Oxyfuel combustion has come a long way, but……

IEAGHG 2nd Oxyfuel Conference 2011

11th – 16th of Sept 2011

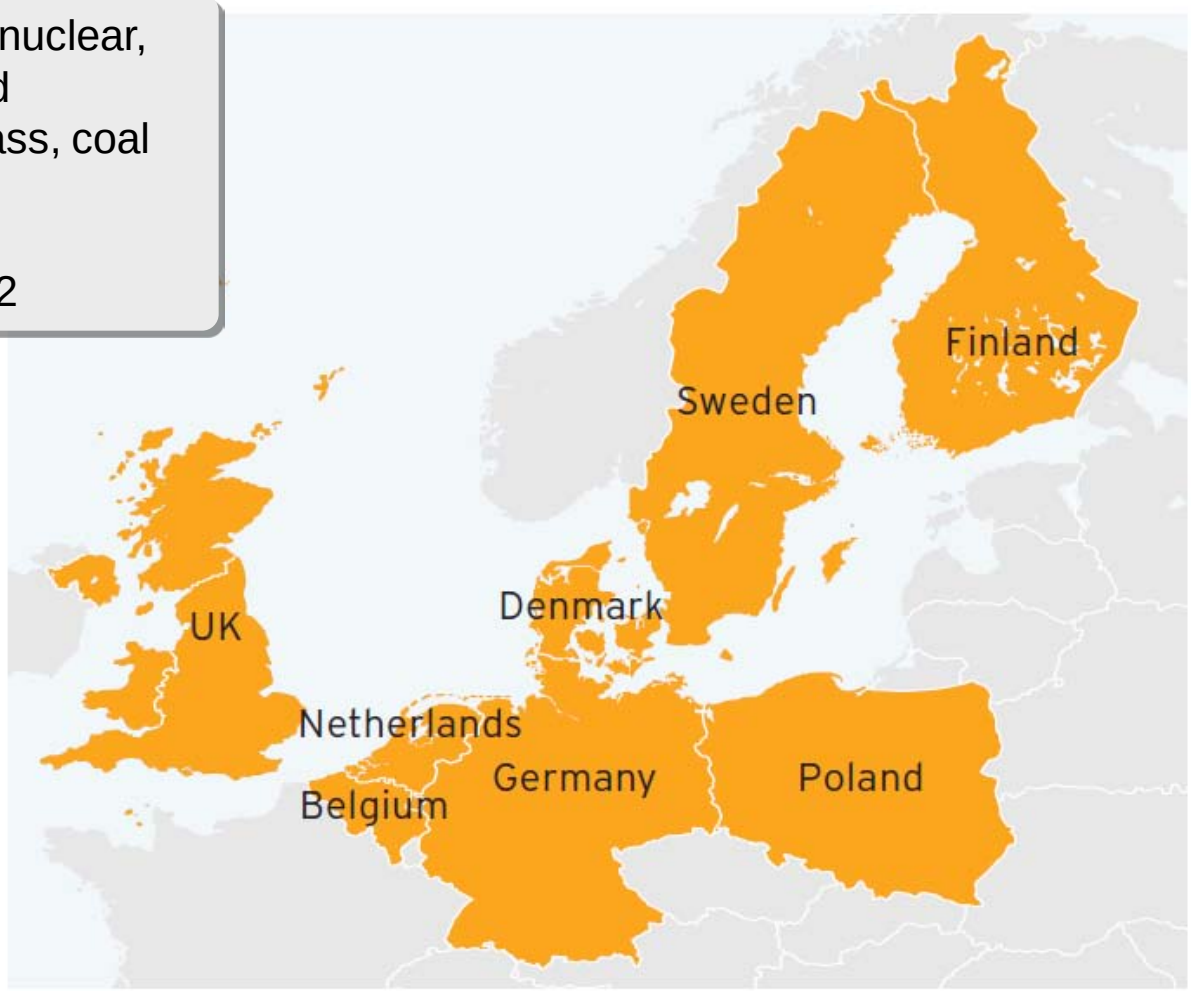
Yeppoon QD, Australia

Lars Strömberg

Vattenfall AB

Vattenfall – A leading European energy company

- 200 TWh electricity - nuclear, hydro, coal, gas, wind
- 40 TWh heat – biomass, coal gas
- 40 000 employees
- 90 million tons of CO2



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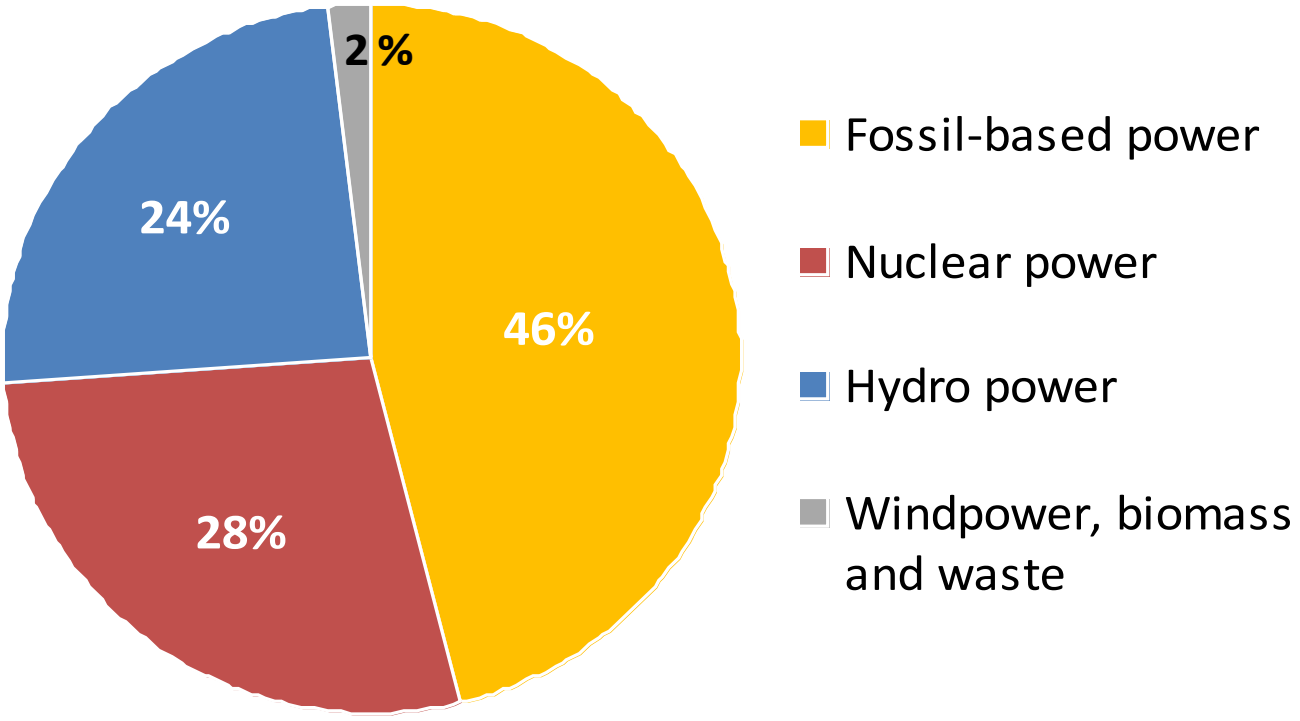
Generation portfolio totalling about 40,000 MW



* Vattenfall has 1200 MW installed capacity from wind and 600 MW under construction.

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CCS - Roadmap to realisation

Conceptual investigations

Experimental Research

0.1 – 0.5 MW_{th}

< €10 million

Pilot plant

30 MW_{th}

€ 100 million

Demonstration plant

300 – 700 MW_{th}

~ € 1000 million

Commercial concept:

~ 1000 MW_{th}

1999

- Theoretical studies

2002

- Research
- Basic principles
- Combustion characteristics

2008

- Demonstration of the process chain
- Interaction of components
- Validation of basic principles and scale-up criteria
- Long term characteristics
- Non-commercial

2013 – 2015

- Verification and optimization of the component choice, the process and reduction of risks
- Must be commercially viable incl. subsidies

2020

- Competitive on the market at that time
- No subsidies

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View on Oxyfuel Pilot Plant

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Results until May 2011

Operating hours	**14.200**
Captured amount of CO2	**11.500 t**
CO_2- removal rate	**> 93 %**
CO_2- purity	**> 99.7 %**

-
- Stable oxyfuel operation
- All emission and safety values contained
- Interaction between all plant components and subsystems validated
- Over 50 tests with Boiler, ASU, CO2 plant and all other components
- Plant availability very high
- Integration of a "cold DeNOx"

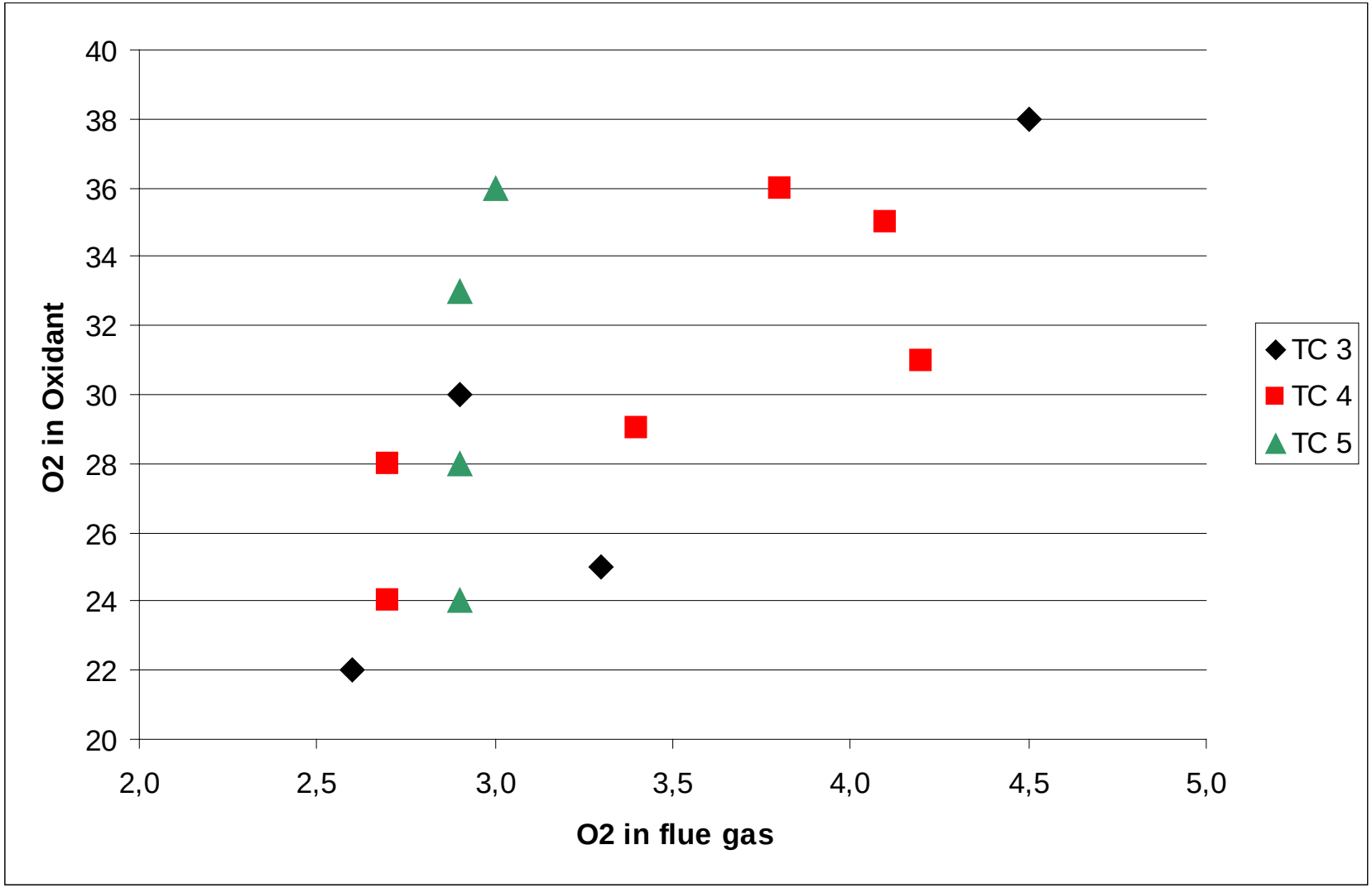
4 different burners tested

New tail end concepts commissioned with good results

Burning coal in the pilot plant

One of the oxyfuel burners

A wide operational envelope – Some experimental settings with one of the burners



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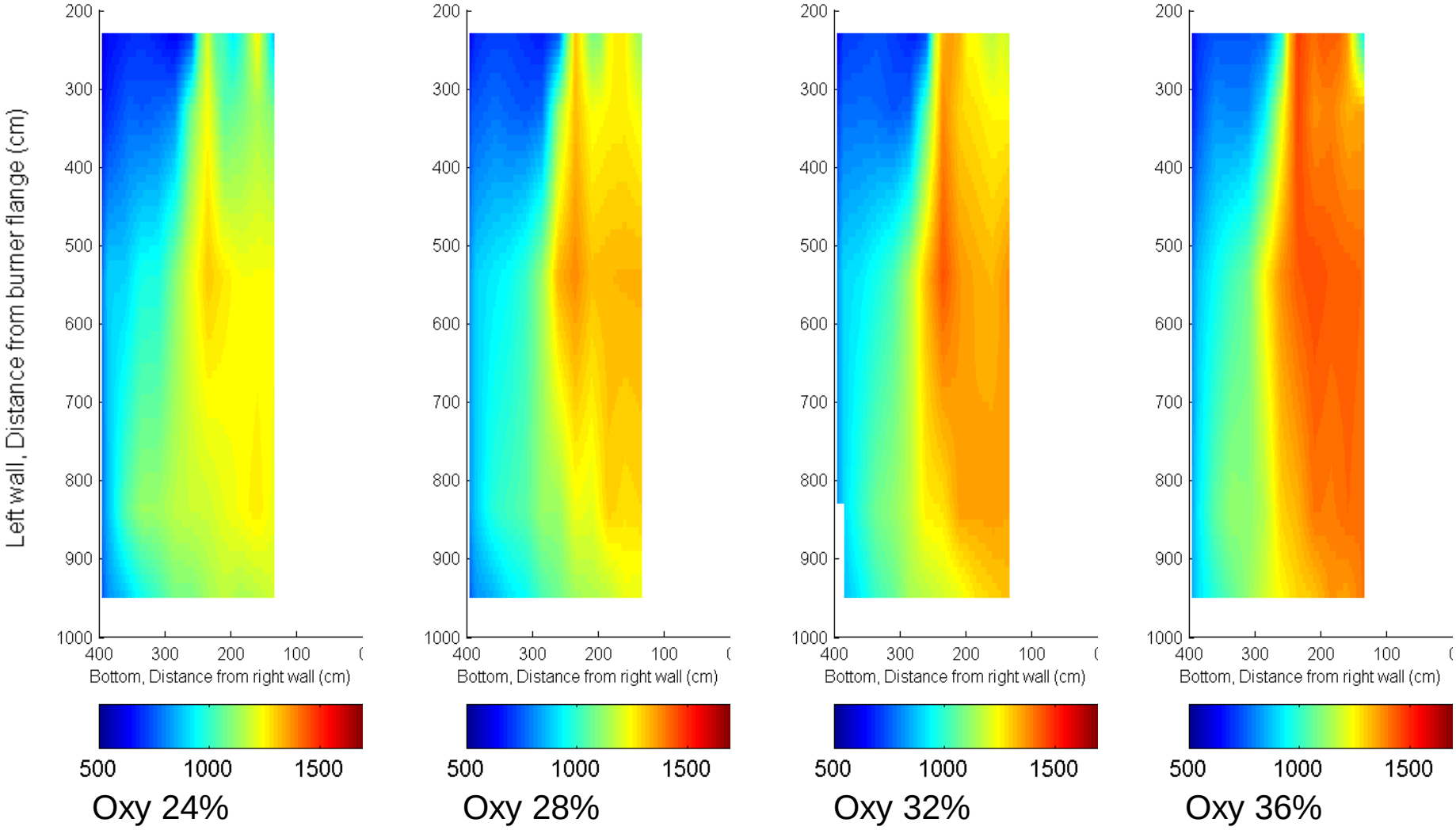
Temperature Comparison (FTIR)
Front View



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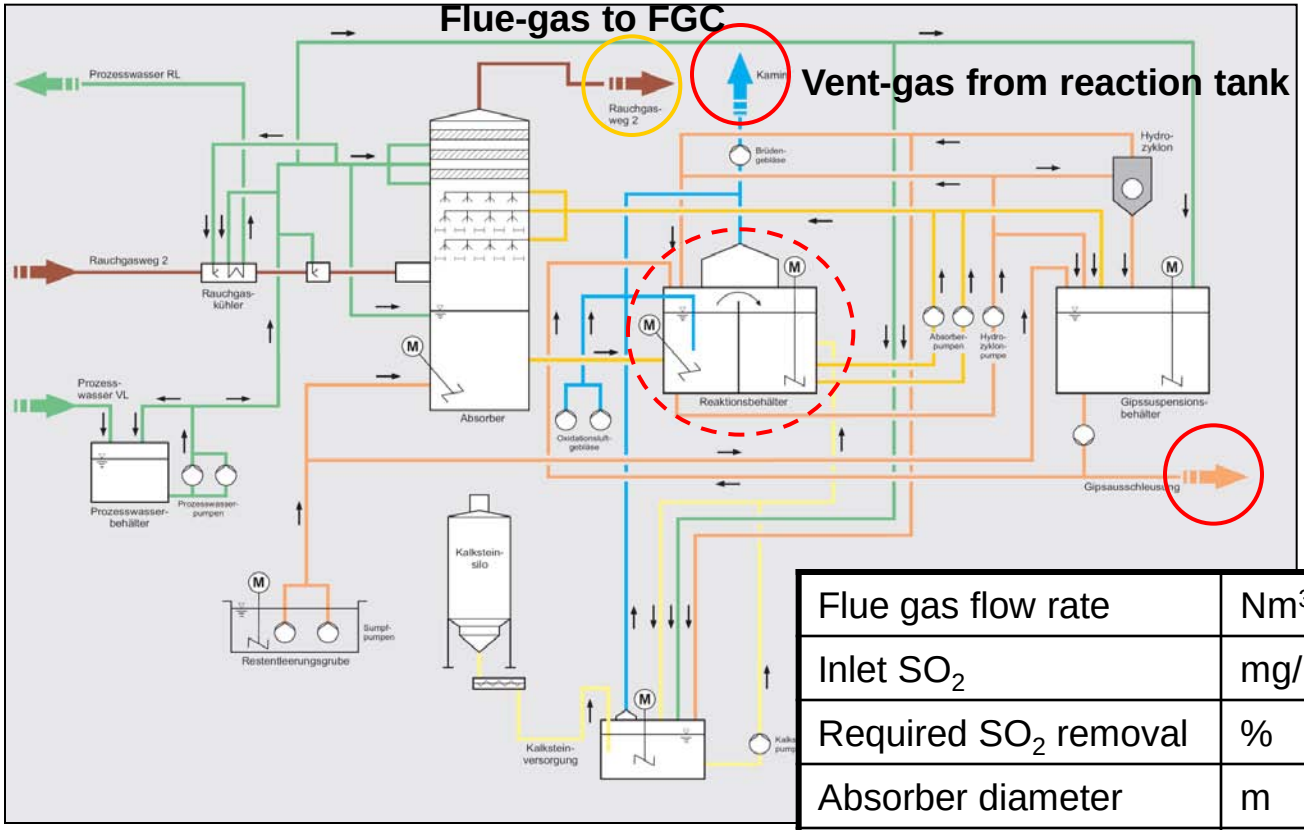
FGD System – Flow Diagram



Tray absorber (3 trays)

Three spray levels

External oxidation

- new emission stream

Gypsum discharge

Flue gas flow rate	Nm^3/h wet	12,000
Inlet SO_2	mg/Nm^3,dry	11,500
Required SO_2 removal	%	99
Absorber diameter	m	1.3
Absorber height	m	16.5
Total slurry volume	m^3	60

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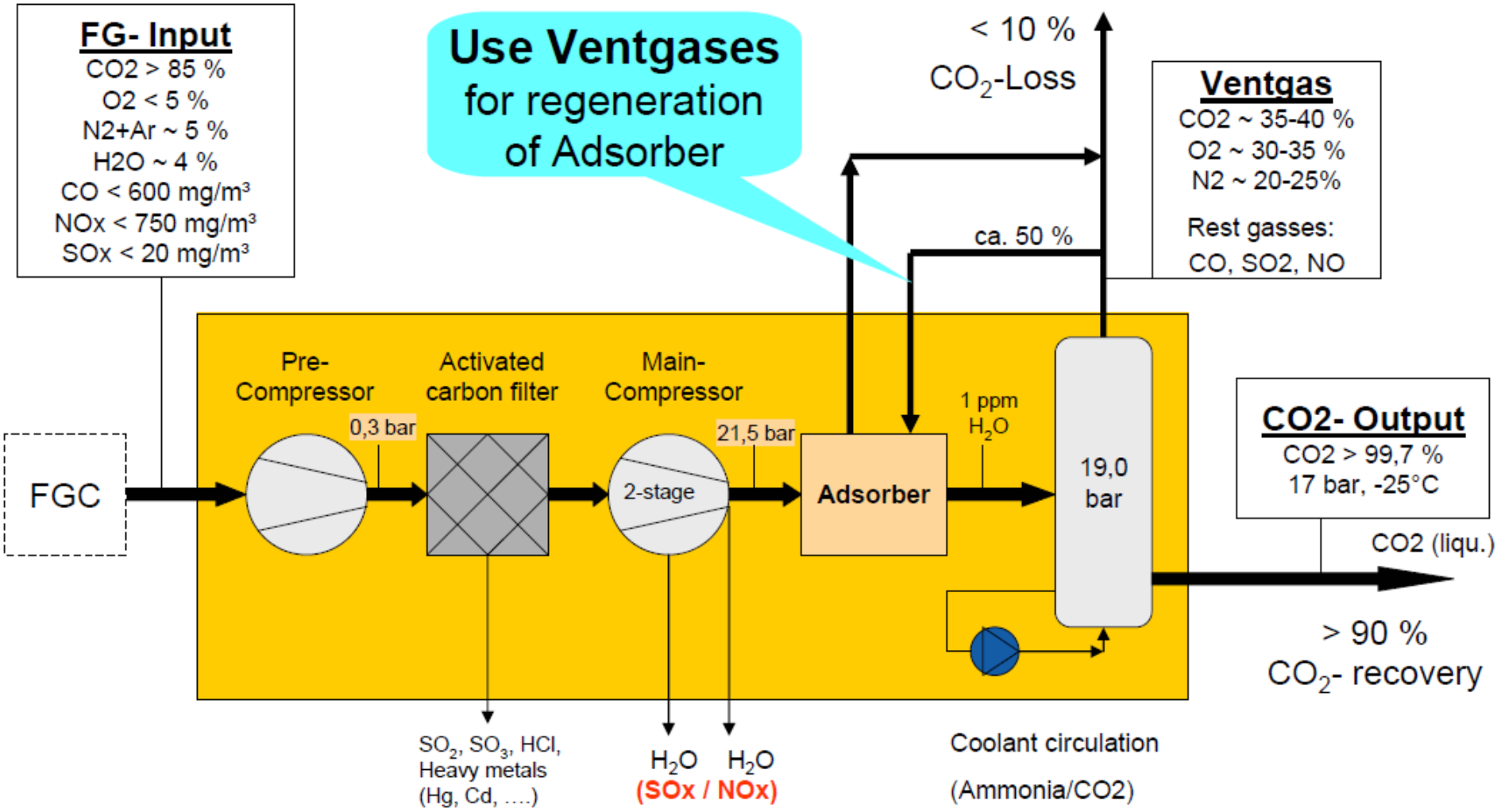
FGC System

Overview Pilot Plant Gas Processing Unit (GPU)



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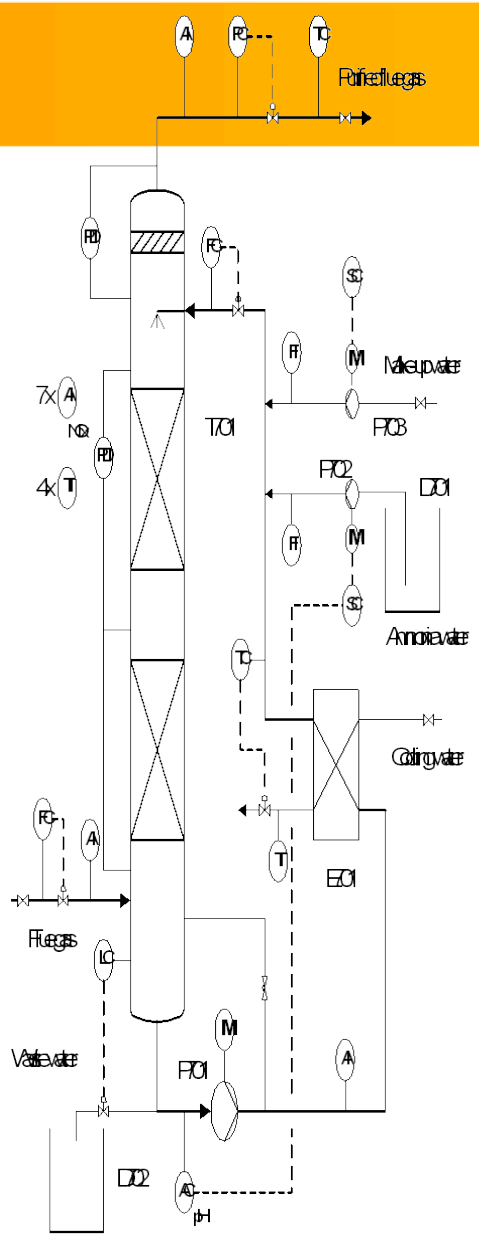
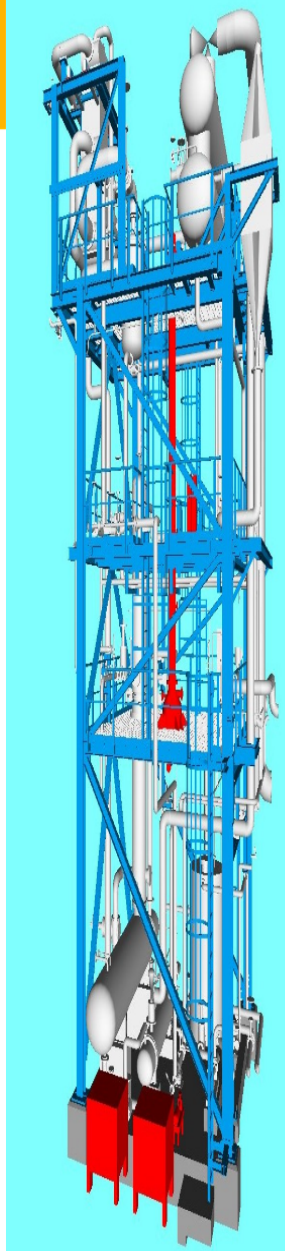
Linde's Alkali Washing Pilot

Absorption of NO_x in ammonia - Under pressurised conditions through a scrubber





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Alternative flue gas and CO2 processing : Scope of project

Characterisation and Evaluation of new technology for CO_2- processing

- Integrated flue gas treatment,
- CO_2-separation
- Membrane unit

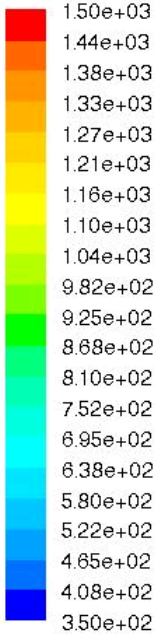
- Technology proved in laboratory scale, now validated
- Specific energy demand reduced 30 – 50 %/t $CO_{2\ sep.}$

Budget

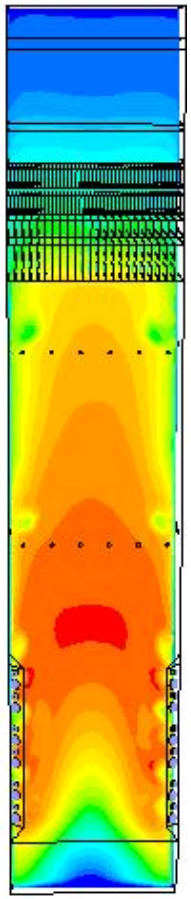
10 Mio € Capital Costs

1,6 Mio € R&D Costs

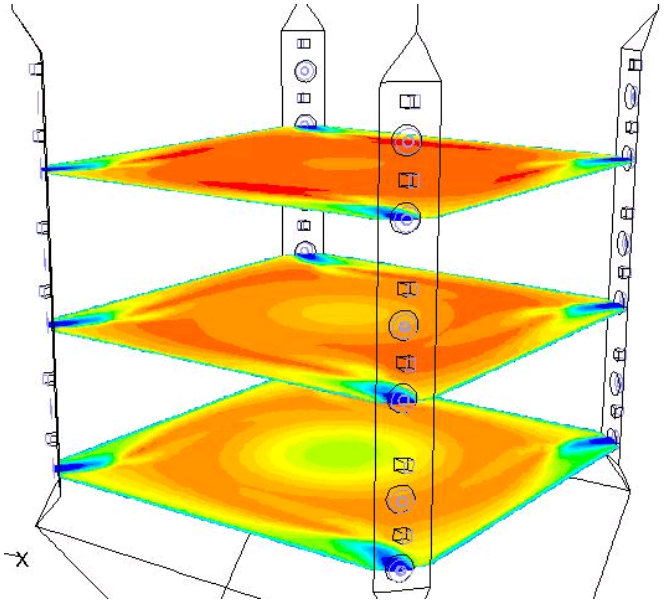
Modelling of CO2 Capture process options



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.

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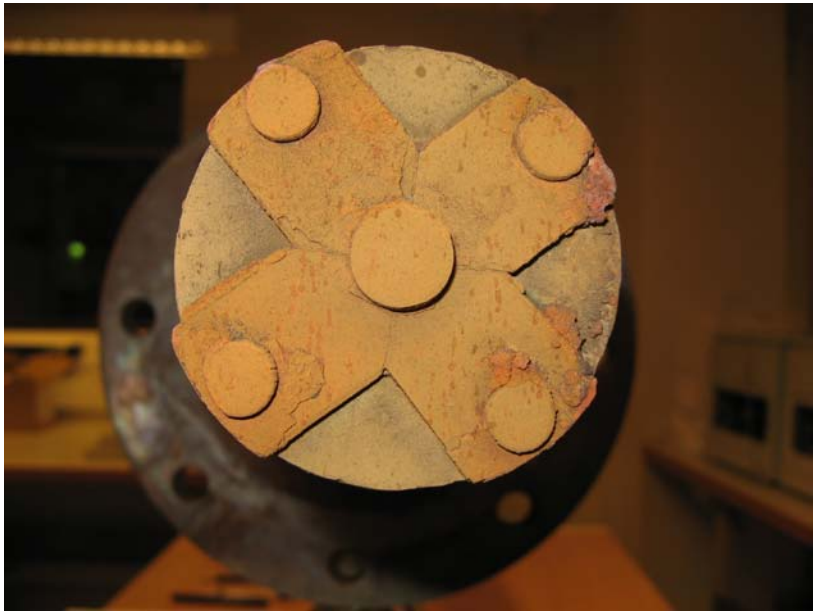
Material testing, corrosion characterisation

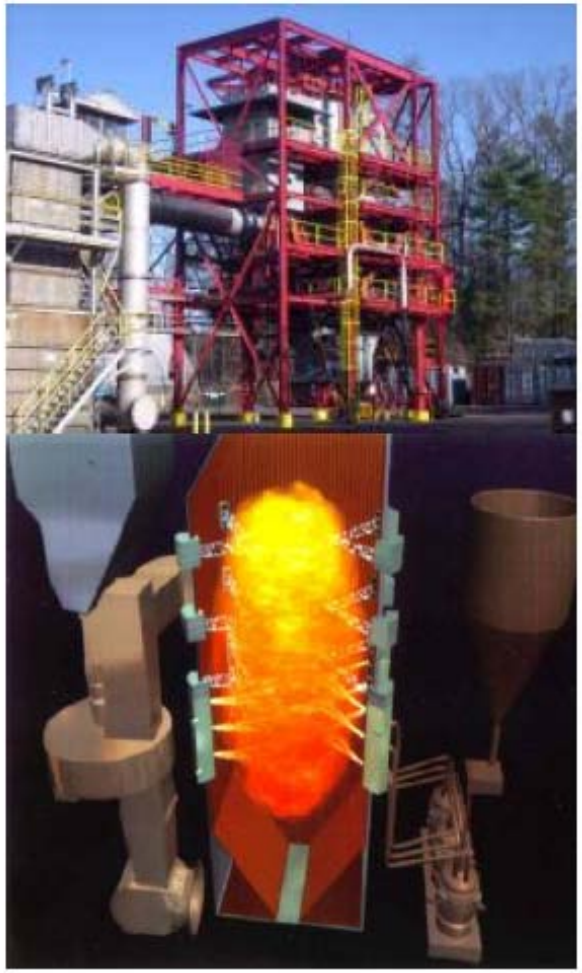
- Testing of common materials used in power plants and some materials under development long time, varying conditions
  - Superheaters, economisers, water walls, ducts, FGD and FGC
  - CO_2 compression (impeller, intercoolers)

- Probe testing and on-line corrosion sensors
  - Cooled and uncooled material probes
  - Metalographic investigations, deposit analysis

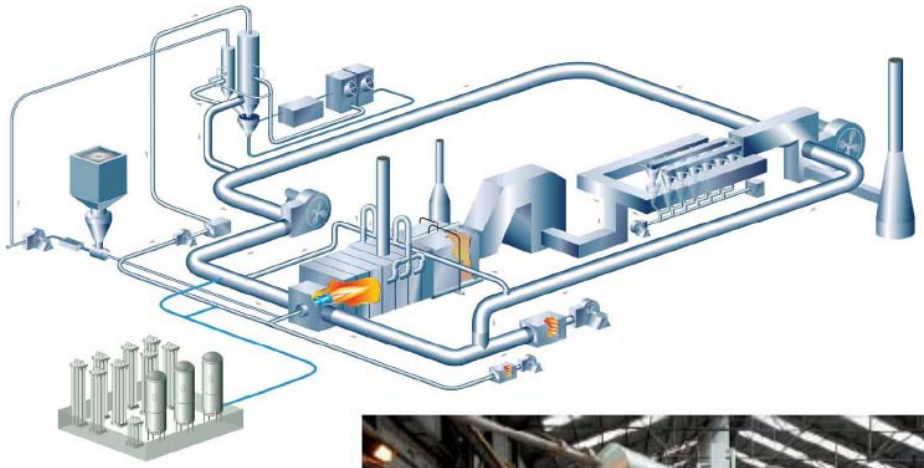


Alstom T-firing and OxyCoal UK2 projects
Burner and firing concept testing in 30-40 MW_{th} scale

Alstom Boiler Simulation Facility



During Summer 2009, Doosan Babcock Energy has commenced its 40MW_t OxyCoal™ demonstration, the world's largest demonstration of an oxyfuel combustion system.



DOOSAN Doosan Babcock Energy

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Overall Conclusions

- The Oxyfuel Pilot Plant operates better than expected and capture rate, CO2 quality, effluent stream characteristics and emission standards are all better than expected.
- No show stoppers have been identified
- The standard boiler works excellent, with a large flexibility
- The standard ESP performs better in oxyfuel mode.
- The standard desulphurization unit works better in oxyfuel mode
- The standard flue gas condensation unit is efficient and well performing
- The gas processing unit performs very well and several design options have been identified
- Alternative technologies for gas processing are tested successfully
- A demonstration plant can be built using standard components with standard chemical engineering and power plant knowledge
- We have filed an application to the EU under the NER 300 program, for a demo based on this experience.

The Costs of CO2 Capture, Transport and Storage

March 2nd, 2011

Lars Strömberg

European Technology Platform for Zero Emission Fossil Fuel Power Plants

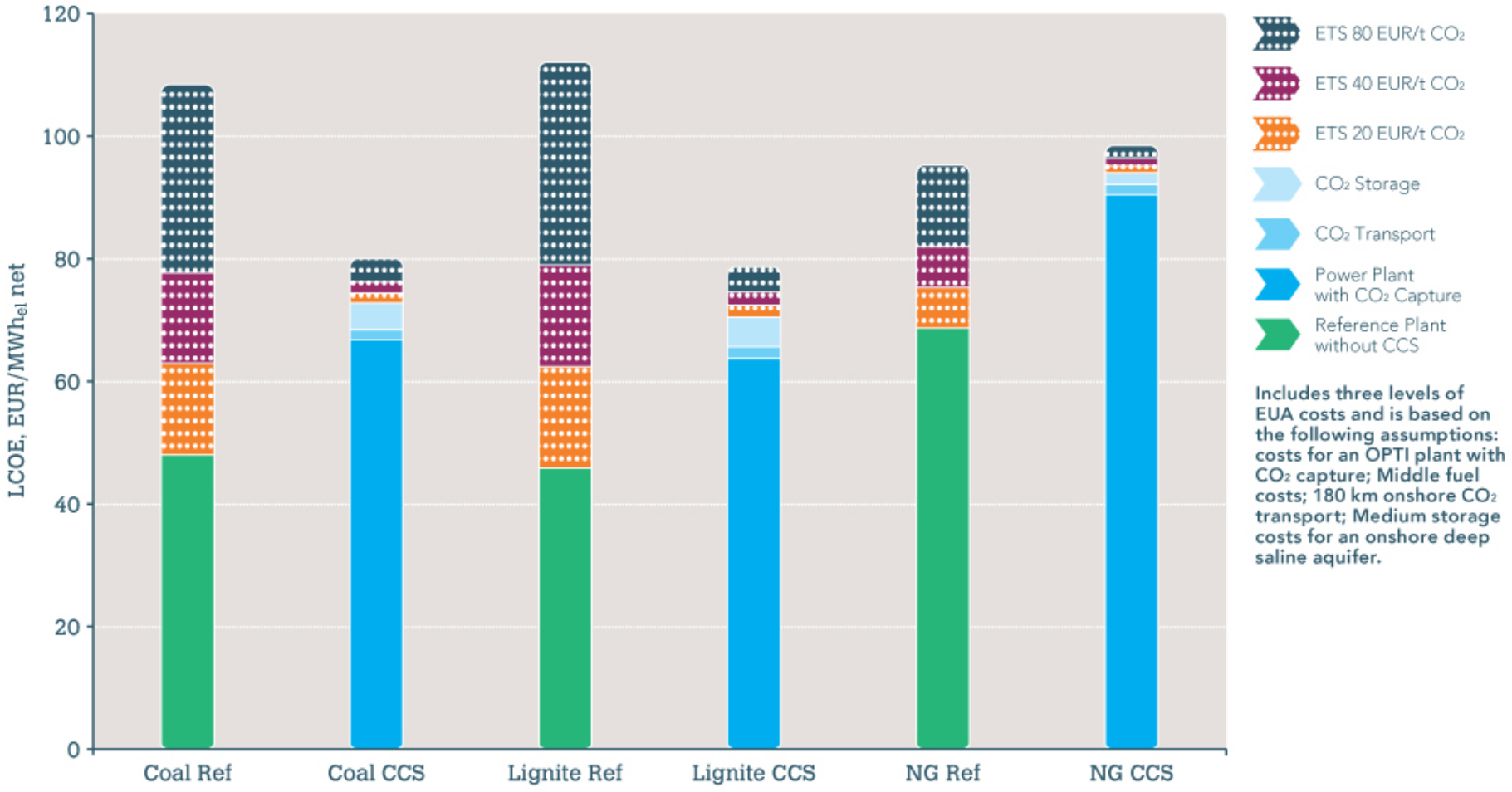
ETP Role:
define a strategic agenda for the development and deployment of technologies in the EU involving major economic or societal challenges.

- Initiated by the European Commission in 2005
- **Unique coalition of stakeholders:**
  European utilities, petroleum companies, equipment suppliers, scientists, academics and environmental NGOs
- Over 300 members from 19 countries

www.zeroemissionplatform.eu

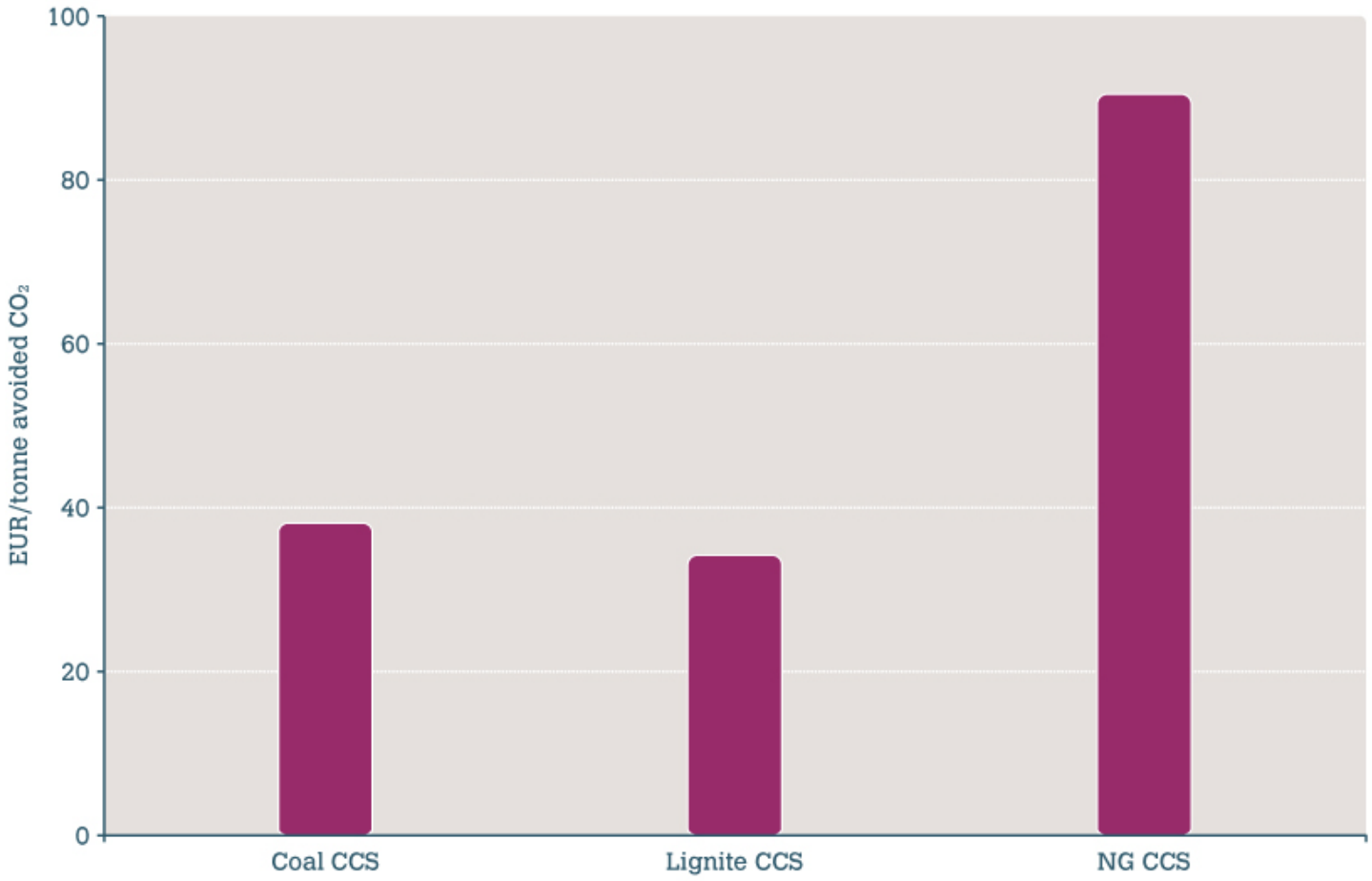
Levelized Cost of Electricity LCOE for Integrated CCS projects (coal and gas)

Figure 1: The Levelised Cost of Electricity (LCOE) of integrated CCS projects (blue bars) compared to the reference plants without CCS (green bars)



CO_2 Avoidance Costs – Price of EUAs to Justify Building CCS Projects vs. Plant w/o CCS

Figure 13: CO_2 avoidance costs for possible plants commissioned in the mid 2020s – the price of EUAs required to justify building CCS projects vs. a plant without CCS from a purely economic point of view (calculated on the same basis as Figure 12)



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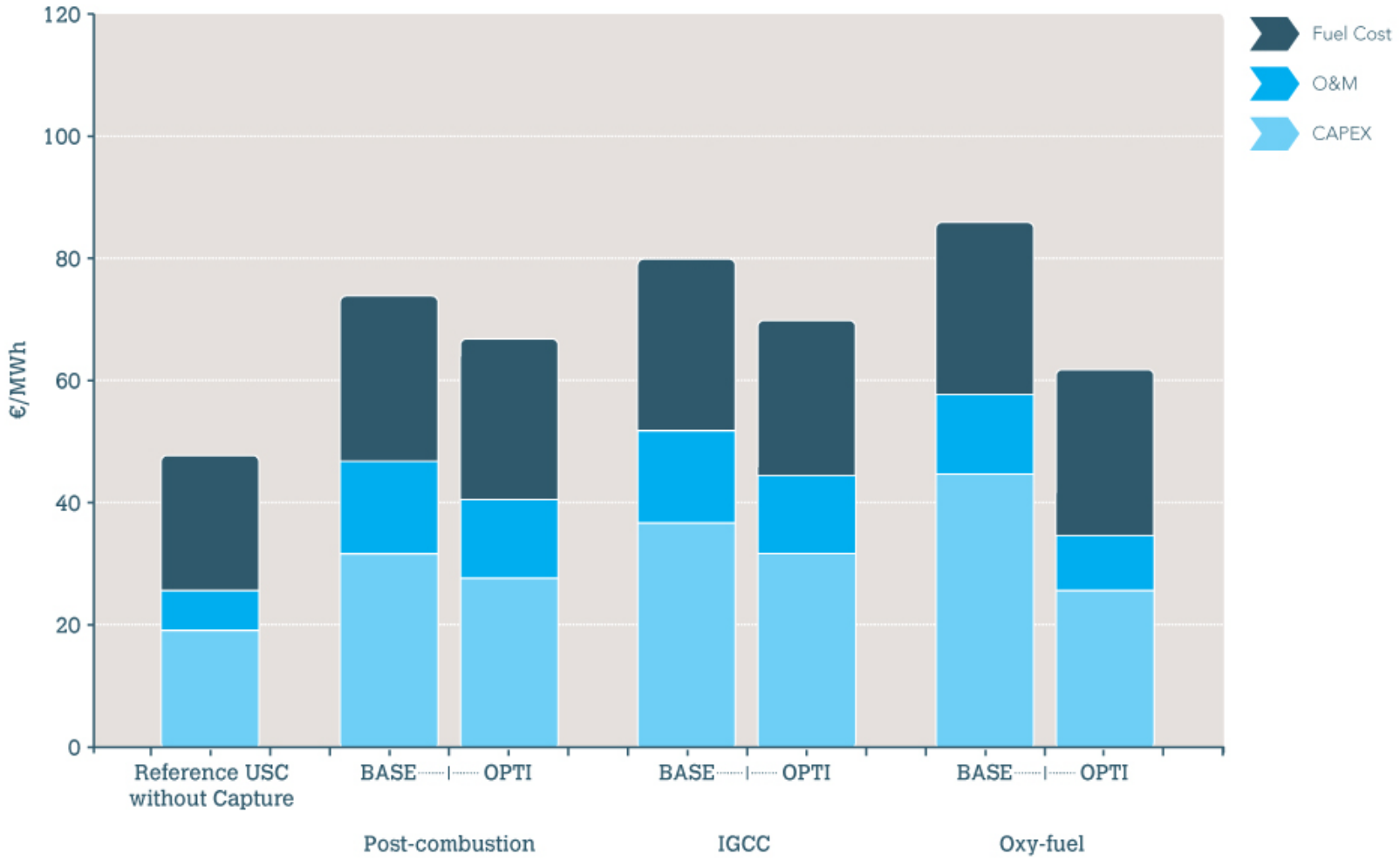
LCOE for Hard Coal Plants with CO_2 Capture (capture-costs only)

Figure 14: The LCOE for hard coal-fired power plants with CO_2 capture (using Middle fuel costs)



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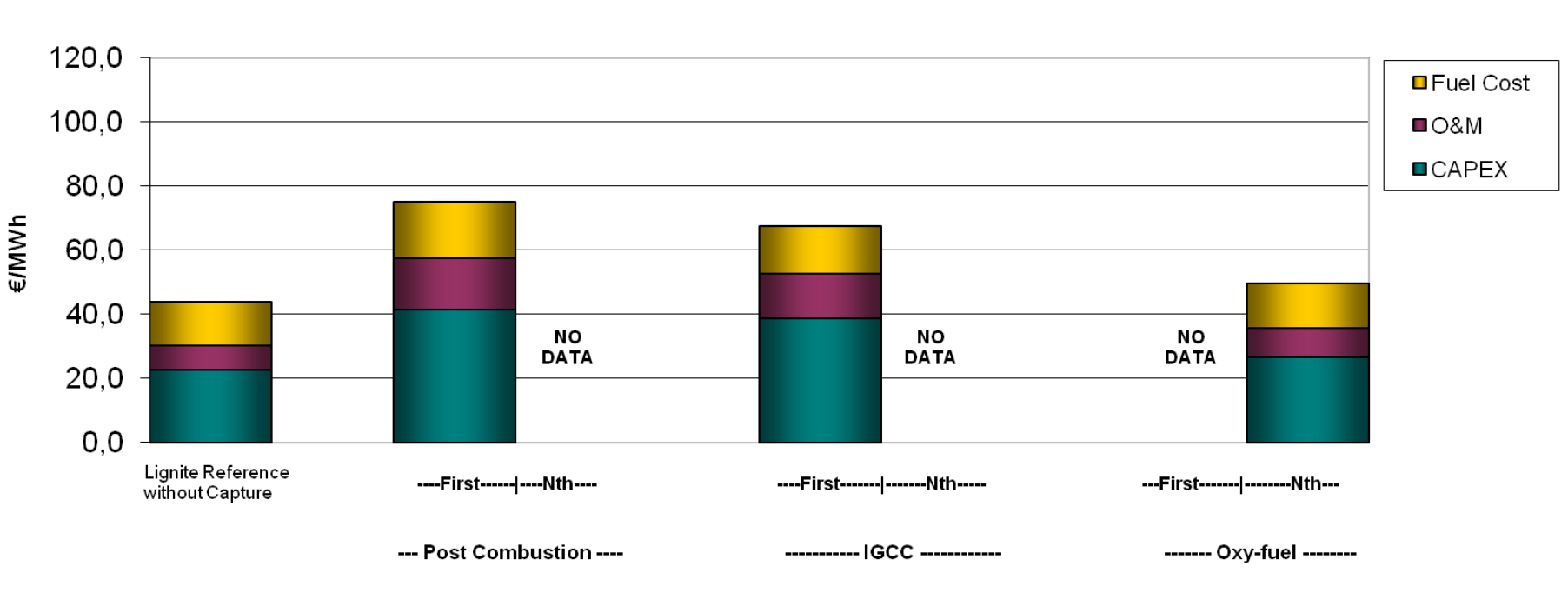
LCOE for Lignite Plants with CO_2 Capture (capture-costs only)



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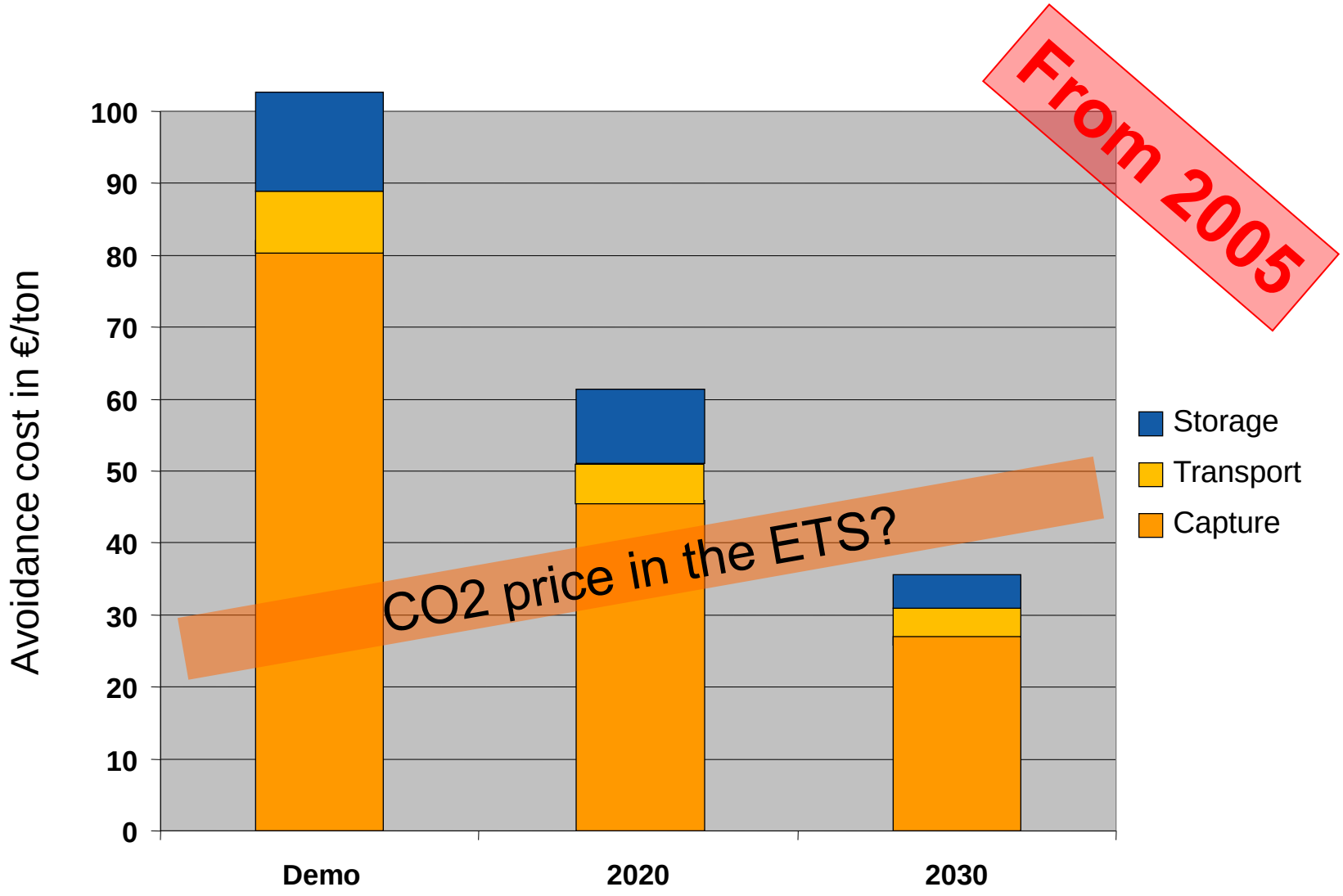
Total cost, including transport and storage (€/ton CO_2)



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Power Plant Lippendorf

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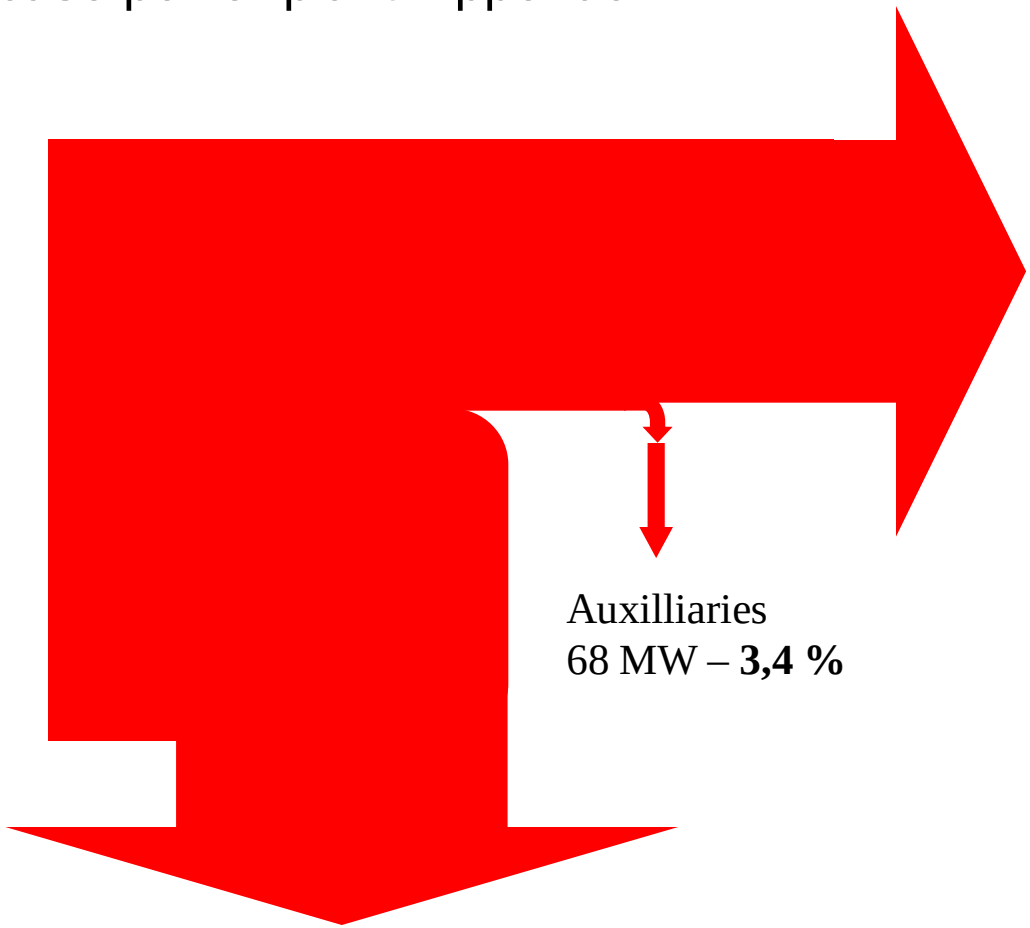
Energy flow diagram for a lignite fired Power Plant

Base case power plant Lippendorf



Energy input
Fuel
2026 MW
100 %

Net electricity output
865 MW – **42,7 %**

Auxilliaries
68 MW – **3,4 %**

Cooling
1093 MW – **53,9%**

From 2001

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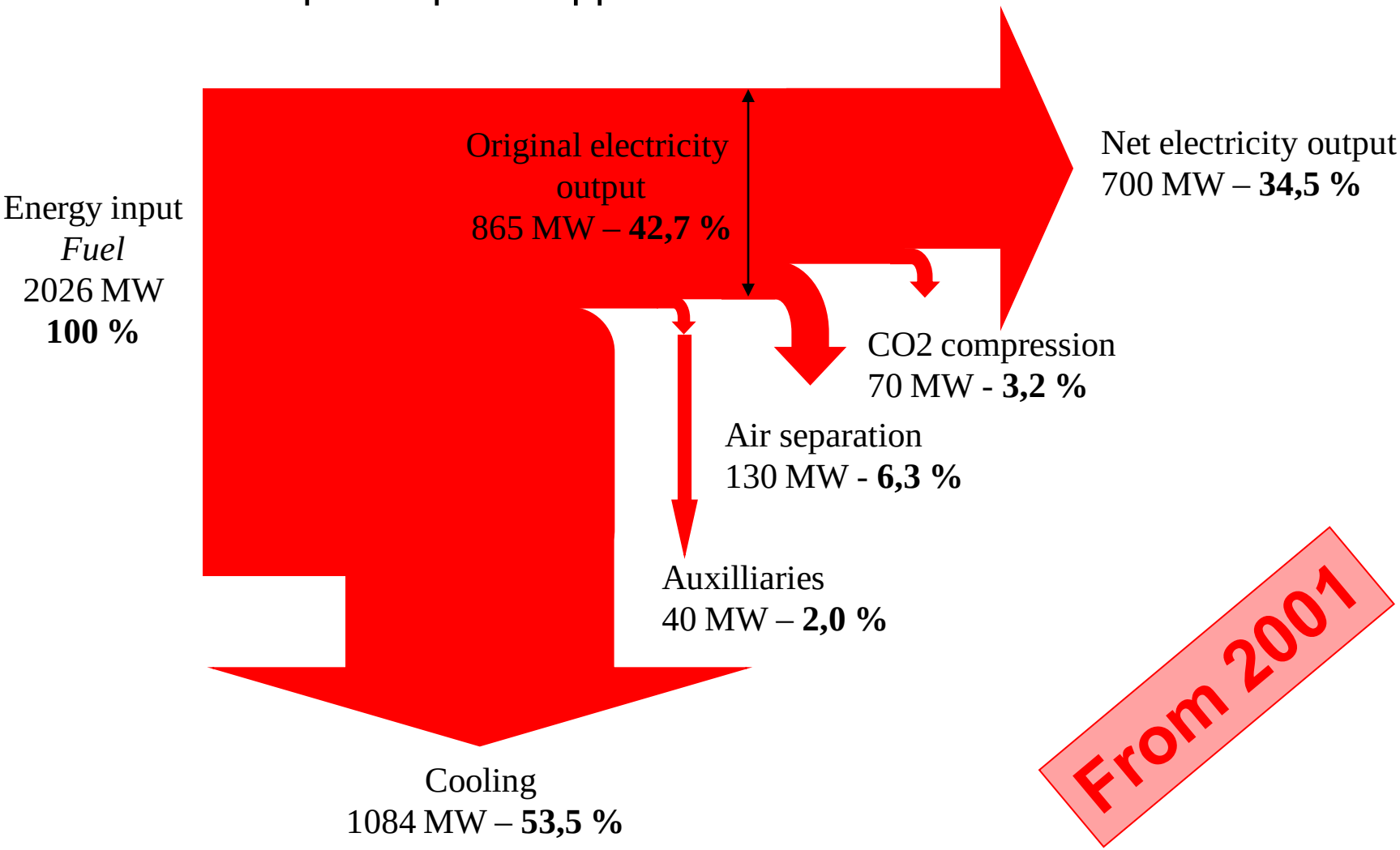
Energy flow diagram for lignite fired plant with O_2/CO_2 combustion

Base case power plant Lippendorf



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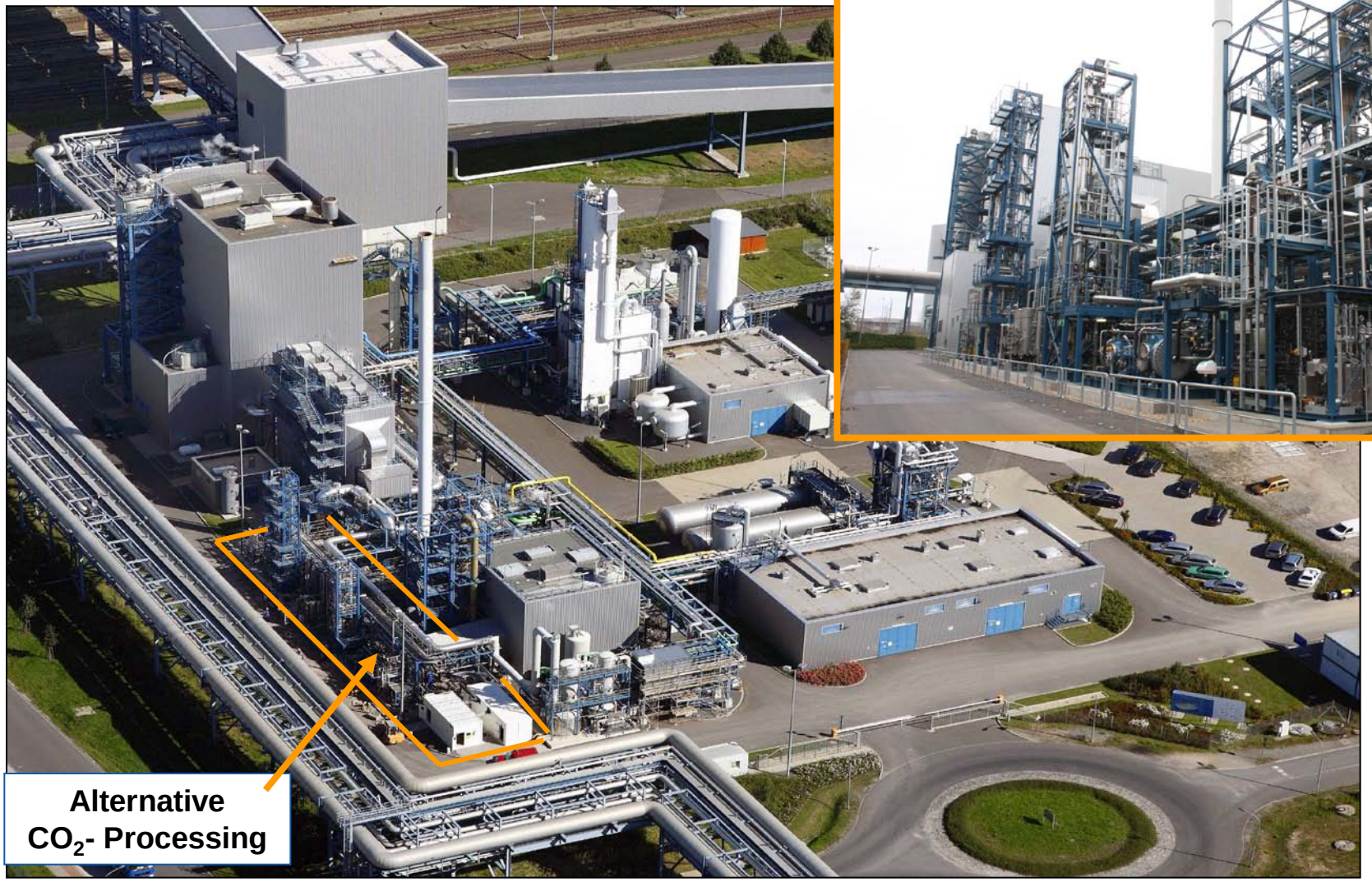
Alternative flue gas and CO2 processing in Schwarze Pumpe



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- Specific energy demand reduced 30 – 50 %/t $CO_{2\ sep.}$

CCS Demonstration Plant Jänschwalde

Demonstration Plant Jänschwalde – Technical data

Compare Lippendorf study from 2001

Oxyfuel:

- Newly build single block at existing power plant site
- Capacity 250 MWe
- Efficiency (net) 36 %
- Separated CO_2 1,34 Mio.t/a
- Specific CO_2-emissions 78 g/kWh

Post combustion capture

- Retrofitting of a part of an existing unit
- Capacity 50 MWe
- Separated CO2 0,39 Mio.t/a
- Specific CO2-emissions 107 g/kWh

CO2 Injection Ketzin

- Preparing for injection of CO2 in Ketzin outside Berlin, in cooperation with GFZ Potsdam

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The Oxyfuel Technology progress under full sail

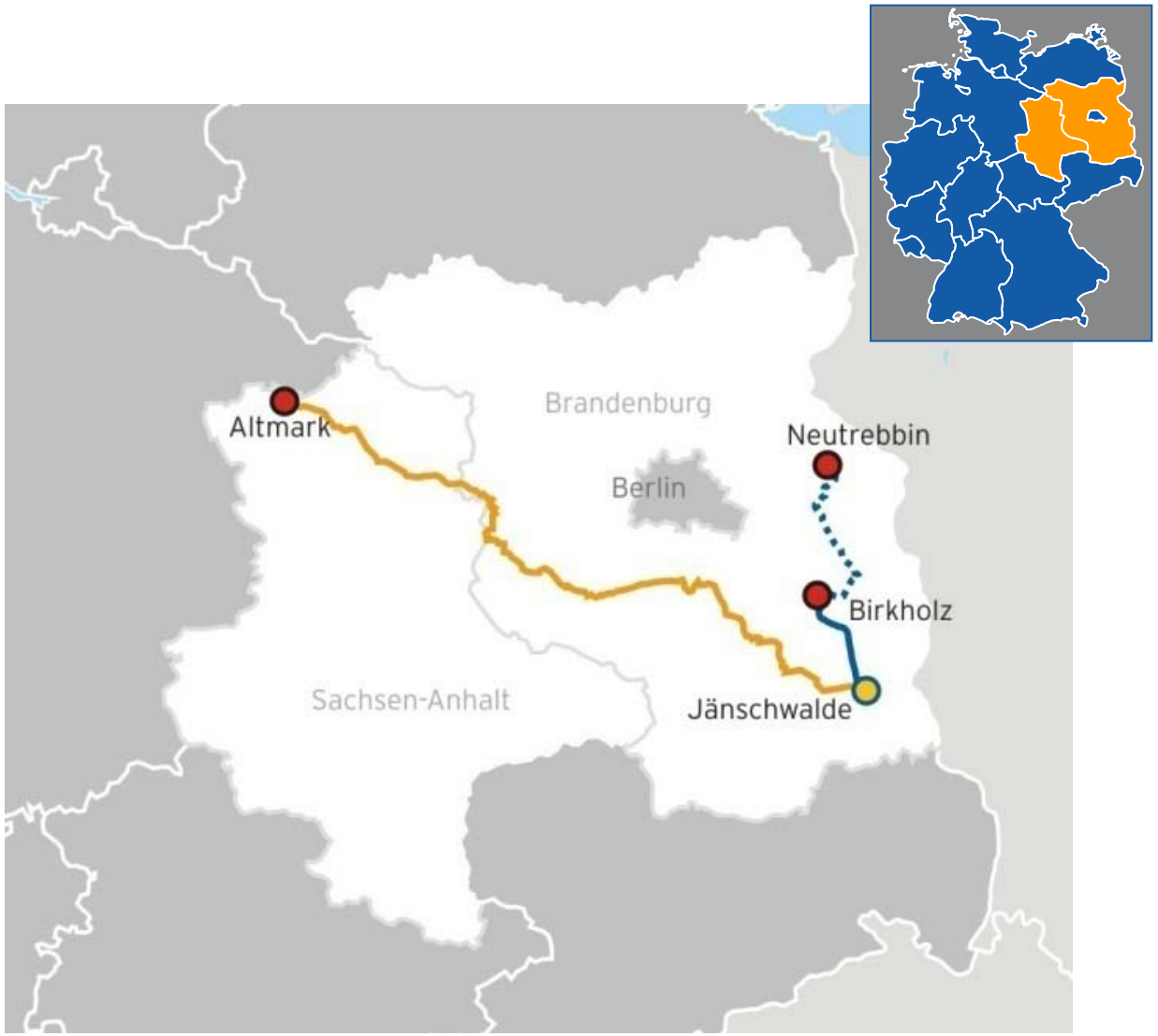
Demonstration Plant Jänschwalde – Potential storage sites

I. Brandenburg

Storage in deep saline aquifers (pipeline 50/140 km)

II. Altmark

EGR pilot project in cooperation with Gaz de France (pipeline 300 km)




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

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

Build trust by communication and transparency

➢ **DIREKT contact**

- Public hearings
- Information via local press and brochures
- Telefon-Hotline 0800-1243683
- www.vattenfall.de/ccs

➢ **PERSONAL contact**

- CCS-Infocenter
- Stakeholder meetings

➢ **TRANSPARENT**

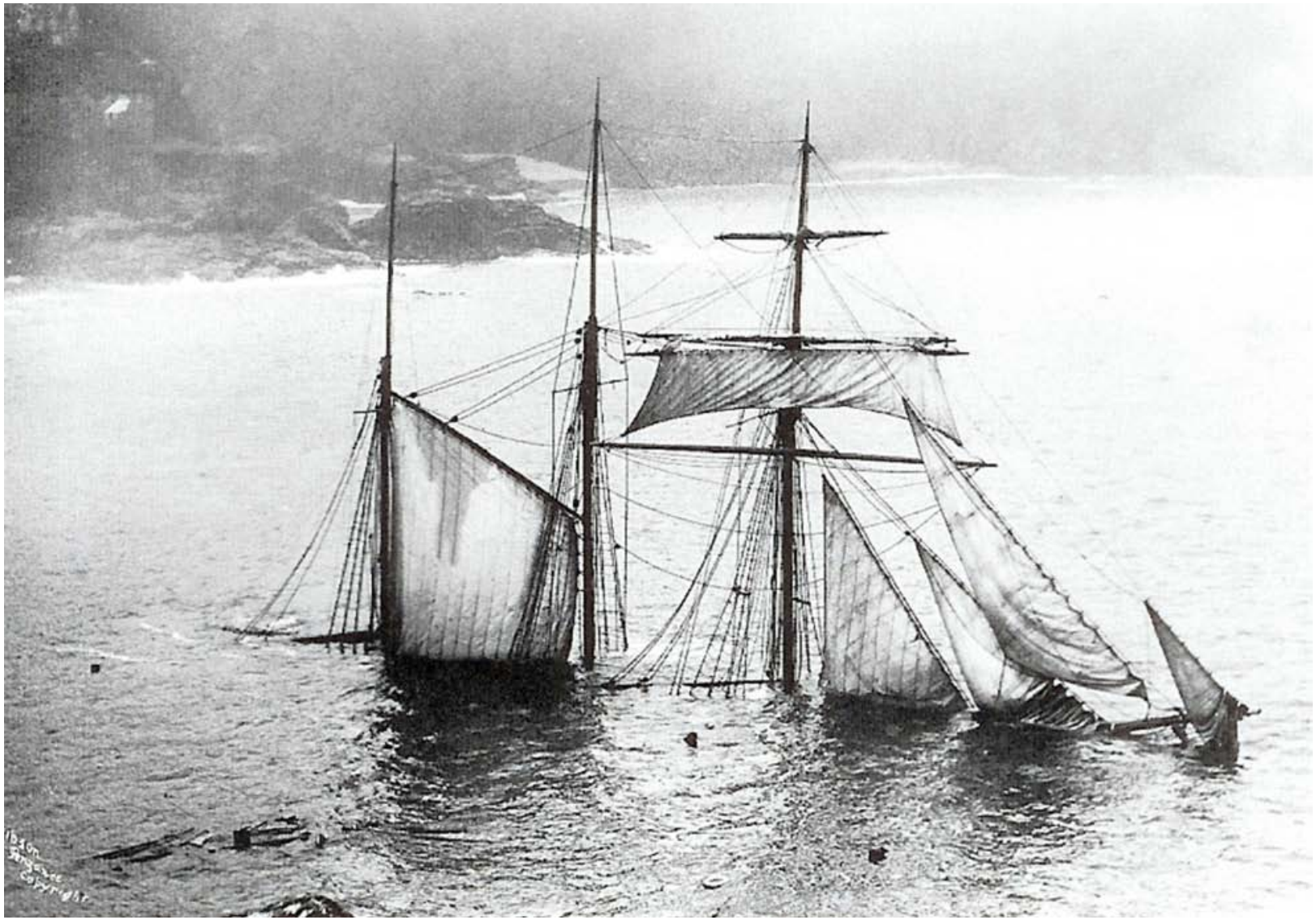
- Regional stakeholder committee
- Applications and permissions are public
- On the internet

And the answer is…….

In Europe we have ran into a blind alley.

- We spend an enormous amount of money on technology development and make very good progress.
  - Own efforts on oxyfuel has progressed very well and we get better experience from our pilot plant than expected
  - We have made large improvement giving lower cost, less energy needed and much better performance.
  - Our demonstration plant is already engineered and designed
  - We are ready to build
- We are effectively stopped everywhere by different parts of the society
  - Regional politicians, implementing the EU law in national legislation effectively killing any attempt to proceed
  - Our colleagues in Denmark, Holland, Germany, Sweden and Italy experience the same
  - Even in Norway they got cold feet when fulfilling promise for transport and storage
- Politicians say we need CCS for several reasons, and we get nowhere at present.

The European CCS demonstration programme ?



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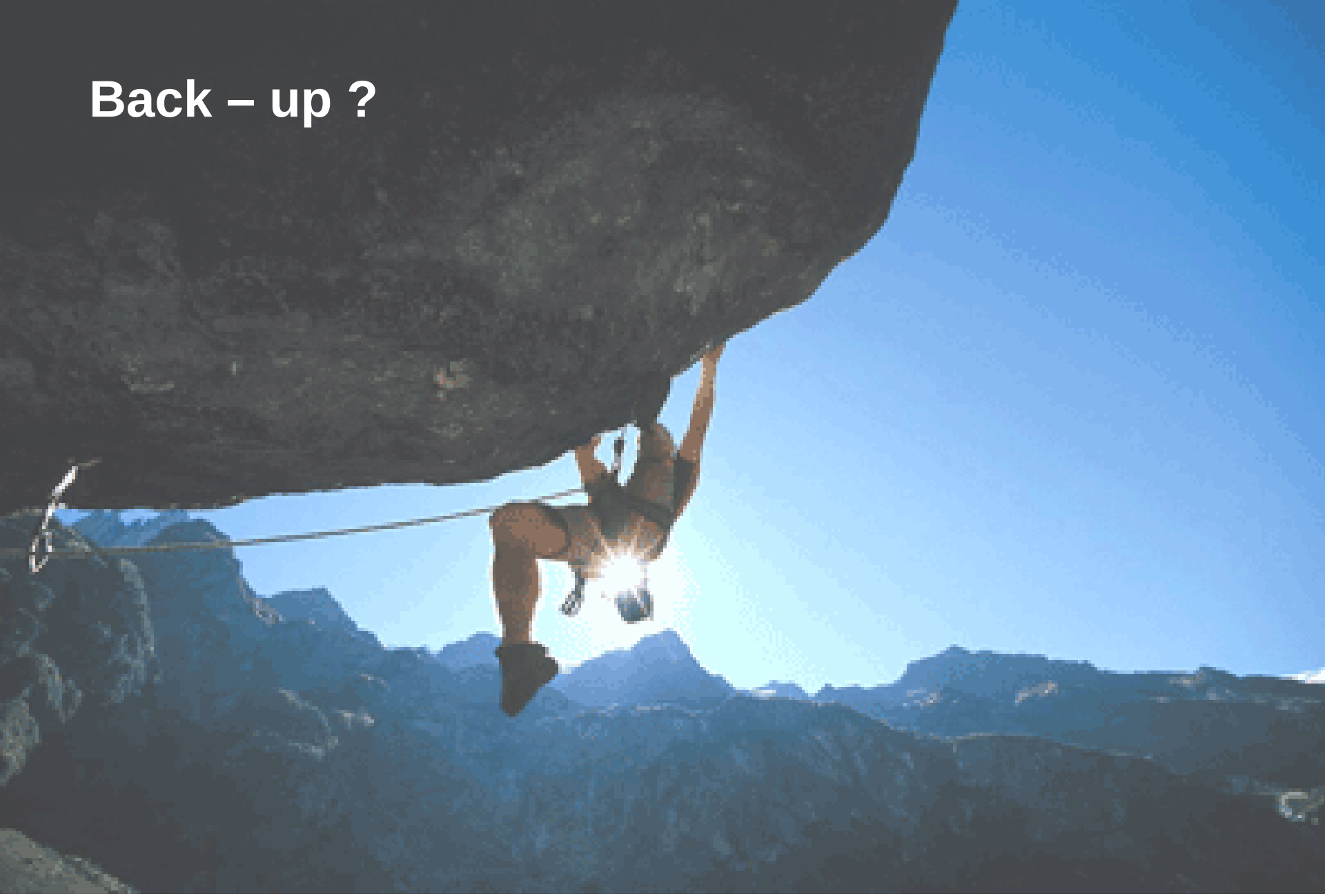
Oxyfuel Combustion Technology - way forward

- Oxyfuel Combustion Technology is very straightforward.
  - We have shown to anyone that it is a simple way forward
  - The process works and it works well
  - The new components as ASU, CPU are easy to incorporate in a power plant, and they works well
  - The traditional components as boilers, ESP, FGD and flue gas condensing unit are well suited also for oxyfuel combustion
- The combustion process is actually easier to handle, since we have another operational factor to utilize, the O2 content.
- The rest products as gypsum and ash are just as good as for conventional processes
- It seems product development will get us as close to “zero emissions” to the atmosphere as is possible
- The CO2 product can be delivered at any desired quality.
- The economy seems superior to competing technologies.

Give us a chance to build a full size unit somewhere !

CCS Demo Plant, Jänschwalde unit G

Back – up ?



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