Università degli Studi Guglielmo Marconi

Innovation Training Lab

Marconi Industry 4.0

CHP AND BLAZE PROJECT

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Laboratory staff

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Ramin Moradi	*PhD*	Andrea Monforti	Grant Student
Andrea Di Carlo	Professor	Elisa Savuto	Res. Fellowship

RESEARCH FIELDS

- **Stationary systems**
  - RES: Solar thermal, Photovoltaic, Biomass, Wind, Hydro, Tidal
  - Machine: ICE, ECE, ORC, FC
  - Thermoc. process: Combustion, Gassification, cracking, reforming, ATFC
  - Electroc. process: Batteries, Ultra capactitor, FC/EL
  - Storage: Thermal (also bi-phase), Electric, Chemical
- **Automotive systems**
  - Driving cycle: vehicles, drones (SWAT)
  - Powertrain: hybrid, elettrical, Hydrogen: HOST, 3emotion

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CHP

- CHP improves energy efficiency through the cogeneration of heat and power in the same plant, using steam or gas turbines, ST/GT, or a combined cycle, CC, or internal combustion engines, ICE, with heat recovery.
- At present, installed electricity generation capacity by CHP in the EU-28 is about 120 GWe (ST 62 GWe, CC 30 GWe, ICE 15 GWe, GT 12 GWe), which generates approximately 11% of EU electricity demand (362 TWh, i.e. on average ≈3000 annual equivalent hours - Eurostat 2017).
- ST, GT and CC are applied to medium-to-large scale; meanwhile ICE, ORC (Organic Rankine Cyle), mGT and FC at small-to-medium scale (but ORC, mGT and FC accounts only for around 0.5% of the installed capacity).

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CHP

- CHP heating capacity is about 300 GWth with a heat production of 775 TWh, i.e. an average of ≈2.5 thermal/electrical power ratio and 2500 annual equivalent hours; Germany, Italy, Poland and the Netherlands have the largest capacity installed (Eurostat 2017).
- Natural gas dominates the CHP fuel market with about 45% share, followed by solid fossil fuels and peat at 18%, oil and oil products at 5%, other fuels at 13% (industrial wastes and coal gases).
- Renewables, mainly biomass and in particular low-cost biomass or biomass waste, are becoming increasingly important having attained 20% of the market (Eurostat 2017).

CHP

- The bioenergy contribution for heating and cooling has currently the largest share (88%) of all RES used for heat and cooling with 76 Mtoe, not far from the 2020 Member States plan of 90 Mtoe (SET-PLAN, action 8, issue paper, 2016).
- CHP systems have significant penetration in the EU industry, producing approximately 16% of final industrial heat demand (Green Public Procurement, CHP Technical background report, 2010).
- CHP plants account for about 60% of EU-28's bioenergy production from solid biomass (EurObserv'ER, 2017).

CHP

- total EU28 energy demand for Heating and Cooling (H/C) equals 51% of the total final energy demand; the majority of the demand for H/C is due to space heating (52%), followed by process heating (30%) and water heating (10%)
- ambitious policy objectives which include, for instance, that all new buildings must be Nearly Zero Energy Buildings (NZEB) from 31st December 2020 (public buildings from 31st December 2018)

CHP

- CHP potential in the buildings sector (District Heating, Hotels, Hospitals Leisure centres & swimming pools, College campuses & schools, Airports, Prisons, police stations, Supermarkets, Shopping centres, Peripheral craft area, Large Office and House)
- Industrial sector (Horticulture and glasshouses, Timber processing, Brewing distilling & malting, Food processing, Wineries, Textile processing, Paper and board manufacture, Pharmaceuticals & fine chemicals, Ceramics, Brick, Cement, Minerals processing, Oil Refineries, Iron and Steel, Motor industry)
- Most biomass (timber industry by-products (off-cuts, sawdust, etc.) black liquor from the paper industry, wood, straw, bagasse, grape marc, animal waste and other solid plant residues) is directly produced in industrial and agricultural facilities that need heat and electricity but there is difficulty in converting different biomass feedstocks in a reliable and economic way

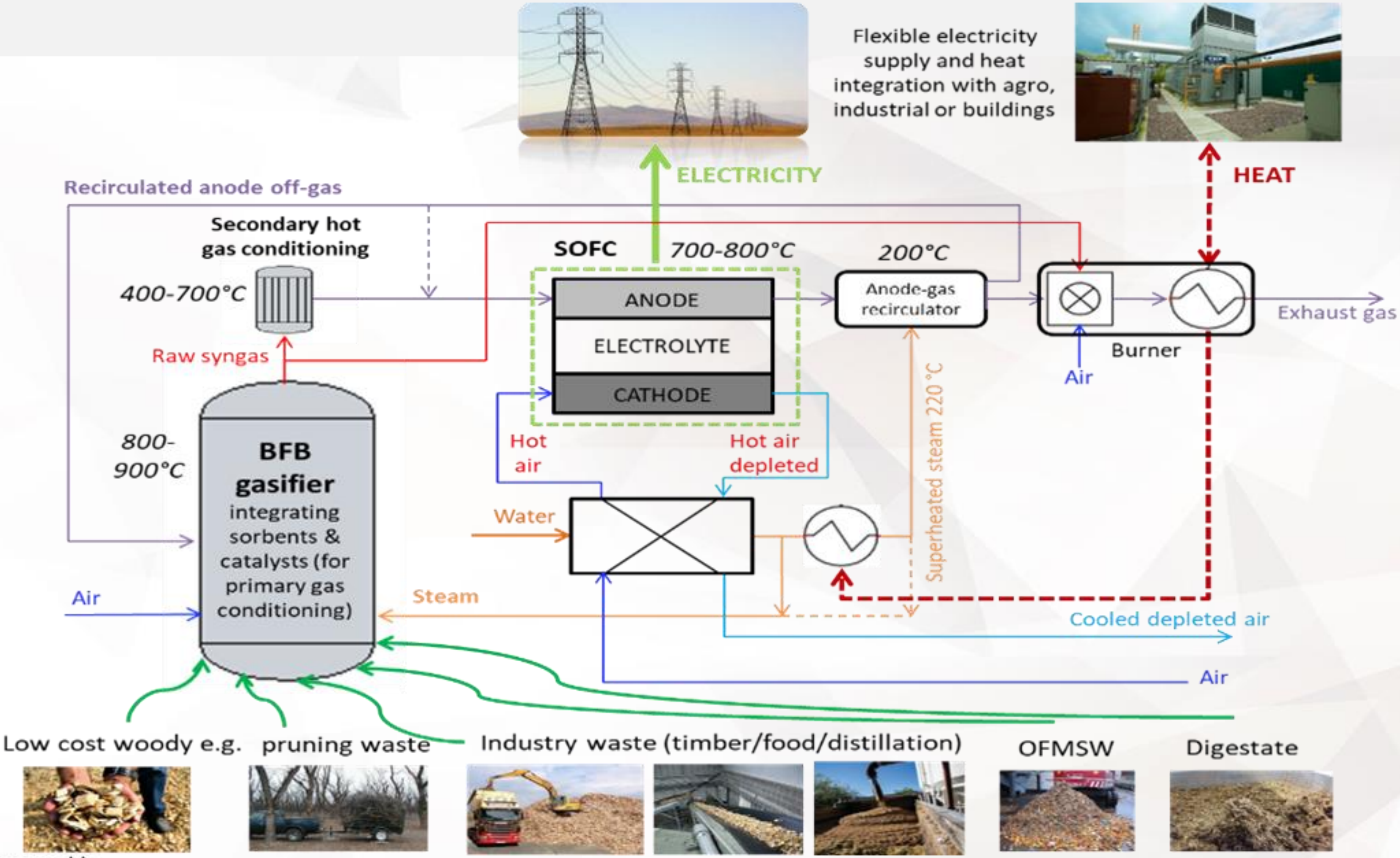
CHP

- Energy efficiency is maximised when a CHP is sized to match a facility's thermal load, resulting in more power than the host site needs.
- Nevertheless, the CHP plants are mainly sized for the constant heating base load, that is only a fraction of the total thermal load, reducing the size at too small CHP and so generating only a small portion of the required heat and less power to the grid

BLAZE

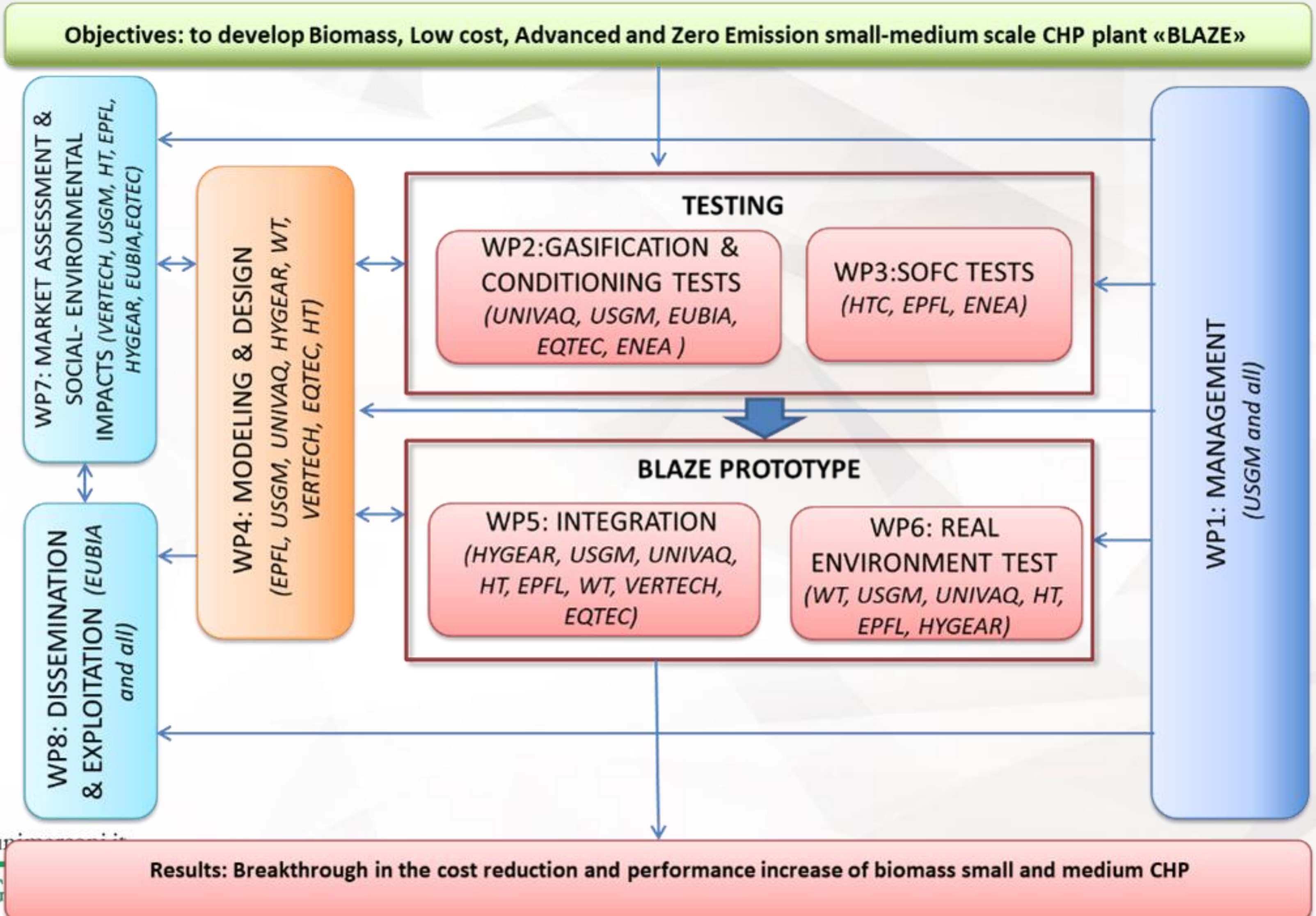
- overall 90% (versus 65%, target SET-PLAN 75%) and electrical 50% (versus 25%, target SET-PLAN >30%) CHP efficiencies for small and medium scale biomass CHP
- near-zero gaseous and PM emissions as well as CAPEX below 4,000 €/kWe (versus the actual 5,000-10,000 €/kWe), and OPEX of ≈ 0.05 €/kWhe (using low cost biomass, i.e. < 80 €/t, respect to the actual greater than 0.10 €/kWhe)
- electricity production cost below 0.10 €/kWh (versus the actual 0.22 €/kWh, SET-PLAN target of 20% cost reduction by 2020, and 50% by 2030).

BLAZE



Flexible electricity supply and heat integration with agro, industrial or buildings
ELECTRICITY
HEAT
Recirculated anode off-gas
Secondary hot gas conditioning
400-700°C
SOFC
700-800°C
200°C
ANODE
ELECTROLYTE
CATHODE
Anode-gas recirculator
Burner
Exhaust gas
Air
Raw syngas
800-900°C
BFB gasifier integrating sorbents & catalysts (for primary gas conditioning)
Hot air
Hot air depleted
Water
Superheated steam 220 °C
Air
Steam
Cooled depleted air
Air
Low cost woody e.g. pruning waste
Industry waste (timber/food/distillation)
OFMSW
Digestate

BLAZE



Objectives: to develop Biomass, Low cost, Advanced and Zero Emission small-medium scale CHP plant «BLAZE»
WP7: MARKET ASSESSMENT & SOCIAL- ENVIRONMENTAL IMPACTS (VERTECH, USGM, HT, EPFL, HYGEAR, EUBIA,EQTEC)
WP4: MODELING & DESIGN (EPFL, USGM, UNIVAQ, HYGEAR, WT, VERTECH, EQTEC, HT)
TESTING
WP2:GASIFICATION & CONDITIONING TESTS (UNIVAQ, USGM, EUBIA, EQTEC, ENEA)
WP3:SOFC TESTS (HTC, EPFL, ENEA)
BLAZE PROTOTYPE
WP5: INTEGRATION (HYGEAR, USGM, UNIVAQ, HT, EPFL, WT, VERTECH, EQTEC)
WP6: REAL ENVIRONMENT TEST (WT, USGM, UNIVAQ, HT, EPFL, HYGEAR)
WP8: DISSEMINATION & EXPLOITATION (EUBIA and all)
WP1: MANAGEMENT (USGM and all)
Results: Breakthrough in the cost reduction and performance increase of biomass small and medium CHP

BLAZE

BIOMASS LOW COST ADVANCED ZERO EMISSION SMALL-TO-MEDIUM SCALE INTEGRATED GASIFIER - FUEL CELL CHP PLANT

Participant No *	Participant organisation name	Country	Short name/type	Main Activity
1 Coordinator	Università degli Studi Guglielmo Marconi	ITALY	USGM/ Research	**WP 1 Management** / WP2 GC -MS tar analysis in conditioning tests /WP4 gasifier plant model/ WP5 Design of the system; Design, manufacturing and acquisition of the system components /WP6 system tests/ WP7 techno -economic plant analysis/ WP8 Diss.& Expl. Strategies, papers and meetings
2	Università degli studi de l'Aquila	ITALY	UNIVAQ/Res	WP1 Management/ **WP2 Gasification and conditioning**/ WP4 Gas ification & Conditioning. detailed models /WP5 Plant preparation / WP6 Gasification & Conditioning tests/ WP8 papers and meetings
3	HTceramix	SWITZERLAND	HTC /SME	WP1 Management/ **WP3 SOFC** single and short FC stacks supplier/ WP5 25 kWe SOFC supplier /WP6 SOFC tests/ WP7 market assessment/ WP8 industrial development
4	Ecole Polytechnique Federale Lausanne	SWITZERLAND	EPFL/Res	WP1 Management/ WP3 SOFC stacks tests/ **WP 4 Model & Design** System optimi sation/ WP5 heat exchanger network desig n, anode gas recirculator/ WP6 25 kWe FC tests/ WP7 techno -economic plant analysis/ WP8 papers and meetings
5	HyGear	NETHERLANDS	HYGEAR / SME	WP1 Management/ WP4 Final system design / **WP5 Integration** Sulfur removal reactor/ 100 kWth gasifier and 25 kWe SOFC integration/ WP6 Operation of the integrated pilot plant / Pilot plant SOFC tests with real syngas / WP7 market assessment/ WP8 industrial development
6	Walter Tosto	ITALY	WT / Large Enterprise	WP1 Management/ WP4 plant design/ WP5 plant Integration/ **WP6 Real environment tests** 100 kWth gasifier /WP8 industrial development
7	VERTECH GROUP	FRANCE	VERTECH/SME	WP1 Management/ WP4 Process modelling and validation/ WP5 Design of the system/**WP7 Techno-economic and socio-environmental analysis** LCA – LCC – S-LCA/ WP8 papers and meetings
8	European Biomass Association	BELGIUM	EUBIA/Non-Profit Association	WP1 Managem ent/ WP2 Biomass supply/ WP7 Market evaluation/ **WP8 Dissemination & Exploitation**
10	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile	ITALY	ENEA / Res	WP1 Management/ WP2 Biomass **gasification**/ WP3 **single FC tests**/ WP8 papers and meetings

BLAZE

- 2015 topic LCE-7 focused on residential CHP systems and intermediate energy carriers.
- 2016 medium and large-scale (>1MW), highly-efficient, low-emission, cost-effective and robust systems with a widen feedstock base, including increased high-temperature heat potential.
- 2017 CHP with transformation of renewable energy into intermediates, improving storage characteristics of upgraded biomass and other renewable and waste carbon sources (power-to-gas and/or power-to-liquid) from excess electricity from renewables.