CIUDEN Development Centre on Oxycombustion Technologies

Monica Lupion
CO_2 Capture Programme
CIUDEN

TCCS6 Conference. Trondheim. June 14-16, 2011

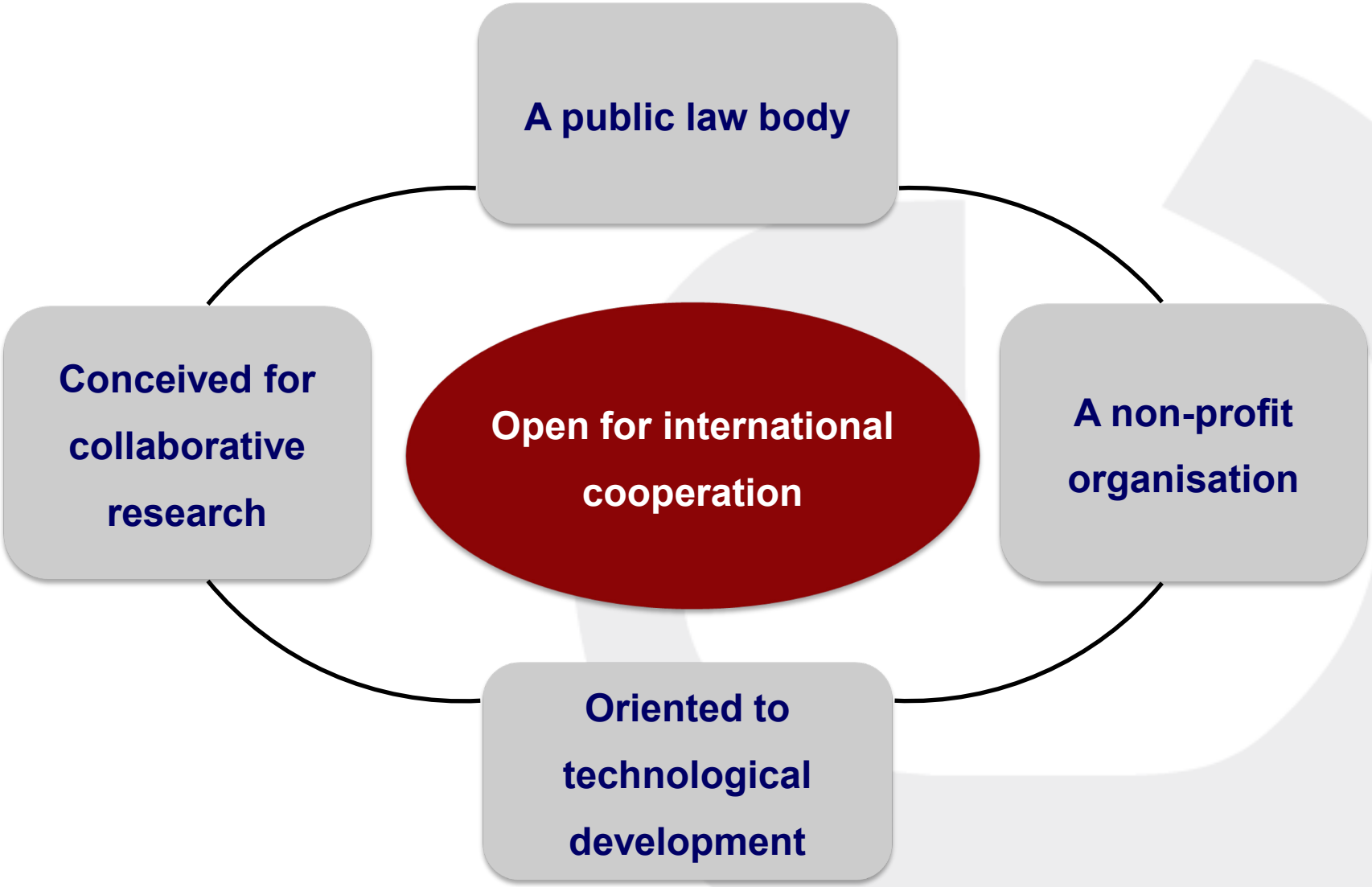
Scope

- Framework
- es.CO_2 technical characteristics
- R&D&D activities

CIUDEN

An initiative of the Spanish Administration

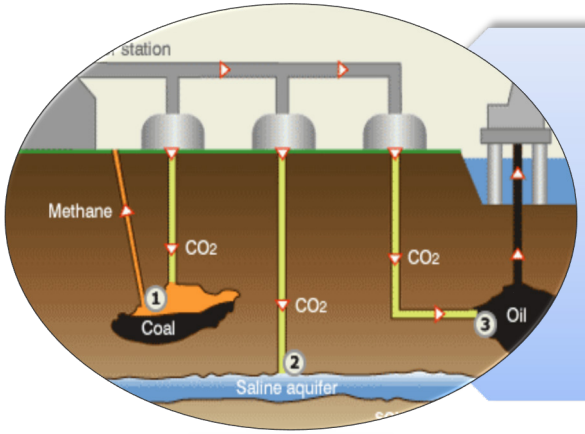
CIUDEN


A public law body
Conceived for collaborative research
Open for international cooperation
A non-profit organisation
Oriented to technological development

CIUDEN general objective

To create a world-wide reference centre for CCS technology development

THROUGH

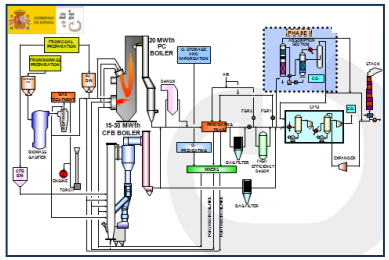


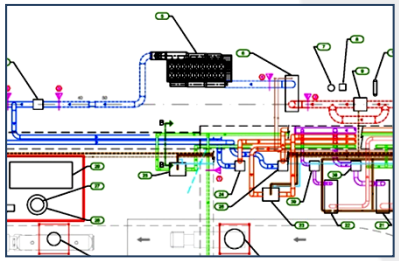
Facilities for CO_2 Capture, Transport and Storage

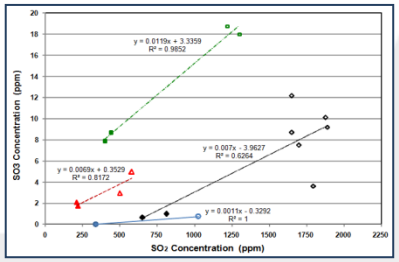
Overhead schedule

Concept developments → **Technology development Engineering** → **Construction** → **Testing plan**

2005 **2007** **2009** **2011**







Main characteristics

Oxycombustion

Pulverized	Circulating	$DeNO_X$
Coal	Fluidized Bed	Dedust
20 MWth	30 MWth	$DeSO_X$

CO_2 purification and compression

+

Biomass Gasifier 3 MWth

Fuels: anthracites, bituminous & subbituminous coals, pet coke, sustainable biomass

Main characteristics

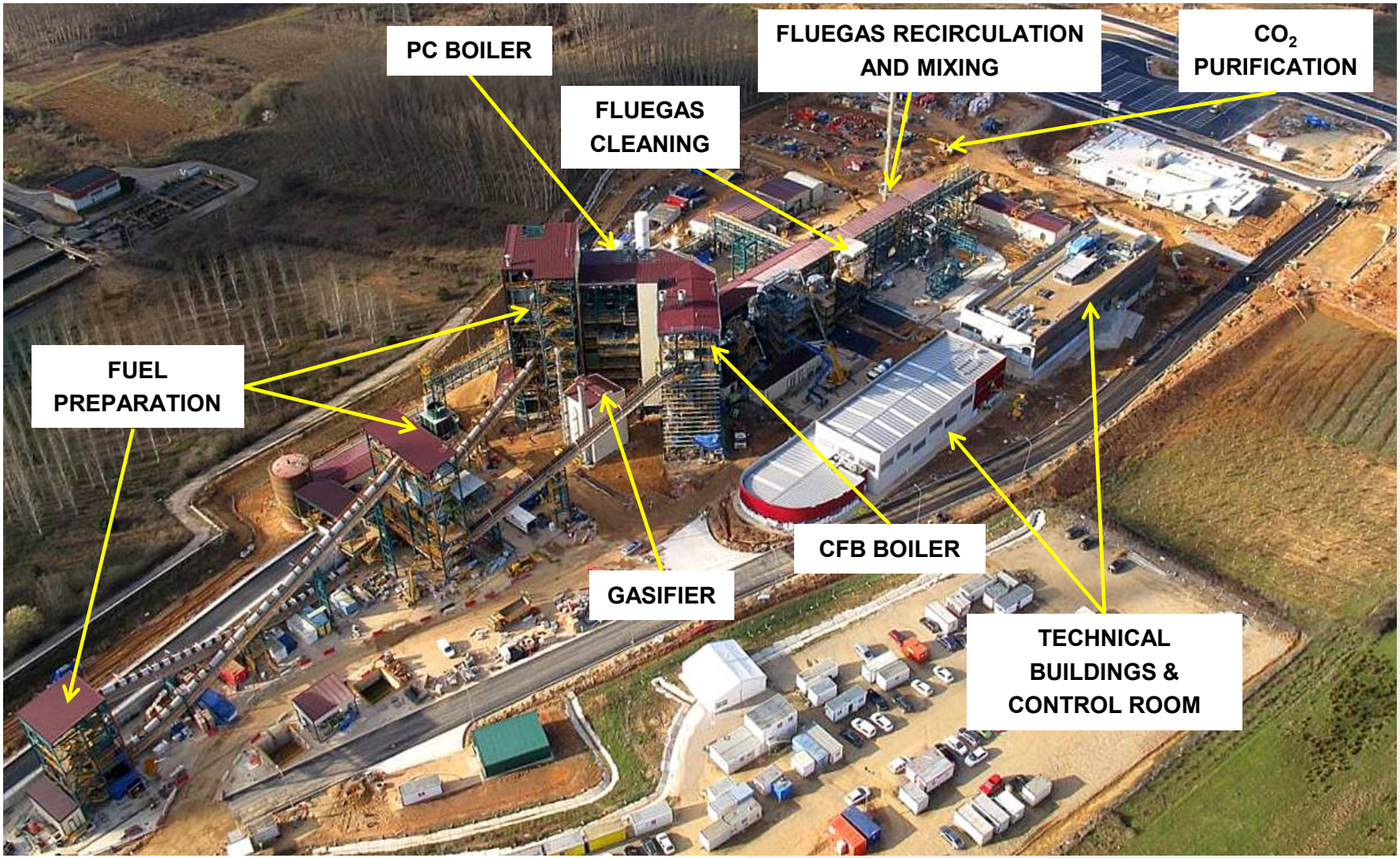
LOCATION	El Bierzo, Leon NW Spain
CAPEX	Phase I 100 M €
OPEX	8 M€/y

Commissioning on going

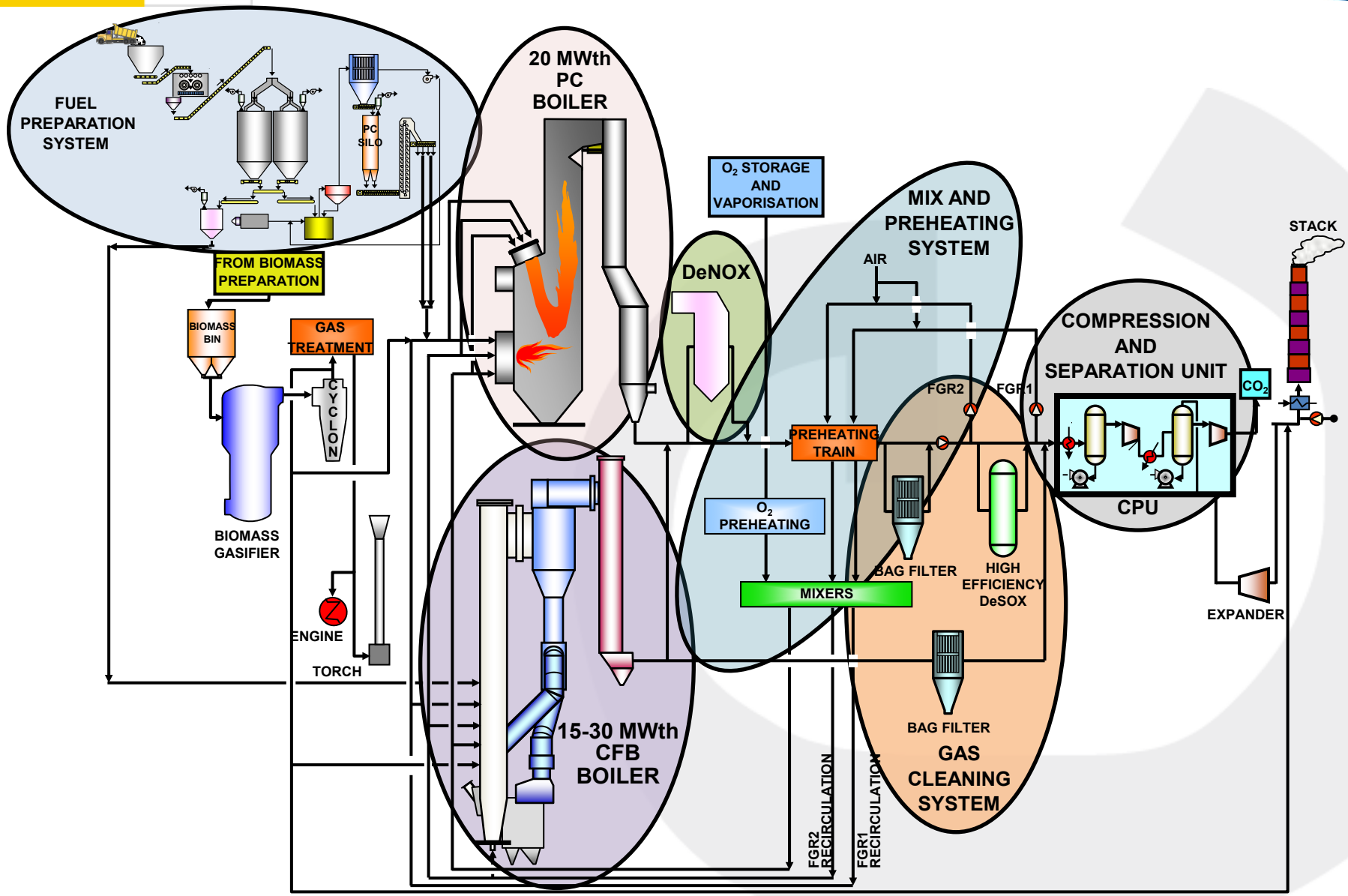
Scope

- Framework
- **es.CO_2 technical characteristics**
- R&D&D activities

es.CO_2 Capture Centre



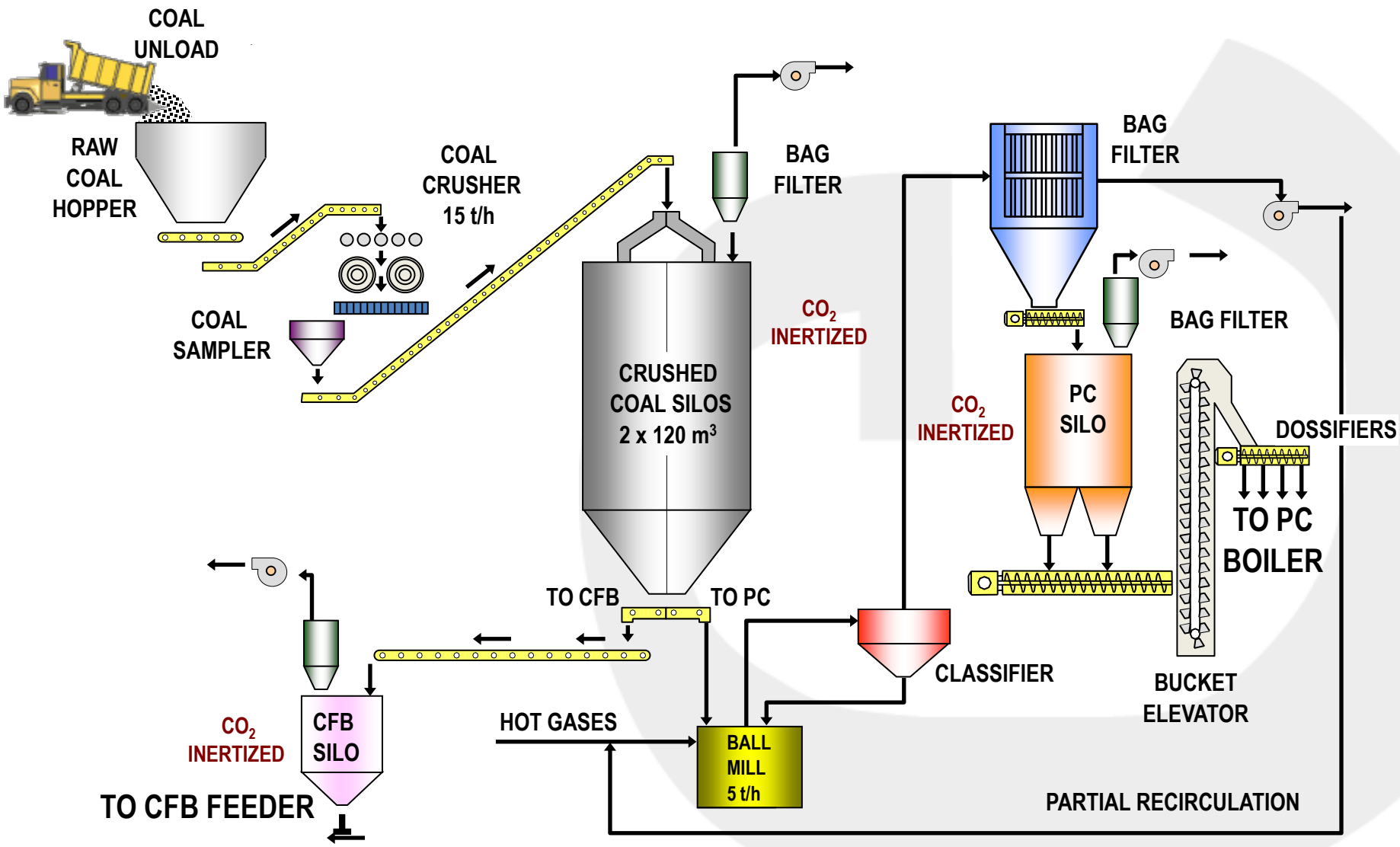
es.CO_2 Capture Centre



Fuel Preparation System

Raw coal hopper	42 m^3
Coal crusher	15 t/h
Crushed coal silos	2 x 120 m^3
Bag filter	47,000 m^3/h
Ball mill	5 t/h
PC silo	80 m^3
Bucket elevator	15 t/h
Dossifiers	4.1-1.2 t/h

Fuel Preparation System



Fuel Preparation System

Proximate analysis as received (wet)	Anthracite	Bituminous	Sub-bituminous	Pet coke
Moisture (%)	8.8	7.5	26.8	6.8
Volatiles (%)	6.5	22.3	36.8	10.6
Ash (%)	32.0	13.8	1.5	0.8
Fixed carbon (%)	52.7	56.4	34.9	81.8
H.H.V. (kcal/kg)	4,888	6,550	4,941	7,785

Design Fuels

Fuel Preparation System - Ball mill

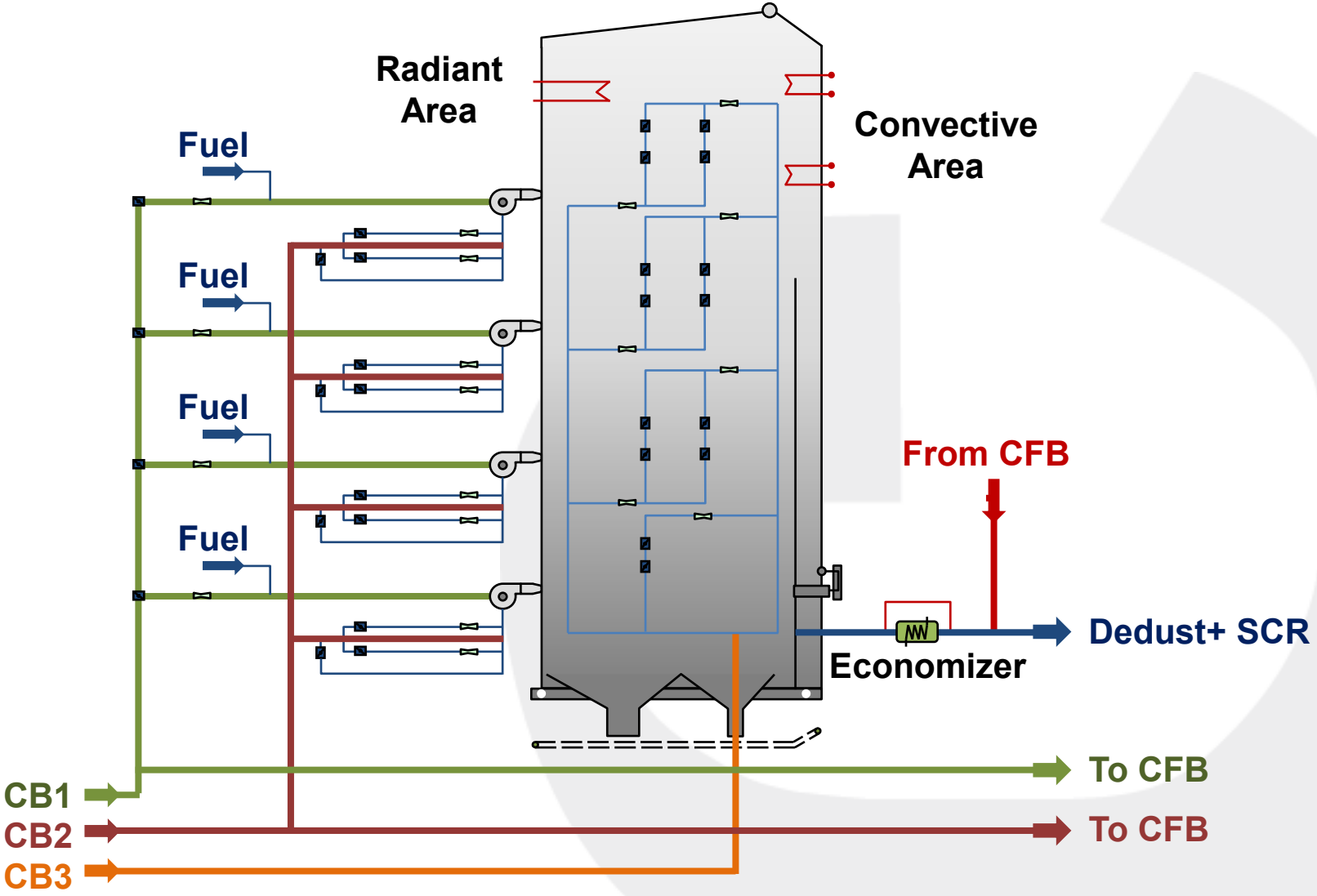
Coal flow	5 t/h
Size distribution	95 %<75 µm 99.7%<150 µm
Inlet/Outlet mill gas temperature	200 ºC / 80ºC
Chamber mill	Diameter: 2.94 m Length: 2 m
Balls	15 t
Weight	45 t

PC Boiler

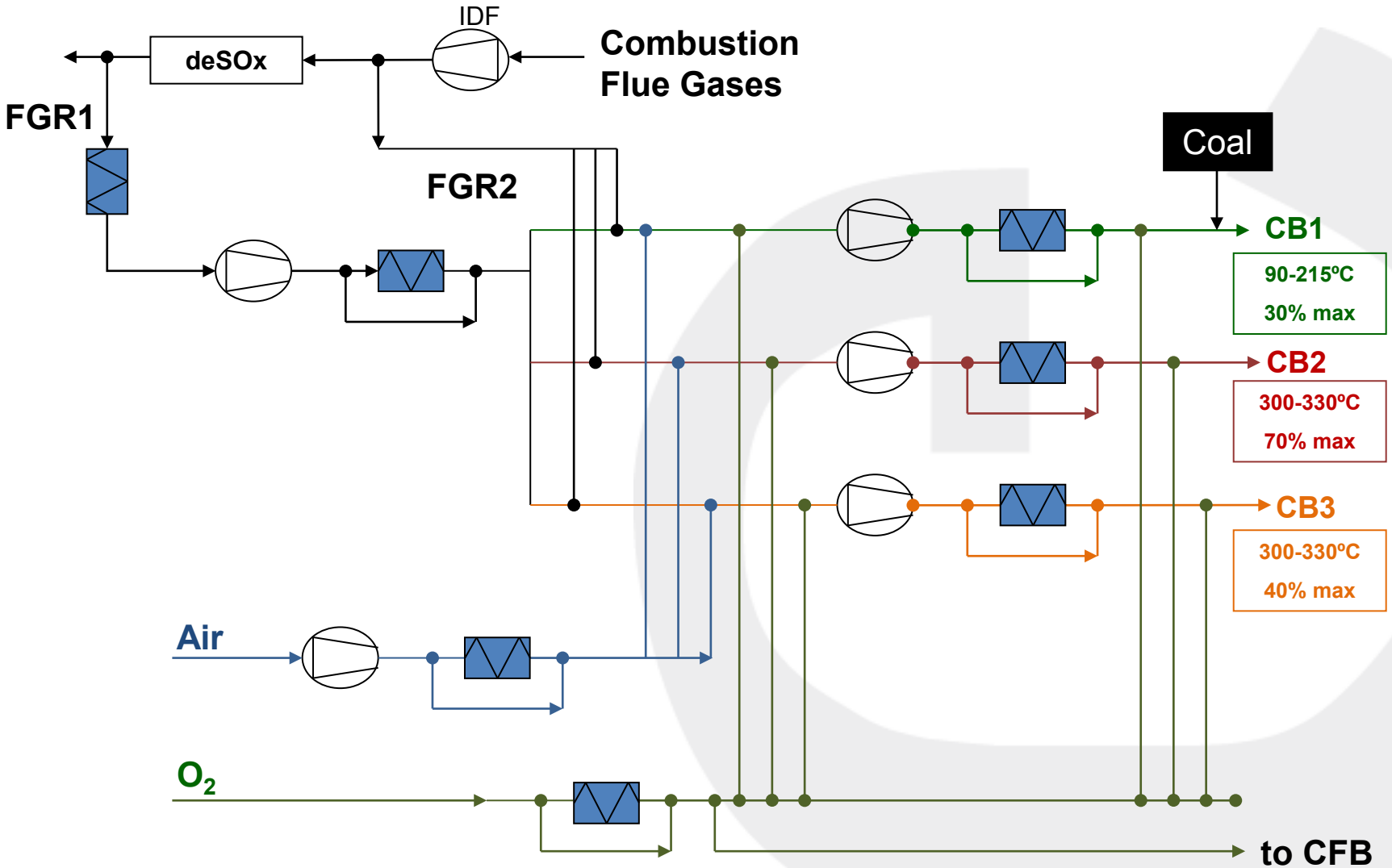
Size (m)	24 x 7.6 x 4.5
Burners	4 horizontal burners 2 vertical burners Biomass feeding system
Mwth HHV Max oxy mode	20
O_2 (kg/h)	6,600
FGR (kg/h)	17,900
Flue gas flow (kg/h)	26,400
Coal flow rate (kg/h)	3,350
Steam (t/h)	25
P(bar) / T (°C)	30 / 420

PC Boiler

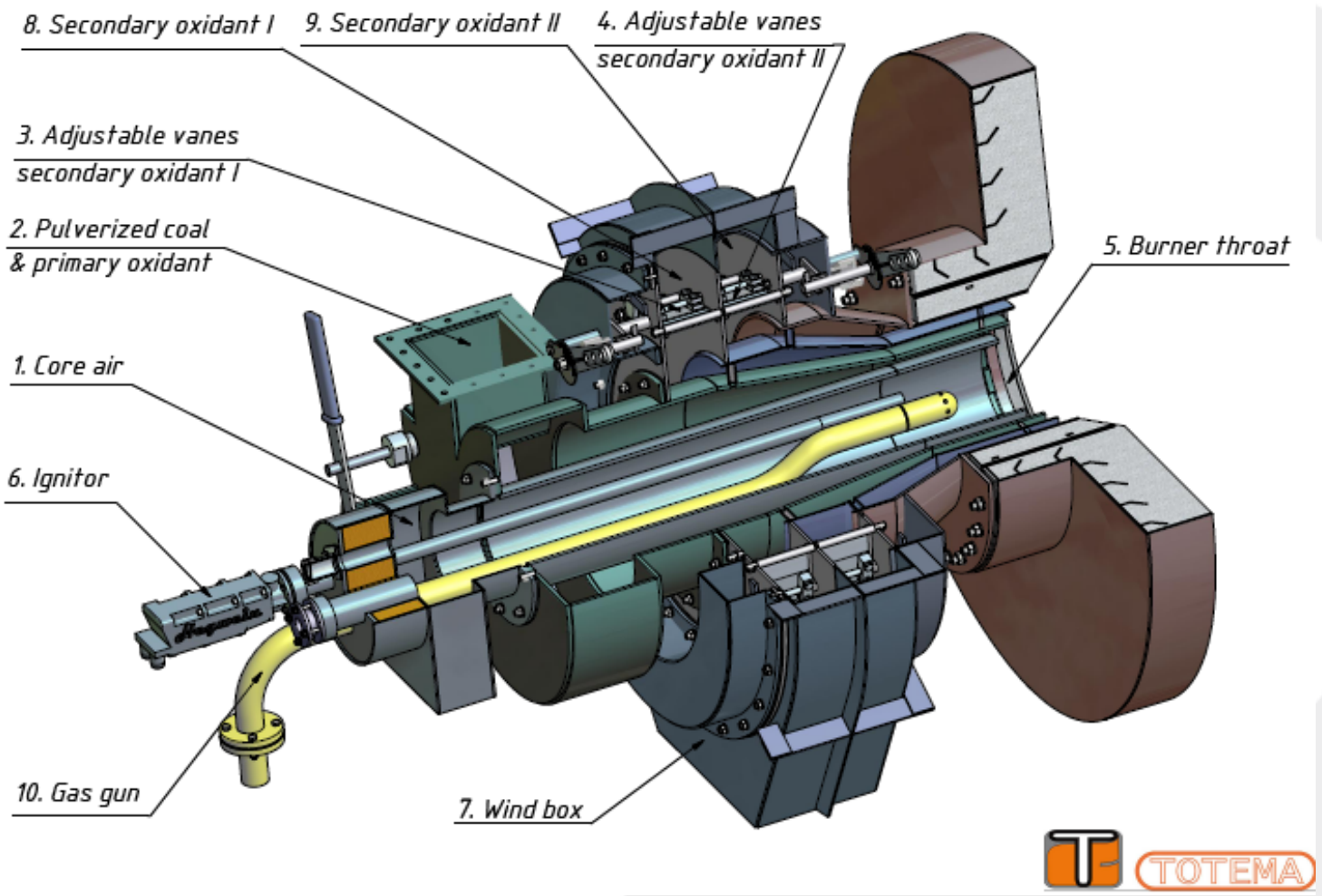
PC Boiler - Diagram



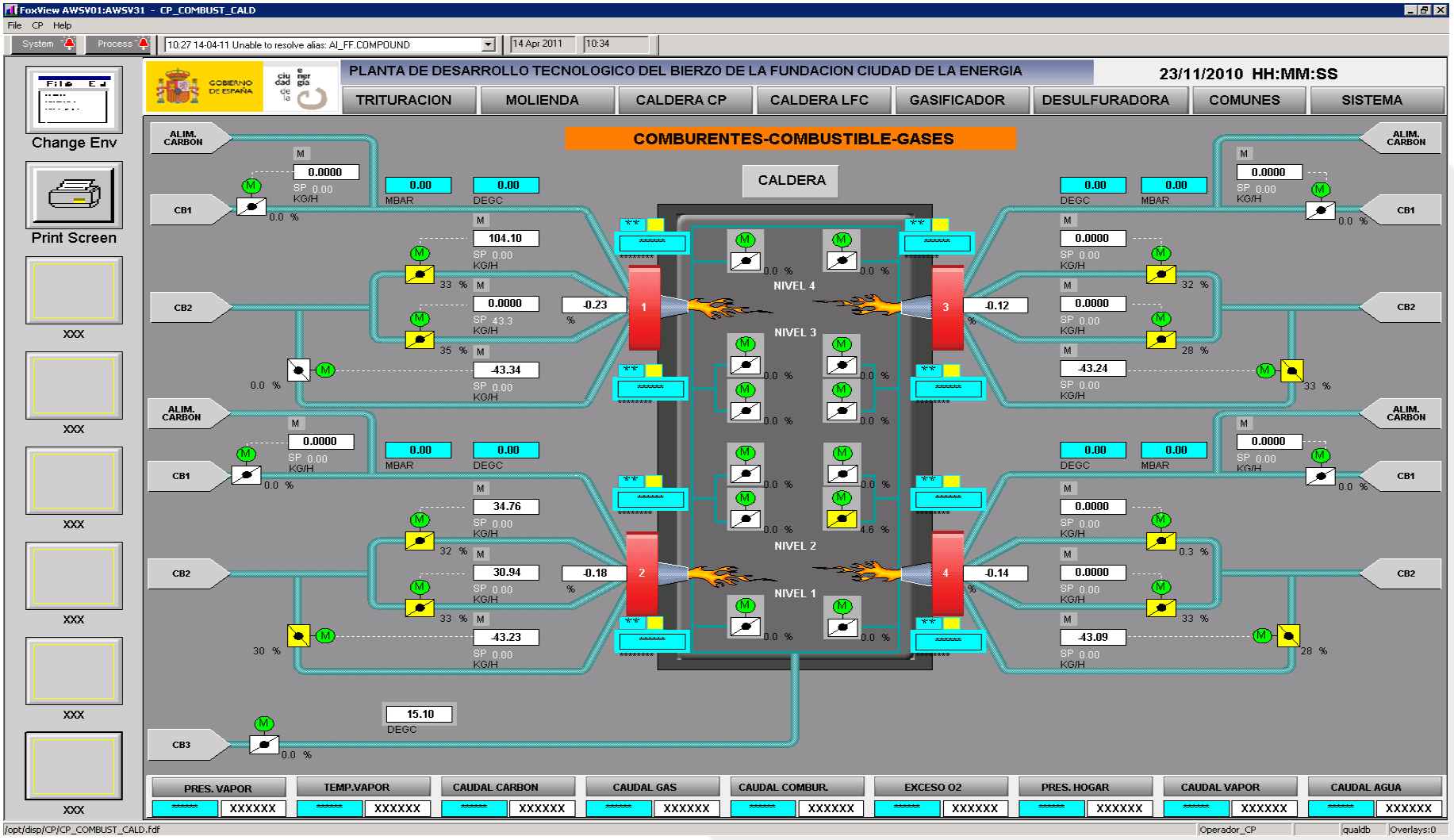
Oxidant Preparation Diagram



PC Boiler – Horizontal burners

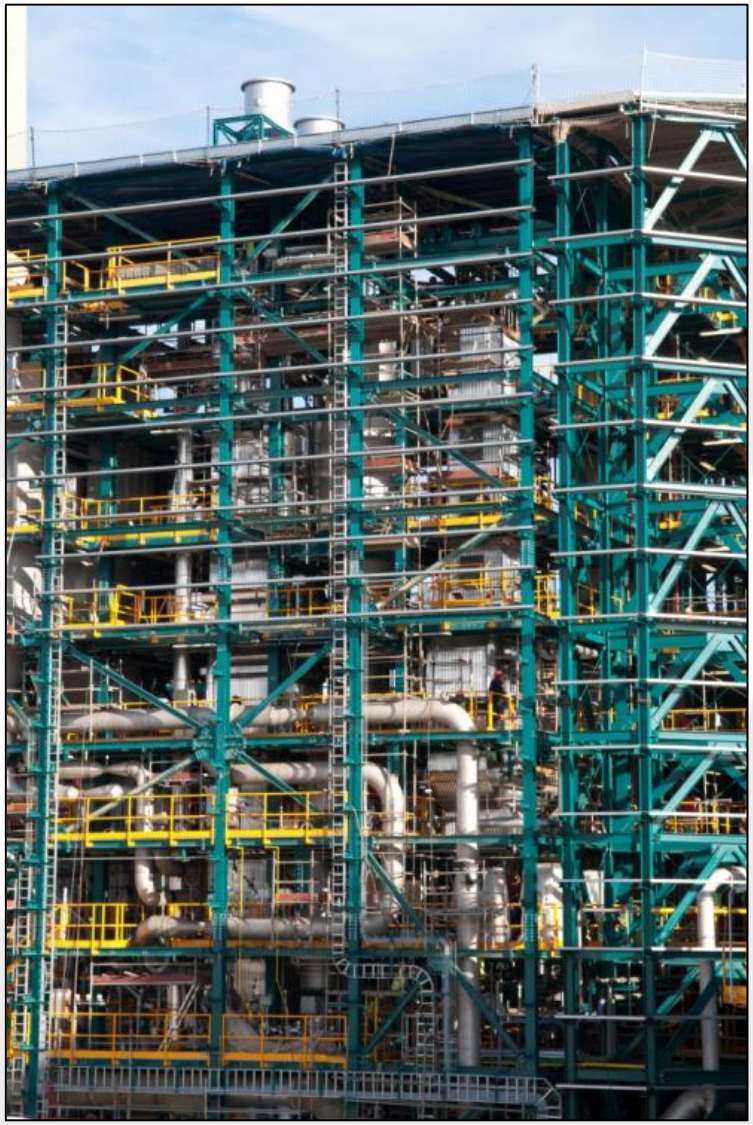


Mimic PC Boiler



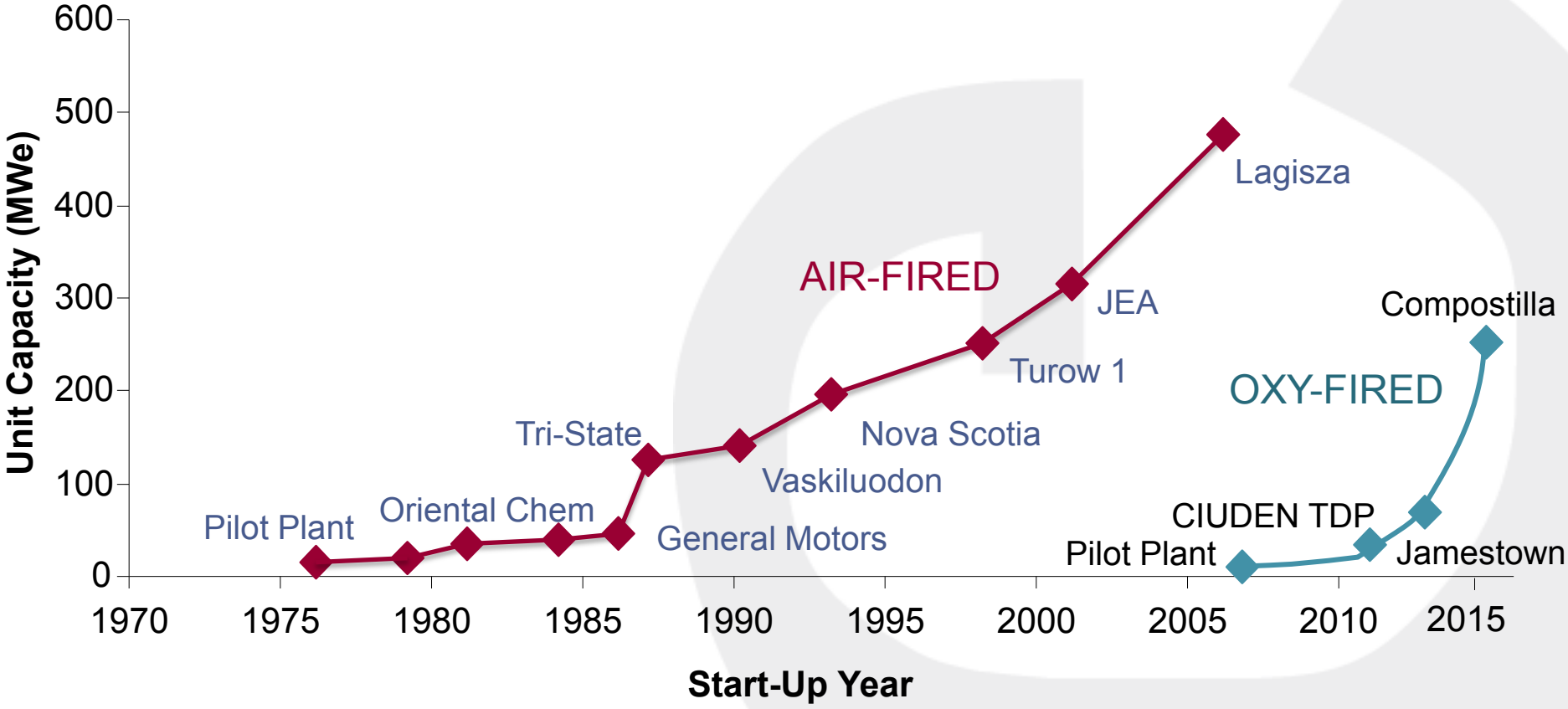
CFB Boiler

Furnace Dimensions (m)	20x2.9x1.7
MW_{th} max oxycombustion	30
O_2 consumption (kg/h)	8,775
Flue gas recycle (kg/h)	25,532
Flue gas (kg/h)	28,800
Coal consumption (kg/h)	5,469
Limestone feed (kg/h)	720
Steam (t/h)	47.5
P(bar) / T (°C)	30 / 250



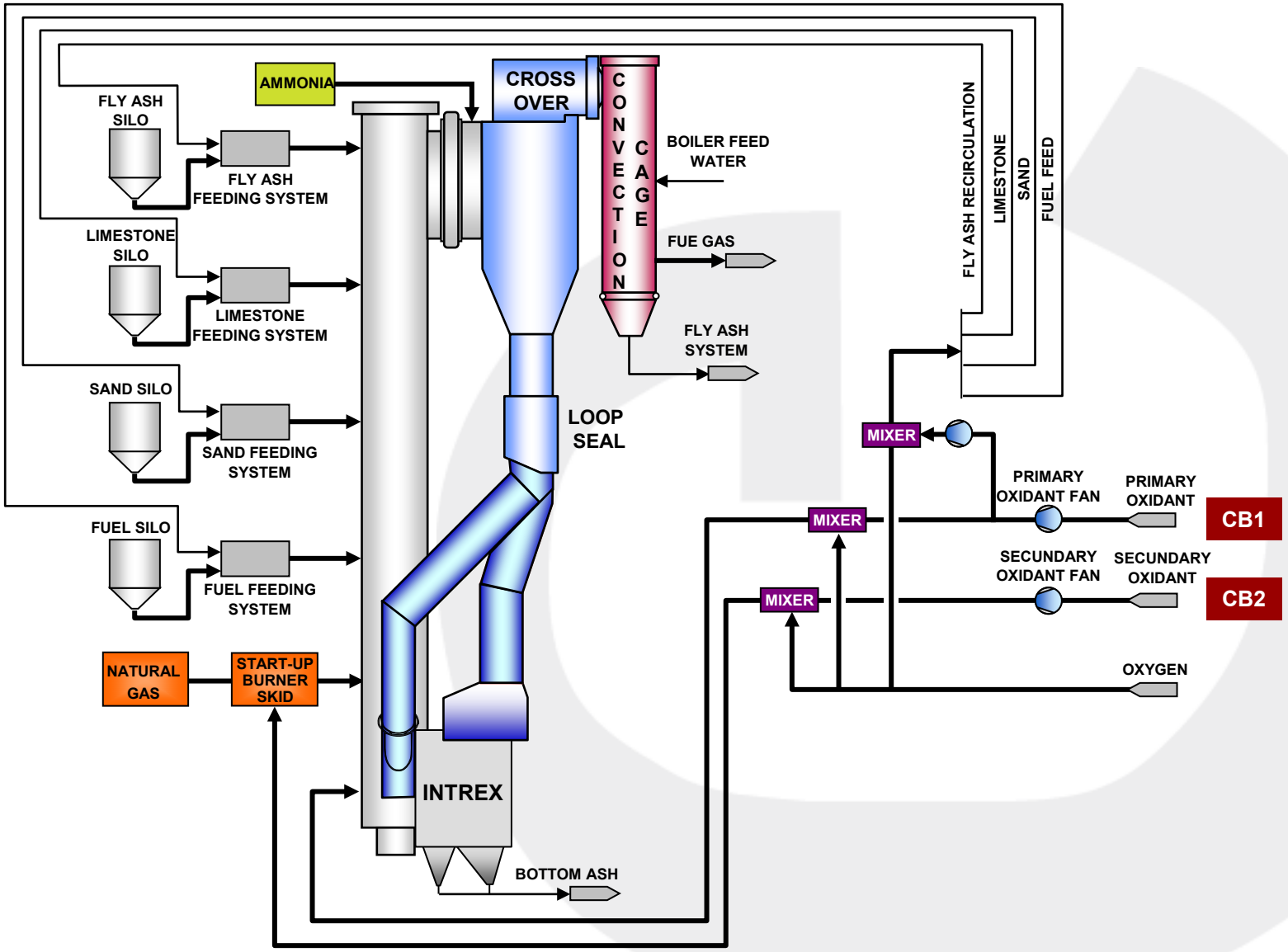
CFB Boiler

Evolution of CFB Unit Capacities



Source: S Santos, IEAGHG. 2010

CFB Boiler - Diagram



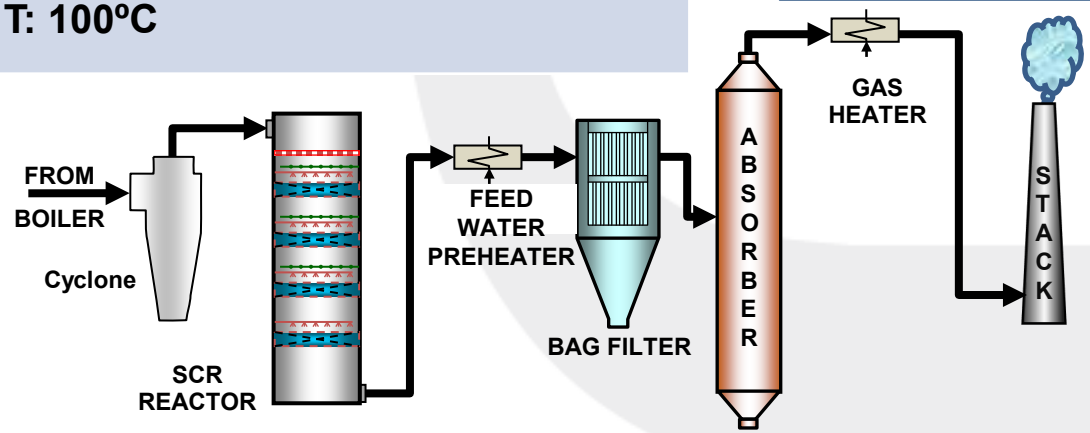
Gasifier

Technology	Bubbling fluidised bed
MW_{th} max	3
Oxidant	Air
Biomass flow rate (t/d)	15
P(barg)	0.3
T (°C)	800
Efficiency (cold gas basis)	98% (75%)
Footprint (m^2)	90

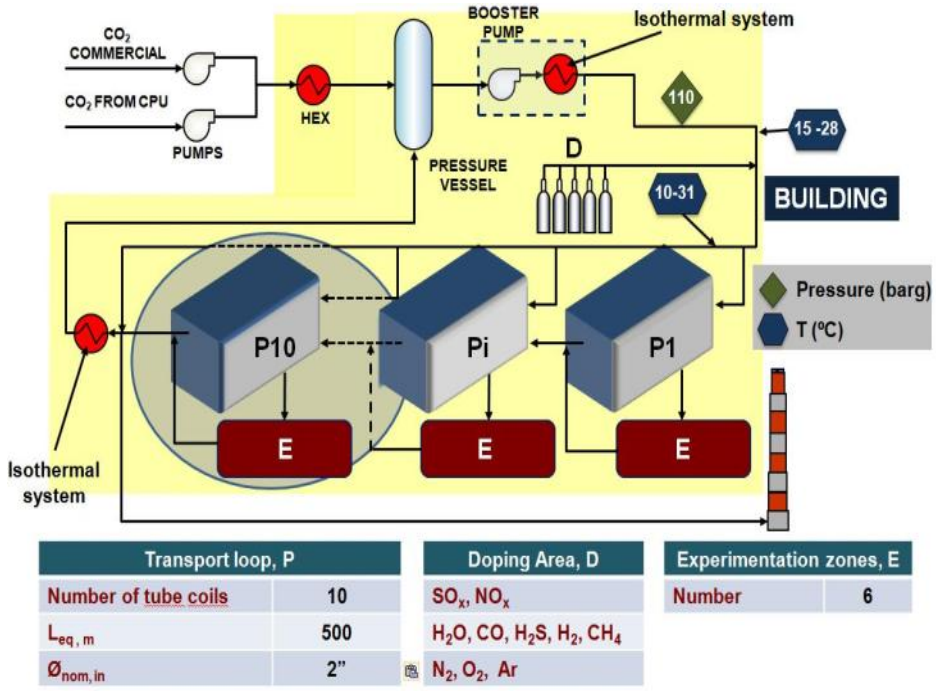
Flue Gas Cleaning

Flue Gas Cleaning

Cyclone	**T: 350-425ºC** **Max ΔP: 150 mmH_2O** **η min: 80%**
SCR	**T: 350-425ºC** **Reduction agent: aqueous NH_3** **η min: 90%**
Bag filter	**T: 200ºC** **Outlet dust: 10 mg/Nm^3 (max)** **η min: 99.5%**
FGD	**T: 200ºC** **Sorbent: $CaCO_3$** **Outlet SO_2 : 15 ppmv (max)** **η min: 99.5%**
Stack	**T: 100ºC**



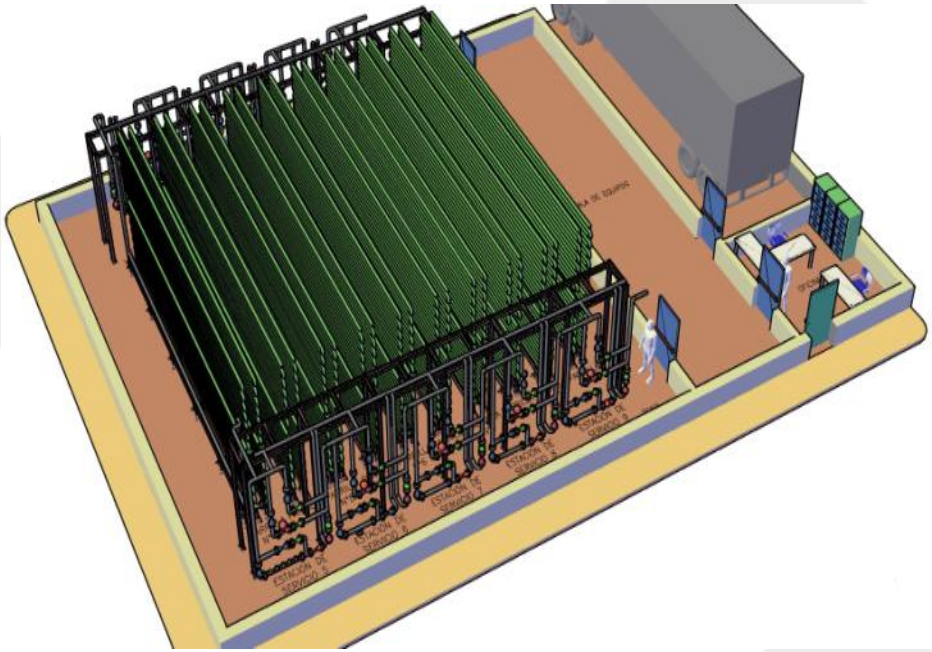
CO_2 Transport Experimental Facility



Transport loop, P	
Number of tube coils	10
$L_{eq,m}$	500
$Ø_{nom,in}$	2"

Doping Area, D
SO_x, NO_x
H_2O, CO, H_2S, H_2, CH_4
N_2, O_2, Ar

Experimentation zones, E	
Number	6



Block diagram of the CO_2 Transport Experimental Facility

3D simulation of CIUDEN´s Facility

Scope

- Framework
- es.CO_2 technical characteristics
- **R&D&D activities**

Current R&D Programme targets

- **Target # 1: Validation and scaling-up of oxyPC, oxyCFB, FGD and CPU technologies**
- **Target # 2: Advanced materials for oxyfiring**
- **Target # 3: Integration and optimization tests of the full process to produce a CO_2 stream ready for transport and storage**
- **Target # 4: 2nd generation oxyfuel power plants**

The “first fire”

CIUDEN LIGHTS THE FIRST FIRE IN THE CO2 CAPTURE CENTRE

2011-04-20 12:31:59

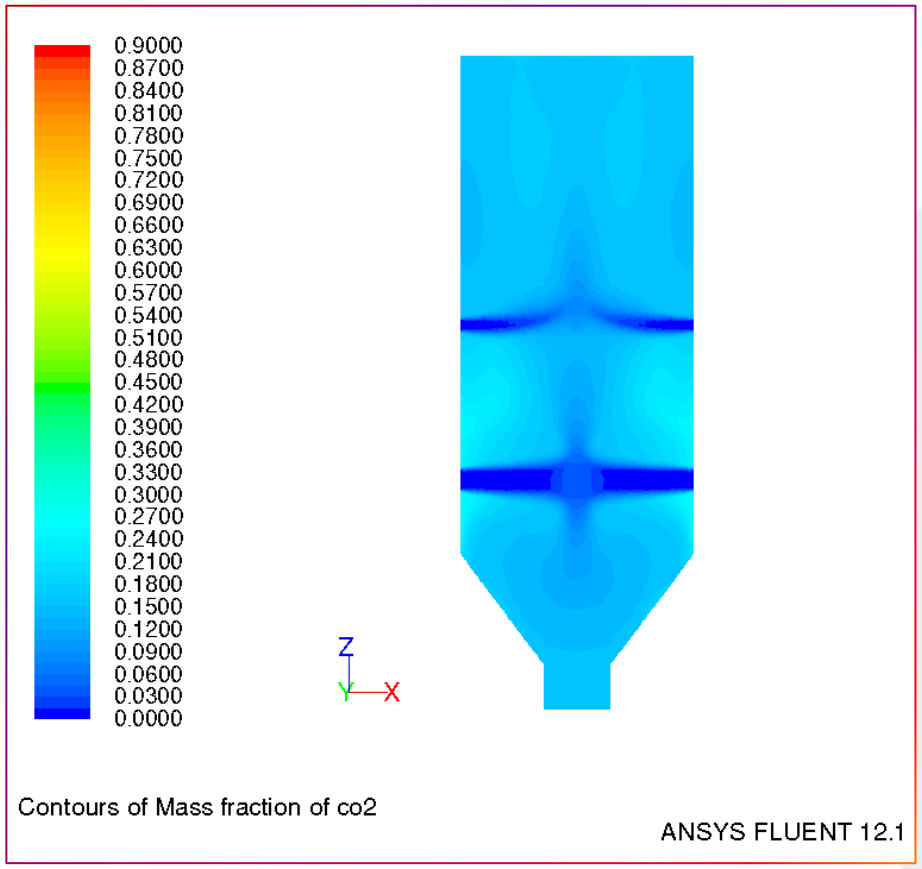
Ponferrada. "Saturday 16 April, at 7:30 pm, a stable and simultaneous ignition of the four burners on the pulverised coal (PC) boiler was carried out, thus reaching this important milestone in the commissioning of the Technology Development Centre for CO2 Capture,

PC Functionality Tests

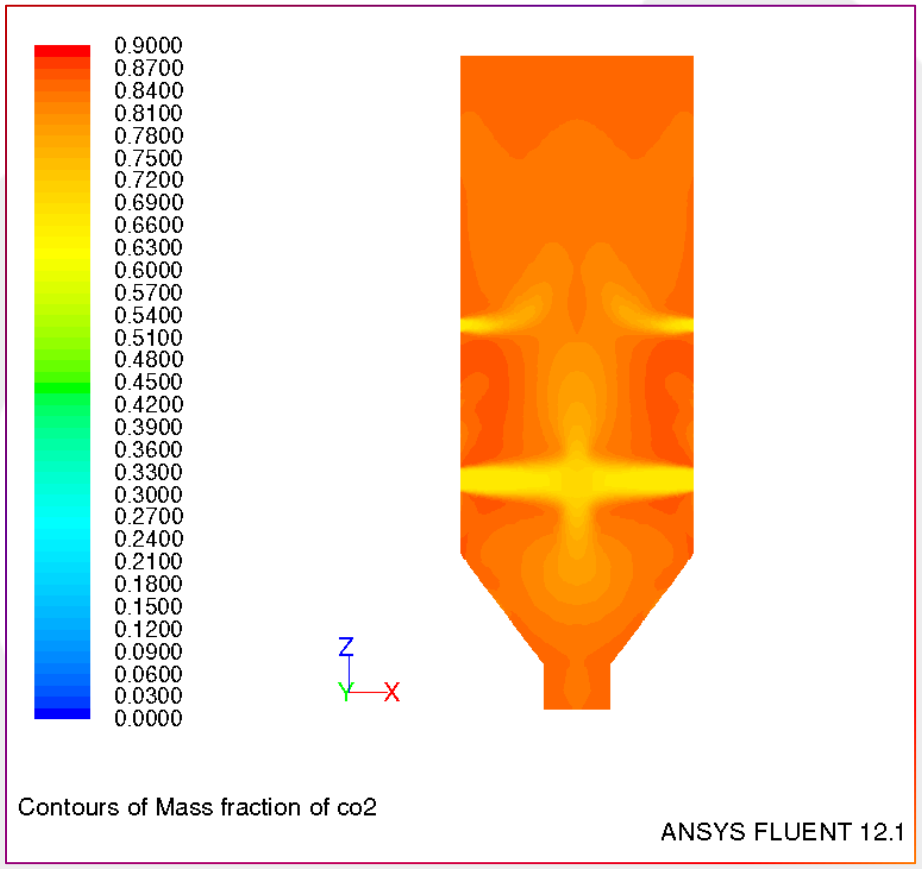
- Safety in oxy combustion
- Switching between air and oxy modes
- Functionality of auxiliary systems in oxy mode
- Boiler load/firing capacity
- Furnace Temperature
- Control range of oxidant oxygen (in each oxidant stream)
- Control range for primary, secondary and terciary stream distribution
- Testing the co-firing of fuel blends
- Reliability of measurements
- Procedures for sampling, furnace profile, fouling/corrosion measurements

PC CFD Modelling

AIR-mode



OXY-mode



PC Experimental Testing Plan

Independent variables

- Coal and combustion characterization
- O_2 concentration in the flue gases
- Burners configuration
- Overfire openings configuration
- Flow rate of FGR
- Composition of FGR

Dependent variables

- Radiation and convection heat flux measurements
- High temperature corrosion of existing and candidate materials
- CFD/Process simulation development and validation
- Efficiency
- Safety issues due to the mixing of comburent stream with a stream containing solid particles
- Coal and combustion characterisation
- Performance of the flame monitoring and control system

PC Experimental Testing Plan

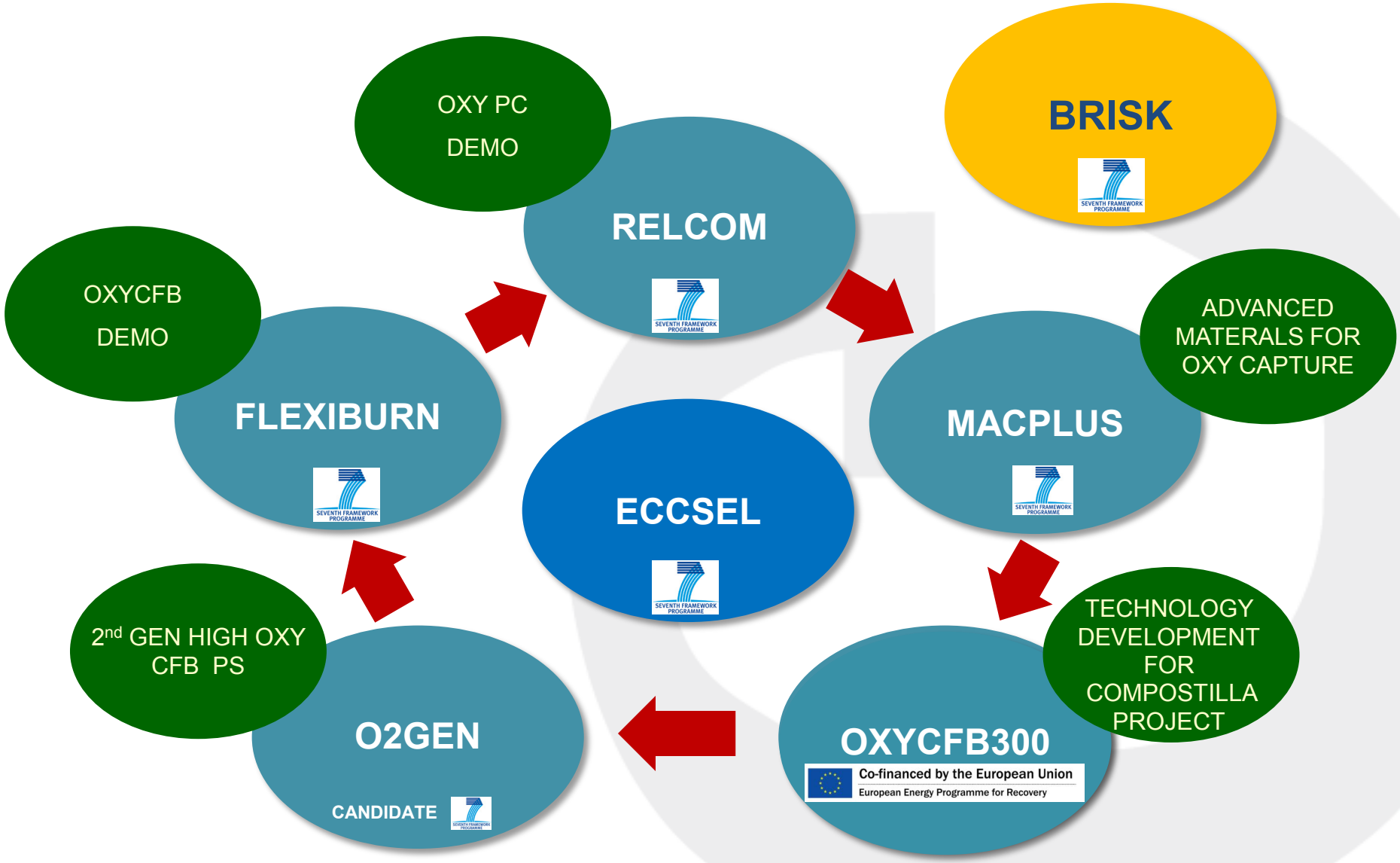
Independent variables

- Coal and combustion characterization
- O_2 concentration in the flue gases
- Burners configuration
- Overfire openings configuration
- Flow rate of FGR
- Composition of FGR

Dependent variables

- Pollutant emissions (SO2/SO3, NO/NO2, Hg)
- Impact of oxy combustion on downstream depuration train
- Kinetics of mercury oxidation
- Air ingress
- Fate of trace elements in oxycombustion
- Characterization of the solid waste, focused on the quantity of carbon / sulphur in ash

Current R&D Programme



R&D Upcoming Areas (I)

Related to currently available technologies at es.CO_2

HIGH O_2 OXYCOMBUSTION	• PF and CFB boiler testing for with increased O_2 concentration • Combustion characteristics in high O_2 concentration • Design and heat managing schemes
SULPHUR COMPOUNDS	• Knowledge and management of S chemistry for solid fuels
CARBON-NEGATIVE SYSTEMS	• Sustainable biomass oxy-co-combustion • Indirect biomass co-combustion via gasification
HYBRID SYSTEMS	• Partial oxycombustion + postcombustion

R&D Upcoming Areas (II)

Based on 2nd Generation Technologies

CHEMICAL LOOPING	• Test at MWth scale of direct chemical looping applied to coal
CO_2 PURITY	• Second generation CPU performance and impact of CO_2 quality on transport and storage behaviour • Cost-efficient solutions to match applicable CO_2 standards
CCS APPLICATION ACROSS CARBON INTENSIVE SECTORS	• Cement industry: oxykilns • Refineries

Further R&D into next-generation technologies must be initiated immediately to enable rapid and wide deployment post-2020

ZEP´s Strategic Deployment Document II

Why this oxy-R&D facility?

- ***Common features:***
  - Simulation of a wide variety of operational modes and fuels
  - Maximum efficiency in view of schedule and budget
  - Small as possible but large enough to be scalable
  - Same level of flexibility for oxy as for a conventional installation

- ***Particularities:***
  - Full integrated process
  - Several burners to investigate flame interaction
  - PC-CFB comparison (20 + 30 MW_{th})
  - Wide range of fuels: anthracites, bit, sub-bit, pet coke, biomass
  - Public R&D institution open for collaboration

Thank you!

Any Questions?

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Target # 1: Validation and scaling-up of oxyCFB

Tasks

- Testing for safe, stable and high-efficiency operation and performance of the 30 MWth CFB boiler
- Test parameters; fuels, T , oxidant and split, fluidization velocity, FGR, sorbents, bed inventory, SO_2 abatement

FLEXIBURN CFB Project

- Objective :Demonstration of flexible high-efficiency CFB combustion technology in air and oxy-modes for CCS

Partners 14

- Industry-driven project
- Technologists, utilities, universities and research institutions

http://www.vtt.fi/sites/flexiburncfb/index.htm

Target # 1: Validation and scaling-up of oxyPC

Tasks

- Demonstration tests at the 20MWth PC oxy-boiler using wall firing configuration
- Measurements: operational and boiler performance parameters , in/outlet gas streams using advanced instrumentation

RELCOM Project

- Objective: R&D&D activities for reliable full-scale deployment of oxy-PC firing

Partners 13

- Balanced cooperation of research bodies, utilities and industry
- Outcome:designs for both retrofit and “new build” oxy-PC plants

Target # 2: Advanced materials for oxyfiring

Tasks

- Testing of advanced refractories for oxyfiring under erosive conditions at the CFB boiler
- Demo tests of fire/steam side protective coatings for operation under oxycombustion environments

MACPLUS Project

- Objective develop and test full-scale prototypes of components to improve performance and reliability of CCS PS

Partners 24

- Balanced cooperation of research bodies, utilities and industry
- Outcome:designs for both retrofit and “new build” oxy-PC plants

Target # 3: Integration and optimization tests of the full process

Tasks

- Integrated TDP for CO_2 capture at 1:30 scale
- Transport TDP for based on a closed-loop test rig 5 km long
- Storage TDP in a saline aquifer for advanced injection and monitoring

OXY CFB 300 Project Phase I

- Objective: Technology development for CO_2 oxy capture, inland transport and storage in saline aquifers supporting FID of a demo 300 MW CCS oxyCFB PS

Partners

3

- Alliance of utility, technologist and CIUDEN
- Target: availability of the technology

The Compostilla Project OXYCFB300

http://www.compostillaproject.es/

Co-financed by the European Union
European Energy Programme for Recovery

Target # 4: 2nd generation oxyfuel power plants

Tasks

- Testing at high O_2 levels for optimum operating conditions
- Testing of suitable materials for boiler components
- CPU optimization to improve efficiency and operability with high oxyfuel flue gas

O2GEN project

UNDER EVALUATION

- Objective: demonstrate the concept of the 2nd generation oxyfuel PS to reduce the efficiency penalty of CO_2 capture down to 5%

Partners

9

- Manufacturers, utilities and state of the art facilities
- Tasks focused on ASU, CFB and CPU