Concept of Vattenfall's Oxyfuel-Demo-Plant

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Agenda

1	Background and motivation for demo plant
2	Overview capture concept for demo plant in Jänschwalde
3	Transport and storage concept
4	Why has Vattenfall cancelled this demo project ?
5	Summary

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Background and motivation

- Vattenfall is dedicated to reduce its CO_2 emissions, aiming at a carbon neutral electricity portfolio by 2050
- Coal fired power plants have the greatest influence and reduction potential, with lignite at the best cost/delivery positíon
- Vattenfall sees the most effective method to lower the CO_2 emissions quickly, substantially and definitely in the CCS technology
- Vattenfall has worked on the CCS technology since 2002 and commissioned an Oxyfuel pilot plant (30 MWth.) in 2008
- We have gained many valuable practical experiences from this Oxyfuel pilot plant during the last 5 years

➔ Ready to scale up to a demo plant

CCS Roadmap

Concept-studies

2002

- theoretical studies

Test rigs 0,1 – 0,5 MW_{th}

2004

- Research
- Basic principles
- Combustion characteristics

Pilot plant 30 MW_{th}

2008

- Demonstration of complete process chain
- Interaction of components
- Validation of test rig results
- Definition of scale-up criteria

Demo plant Jänschwalde 300 MW_{el}

2015/2016

- Verification and optimisation of component selection
- Reducing risks
- Proofing of economical viability

Full scale plant 500 – 1.000 MW_{el}

> 2020

- Economic and competitive power plant concept

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CCS Demonstration Plant in Jänschwalde

Demonstration Plant Jänschwalde – Technical data

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
  (equivalent to treated amount of flue gas)
- Separated CO2 0,39 Mio.t/a
- Specific CO2-emissions 107 g/kWh
  (related to treated amount of flue gas)

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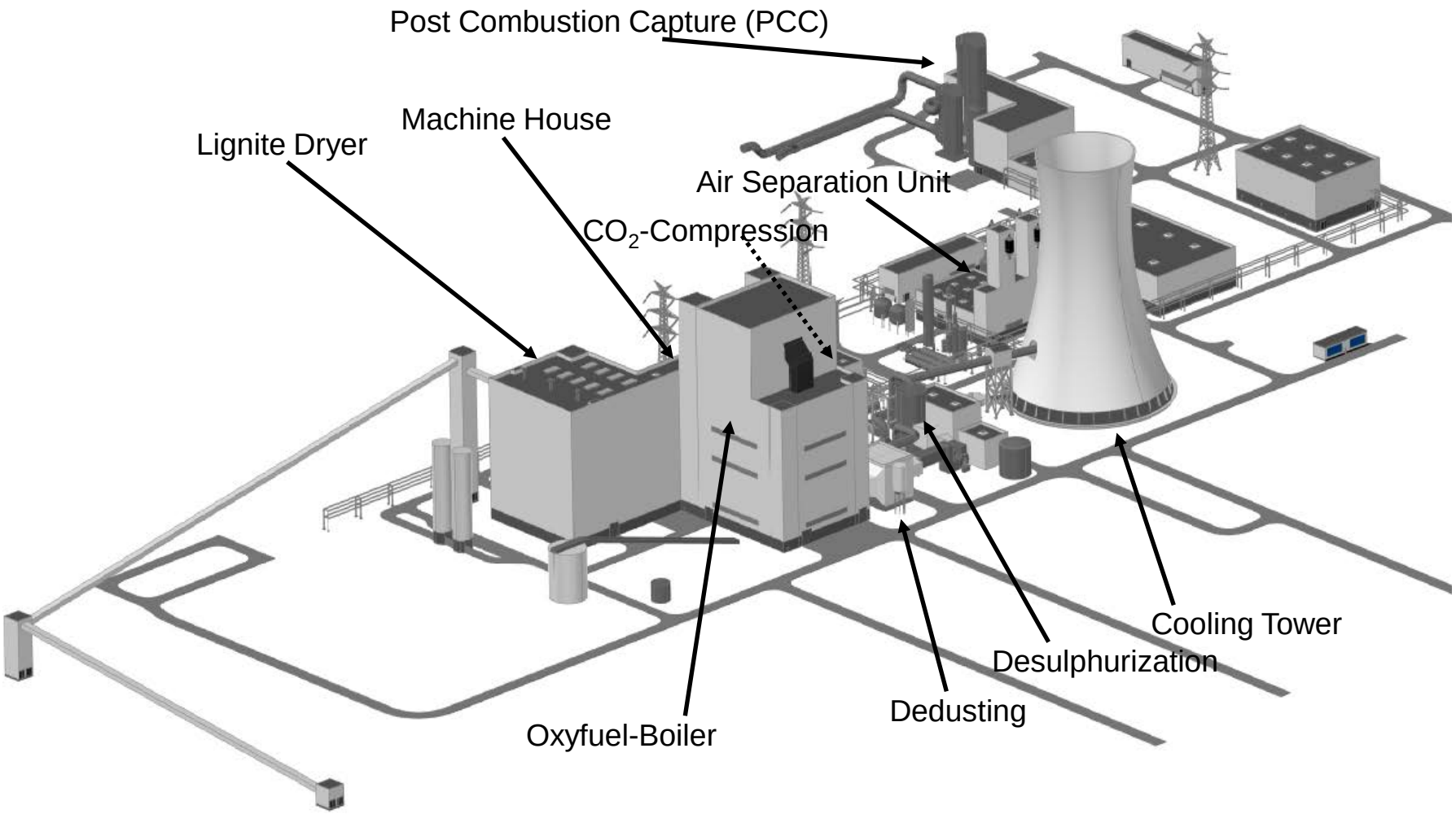
Demonstration Plant Jänschwalde – Capture in detail



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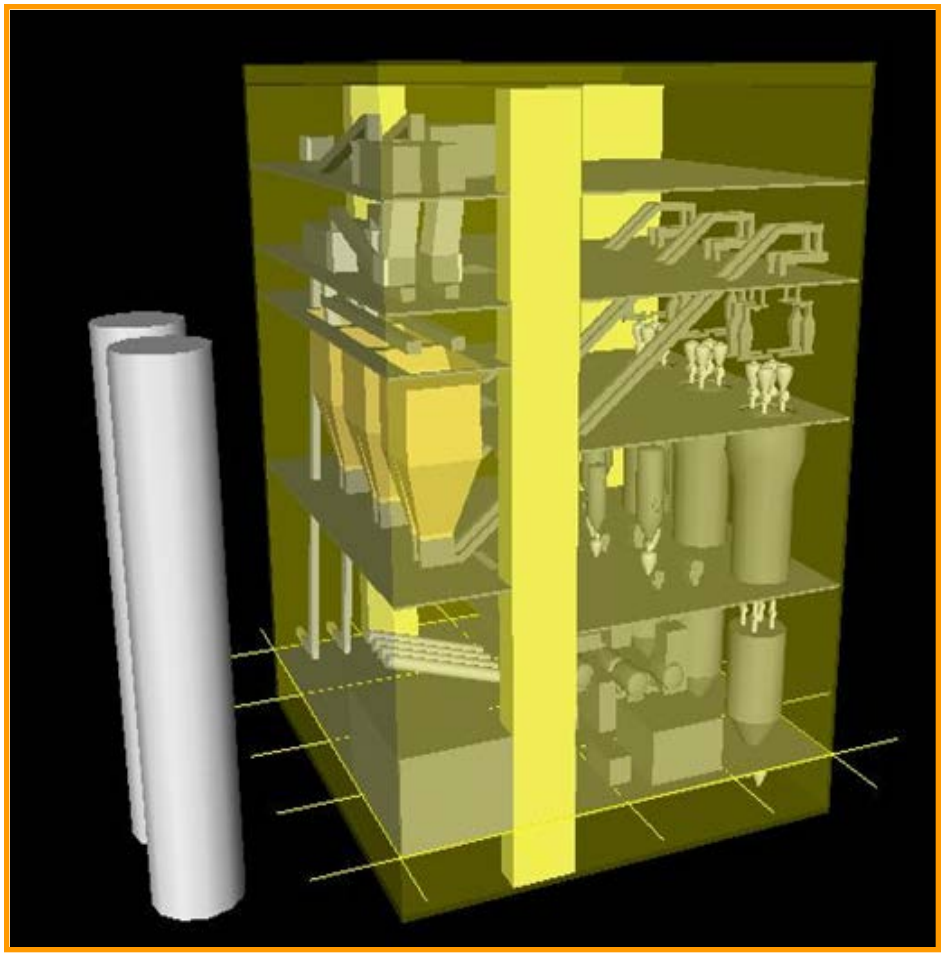
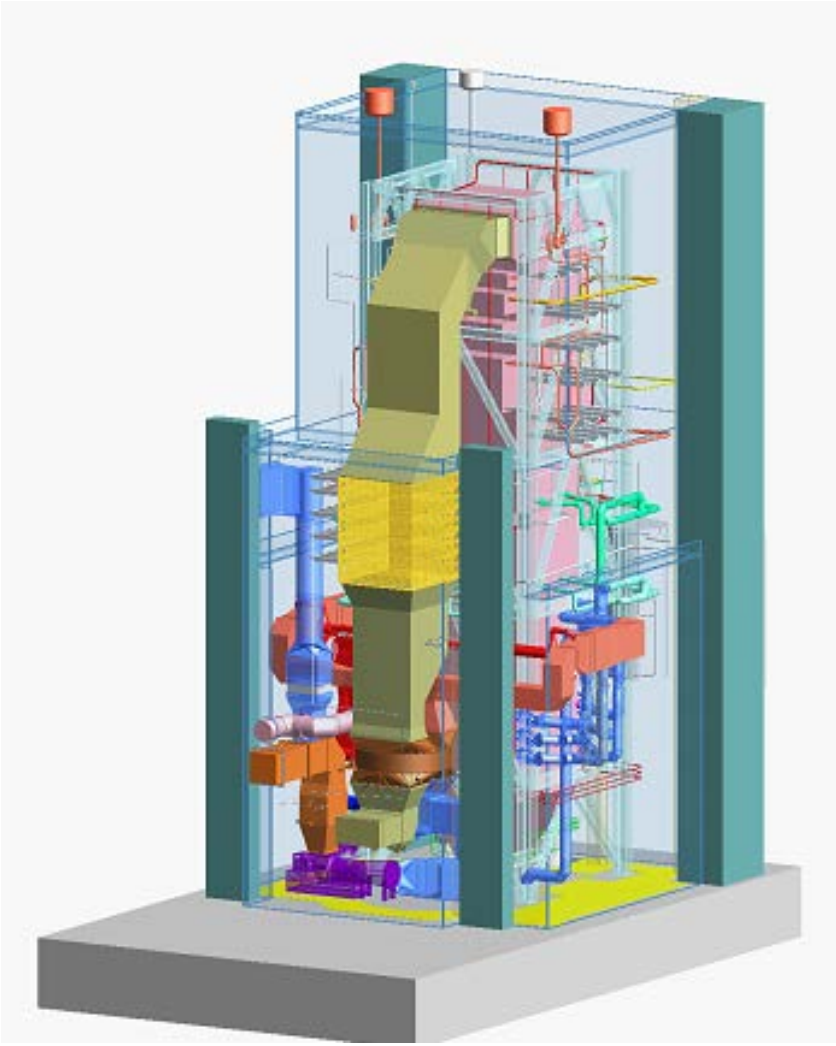
Specifications of lignite drying plant (PFBD)



- Technology: pressurized fluidized bed drying (PFBD)
- 3 drying lines (103 t/h dry lignite)
- operating pressure of dryers: 4 bar_a
- throughput of raw lignite: up to 3 x 79 t/h
- water content of raw lignite: Ø 53.4 %
- throughput of dry lignite: up to 3 x 44 t/h
- water content of dry lignite: 6 - 12 Ma.-%
- heat supply of 25 MW equals 13 kg/s steam to each drying line

Oxyfuel boiler

- forced-circulation boiler
- parameters (state of the art):
  - live steam temp. 600 C
  - live steam pressure 286 bar
  - live steam quantity 178 kg/s
  - re-heater steam temp. 610 C
- specifics:
  - flue gas recirculation
  - gas pre-heater
  - $DeNO_X$ in 2nd draught (optional)
  - CO_2 sealing gas system
  - CO_2, O_2 alarm devices
  - Co-firing of residual gases from PFBD



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Air Separation Unit (ASU)

Main data:

• Produced Oxygen	115,500 Nm³/h (GOX)
• Oxygen purity	95% O_2
• Main Air Compressor (MAC)	2 x 50%
• Cryogenic part	single line
• Load range ASU*	50 – 100%
• Load range MAC	75 – 100%
• Load change requirements	5%/min, O_2 2%
• Oxygen pressure battery limit boiler	1.2bar(a) 50mbar
• O_2 Backup system (2x250m³ LOX)	60% load for 4hours
• N_2 Backup system (1x250m³ LIN)	
• Offered energy consumption	≈ 28 – 34 MW_{el}

*50-75% - Oxygen blow-off / expected time 4% of annual hours

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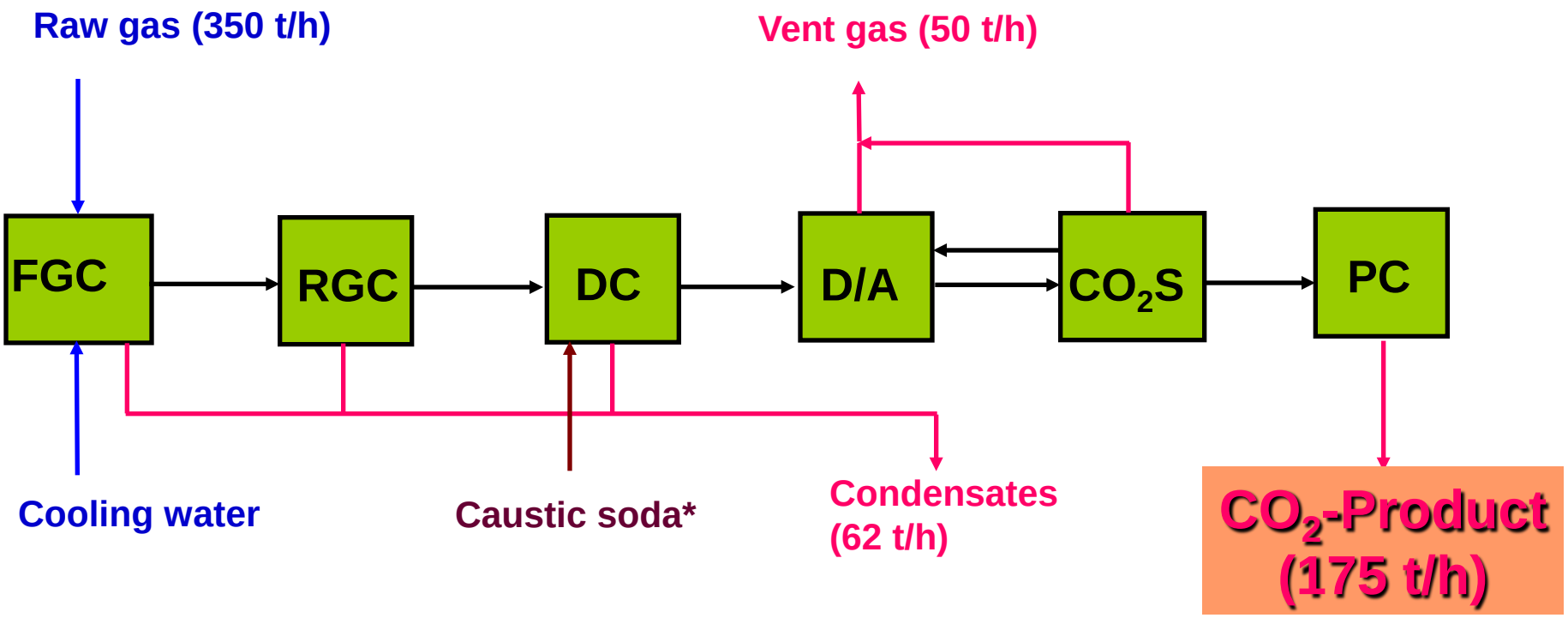
Simplified block diagram CO_2-process



FGC	– Flue gas condenser	RGC	– Raw gas compression (≈28 bar)
DC	– Direct cooler / DeNOx*	D/A	– Dryer/Adsorber + Mercury adsorber
CO2S	– CO_2-Separation	PC	– Product compression (125 bar)

* depending on technical concept

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CO_2 processing unit (CPU)

Main data:

• Raw gas input	275,000 Nm³/h
• CO_2- content in raw gas (wet)	45 - 58 Vol.-%
• CO_2- content in product gas	> 95 Vol.-%
• Oxygen content in product CO_2	< 0.8 Vol%
• Final pressure	125 bar
• Recovery rate	> 90%.... 93 %*
• Load change requirements	5%/min
• Load range GPU	50 – 100% **
• Product compression unit	combined compressor/pump
• Offered energy consumption	≈ 23 – 34 MW_{el}

* depending on CO_2-content in raw gas

** 50-75% - by-pass / expected time 4% of annual hours

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Oxyfuel – process flow sheet

- Optimization and layout for oxyfuel operation, air operation possible
- Flue gas recirculation after FGD (reduction of SO_2 content of flue gas)
- Oxygen mix as pre-mixd mode
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Operating figures

		Unit G Oxyfuel	Unit F with PCC (PCC: 50 MW behind boiler F2)	Unit F (conventional)
mode of operation		demo	base load	base load
fuel		dry lignite	raw lignite	raw lignite
gross output capacity	MW	250	519	530
own consumption	MW	83	37	30
net output capacity	MW	167	482	500
efficiency (gross)	%	53	39	39
efficiency (net)	%	36	35	36
lignite demand (raw lignite)	million t/a	1.5	4.1	4.1
specific CO_2-emission	g/kWh_{net}	78	933	1,004
captured CO_2 (7.700 operating hours/a)	million t/a	1.3	0.4	-

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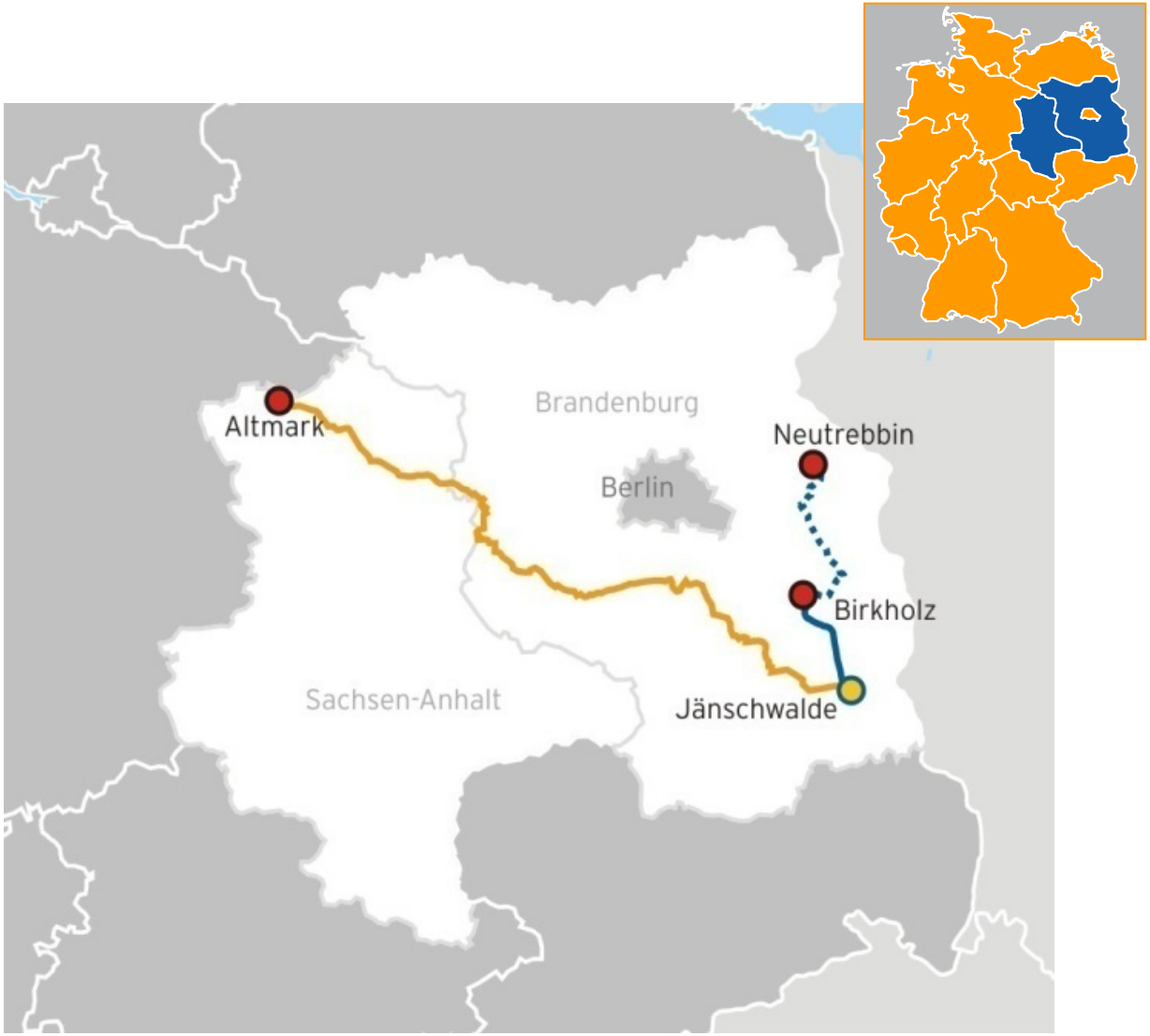
Demo Plant Jänschwalde – Potential storage sites

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)



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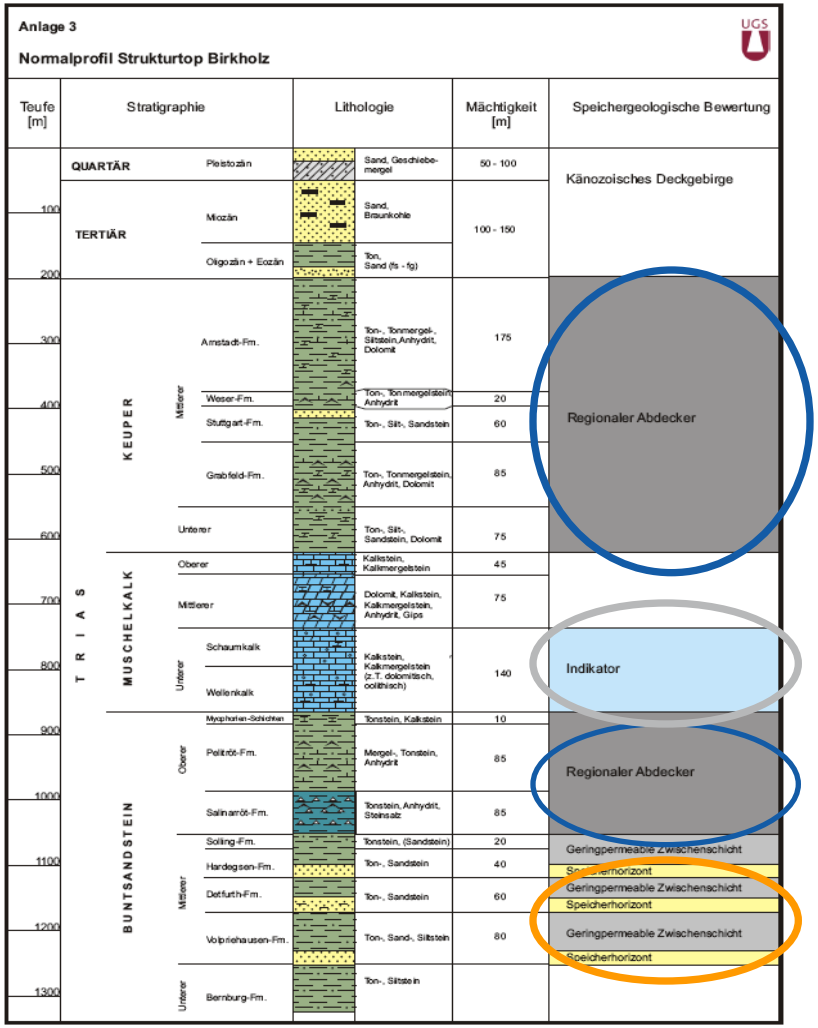
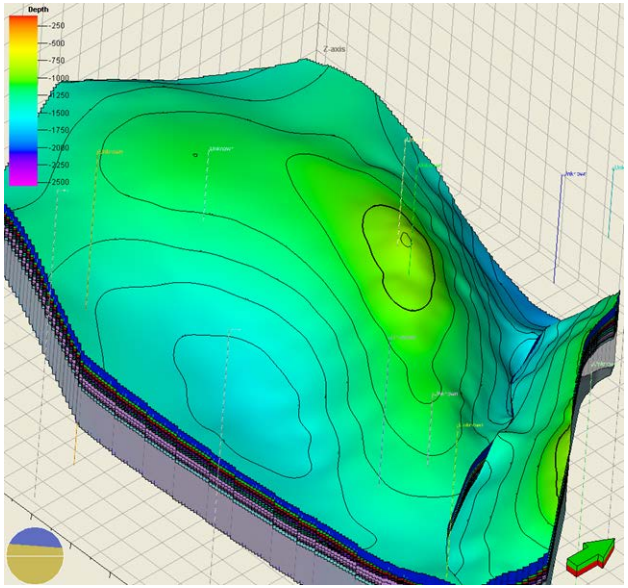
Geology for storage

Geological profile



3-D model



Cap rock II

Indicator horizon

Cap rock I

Storage (Bunter)

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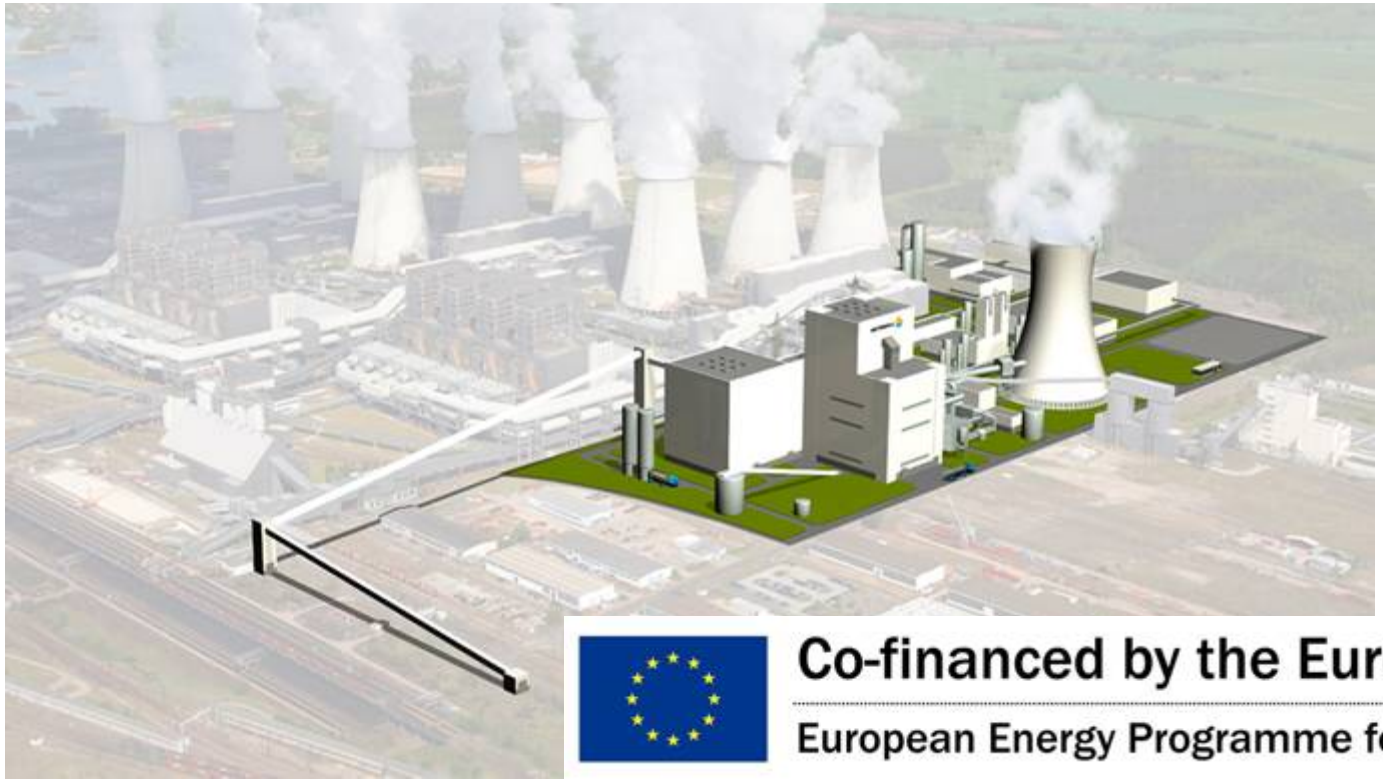
Demonstration Plant Jänschwalde – Investment cost

CCS demonstration project Jänschwalde
Total investment: approx. 1.5 Mrd. €
from it: 1,2 bl. € Capture and 0,3 bl. € Transport & Storage



Co-financed by the European Union

European Energy Programme for Recovery

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German CCS law – “carbon dioxide storage law” (Aug.17, 2012)

- Applicable for demonstration projects applying for storage permit until 31.December 2016
- Limitation of storage volume: 1,3 million t CO_2 per project and annum; 4 million t per annum in general
- Opt-out clause for Federal States
- Financial security and other financial burdens: provisions from the first saved tonne of CO_2 (amount indetermined), security for post-operational treatment, levy for the municipalities (3 % of the certificate value for the CO_2 amount stored in respective year)
- Priority of other underground technologies (geothermal energy, natural gas storage) over the storage of CO_2
- Extensive rights of land owners

➔ Insupportable conditions for a long-term investment

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Why has Vattenfall cancelled this demo project ?

- Boundary conditions for a 1.5 bl. € investment in a first-of-a-kind CCS industrial-scale demo plant were clear right from the start: proper regulatory and legal framework, EU co-funding, reliable market conditions (electricity and CO2 prices)
- Two out of these three conditions failed:
  - the business environment deteriorated due to the financial market meltdown and economic cirises, resulting in a 50% loss on EEX revenue compared to 2008 baseload prices
  - EU-wide transposition of the EU CCS Directive failed to deliver a stable and investment-friendly framework for an FID on such a scale
- In Germany, political support CCS faltered in the light of alternating energy concepts: first nuclear lifetime extension, then U-turn „Energiewende“ (Energy turn), with enforced nuclear phase-out, great expectations for renewable energies and little concern for coal/lignite.
- The German CCS law essentially falls short of delivering any investment certainty and incentive. Thus, Vattenfall had to cut the losses.

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Summary

- Vattenfall has gained many valuable practical experiences from the Oxyfuel pilot plant
- Vattenfall is technically ready to scale up for a demo plant
- CCS concept was worked out for a 300 MW Plant in Jänschwalde
- This concept was based on Oxyfuel and Postcombustion capture technology with pipeline transport and onshore storage in saline aquifers
- European funding was acquired, further funding possible
- Vattenfall had to cancel this demo project because of lacking political support in November 2011
- Boundary conditions of German CCS law prevent investment decisions for long-term CO2 storage

➔ Vattenfall remains committed to build a coal fired power plant with CCS technology in the future, if public acceptance is existing

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CCS Roadmap: skip the demo step!

Concept-studies	Test rigs 0,1 – 0,5 MW_{th}	Pilot plant 30 MW_{th}	Demo plant Jänschwalde 300 MW_{el}	Full scale plant 500 – 1.000 MW_{el}
2002	**2004**	**2008**	**2015/2016**	**> 2020**
• theoretical studies	• Research • Basic principles • Combustion characteristics	• Demonstration of complete process chain • Interaction of components • Validation of test rig results • Definition of scale-up criteria	• Verification and optimisation of component selection • Reducing risks • Proofing of economical viability	• Economic and competitive power plant concept

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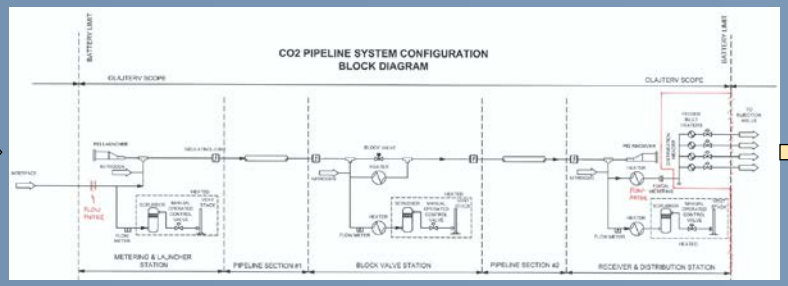
Thank you for your attention!

Power plant

Pipeline



Storage