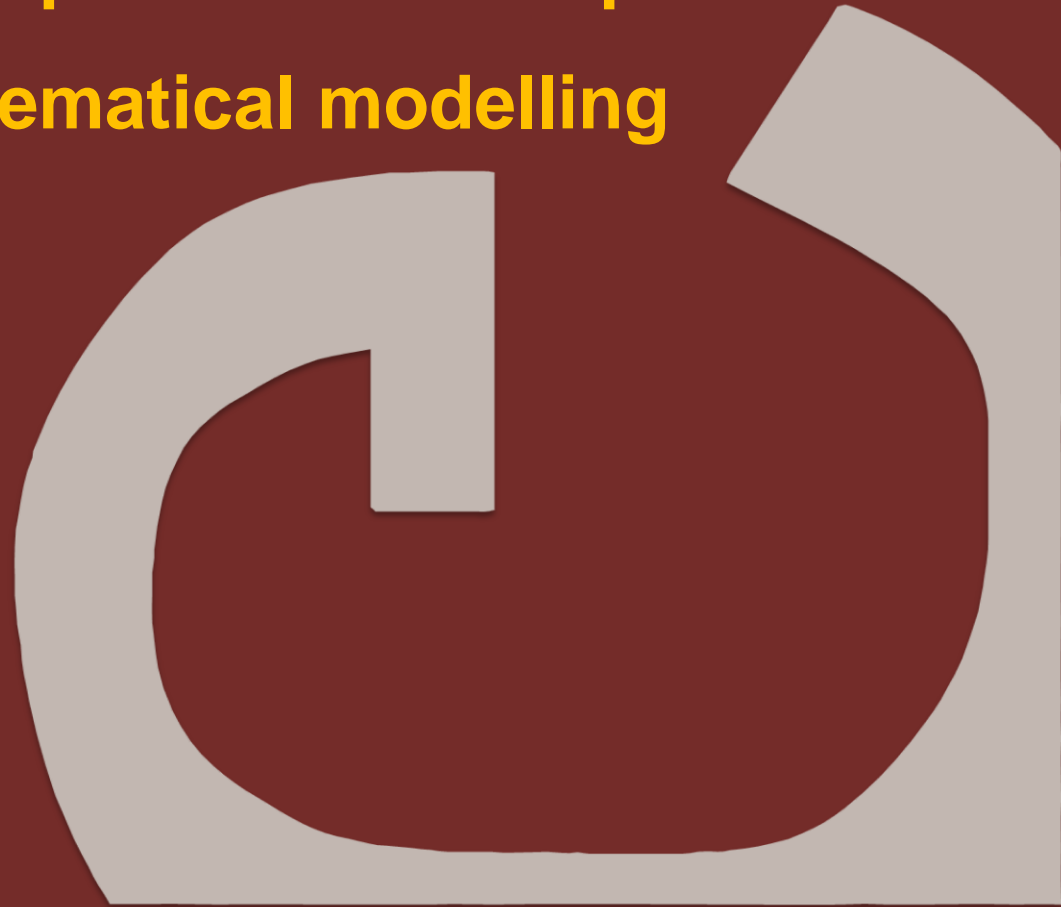




# The CIUDEN Center for Technological Development of CO<sub>2</sub> Capture and Transport. Opportunities for mathematical modelling



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Technical Director  
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Santiago de Compostela, May 23, 2011



- ❶ **Fundación Ciudad de la Energía (CIUDEN).**
- ❷ **CIUDEN s Technology Development Centre for CO<sub>2</sub> Capture: Technical characteristics.**
- ❸ **R&D&D activities.**
- ❹ **Applied research results: Modelling PC Boiler.**





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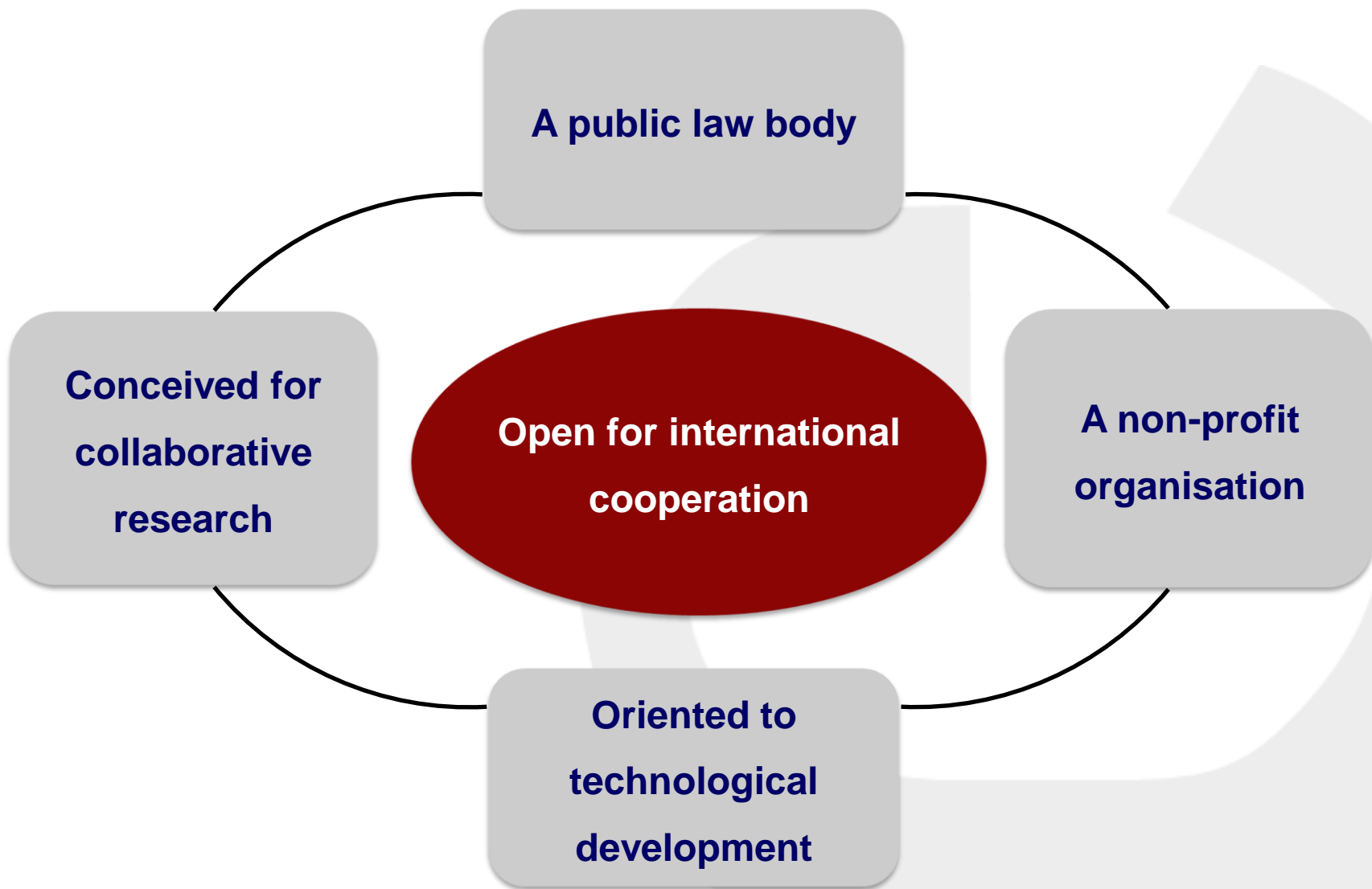
# Fundación Ciudad de la Energía: CIUDEN

## An initiative of the Spanish Administration





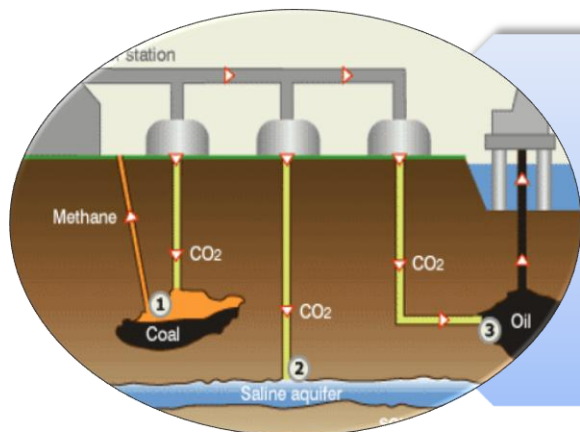
# Attributes





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

**THROUGH**



**Plants for CO<sub>2</sub> Capture,  
Transport and Storage**





# Our three-pronged strategy

## Capture

- To validate close-to-market and emerging technologies for application at commercial scale

## Transport

- To obtain technical criteria for design, management and safe operation of CO<sub>2</sub> pipelines through long-term runs

## Storage

- To develop technologies and processes for injection and monitoring in saline aquifers to support industrial-scale activities





## Oxycombustion

**Pulverized  
Coal  
20 MWth**

**Circulating  
Fluidized Bed  
30 MWth**

**DeNO<sub>x</sub>  
Dedust  
DeSO<sub>x</sub>**

**CO<sub>2</sub> purification and compression**

**+**

**Biomass Gasifier 3 MWth**

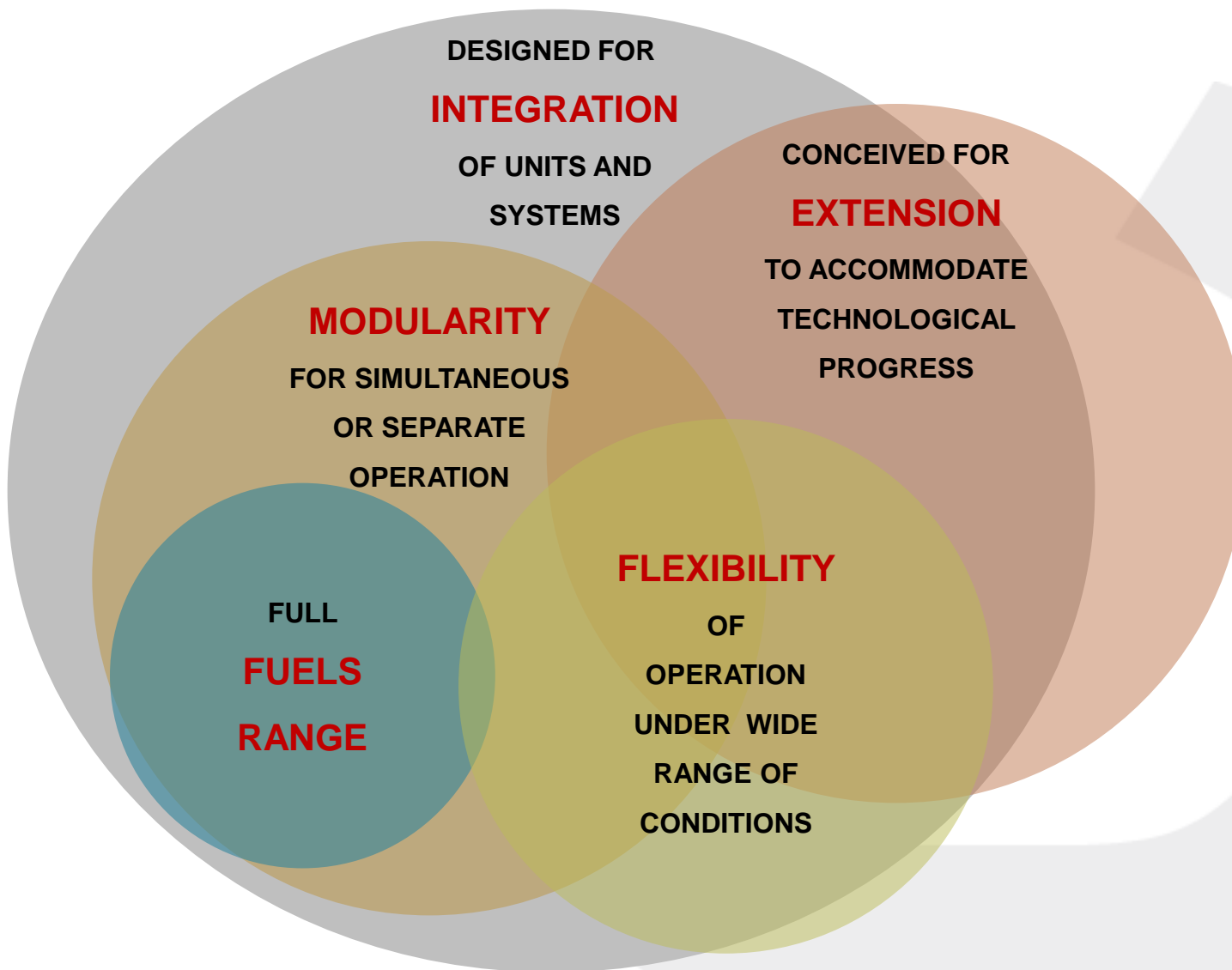
Fuels: anthracites, bituminous & subbituminous coals, pet coke, sustainable biomass







# Main characteristics





**LOCATION**

**El Bierzo,  
Leon  
NW Spain**

**CAPEX**

**Phase I  
100 M €**

**OPEX**

**8 M€/y**



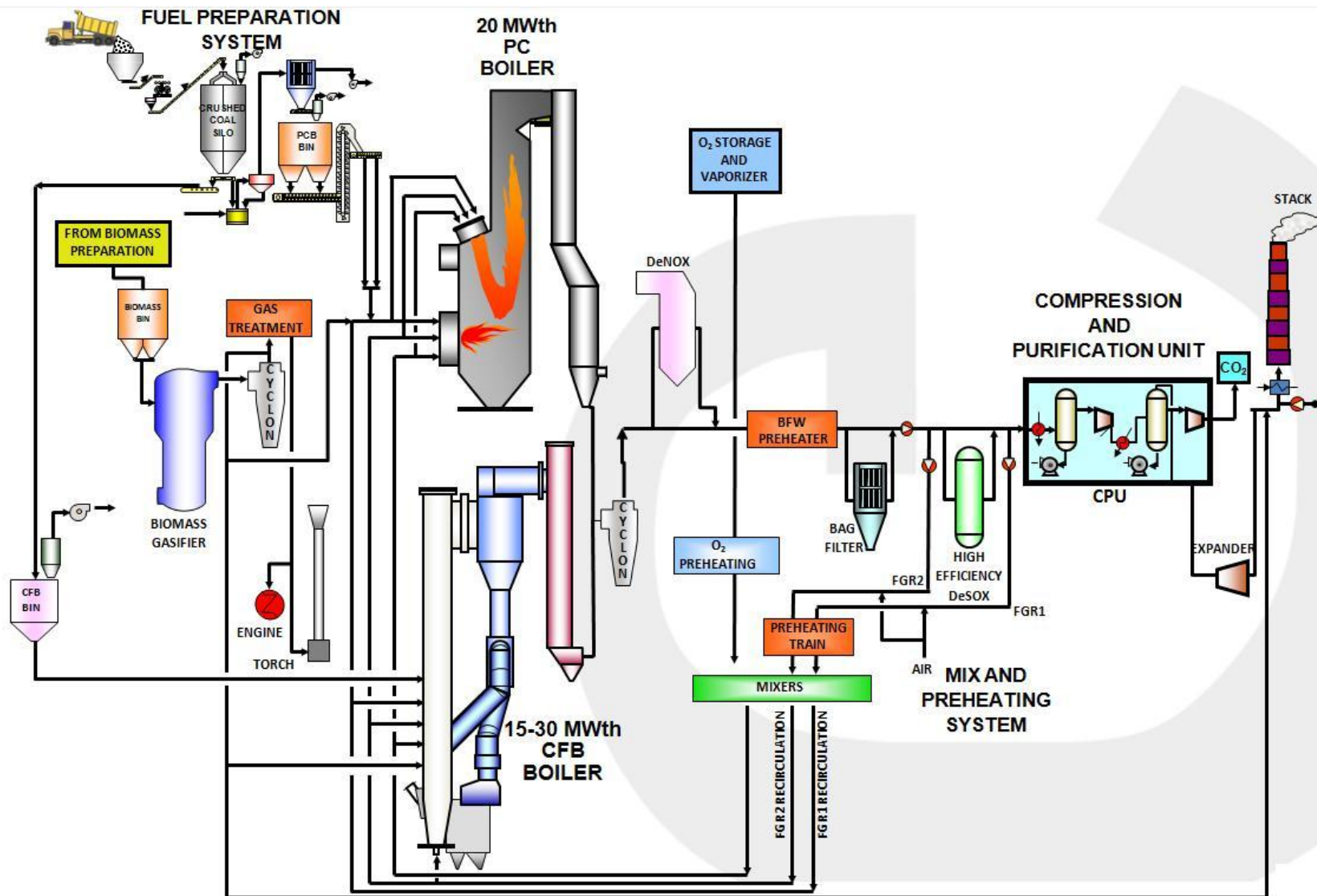
**Commissioning on going!**





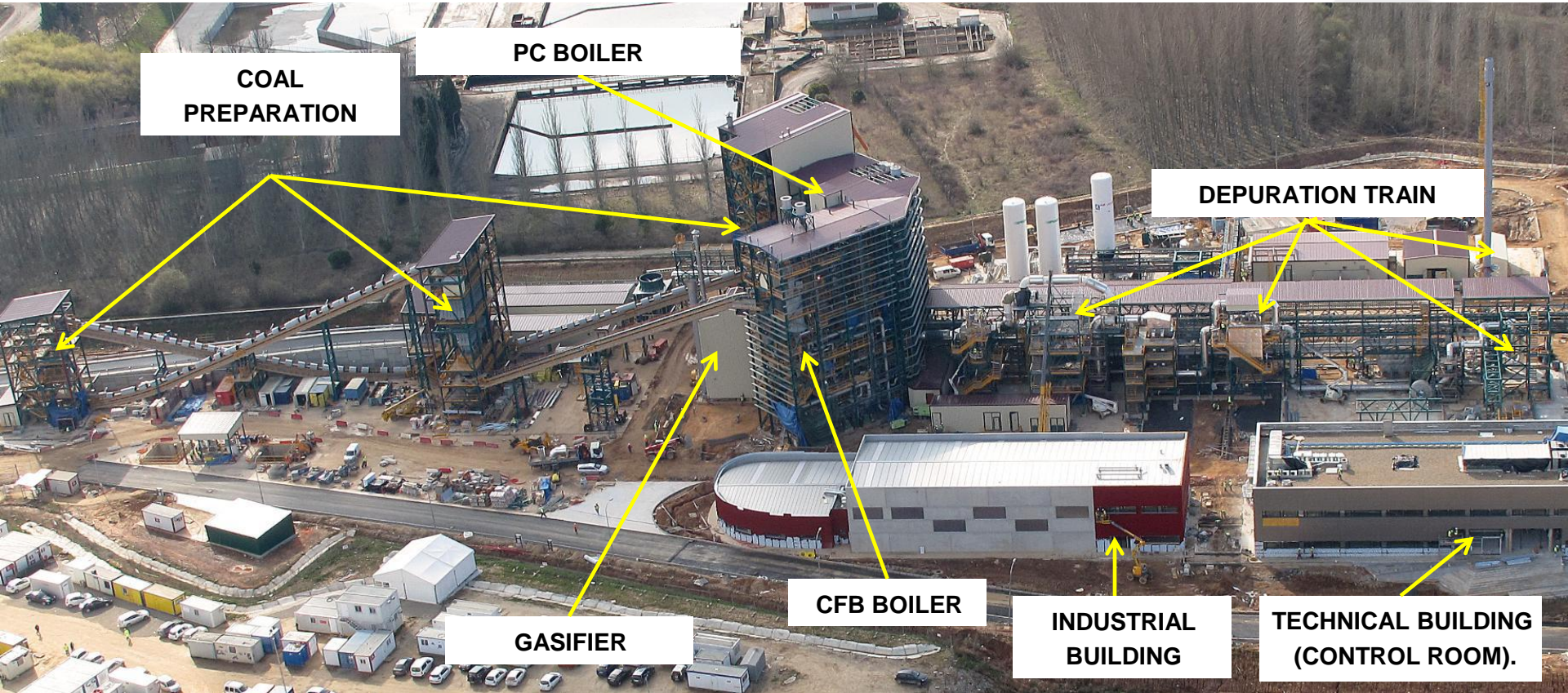
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# es.CO<sub>2</sub> Capture Centre: North bird's eye view





# es.CO<sub>2</sub> Capture Centre: Technical data summary



## FUEL PREPARATION UNIT

- Crusher: 15 t/h
- Crushed coal silos: 240 t
- Mill: 5 t/h

## PULVERIZED COAL BOILER (PDB)

- 20 MWt: 3,4 t/h pulverized coal
- 4 horizontal burners + 2 vertical burners
- Biomass co-combustion 25%
- Steam 30 bar & 420°C
- 6,6 t/h O<sub>2</sub>

## CIRCULATED FLUIDIZED BOILER (CFB)

- 30 MWt: 5,5 t/h crushed coal
- Biomass co-combustion
- De-SO<sub>x</sub>.
- Steam 30 bar & 250°C
- 8,8 t/h O<sub>2</sub>

## DEPURATION TRAIN

- Cyclon.
- DeNO<sub>x</sub> (SCR): < 40 ppmv NO<sub>x</sub>
- Filter: < 15 mg/Nm<sup>3</sup>
- DeSO<sub>x</sub> > 95%
- Flow rate of design: 23.215 Nm<sup>3</sup>/h

## COMPRESSION AND PURIFICATION UNIT

- Compressors.
- Dryers.
- Cold box, including elimination of inerts.

## UTILITIES

- O<sub>2</sub>: 10,6 t/h
- CO<sub>2</sub>: 3 t/h (inertización)
- Electric power: currently, 4 MVA; at most, 10 MVA
- Natural gas: 1.500 Nm<sup>3</sup>/h

## STAFF

- 16 R&D department.
- 20 Operation & Maintenance.
- 3 Administration.

## SITE AREA

65.000 m<sup>2</sup>

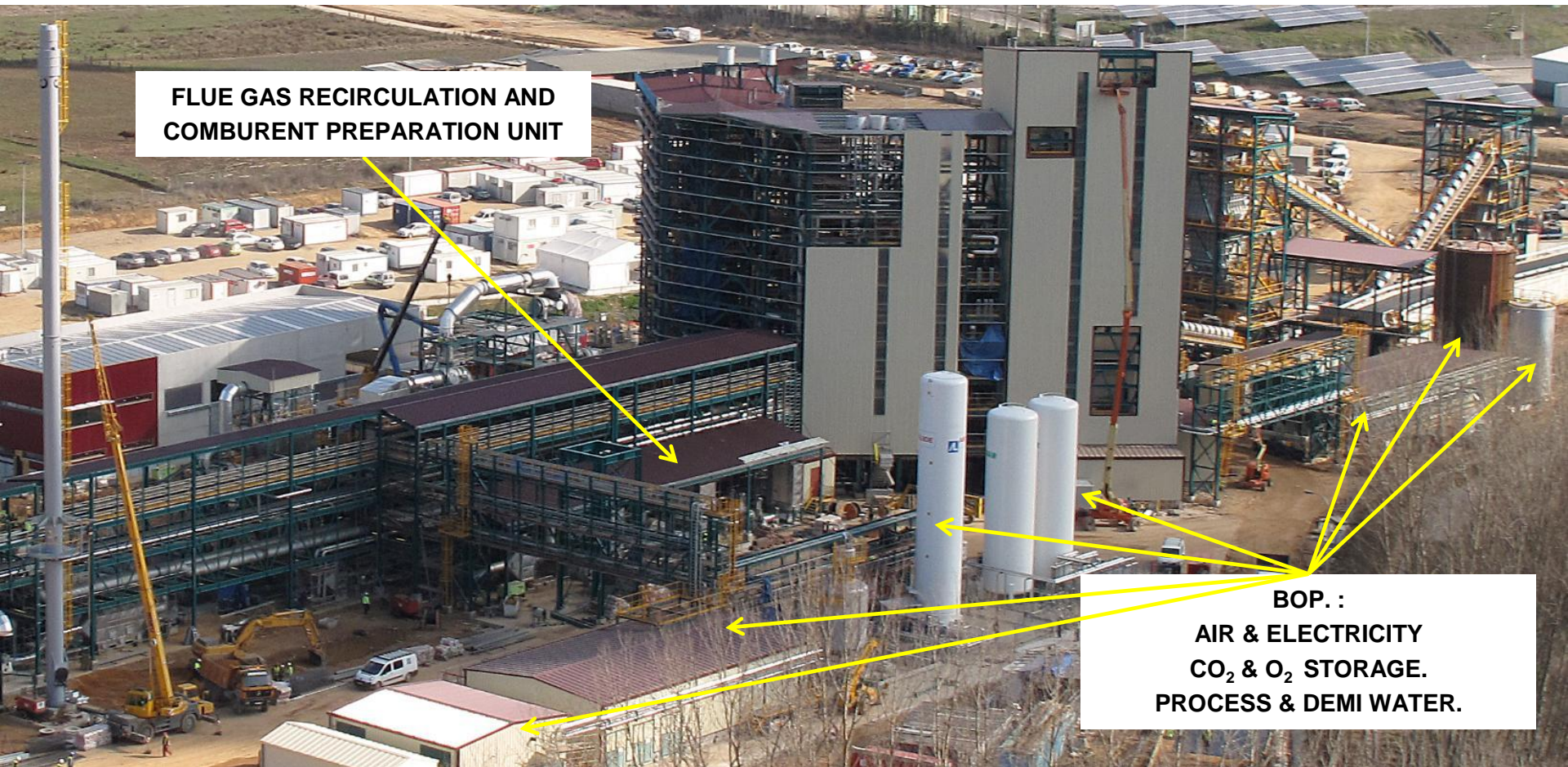
## BUILDINGS

- Technical: 3.500 m<sup>2</sup>
- Industrial: 1.300 m<sup>2</sup>





# es.CO<sub>2</sub> Capture Centre: South bird's eye view









# Fuel preparation system



<b>Size (m)</b>	24 x 7.6 x 4.5
<b>Burners</b>	4 horizontal burners 2 vertical burners Biomass feeding system
<b>MWth HHV max oxy mode</b>	20
<b>O<sub>2</sub> (kg/h)</b>	6600
<b>FGR (kg/h)</b>	17900
<b>Flue gas flow (kg/h)</b>	26400
<b>Coal flow rate (kg/h)</b>	3350
<b>Steam (t/h)</b>	25
<b>P(bar) / T ( C)</b>	30 / 420





# PC Boiler



# CFB Boiler

Furnace Dimensions (m)	20x2.9x1.7
MW <sub>th</sub> max oxycombustion	30
O <sub>2</sub> consumption (kg/h)	8775
Flue gas recycle (kg/h)	25532
Flue gas (kg/h)	28800
Coal consumption (kg/h)	5469
Limestone feed (kg/h)	720
Steam (t/h)	47.5
P(bar) / T ( C)	30 / 250







GOBIERNO  
DE ESPAÑA

energía  
ciudad  
de la

# CFB Boiler







# Flue gas cleaning

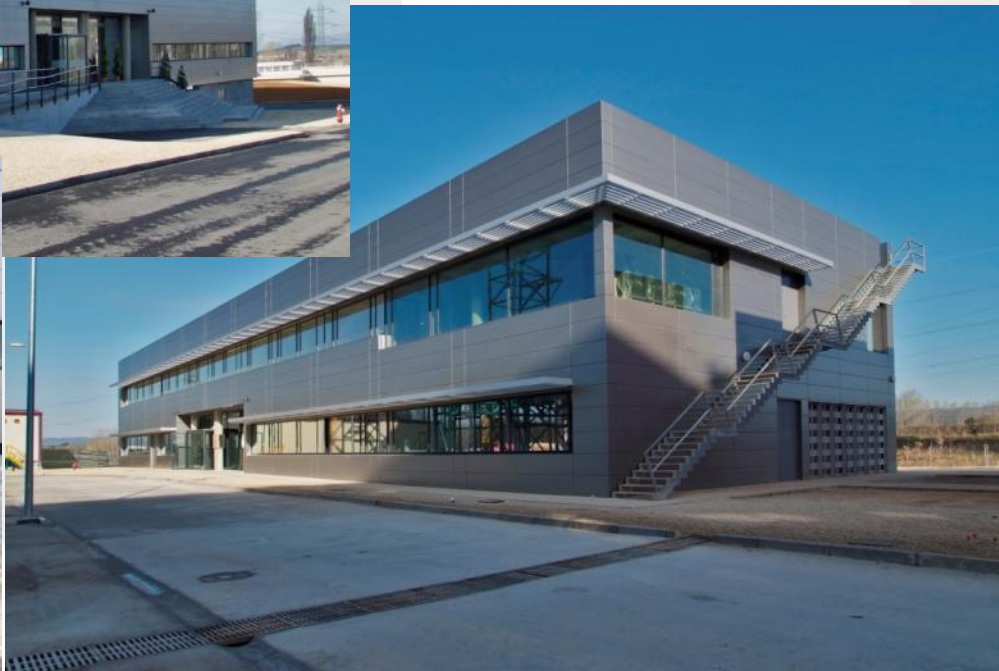


Technology	Bubbling fluidised bed
MW <sub>th</sub> max	3
Oxidant	Air
Biomass flow rate (t/d)	15
P(barg)	0,3
T ( C)	800
Efficiency ( cold gas basis)	98% (75%)
Footprint ( m <sup>2</sup> )	90





# Technical buildings







GOBIERNO DE ESPAÑA

energía  
ciudad de la

# Control Room





## 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,

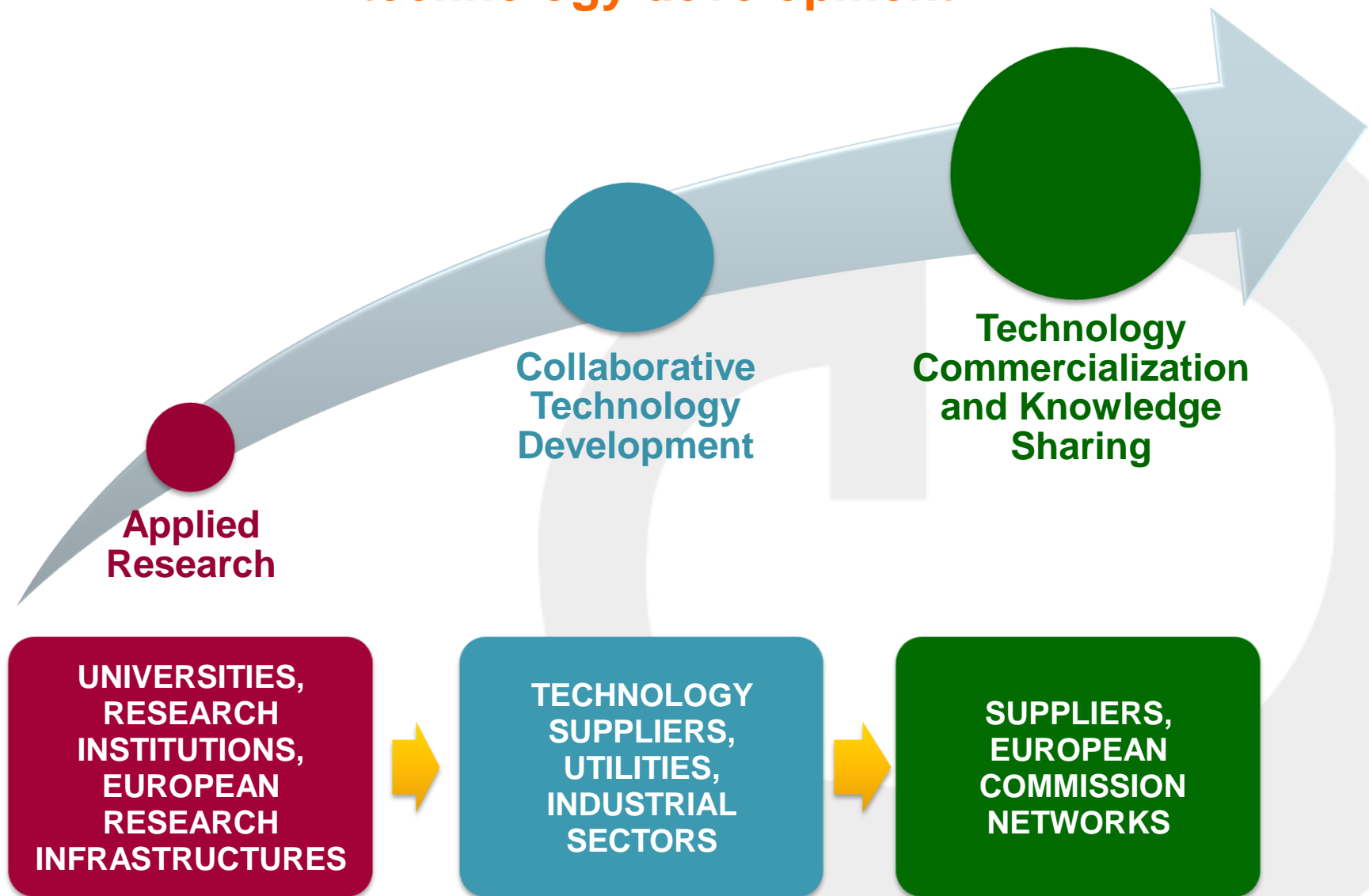




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# CIUDEN s vision for CCS technology development





-  **Target # 1: Validation and scaling-up of oxyPC, oxyCFB, FGD and CPU technologies**
-  **Target # 2 : Integration and optimization tests of the full process to produce a CO<sub>2</sub> stream ready for transport and storage**



## Objective

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

## Key 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<sub>2</sub> abatement

## Partners 14

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

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





## Objective

- **Technology development for CO<sub>2</sub> oxy capture, inland transport and storage in saline aquifers supporting FID of a demo 300 MW CCS oxyCFB PS**

## CIUDEN s Tasks

- **Integrated TDP for CO<sub>2</sub> 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**

## Partners 3

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

<http://www.compostillaproject.es/>





## Objective

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

## Key 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

## Partners 13

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





## Objective

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

## Key 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

## Partners 24

- Equipment and materials manufacturers, utilities and research institutions



## UNDER EVALUATION

### Objective

- Demonstrate the concept of the 2nd generation oxyfuel PS to reduce the efficiency penalty of CO<sub>2</sub> capture down to 5%

### Key Tasks

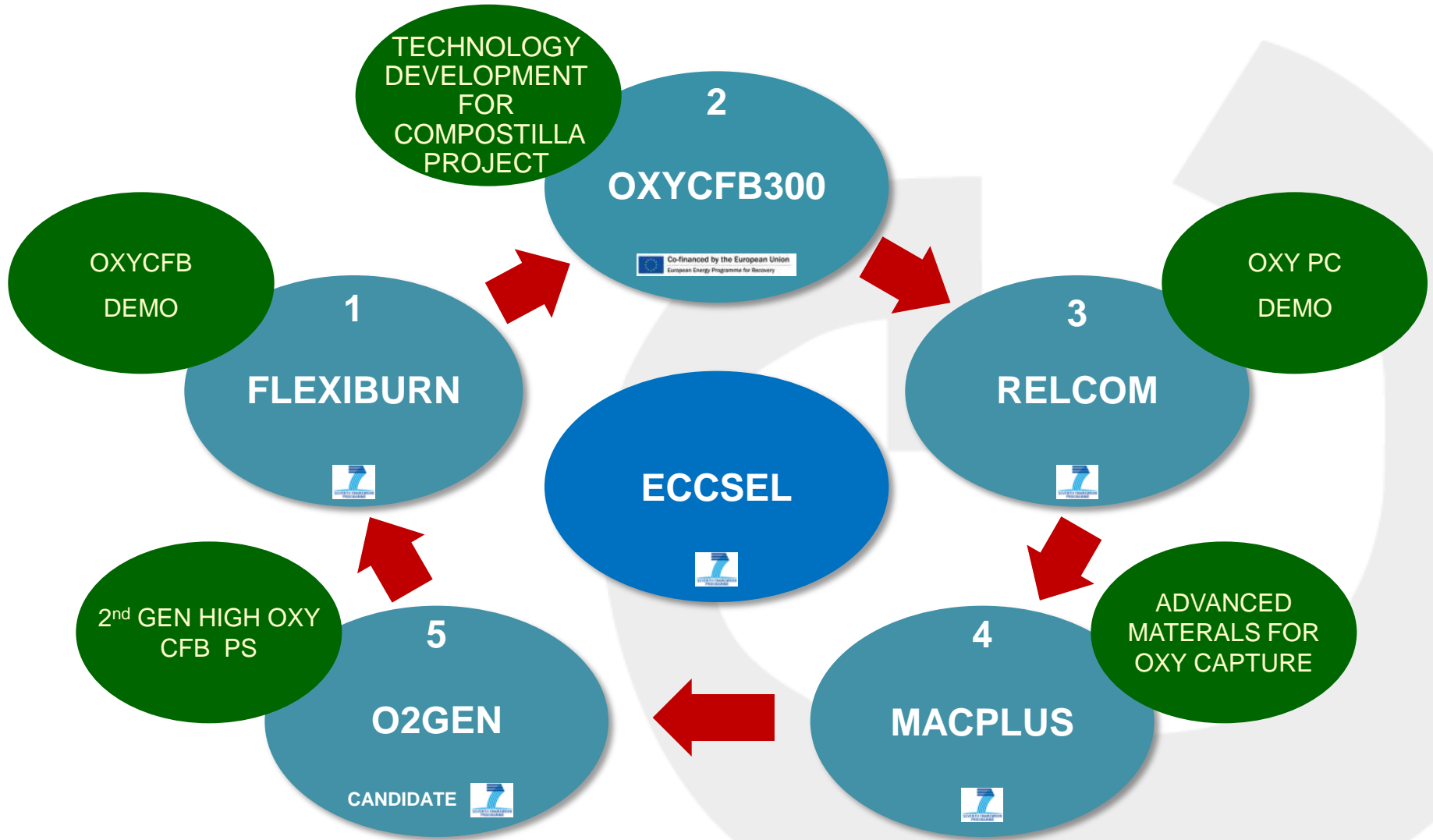
- Testing at high O<sub>2</sub> levels for optimum operating conditions
- Testing of suitable materials for boiler components
- CPU optimization to improve efficiency and operability with high oxyfuel flue gas

### Partners

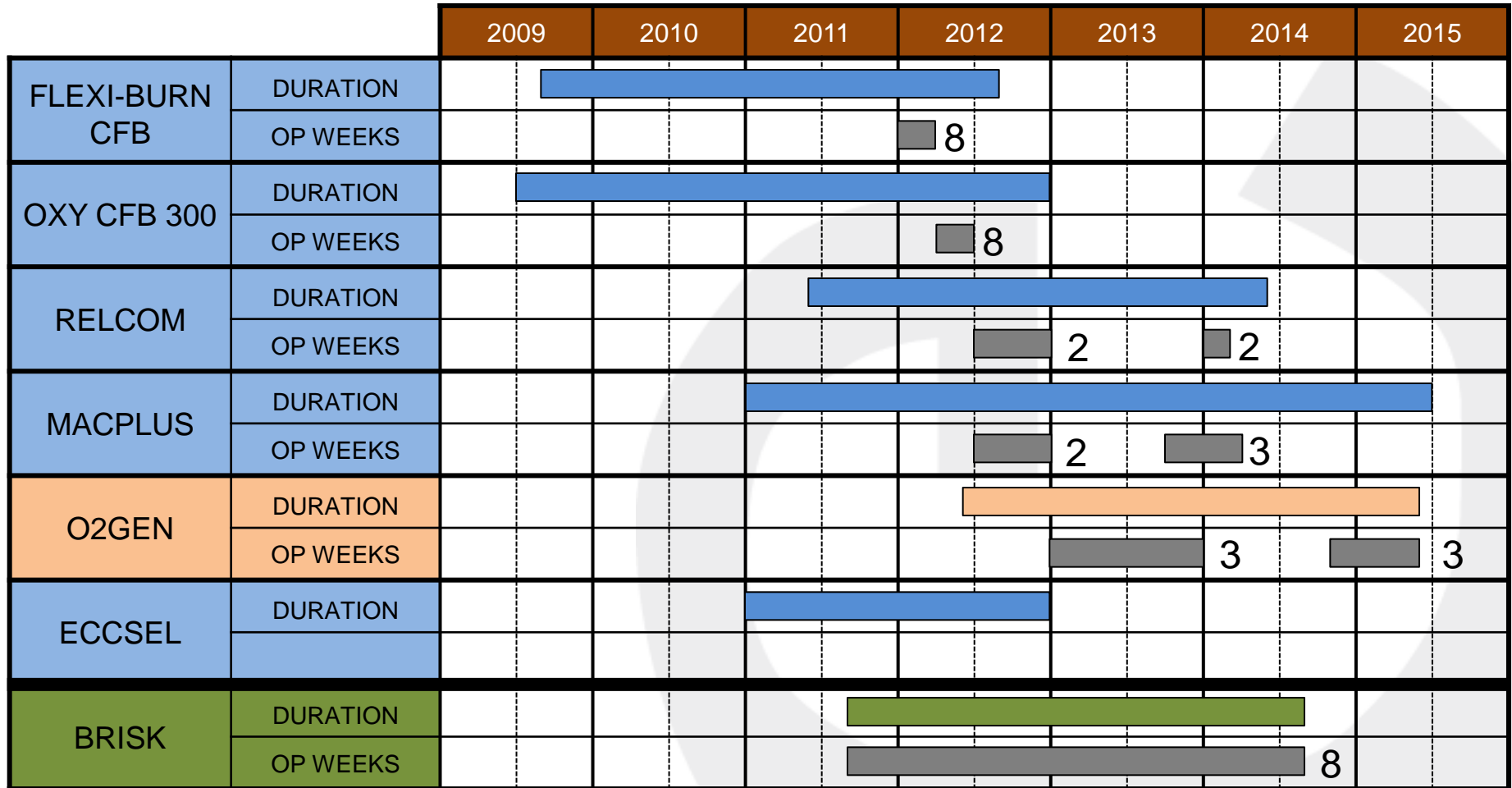
- Manufacturers, utilities and state of the art facilities
- Tasks focused on ASU, CFB and CPU



# The rationale for CIUDEN'S on-going R&D programme



# R&D Schedule



■ GRANTED  
■ NEGOTIATION  
■ Under evaluation

■ TEST CAMPAIGN





Related to currently available technologies at es.CO<sub>2</sub>

## HIGH O<sub>2</sub> OXYCOMBUSTION

- PF and CFB boiler testing for with increased O<sub>2</sub> concentration
- Combustion characteristics in high O<sub>2</sub> 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



## Based on 2<sup>nd</sup> Generation Technologies

**CHEMICAL LOOPING**

- Test at MWth scale of chemical looping applied to coal

**CO<sub>2</sub> PURITY**

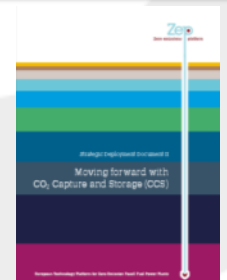
- Second generation CPU performance and impact of CO<sub>2</sub> quality on transport and storage behaviour
- Cost-efficient solutions to match applicable CO<sub>2</sub> standards

**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*





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## Semi-industrial size

- Results will be particularly valuable to scale-up.
- Easy to operate.

## Flexibility

- Process units designed to carry out testing campaigns.

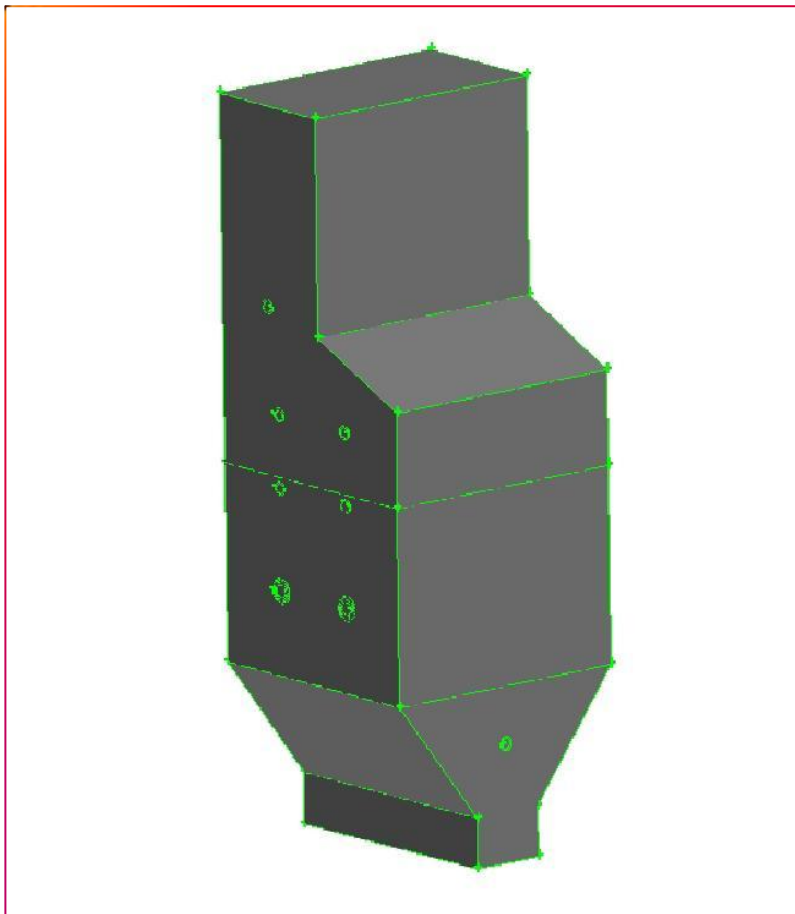
## Monitoring

- More points to measure process variables (compared with a commercial plant).
- Increase of possibilities for validation of model results.

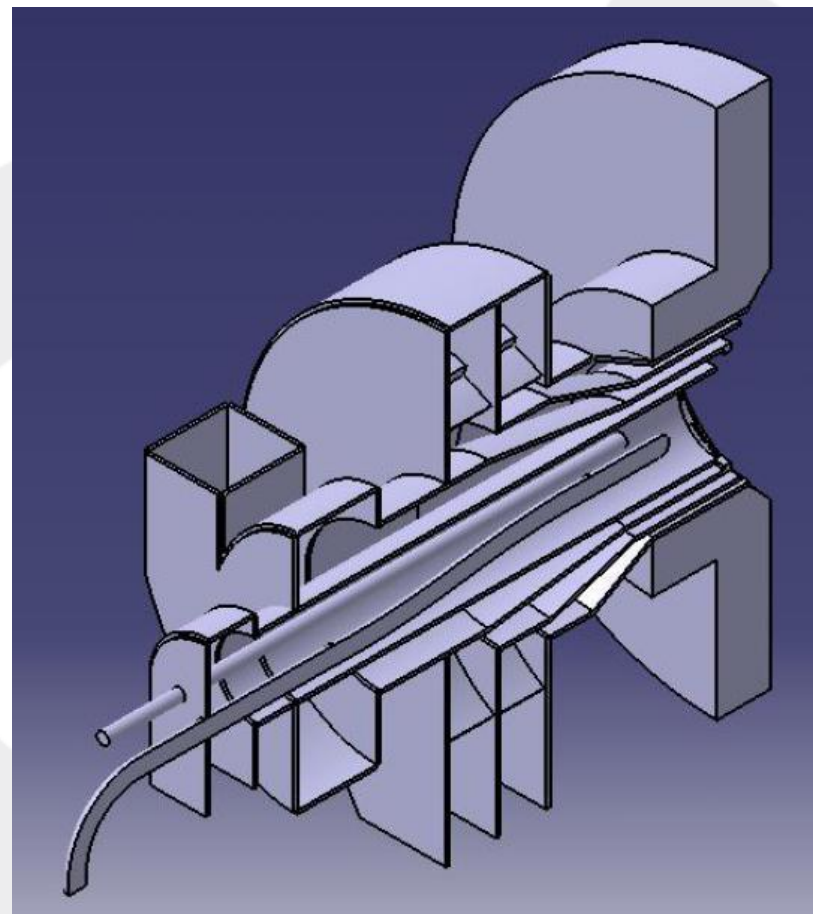




## PC BOILER

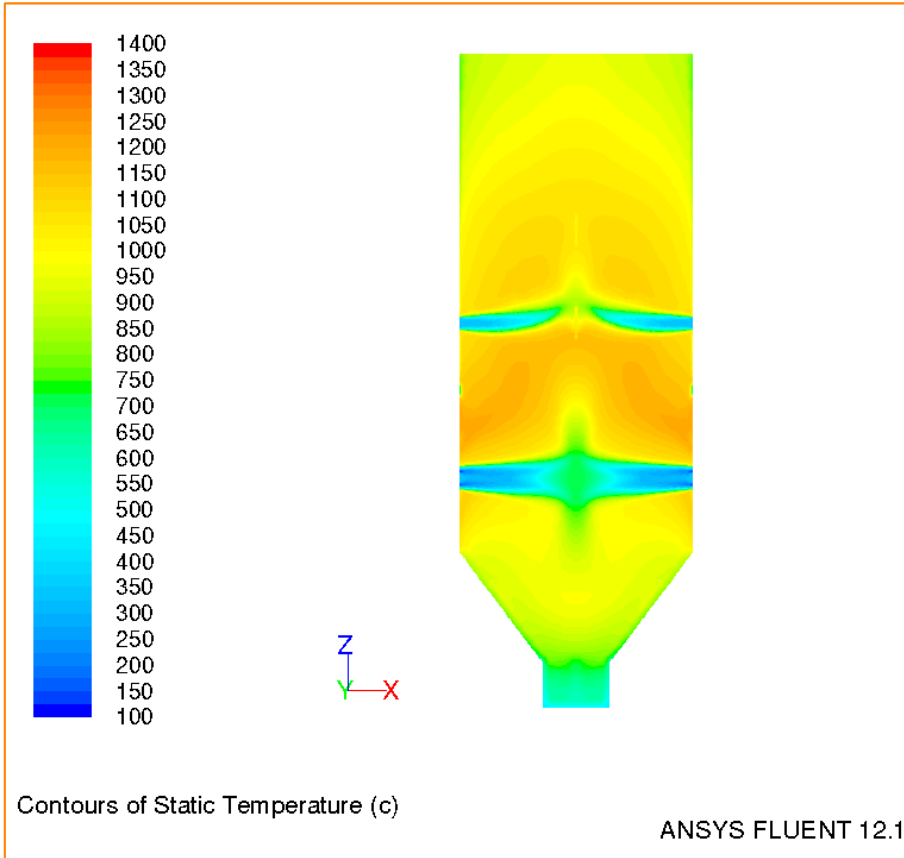


## BURNER

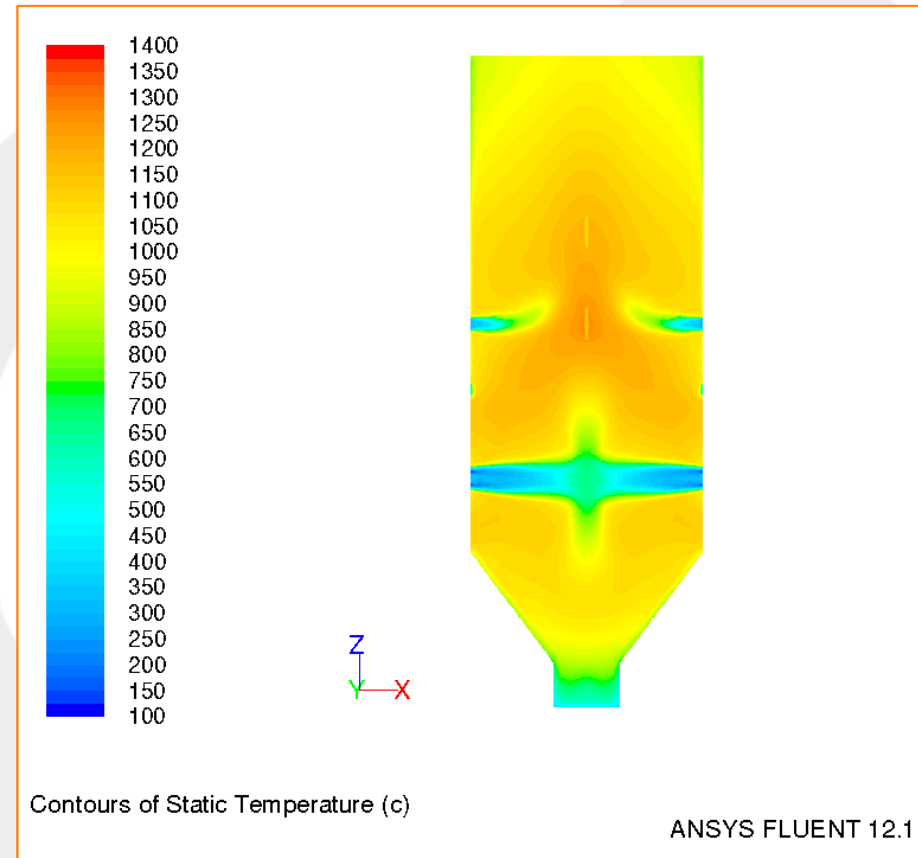


# PC Furnace Results (I): Temperature profiles

## AIR-mode

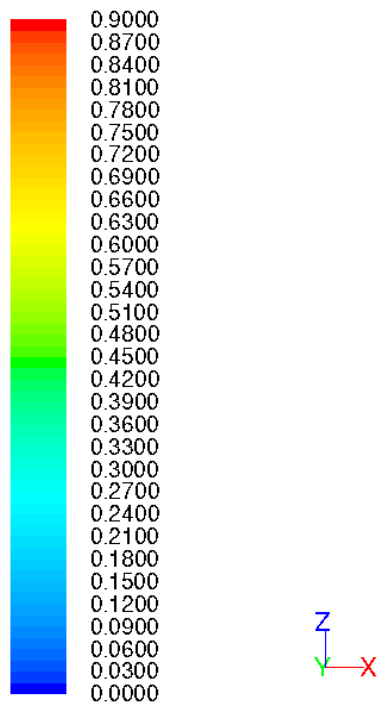


## OXY-mode



# PC Furnace Results (II): CO<sub>2</sub> concentration

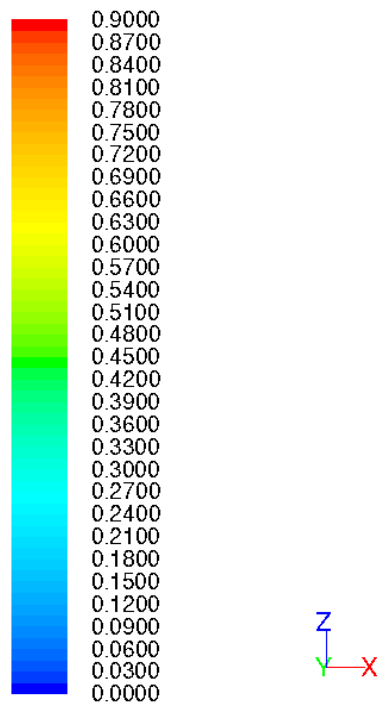
## AIR-mode



Contours of Mass fraction of co2

ANSYS FLUENT 12.1

## OXY-mode



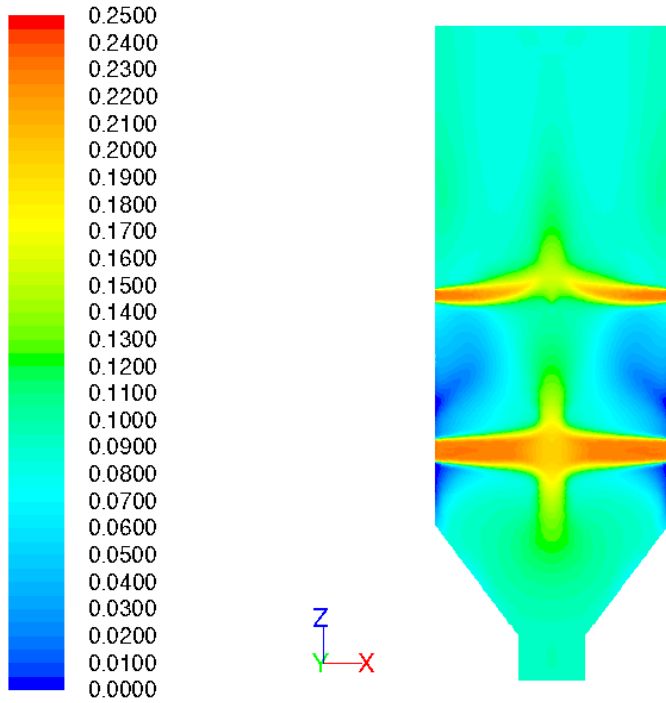
Contours of Mass fraction of co2

ANSYS FLUENT 12.1



# PC Furnace Results (III): O<sub>2</sub> concentration

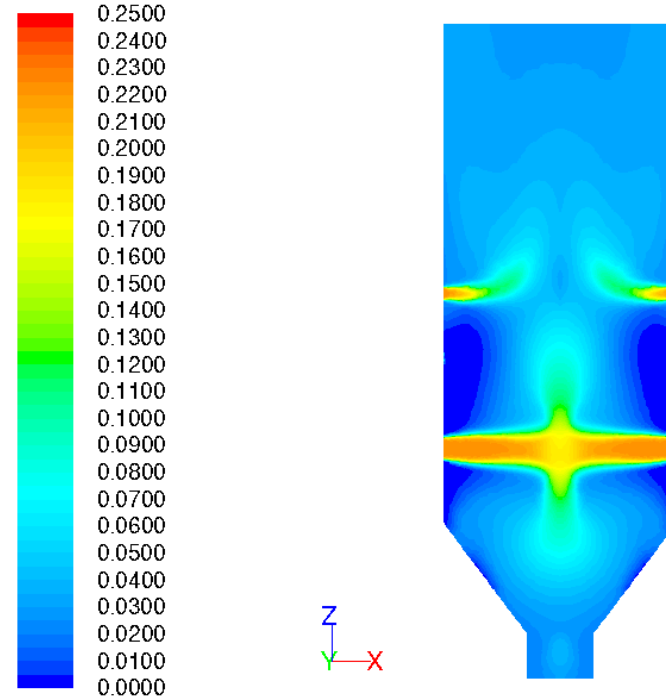
## AIR-mode



Contours of Mass fraction of o2

ANSYS FLUENT 12.1

## OXY-mode



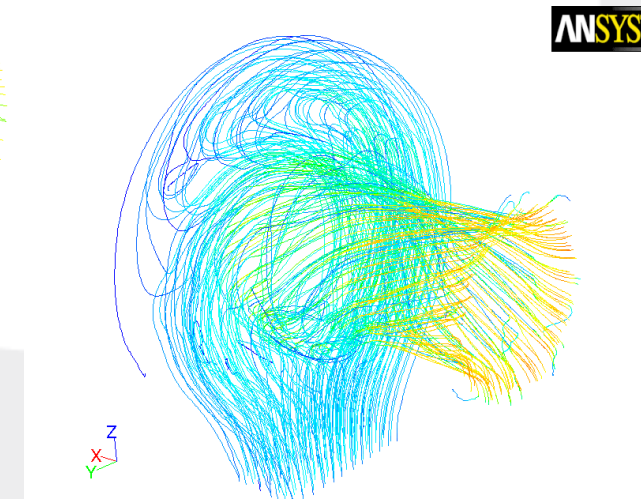
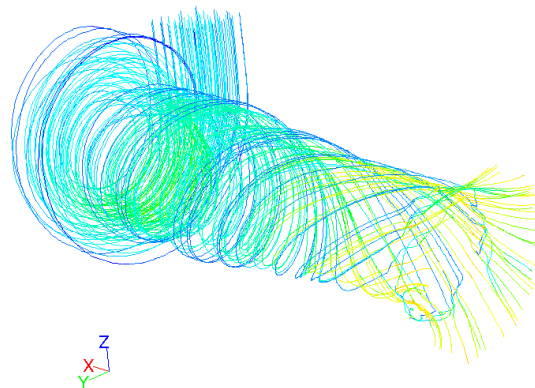
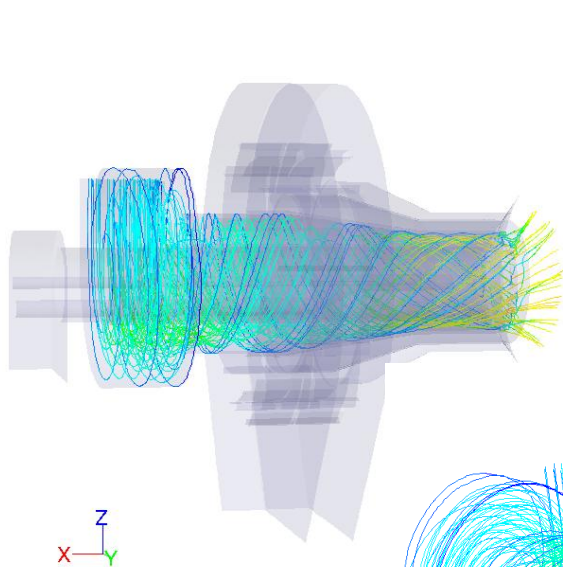
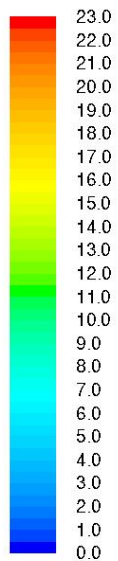
Contours of Mass fraction of o2

ANSYS FLUENT 12.1





# PC Burner Results (IV): Secondary oxidant







**Thanks for your attention**

