Carbon Capture and Storage

Technology and economy

MIT Electricity Markets Workshop
EDF Tower, La Défence Paris

July 3, 2008

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Vattenfall has declared that we will reduce our emissions by 50% until 2030 and the remaining until 2050

The Vision

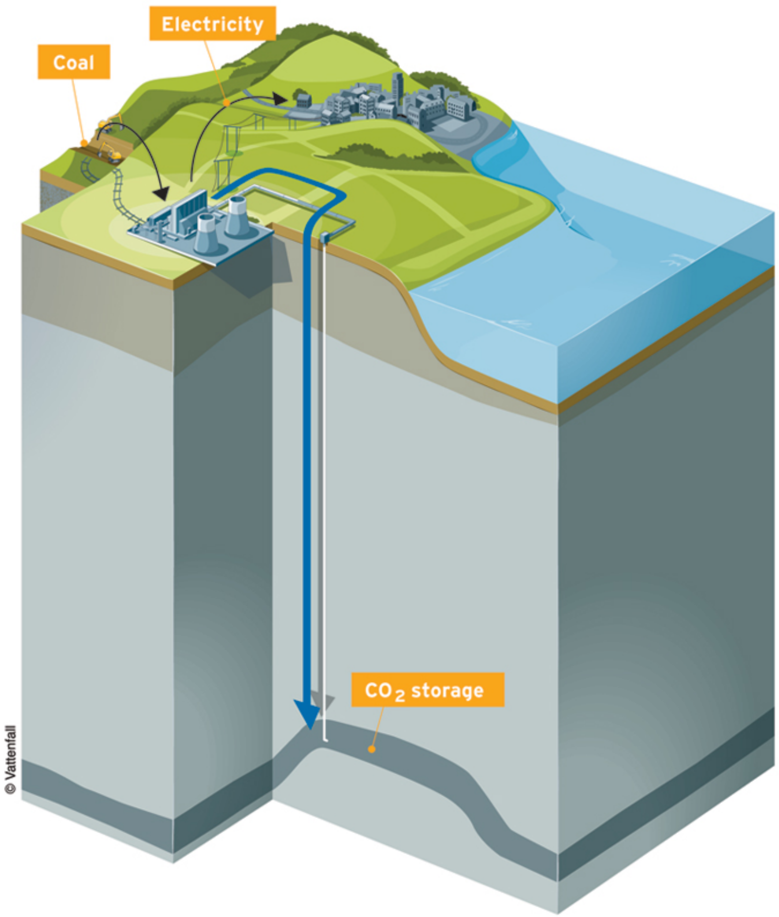
To show that it is possible to create a coal fired power plant with “zero emissions”

- There are primary technology options commercially available in 2020
- The cost for carbon dioxide reduction is lower than 20 €/ton of CO_2
- There are even better technologies available after 2020

The CO_2 free Power Plant project

www.vattenfall.com/ccs

Communication of CCS



- ✓The capture part of the chain by far contains the largest cost (80%)
- ✓The transport part of the chain constitutes the longest lead times and most difficult infrastructure
- ✓The storage is the part people have most concerns about.
- ✓Permitting and legislation issues are critical
- ✓The cost is considerable, and demos give higher cost than mature technology

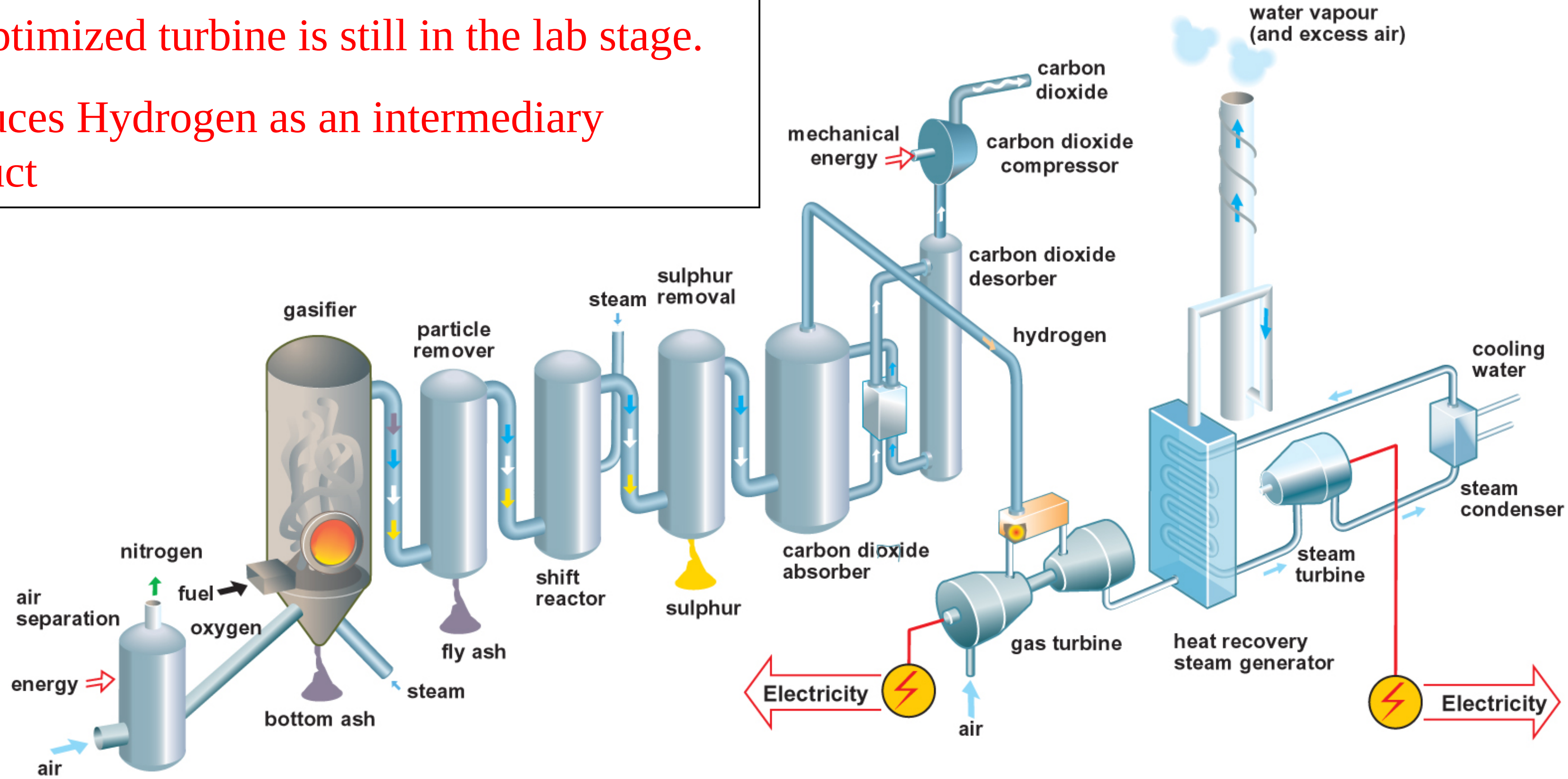
Capture technologies

Pre-combustion capture

This technology might be competitive. IGCC without capture exists in five demo plants.

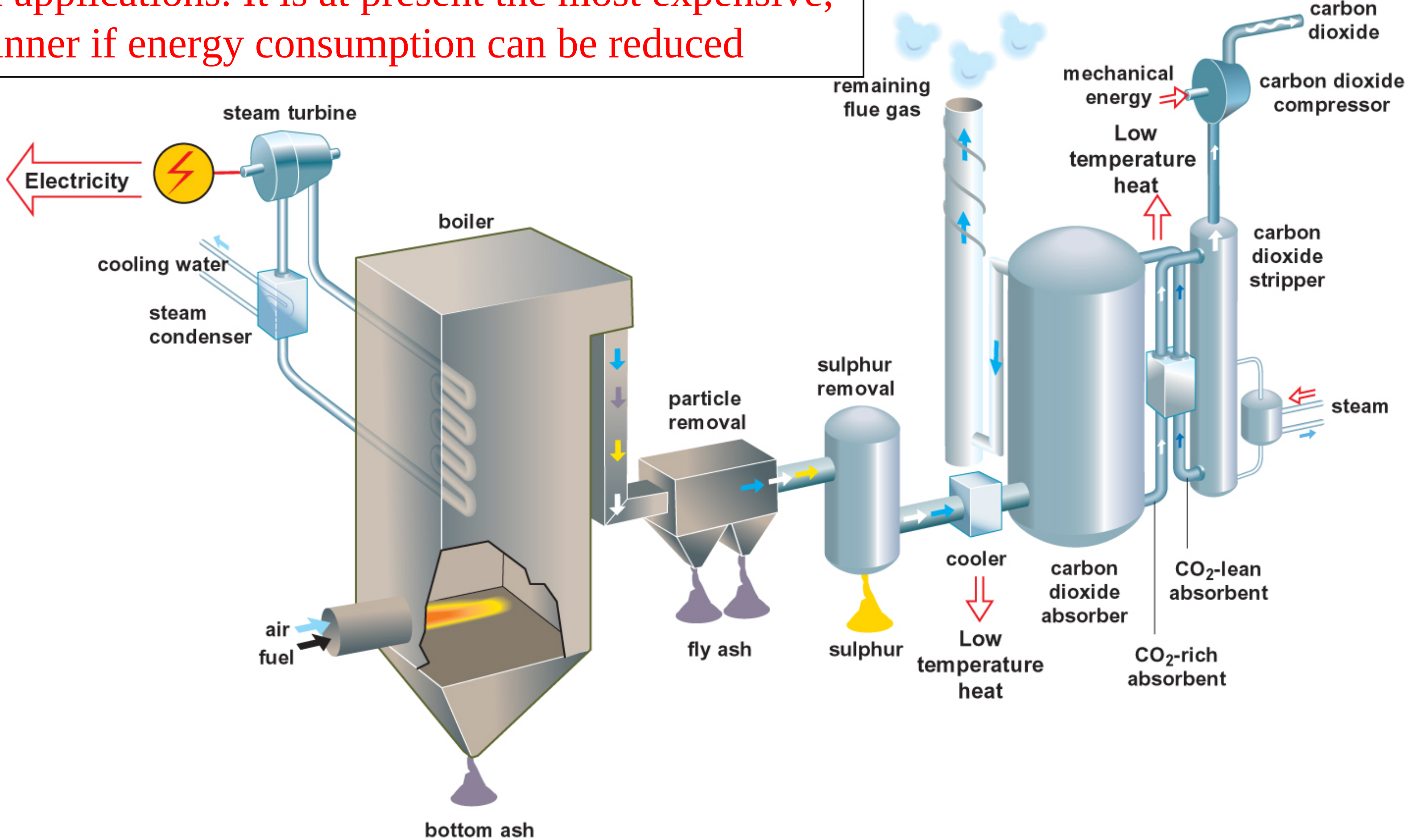
An optimized turbine is still in the lab stage.

Produces Hydrogen as an intermediary product



Post-combustion capture

Technology is commercially available in medium scale for industrial applications. It is at present the most expensive, a winner if energy consumption can be reduced



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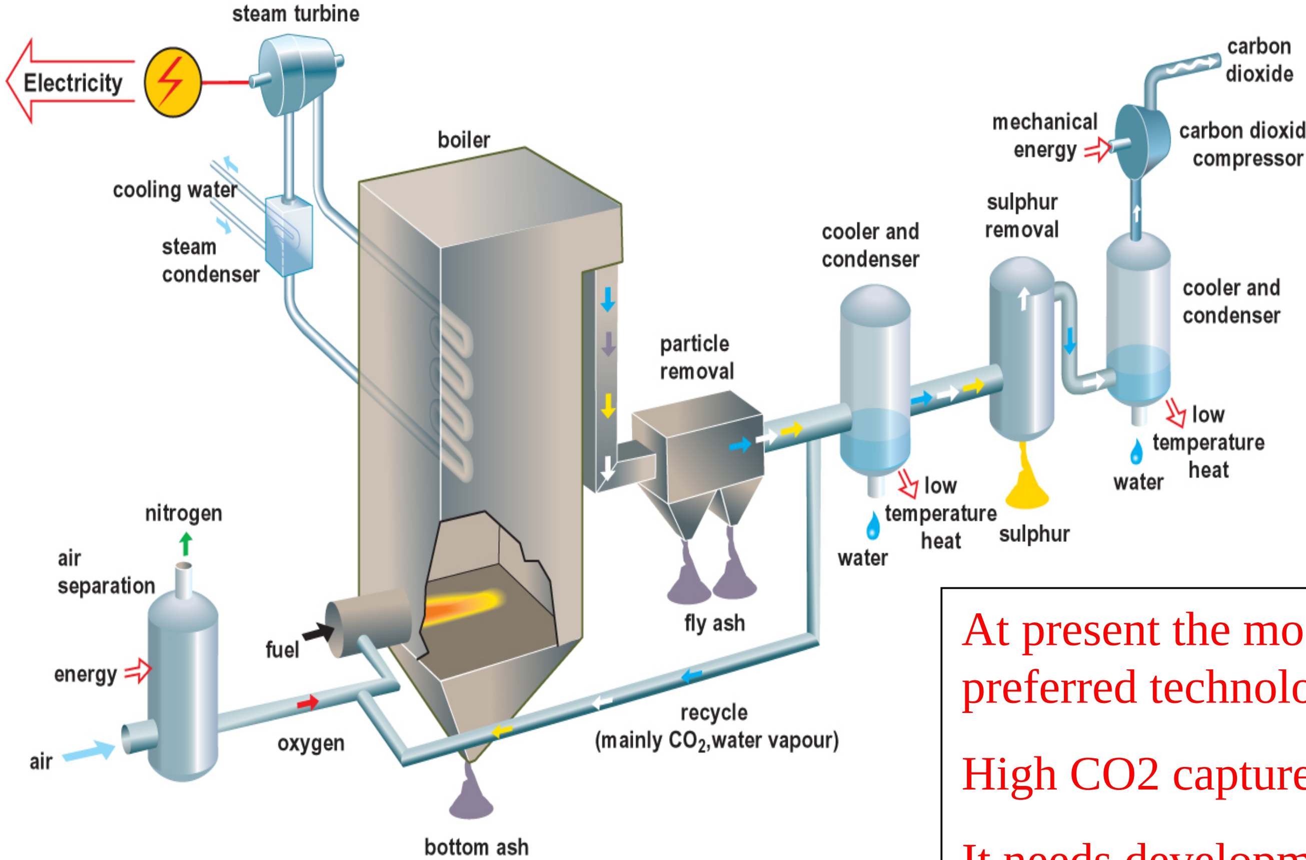
O_2/CO_2 combustion is the preferred option at present



At present the most competitive and preferred technology for coal.

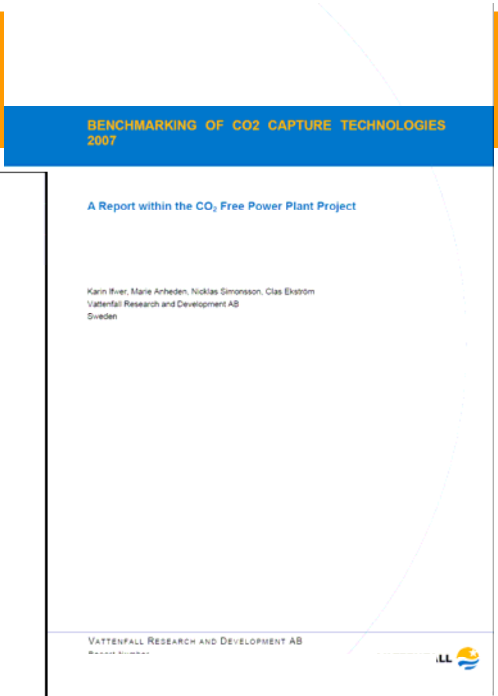
High CO2 capture rate

It needs development, pilot and demo plants to validate design data

Benchmarking of the technology options

CO_2 free Power Plant project
Benchmarking

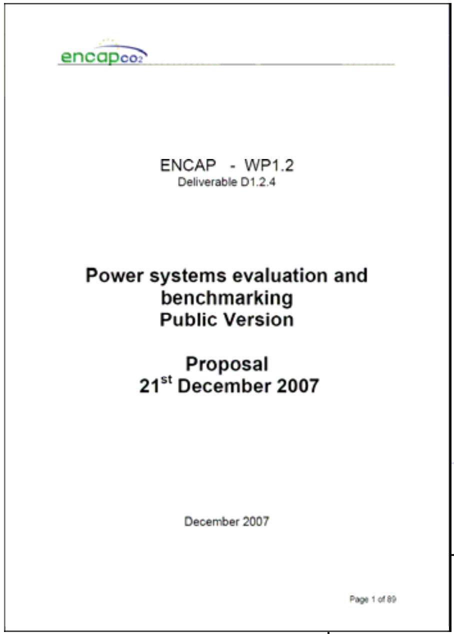
- Annual updates of our internal benchmark study
  - Our best knowledge is summarized at each time
- A multitude of other benchmark studies are made
  - ENCAP project (RWE, Siemens, Alstom, Linde, Statoil …..)
  - The EU Technology Platform (ZEP)


BENCHMARKING OF CO2 CAPTURE TECHNOLOGIES
2007

A Report within the CO_2 Free Power Plant Project

Karin Ifwer, Marie Anheden, Nicklas Simonsson, Clas Ekström
Vattenfall Research and Development AB
Sweden

VATTENFALL RESEARCH AND DEVELOPMENT AB


encapco2

ENCAP - WP1.2
Deliverable D1.2.4

Power systems evaluation and benchmarking
Public Version

Proposal
21st December 2007

December 2007

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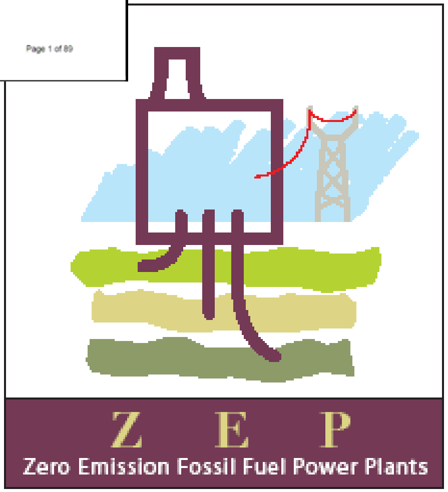
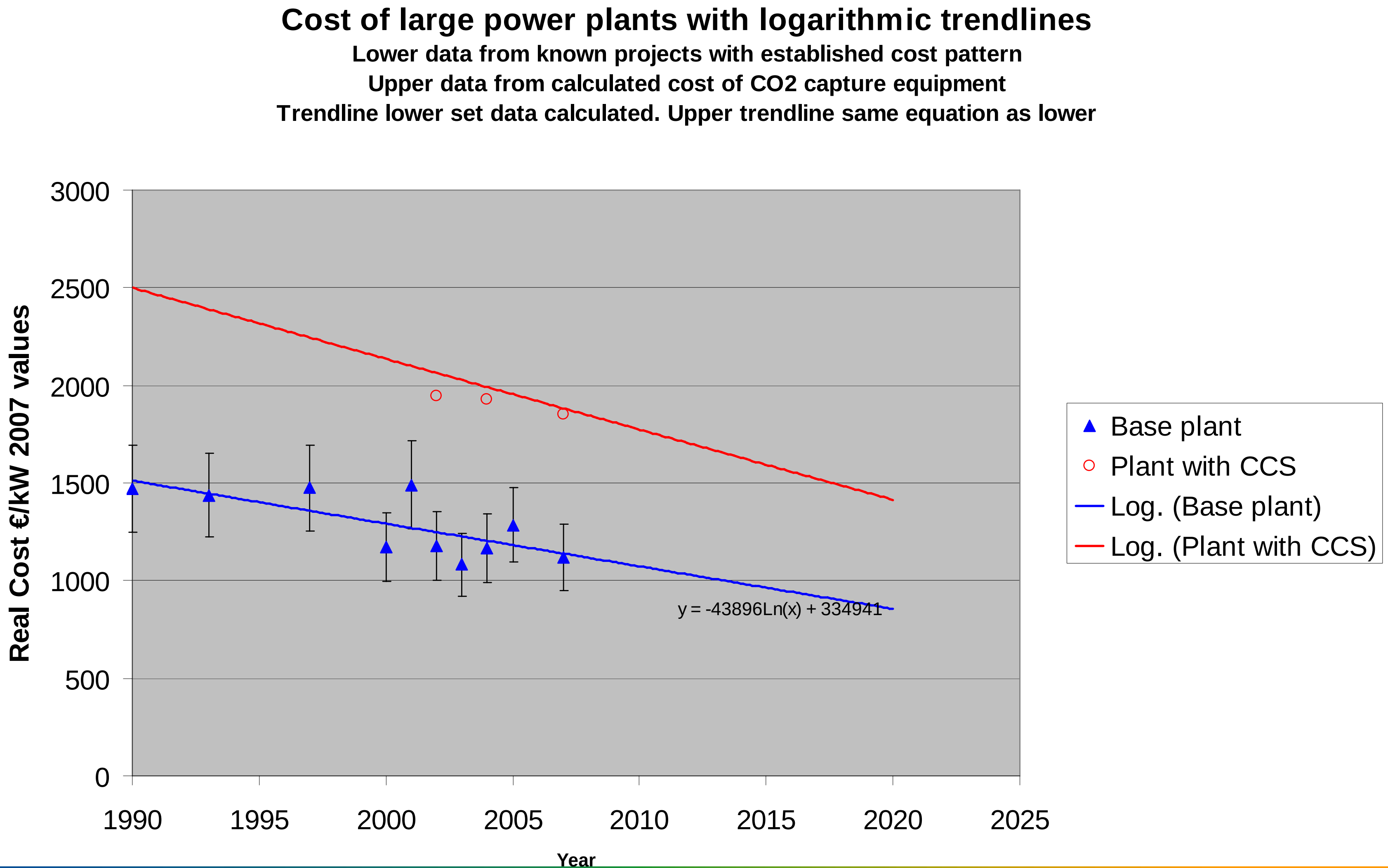


Investment costs for large power plants



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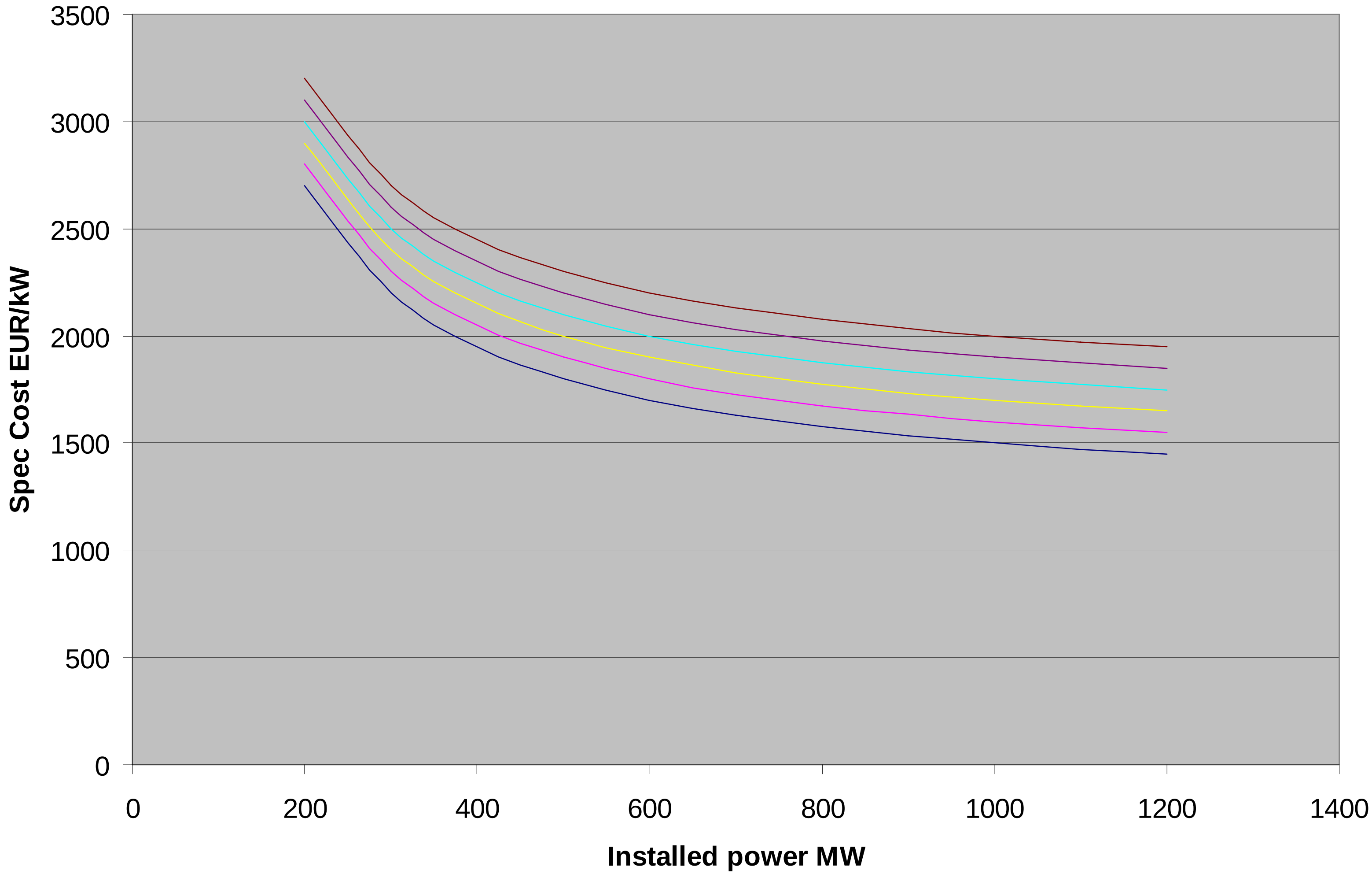
Specific investment for varying size of plant



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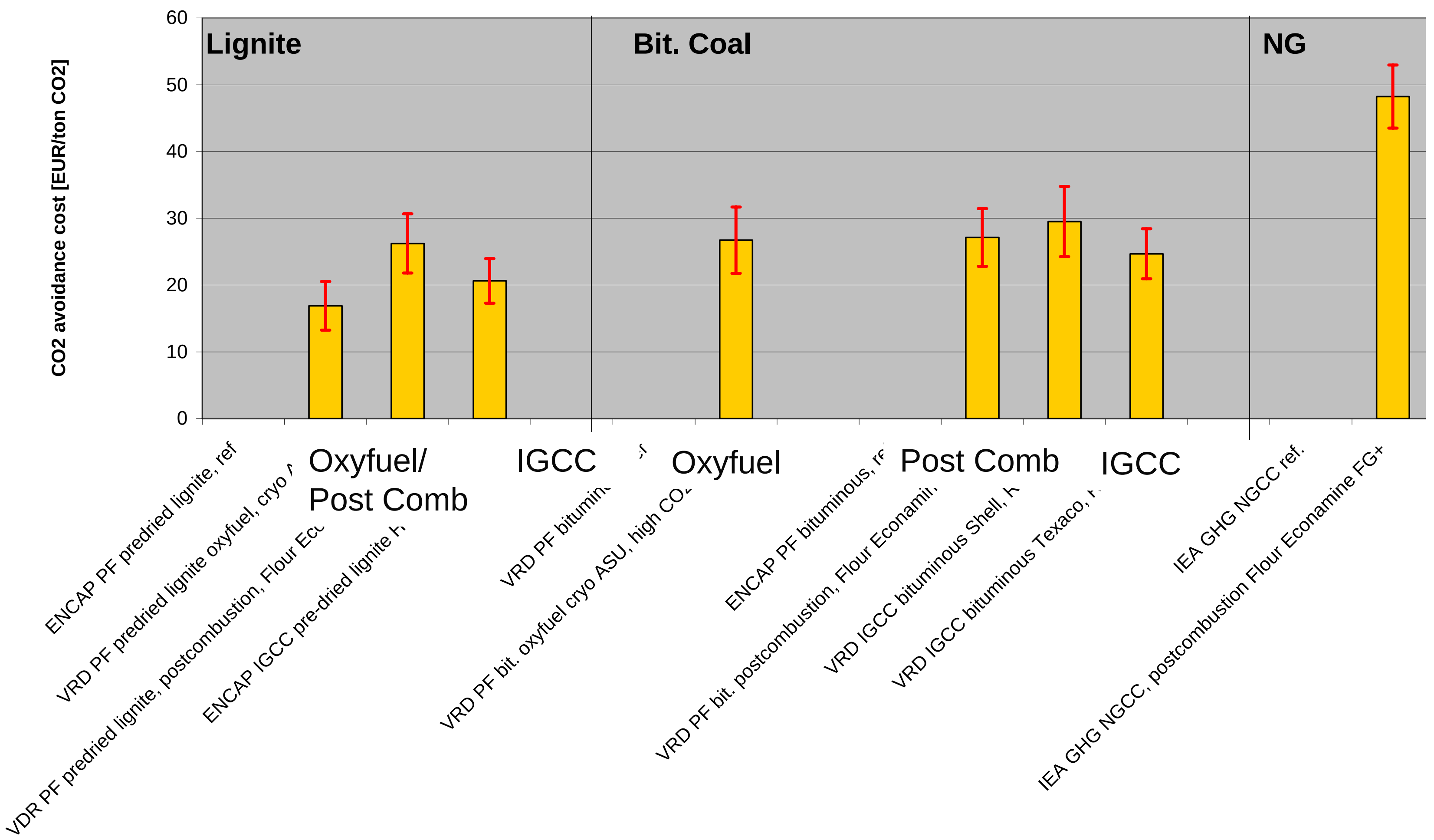
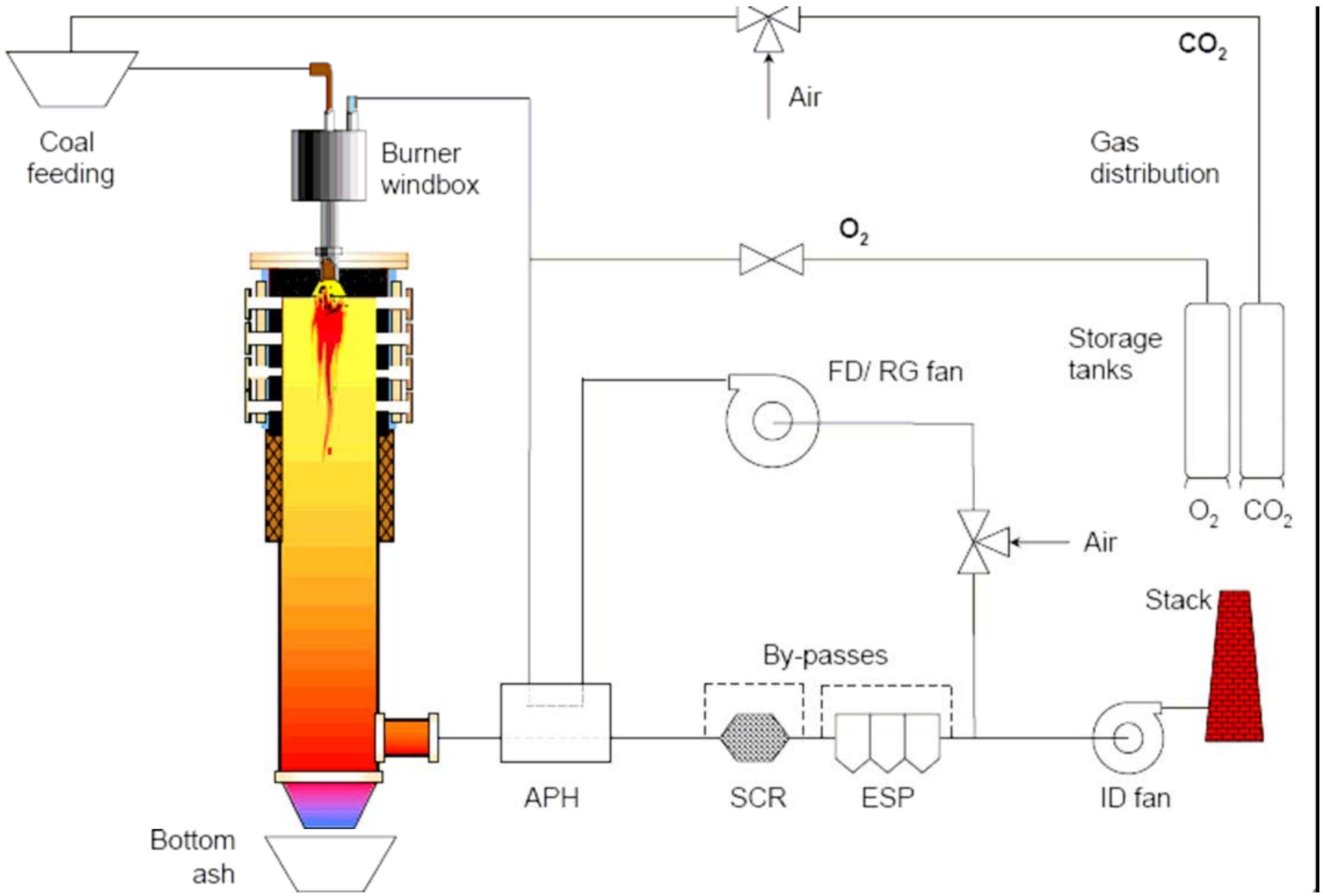
CO_2 free Power Plant project
CO_2 avoidance costs Investment costs varied

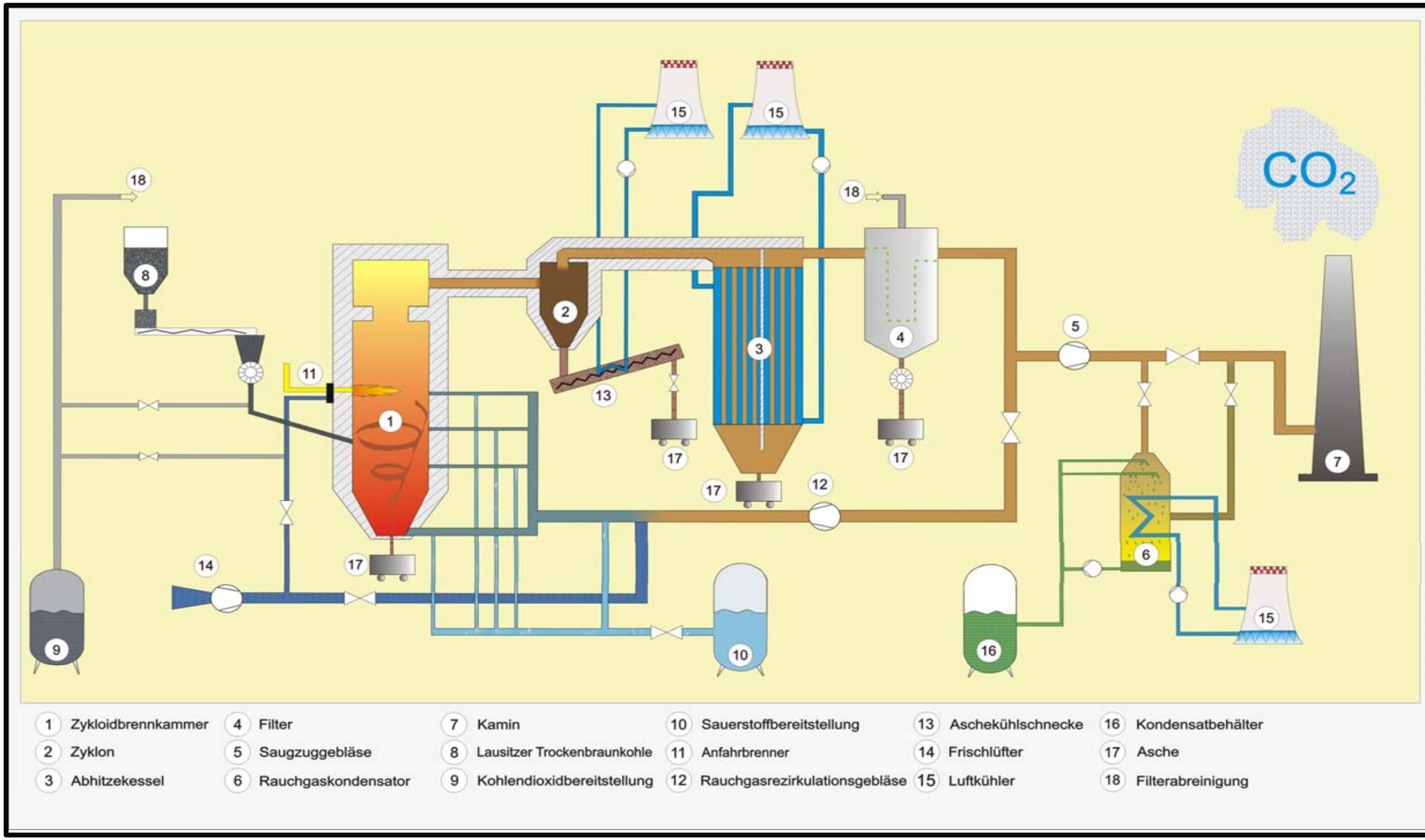


Going from visions to reality

Lay out of test rig at IVD Stuttgart



CEBra test rig at Jänschwalde



Chalmers Oxyfuel test rig

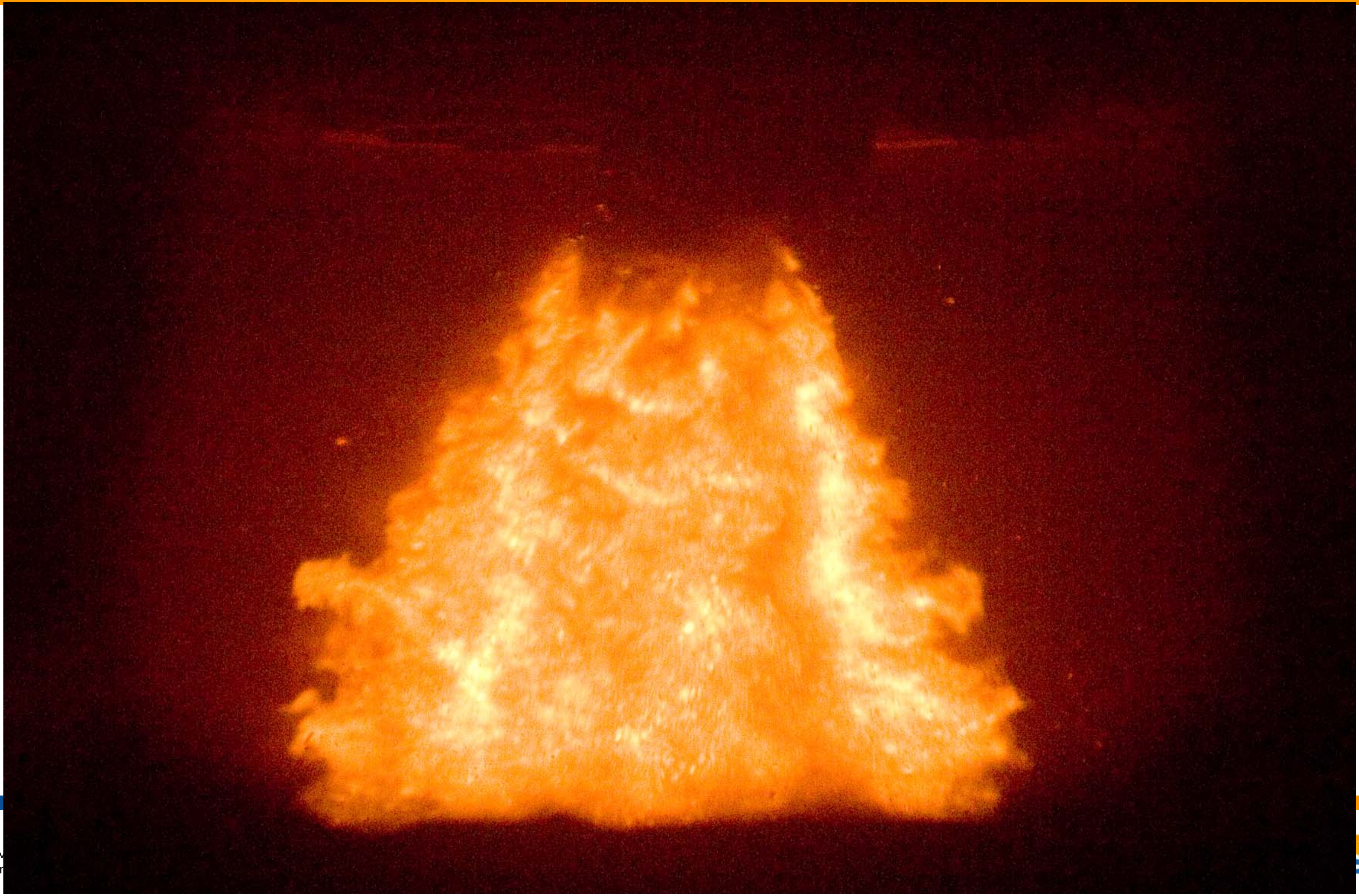
Radiation characteristics

a. b. c.

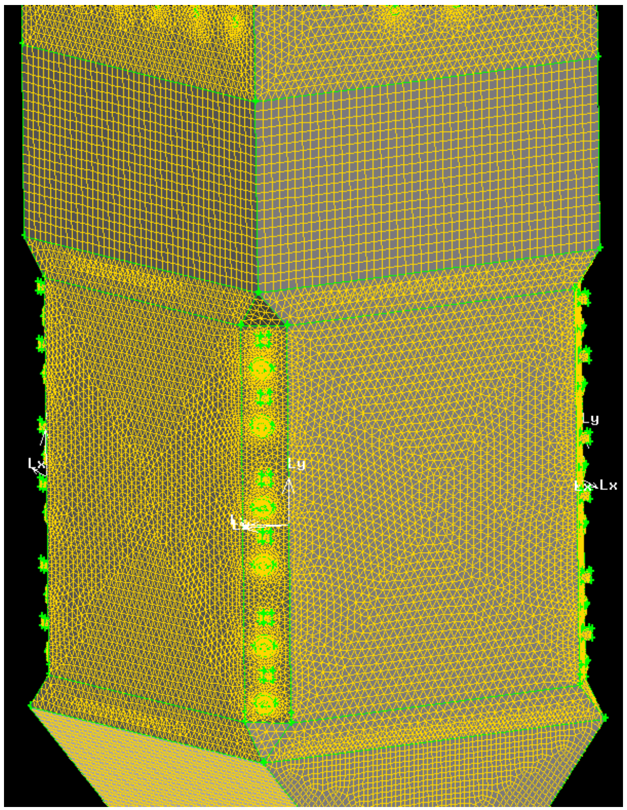
Figure 6.10. Photographs of the of (a) the air flame, (b) the OF 21 flame and (c) the OF 27 flame, 215 mm from the burner inlet.

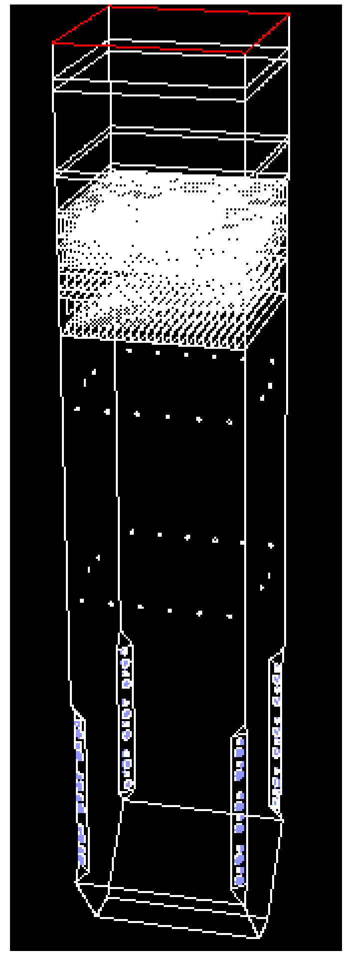
Chalmers Oxyfuel test rig (Coal and Air)

Chalmers Oxyfuel test rig (Coal and 27 % oxygen)



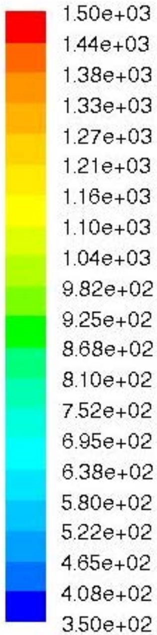
Geometry and mesh



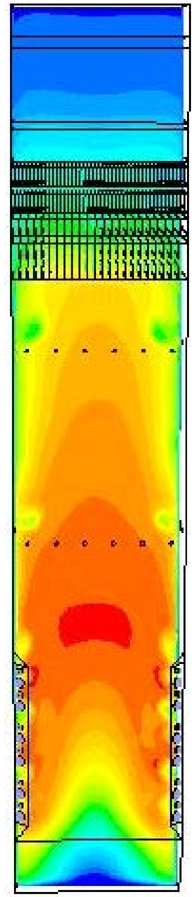


The computational domain consists of the complete furnace and the flue gas channel to the economizer. The computational mesh consists of 2.3 million cells. Both hexahedral and tetrahedral cells are used. The concentration of cells is denser in the burner area and around the OFA inlets. The super heaters are modelled as infinitesimally thin plates or as a heat sink and porous media.

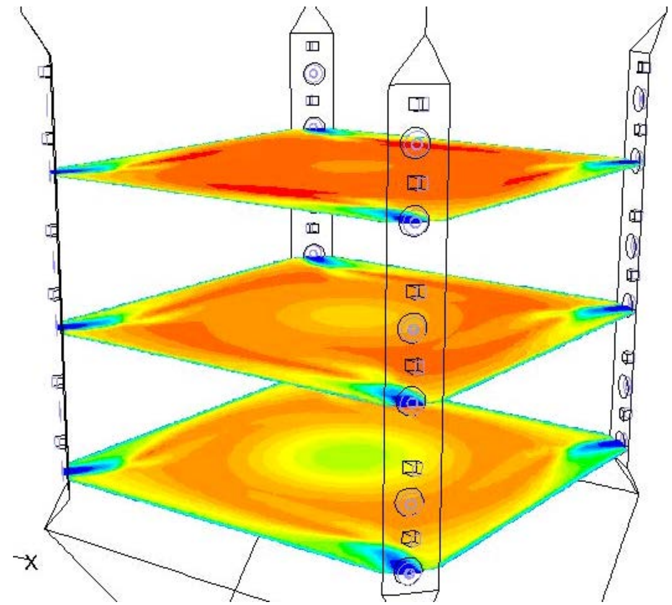
Temperature profiles



Scale in ºC, red indicates 1500ºC or more, dark blue indicates 350ºC or less

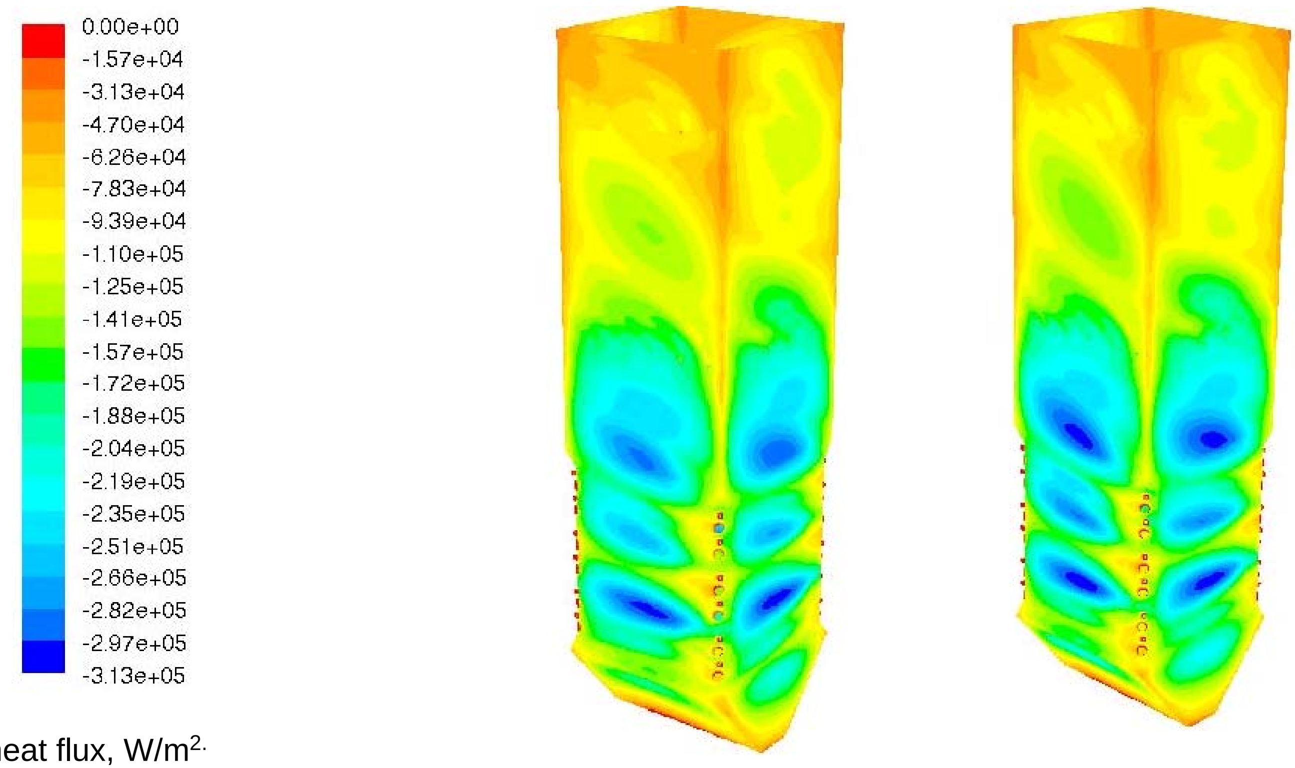


Temperature profile in a cross section through the centre of the furnace.



Temperature in three horizontal cross sections trough the burner rows 1,3 and 5 counted from the bottom of the furnace.

Heat transfer to the furnace walls



Surface heat flux, W/m^{2}.
Note that negative fluxes are fluxes from the furnace, i.e. blue indicates high heat transfer to the walls from the furnace.

Heat transfer to the four walls in the furnace.

Lars Strömberg Vice president R&D

”Zero Emission” ????

Oxyfuel technology:

- It is possible to process the CO_2 after the boiler to reach
  - > 95 % capture rate (100 % possible)
  - > 98 % purity (100 % possible)
- The gases contained in the off gas is beside CO_2 mainly
  - Argon
  - Nitrogen
  - Water vapour
- No sulphur oxides will be emitted
- No nitrogen oxides will be emitted
- All particulates will be removed, including all solid metals and submicron PM
- No sulfur or nitrogen oxides in liquid CO_2

From R&D to the real thing

10 years of continuous research – now resulting in several larger CCS projects

Plant	**Schwarze Pumpe,** Germany	**Mongstad,** Norway	**Altmark** Germany	**Demoplants,** Germany, Denmark, Poland
Type	Large scale pilot	Large scale pilot	Storage testing, EGR	Demonstration plants
Capacity	30 MW	100 kton CO_2/a (~35 MW)	100 kton CO_2 (3 yr test phase)	250 - 350 MW
Fuel	Lignite, hard coal	Gas from refinery	-	Hard coal, Lignite
Techn.	Oxyfuel	Post-combustion	EGR,Old gas field, 400Mton	Post-combustion and oxyfuel
Operation	2008	2010	2009	Ca 2015

View of the Schwarze Pumpe Pilot Plant June 2008

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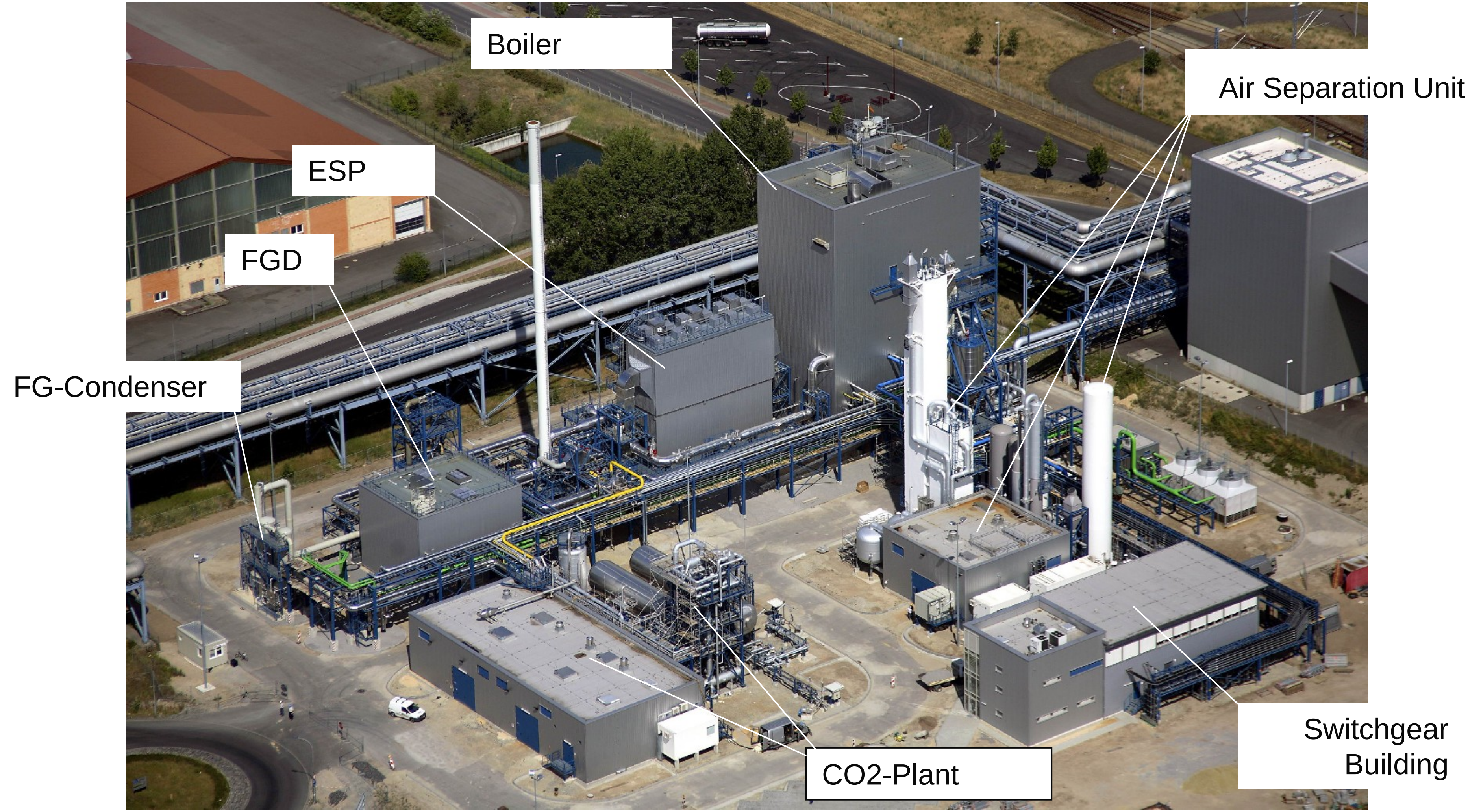
View on building site (June 2008)



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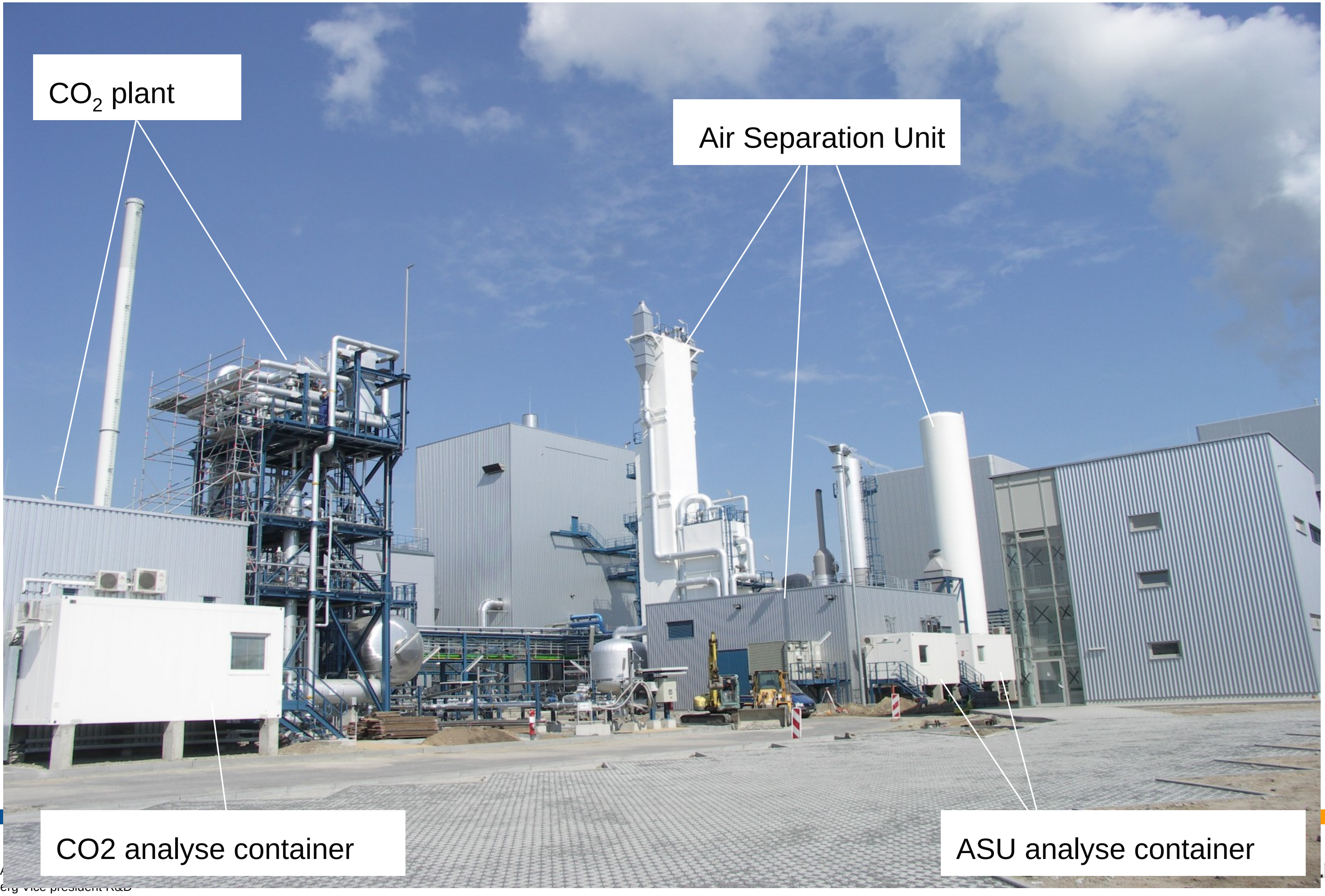
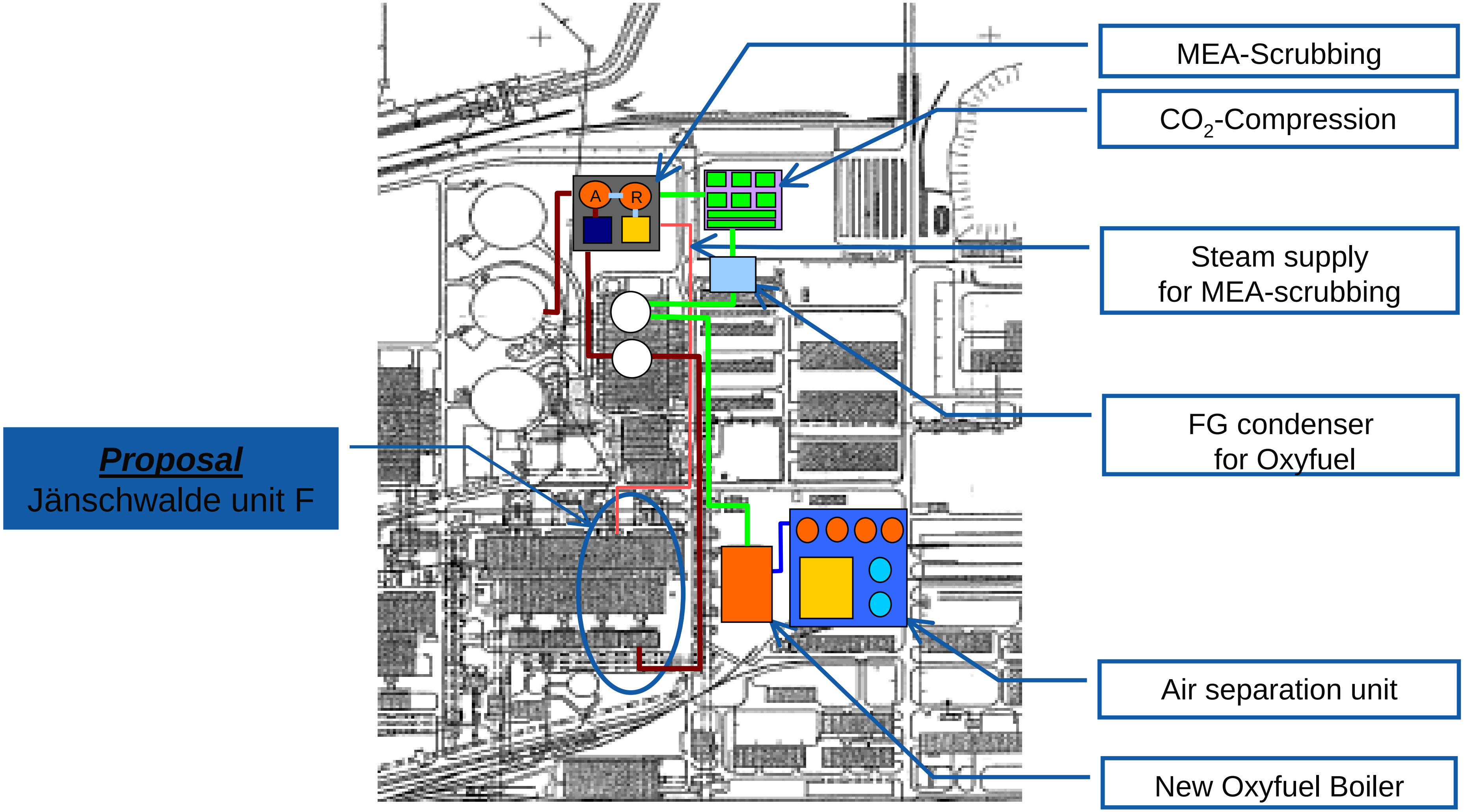
New components : ASU and CO_2 plant



CO_2 plant in detail (June 2008)

Demo plant Jänschwalde - Draft layout



Variants of CO_2-Reduction Technologies

New Oxyfuel Boiler
(Erection beside the existing Boiler)

CO_2-Post Combustion
(behind existing Mono-Boiler)

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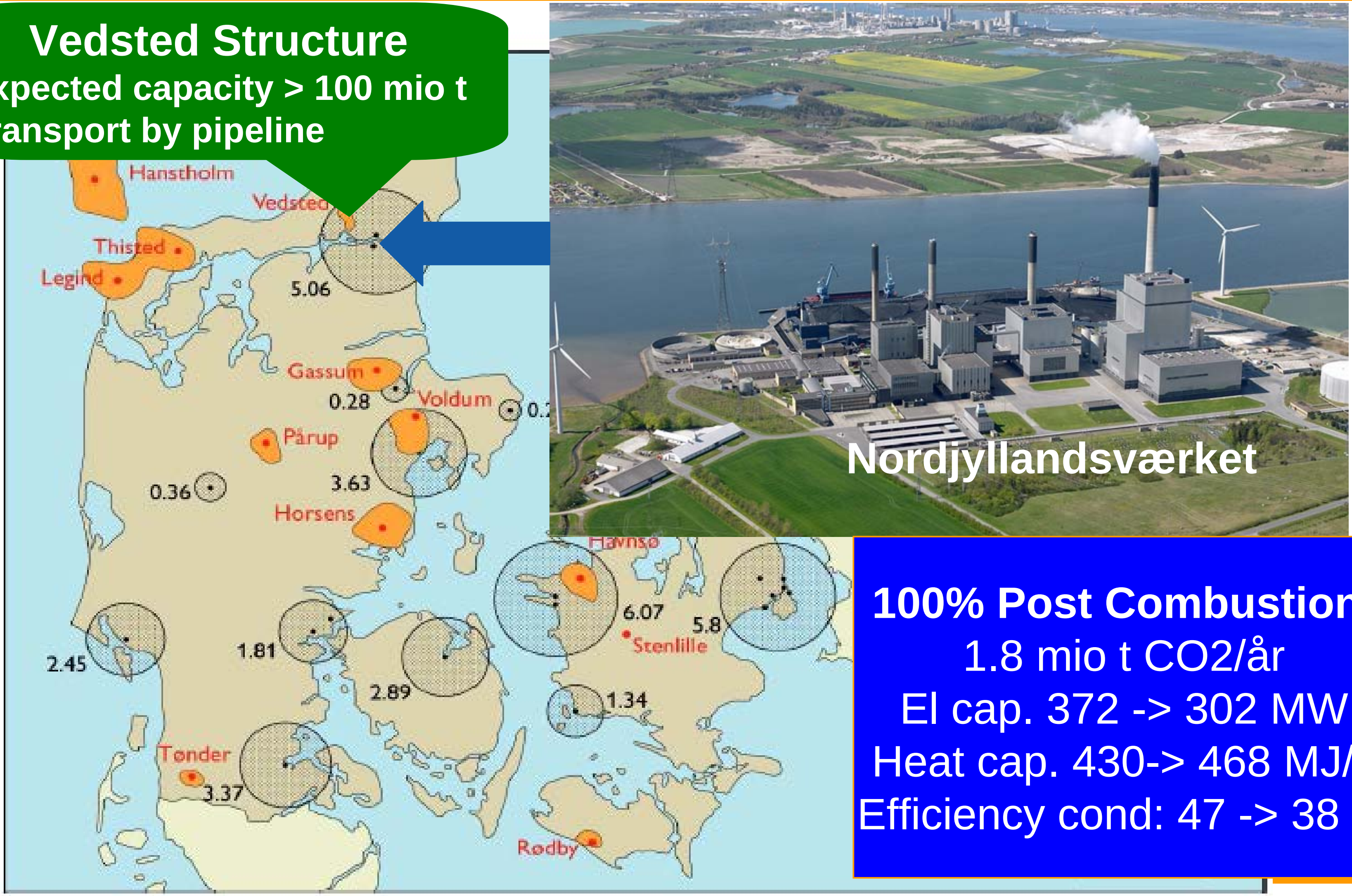
View of ASU O_2-capacity 17.500 to/day (Linde AG)

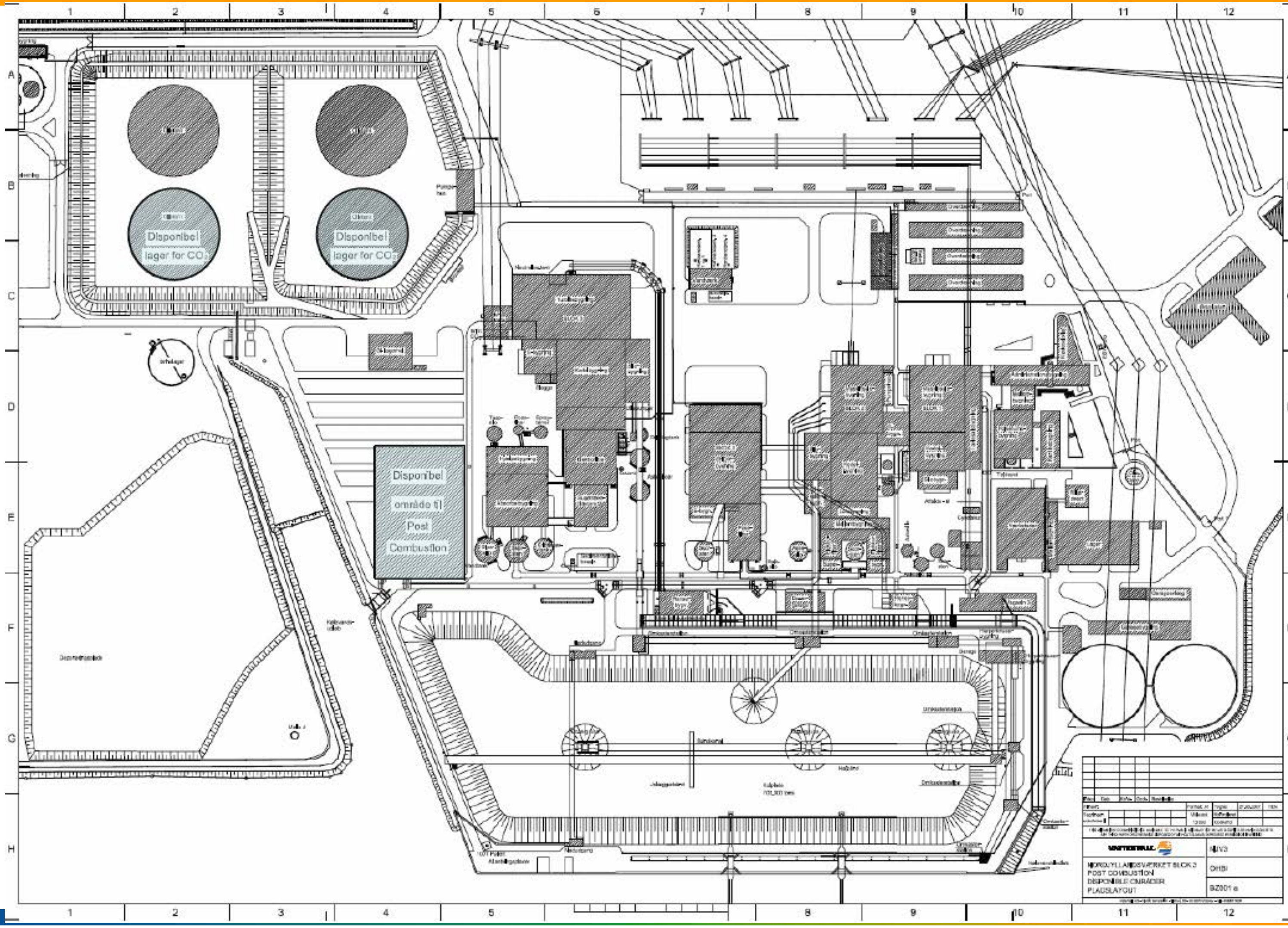
CCS demo project close to Aalborg, Denmark

Vedsted Structure
Expected capacity > 100 mio t
Transport by pipeline



100% Post Combustion:
1.8 mio t CO2/år
El cap. 372 -> 302 MW
Heat cap. 430-> 468 MJ/s
Efficiency cond: 47 -> 38 %

Nordjylland Post-combustion demo




DALUISO A/S
4-6 vibrator trucks 25 ton
Distance between vibrations app. 10 m
Daily capacity app. 7 km
Manning 60 – 80


V-2
437
Zachowaj bezpieczną odległość 5 m. od pracującego wibratora!
Beholde en sikker afstand af 5 meter fra gaaende vibrator!
428

Conclusions

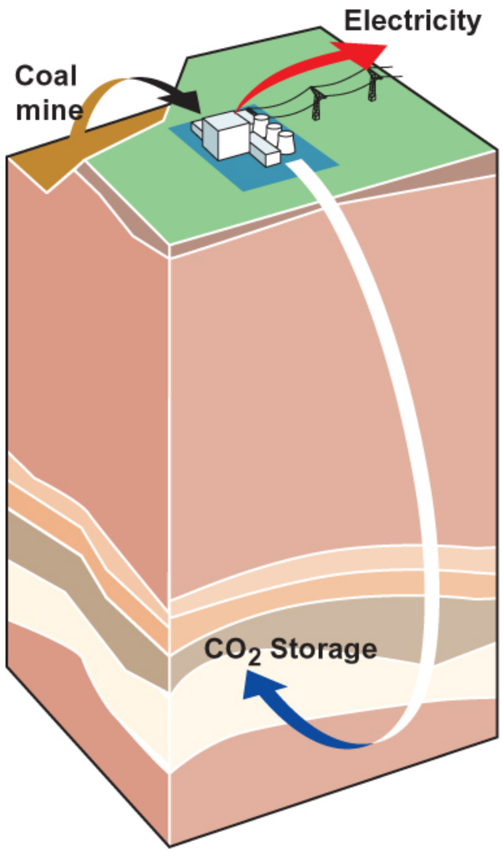
A demo plant costs twice as much as a commercial plant

A small plant costs more than a large plant

The technology will not be ready until we have several demos in operation

The public concern lies in the storage part of the chain, while the cost mainly stems from the power plant

To establish the infrastructure for transport and storage will be critical for the cost and the time needed



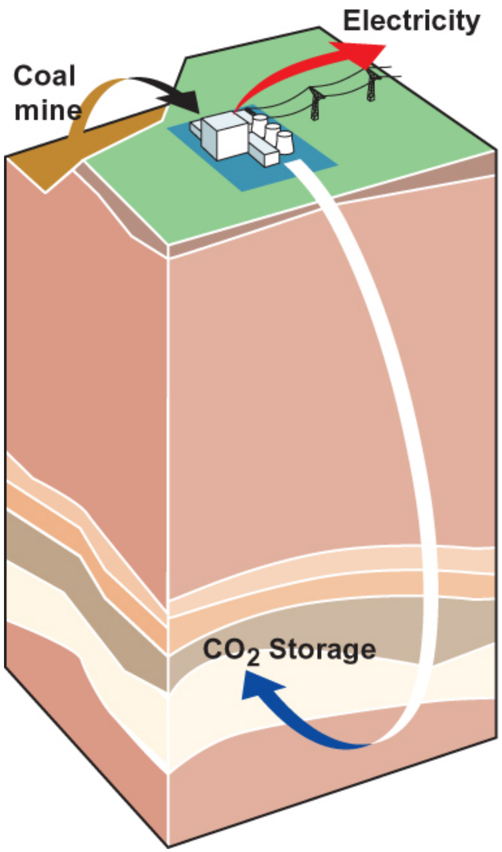
Conclusions (2)

We are on the way to realize our visions

We will make it at a cost around 20 €/ton

The technology will not be ready until 2020

The critical line is the seven+ years to realize a demo plant including capture, transport and storage

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