Innovation Training Lab

Biomass – Hydrogen –CHP -CCS: UNIFHY and BLAZE projects

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Topic SP1-JTI-FCH.2011.2.3

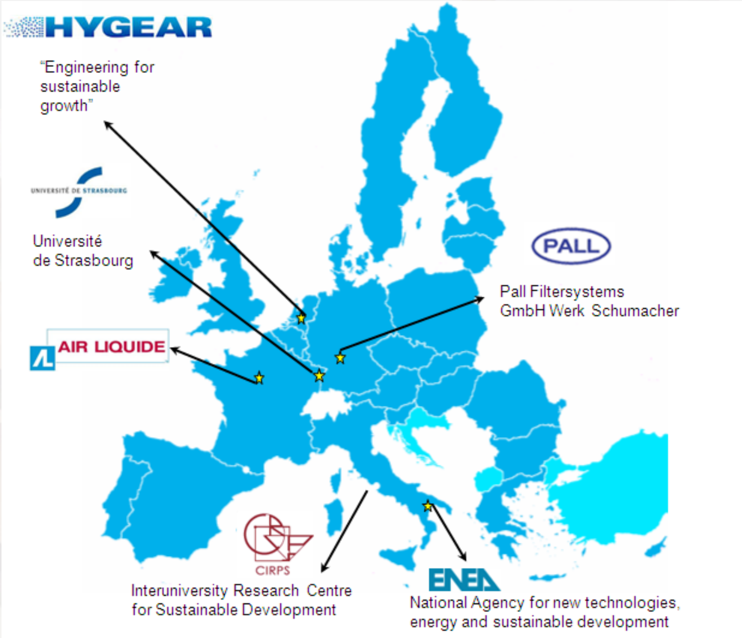
- Goal: thermal system for continuous hydrogen (purity PEMFC grade) production from solid and liquid biomass
- Way: materials and reactors at a precommercial scale, by-products and effluents, LCA/LCI analysis, Economical assessment of pre-treatment of feedstock (sewage sludge, MO, other wastes)

TARGET

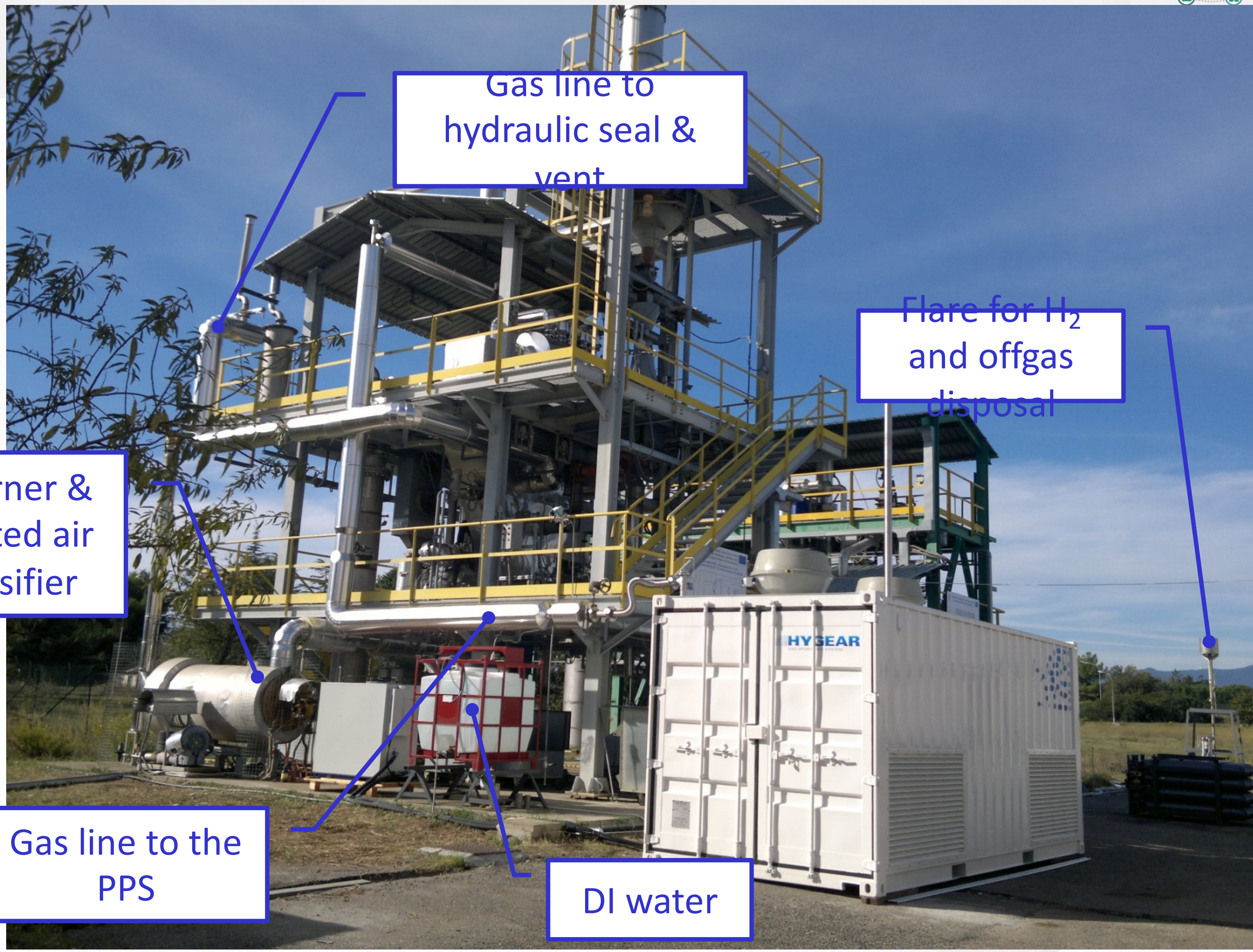
- Efficiency: HV gas/feedstock > 66%, including purification
- Cost: 5 €/kg of H2, including CAPEX
- Durability: > 10 years (80,000 h) with availability > 95%
- Scalability: to 500 kg/day

PROJECT OVERVIEW

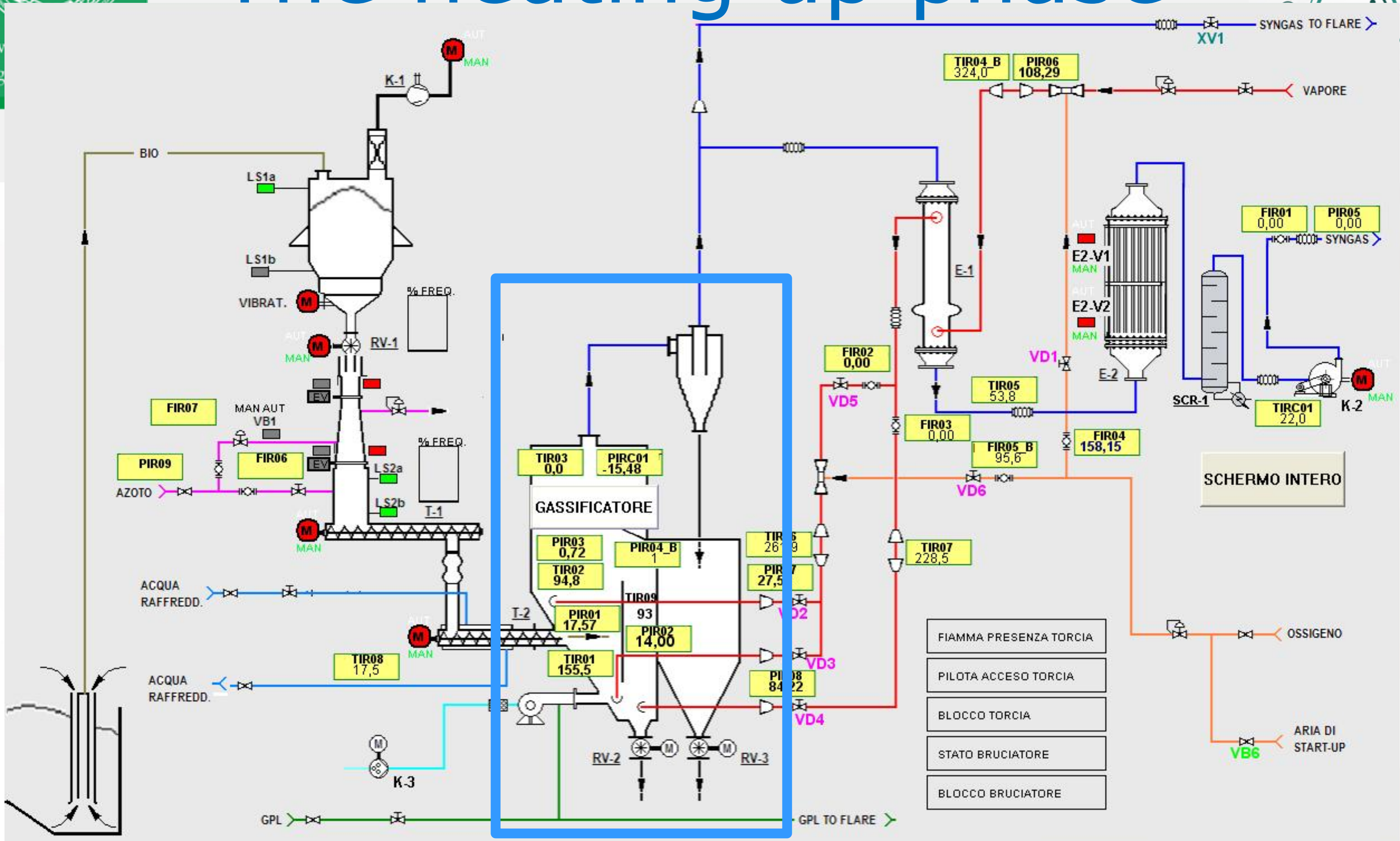
- UNIfHY: UNIQUE gasifier for hydrogen production
- Call topic: SP1-JTI-FCH.2011.2.3 BTH - Biomass-to-hydrogen (Thermochemical route)
- Duration: 09-01-2012 / 08-31-2015
- Budget: 3,555,652.00 €, EU contribution: 2,203,599.00 €
- Overall purpose of project: The project aims to develop a biomass steam gasification process coupled to syngas purification to produce pure hydrogen from biomass, increase well-to-tank efficiency and contribute to a sustainable energy portfolio, exploiting results obtained in past R&D EU projects on hot gas catalytic conditioning.
- Stage of implementation: Mid Term review passed satisfactorily, 05-14-2014



The 1000 kWth UNIfHY Integrated Plant



The heating up phase



TIR 01: Temp. at the bottom of the gasifier

TIR 03: Temp. at the top of the gasifier

(≅ Top of the ceramic candles)

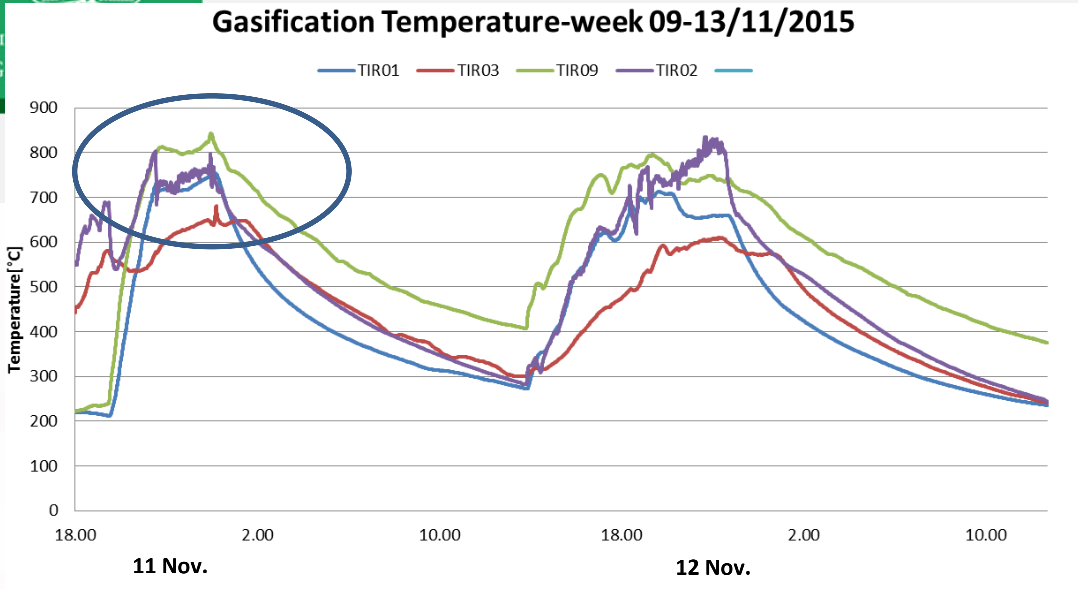
TIR 09: Temp. inside the bed material

TIR 02: Temp. at the surface of the bed material

(≅ Bottom of the ceramic candles)

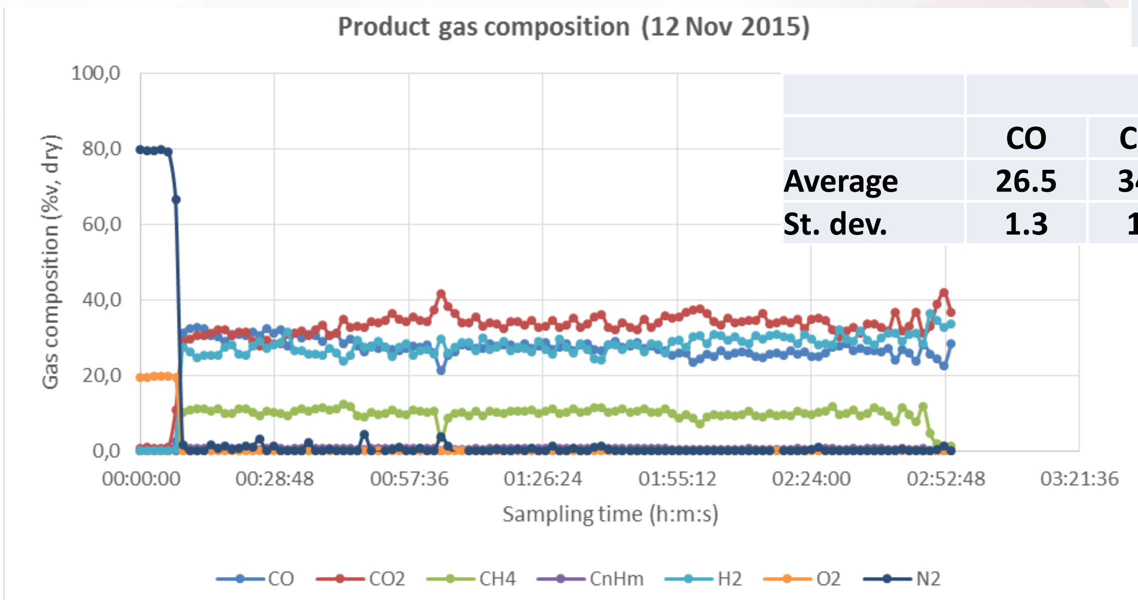
$\Delta T_{Candles}$: TIR 02 – TIR 03

Operation of the integrated system



Operating conditions (11 Nov 2015)	
Biomass feeding rate [a)] (kg_{dry}/h; kg_{wet}/h)	122; 140
O2 (kg/h)	44 - 46
Steam (kg/h)	48 - 50
Equivalence Ratio (ER)	0.25
Steam/Biomass [b)] (S/B)	0.4
Feeding rate to PPS (Nm^3_{dry}/h; @ H2O 35 %v)	25 - 30

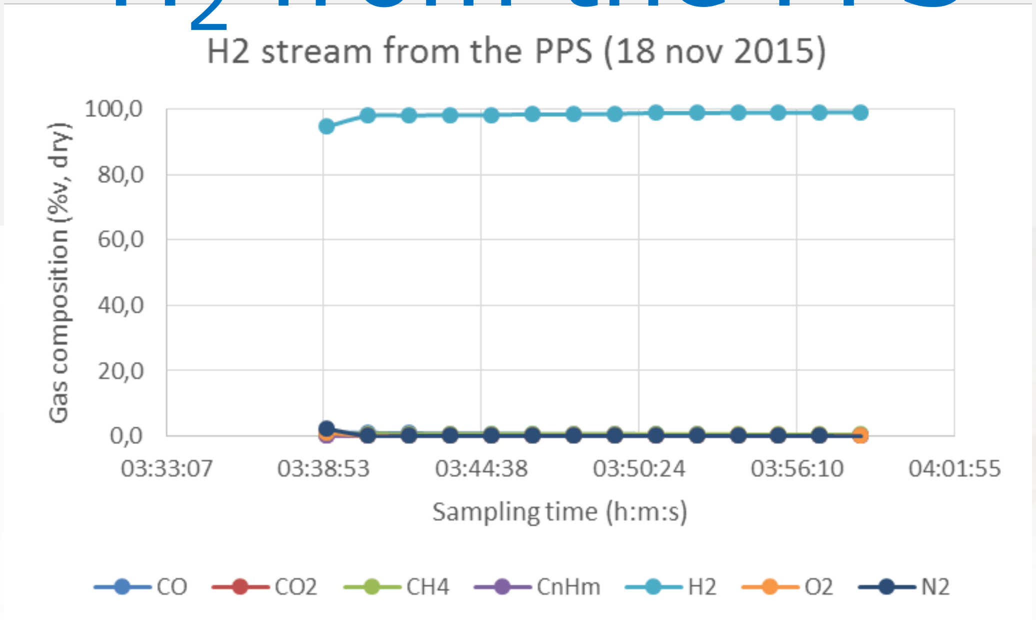
a) Humidity content: 12 %-wt; b) Biomass dry



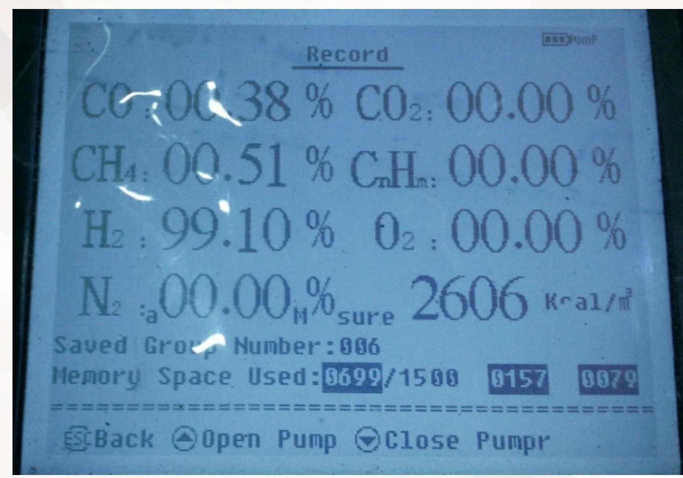
	Average gas composition (%v, dry)						
	CO	CO2	CH4	CnHm	H2	O2	N2
Average	26.5	34.3	10.0	0.54	28.5	not det.	0.12
St. dev.	1.3	1.5	0.9	0.07	1.8		0.3

1000 kW_{th} gasification pilot plant with *in-vessel* high temperature gas filtration. D. Barisano, G. Canneto, F. Nanna, A. Villone, E. Fanelli, C. Freda, G. Cornacchia, G. Braccio, P.U. Foscolo, S. Heidenreich, E. Bocci. Submitted to the 24th EUBCE in Amsterdam, The Netherlands.

H_2 from the PPS

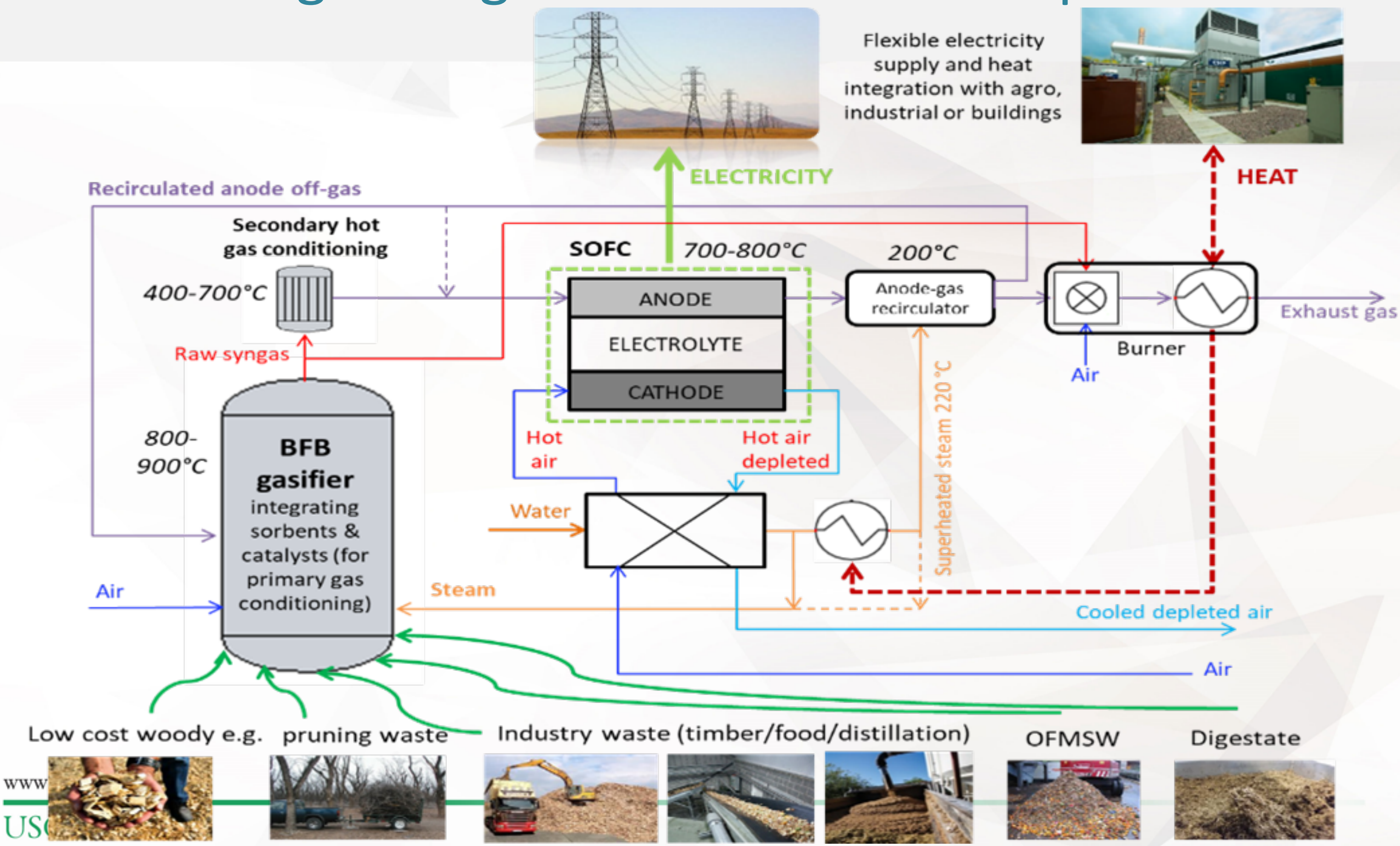


		H2 (%v)						
Ora	Sampling time	CO	CO2	CH4	CnHm	H2	O2	N2
22:59:00	03:39:00	0,93	0,33	0,62	0,00	94,83	1,07	2,22
23:00:30	03:40:30	0,97	0,26	0,64	0,00	98,11	0,00	0,02
23:02:00	03:42:00	0,86	0,28	0,60	0,00	98,24	0,00	0,02
23:03:30	03:43:30	0,78	0,19	0,63	0,00	98,38	0,00	0,02
23:05:00	03:45:00	0,76	0,24	0,60	0,00	98,38	0,00	0,02
23:06:30	03:46:30	0,63	0,18	0,57	0,00	98,61	0,00	0,01
23:08:00	03:48:00	0,61	0,18	0,60	0,00	98,59	0,00	0,02
23:09:30	03:49:30	0,56	0,13	0,54	0,00	98,74	0,00	0,03
23:11:00	03:51:00	0,46	0,00	0,51	0,00	99,01	0,00	0,02
23:12:30	03:52:30	0,46	0,06	0,52	0,00	98,93	0,00	0,03
23:14:00	**03:54:00**	**0,38**	**0,00**	**0,51**	**0,00**	**99,10**	**0,00**	**0,01**
23:15:30	03:55:30	0,35	0,10	0,49	0,00	99,04	0,00	0,02
23:17:00	03:57:00	0,34	0,00	0,50	0,00	99,14	0,00	0,02
23:18:30	03:58:30	0,29	0,10	0,47	0,00	99,20	0,00	-0,06
0:44:00	**05:24:00**	**0,07**	**0,00**	**0,45**	**0,00**	**99,46**	**0,00**	**0,02**



BLAZE

Biomass Low cost Advanced Zero Emission small-to-medium scale integrated gasifier - fuel cell CHP plant



CHP IN EU-28 (Eurostat)

- 120 GWe (ST 50%, CC 25%, ICE 13%, GT 10%): 362 TWh -> ≈3000 AEh (≈ 11% of electricity demand).
- 300 GWth: 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)

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).

BLAZE ACTIVITIES

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

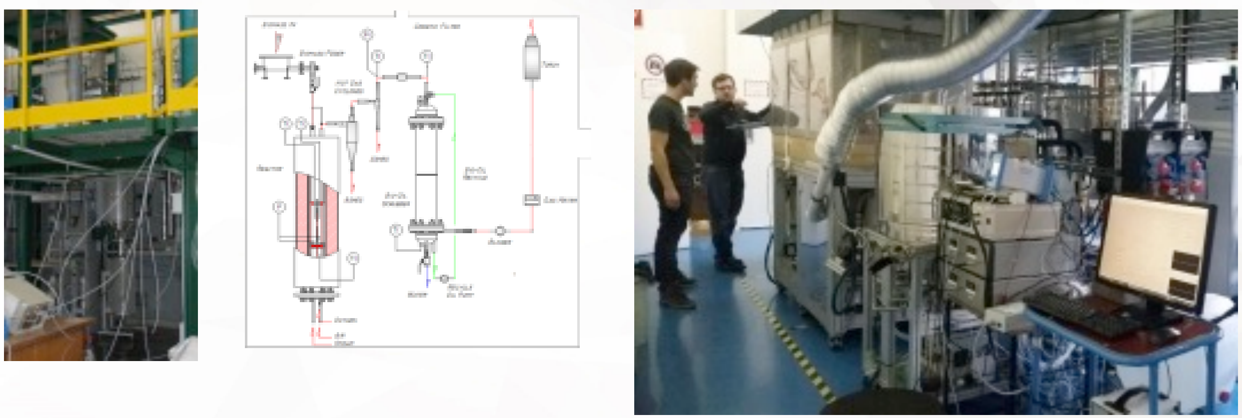
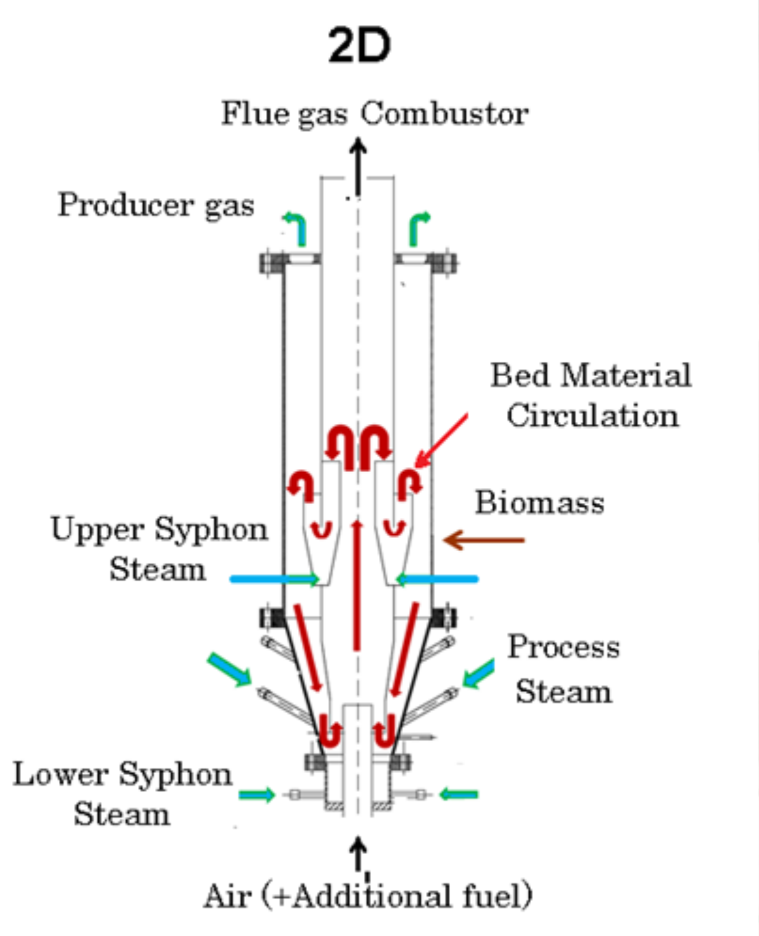


Fig. 3. ENEA gasification and EPFL/SP stack SOFC test rig

100 kWth Gasifier

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



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

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.

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

THANKS FOR THE ATTENTION

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