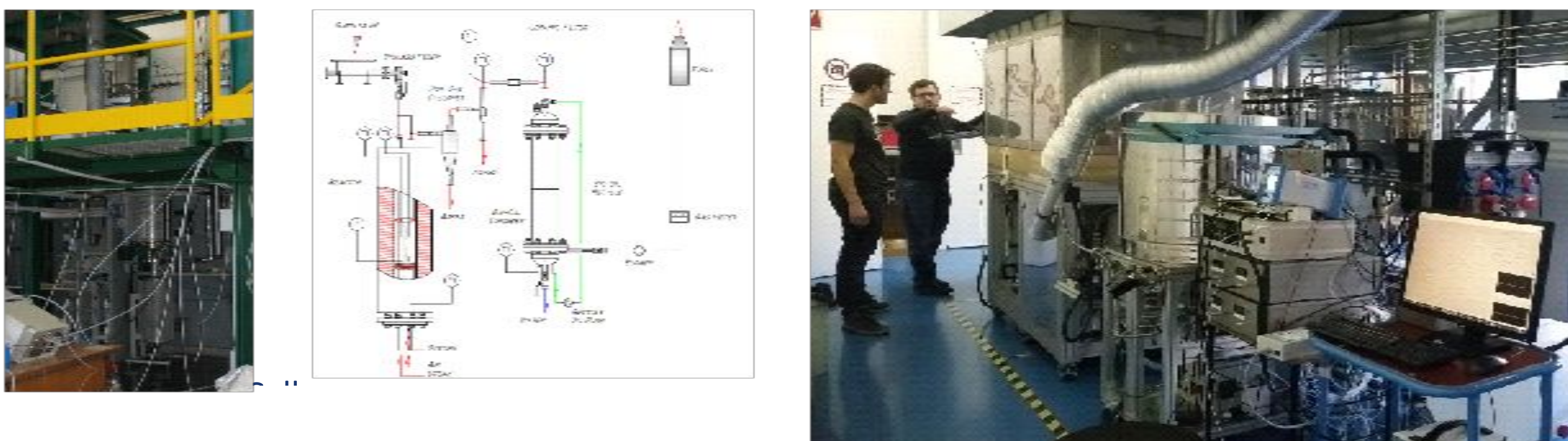
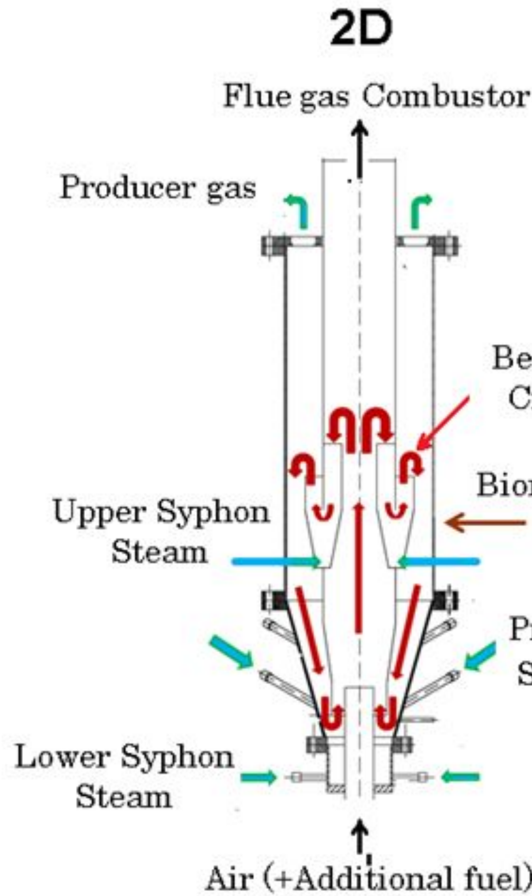


Fig. 3. ENEA gasification and EPFL/SP stack SOFC test rig

100 kWth Gasifier

Togheter with **WT** and **USGM**, **UNIVAQ** developed the 100 kWth dual fluidized bed gasifier used in **BLAZE**



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SOFC system

Large Stack Module (LSM)

- Power output 25 kWe, integrating 4 stacks of 6.5 kWe
- Fuel: H_2, SMR (preliminary)
  - Max convertible flow H2: 280Nl/min
  - Max convertible flow CH4: 70NL/min
- Oxidant: Air
  - Maximum tolerated flow 5600 Nl/min
- 1699 x 792 x 1385 mm
- 1505 kg

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