# Fundación Ciudad de la Energía (CIUDEN)

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Cranfield University

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GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO
ciudad de la energía

# CIUDEN – An initiative of the Spanish Administration

CIUDEN was created by the Spanish Government in 2006 as a R&D institution fully conceived for collaborative research in CCS and CCTs.

An initiative to strength to social, industrial and technological base in El Bierzo and by extension in Spain and Europe.

GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO

DEPARTMENT OF INDUSTRY, ENERGY AND TOURISM

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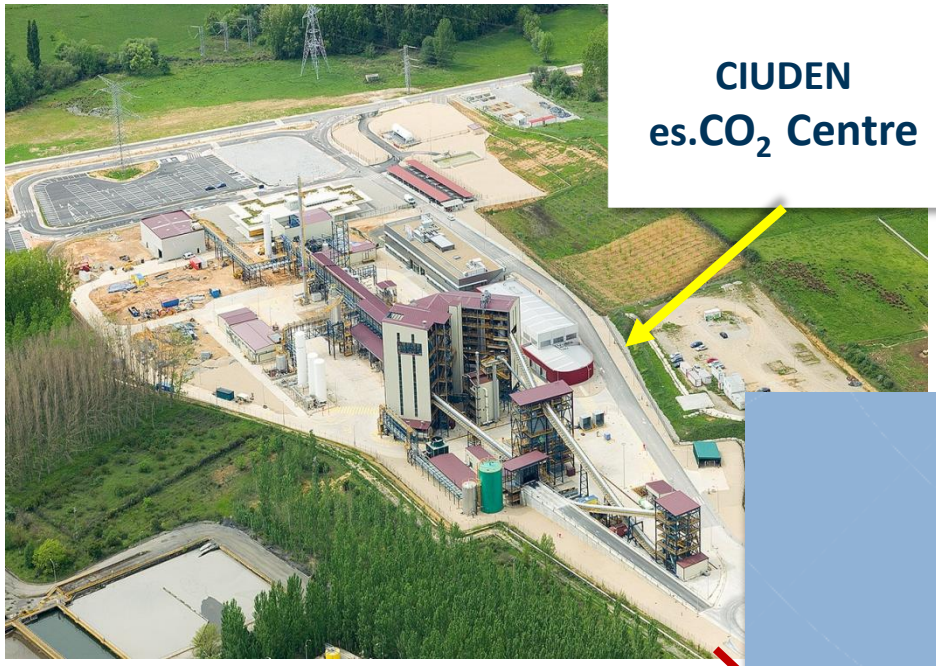
# CIUDEN – Focus on doing the doable

**Complete CCS**
**(capture, transport & storage)**

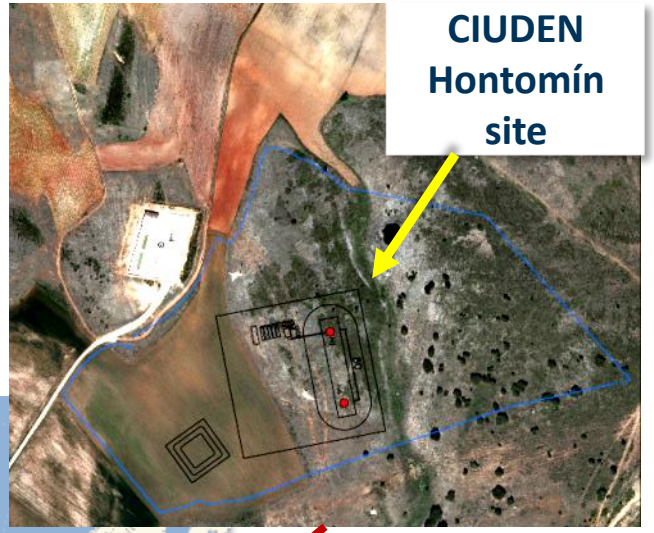
**Preindustrial size installations**

**Comprehensive technological development**

# CIUDEN´s Technology Development Centres for $CO_2$ Capture, Transport and Storage (es.$CO_2$)

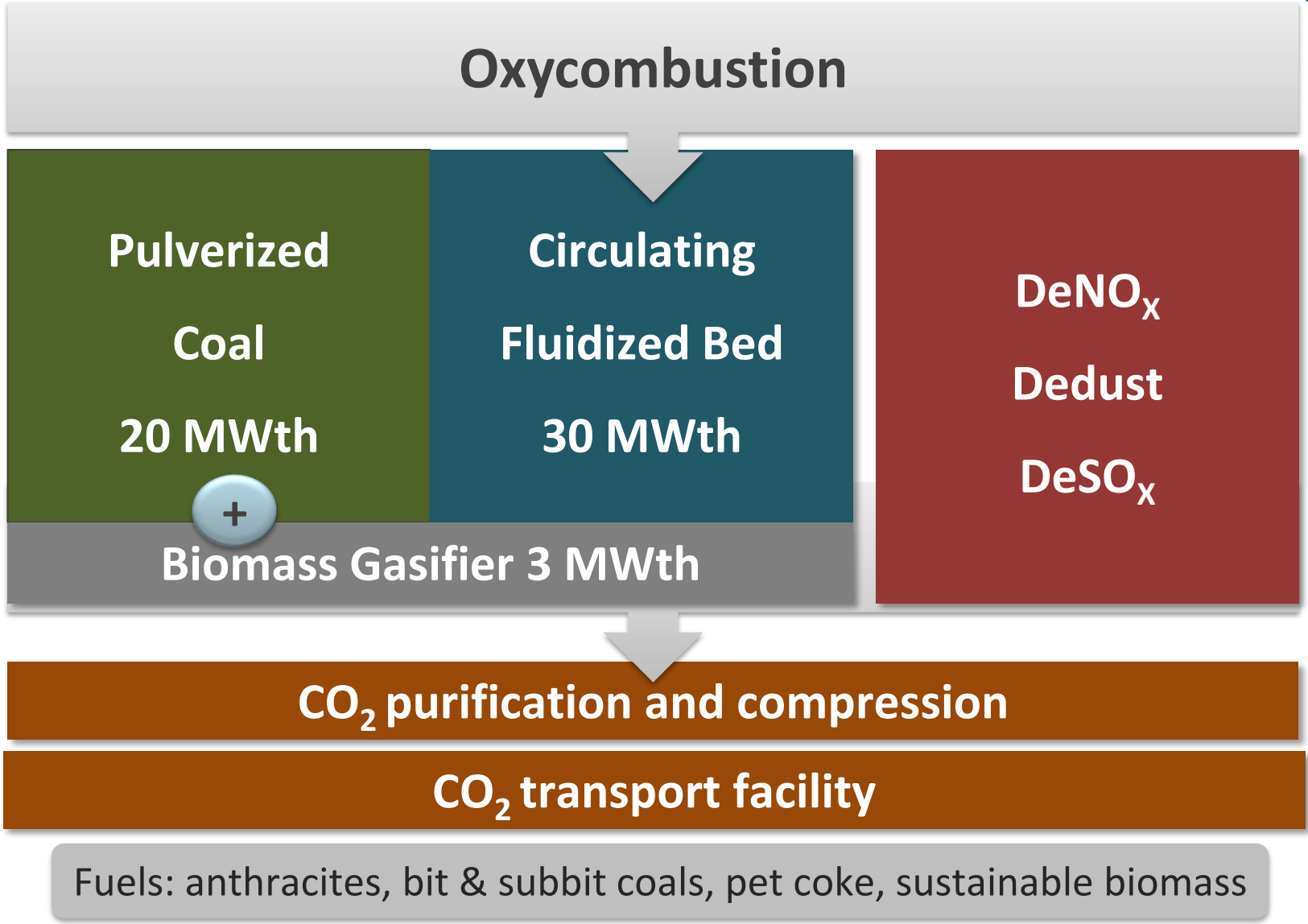


**CIUDEN es.$CO_2$ Centre**

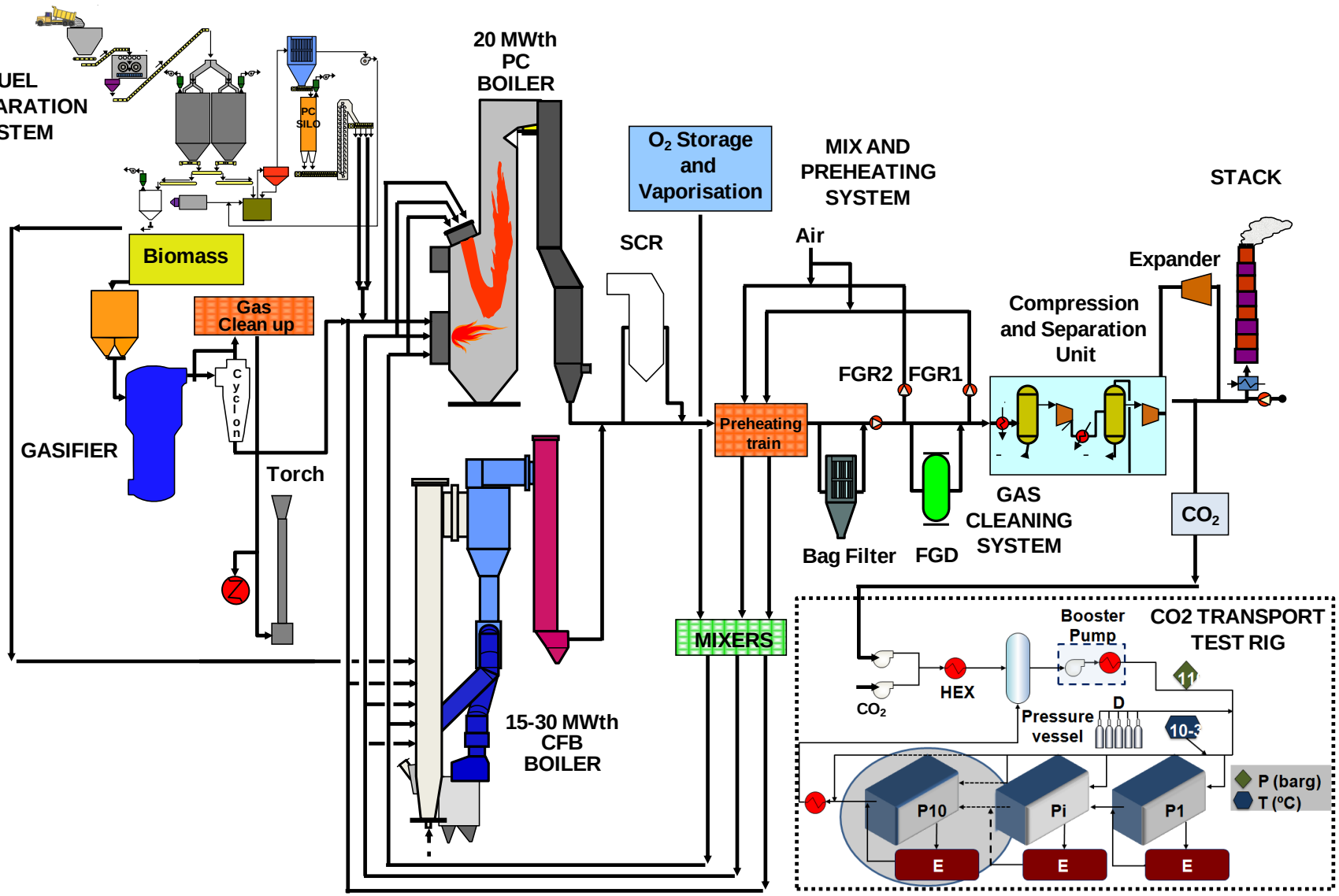


**CIUDEN Hontomín site**

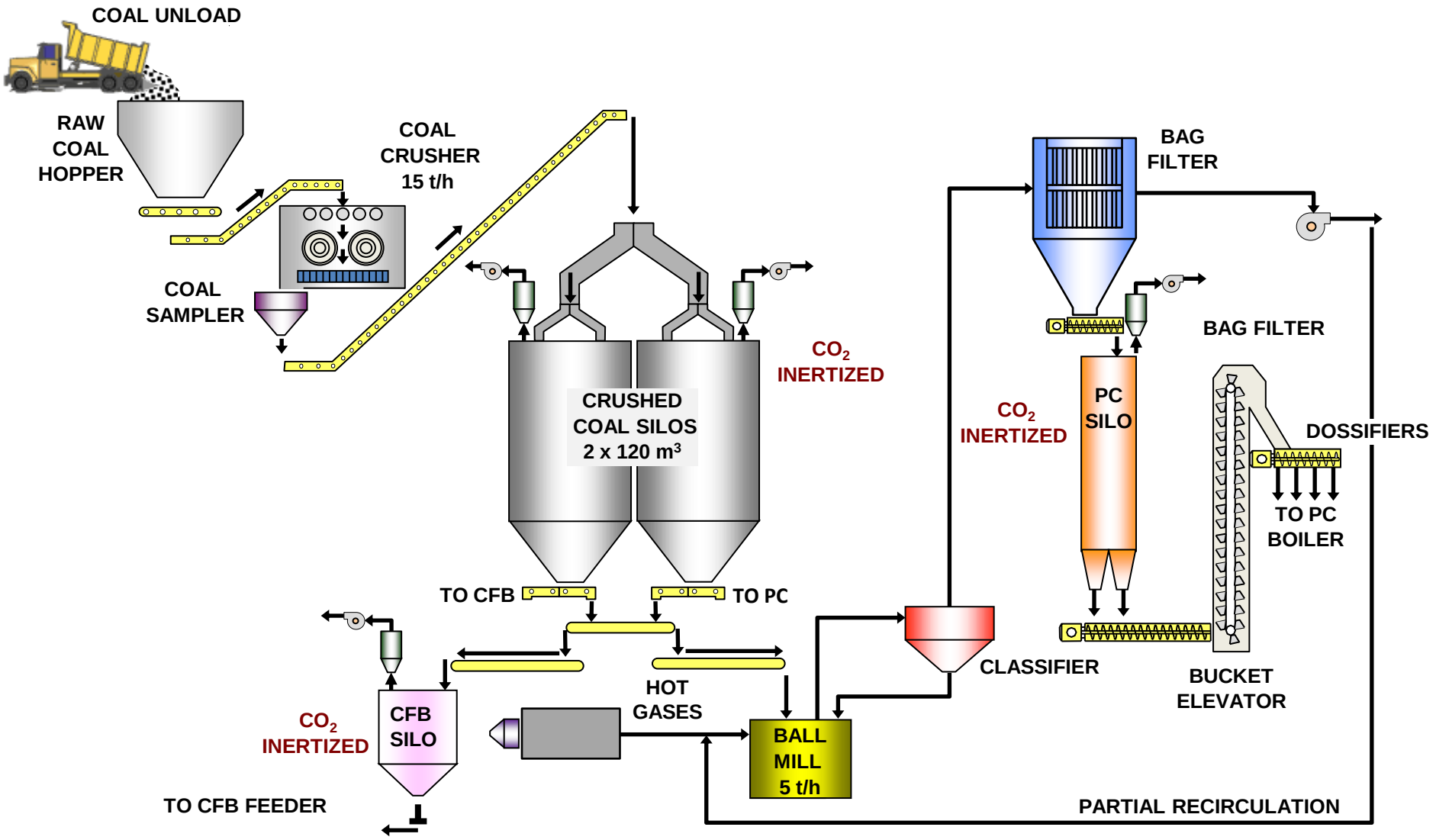
# es.$CO_2$ - Technical data



# es.$CO_2$ - Schematic diagram



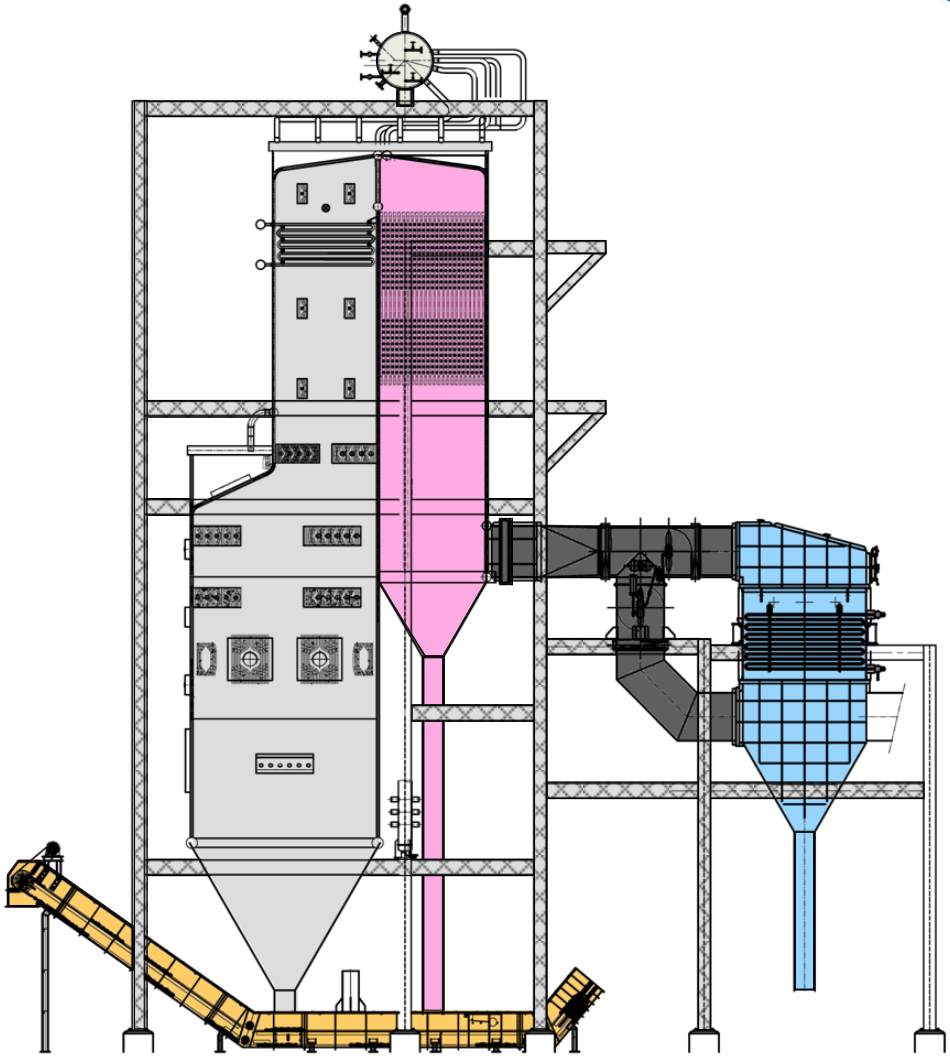
# Fuel preparation system



# Fuel preparation system

# Pulverised coal boiler (PC)

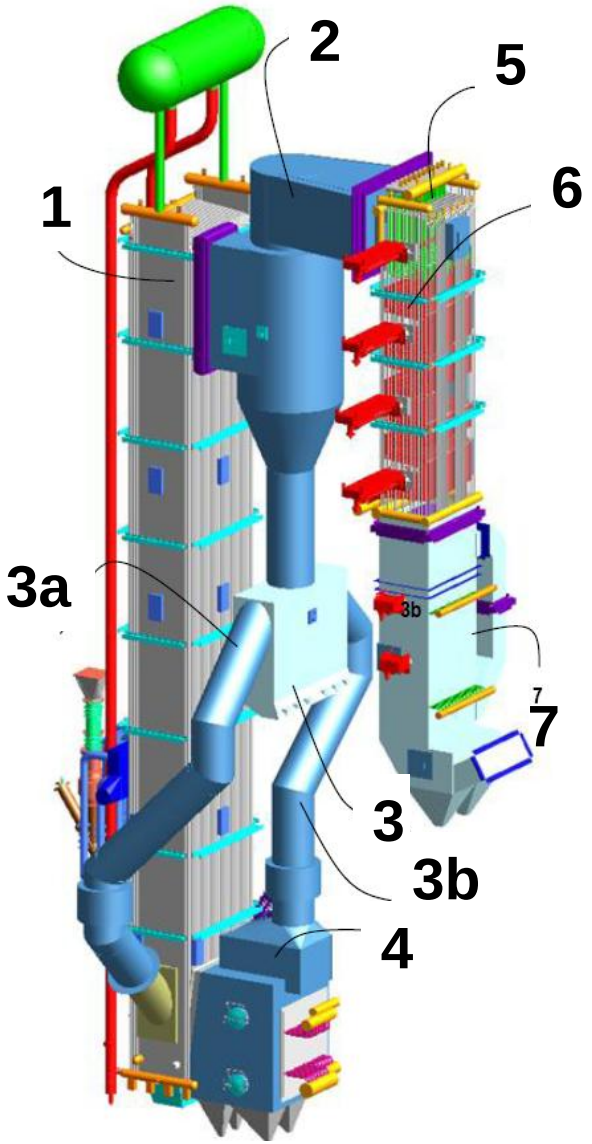
| | |
|---|---|
| **Size (m)** | 7,6x4,5x 24 |
| **Burners** | 4 horizontal + 2 vertical |
| **MWth HHV Max oxy mode** | 20 |
| **$O_2$ (kg/h)** | 6,600 |
| **FGR (kg/h)** | 17,900 |
| **Flue gas flow (kg/h)** | 26,400 |
| **Coal flow rate (kg/h)** | 3,350 |
| **Steam (t/h)** | 25 |
| **P(bar) / T (°C)** | 30 / 420 |



# Pulverised coal boiler (PC)

# Circulating fluidised boiler (CFB)

| | |
|---|---|
| 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 |

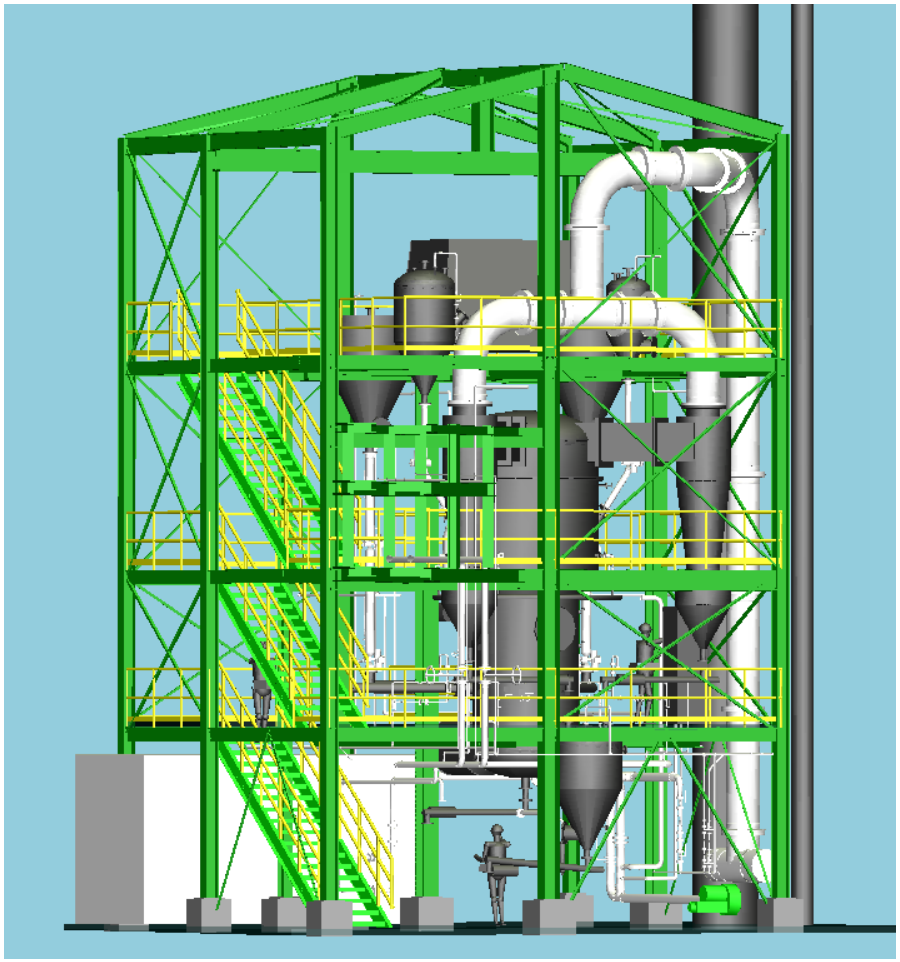



- (**1**) Water-wall furnace
- (**2**) Solid separator
- (**3**) Ash sealing-direction device
- (**3a**) Ash duct to the furnace
- (**3b**) Ash duct to the cooler
- (**4**) Furnace cooler
- (**5**) Heat recovery zone
- (**6**) Convective evaporator bank
- (**7**) Economizer

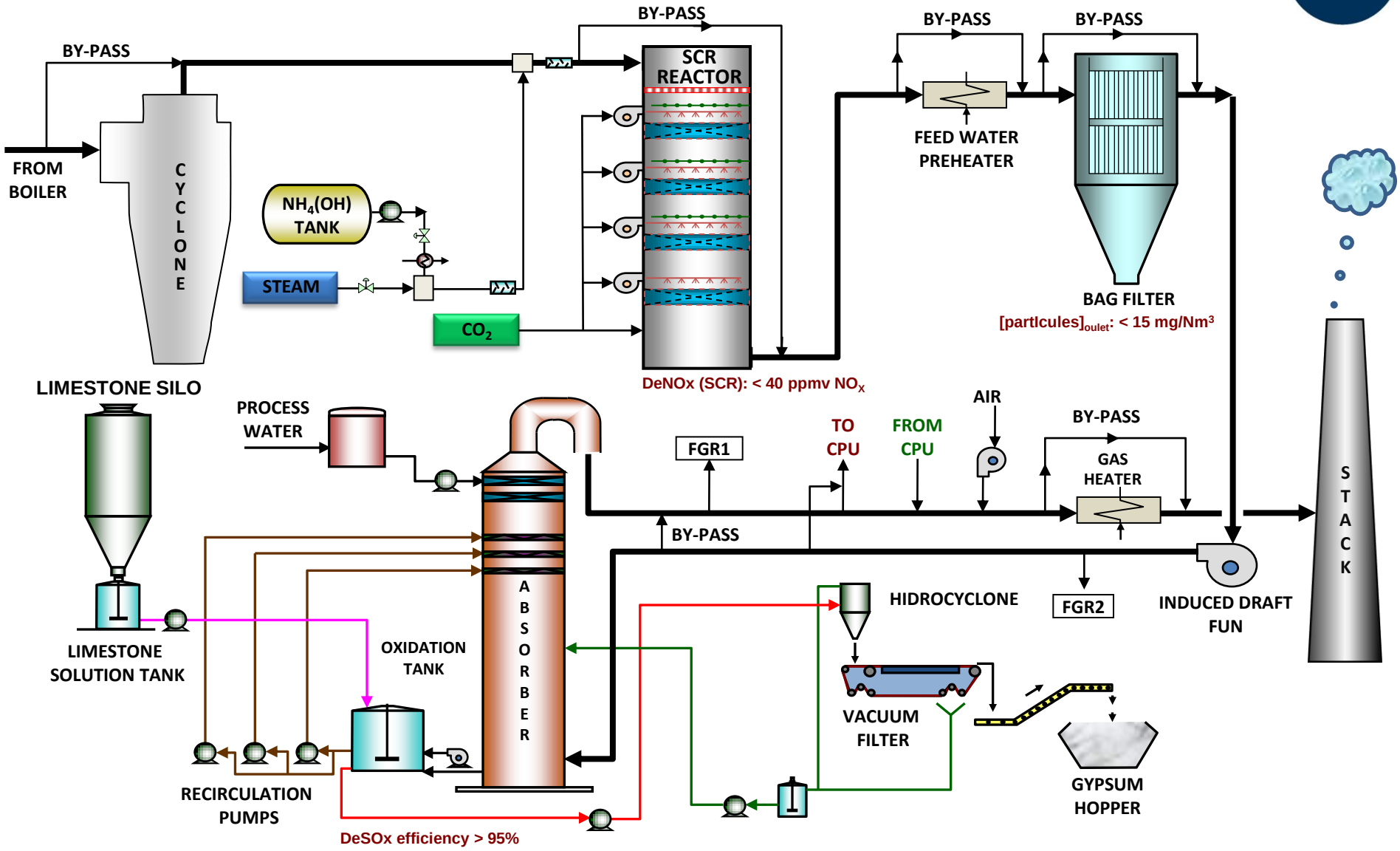
# Circulating fluidised boiler (CFB)

# Gasifier

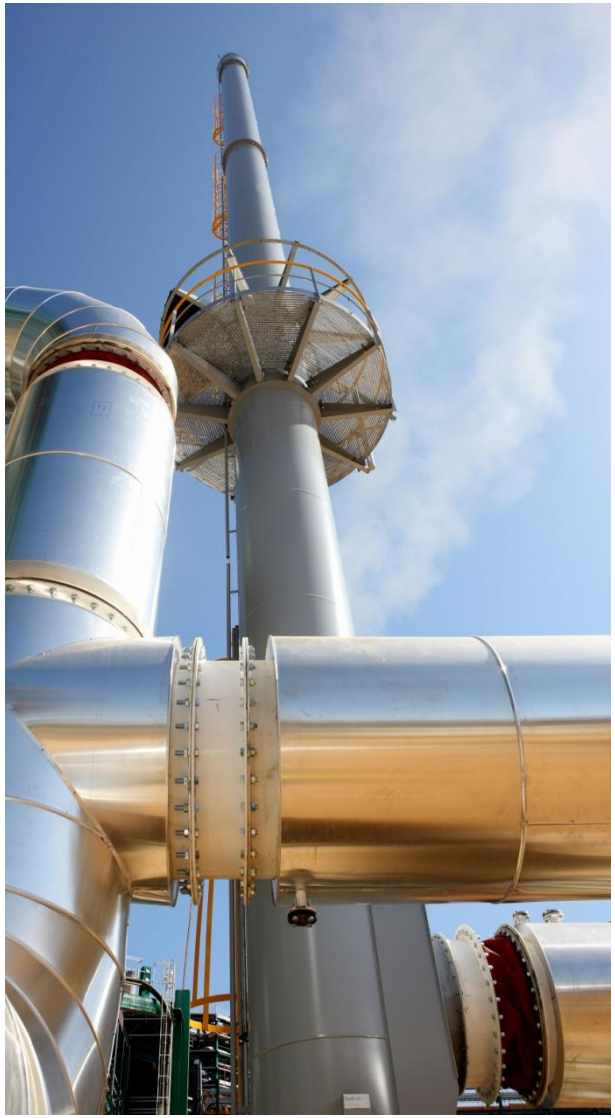
| Technology | Bubbling fluidised bed |
|---|---|
| $MW_{th}$ max | 3 |
| Oxidant | Air |
| Biomass flow rate (t/d) | 15 |
| P (barg) | 0,3 |
| T (°C) | 800 |
| Efficiency (cold gas basis) | 98% (75%) |
| Footprint ( $m^2$) | 90 |



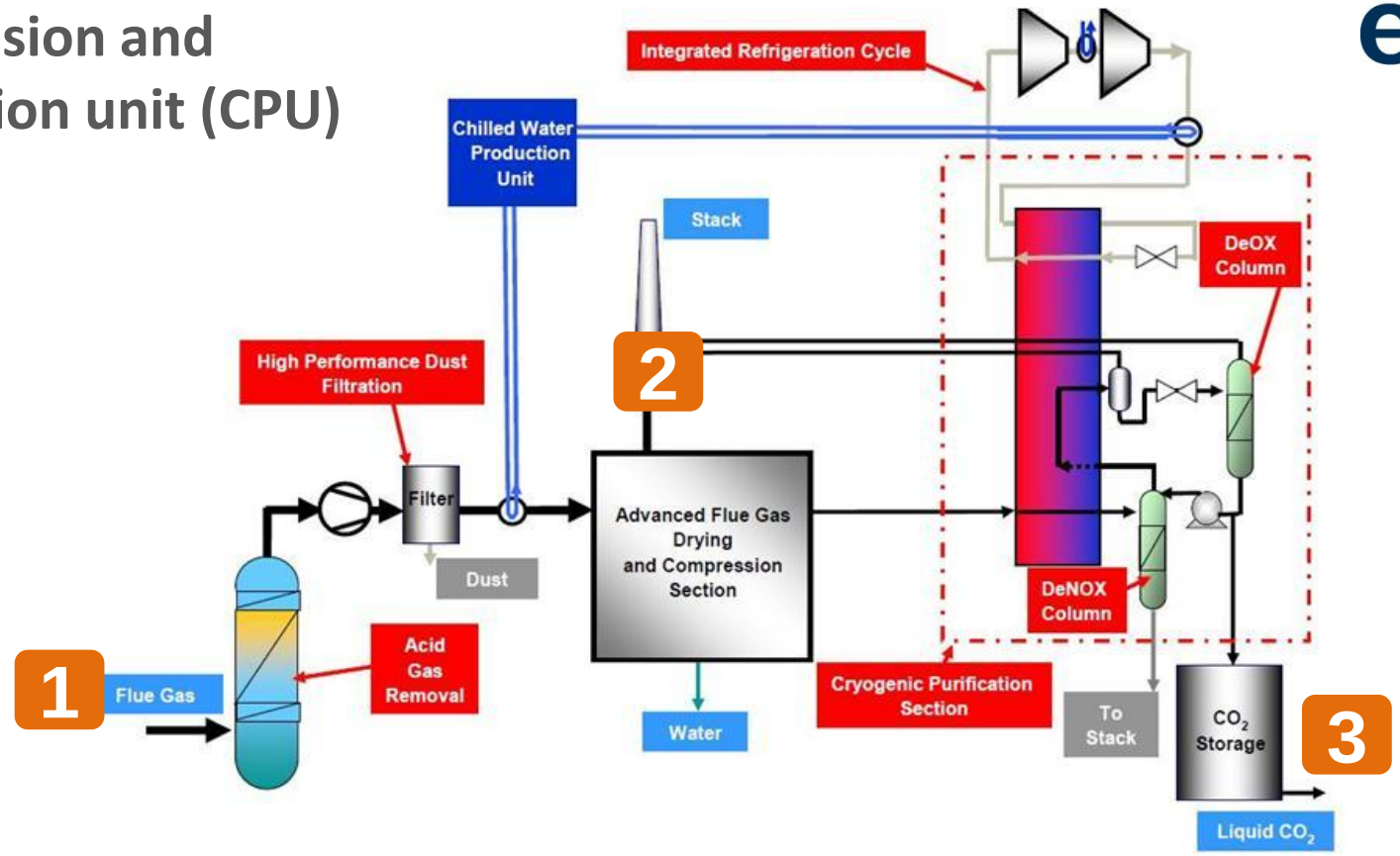
# Flue-gas cleaning



# Flue-gas cleaning



# Compression and purification unit (CPU)

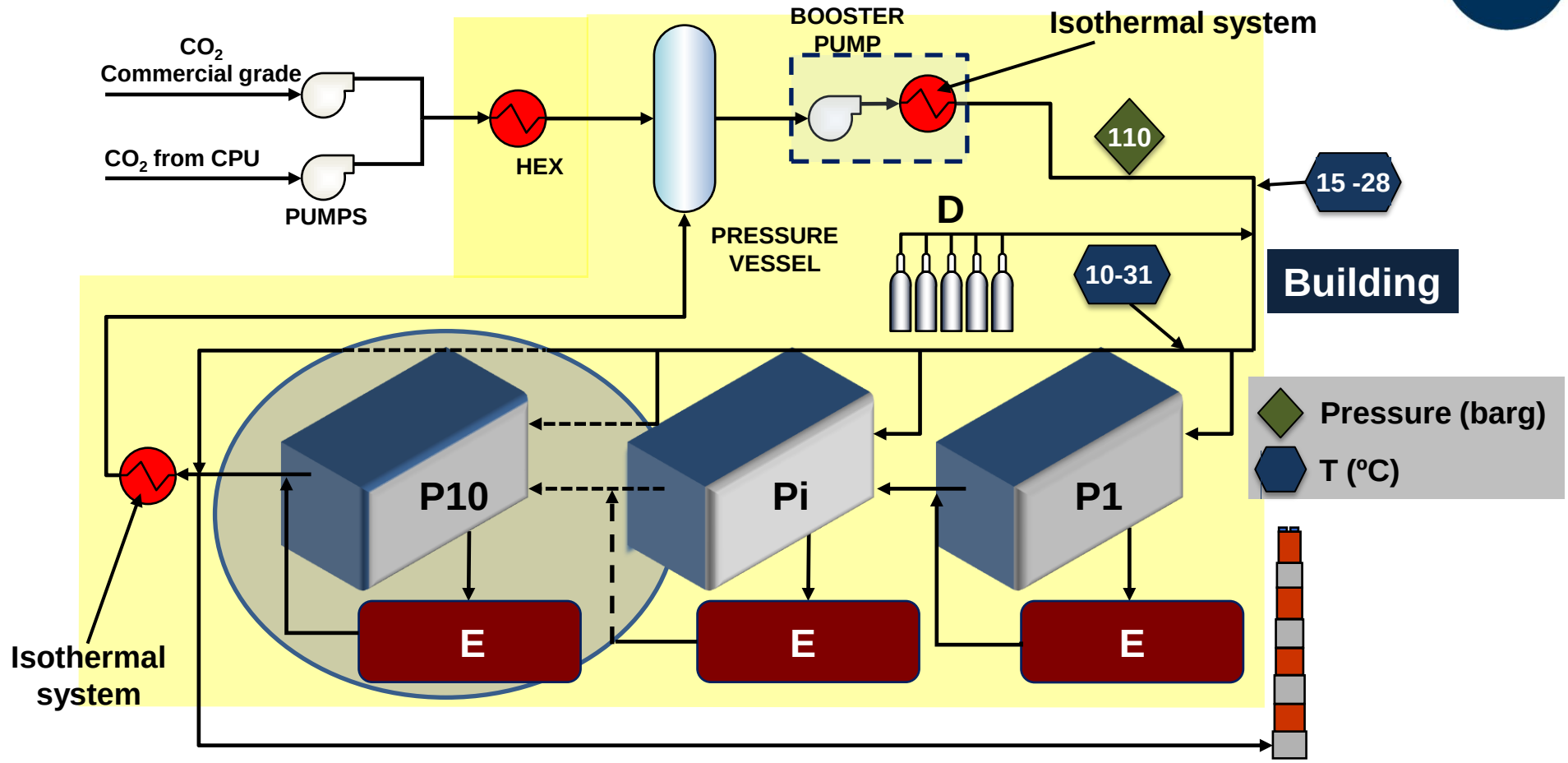



| | 1 Inlet flue gas | 2 $CO_2$ before cryogenics | 3 $CO_2$ captured |
|---|---|---|---|
| **Mass flow** | ≈ 8000 kg/h | ≈ 6800 kg/h | ≈ 420 kg/h |
| **Temperature** | ≈ 200 ºC | ≈ 32 ºC | ≈ -30 ºC |
| **Pressure** | ≈ 1 barg | ≈ 1 barg | ≈ 14 barg |
| **$CO_2$** | 70 % v w/b | 85 % v w/b | 99% v |
| **$H_2O$** | 15 % v | < 1 ppmv | < 1 ppmv |
| **$SO_2$** | 500 ppmv | < 1 ppmv | < 1 ppmv |
| **$NO_x$** | ≈ 50 ppmv | ≈ 50 ppmv | < 10 ppmv |
| **Non-condensable (%v)** | Rest | Rest | Rest |

# Compression and purification unit (CPU)

- Inlet Flow rate: 4,500 $Nm^3/h$
- $CO_2$ captured: 11 t/d
- Purity of CO2 captured: ≥99%

# $CO_2$ Transport experimental facility




| Transport loop, P | |
|---|---|
| Number of tube coils | 10 |
| $L_{eq}$, m | 300 |
| $Ø_{nom, in}$ | 2” |

| Doping Area, D |
|---|
| $SO_x$, $NO_x$ |
| $H_2O$, CO |
| $N_2$, $O_2$, Ar |

| Experimentation zones, E | |
|---|---|
| Number | 6 |

# $CO_2$ Transport experimental facility

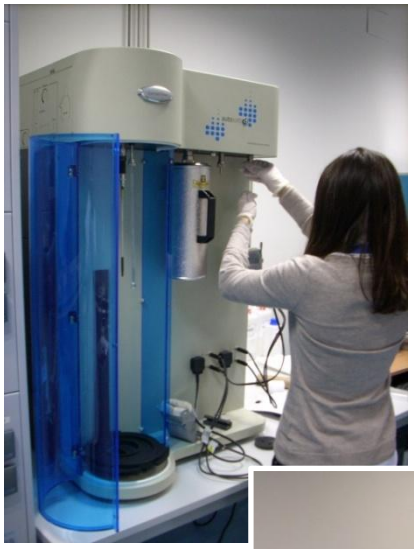
| | |
|---|---|
| **Operating P (barg)** | 80 - 110 |
| **Operating T (ºC)** | 10 / 31 |
| **Pipeline size (inch)** | 2 |
| **Total pipeline length (m)** | 3,000 |
| **Recirculation Pump ($m^3/h$)** | 15 (Gear pump) |
| **High Pressure Vessel ($m^3$)** | 4.5 |
| **Pressure Drop (bar)** | 30 |
| **Building ($m^3$)** | 23x18x8.5 |
| **Pipe material** | CS (2 tube coils SS) |

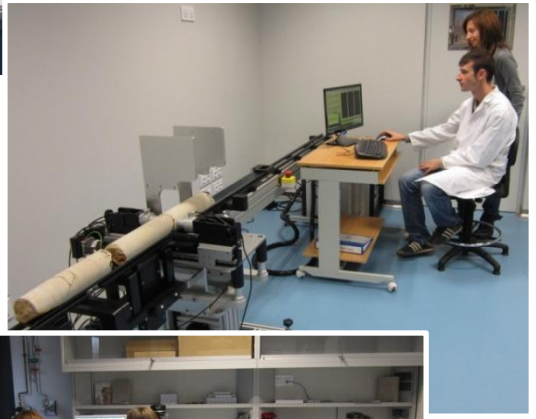
# $CO_2$ Transport experimental facility

- $CO_2$ from CPU or commercial $CO_2$ doped with trace elements (**simulating any CCS composition**)
- **3,000 meters** piping length & **2”** pipe diameter
- Operating pressure **80 bar to 110 bar**
- Operating temperature **10°C to 31°C**
- Doping of **$SO_x$, $NO_x$, $H_2O$, CO, $H_2S$, $H_2$, $CH_4$, $N_2$, $O_2$, Ar**
- **6 experimental areas** for depressurization, leakage, fracture, instrumentation, material corrosion and pressure drop

# es.$CO_2$ - CCS laboratory

- **Petrophysical and petrographic** characterization of reservoir and seal rocks
- **Water and gas analysis**
- Research on **durability and reactivity** of materials
- **Coal characterization**
- **Control of** capture plant **process parameters**





# es.$CO_2$ - Control room and operation


# es.$CO_2$ – October 2012
# CFB Oxycombustion $CO_2$ capture for the first time with the CPU unit

- **3000 h operation**
- **Good performance**
- **High purity $CO_2$ (>99%)**

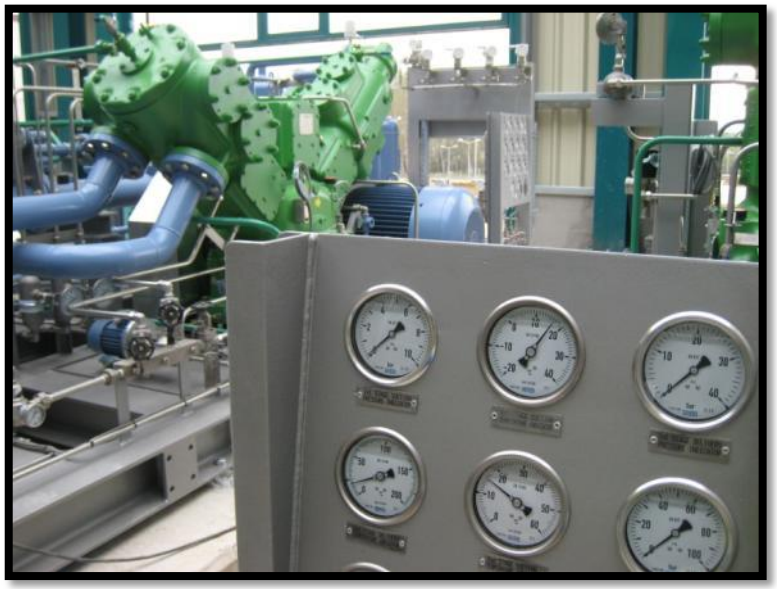
carbon capture journal

**CIUDEN completes oxyfuel CFB carbon capture test**
**Capture, Oct 07 2012 (Carbon Capture Journal)**

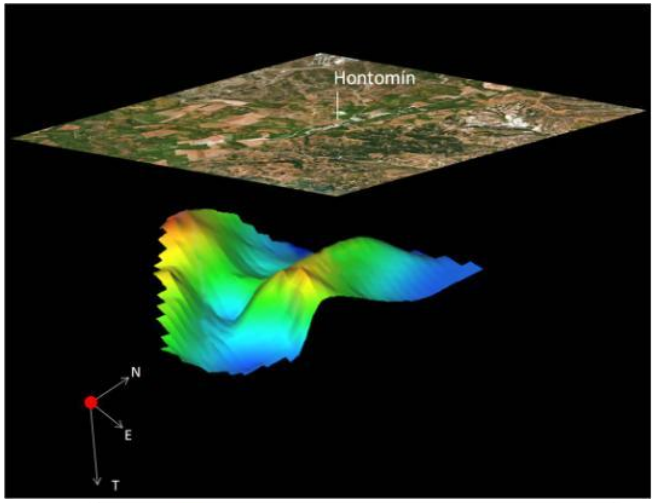
*- For the first time in the world CO2 has been captured using oxycombustion in circulating fluidized bed (CFB) technology, said CIUDEN.*

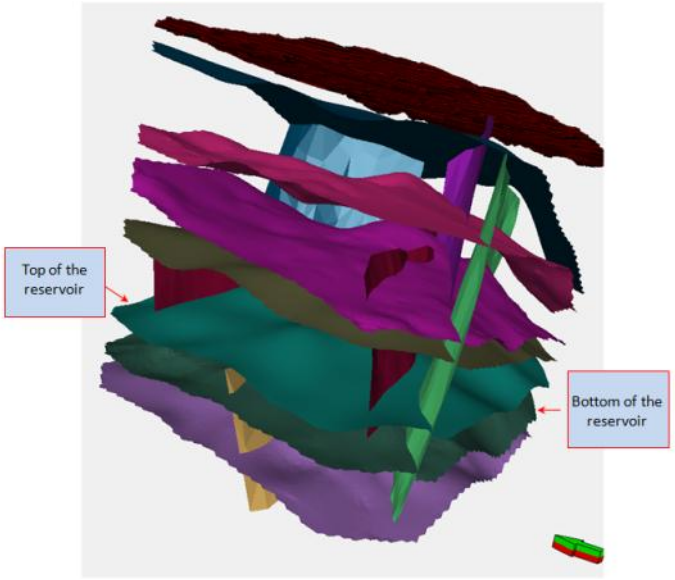
The Fundación Ciudad de la Energía (CIUDEN) has successfully completed the full CO2 capture process using oxycombustion in a circulating fluidized bed (CFB) boiler provided by Foster Wheeler at its es.CO2 pilot facility in Spain.

es.CO2 has now become one the world's most outstanding references on CCS, said CIUDEN, and this now opens up a promising line of application of these technologies on a commercial scale, strengthening R&D in areas of industrial interest and generating knowledge.



# CIUDEN´s objectives related to onshore geological storage of $CO_2$ in deep saline aquifers (SA)




- To demonstrate its feasibility and safety
- To develop methodologies and technologies
- To facilitate technical criteria for Regulating Authority
- To increase scientific knowledge through R&D programmes

To achieve these objectives
A **real scale Technological Development Plant**
is **required**

The location fulfils the internationally established geological criteria for installations of this kind and it follows the guidelines suggested by ZEP*.

** Accelerating the demonstration of $CO_2$ geological storage in Europe (March 2013).*

# Lessons learnt on the CFB boiler operation

- More than 3000 hours of operation
- Several fuels & blends: anthracite/sub-bit/petcoke/biomass
- De-NOx and De-SOx in situ with good results for emissions limits
- Higher thermal power for the same size boiler
- $CO_2$ concentration in flue gases over 85% (dry basis)

But some issues still need to be solved such as:

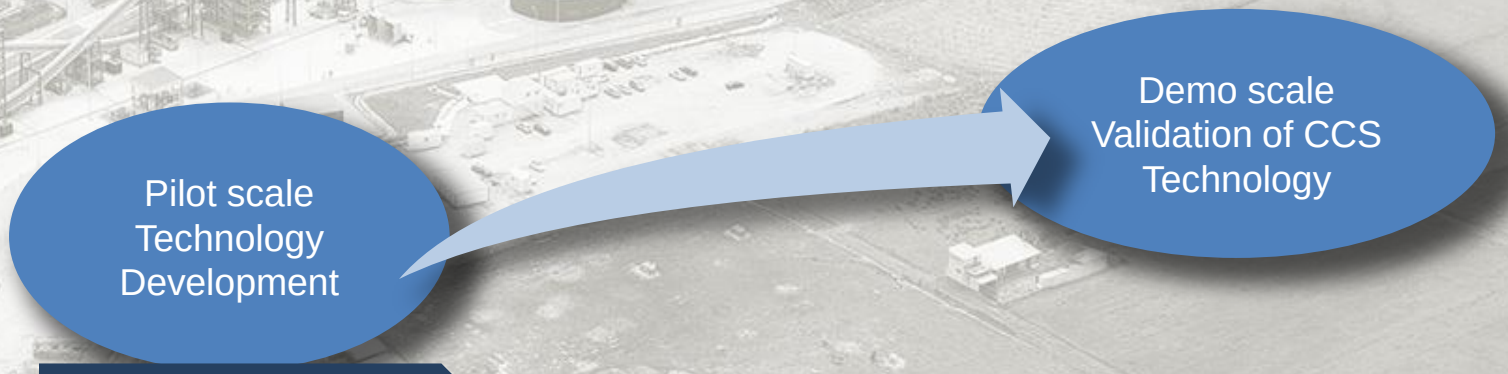
- Solids feeding
- Cold spots – acid condensation
- Air infiltration/gas leakage (tightness)
- Materials – refractory, metallic parts...
- Solids agglomeration

# Future work

- New materials and processes
- Acid corrosion control
- Energy efficiency improvements
- Biomass and biogas co-firing
- Comprehensive approach to agglomeration issues
- Model validation
- Scale up of results for commercial facilities design
- $CO_2$ pipeline integrity, corrosion, materials and safety protocols
- Equipment and instrumentation behaviour in $CO_2$ transport with impurities and fluid phases
- Geological storage processes and operational issues
- Training and operational protocols development
- Continue with public awareness
- Advice for regulation and standards development

# OXYCFB300 – Compostilla Project

- ✓ **Phase I** of EEPR Project is about to be completed with manageable delays.
- ✓ **Front End Engineering Design** (FEED) is about to be finalised.
- ✓ **Experimental phase** has been **successfully completed** in CIUDEN TDP.




**2009-2012** **Phase I Technology development**



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

# CIUDEN´s on-going R&D Programmes

**OXYCFB300**
Demo 300Mw CCS oxy-CFB power station, technological development on capture and storage

**FLEXIBURN CFB**
Flexible high-efficiency CFB combustion technology

**R&DIALOGUE**
Social perception of low carbon technologies

**MACPLUS**
Advanced materials for oxy-capture

**ECCSEL PPI**
European distributed and integrated research infrastructure

**BRISK**
Biomass gasification

**O2GEN**
2nd generation oxy-fuel power station

**RELCOM**
Oxy-PC firing

**IMPACTS**
$CO_2$ quality for transport and storage

**BiOxySorb**
Co-combustion of 2nd generation biomass under air and oxy-fuel conditions in PC boilers; and emission control by sorbent injection.

# Why with CIUDEN

**CIUDEN OFFERS**

- es.$CO_2$ Centre facilities unique in Europe
- Flexibility and complete control of the operation process
- Highly qualified personnel
- Auxiliary facilities such as training centre, videoconference rooms, workshop, meeting rooms, etc.
- Own laboratories with specialized equipment and personnel
- Experimented team in international workbench
- Management of fuels and other raw materials for test development
- All CCS chain for a complete development of your project
- International showcase for your project

# How to collaborate with CIUDEN

TECHNOLOGICAL ASSOCIATION AGREEMENT (medium to long term R&D activities)

SPECIFIC COLABORATION AGREEMENTS (R&D specific project)

**R&D AT CIUDEN**

SERVICE CONTRACT (R&D direct service)

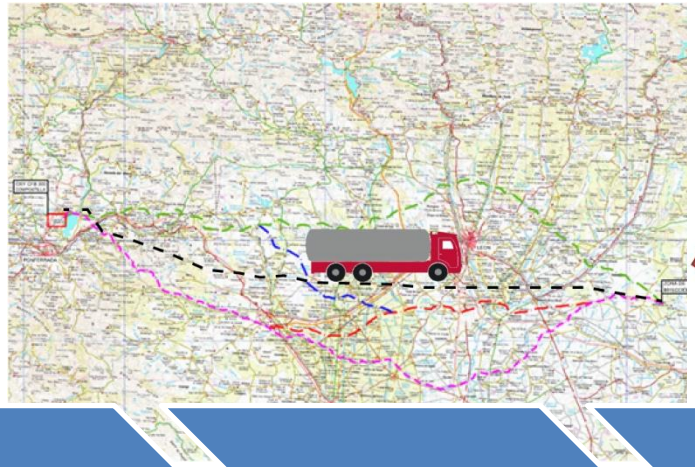
PROJECT CONSORTIUM AGREEMENT (European and international projects with other partners involved)

CIUDEN is opened to any agreements which fits better with your company or entity. Recommend a model and we will develop it together!!

# CIUDEN Clean Coal Technologies Development Programmes

CIUDEN is willing to contribute to the development of
**Carbon Capture, Transport and Geological Storage**

*es.$CO_2$ Centre*




*Hontomín Centre*

Capture → Transport → Storage

**Full chain of CCS in preindustrial size installations**

# CIUDEN´s capabilities

## ✓ Capture

* Upgraded capture plant could produce tens of thousands tonnes/year of $CO_2$ with a purity up to 99%.

## ✓ Transport

* $CO_2$ could be transported by tanks.
* Experimental Transportation plant can deal with issues related to the transport of CO2 produced with different technologies.

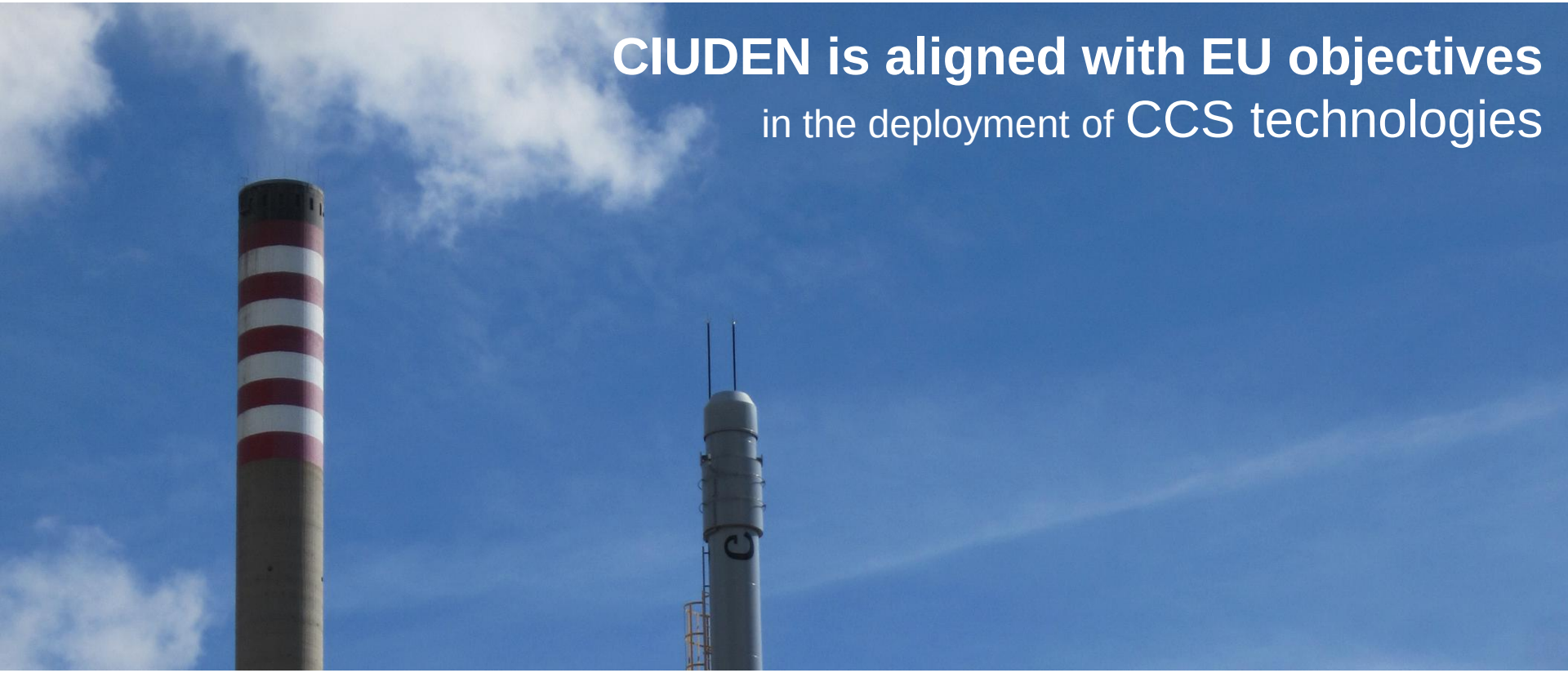
## ✓ Storage

* Storage plant can inject several tens of thousands tonnes per year of $CO_2$ in a deep on-shore saline aquifer.

## ✓ Permitting

* CIUDEN has **all necessary permits** for capture and storage (of up to 100,000 t; estimated site capacity 1.900.000 t).

# CIUDEN´s positioning



## CIUDEN is aligned with EU objectives
in the deployment of CCS technologies

Contribution to R&D **in capture and transport**
from the Technology Development Centre for $CO_2$ Capture (es.$CO_2$).

Development of scientific and operational knowledge **in $CO_2$ geological storage in saline aquifer** from the Hontomín plant.

Oxyfuel Combustion Conference

**9 – 13 September**, 2013

Ponferrada (Spain)

*Templar Castle*

*es.CO$_2$ Centre*

# *THANK YOU VERY MUCH FOR YOUR ATTENTION*

*For further information, please contact*
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