Annual CSLF Meeting in Berlin
26 – 30 September 2005

G. Girardi - Italy

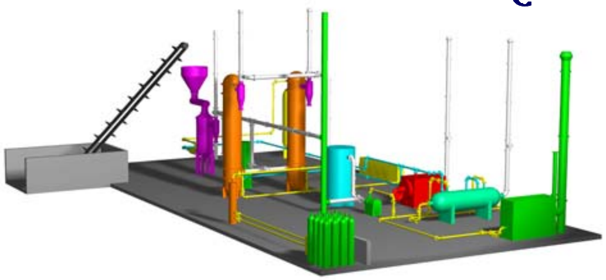
ITALIAN ROADMAP: Project's Proposal for CSLF

Two Projects, in Berlin, for endorsement:

- ZECOMIX
- COHYGEN

Presentation of ZECOMIX Project

COAL GASIFICATION
FOR HYDROGEN & POWER GENERATION
WITH ZERO EMISSIONS
AND VERY HIGH EFFICIENCY



This initiative is a part of a wider project proposed and managed by ENEA in the framework of a **three year program on hydrogen sponsored by the Italian government** named *New technologies and processes for the transition towards "hydrogen system"*
and is aimed at developing technologies, components and advanced systems to promote the diffusion of hydrogen as a energy carrier to be used in different areas of application

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PROJECT SCOPE

ENEA ZECOmix

to study and test a zero emission/high efficiency process, named ZECOMIX, which produces both hydrogen rich gas mixture (and pure hydrogen) and electricity from coal

It is made by 3 sections:

- H_2 production by advanced coal gasification process (**ZEC**)
- CO_2 capture
- Electricity production by advanced high efficiency H_2-O_2 cycle with gas turbine (**ZECOTECH**)

Zero
Emission
Coal

ZECOMIX

Zero
Emission
COmbustion
TEChnologies
using **H**$_2$

ZECOMIX Project main data

- **Project cost:** 6.7 M EURO (8 USD)
- **Coordinator:** ENEA
- **Industrial partners**

  Ansaldo Ricerche – other subcontractors - Sotacarbo
- **Universities**

  Rome1, Rome3, L'Aquila, Cassino, Naples Politecnico di Milano
- **Start date:** 28 July 2005
- **End date:** December 2008
- **Funding:** Government (70%), Partners (30%)
- **Activities:**

  experimental tests in laboratory test rigs and small scale pilot plant

  simulation: advanced 3D codes (LES), process simulation /optimization

  process control

ZECOMIX Project: main goals

- Technologies, components and new systems for **hydrogen production**
  - Gasification with oxigen
  - Hydrogasification

  and for H_2/CO_2 separation
  - carbonatation process with calcium oxide, and calcination for calcium dioxide regeneration
- Oxy firing: **H_2-O_2 combustion with steam recycling**
- High efficiency / ultra low - emissions **combustion using H2 rich gas mixture**
- **Plant Integration**; Pre combustion technologies integrated in advanced high temperature gas turbine cycles
- Plant simulator

ZECOMIX Project: Tasks

1. Study and symulation of ZECOMIX processes

2. Cycle analysis and development of process symulator

3. ZECOMIX pilot plant design

4. Realization and start up of ZECOMIX pilot plant

5. Hydrogasification experimental tests on laboratory test rigs

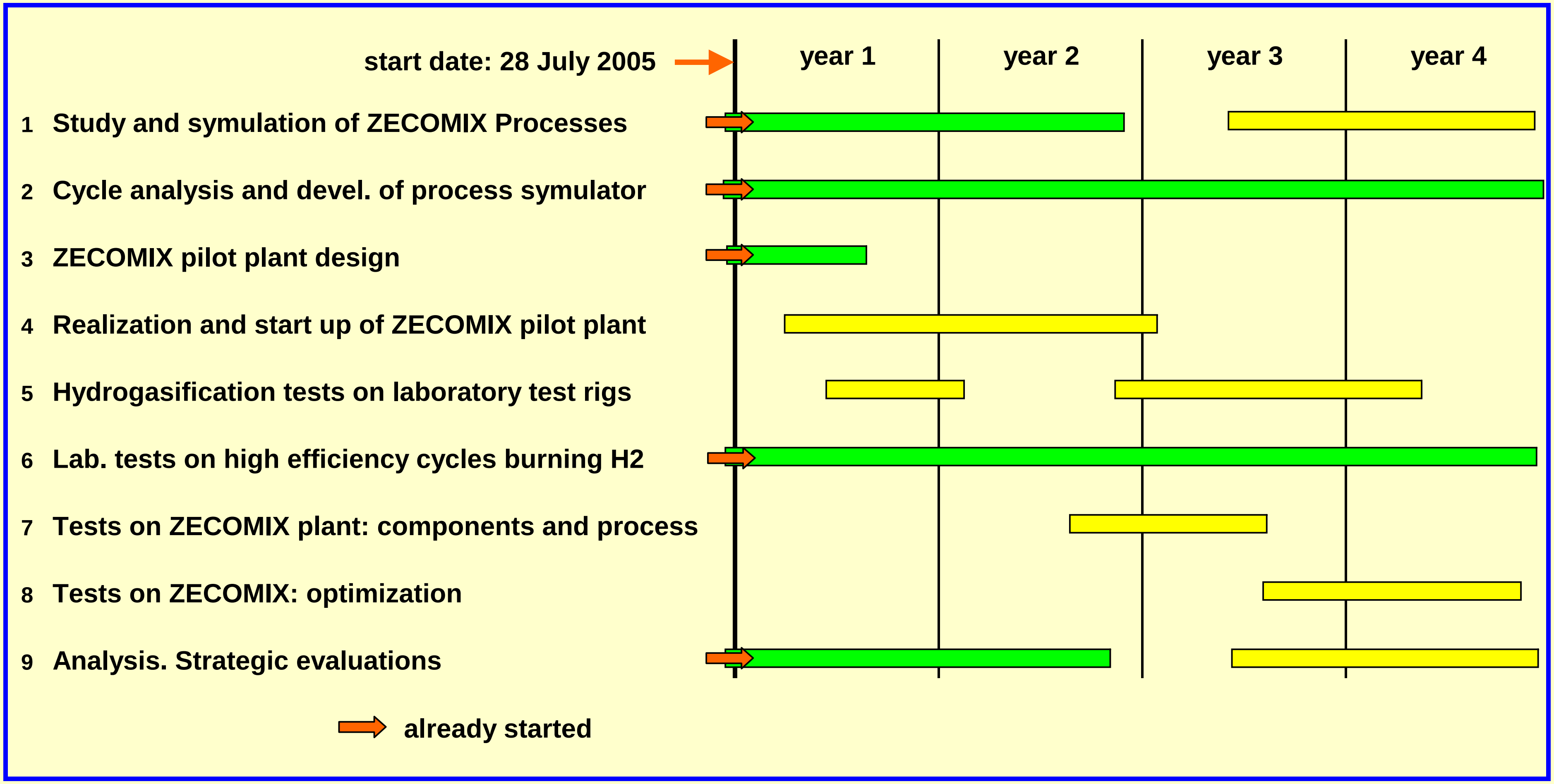
6. Laboratory experimental tests on high efficiency thermodynamic cycles burning H2

7. Tests on ZECOMIX pilot plant: characterization of components and integrated process

8. Tests on ZECOMIX pilot plan for optimization of components and integrayted cycle

9. Scientific, technical and economic analysis. Strategic evaluations

Timing


start date: 28 July 2005
year 1
year 2
year 3
year 4
1 Study and symulation of ZECOMIX Processes
2 Cycle analysis and devel. of process symulator
3 ZECOMIX pilot plant design
4 Realization and start up of ZECOMIX pilot plant
5 Hydrogasification tests on laboratory test rigs
6 Lab. tests on high efficiency cycles burning H2
7 Tests on ZECOMIX plant: components and process
8 Tests on ZECOMIX: optimization
9 Analysis. Strategic evaluations
already started

ZECOMIX Project: main areas

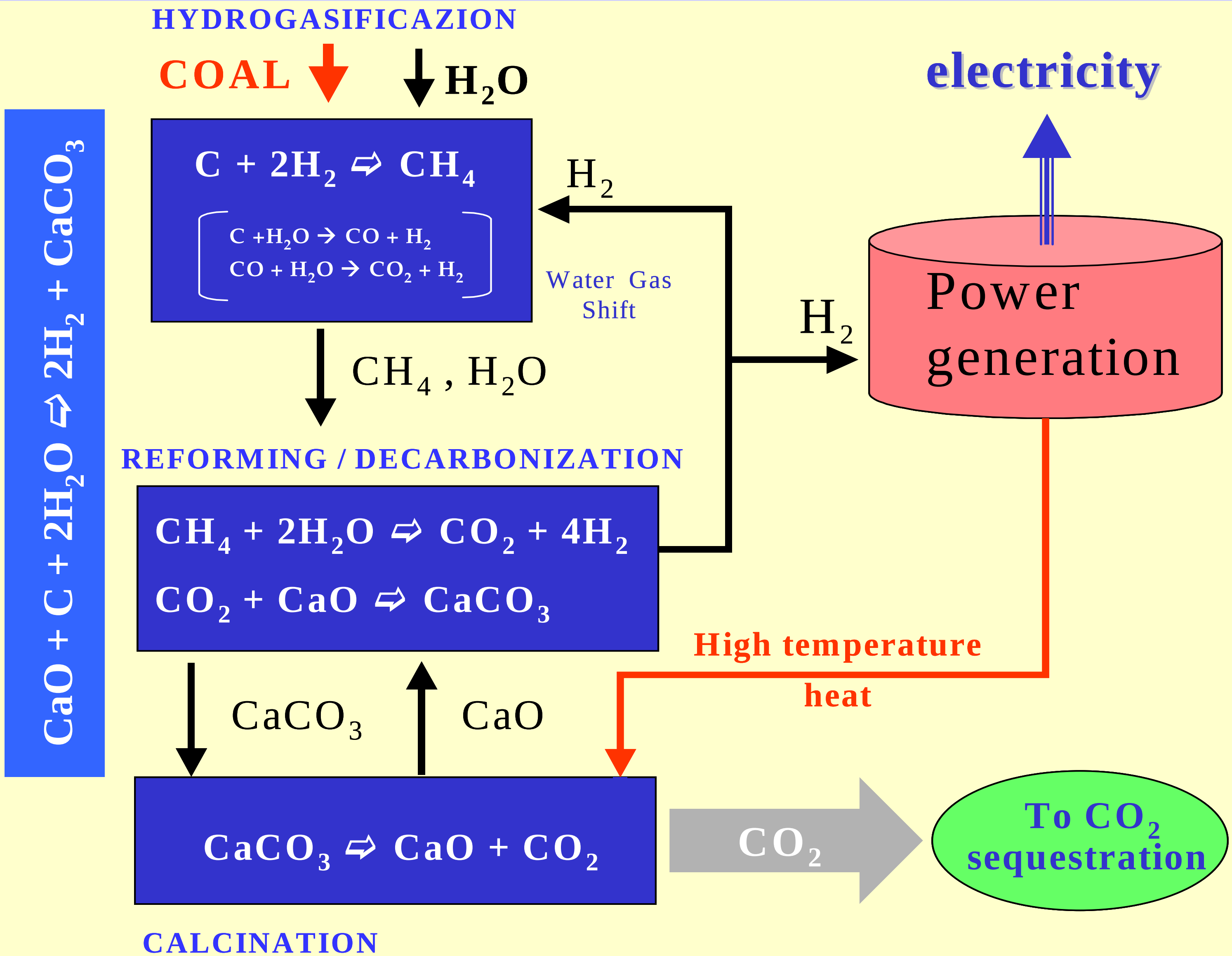
1. Chemical Analysis
System Analysis
Process Simulation

2. Combustion and
Energy conversion
Gas Turbines

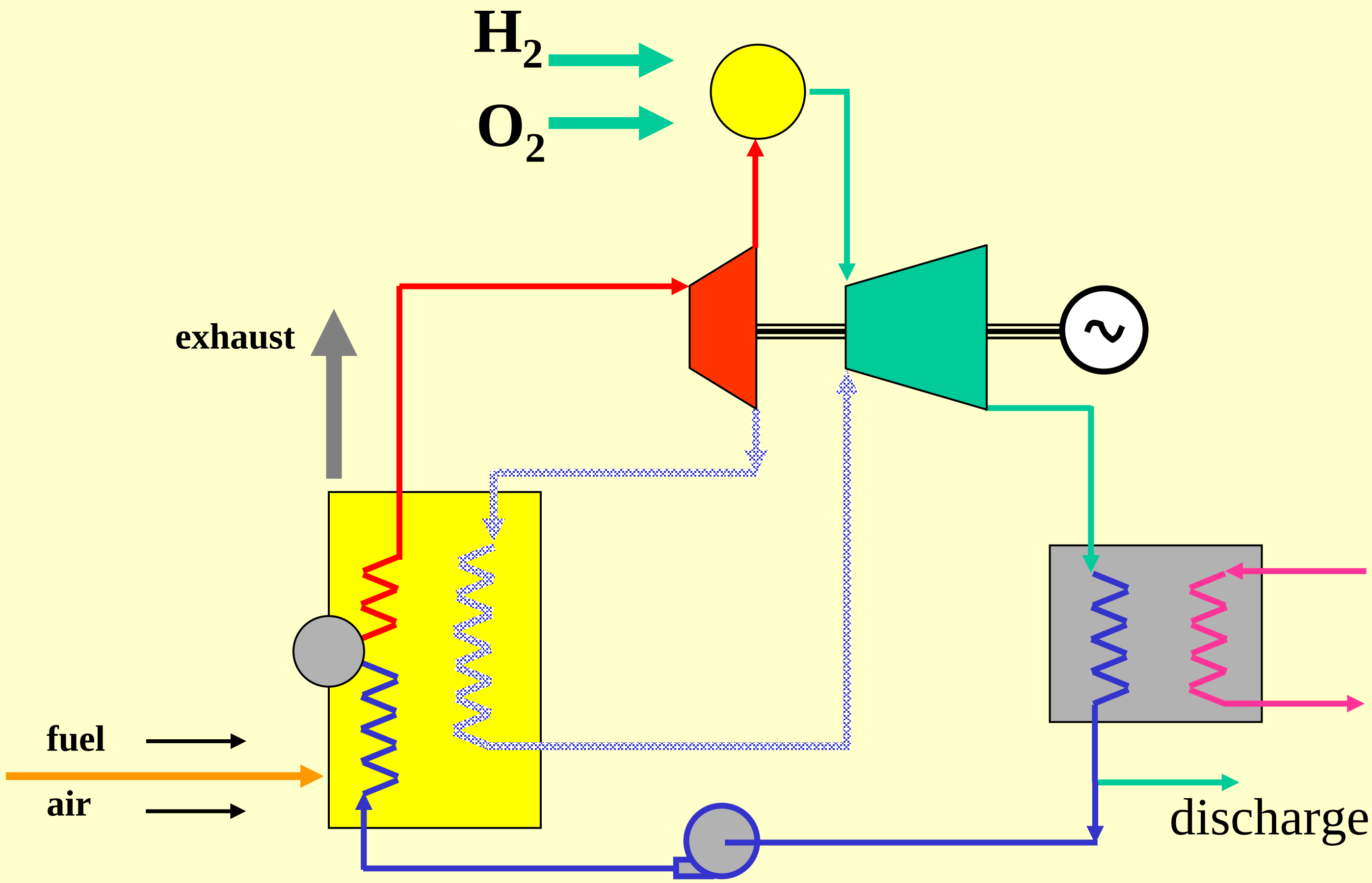
3. High Performance
Computing
Advanced CFA

4. ZECOMIX pilot plant
realization and
operation

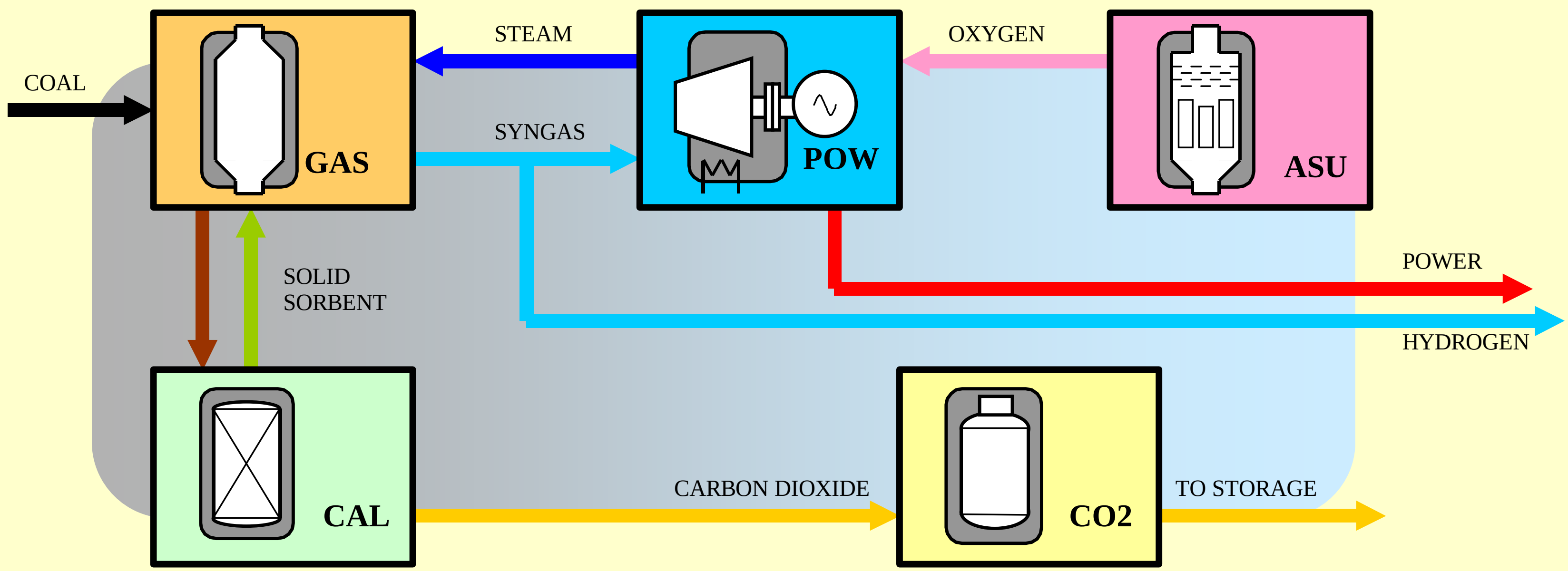
Hydrogasification main reactions



ZECOTECH simple scheme (for repowering)



Integration of Main Sub-systems



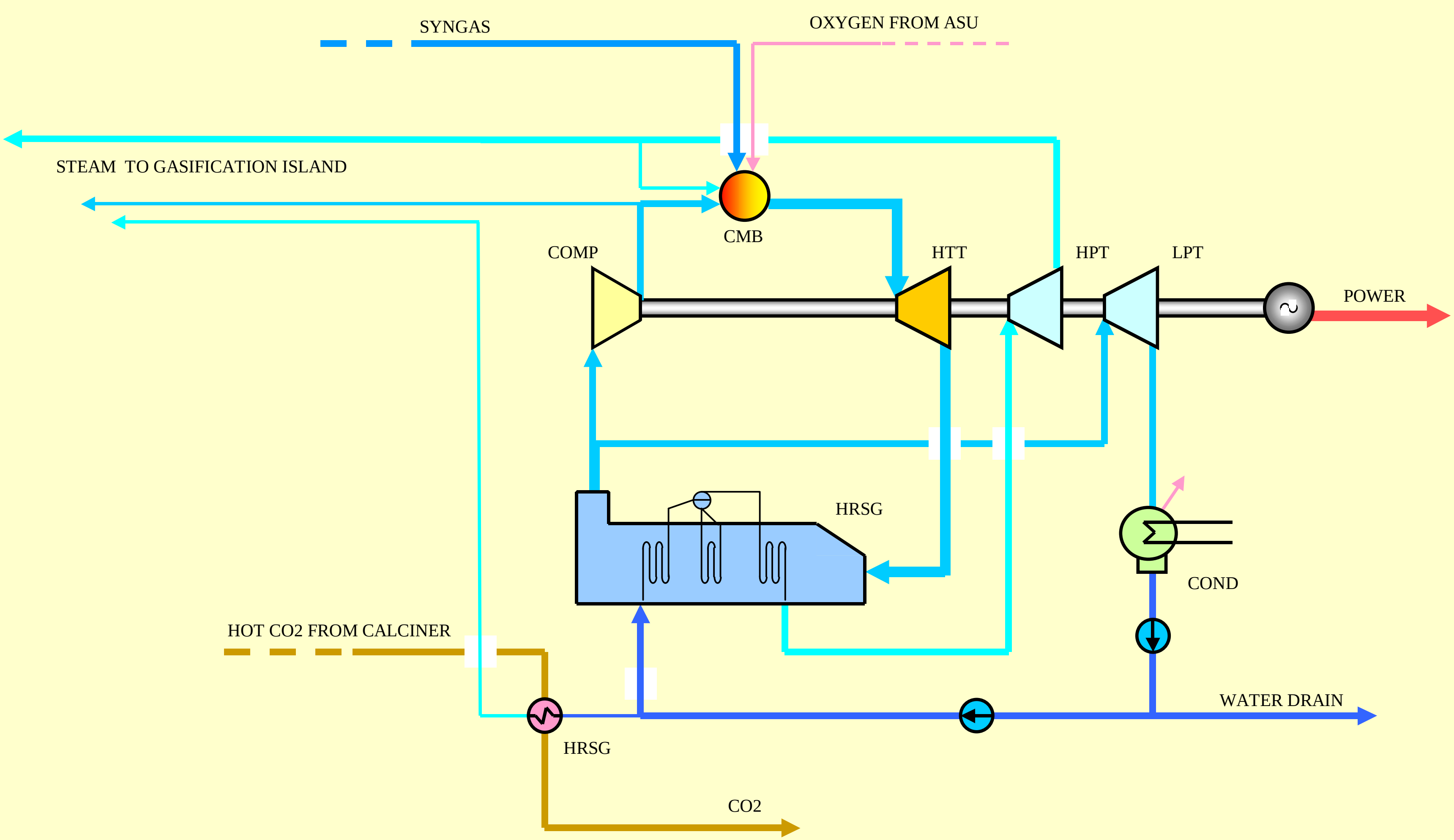
Main sub-systems : GASIFICATION

POWER PRODUCTION

SORBENT CALCINATION

CO2 DRYING & COMPRESSION + Air Separation Unit

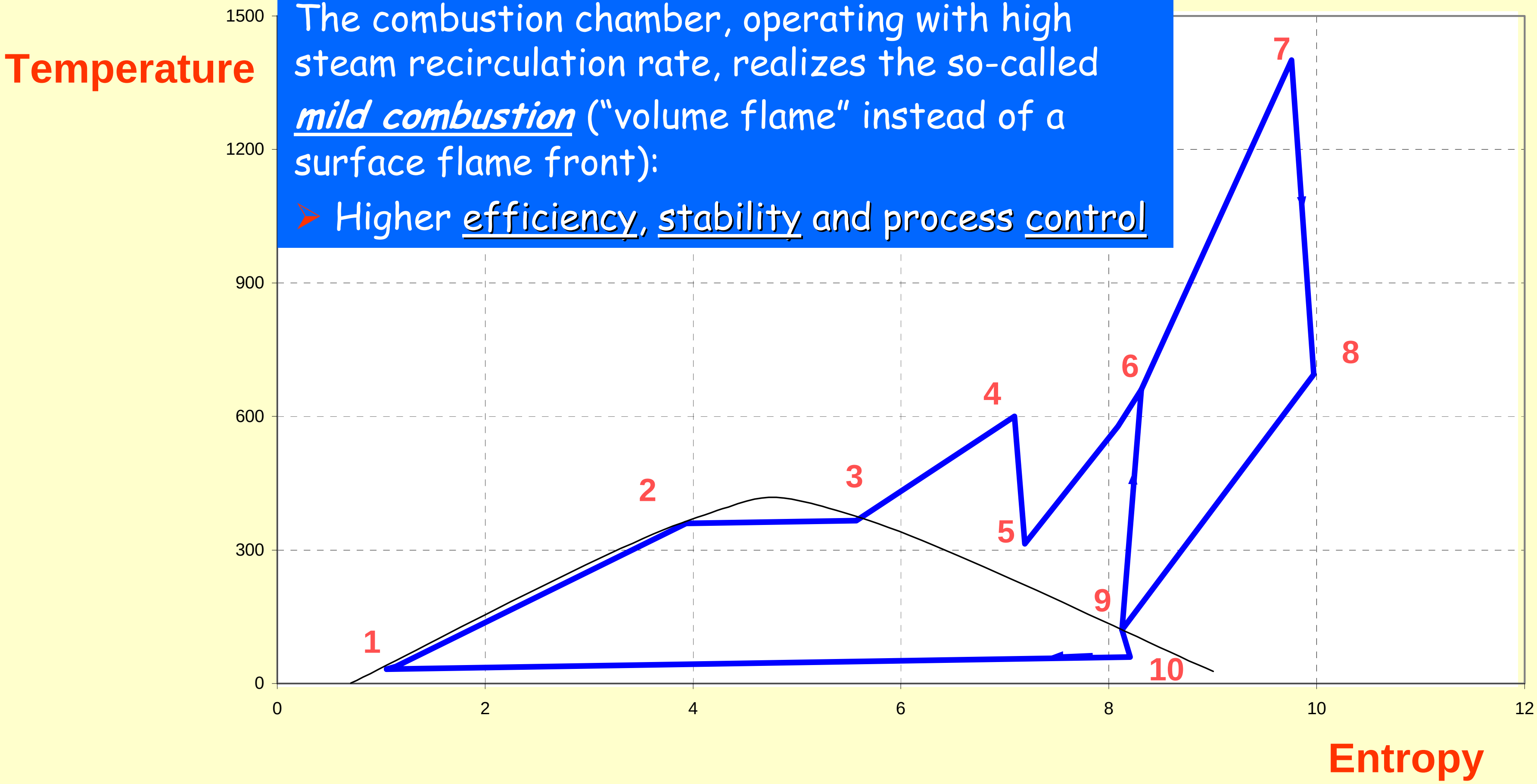
Reference Power Section



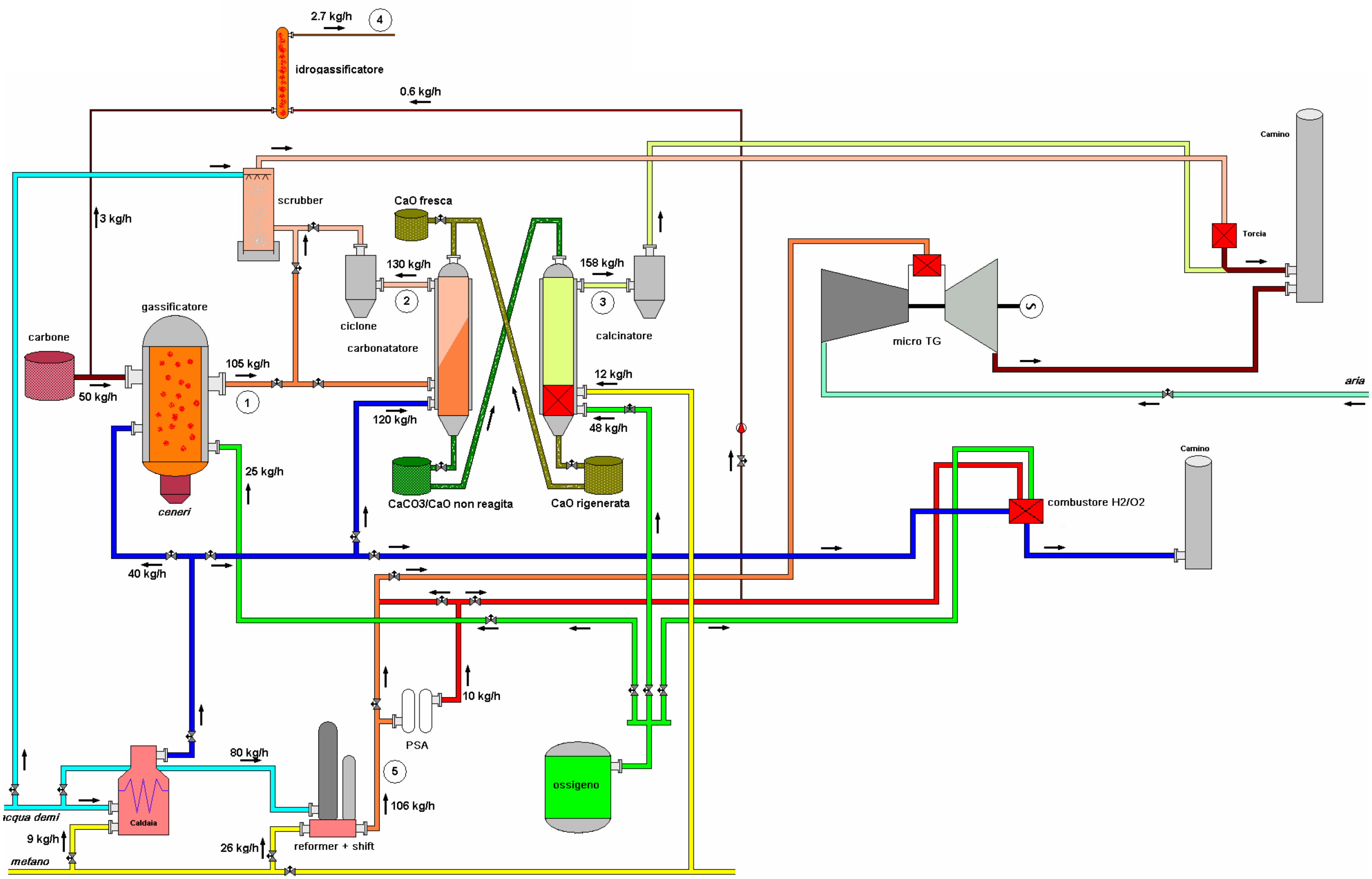
Power Section Thermodynamic cycle

The gas turbine operates with H_2 and O_2: its ***Steam Combustor*** produces a ultra superheated steam which expands inside the *gas turbine*.
The combustion chamber, operating with high steam recirculation rate, realizes the so-called ***mild combustion*** ("volume flame" instead of a surface flame front):

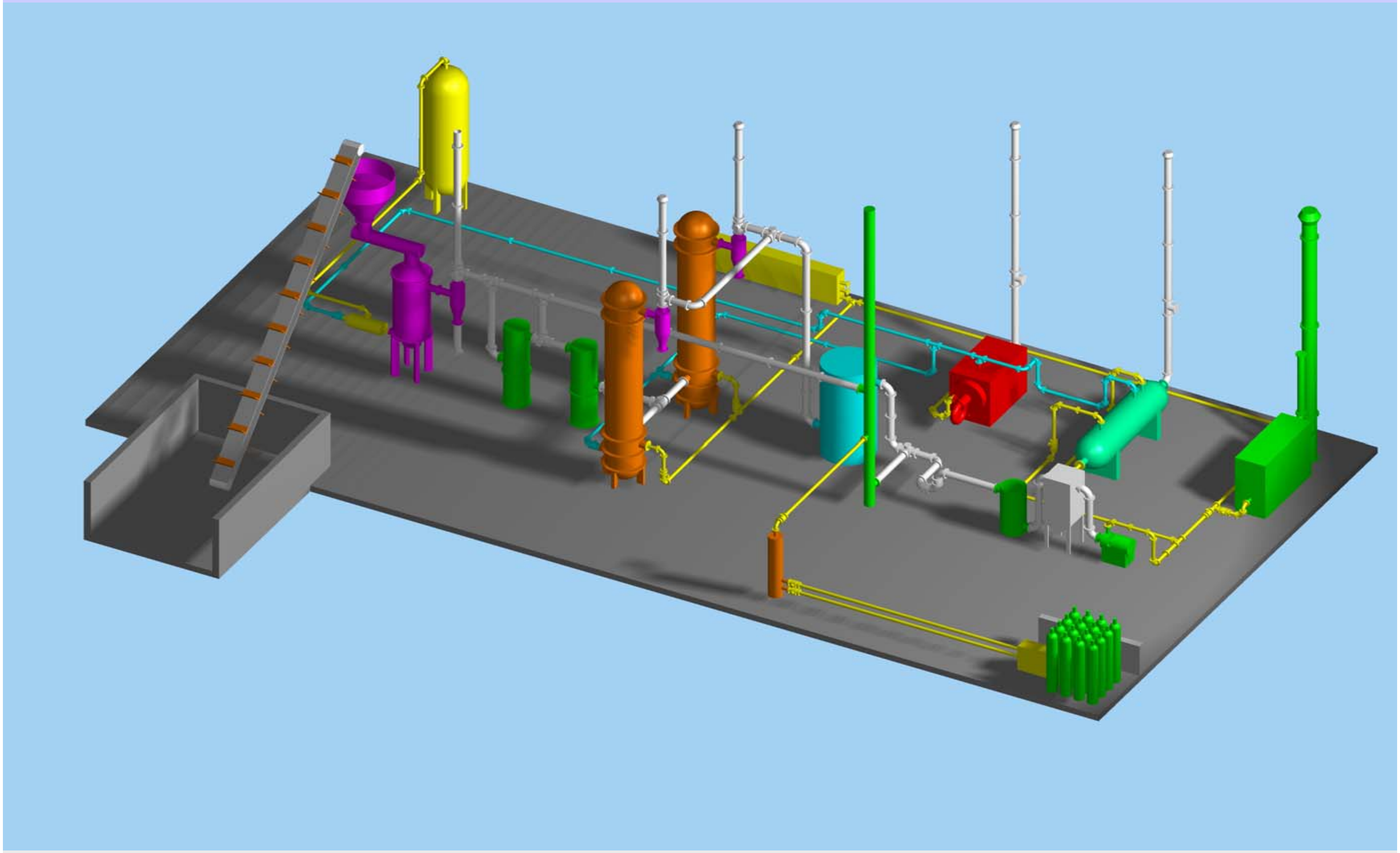
- Higher efficiency, stability and process control



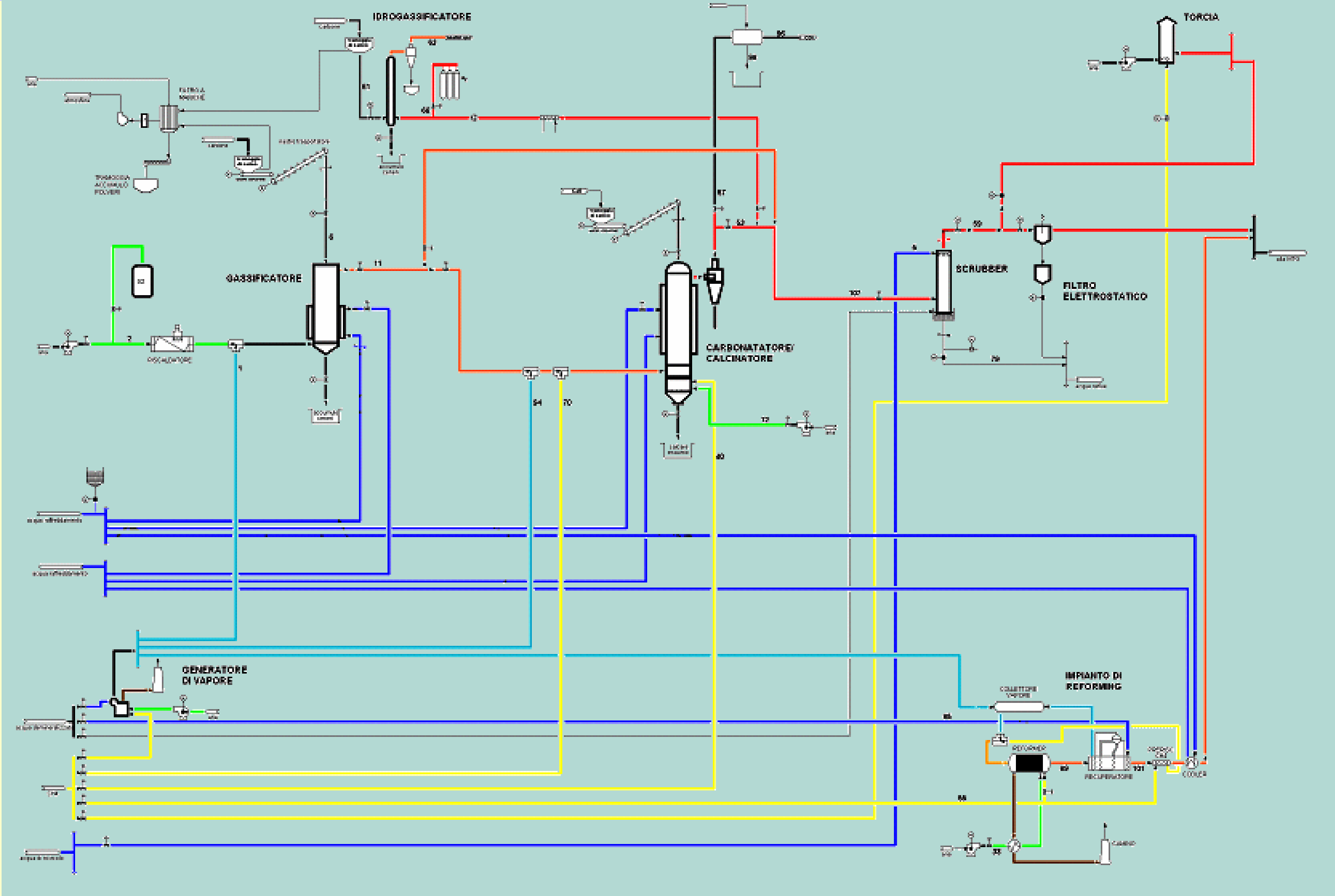
ZECOMIX Pilot Plant scheme



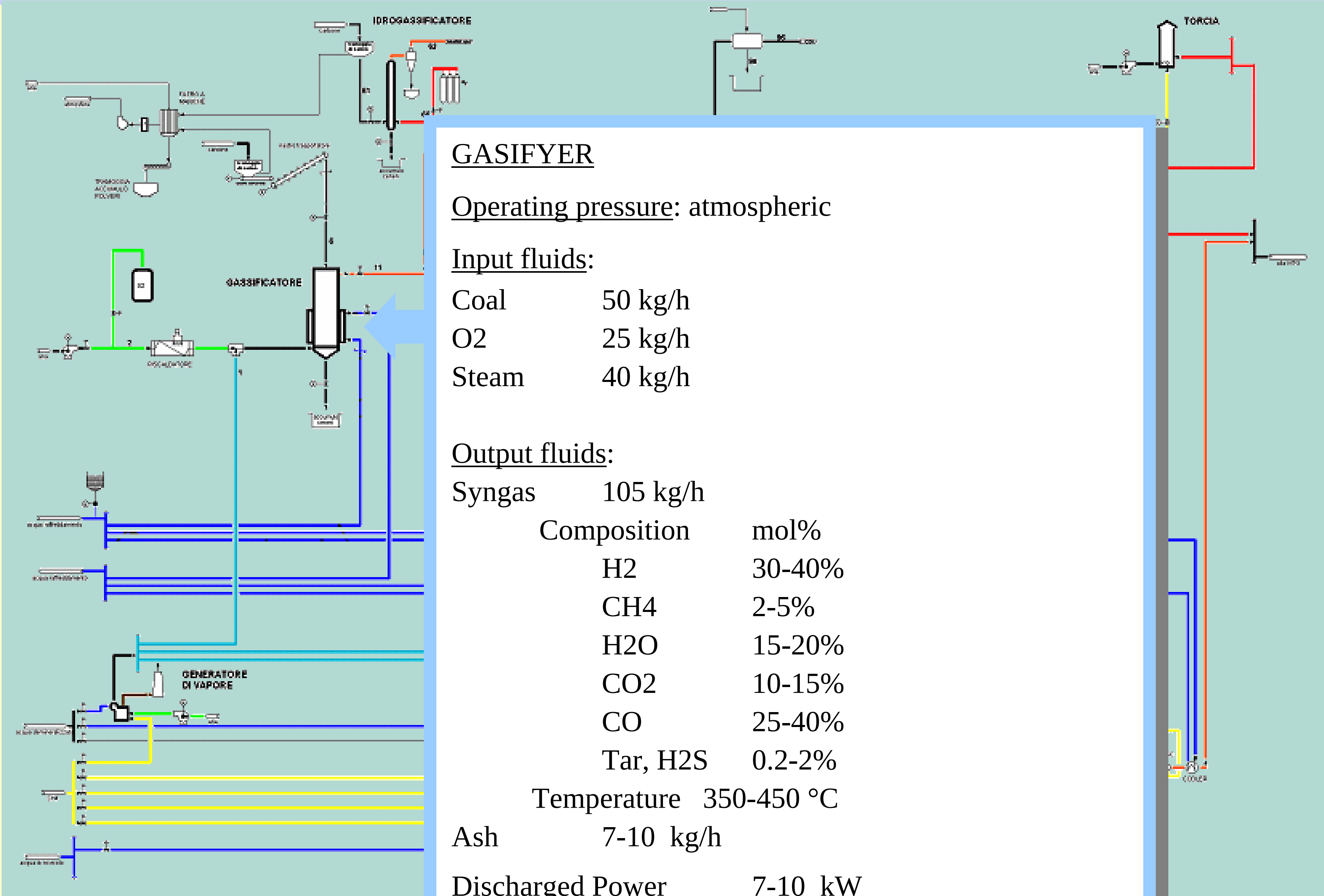
ZECOMIX Pilot Plant lay-out



ZECOMIX main components characteristics



ZECOMIX main components characteristics



GASIFYER

Operating pressure: atmospheric

Input fluids:

Coal	50 kg/h
O_2	25 kg/h
Steam	40 kg/h

Output fluids:

Syngas 105 kg/h

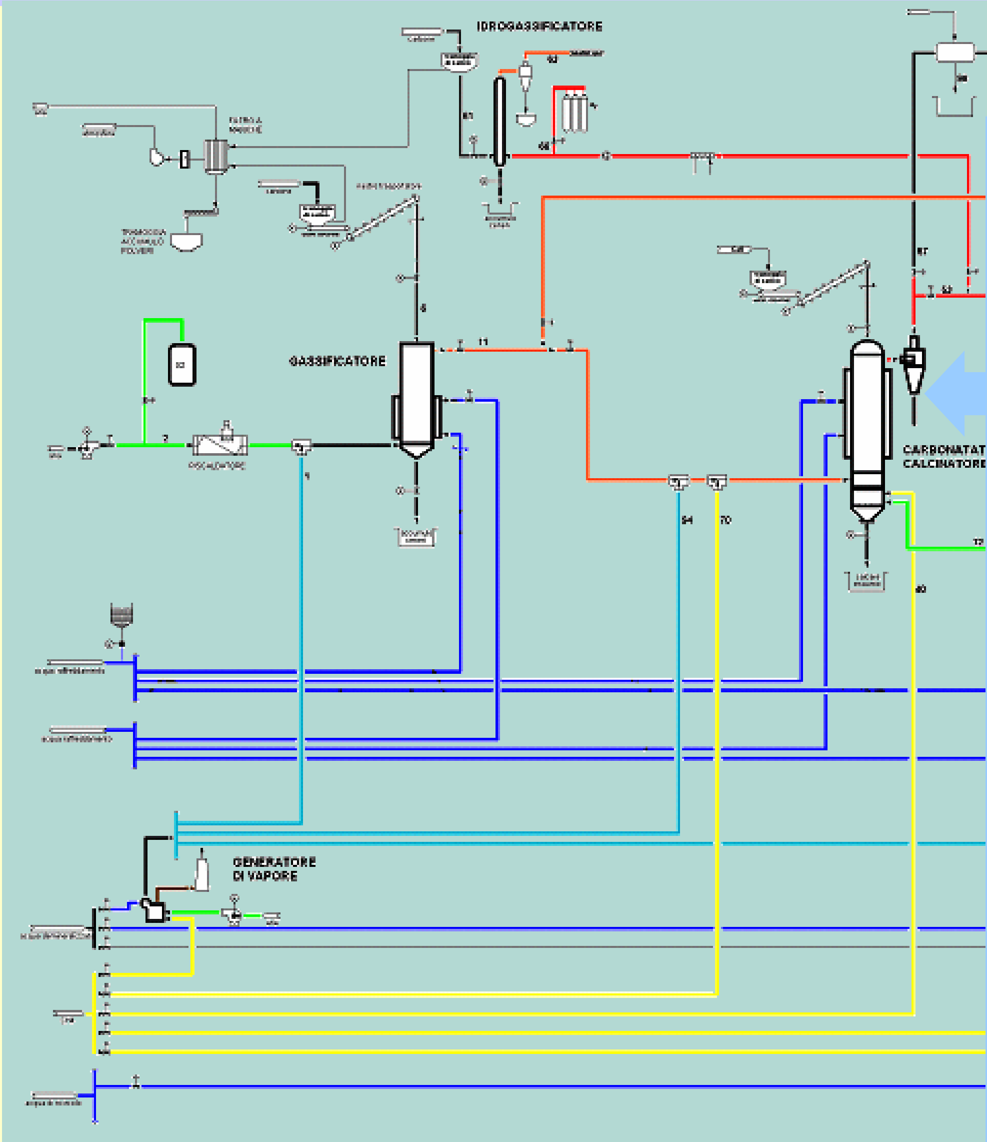
Composition	mol%
H_2	30-40%
CH_4	2-5%
H_2O	15-20%
CO_2	10-15%
CO	25-40%
Tar, H_2S	0.2-2%

Temperature 350-450 °C

Ash 7-10 kg/h

Discharged Power 7-10 kW

ZECOMIX main components characteristics



CARBONATOR

Operating Pressure: atmospheric

Input fluids:

Syngas	105 kg/h
Steam	120 kg/h
CH_4	0-30 kg/h

Output fluids:

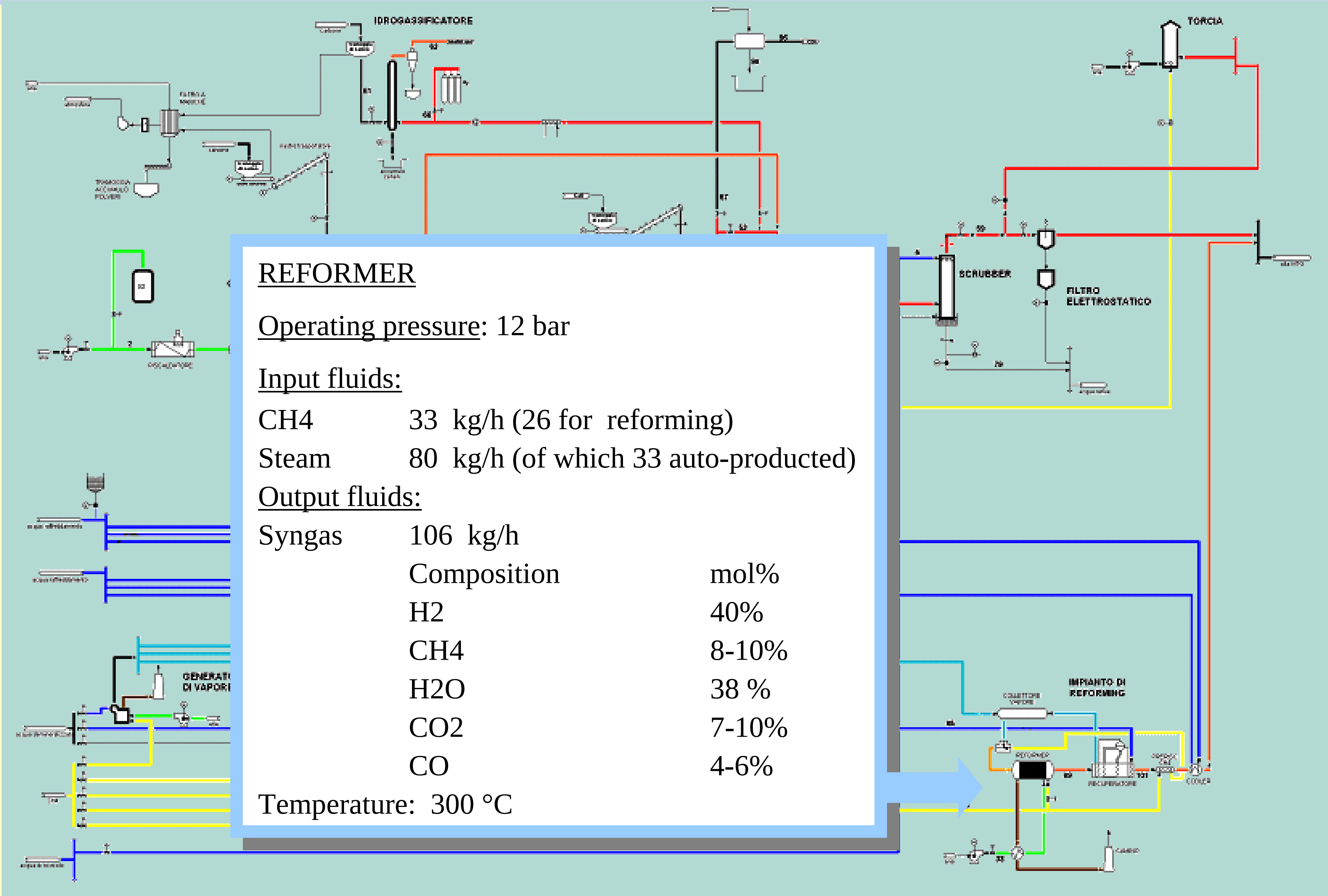
Syngas 130 kg/h

Composition	mol%
H_2	40-60%
CH_4	0.1-2 %
H_2O	30-60 %
CO_2	1-3 %
CO	0.3 2%
Tar, H_2S	0.1-1%

Temperature 650 °C

Exhaust power 0 – 70 kW

ZECOMIX main components characteristics



REFORMER

Operating pressure: 12 bar

Input fluids:

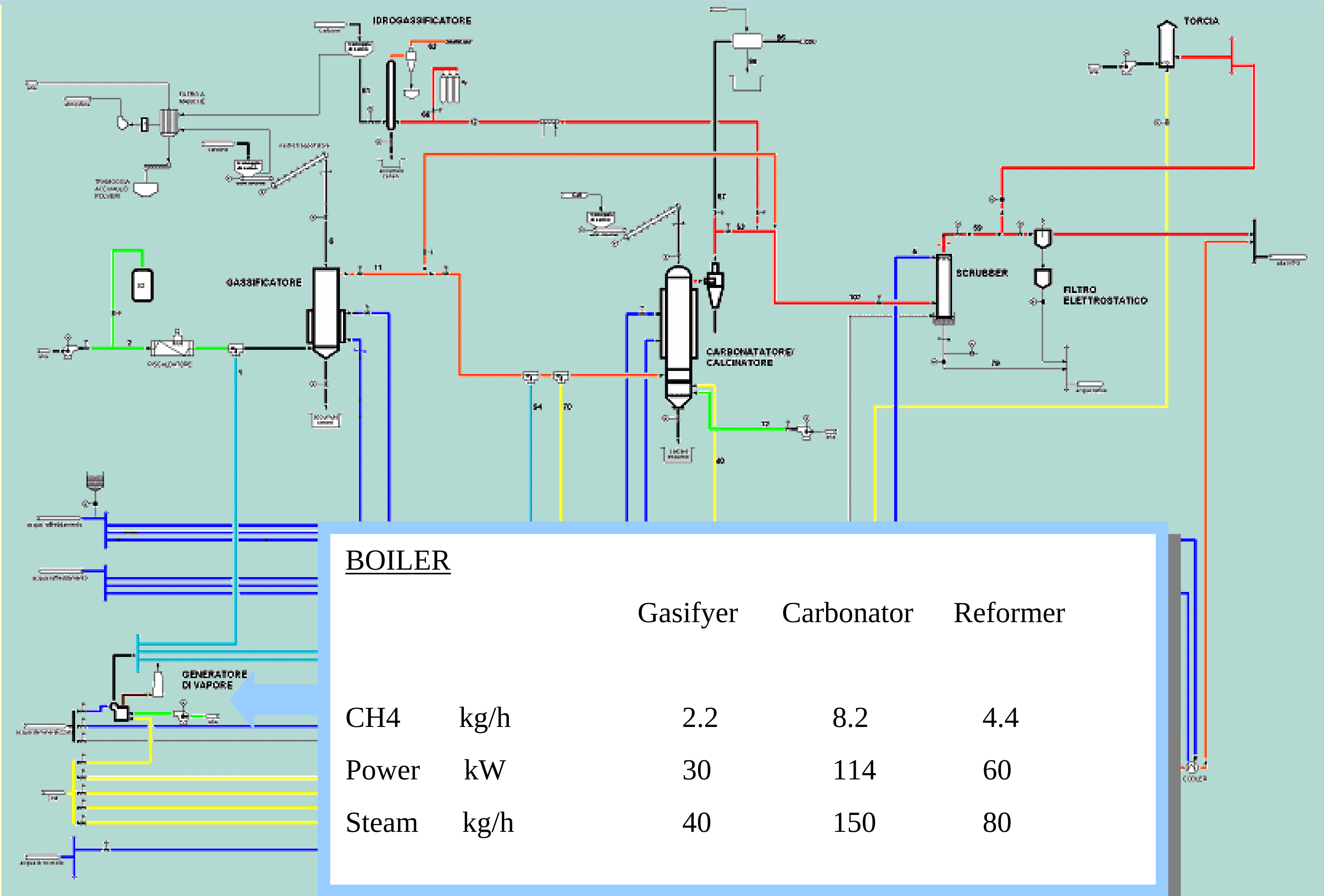
CH_4	33 kg/h (26 for reforming)
Steam	80 kg/h (of which 33 auto-producted)

Output fluids:

Syngas	106 kg/h	
	Composition	mol%
	H_2	40%
	CH_4	8-10%
	H_2O	38 %
	CO_2	7-10%
	CO	4-6%

Temperature: 300 °C

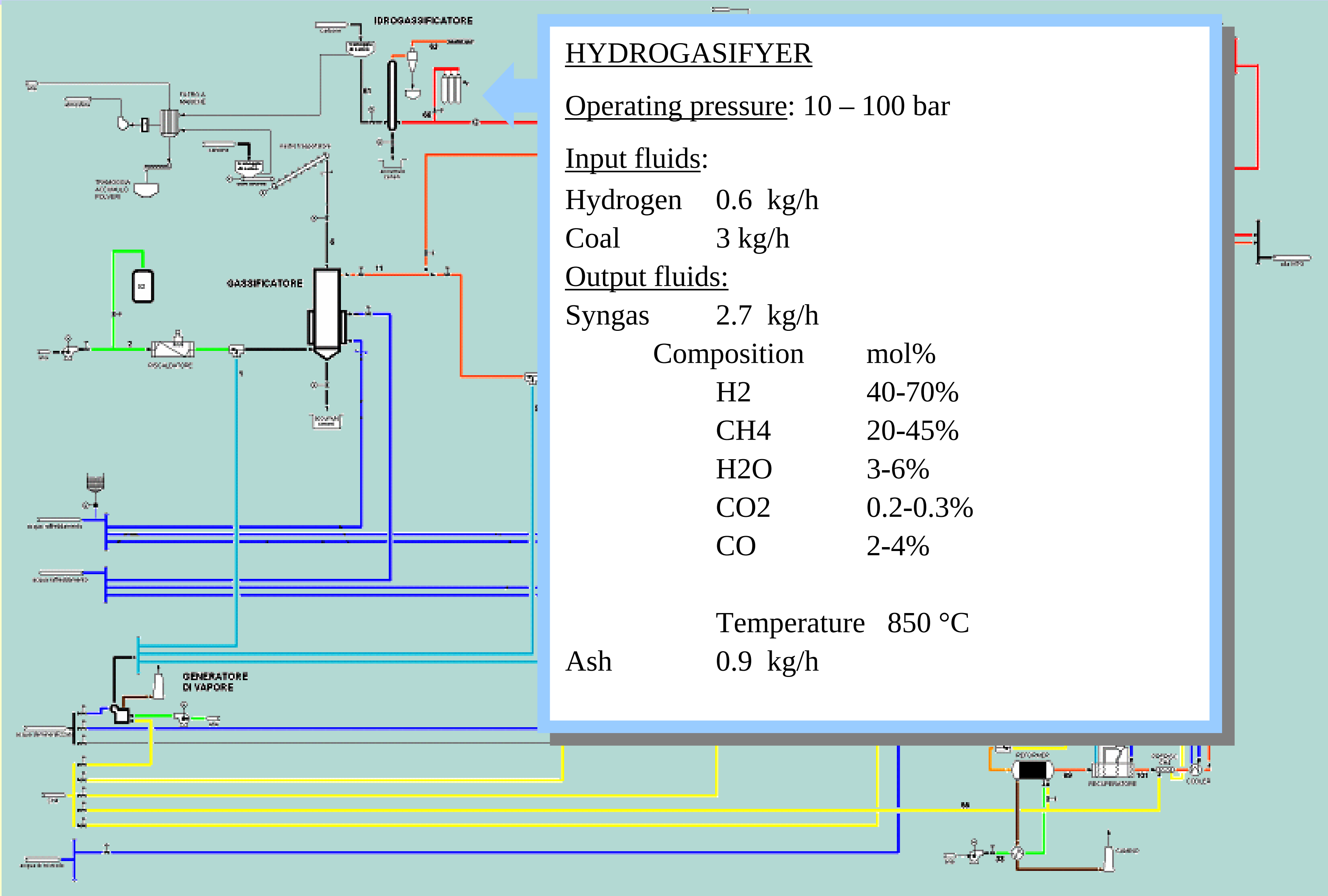
ZECOMIX main components characteristics



BOILER

		Gasifyer	Carbonator	Reformer
CH4	kg/h	2.2	8.2	4.4
Power	kW	30	114	60
Steam	kg/h	40	150	80

ZECOMIX main components characteristics



HYDROGASIFYER

Operating pressure: 10 – 100 bar

Input fluids:

Hydrogen	0.6 kg/h	
Coal	3 kg/h	

Output fluids:

Syngas	2.7 kg/h	
	Composition	mol%
	H_2	40-70%
	CH_4	20-45%
	H_2O	3-6%
	CO_2	0.2-0.3%
	CO	2-4%
	Temperature	850 °C
Ash	0.9 kg/h	

ZECOMIX site at ENEA Casaccia Centre

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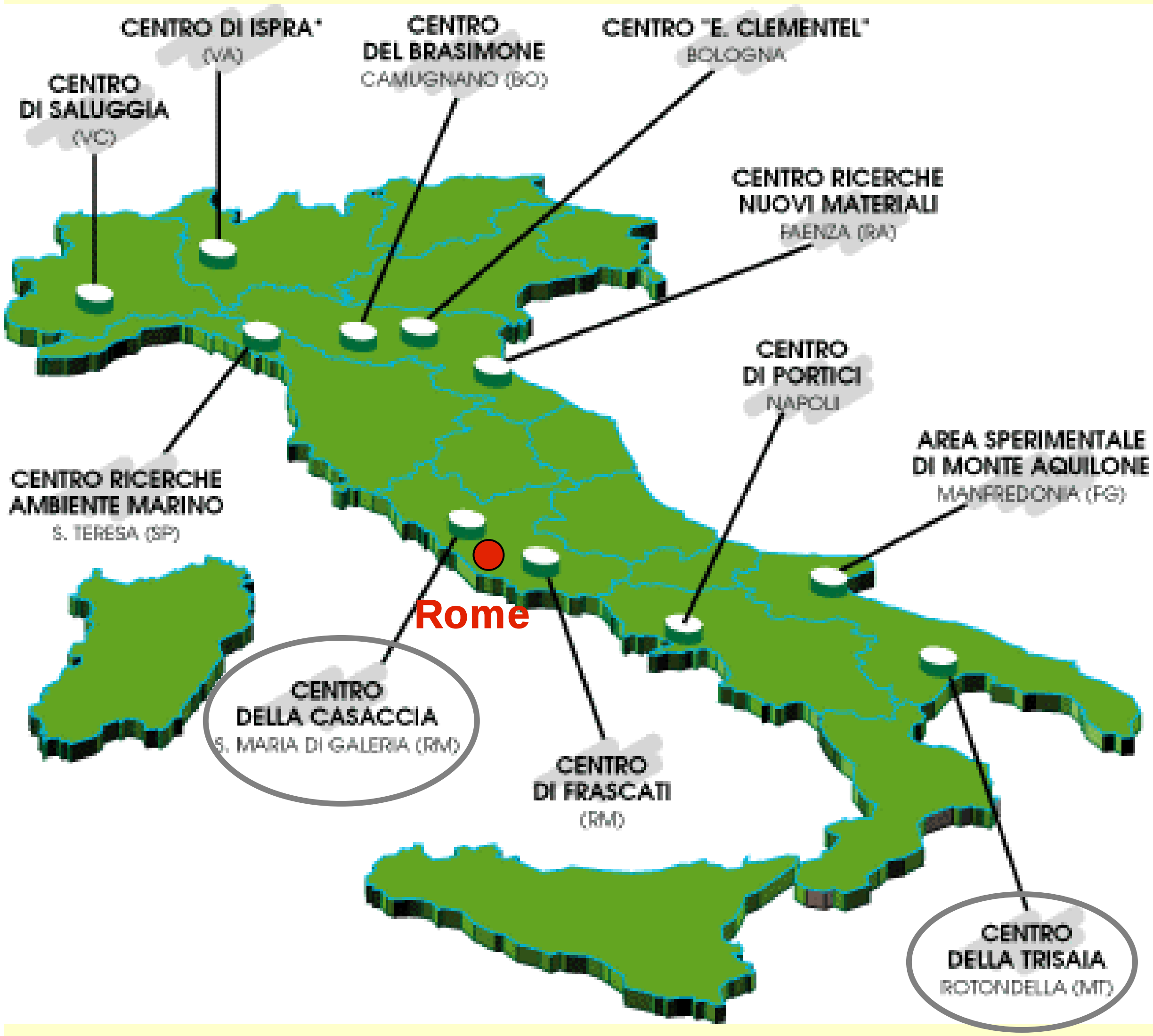
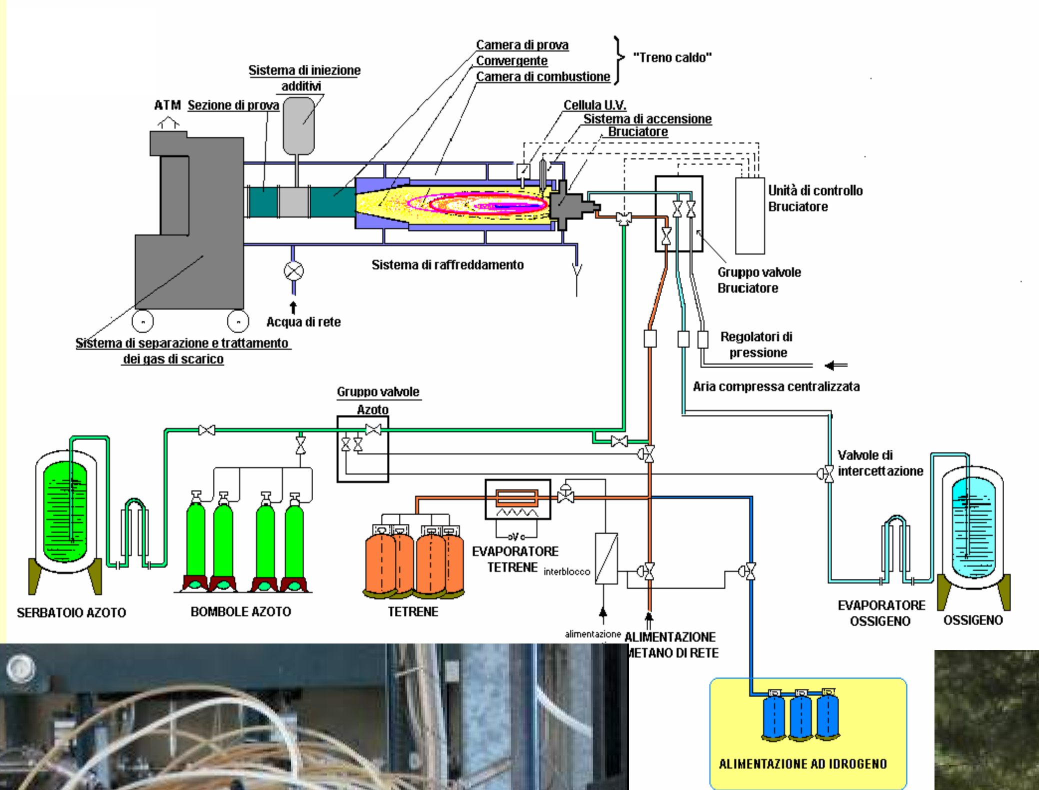
ENEA CENTRES



ENEA Casaccia

The largest ENEA research centre located 25 km North-West of Rome, nearly 2000 employees

MICOS test rig



Multifuel Test Rig - also **H2** for High Temperature combustion

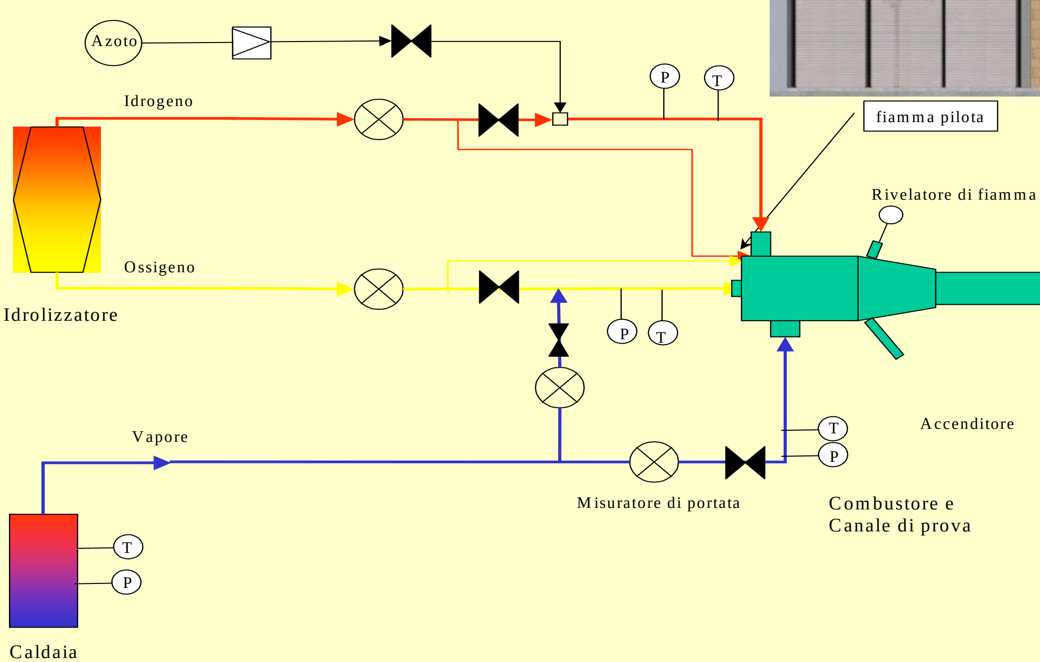
T max = 3500 °K

Reduced autonomy (2h)

IDEA and COMET-HP test rigs

IDEA test rig

Combustion of H2/air and H2/O2
Diluted with steam
Thermal Power = 150 kW
Unlimited autonomy



COMET-HP test rig:

Tets of gas turbine burners
Pressure = 10 bar;
air Temperature = 450°C
Thermal Power = 1,2 MW

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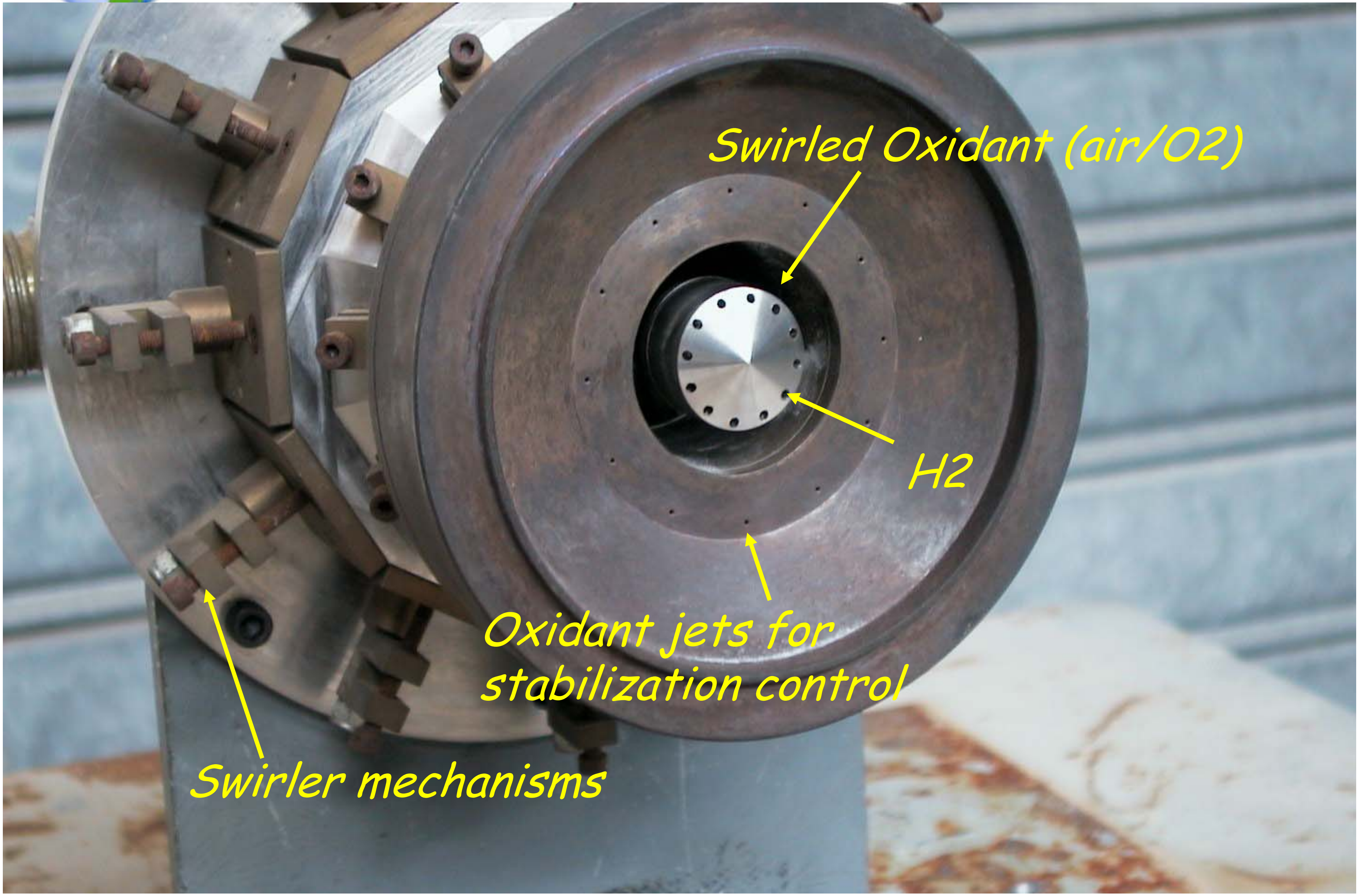
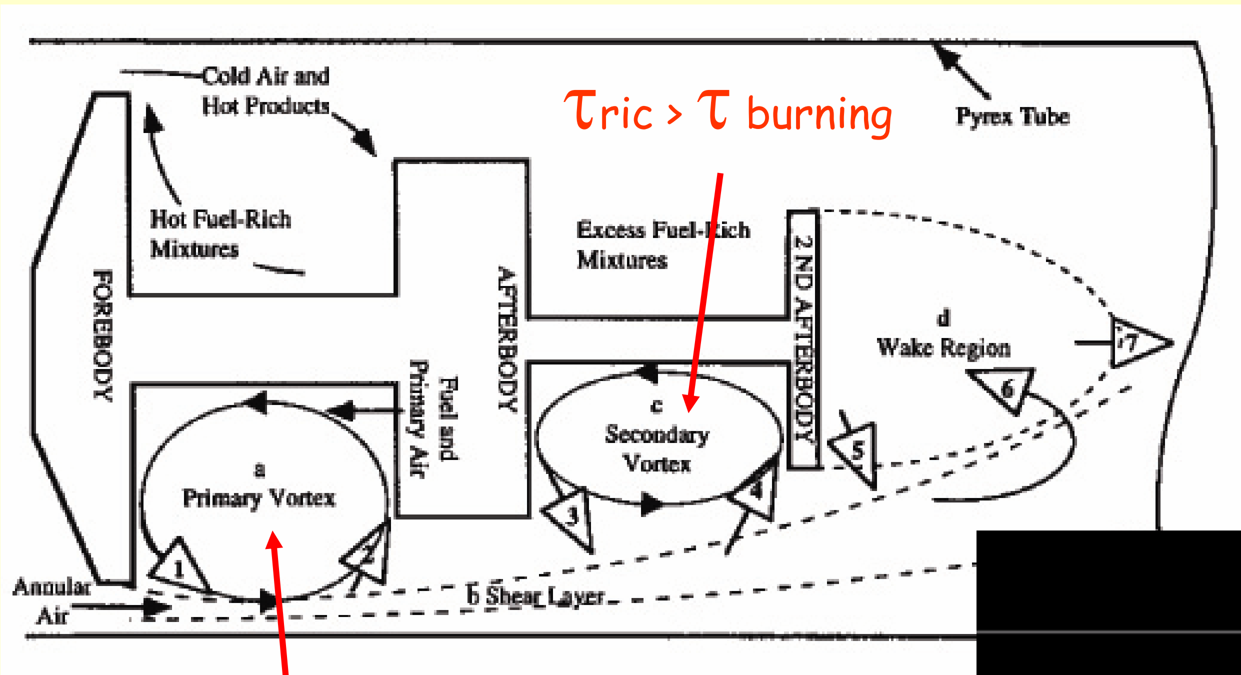
Tests for stability characterization of H-120 DIFFUSIVE Burner:for H2/Air or H2/O2

ENEA ZECOmix



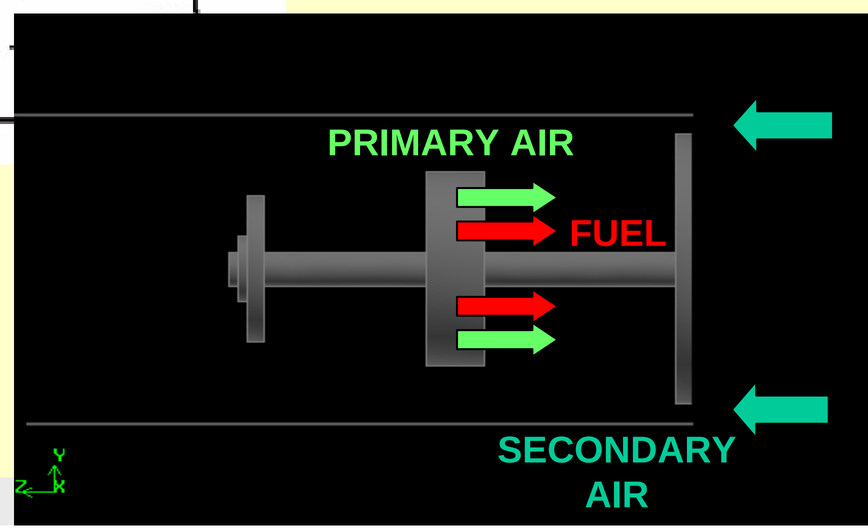
Trapped Vortex Combustion strategy

Create a stable vortex system in a cavity, where fuel and oxidant are injected, mixed and burnt with minimum pressure drop



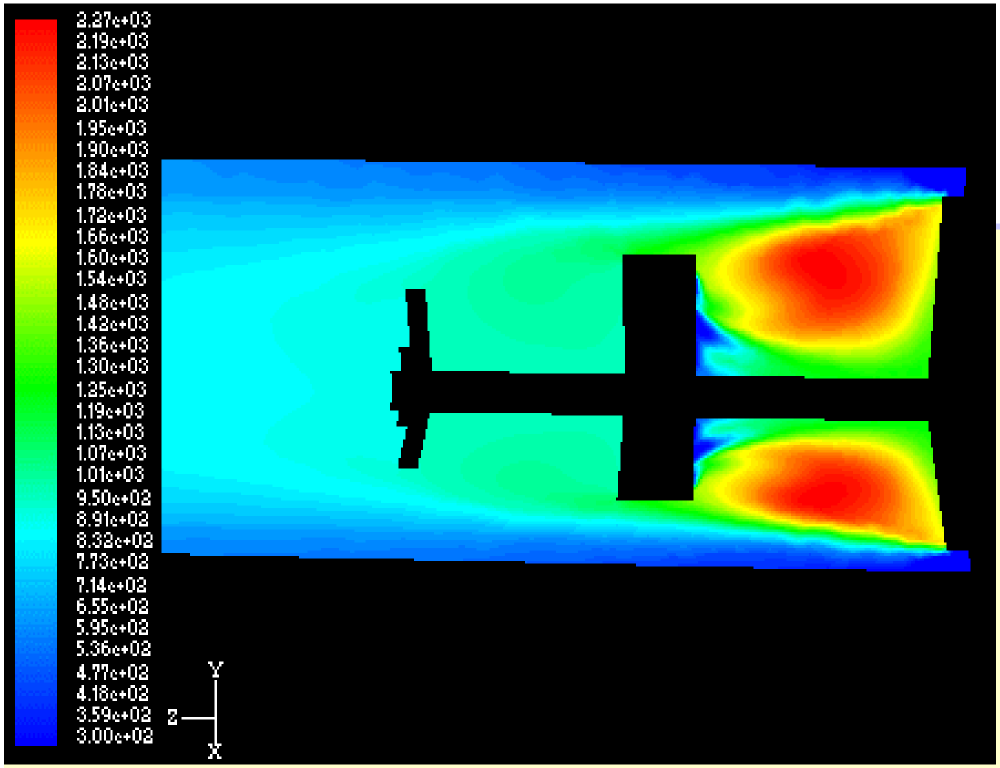
$\tau_{ric} > \tau_{mix} + \tau_{delay} + \tau_{burning}$

The anchorage of the flame is assured by recirculation of hot combustion products



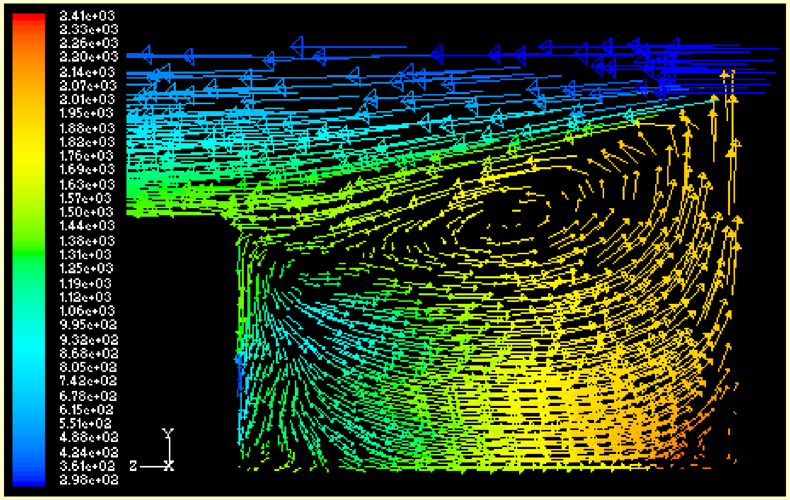
TVC

Combustion of CH_4 : Temperature distribution

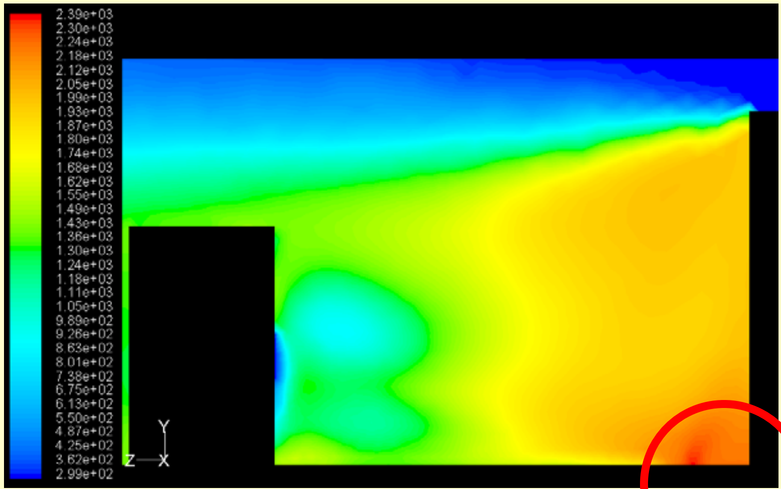


- Stable Combustion
- Stationary vortex
- No stratification → good mixing

Combustion of H_2



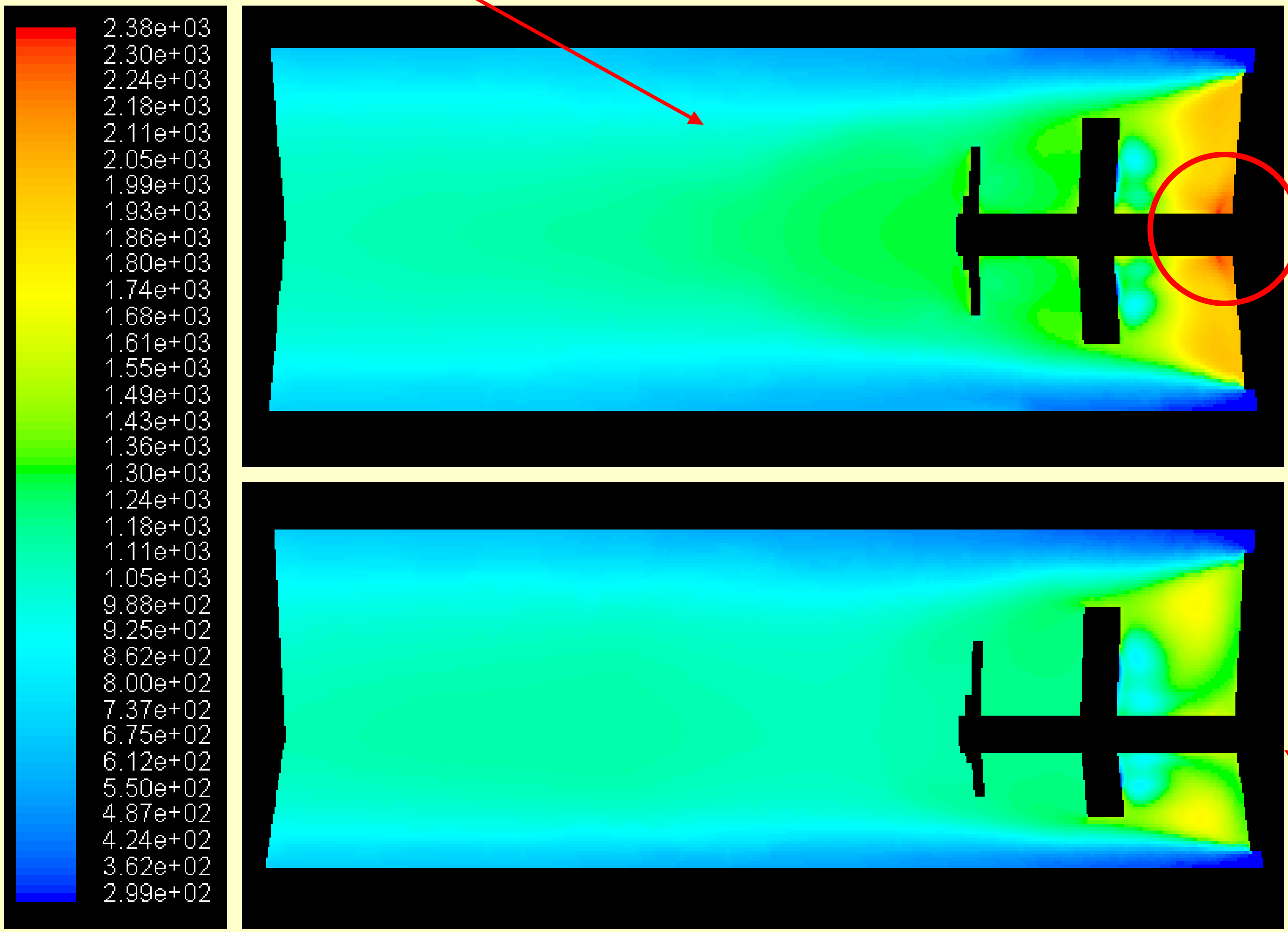
Flow field



Temperature

Trapped Vortex Combustion strategy

Pure H2



- Combustion is almost complete (*combustion efficiency is close to unity*)
- *Pressure drop is very low and comparable to other fuels' results*

$H_2 + H_2O$