Carbon Capture and Storage

- Technology, costs and way forward

Presentation by:

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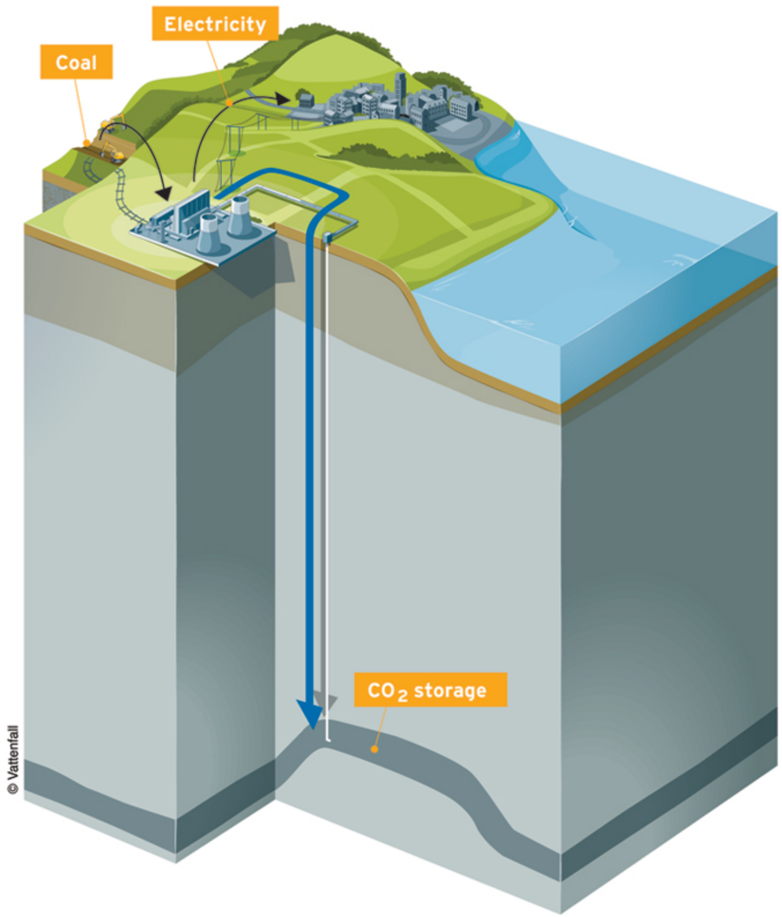
Berlin, 8 September 2008

Carbon capture and storage, or CCS



- The capture part of the chain has by far the highest cost (75 %)
- The transport part of the chain constitutes the longest lead times
- The storage is the part people have most concerns about.

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Carbon Capture and Storage
How does it work ?

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The CO_2 capture and storage principle

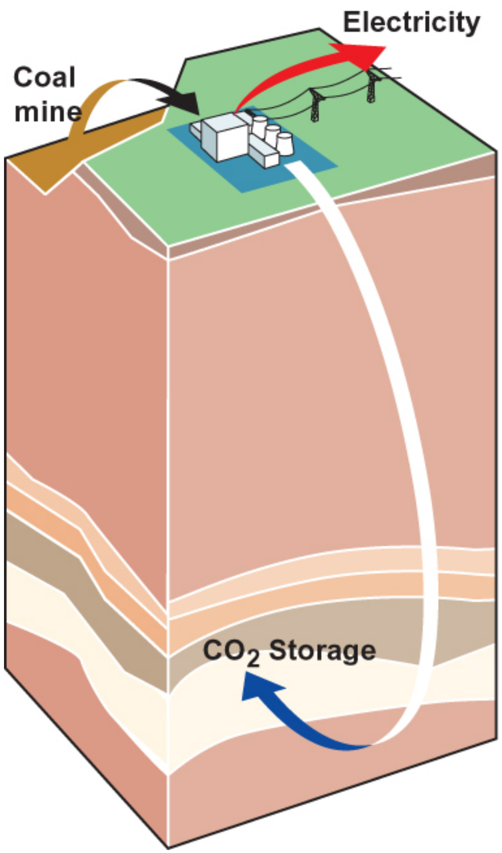
The CO_2 can be captured

from the fuel gases

from the fuel before the combustion process.

The CO_2 is cleaned and compressed to a liquid state

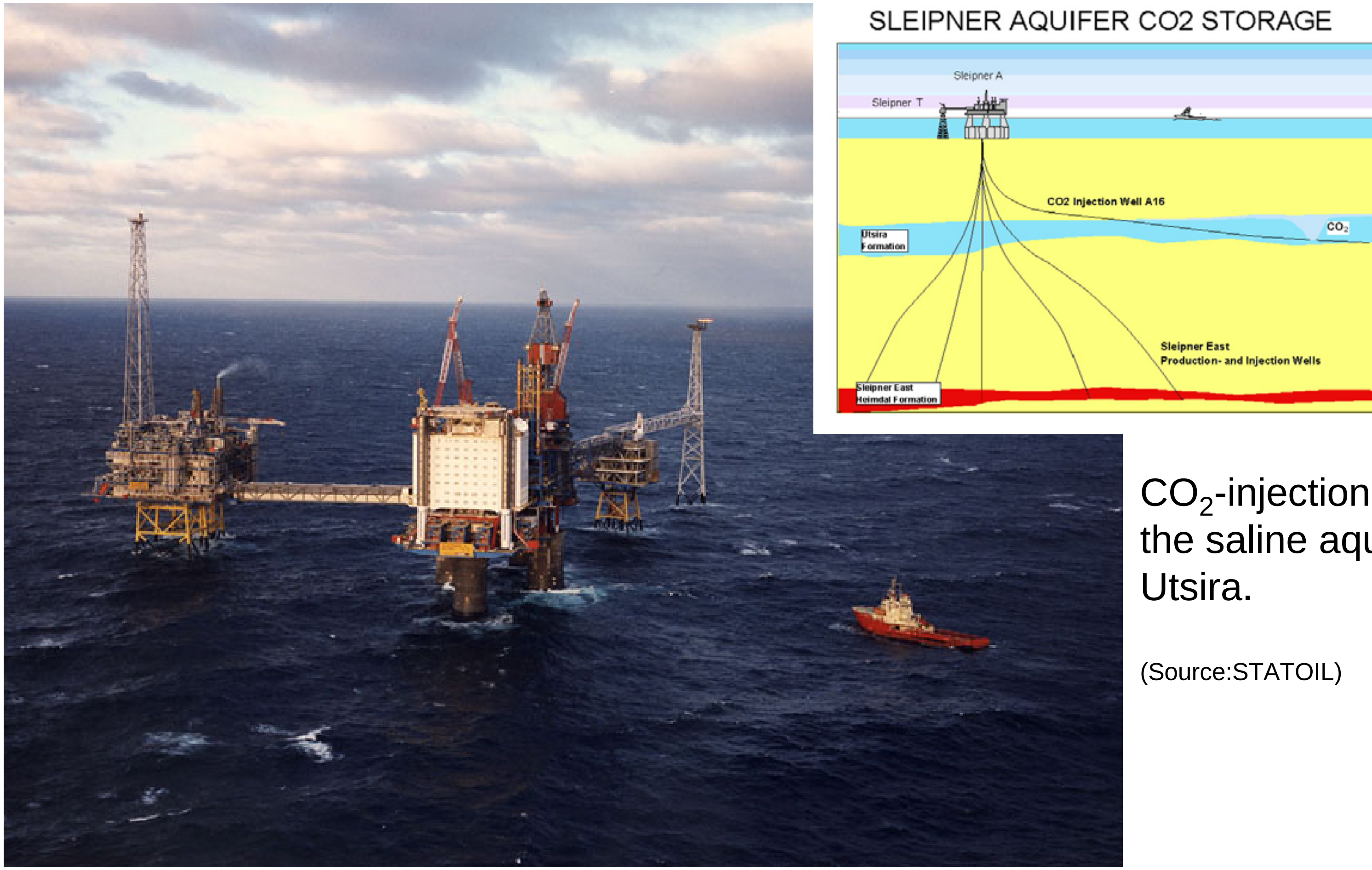
The CO_2 is pumped as a liquid down into a porous rock formation for permanent storage.



Carbon dioxide storage

- Stored in porous rock formations deeper than 1000 meter
  - The rock has 5 – 20% porosity.
  - It is the same type of formation as where oil and gas is found
  - It remains liquid due to its own hydrostatic pressure
  - There is no pressure difference between the liquid CO_2 and the surrounding

Storage of CO_2 in a Saline Aquifer under the North Sea

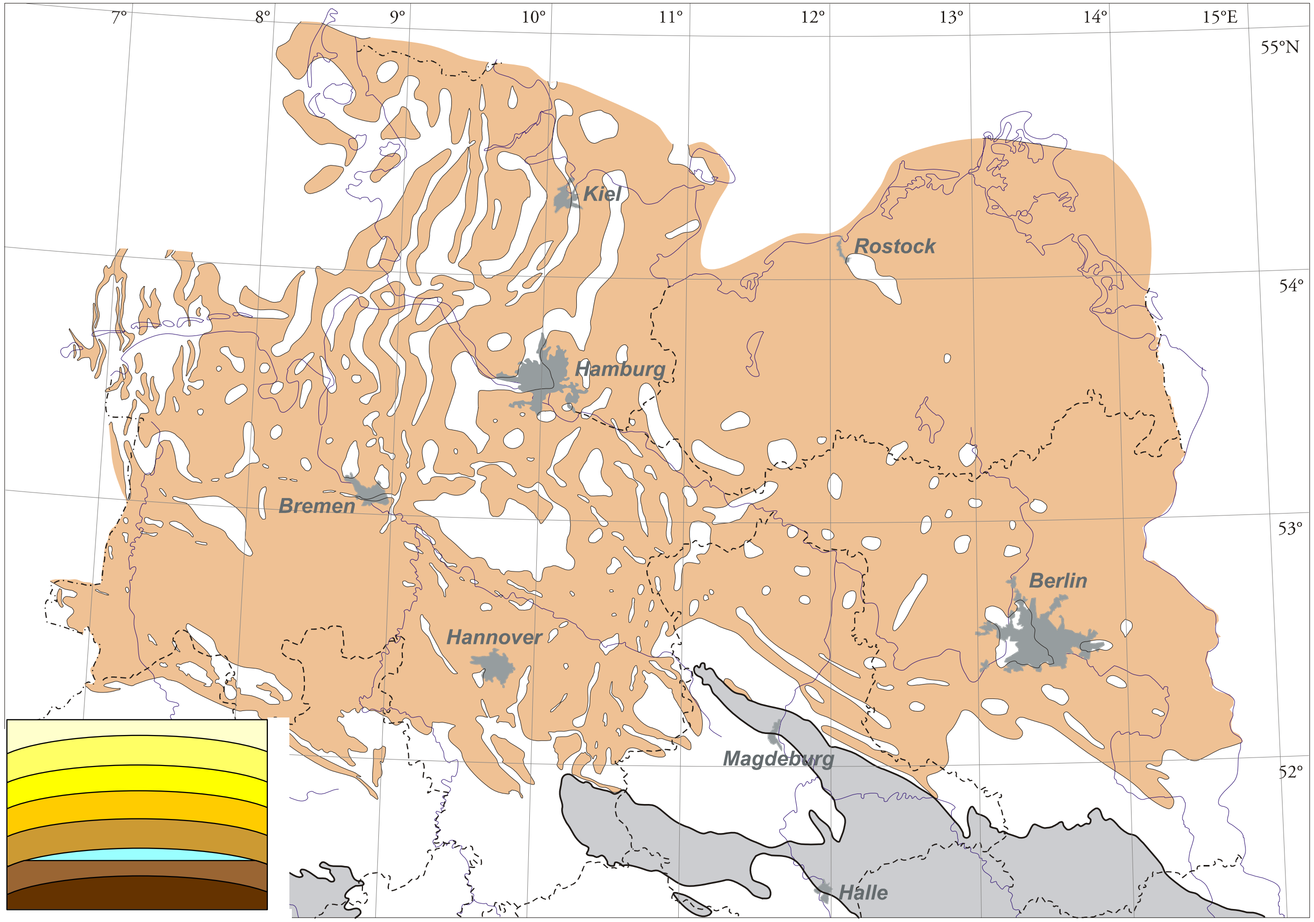


CO_2-injection into the saline aquifer Utsira.

(Source:STATOIL)

The Sleipner field. Oil and gas production facilities. (Source: STATOIL)

Storage Capacity, saline aquifers



Distribution of Rhetian   Basement below Cenozoic cover

Present day distribution of the Rhetian - aquifers (a. DIENER et al. 1984, FRISCH & KOCKEL 1998)

There exists more storage capacity within Europe (and in the world) than the remaining fossil fuels

Sources:

Franz May,
Peter Gerling,
Paul Krull,
Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

CO_2 transport

- CO_2 is transported
  - In liquid state at temperatures of minus 15 degrees C and 15 bar pressure in containers
  - In supercritical state at room temperature and above 70 bar in pipelines.

- CO_2 transport from a power plant will always be made by pipelines, and if applicable with ships.

- A large (1000 MW) coal fired power plant produces about 5 million tonnes of CO_2 per year.

- A demonstration plant produces 1 million tonnes per year.

- Transport costs are depending very much on volumes, beside the distance of course.

CO_2 pipelines in operation in the USA

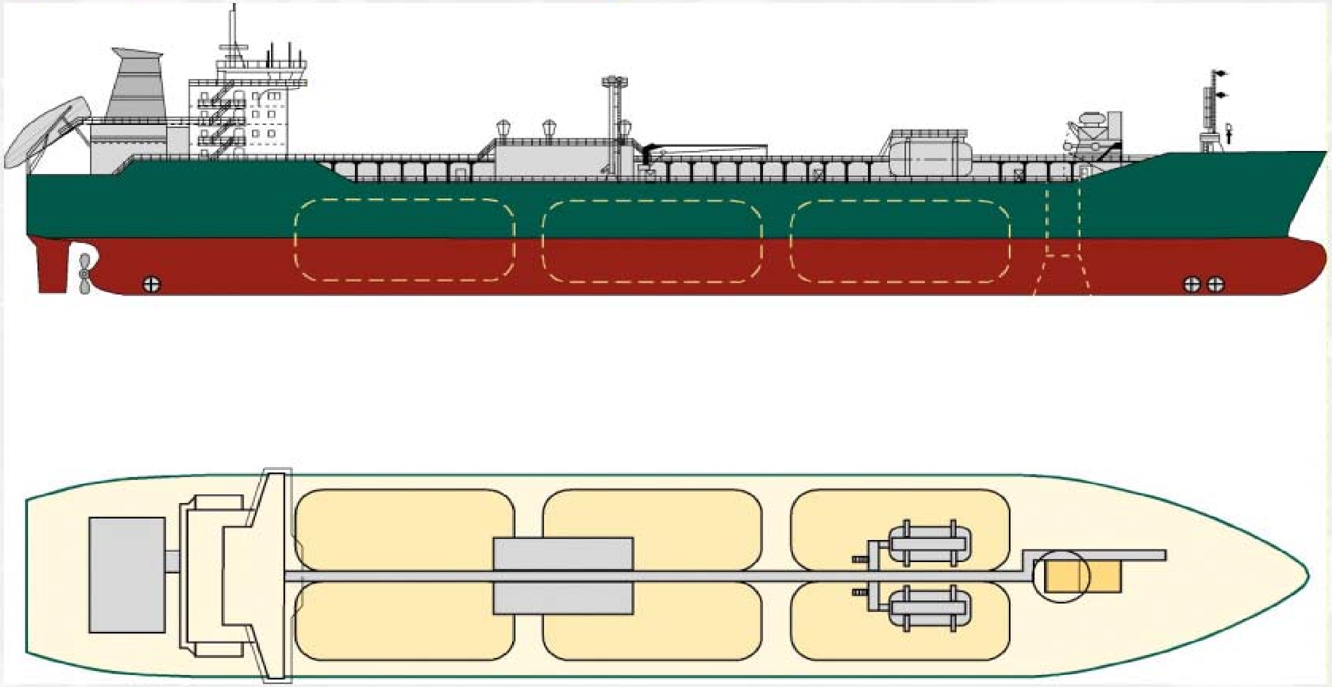
Transportation with water carriers

STATOIL

Transportation of CO_2 in Semi-Cooled Ships.

Illustrated ship has a carrying capacity of 20 000 m3

Project participants: Navion, SINTEF, Vigor and Statoil



The technical solutions

Carbon dioxide capture

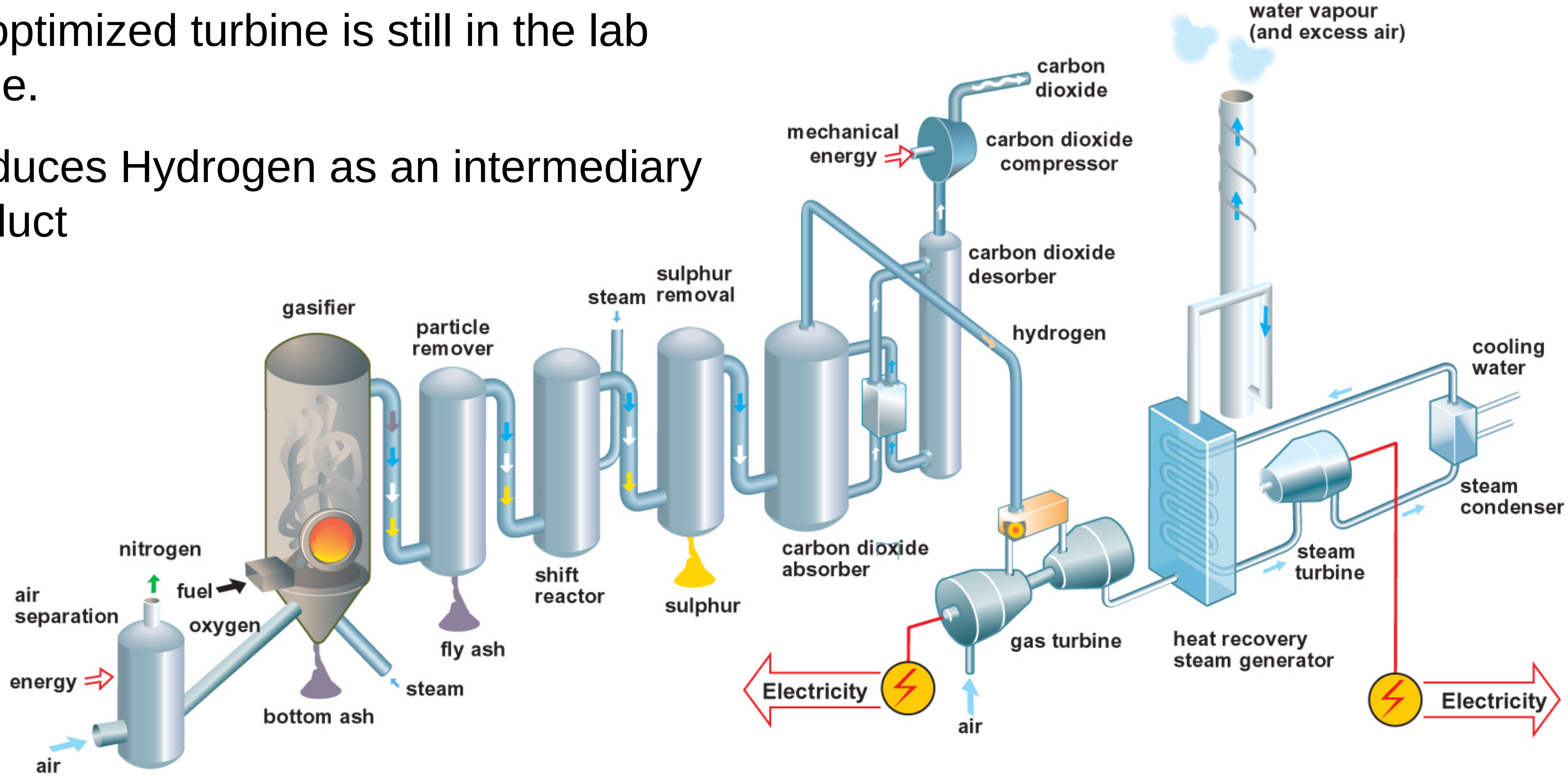
- Three capture technologies have chance to reach commercial status in 2020.
- Other technologies, superior to the first, exists but cannot be ready in time.
- There is no „silver bullet“ and several technologies will coexist in the future, adopted to different plants and situations.
- All technologies with components and systems are known, but scale-up and integration to a complete plant is needed.

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



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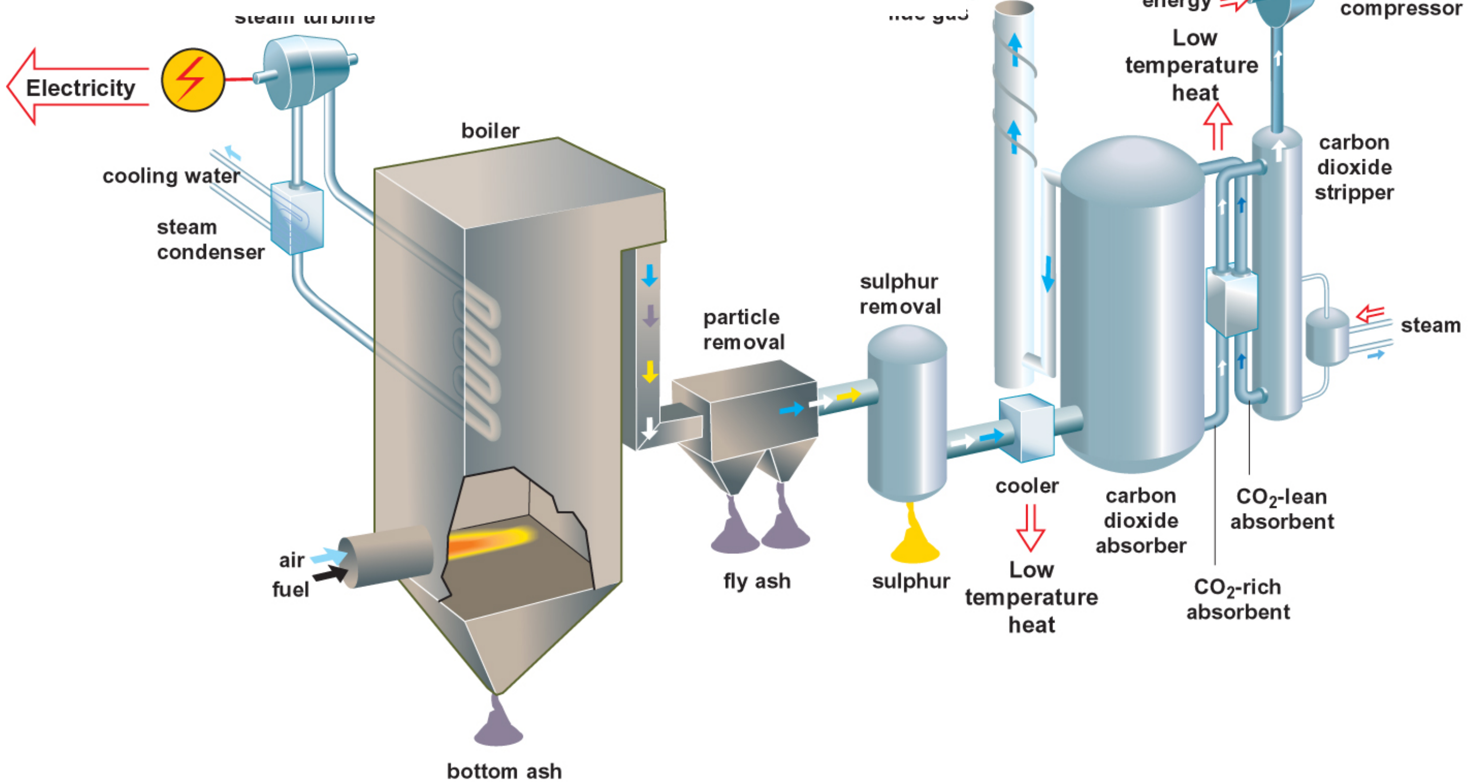
Post-combustion capture

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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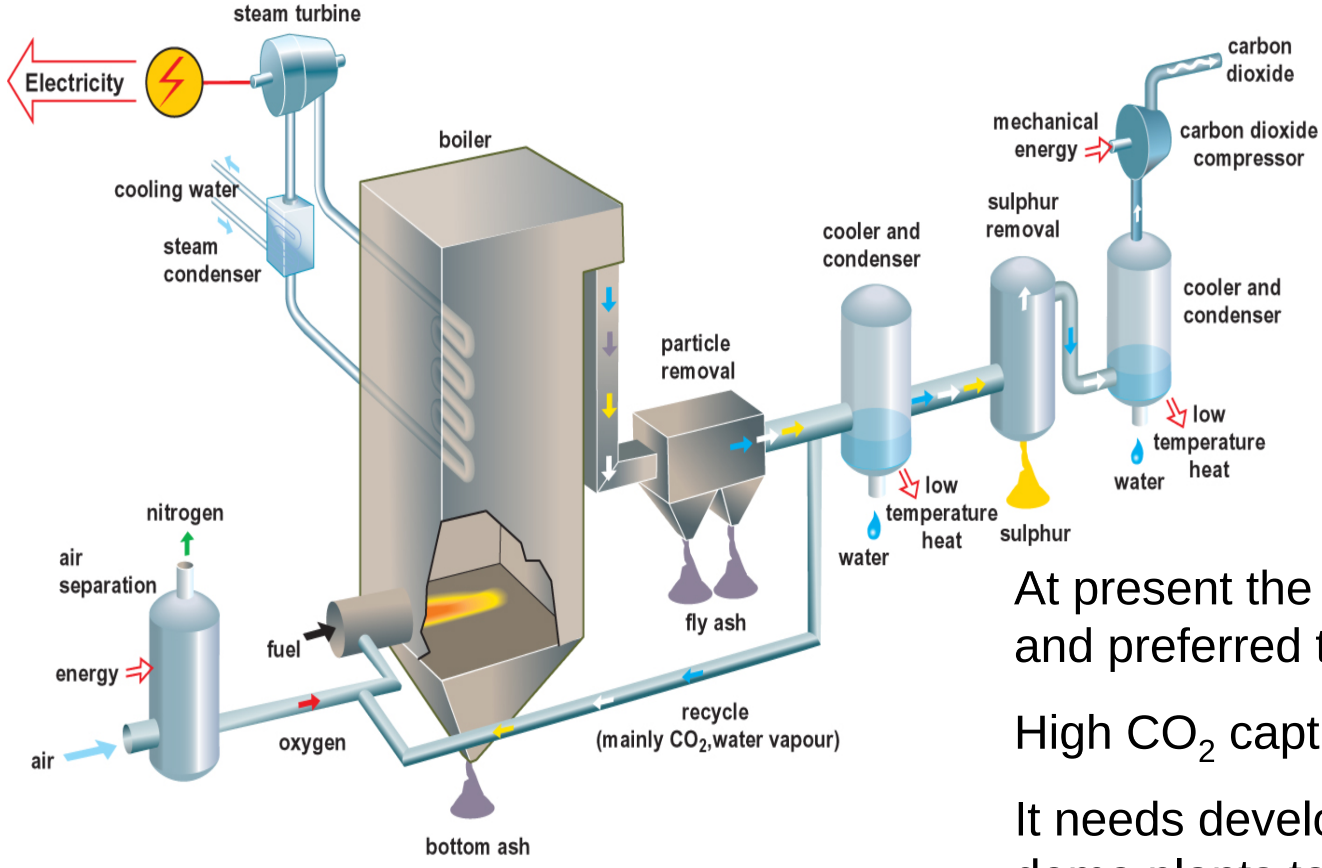
O_2/CO_2 (oxyfuel) combustion a preferred option



At present the most competitive and preferred technology for coal.

High CO_2 capture rate.

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

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The cost to avoid CO_2 emissions

Cost calculations

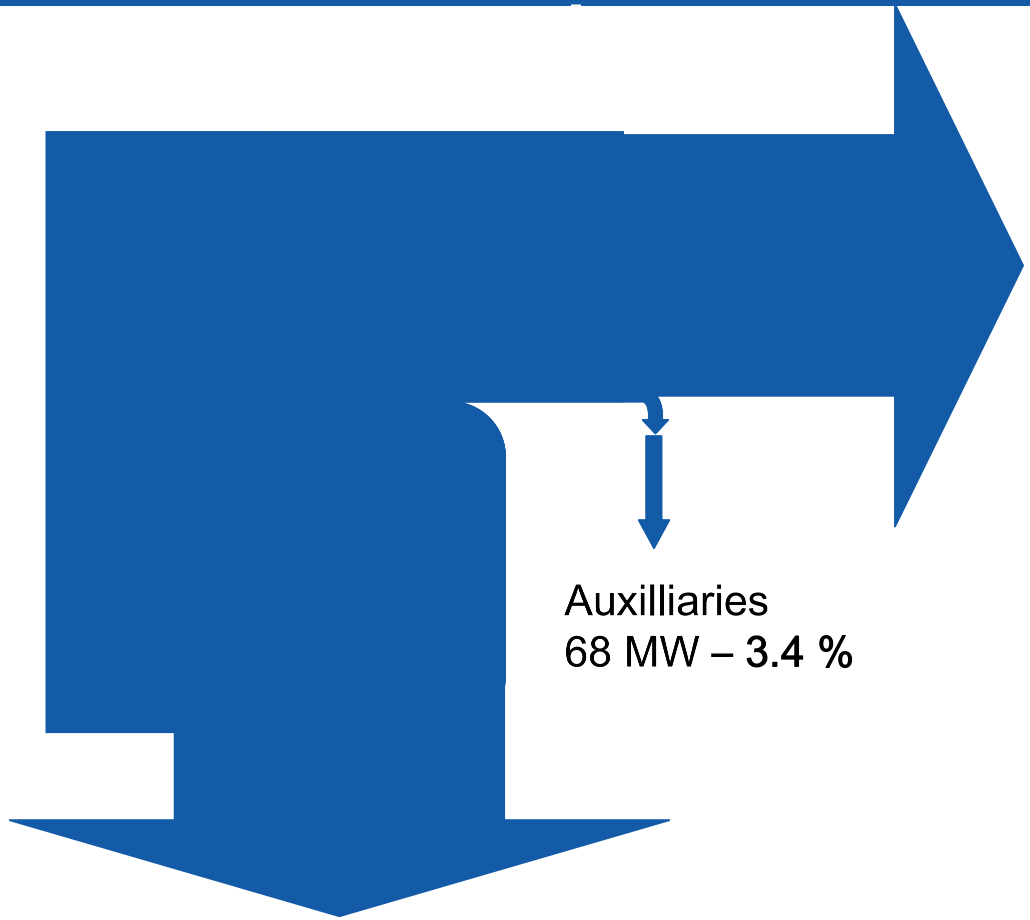
Many figures are floating around, between 0 and 100 €/tonne, depending on the assumptions

- Economic calculation principles
- Time
- Small – large
- Fuel choice
- First of a kind – demo – mature technology

Cost calculations

- Avoidance cost is the extra cost to avoid emission from a plant, but still producing the same amount of useful energy.
- The avoidance costs stem from
  - Higher investment costs for the plant
  - The capture costs energy, or expressed in another way: a CCS plant has lower efficiency
  - Maintenance will be higher and availability will be lower for a CCS plant
  - Cost for transport of the CO_2
  - Cost for storing the CO_2
- The avoidance cost is related to an alternative
  - A similar plant without CCS

Energy flow diagram for a lignite fired power plant



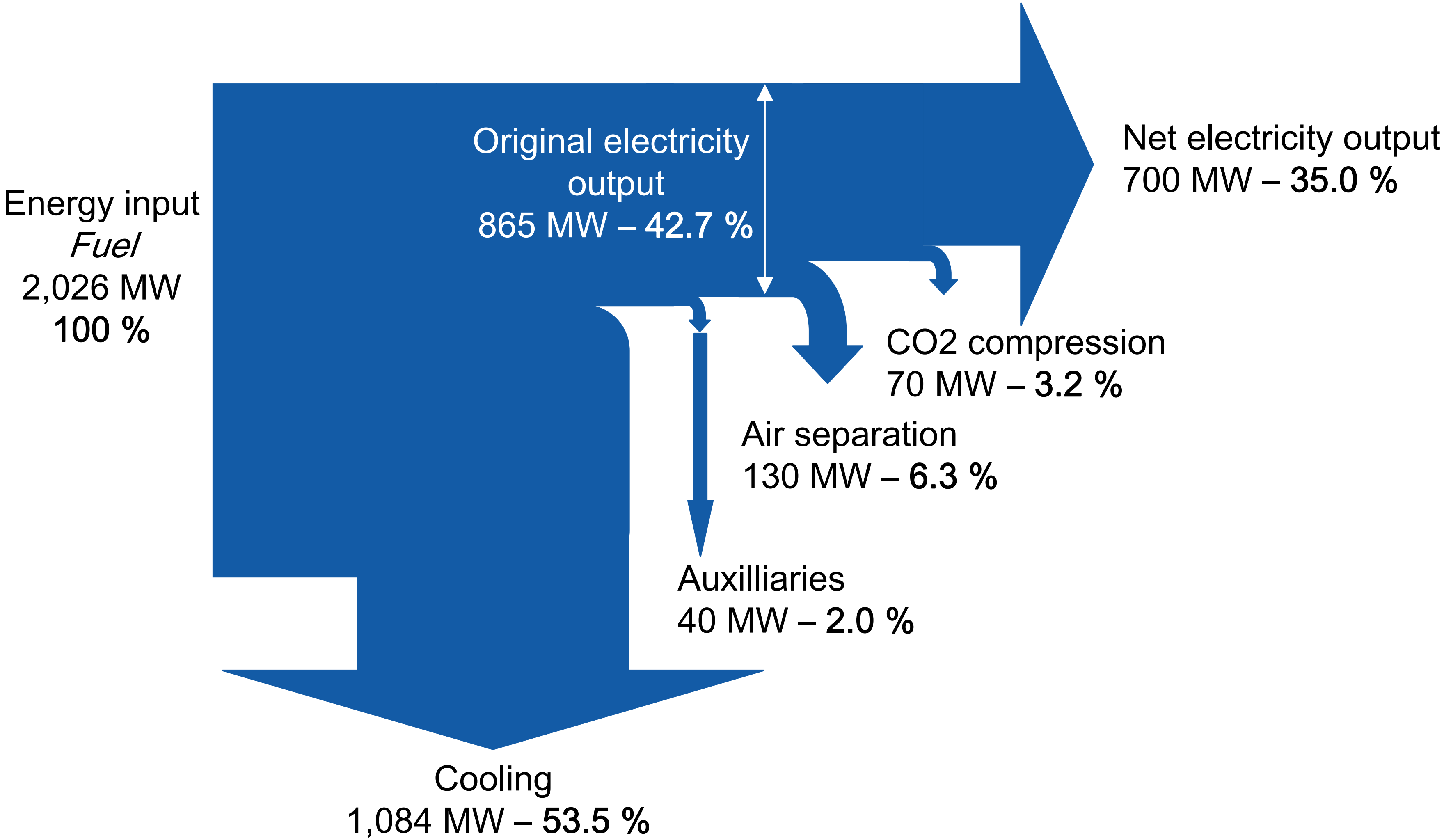
Energy input
Fuel
2,026 MW
100 %

Net electricity output
865 MW – **42.7 %**

Auxilliaries
68 MW – **3.4 %**

Cooling
1,093 MW – **53.9%**

Energy flow diagram for lignite fired plant
with O_2/CO_2 combustion



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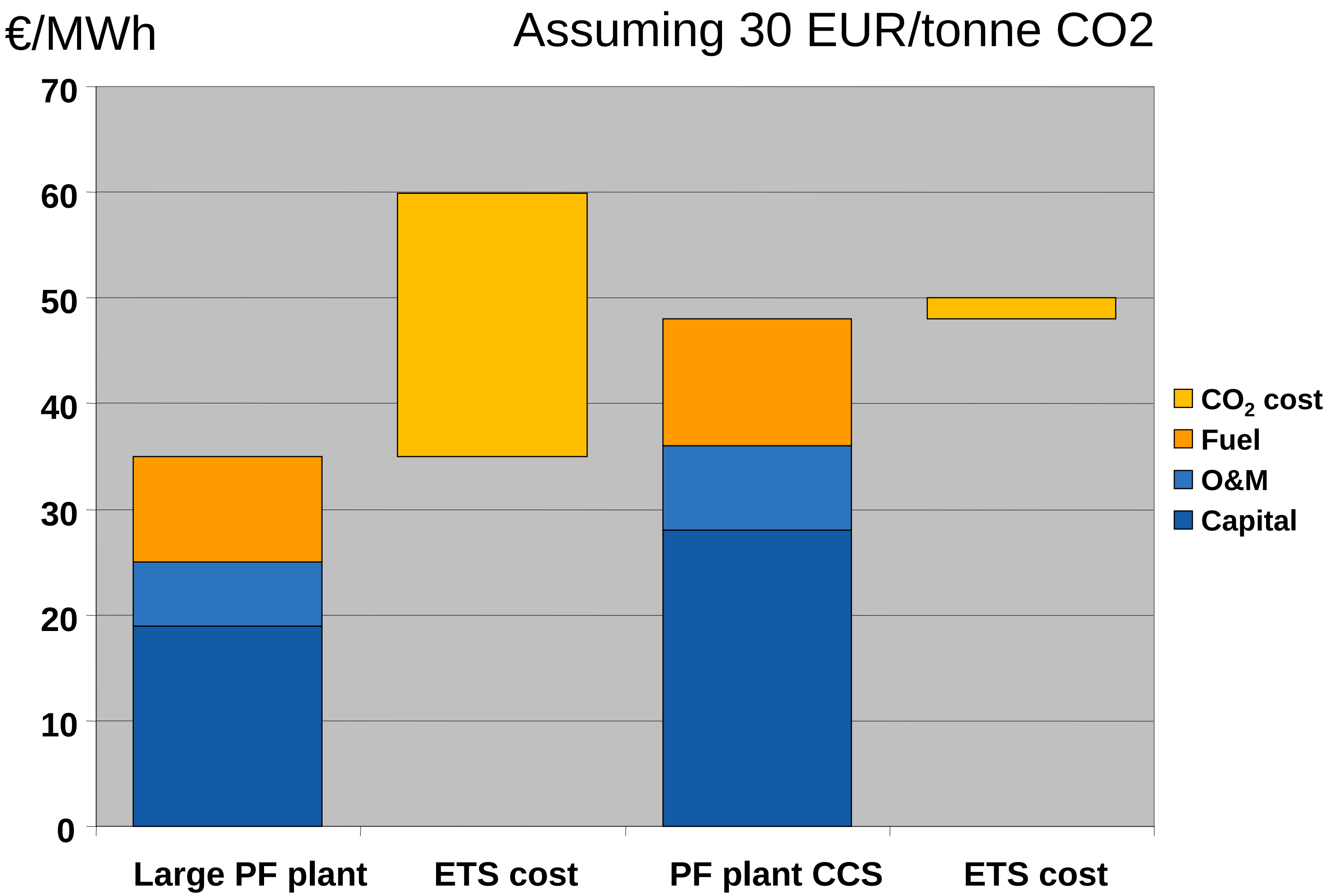
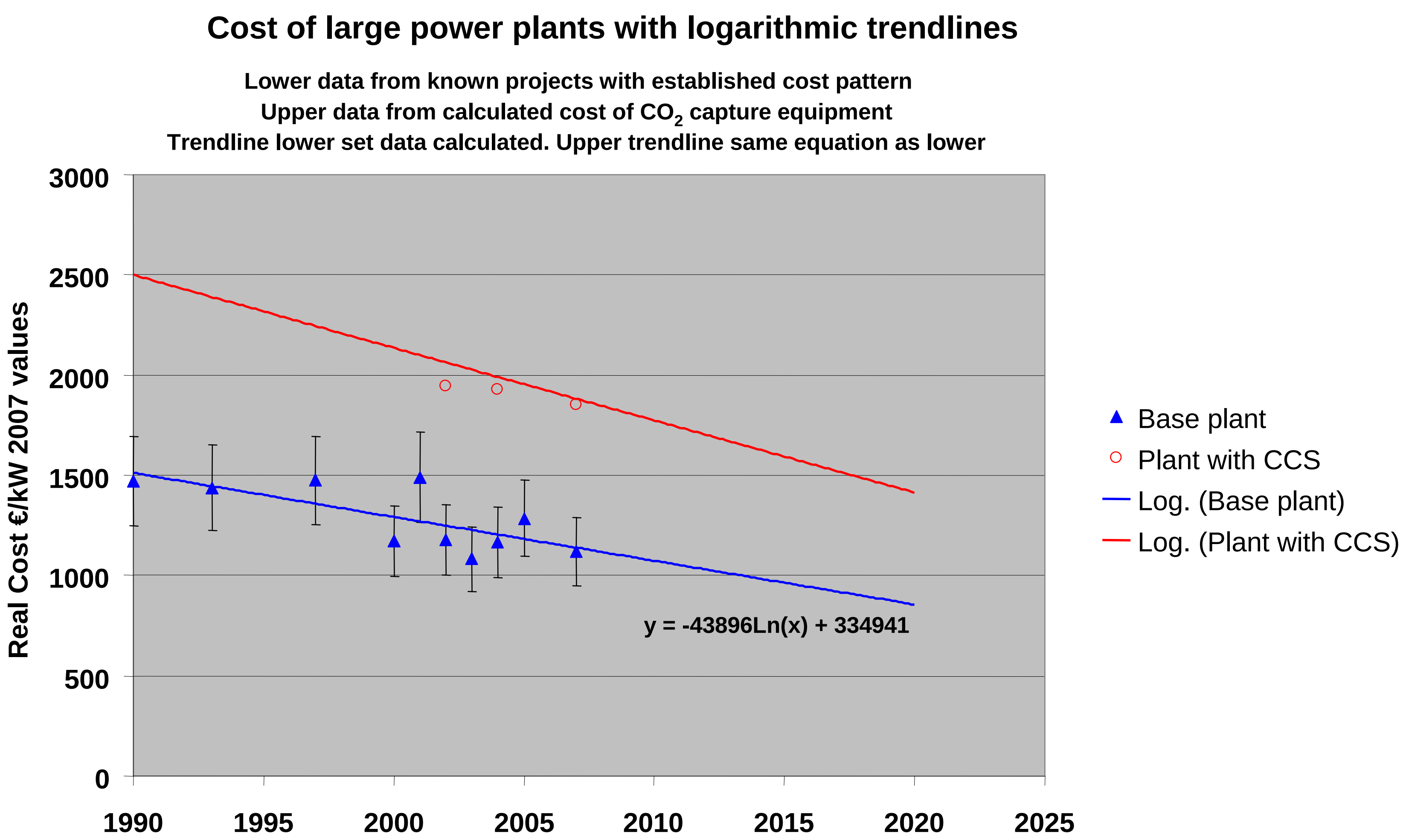
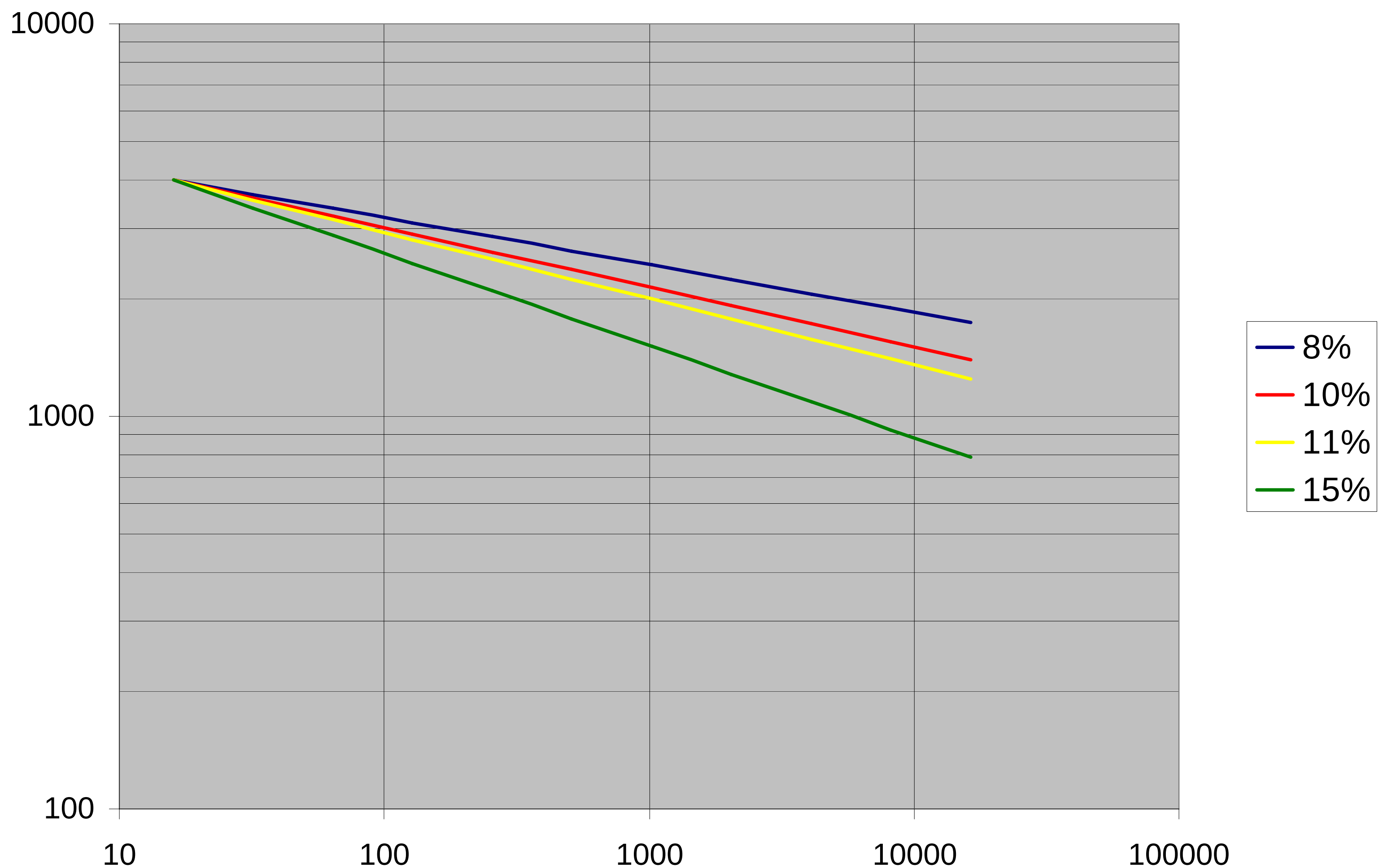
Electricity generation costs



Investment costs for large power plants



Learning curves



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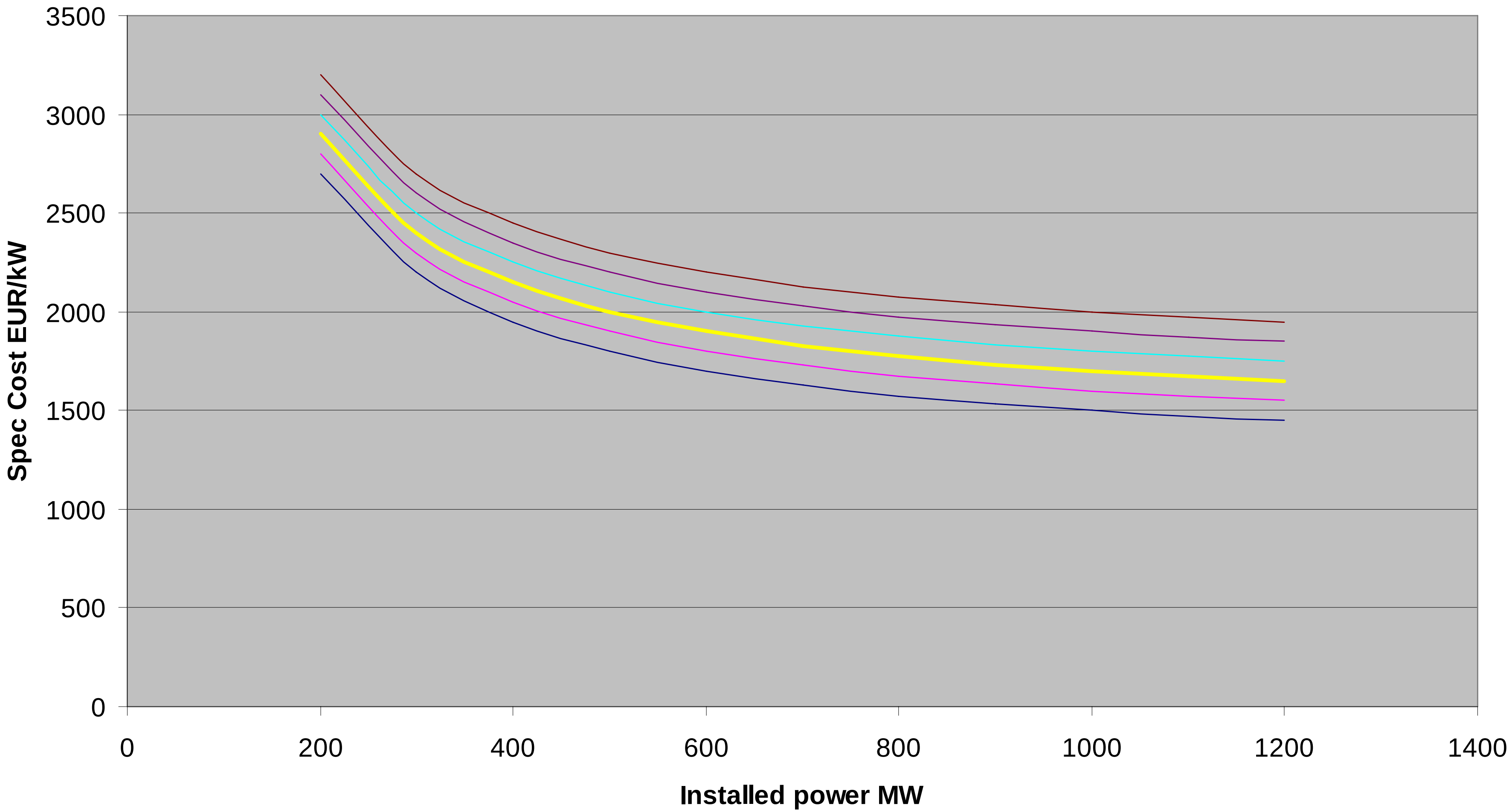
Specific investment for varying size of plant



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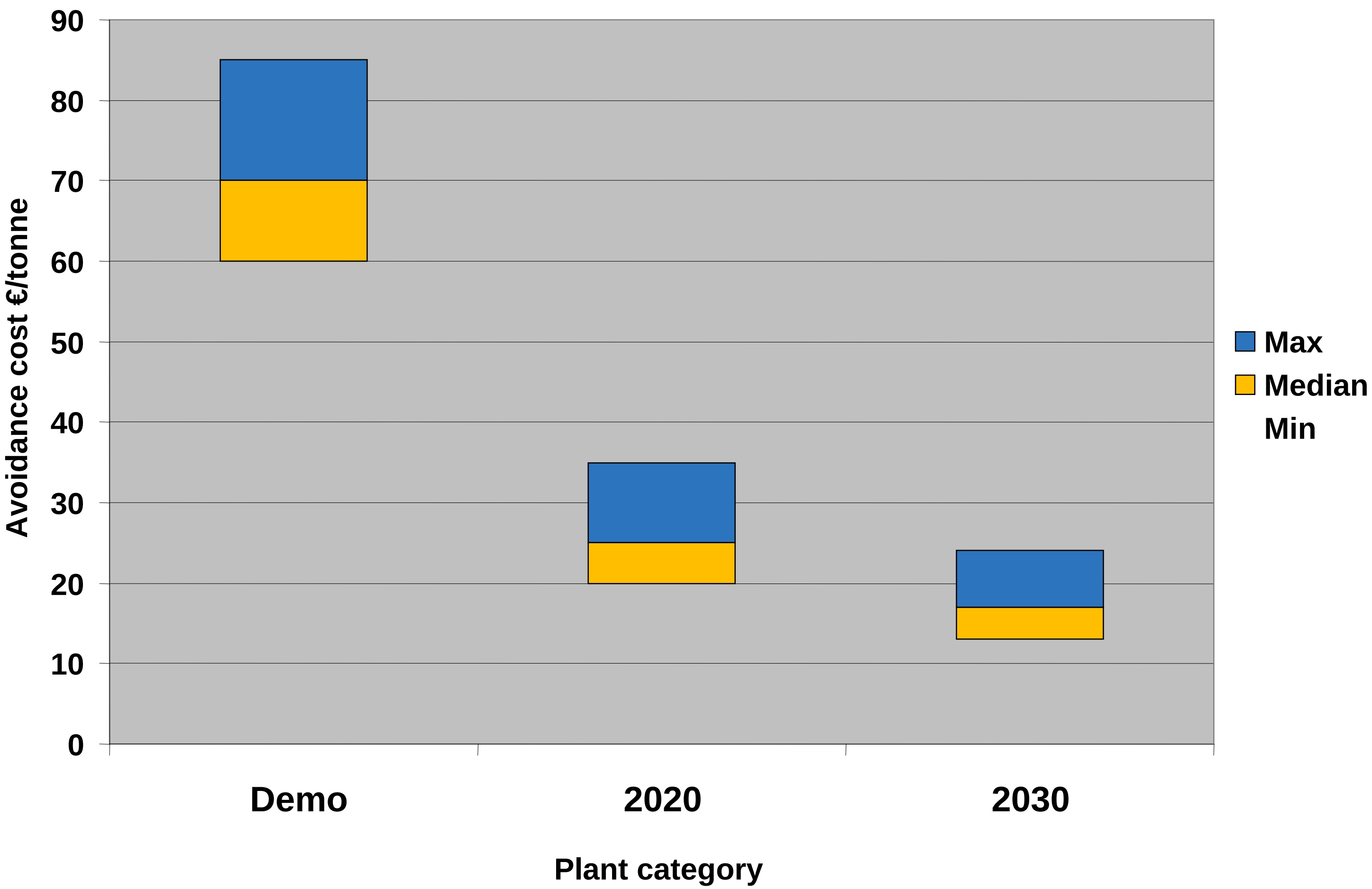
Cost development over time for CCS



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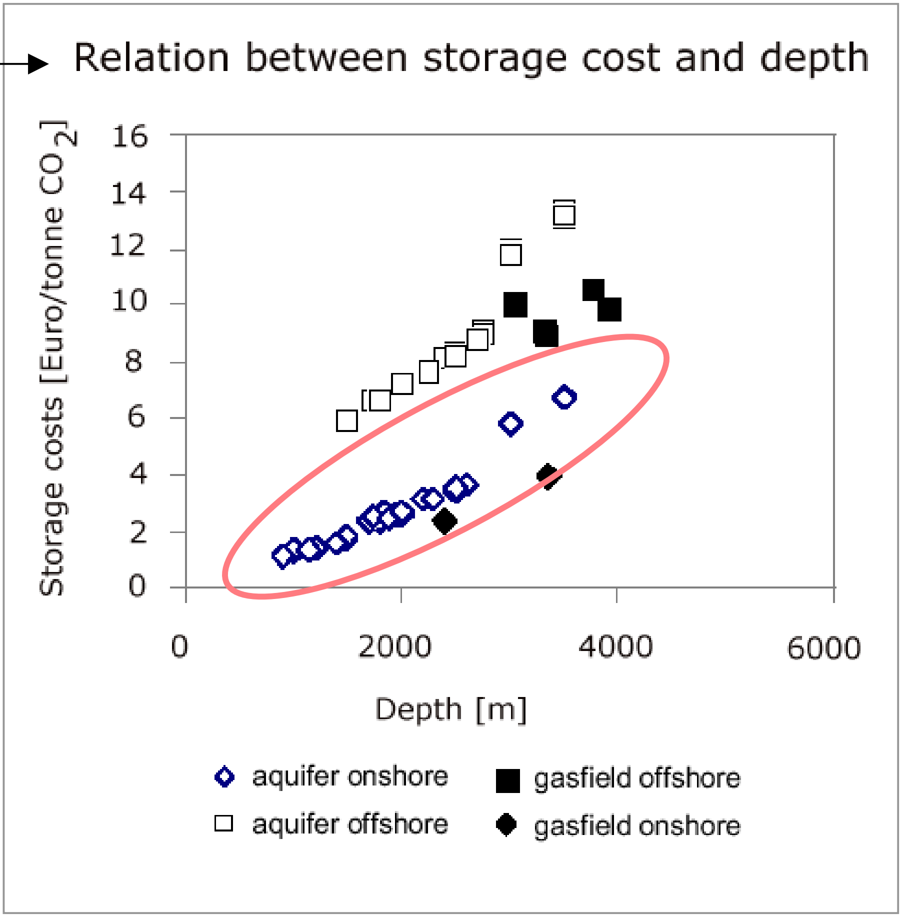
Storage cost estimates

Storage in aquifer traps (GESTCO Figures)

- Costs depend strongly on the depth of subsurface layers used for storage.
- The costs consist of mainly three parts
  - — The drilling cost dominates.
  - — The closure cost is significant, but relatively seen as small.
  - — The operating cost over 40 – 50 years is low, but in total second largest.



Källa: Christian Bernestone, Gestco

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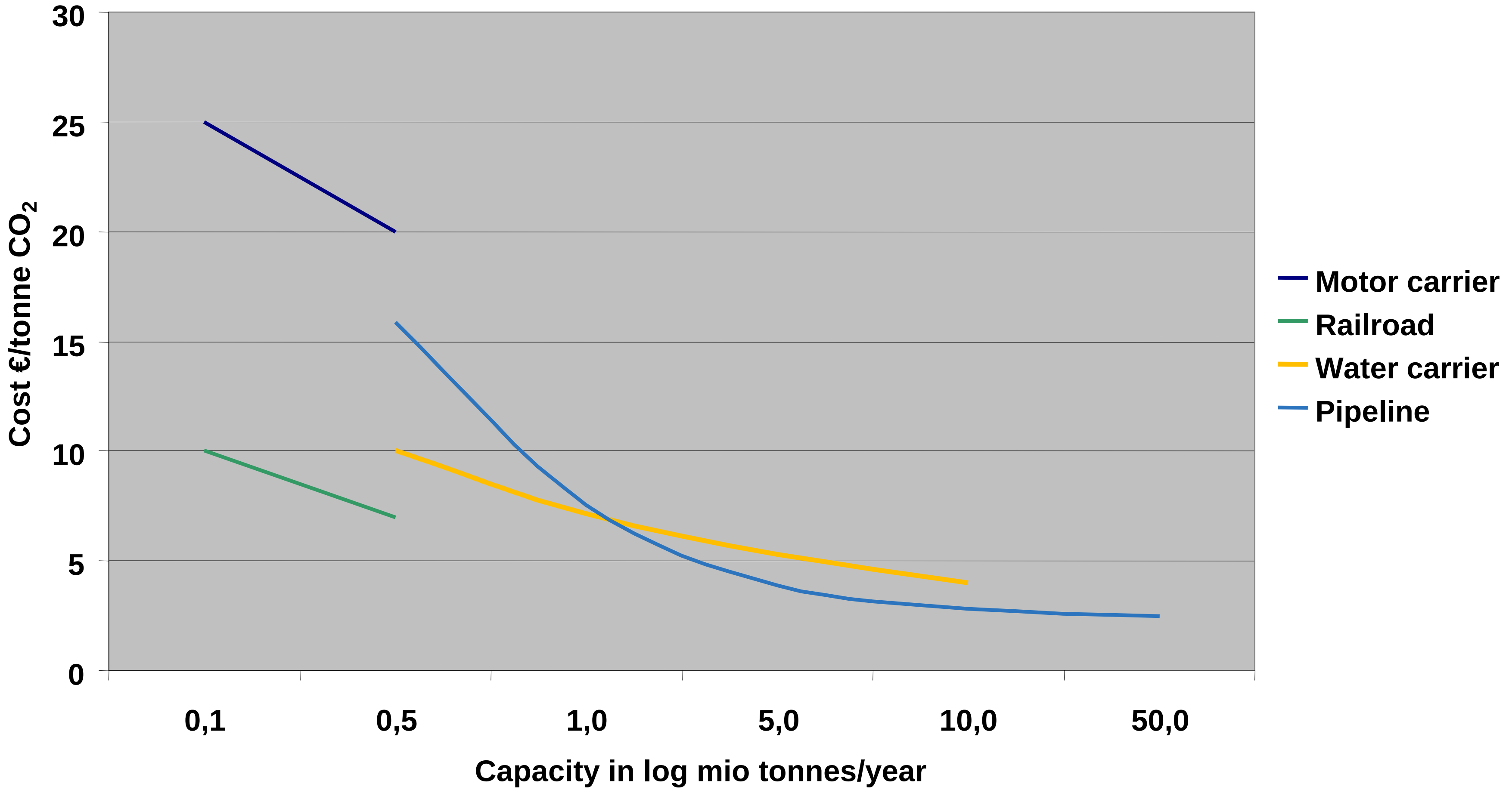
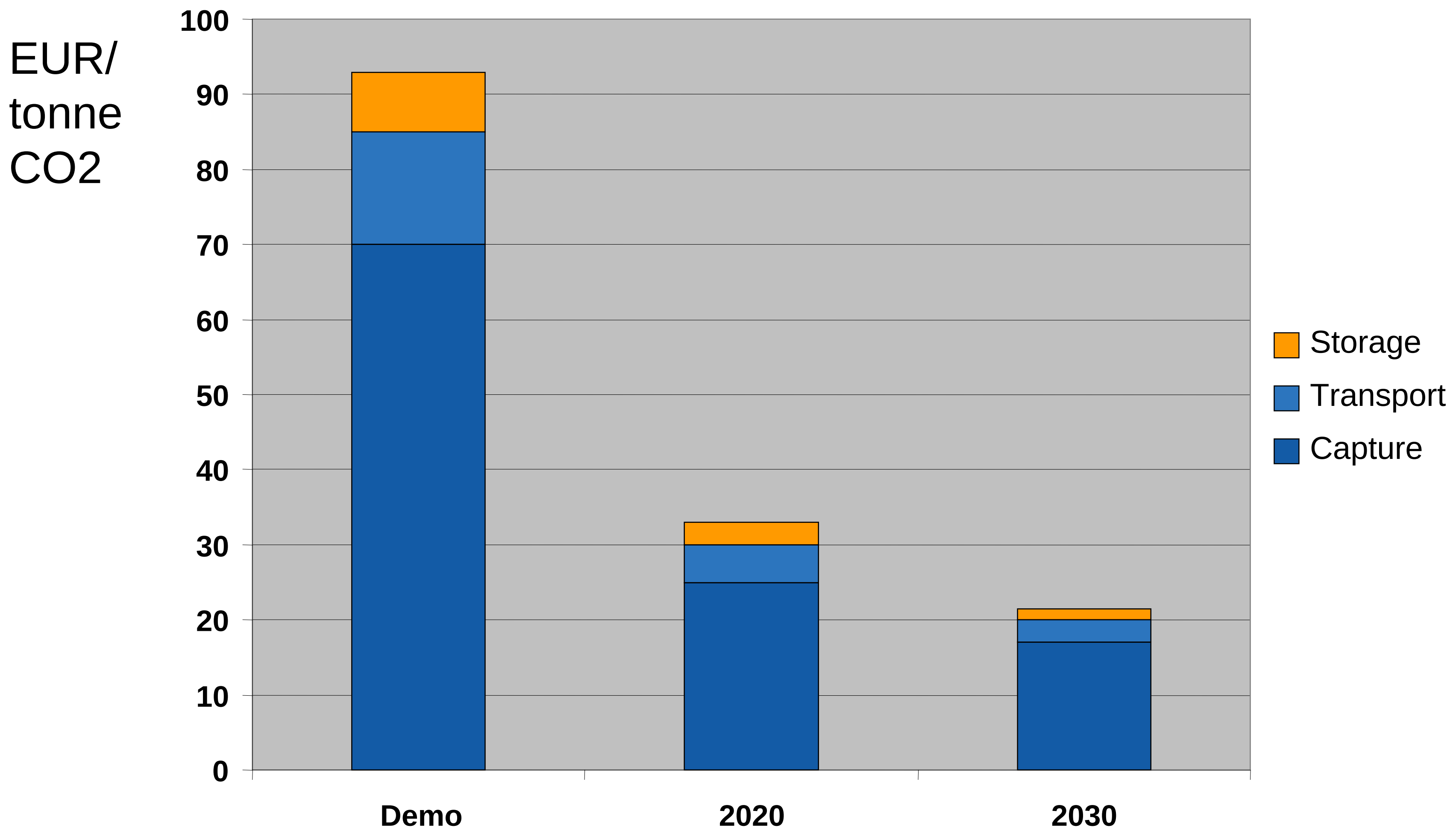
Transport costs for CO_2 - cost and capacity ranges



Source: Odenberger M, Svensson R, Analysis of Transportation Systems for CO2, Chalmers, 2003

Total cost, including transport and storage



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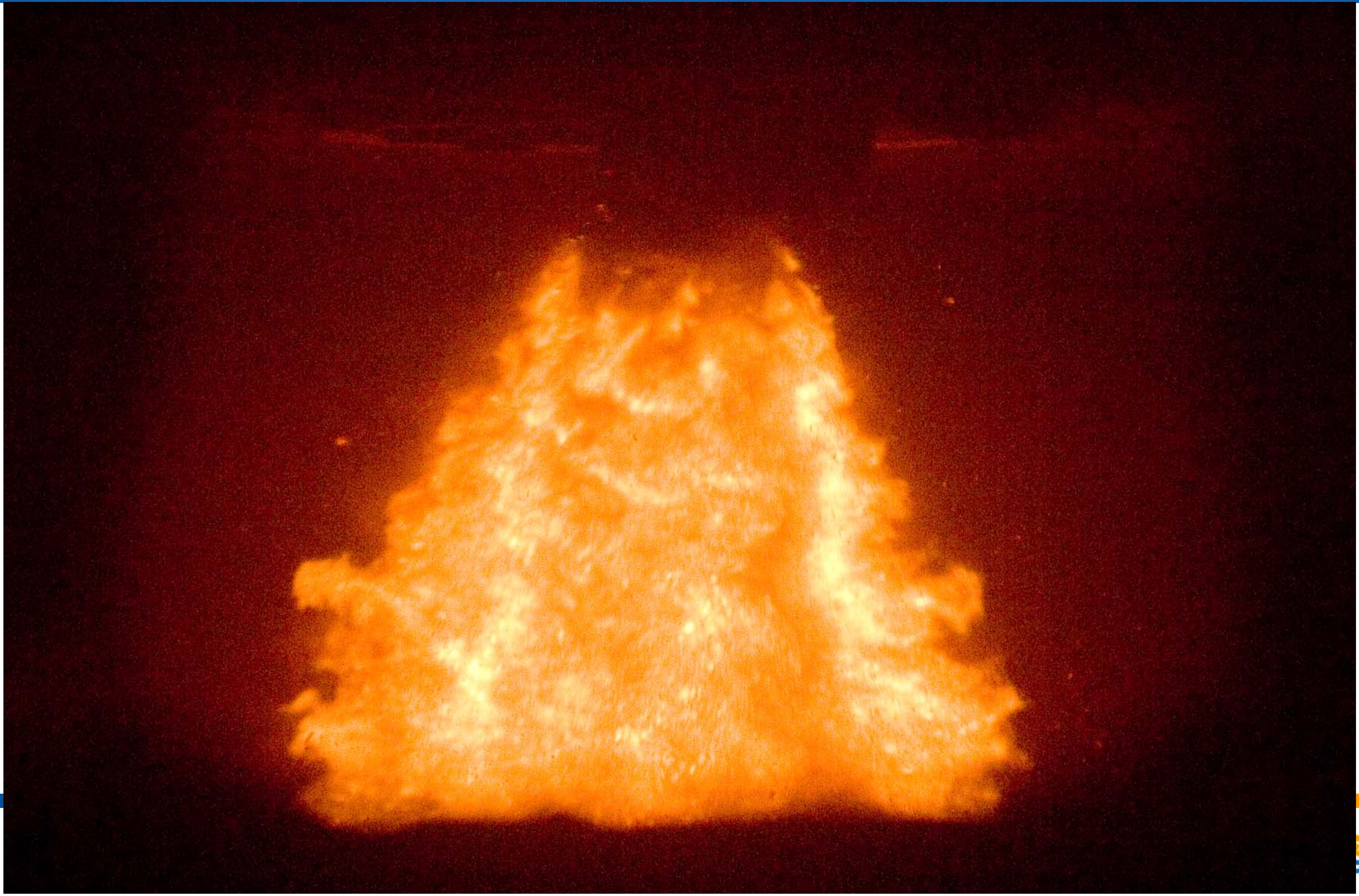
From R&D to the real thing

Chalmers Oxyfuel test rig (Coal and Air)

Chalmers Oxyfuel test rig (Coal and 27 % oxygen)



10 years of continuous research – 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, 400 mton	Post-combustion and oxyfuel
Operation	2008	2010	2009	Ca 2015

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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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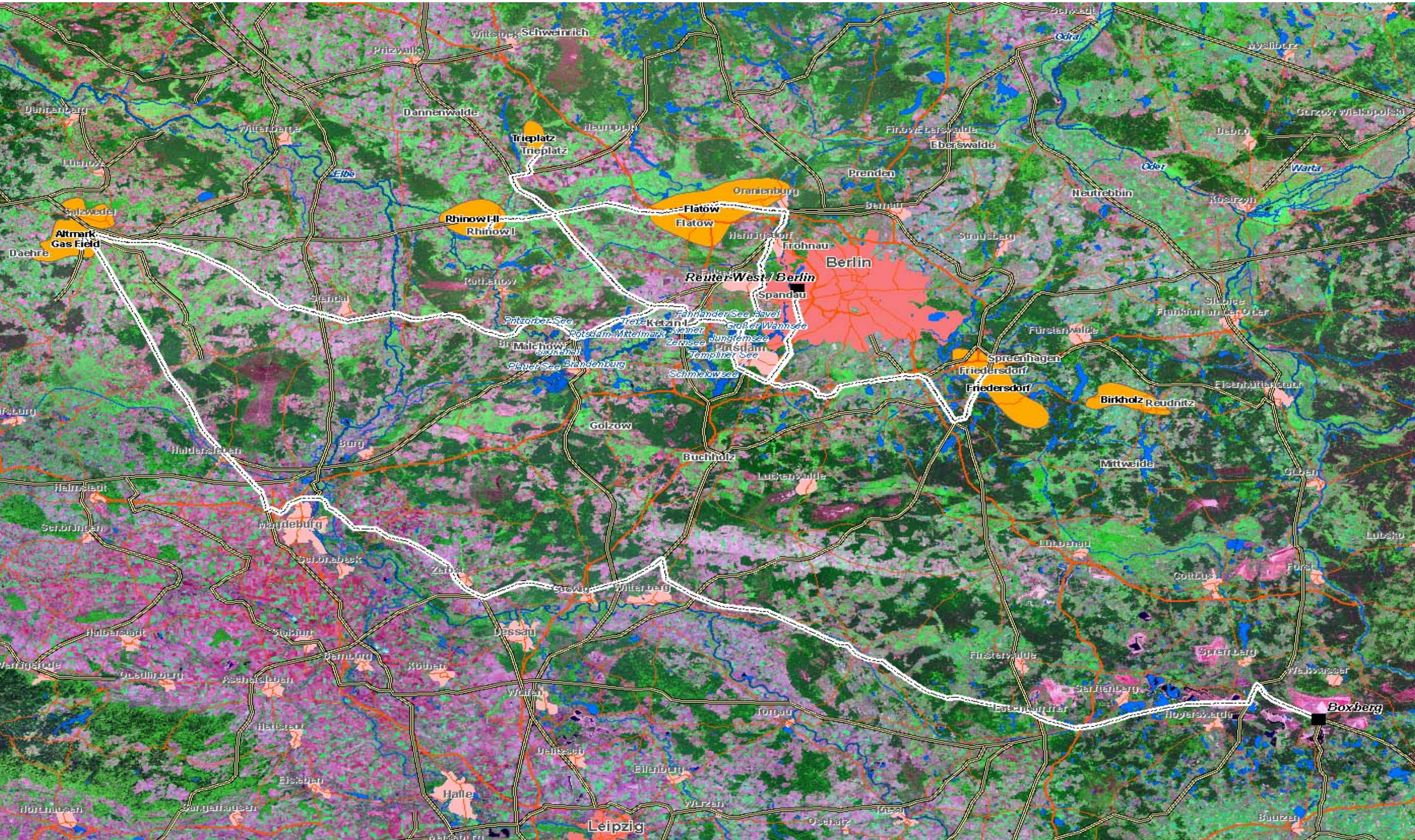
Map over preliminary pipeline routes

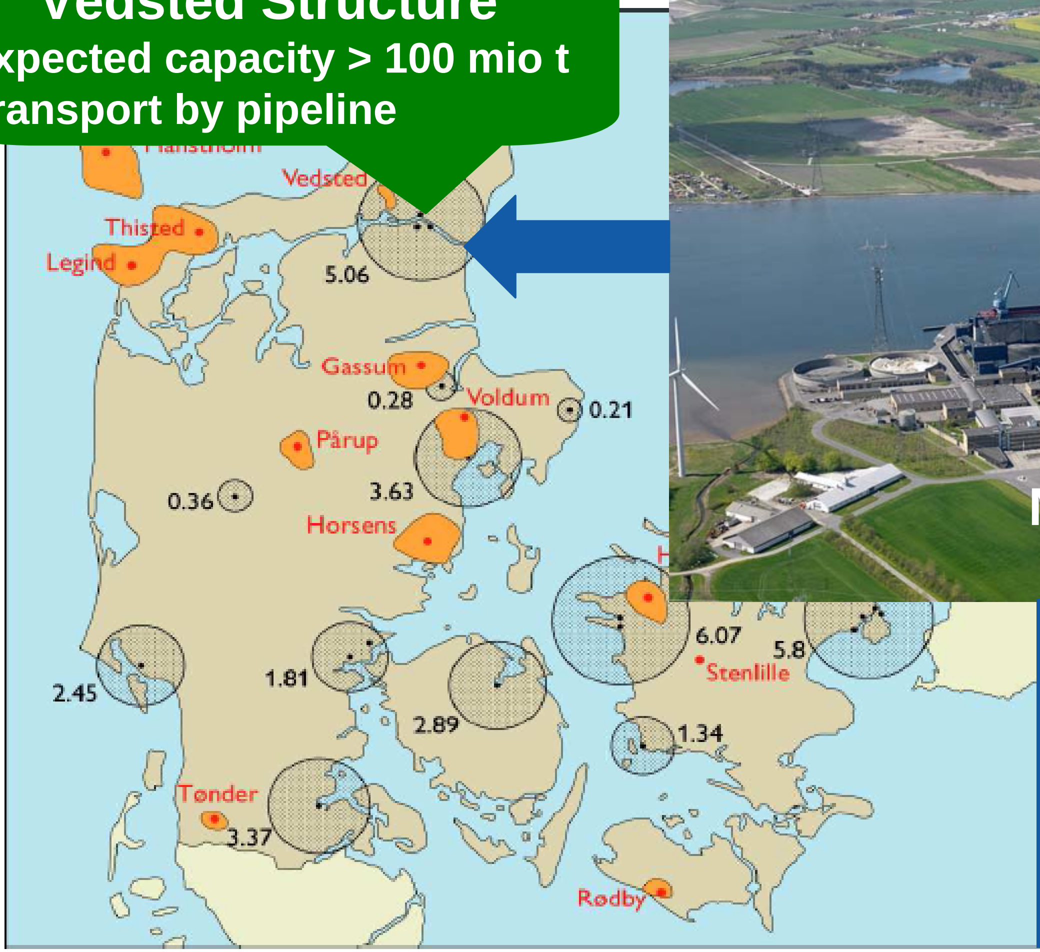


CCS demo project close to Aalborg, Denmark

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 %

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DALUISO A/S
4-6 vibrator trucks 25 tonnes
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

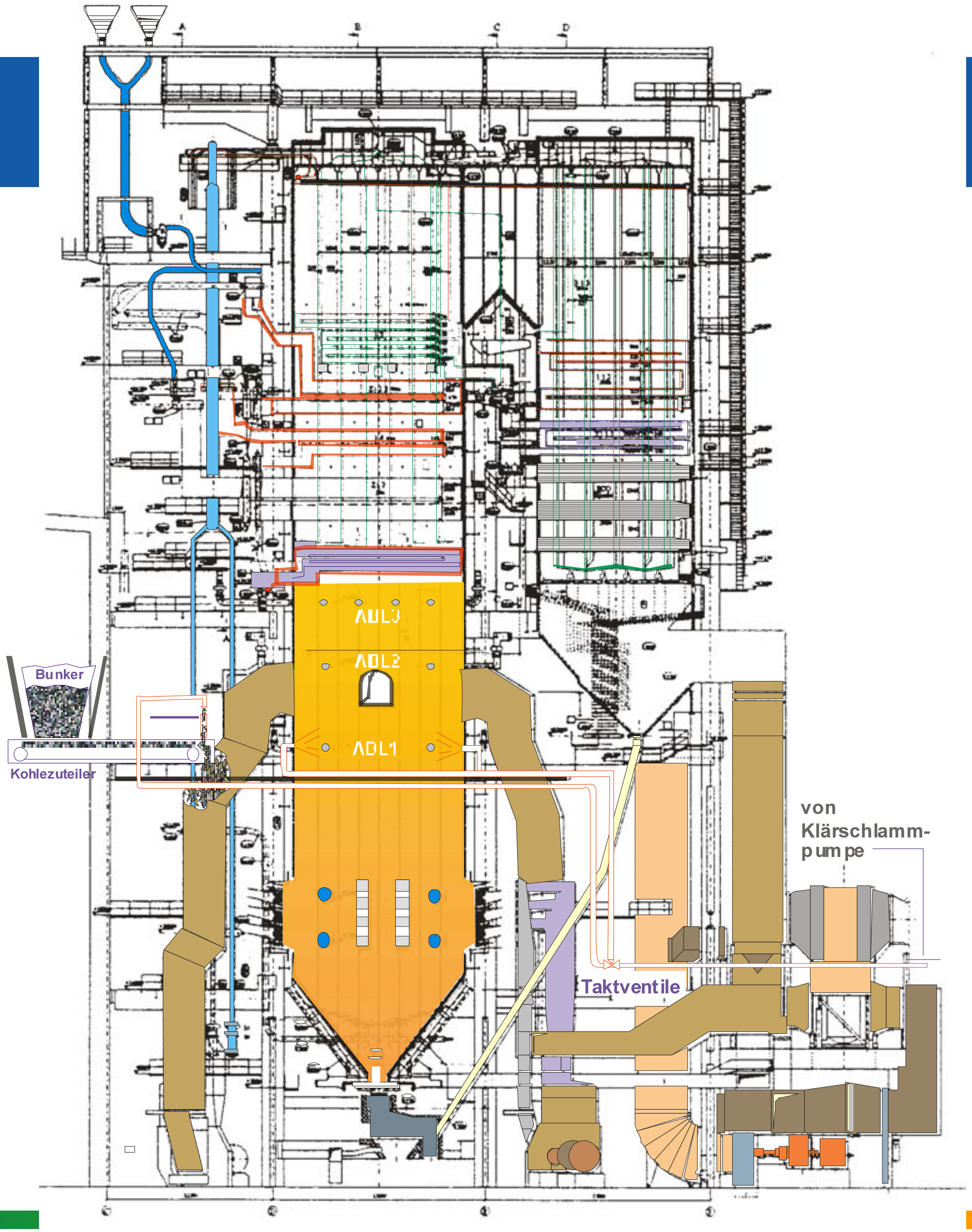
The oxyfuel pilot plant

Boxberg IV

Why Oxy-fuel technology ?

We work with all technologies, but:

- Oxyfuel technology is the technology giving lowest costs at present.
- It is suitable for coal and have relatively little development work left.
- We can build on our good experience with present PF technology.



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Oxyfuel - ”Zero Emission” ????

- It is possible to process the CO_2 after the boiler to reach
  - > 95 % capture rate (100 % technically 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

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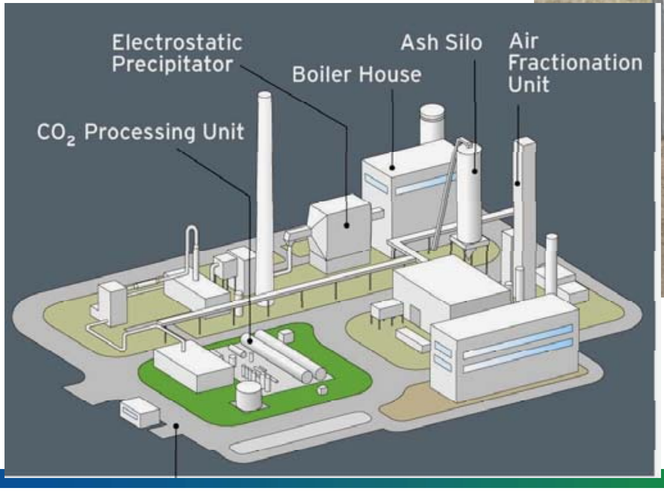
The Pilot CCS Plant

The Pilot Plant's groundbreaking took place in May 2006.

The plant was commissioned in July 2008



View of the Schwarze Pumpe Pilot Plant June 2008

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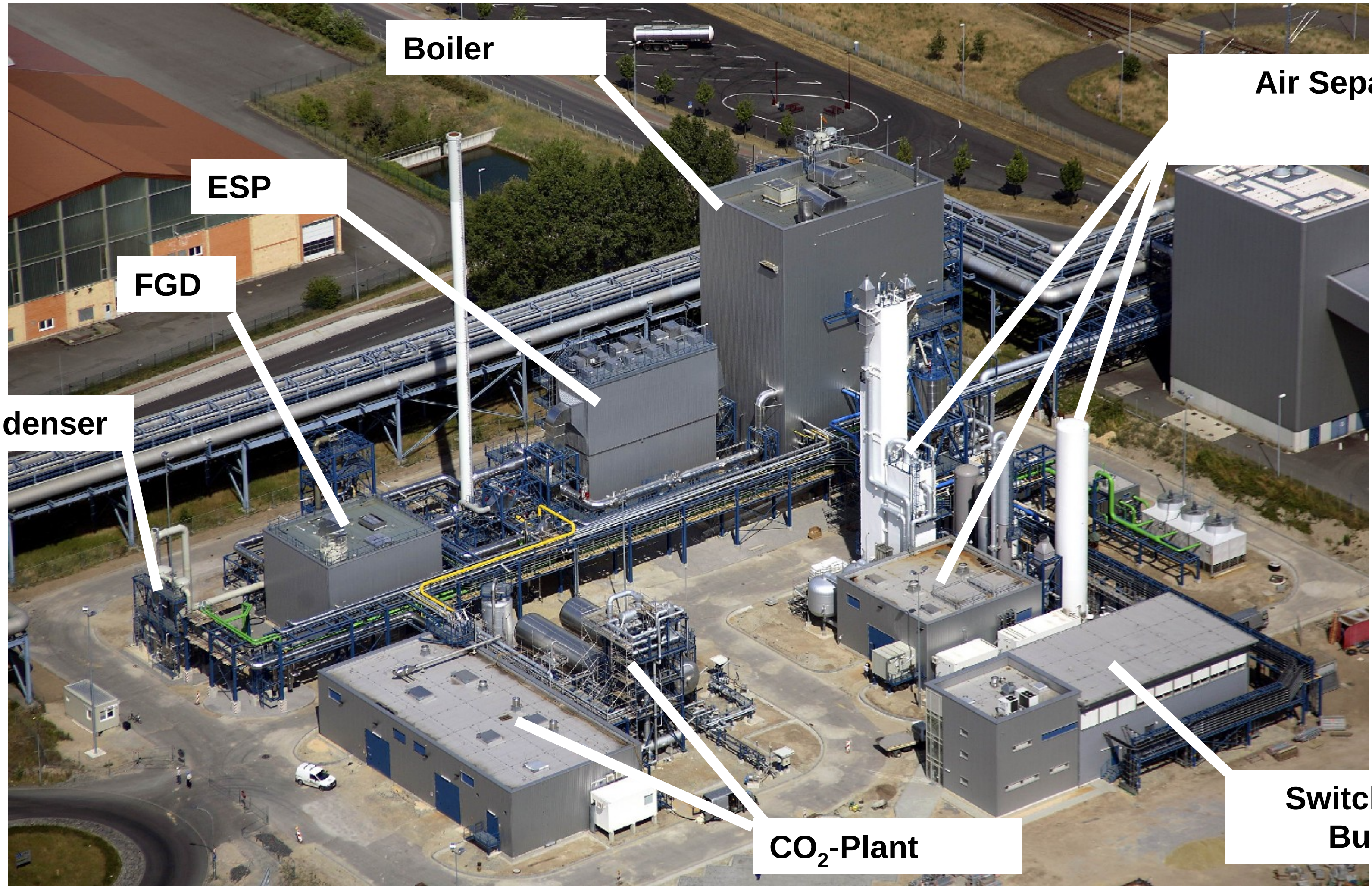
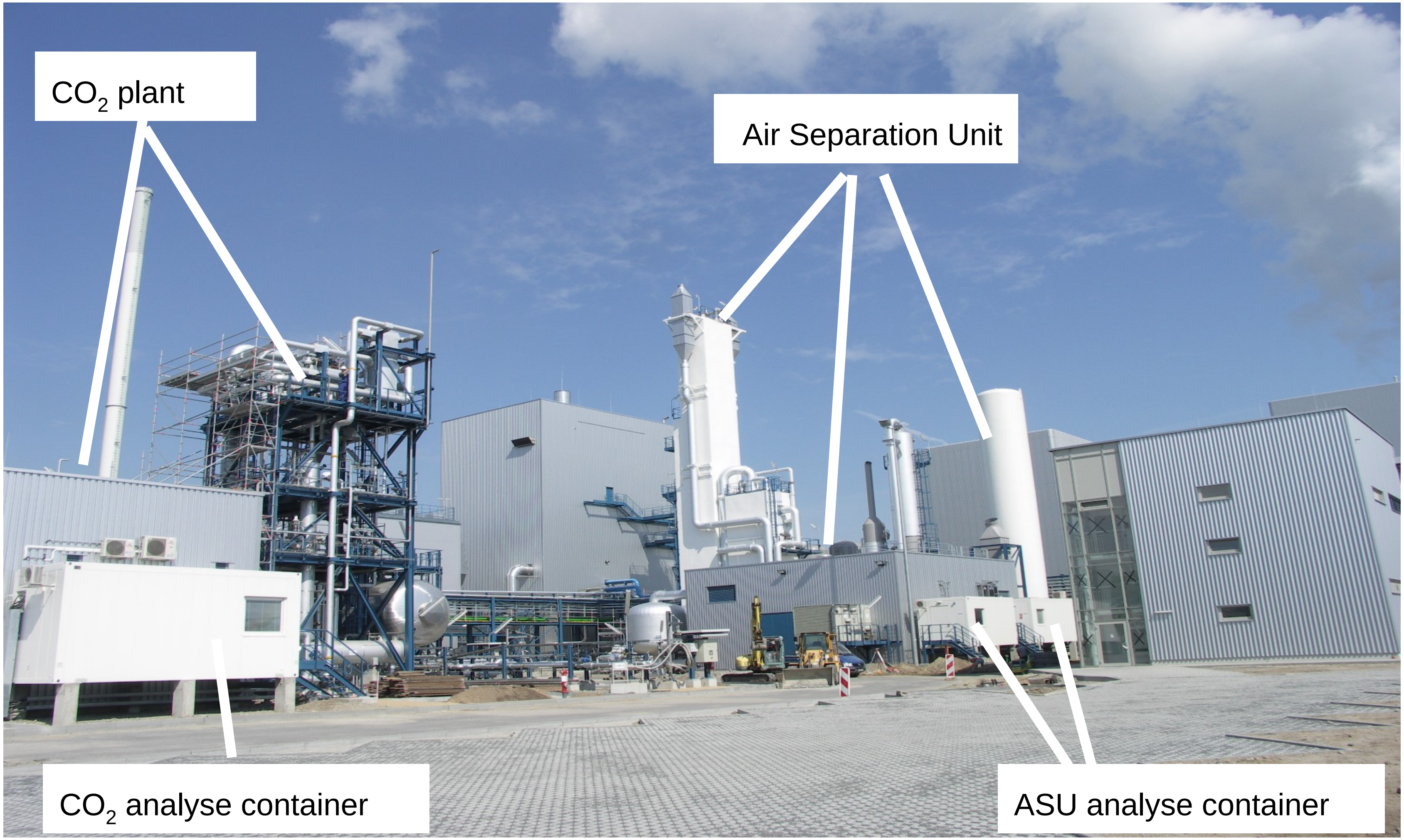
View on building site (June 2008)



New components : ASU and CO_2 plant



CO_2 plant in detail (June 2008)

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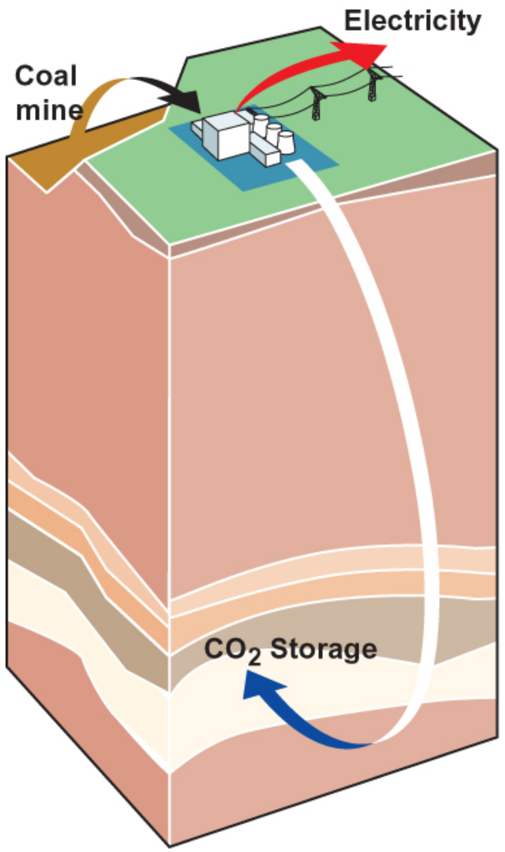
CCS conclusions

We are on the way to realise our visions



We will make it !

I still believe it is possible at a cost around 20 €/tonne

The technology will not be ready until 2020

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

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Ocean Energy

“The next technology to be commercially viable”

A small but substantial potential in some locations.

Thank you for your attention!

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