FLAMELESS PRESSURIZED OXY-COAL

Sulcis Technology Center

FPOC 50 MWth Large Pilot

a step-ahead in technology development
of a ready-for-CCS competitive and retroffittable carbon-capture solution

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CCS Workshop

agenda

- FPOC at Sulcis “Clean Energy” Technology Centre
- FPOC performance validation at 50 MWth
- Review of FPOC competitive positioning
    - vs CCS competitors
    - FPOC «ready for CCS» vs SCPC
- Scale up philosophy and analysis

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CO_2 TECHNOLOGY CENTRE - SULCIS

itea FLAMELESS TECHNOLOGY

A CONSORTIUM BETWEEN SOTACARBO AND ENEA

is managing

THE CONSTITUTION of a CENTER OF EXCELLENCE for CLEAN ENERGY TECHNOLOGY

based on

PRESSURIZED OXY-COMBUTION TECHNOLOGY

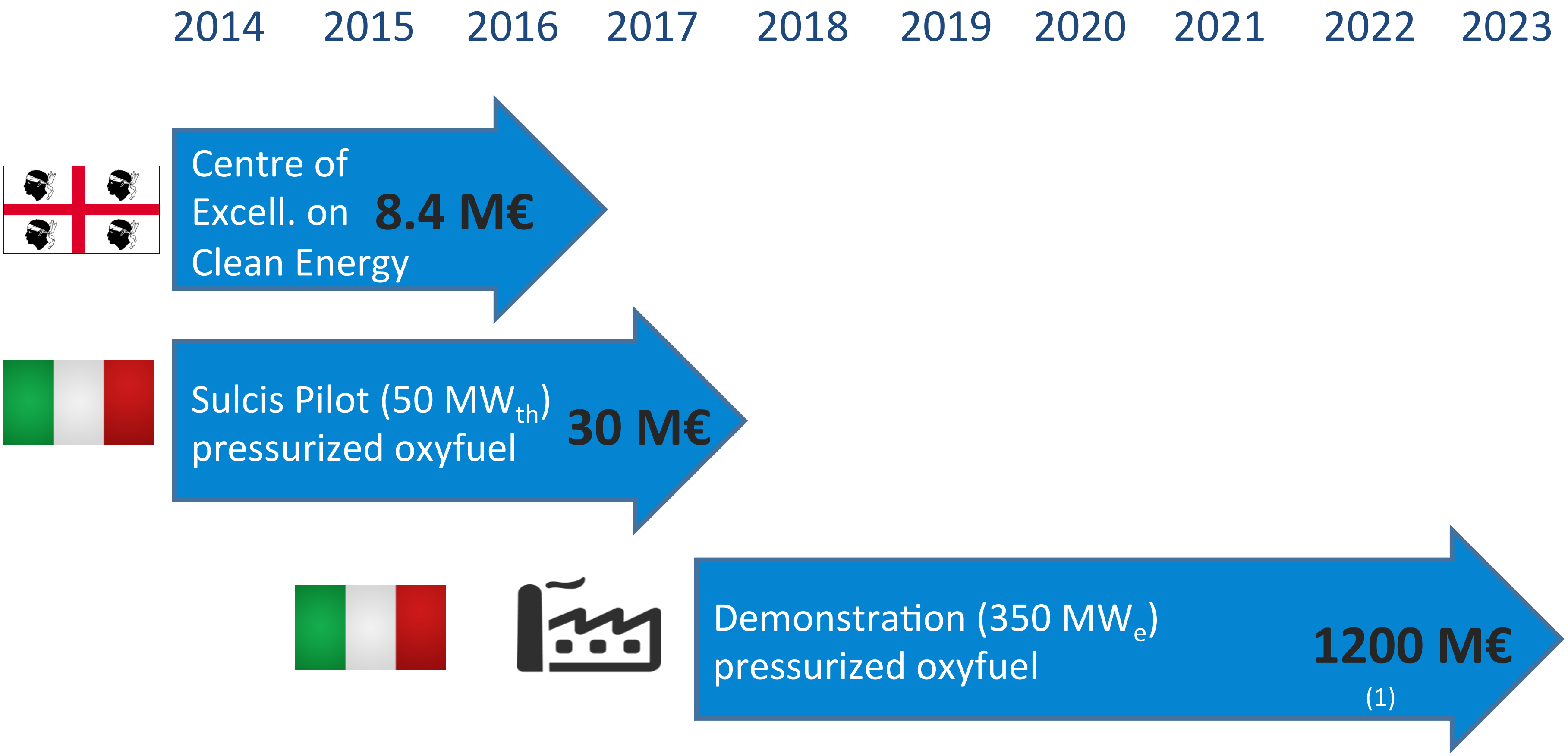
contributed by

ITEA Spa (Sofinter Group)

It will materialize the more promising R&D Project for Coal CCS Technology

that ITALY contributes to Environment SAVING

CCS FLAMELESS PRESSURIZED OXY-COMBUTION R&D PROJECTS AND RELEVANT GRANTS



Italian law 21 Feb. 2014, N. 9:

Incentive for covering CCS extra costs: 30 €/MWh; maximum: 2.100 GWh/yr.

(1) **60 M€/y = 1.2 Billion € in 20 years**

Why Flameless Pressurized Oxy-Coal Combustion

FPOC

FPOC: Process Validation

- 5 MW_{th} oxy pilot station has been erected ten years ago by ITEA in cooperation with ENEA
- Extended validation tests done (ITEA – ENEL – ENEA – Sotacarbo) - Key results analysis with M.I.T. support

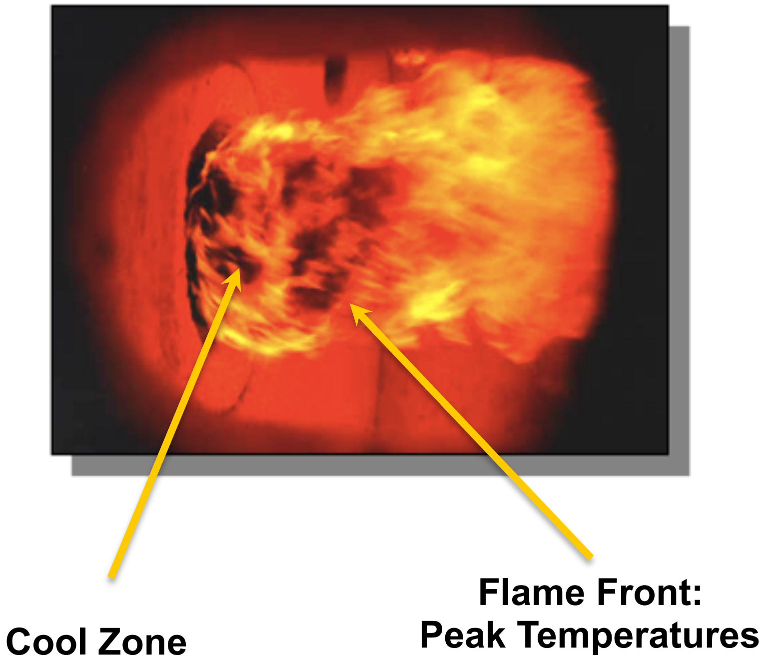
FPOC

FPOC: Picturing Innovative Process Fundamentals

Traditional "flame" combustion

"chaotic"

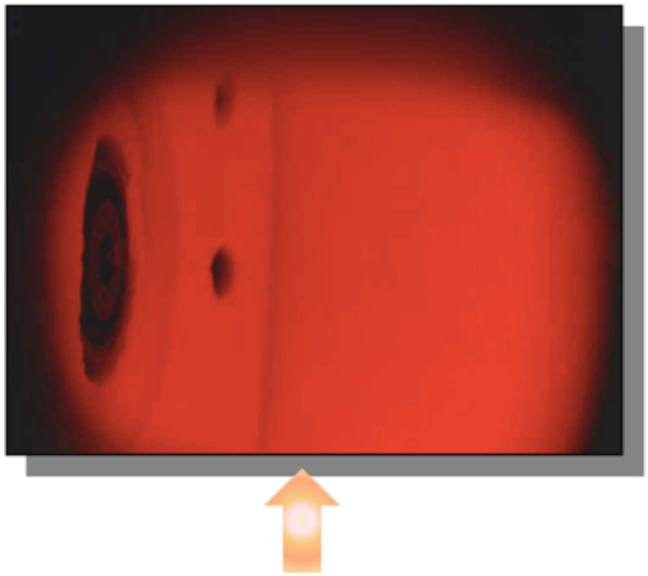
non locally controllable



Itea «Flameless combustion »

MILD, flameless, « volume combustion»

volume expanded - controllable



FPOC

FPOC: Innovative Approach to Combustion

TRADITIONAL APPROACH TO COMBUSTION

Flame combustion

- Chaotic process/non controllable
- Formation of dangerous products during combustion
- Expensive/complex fumes treatment lines
- Heavy and Fly ashes with questionable disposal
- Plants with limited rangeability
- Low CO_2 concentration in outlet fumes

NEW APPROACH

Flameless oxy-combustion

- High and uniform temperature
- Total absence of dangerous products during combustion
- Simple fumes treatment
- Incombustible ashes reduced to vitrified inert slugs
- High plant rangeability (10 => 100%) at constant performance
- High CO_2 concentration in outlet fumes
- Flexible fuel

FPOC

FPOC: A new way of burning at "near zero" emission

- The lowest emissions rank that known combustion technologies can guarantee.
- The ashes are reduced to totally inert vitrified beads.
- 95-98% of introduced heat (LHV) is recovered.
- High rangeability of the combustion process (from 10% to 100% at constant emission performance)
- Extended acceptance of water content in the fuel (LHV as low as 4-5 MJ/kg)
- Ease in commercial CO2 recovery for different utilizations
- Capability to simultaneously burn different kinds of waste and fuels
- Compact relatively small plant, highly automated
- Competitive CAPEX.

FPOC

Established Performances - on the basis of the experience already done

- Few unit operations; fumes «as such» recycled to combustor and hot fumes quencher
- Flexible Fuel : quality and low rank coal with almost the same efficiency and emission
- Coal can be fed as grinded (not pulverized) slurry with water: slurry logistic avoids coal dust pollution
- Coal ashes are disposed as vitrified zero-Carbon inert pearls; therefore can be used as recycled material
- A plant based on this technology can easily follow daily cycling requirements of the grid
- "Clean" fumes produced allows power recovery from hot fumes turboexpansion
- "Clean" fumes, concentrated CO_2 (>90%) ease a simple, inexpensive, CO_2 caption process (compression an condensation only)

FPOC: Competitive Positioning

Background for Economics Comparison

This technology (in CCS and "ready for CCS set up) is subject to comparison with both:

- competing CCS technologies
- current state of art of SC coal fired power plants (in non-CCS set up)

Considering:

- 550 MWe net Super Critical coal power station baseline
- Figures relevant to overall hardware installed
- Standard methods (DOE-NETL) – LCOE
- Key indexes: CAPEX (Capital Expenditure), LCOE (Levelized Cost of Energy)

- We intend as «ready for CCS» a coal power plant, based on flameless oxy-combustion, that produces fumes, ultra low emission level, constituted by concentrated CO_2 delivered to the atmosphere
- Such plant can be retrofitted with modular units for compression and storage of CO_2, in accordance with the entity of CO_2 permitted emissions
- With a retrofitting corresponding to the compete transformation to a 100% CCS coal power plant, the final LCOE cost should remain in the range of 20% cost increase for standard quality coal and 10% cost increase for low quality coal.
- The LCOE of such a plant corresponding to the LCOE presented before with cost deduction of the non compressed and stored CO_2 portion

FPOC

CCS Technologies Competitive Positioning; Base Line: SC Power Station

Parameter	unit	Non-CCS	CCS					CCS ready
			Post capture	Oxy-combustion				
		SC base line	SC + amine	IGCC (1)	Atmospheric Oxy-Comb (1)	FPOC Flameless Pressurized Oxy-comb (1)	FPOC optimized (post 50 MWt pilot) (1)	FPOC CCS ready (1)
Power in	MWth	1345	1880	1770	1760	1520	1425	1425
Gross Power	MWe	580	661		786	723	681	681
Net Power	MWe	550	550	550	550	550	550	613
Efficiency	%	40.9	29.3	31.0	31.3	36.2	38.6	42.9
Capital	M€	936	1693	2403	2350	1690	1390	1210
CAPEX	€/kWenet	1700	3078	4370	4270	3700	2710	1974
LCOE	€/MWh	76	133	140	137	104	91	75
LCOE with low rank coal (-35% coal cost)						94 (2)	82 (2)	68 (2)

Note: Location in Europe - Quality coal - CO2 storage not included
Elaborated according to std methods (DOE-NETL)
(1) Recent advance 0.16 kWh/kg O2 applied to all Oxy-combustion technologies
(2) FPOC only performs low rank coals, with efficiency and Opex almost equivalent to quality coals

FPOC

FPOC Industrial Development Pathway

50 MWt large pilot unit at Sulcis

Highlights on key improvements to be validated at Sulcis pilot

- Efficiency improvement (LHV basis) from 36,2 % to 38,6 %
- CAPEX reduction from 3700 to 2710 €/KWe net
- Levelized Cost Of Energy, CCS set up, from 104 to 91 €/MWh (with quality coal)

and

the dominant technology development problem

Validation of Combustor Scale up Rules

to make future Demo and Industrial Unit bankable

FPOC: Combustor Scale-Up

Mandatory Combustor Scale-up Objectives

- Maintain emission performance, with the same volumetric efficiency
- Combustor rangeability (5% standby to 100% load) at constant emission performance
- Rapid (< 30’ from standby) load uptake and downs
- Firing block without any draw back on hardware

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FPOC: Combustor Scale-Up

FPOC theoretically allows different combustor set-up.

opportunity for

Selection of the more promising combustor set up

based on process fundamentals analysis

- To maintain the best "isothermal" (flat temperature) profile
- To maintain the fastest feeding heat up speed
- To reduce molten slag steady hold up
- To avoid wall temperature decline in heat demanding combustor zone, nearby feeding and fumes recycle inlet (to avoid slag viscosity increase and thickening)

FPOC: Combustor Scale-Up

Process analysis concluded:

established once-through, horizontal set up:

- could be limited in scale, with low LHV (low rank) fuels
- lower performer vs scale up objectives

while, vertical, in-and-out (feeding, exiting fumes) from the top set up:

- fulfils (best fit) with all scale up objectives
- towards combustor of 500+ MWt module and above

Vertical set up became the choice for next technology development step

FPOC: Combustor Scale-Up

Vertical Set up

ACTIONS IN PROGRESS

- Sulcis 50 MWt large pilot have been consequentially engineered.
- Physical-chemical, fluid-dynamics, numerical model elaboration is in progress.
- Erection of a vertical scaled down (5 MWt) combustor is in progress (completion and commissioning October 2015) at ITEA 5 MWt pilot unit

to finally perform

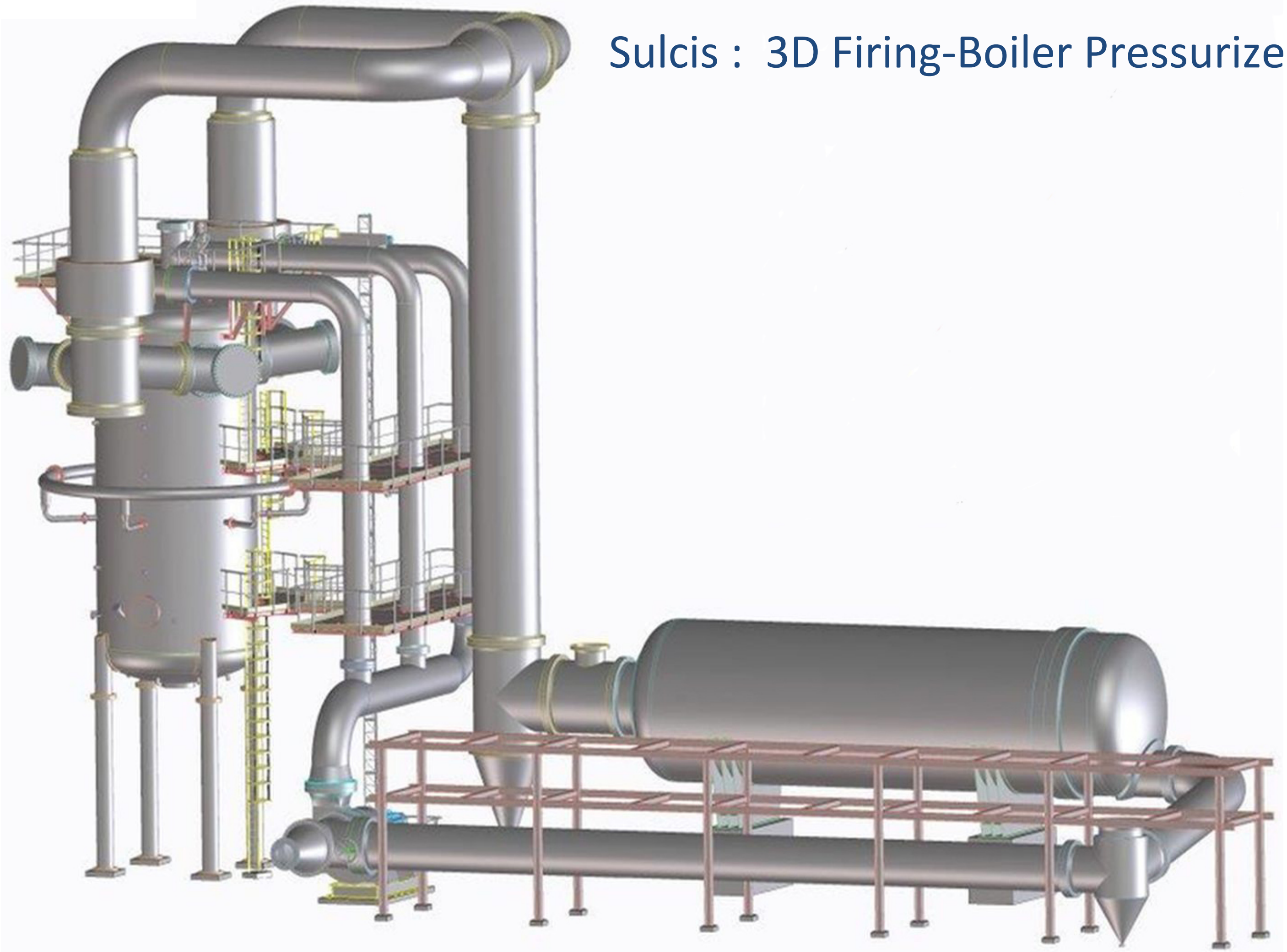
Model numerical parameters adjustments and validation, 5 to 50 MWt

on the more promising set up

to cross off any process risk in the pathway to demo and industrial units

FPOC: Combustor Scale-Up

Sulcis : 3D Firing-Boiler Pressurized Loop 50+ MWt



THANK YOU FOR YOUR ATTENTION