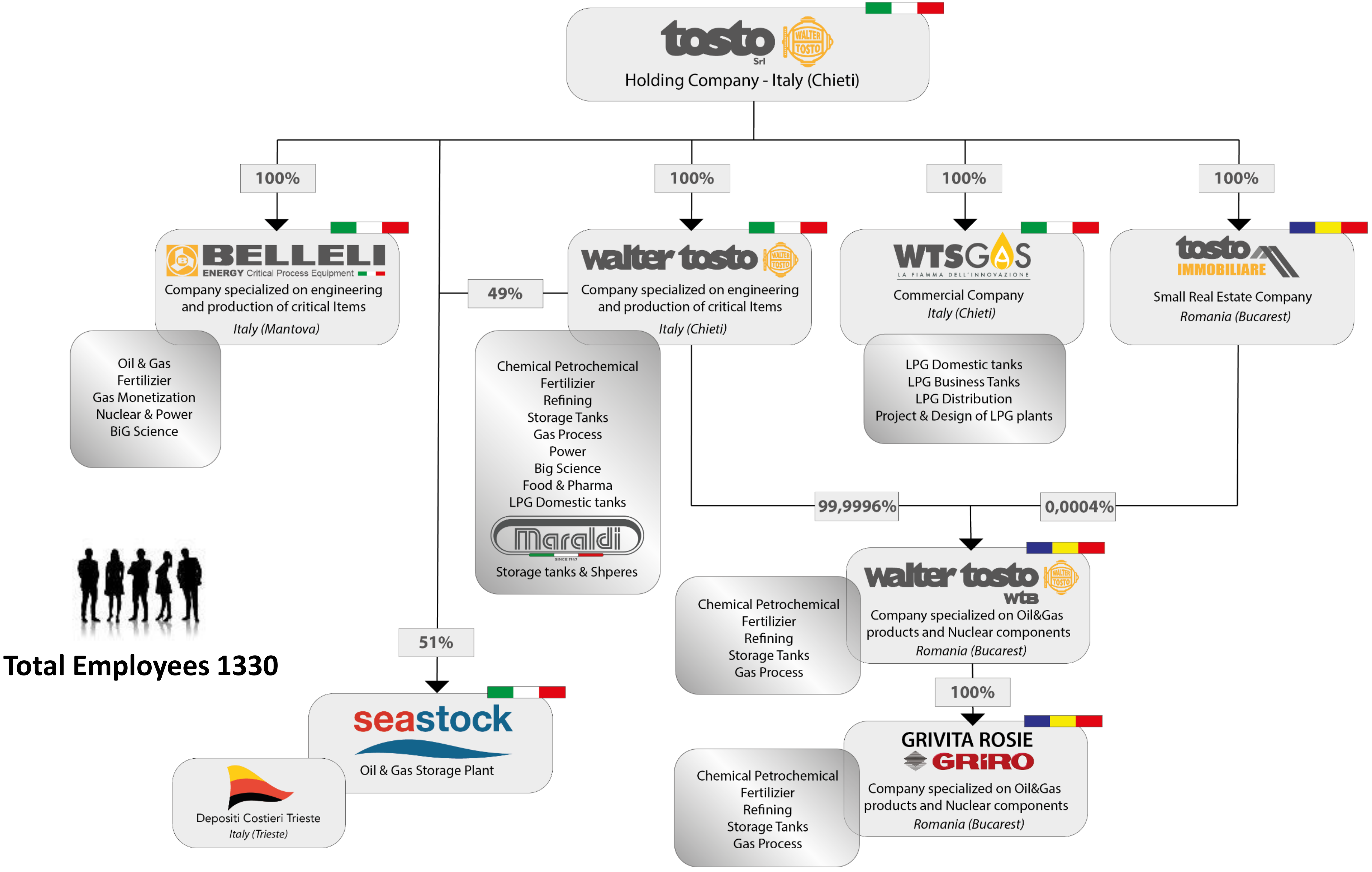
Highly efficient and fuel-flexible technology for combined heat and power from biomass via gasification coupled with SOFC

IEA Bioenergy Task 33 Workshop

2 December 2021

Tosto Group


tosto Srl
Holding Company - Italy (Chieti)
100%
BELLELI ENERGY Critical Process Equipment
Company specialized on engineering and production of critical Items
Italy (Mantova)
Oil & Gas
Fertilizier
Gas Monetization
Nuclear & Power
BiG Science
49%
100%
walter tosto
Company specialized on engineering and production of critical Items
Italy (Chieti)
Chemical Petrochemical
Fertilizier
Refining
Storage Tanks
Gas Process
Power
Big Science
Food & Pharma
LPG Domestic tanks
Maraldi
Storage tanks & Shperes
100%
WTSGAS
LA FIAMMA DELL'INNOVAZIONE
Commercial Company
Italy (Chieti)
LPG Domestic tanks
LPG Business Tanks
LPG Distribution
Project & Design of LPG plants
100%
tosto IMMOBILIARE
Small Real Estate Company
Romania (Bucarest)
99,9996%
0,0004%
walter tosto wtb
Company specialized on Oil&Gas products and Nuclear components
Romania (Bucarest)
Chemical Petrochemical
Fertilizier
Refining
Storage Tanks
Gas Process
100%
GRIVITA ROSIE
GRiRO
Company specialized on Oil&Gas products and Nuclear components
Romania (Bucarest)
Chemical Petrochemical
Fertilizier
Refining
Storage Tanks
Gas Process
51%
seastock
Oil & Gas Storage Plant
Depositi Costieri Trieste
Italy (Trieste)
Total Employees 1330

Company Markets

Refining

Crude Oil Distillation unit

Vacuum distillation unit

Naphtha hydrotreater unit

Catalytic reforming unit

Alkylation unit

Isomerization unit

Distillate hydrotreater unit

Amine gas treater, Claus unit, and tail gas treatment

Fluid catalytic cracking (FCC) unit

Hydrocracker unit

Visbreaker unit

Delayed coking

Chemical & Petrochemical

Ethane cracking: PE/HDPE/LDPE/PP

EB/SM Styrene

Ethylene Oxide (EO)

Ethylene Glycol (EG)

PVC

Propylene Oxide (PO) and

Tertiary Butyl Alcohol (TBA)

Ammonia

Methanol

Urea

Gas Process

Natural Gas Processing (NGL)

Liquefied Natural Gas (LNG)

Gasification Plant

LPG Storage

Gas to Liquid (GTL)

Power

Conventional

Nuclear

Renewable

Licensors

Ammonia	Methanol	Power	Hydrogen and Circular Economy
KBR	HALDOR TOPSØE	AREVA	FOSTER WHEELER
Uhde ThyssenKrupp	MITSUBISHI HEAVY INDUSTRIES	ANSALDO ENERGIA	HALDOR TOPSØE
HALDOR TOPSØE	AIR LIQUIDE	GE ALSTOM	MEMBER
YARA	Eni Snamprogetti	EDF	
CASALE	KBR	KEPCO	
	Lurgi	HITACHI	
	Davy Process Technology	SIEMENS	
	YARA		

Walter Tosto has experience with Licensors listed

Innovation Activities

Walter Tosto participated to R&D project on Styrene technology. The activities included the design and operation of a pilot plant. The scope of Walter Tosto was mechanical design of the reactor including the mechanical optimisation, material analysis and tests for corrosion and erosion, analysis of the mock-up of a reactor.

Walter Tosto has carried out a detailed study for a major process licensor, specifically aimed at identifying the optimal fabrication solutions and possible fabrication alternatives related to the internal tube bundle of a GTL Reactor to be used in the Fischer-Tropsch process.

The challenge

The study was based on the licensor's requirement to have the bundle made-up of bended tubes in U-shape or Snake-shape (instead of having the standard solution of one elbow connecting two straight tubes), in order to minimize the amount of "elbow to tube" weldings and therefore benefit from higher resistance against fouling, corrosion and leakage.

New Fabrication Design

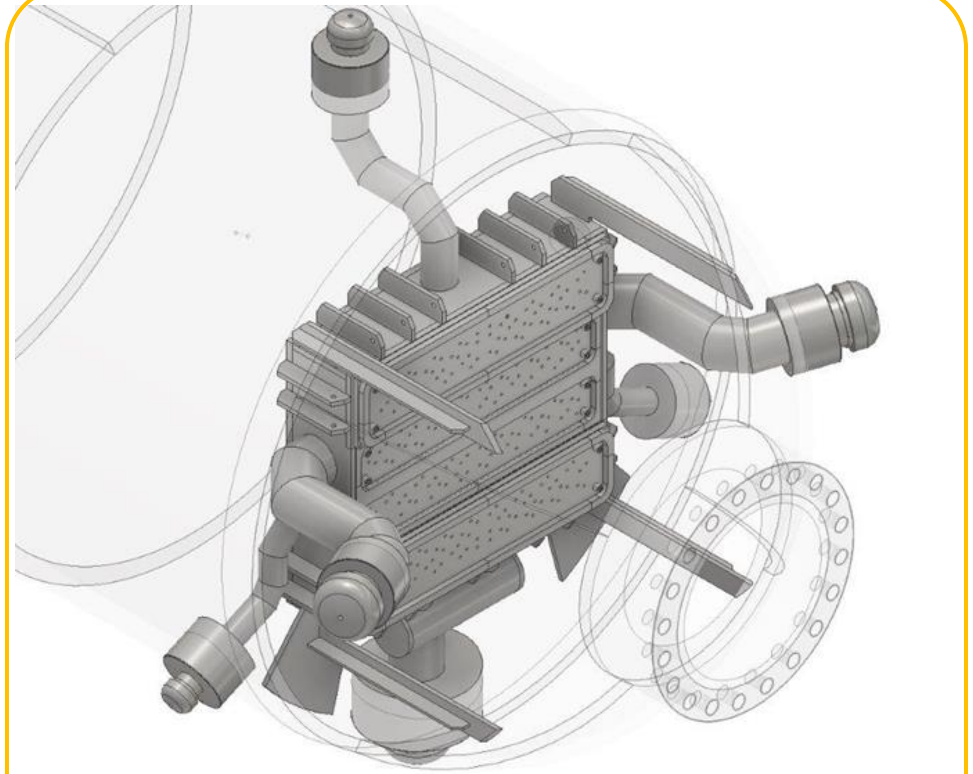
After having analysed the effect of the welded joints on the process performance, the licensor requested Walter Tosto to study the two fabrication options of the internal tube bundle as follows:

1) Optimization of "elbows to the tubes" welding process in order to minimize the internal protrusion of the weld seam (in the range of tenth of a millimeter). The weld protrusion was required to be kept as low as possible in order to reduce the amount of deposited product inside the tubes and consequently allowing a reduction of the fouling factor on the internal surface of the tubes with high benefit on process performance.

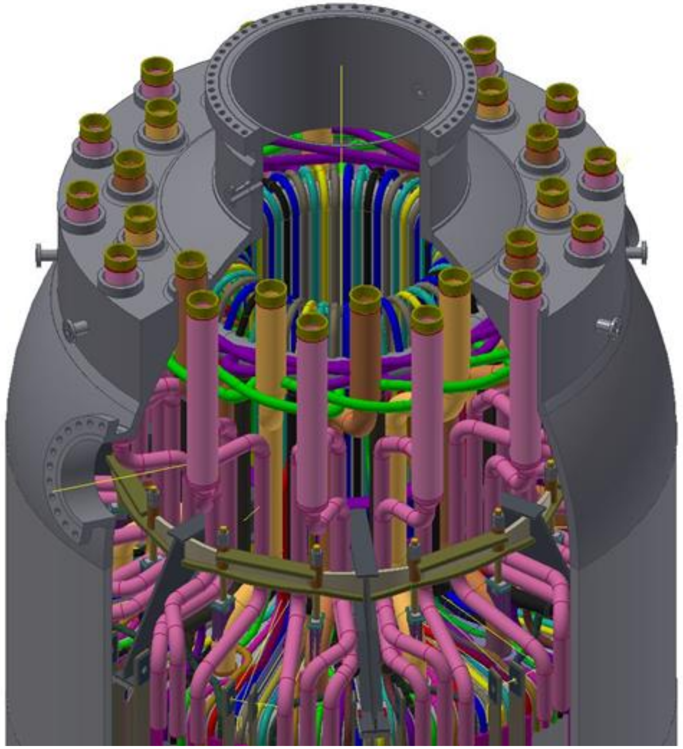
2) Study the possibility of assembly the internal tube bundle starting from longer tubes and bending them in U-shape or snake-shape using special bending machines in order to obtain several bends of the tube bundle starting from a single seamless tube, thus drastically reducing the number of welds (tubes-elbows) required for the assembly of the tube bundle itself.

Activities

Cases of cooperation with licensors for the design and/or industrialization of complex design appliances



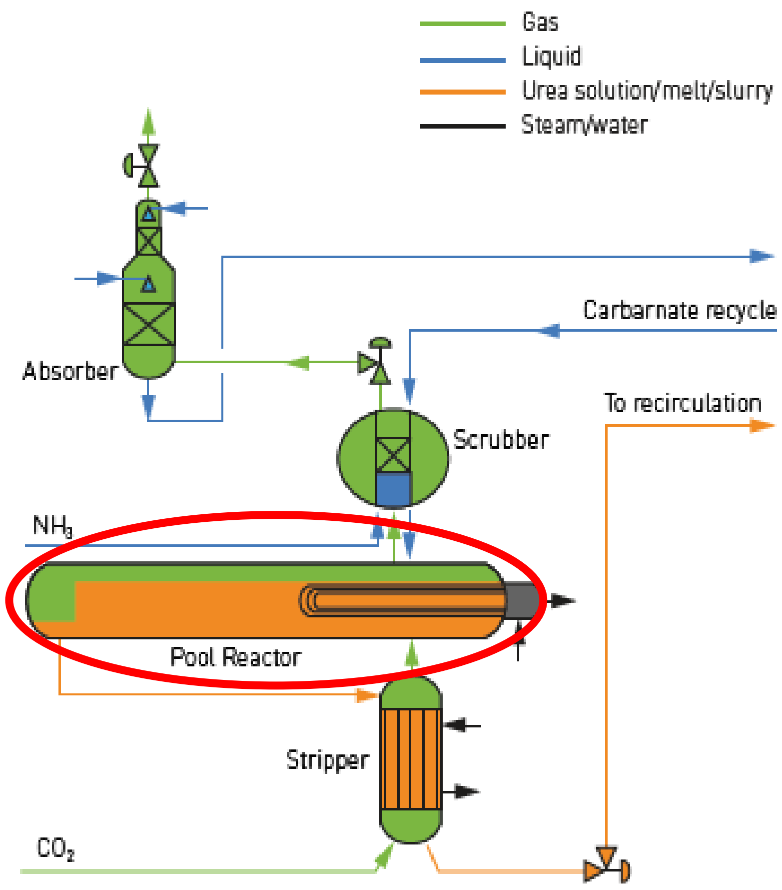
Case study 1
Ultra Low Energy Urea Pool Reactor

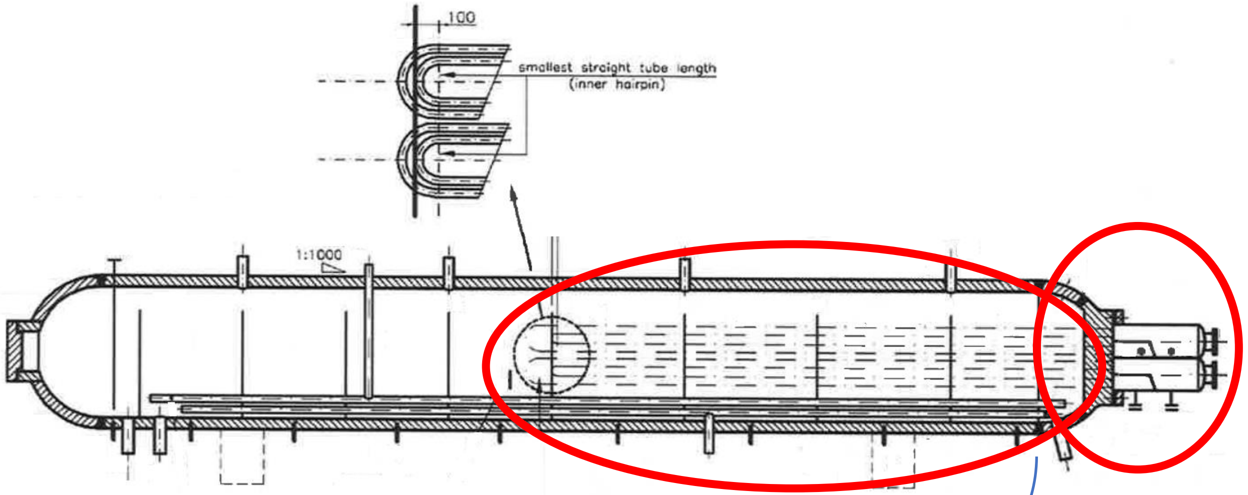


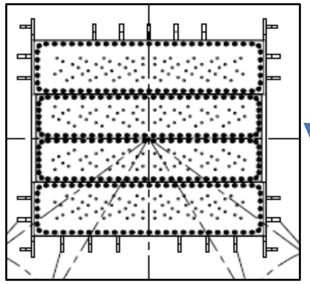
Case study 2
Radiant Syngas Cooler - IGCC Plant

Case Study-1

Ultra Low Energy Urea Pool Reactor





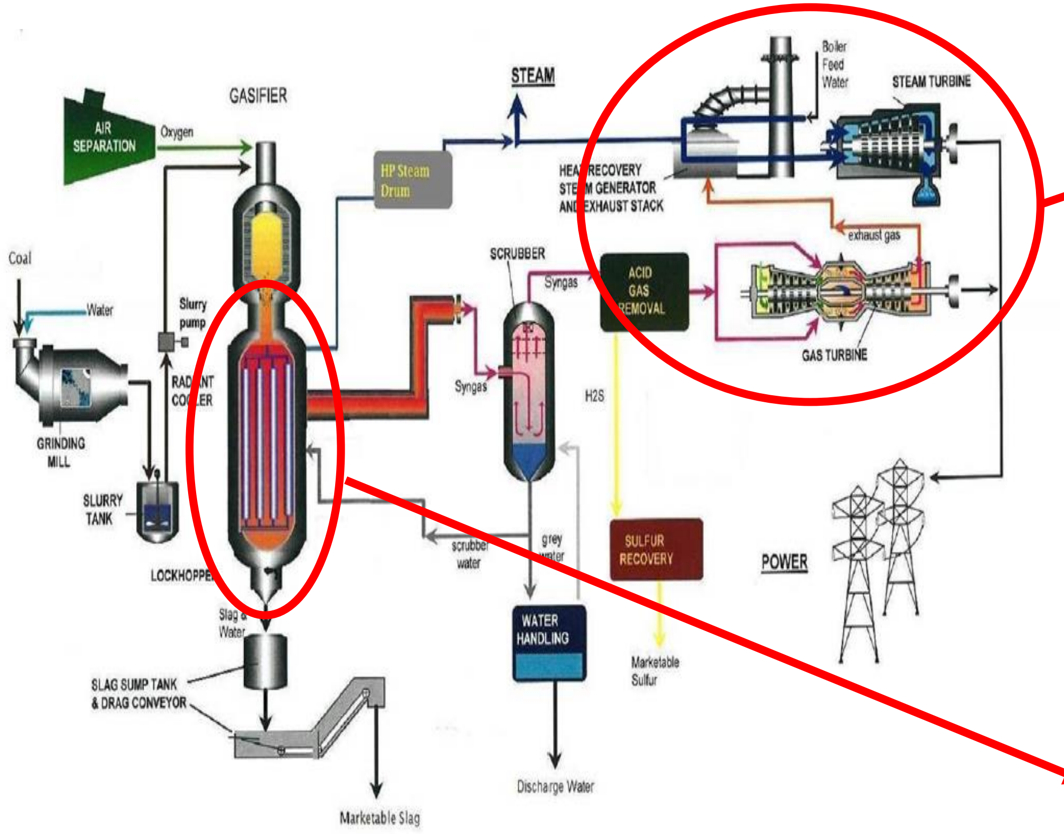


The target

Ultra Low Energy plant (ULE) able to reduce the energy consumption of 35-40% compared to a standard plant.

Case Study-2

Radiant Syngas Cooler - IGCC Plant (Integrated Gasification Combined Cycle)



THE TARGET

Design optimization of Radiant Syngas Cooler to heat exchange improvement to recovery High Pressure Steam to use in the combined Cycle.

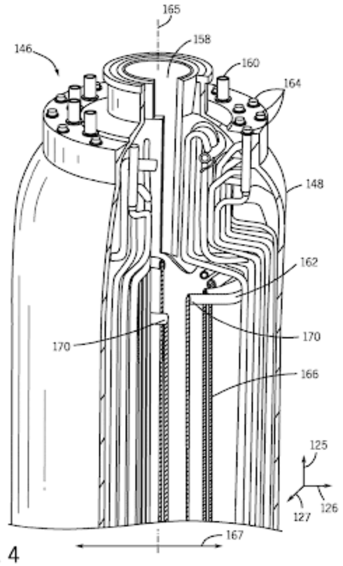


FIG. 4

Radiant Syngas Cooler

Activities

Parco
Scientifico e
Tecnologico d'Abruzzo

Walter Tosto is supporting the activities of Scientific and Technological Park of Abruzzo by:

- using the laboratories for the mechanical testing
- building equipment for the pilot plants operating at the Park
- participating to national and international R&D projects

ASSOCIAZIONE
ITALIANA
PRESSURE
EQUIPMENT

Being the founding member of **AIPE (Italian Association of Pressure Equipment)**, Walter Tosto follows the activities of AIPE in H2IT (Italian Association of Hydrogen and Fuel Cells).

Additionally, **Walter Tosto performs various industrial research and customer support activities** for the storage of hydrogen.

Solar PV industry

Polysilicon Reactors

PPPE - China

Gasification - a key technology in the energy transition and for the circular economy

CHP via SOFC

BLAZE

Low cost Advanced Zero Emission small-to-medium scale integrated gasifier-fuel cell combined heat and power plant

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Gasification of Biomass and Waste

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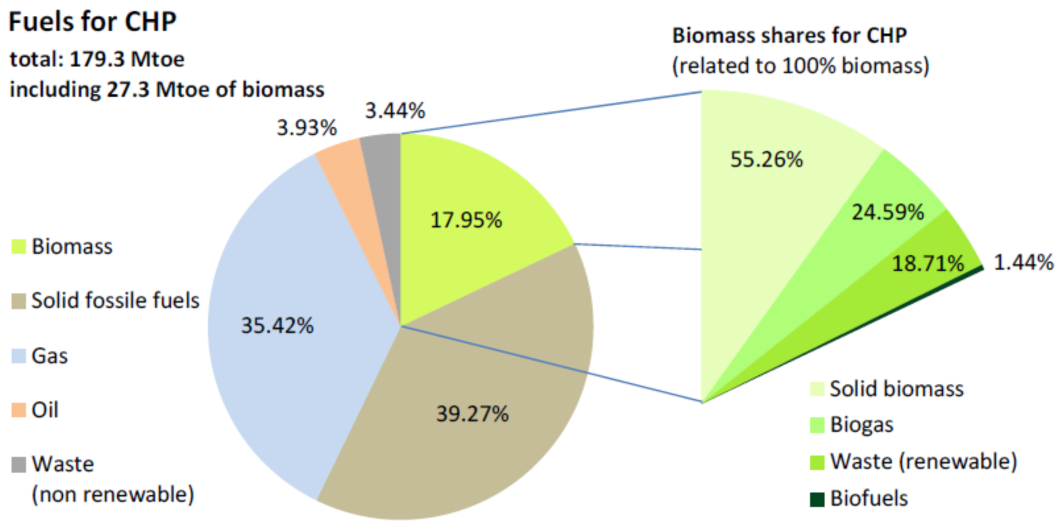
Role of CHP in the energy transition



Source: AEBIOM Statistical report 2017

Currently, the majority of heat is supplied as saturated steam or hot water from local fossil-fuelled plants by using electricity from the grid. There is a great potential for energy and emissions savings when both heat and power is produced locally and from renewable fuel such as biomass.

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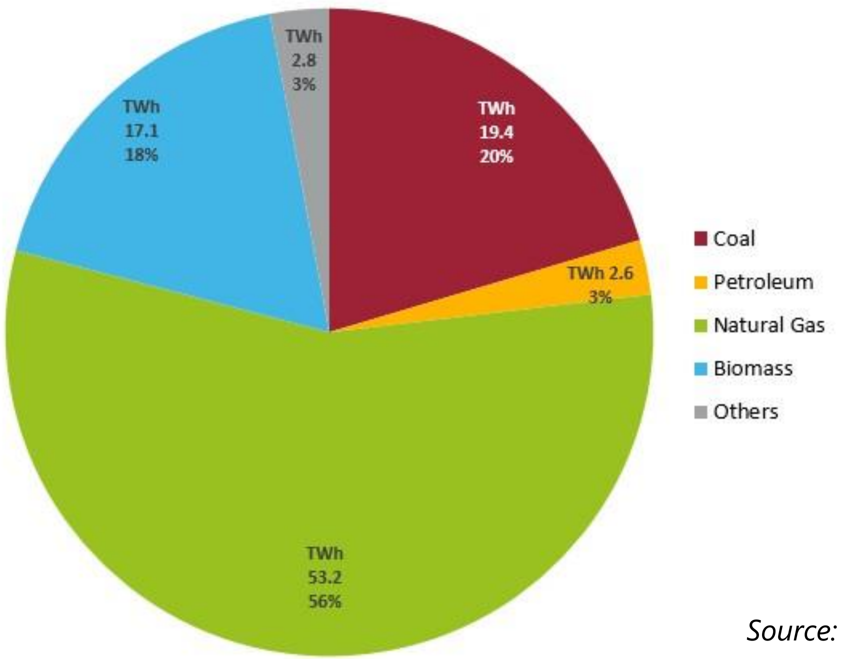
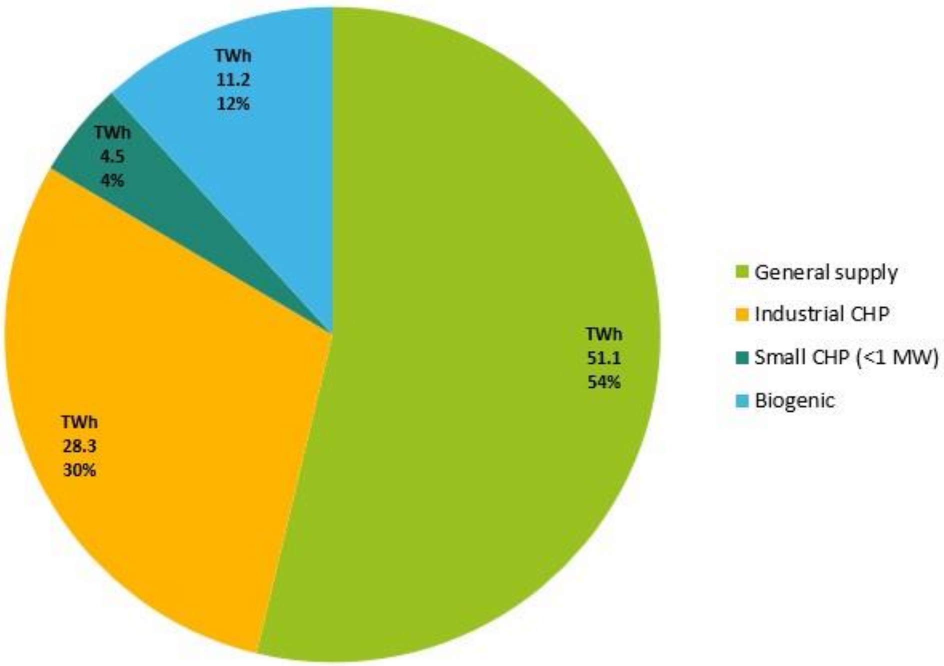
Role of CHP in the energy transition





Source: Öko-Institut 2014

On average in the EU: 50% of energy consumption is in the form of heat, 25% as electricity and 25% in transportation. Therefore, decarbonisation of heating will help to reach the emission reduction targets. Flexible CHP will be at the forefront providing a balancing power to the electrical system and heating.

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BLAZE

Horizon 2020
European Union Funding
for Research & Innovation

BLAZE is an EU-funded research project.

It involves industry, universities and associations, and is coordinated by Guglielmo Marconi University (USGM).

UNIVERSITÀ DEGLI STUDI DI TERAMO

EPFL

ENEA

WALTER TOSTO

SOLID POWER

HYGEAR

EnerecO

EUBIA

etaflorence renewableenergies

- 9 WPs
- > 4 years project
- 4.3 M€
- 10 partners

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OBJECTIVES

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The technology is developed for a CHP capacity range from small (25-100 kWe) to medium (0.1-5 MWe) scale. Pilot plant is the integration of various innovative technologies:

- dual bubbling fluidised bed technology integrated with high temperature cleaning & conditioning system
- high temperature gas cleaning for HCl and H2S removal
- thermal and chemical integration of SOFC (efficient gas recirculation of the fuel cell anode exhaust to the gasification process)

Parameter	Current	BLAZE
electrical efficiency	≈ 25%	≈ 50%
investment cost	≈ 10,000 €/kWe	≈ 4,000 €/kWe
operating cost	≈ 0.10 €/kWhe	≈ 0.05 €/kWhe
electricity production cost	≈ 0.20 €/kWh	≈ 0.10 €/kWh
Negligible gaseous and particulate matter emissions		

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WORK PACKAGES

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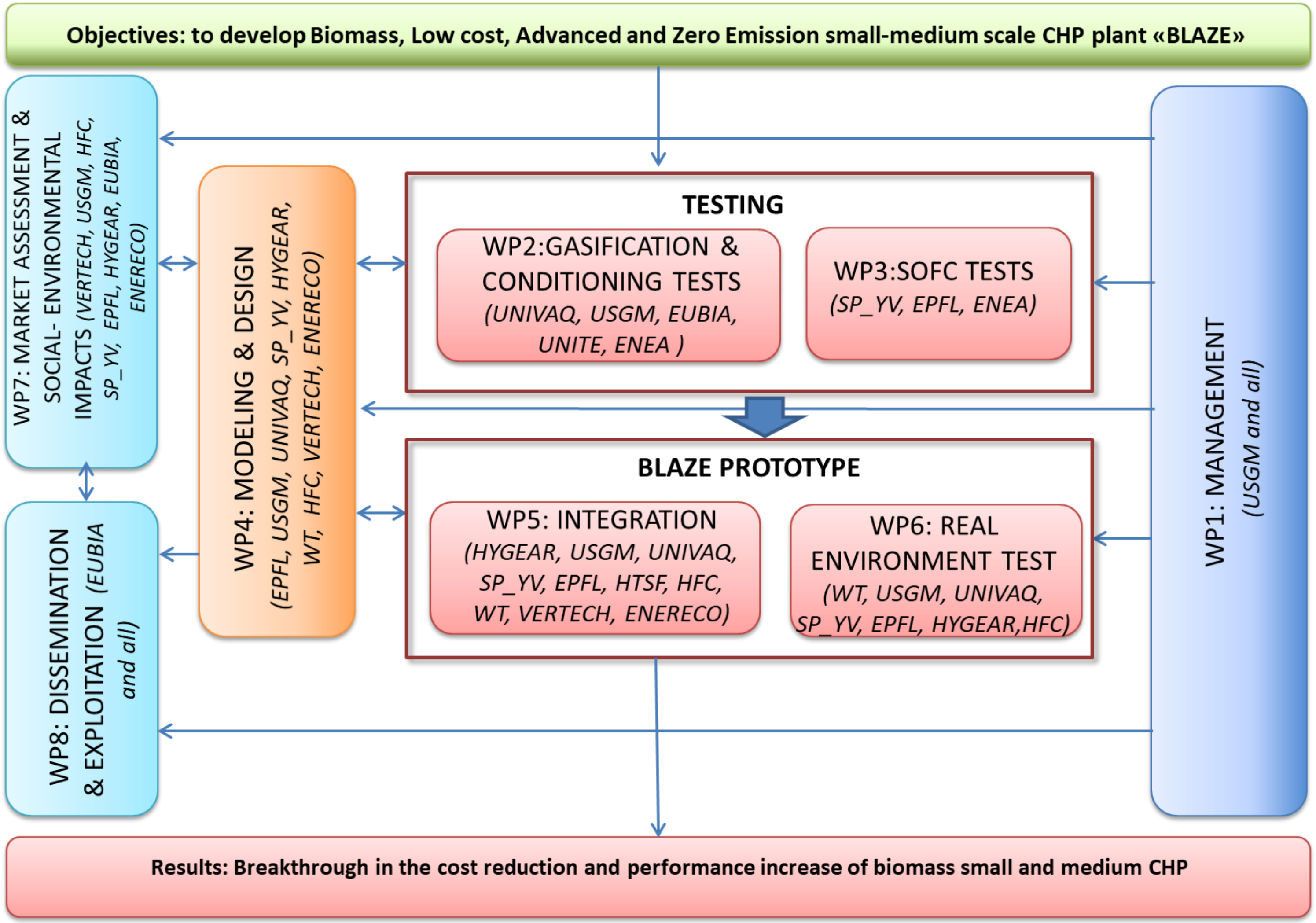

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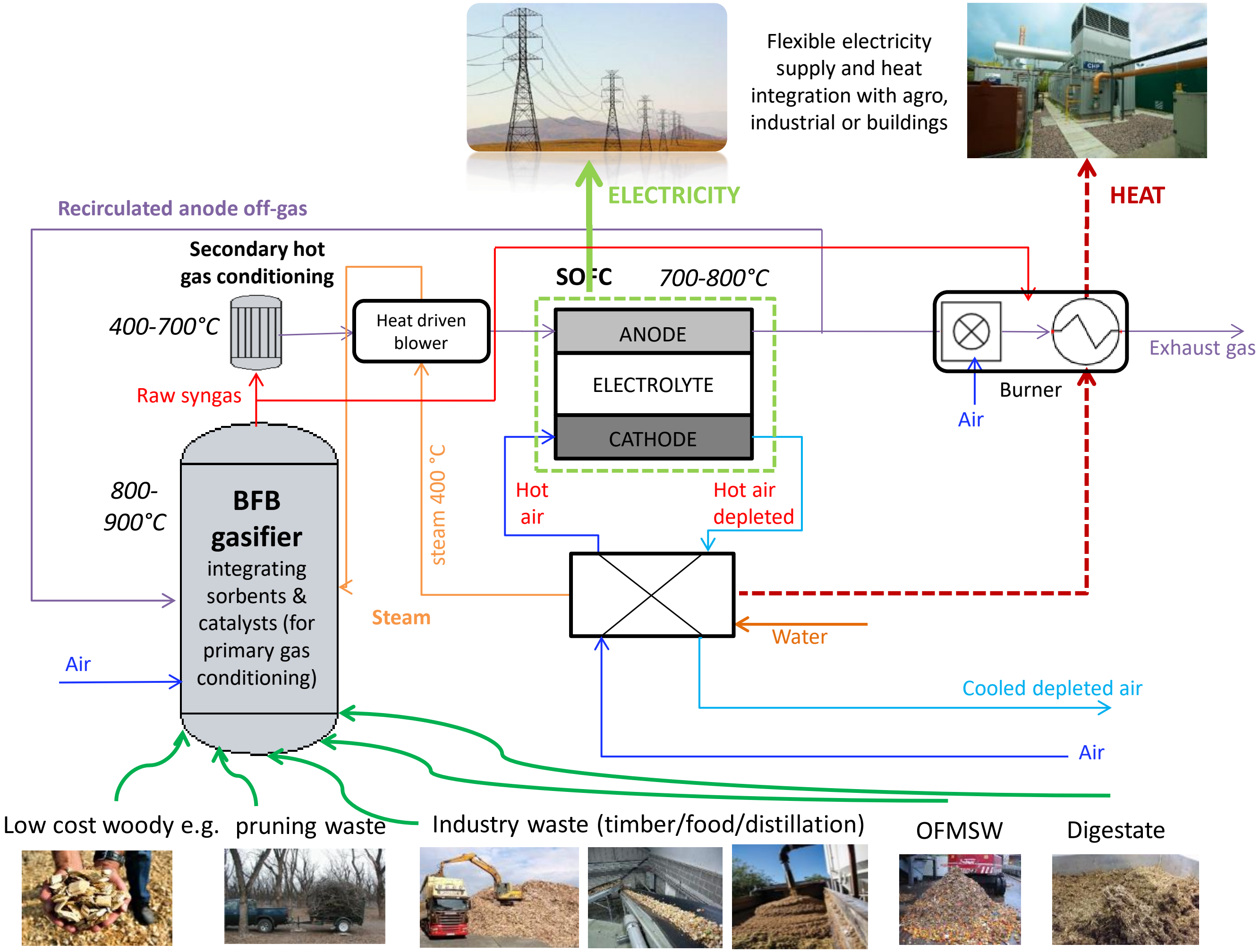
PILOT PLANT



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PROCESS FLOW DIAGRAM

BLAZE

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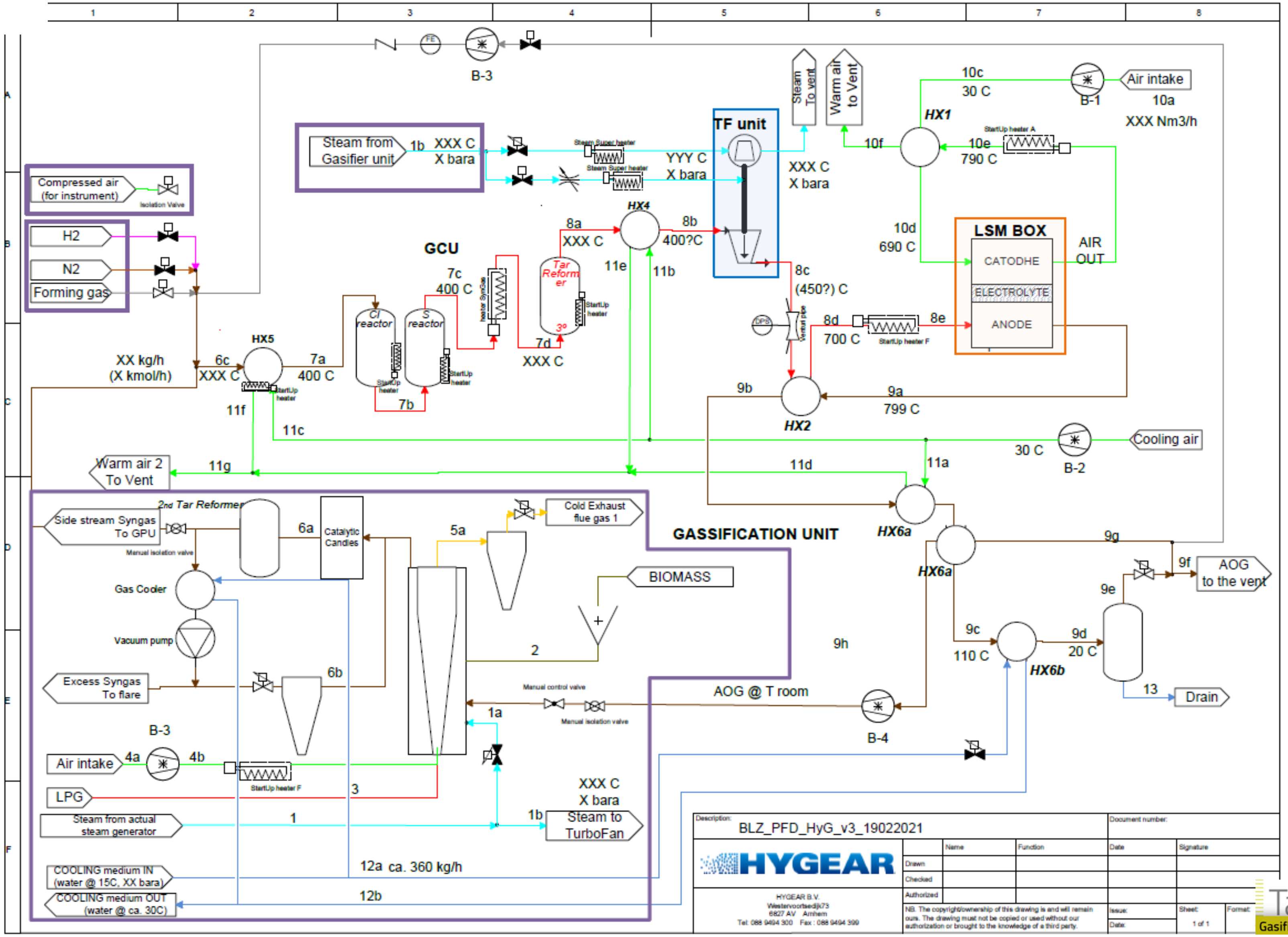

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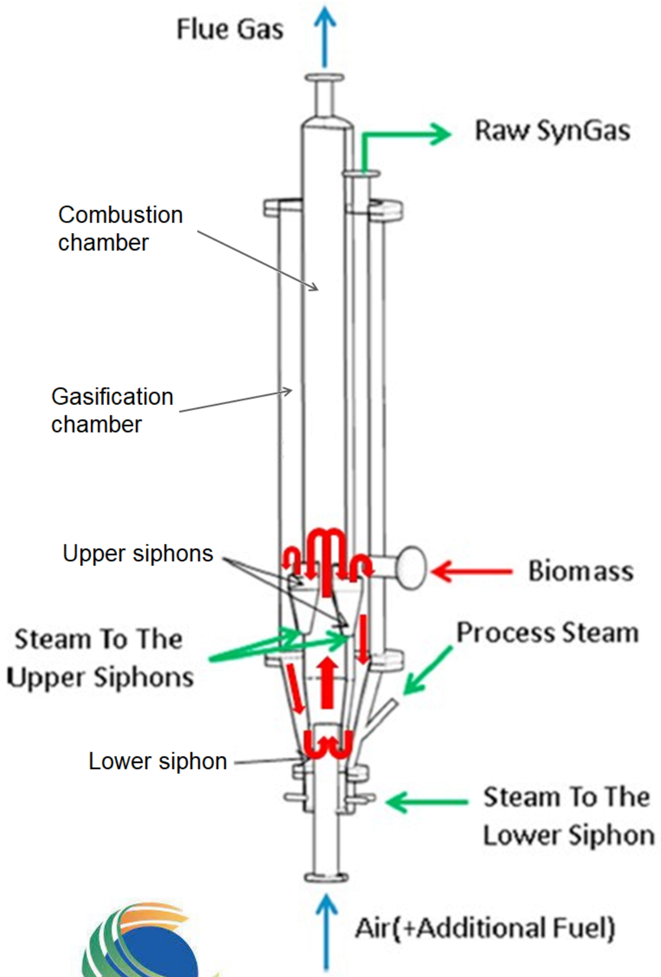
GASIFIER

100 kWth dual bubbling fluidised bed



Innovative design:

- Two **concentric cylindrical** reactors in bubbling regime
- Heat exchange between chambers by bed circulation and **heat transfer through the wall**
- External **gasification** reactor – **slow bed** $u=1,5\text{-}3^*u_{mf}$; fed with biomass (hazelnut shells) and fluidized with steam
- Internal **combustion** reactor – **fast bed** $u=5\text{-}10^*u_{mf}$; fluidized with air (+ additional fuel: LPG)
- **Siphons** fluidized with steam ($u=1,5^*u_{mf}$), for bed material+char circulation and heat transfer
- Bed material **olivine** sand, mildly catalytic

Biomass feeding rate = 15 and 20 kg/h

Syngas composition (%vol dry):

H_2 = ≈ 33-36%;

CO = ≈ 22-24%;

CO_2 = ≈ 18-23%;

CH_4 = ≈ 10-12%

Leakage tests demonstrated small leakage accounting for 3% between combustor and gasifier

BLAZE
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GASIFICATION UNIT

dual bubbling fluidised bed technology integrated with high temperature cleaning & conditioning system

Cochlea

Biomass hoppers

Gasifier

Backpulse system for candle regeneration

Vessel with filter candles

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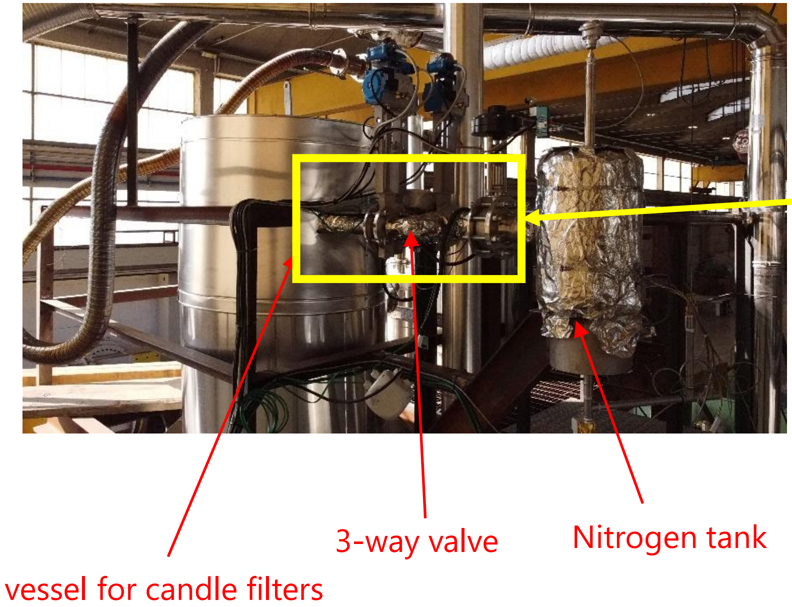
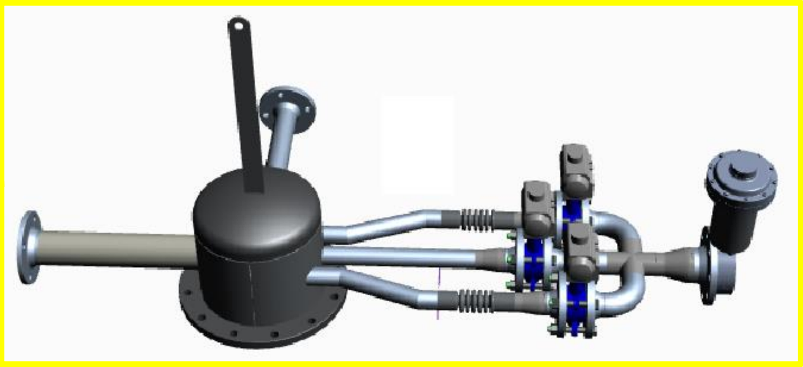
HOT GAS CONDITIONING

backpulse system





The back-pulse system has been installed on the upper section of the candles vessel, in order to operate a backflow of N2 through the candles to eliminate the solid particulate accumulated on the external surface of the filters.

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GAS CLEANING UNIT

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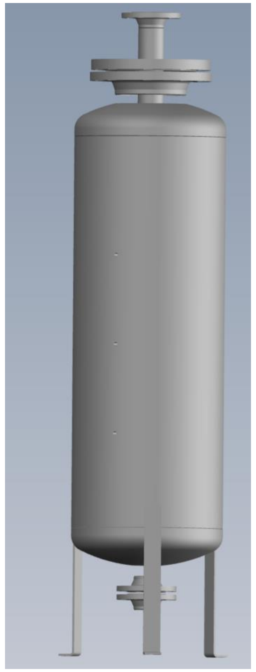
Gas Cleaning Unit (GCU) design

- Selection of commercial available absorbent materials
- Equilibrium calculation for the S and Cl removal reactions
- Rector volume sizing and vessels design
- Selection of heat exchangers and heaters for the proper GCU operation

HCl reactor design

- Vessel has been designed
- Reactor is equipped with 6 TCs to monitor the temperature profiles
- An external band heater will be used to heat up the reactor during the system start-up
- Vessel will be thermally insulated
- Sorbent material has been acquired



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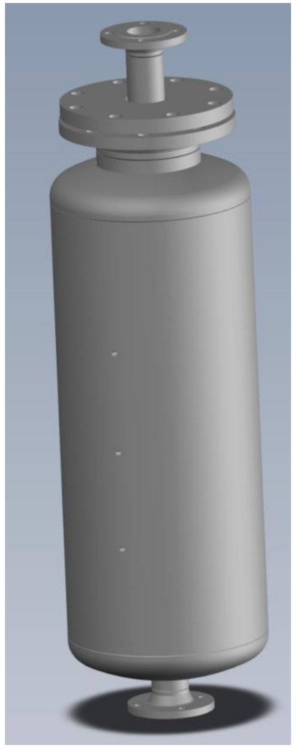
GAS CLEANING UNIT

H2S reactor design

- Vessel has been designed
- Reactor is equipped with 6 TCs to monitor the temperature profiles
- An external band heater will be used to heat up the reactor during the system start-up
- Vessel will be thermally insulated
- Sorbent material has been acquired



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SOFC SYSTEM

Large Stack Module (LSM)

- Power output: 25 kWe (integrating 4 stacks of 6,5 kWe)
- Fuel: Hydrogen, Methane reformate and Syngas
  - Nominal convertible flow **H2:** 280 NL/min
  - Maximum convertible flow **CH4:** 70 NL/min
- Oxidant: Air
  - Maximum tolerated flow: 5600 NL/min
- 1699 x 792 x 1385 mm
- 1505 kg

Scale-up: related cluster of 25 kWe system for higher capacity applications (e.g. medium CHP, grid storage, Power-to-Gas and steam electrolysis)

Advantages: higher electrical efficiency, lower emissions and noises, fuel flexibilities, reversible operation capability (fuel cell and electrolysis mode), lower SOFC temperatures and better CHP management

CONCLUSIONS

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- The use of CHP technology will contribute to pursue energy savings targets intended within the energy efficiency policy measures
- Flexible CHP will boost wind and solar energy to ensure a continuous supply when availability is limited
- Biomass gasification is regarded as a promising option for the sustainable production of hydrogen rich gas used in fuel cells for power generation
- CHP via SOFC can be a solution for the locations with high spark spread (high electricity cost and low natural gas cost) or in the countries with lower grid reliability. It offers flexible operation with low emissions
- BLAZE plant will propose small-to-medium scale integrated gasifier-fuel cell combined heat and power plant for the decarbonisation of heat and power generation

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Thank you for your attention