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Gasification of a municipal solid waste in a pilot scale bubbling fluidized bed reactor

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GASIFICATION of a MSW in a PILOT SCALE BFB REACTOR

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AMRA - Analysis and Monitoring of Environmental Risk

The Framework
and
the Scope of the Study

Main Goals of a Waste Management System

i) **Protection of human health and the environment**, than reduction of emissions, monitoring of toxicological effects and minimization of health risks, minimization of GHSs;

ii) **Conservation of resources**, such as materials, energy, and land;

iii) ***After-care-free* waste management**, meaning that neither landfills nor WtE, recycling or other treatments leave problems to be solved by future generations;

iv) **Economic sustainability** of the whole cycle of MSW management, also in a welfare economy perspective.

Waste Management Guidelines

i) **Efficient service of collection and disposal**,

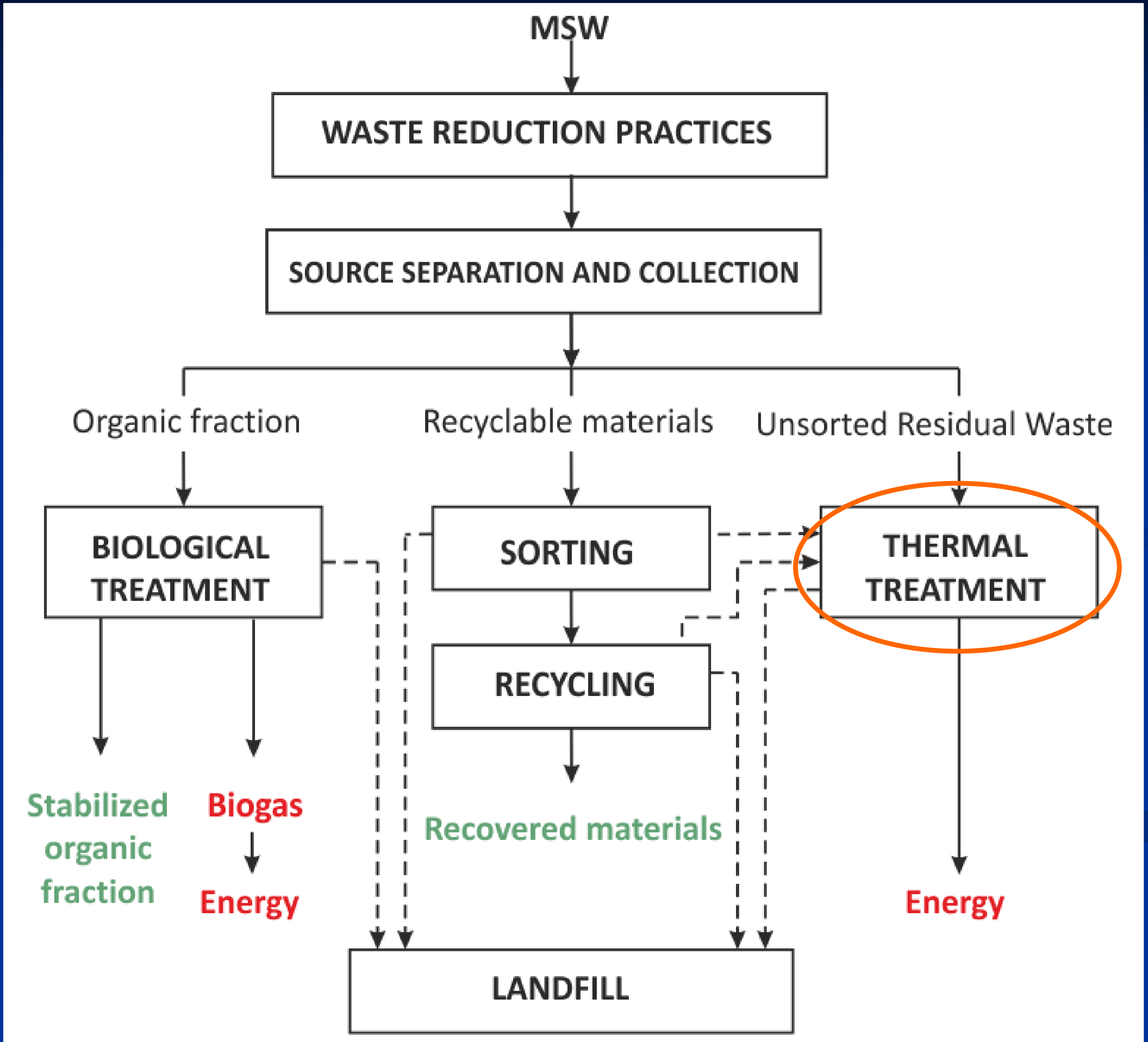
ii) **Minimization of Landfill Option**, which is becoming crucial due to the continuously reducing space for sanitary landfills;

iii) **Minimization of Operations Entailing Excessive Consumption of raw materials and energy** without yielding an overall environmental advantage;

iv) **Maximization of Material Recovery**, albeit in respect of the previous point;

v) **Maximization of Energy Recovery from materials that cannot be efficiently recycled**, in order to save both landfill volumes and fossil-fuel resources.

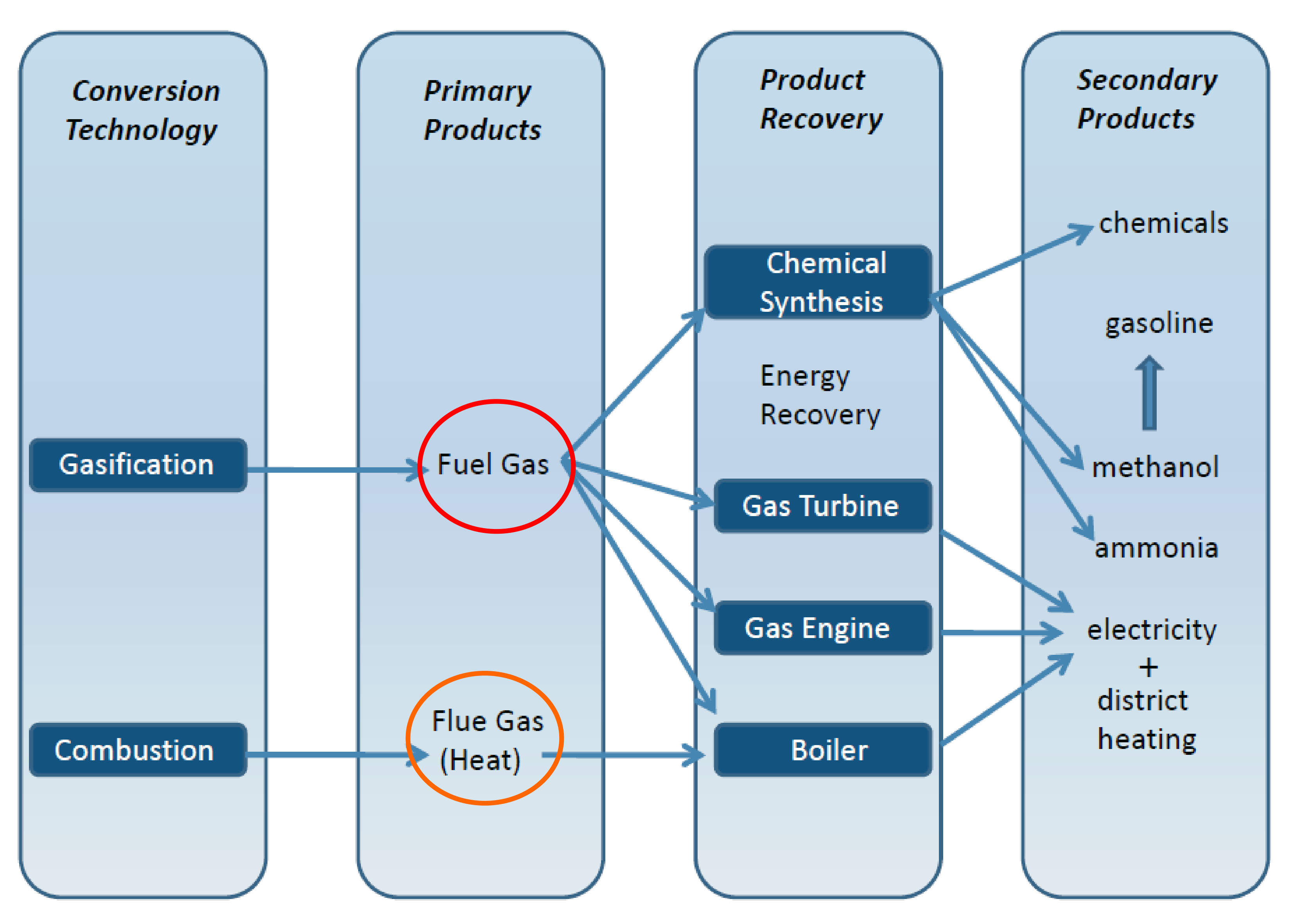
A Sustainable WM system



Role of WtE in a sustainable WM system

1. **Reduction of mass and volume of waste**, therefore preserving landfill space;
2. **Sustainable energy recovery** from the solid waste stream;
3. **Recovery of material** from solid residues;
4. **Destruction of a number of organic contaminants** present in the waste stream;
5. **Reduction of greenhouse gas emissions** with respect of anaerobic decomposition in landfills;
6. **Separation of inorganic components from the organic fraction**, so allowing reuse or inertization and preventing dispersion and accumulation of hazardous constituents in the environment and recycled products.

Types of WtE processes



Taxonomy of gasification technologies

Criteria	Types
Heat supply	▪ auto-thermal (directly heated) ▪ allo-thermal (indirectly heated)
Temperature	▪ low-temperature (typically below 900°C) ▪ high-temperature (typically above 1200°C)
Gasification agent	▪ air ▪ oxygen enriched-air ▪ oxygen ▪ steam
Number of treated fuels	▪ gasification ▪ co-gasification
Reactor type	▪ fixed bed: up-draft ; down-draft; shaft furnace ▪ fluidized bed: bubbling, circulating, internally circulating, dual ▪ rotary kiln ▪ moving grate ▪ plasma: single and double stage
Bottom ash status	▪ dry bottom ash ▪ vitrified slag (melting system)
WtE configuration	▪ heat gasifiers ▪ power gasifiers

Scope

• to assess the technical feasibility of a BFBG able to treat 5000 t/y of a SRF obtained from a sorting process of MSW.

To this end, a number of tests were carried out in a pilot scale BFBG.

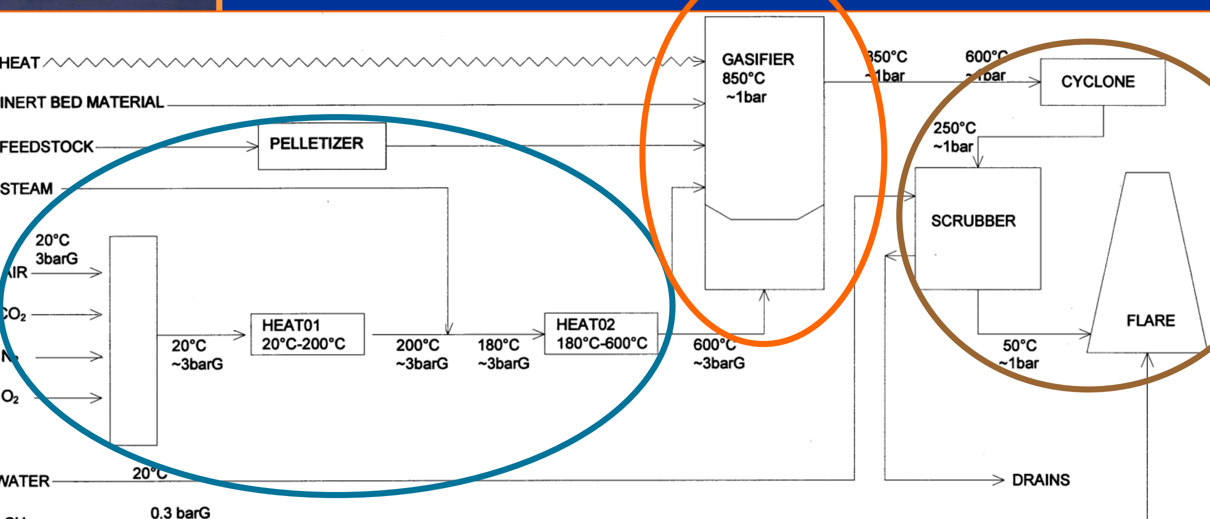
The experimental data were processed by mass and energy balances, in order to obtain information useful to define design solutions and a suitable plant configuration for energy generation.

The Pilot Scale BFBG and the Materials Tested

The FluGas reactor

The FluGas reactor

Geometrical parameters	ID: 0.381m; total height: 5.90m; reactive zone height: 4.64m; wall thickness:12.7mm
Feedstock capacity	100 kg/h
Thermal output	up to about 400kW
Typical bed amount	145 kg
Feeding system	over-bed air-cooled screw feeder
Gasifying agents	Air (but also: oxygen, steam, carbon dioxide)
Range of bed temperatures	700-950°C
Range of fluidizing velocities	0.3-1m/s
Flue gas treatments	cyclone, scrubber, flare
Safety equipments	water seal, safety valves, rupture disks, alarms, nitrogen line for safety inerting

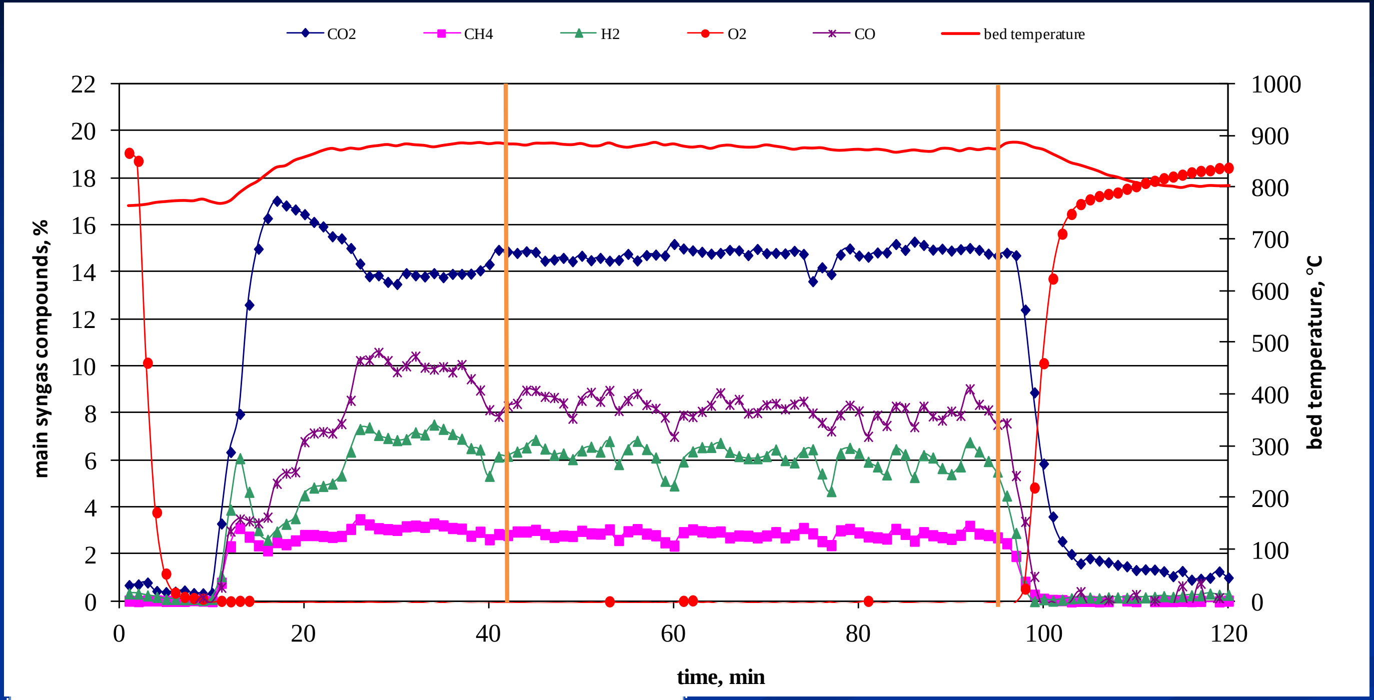


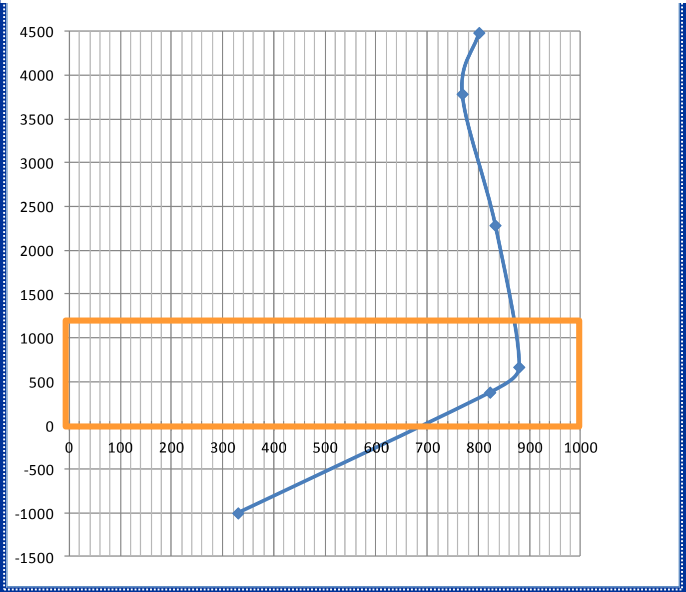
The materials tested

Ultimate analysis, $\%_{wt,\,ar}$	
C	41.2-45.4
H	6.0-6.5
N	0.66-0.70
S	0.1-0.3
Cl	0.1-0.2
O (by diff.)	22.9-24.2
Moisture	3.7-9.1
Ash	18.5-20.4
Heating value, MJ/kgfuel, ar	
LHV	16,600-19,200

Olivine	Mg-Fe silicate
Chemical composition, %	
SiO_2	39-42
MgO	48-50
Fe_2O_3	8-10.5
CaO	<0.4
K_2O	-
TiO_2	-
Al_2O_3, *Cr_2O_3*, *Mg_3O_4*	0.8
LOI (loss of ignition)	0.20
Size range, µm	200 ÷ 400
Sauter mean diameter, µm	298
Particle density, kg/m³	2900

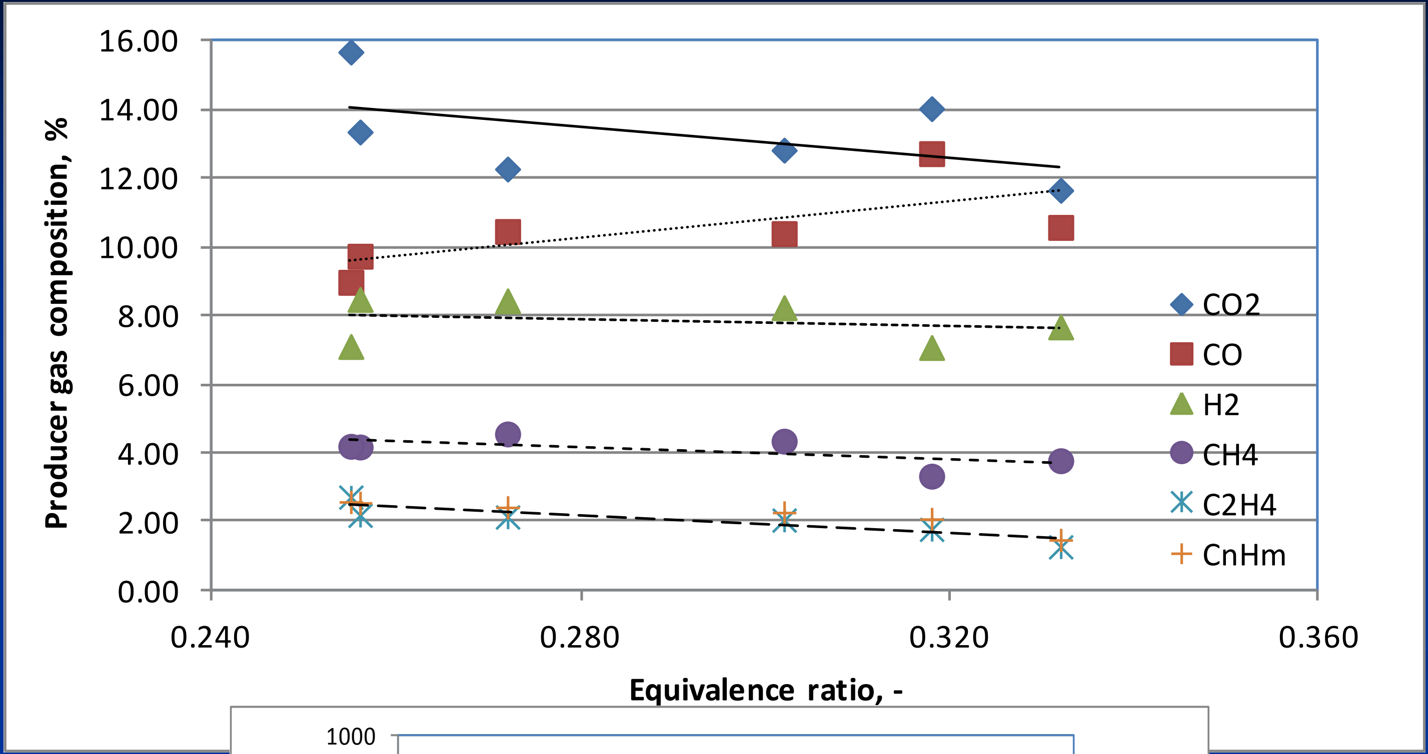
The experimental procedure

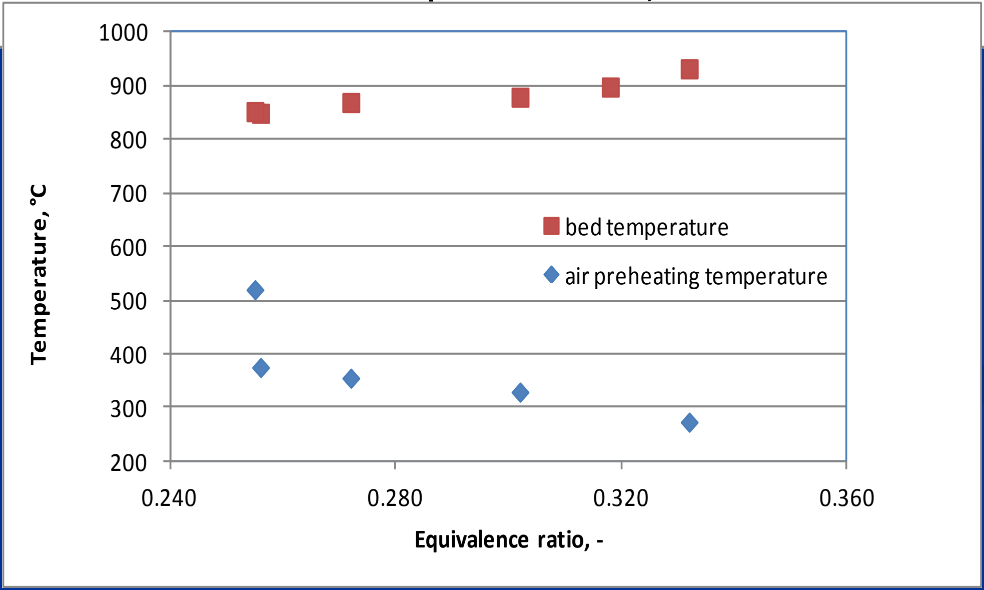




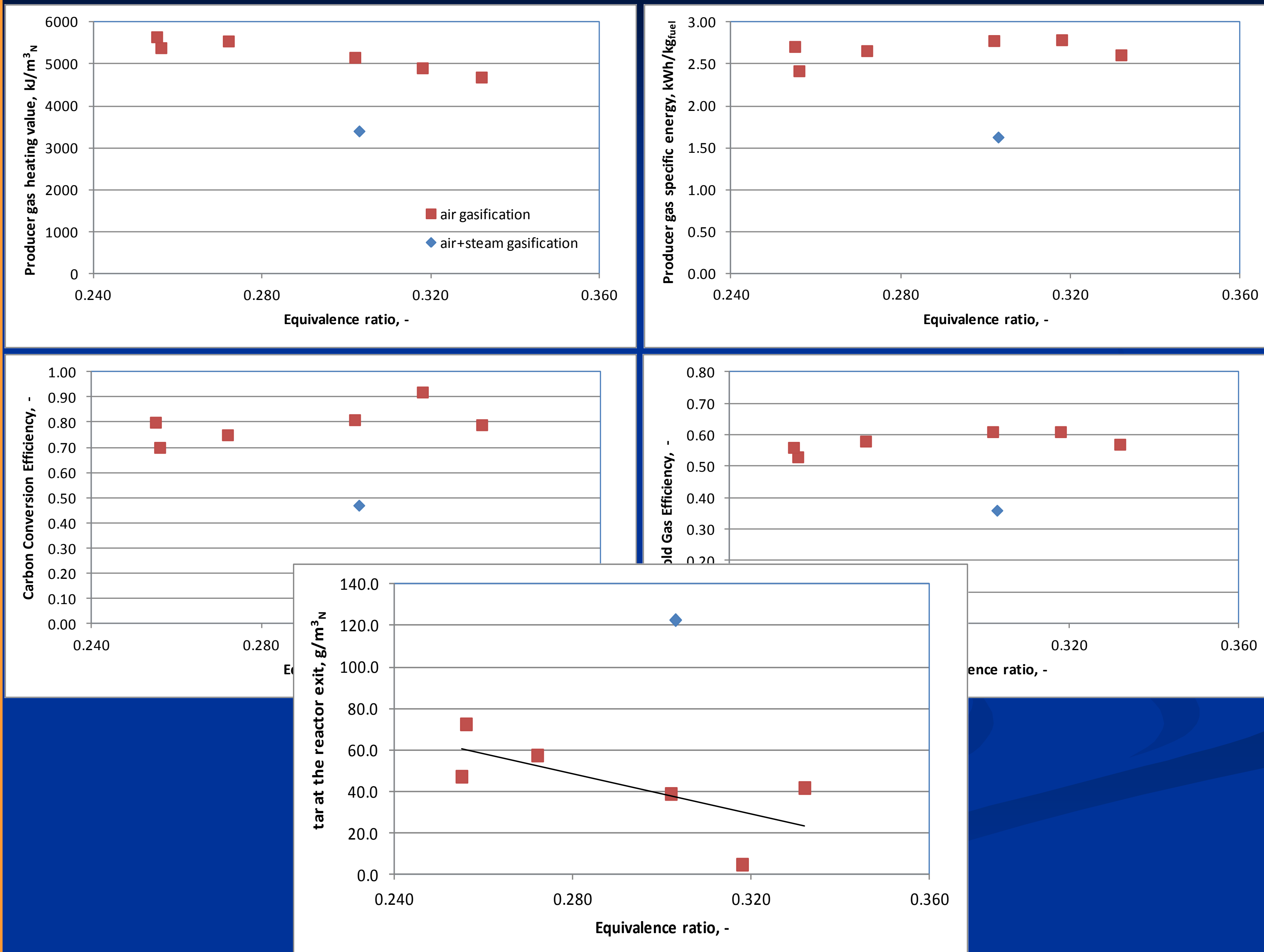
The Experimental Results

Syngas composition





Process performance



The
Proposed Plant
Configuration

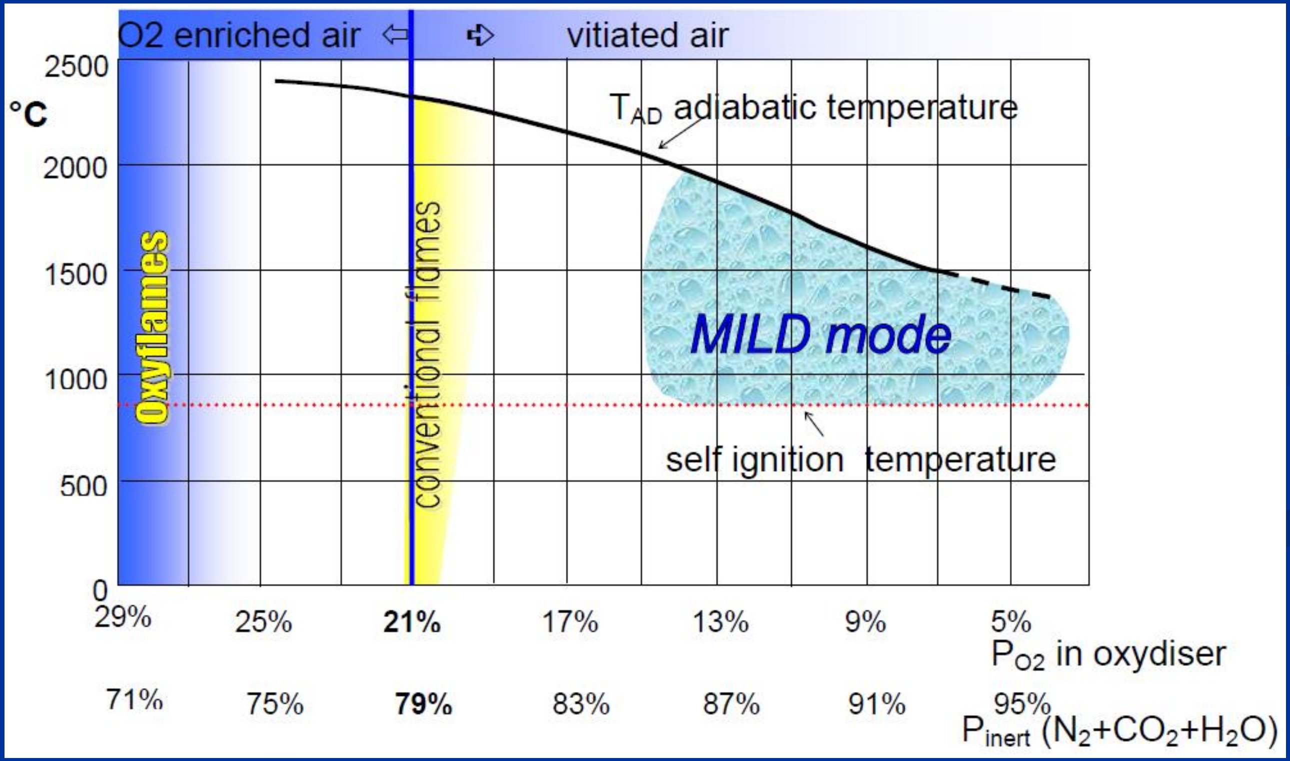
Plant configuration: gasification section

The experimental activity carried out with the pilot scale BFB gasifier indicates that it is not easy to obtain an efficient and sustainable cleaning of the syngas. A "heat gasifier“ configuration has been adopted, where the syngas is directly burned and the flue gases are then cleaned.

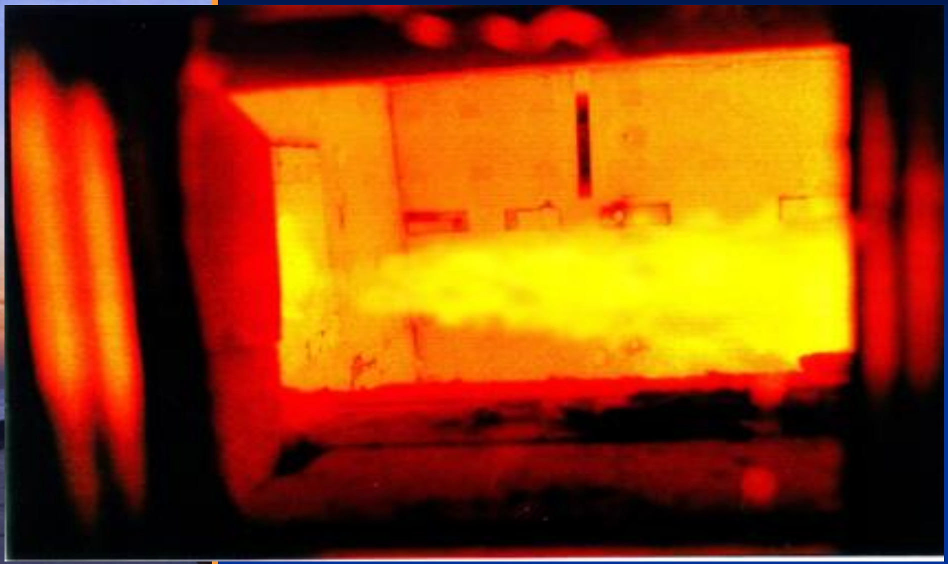
Parameters of the proposed BFB reactor	
Nominal net electric power output	400 kWe
Annual SRF throughput	5000 t/y
BFBG internal diameter	1.4 m
BFBG height	4.0 m

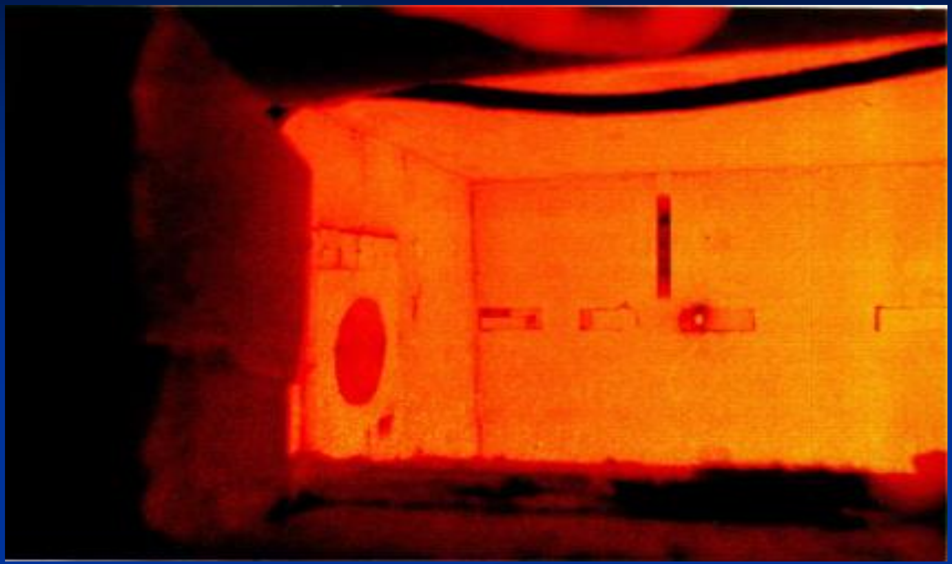
Plant configuration: syngas combustion section

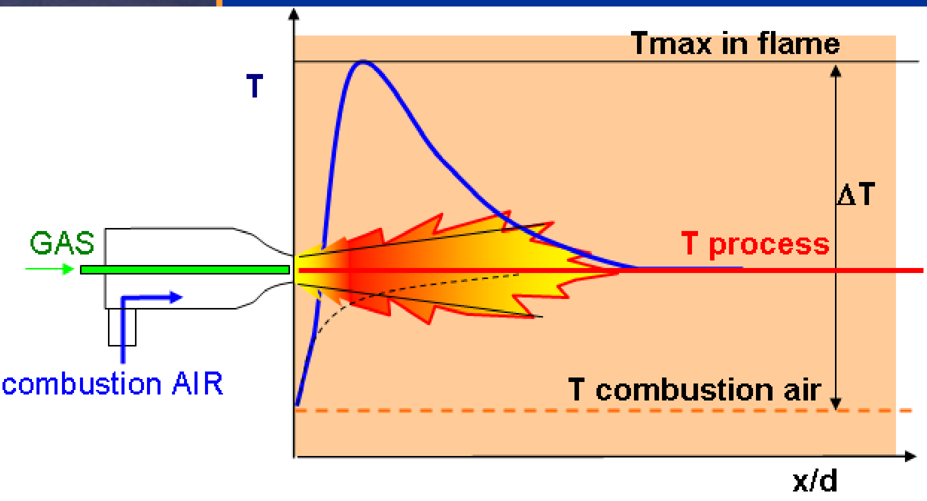
A **mild combustion system** has been proposed for syngas burning. The process occurs with a remarkable dilution of fuel and oxidizer, which are both locally mixed with a "ballast" of inert gases before they react. As a consequence, the ranges of T and concentration result remarkably different from those of standard combustion processes.

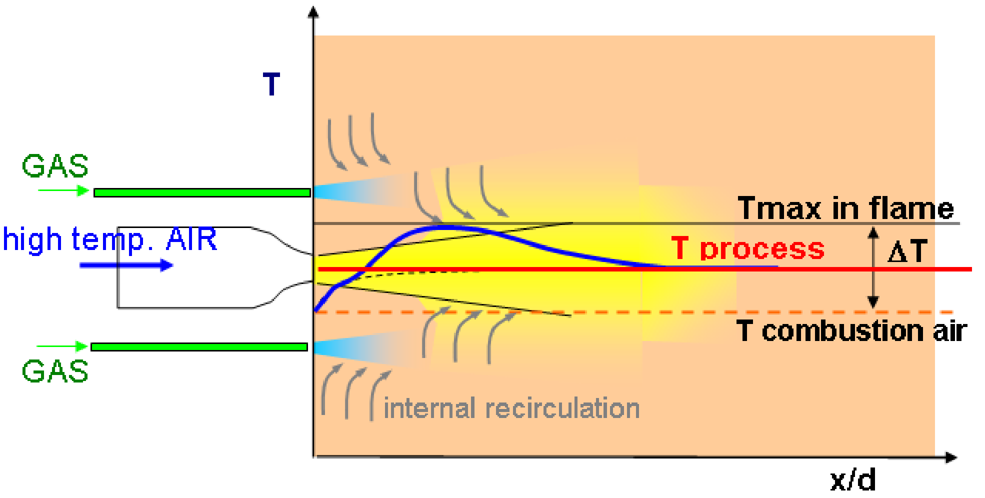


Plant configuration: syngas combustion section



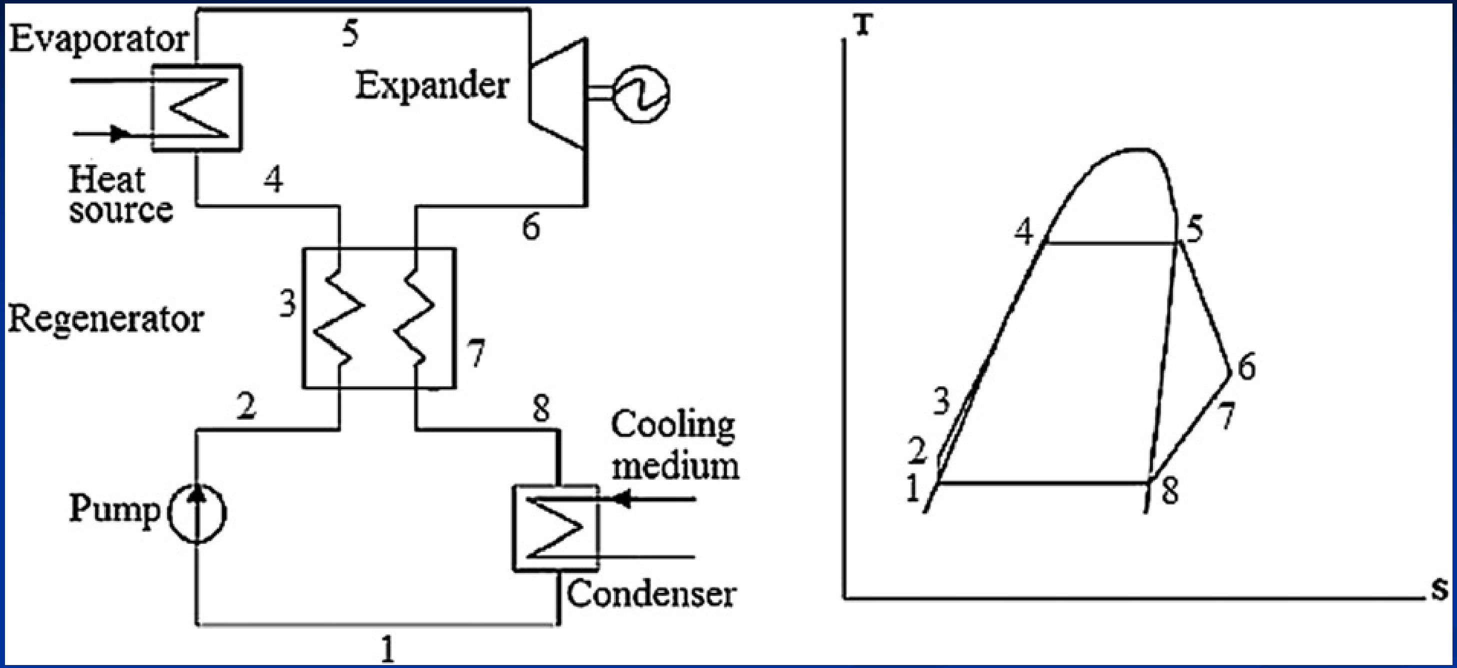






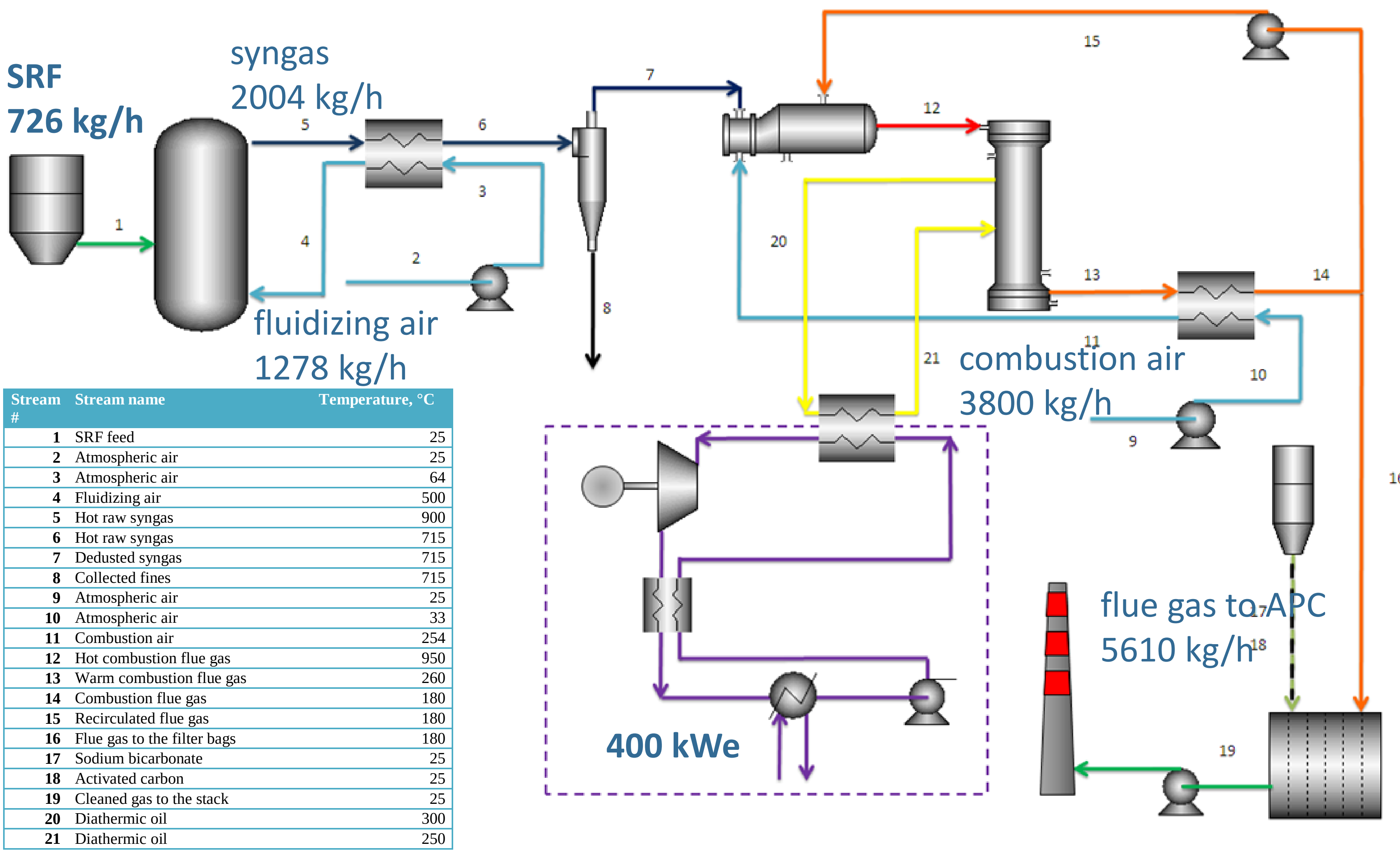
Source: Milani and Saponaro, 2001

Plant configuration: energy generation section



ORC turbine included in the proposed configuration	
Thermal input	2400 kWt
Diathermic fluid	Thermooil
Inlet temperature (base load)	300°C
Outlet temperature (base load)	250°C
Organic fluid	Silikon oil
Thermal output (condenser)	1600 kWt
Cooling fluid	water
Inlet temperature (base load)	60°C
Outlet temperature (base load)	80°C
Net Electric Power output (base load)	400 kWe
Net electric efficiency (base load)	17.7%

Plant configuration: process flow diagram



Stream #	Stream name	Temperature, °C
1	SRF feed	25
2	Atmospheric air	25
3	Atmospheric air	64
4	Fluidizing air	500
5	Hot raw syngas	900
6	Hot raw syngas	715
7	Dedusted syngas	715
8	Collected fines	715
9	Atmospheric air	25
10	Atmospheric air	33
11	Combustion air	254
12	Hot combustion flue gas	950
13	Warm combustion flue gas	260
14	Combustion flue gas	180
15	Recirculated flue gas	180
16	Flue gas to the filter bags	180
17	Sodium bicarbonate	25
18	Activated carbon	25
19	Cleaned gas to the stack	25
20	Diathermic oil	300
21	Diathermic oil	250

Conclusions

- A gasification based, small-scale waste-to-energy plant, having a nominal throughput of 5000 t/y of a Secondary Recovered Fuel obtained from unsorted residual waste, has been investigated.
- The technical performances of a heat gasifier configuration of this plant have been quantitatively assessed. Mass and energy balances of the proposed plant were based on the experimental data obtained from a pilot scale bubbling fluidized bed air gasifier.

Conclusions

- An innovative mild combustion system has been pro posed to burn the syngas and has been coupled with an Organic Rankine Cycle generator.

- The results, together with those of a preliminary economic analysis, indicate that the proposed plant configuration, including a bubbling fluidized bed reactor, a mild combustion system, a 400kWe ORC generator and a simple air pollution control system, appears fully sustainable.

THANK YOU

for your kind attention