Vattenfall's Oxyfuel Pilot Plant

First Experiences from Commissioning and Operation

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Decision process for the Oxyfuel Pilot Plant

2002

GAP Analysis

- Start of project
- Available components
- Known process steps
- Degree of development

2003

Technology Benchmark

- Evaluation of different steps of development
- Decision to develop Oxyfuel

2004

Feasibility Study

- Financial frame
- Comparing scales
- Possible sites
- Risks

2005

Decision for Oxyfuel Pilot Plant

- Building site: Lausitz area
- Scale: 30 MW_{th}
- Complete process chain from ASU to CO_2- processing

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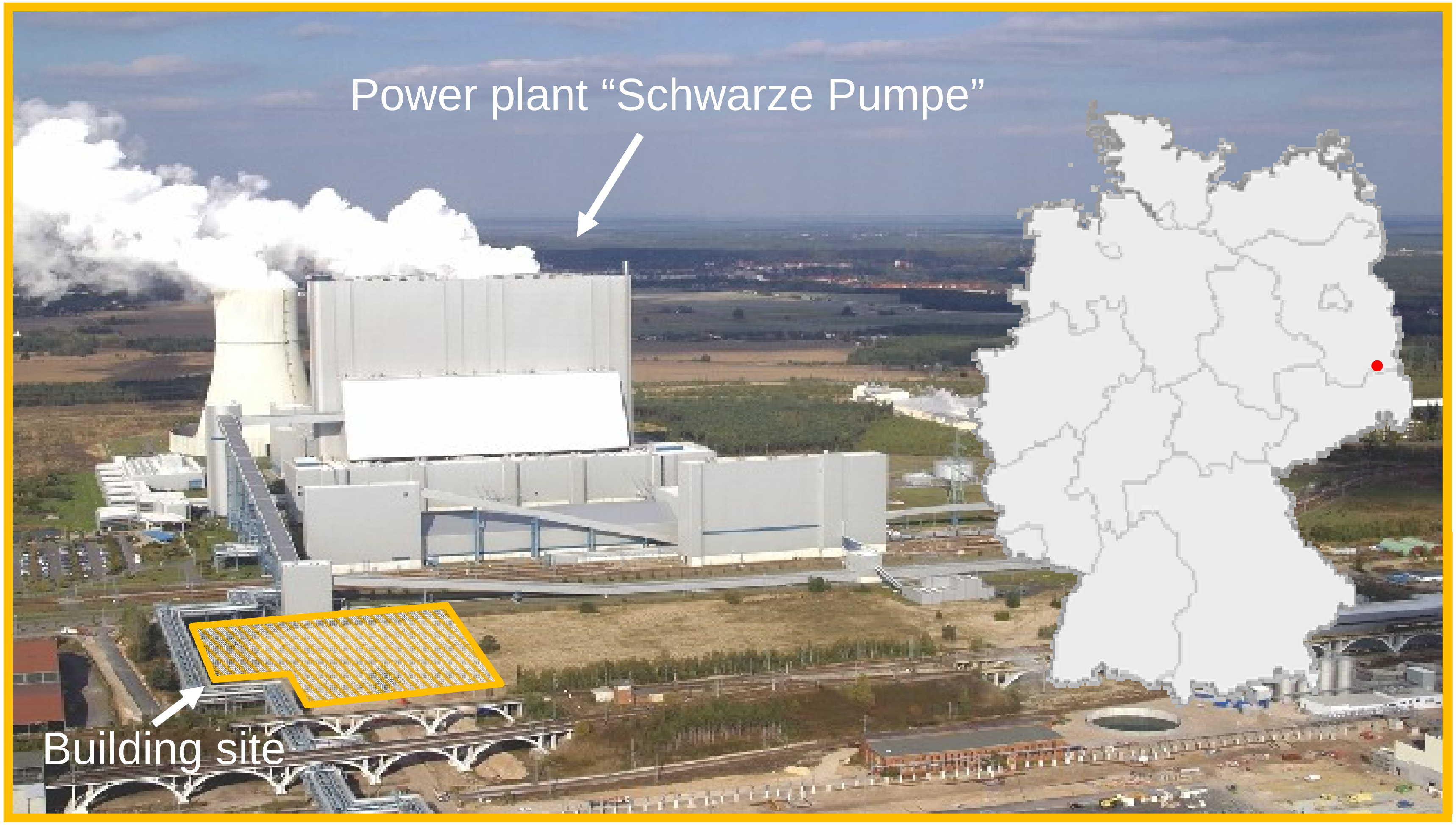
Design considerations for Oxyfuel Pilot Plant

- Basic purpose is to provide operating information to be able to later scale-up the technology to a 400-600 MW_{th} demonstration power plant
- Realization a complete process of coal input and oxygen production up to separation of CO_2
- Possible to operate on full load in air-firing mode and oxyfuel mode
- Designed to be able to operate on lignite and in a second phase on bituminous coal

Location of the Oxyfuel Pilot Plant



Time schedule of the project

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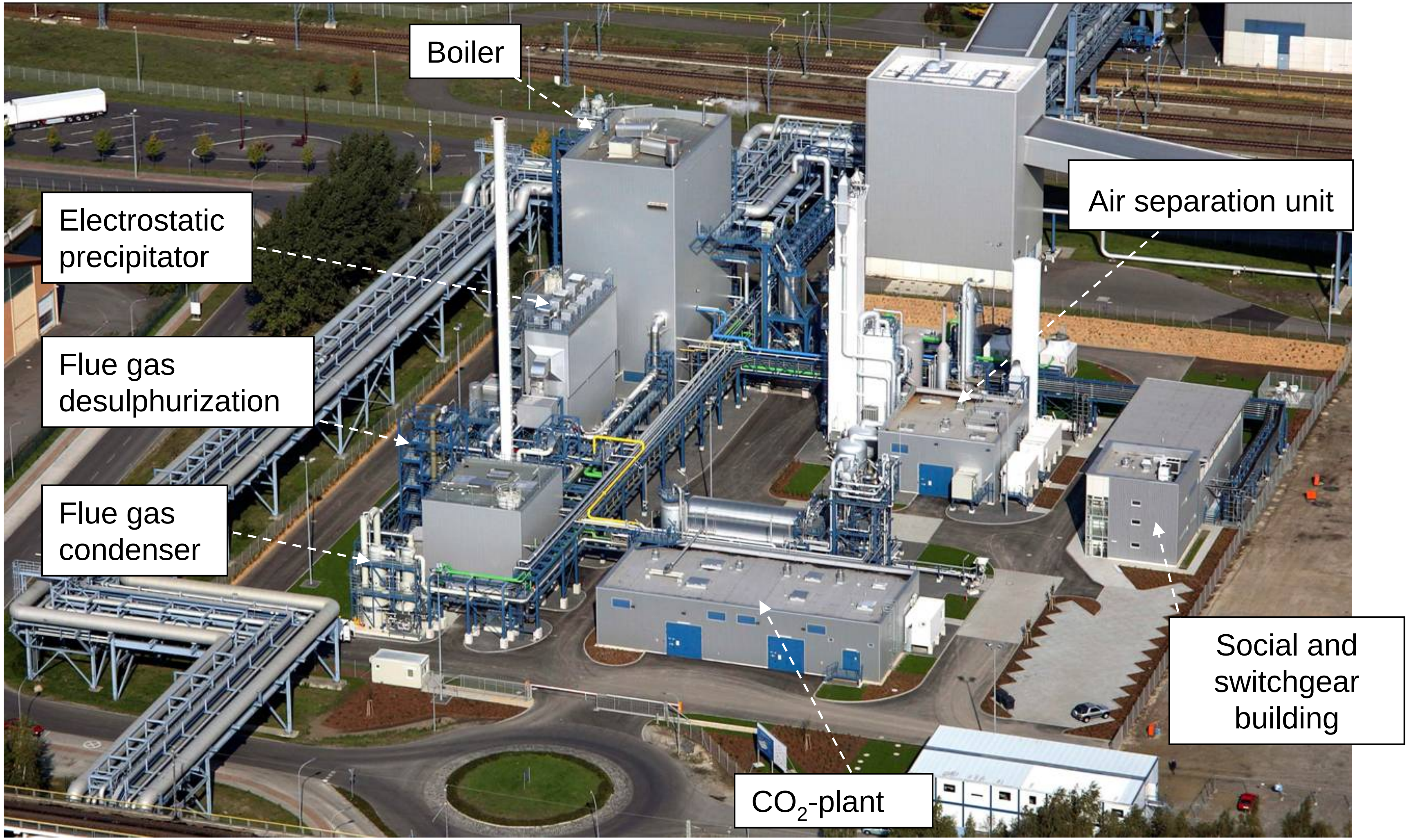
View on the Oxyfuel Pilot Plant



Webcam: www.Vattenfall.de/CCS

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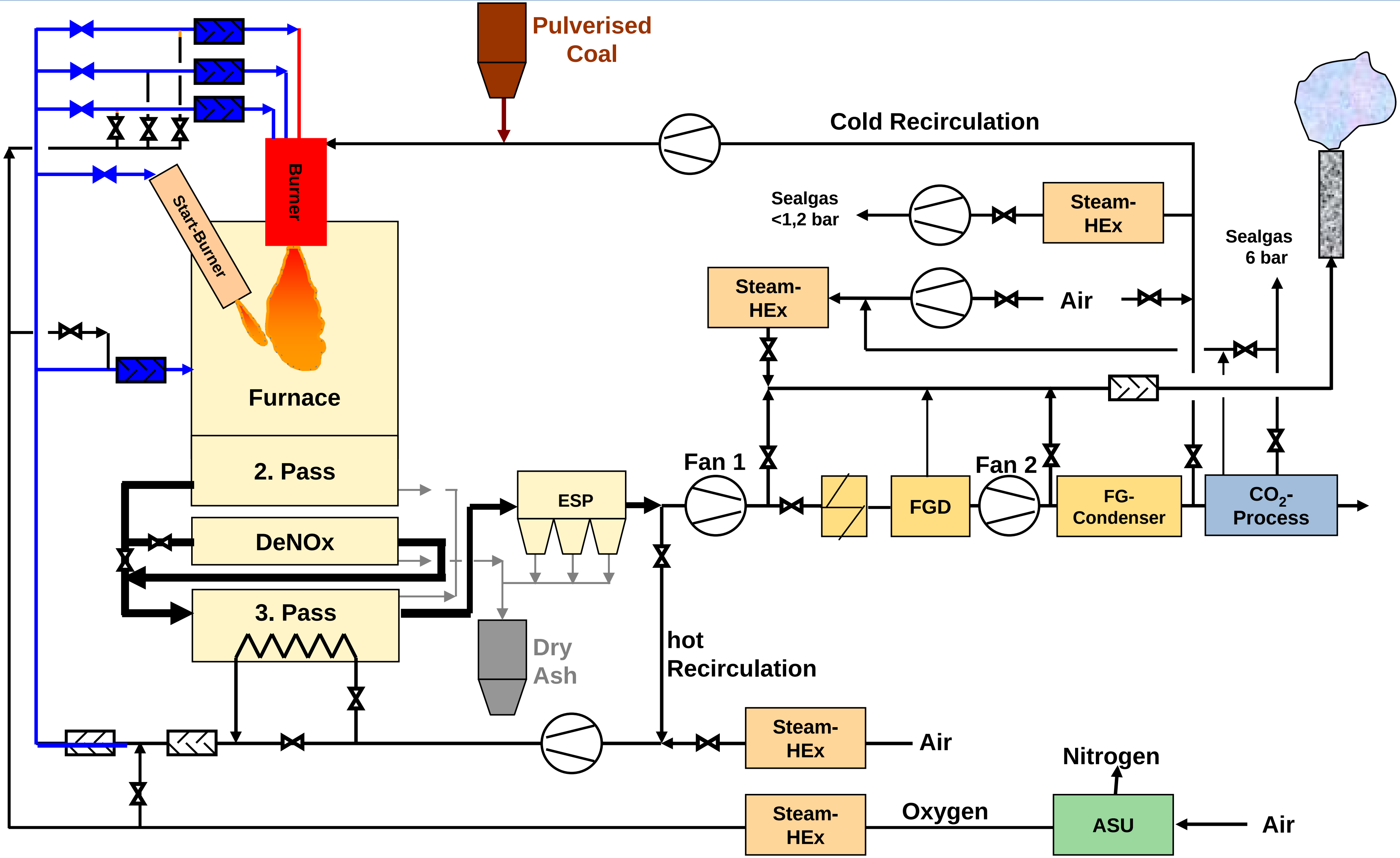
Basic data

Boiler: dust fired	Combustion heat performance Steam production Steam parameter	30 MW_{th} 40 t/h 25 bar / 350 °C
Coal: pulverized lignite (Lausitz)	LHV Moisture Carbon content	21.000 kJ/kg 10,5 % 56 %
Media:	Coal demand Oxygen (purity > 95%) CO_2 (liquid)	5,2 t/h 10 t/h 9 t/h
Other:	Required area CO_2 capture rate Investment	14.500 m² > 90 % 70 Mio. €

System overview of Oxyfuel Pilot Plant



Challenges

- 4 operating states
  - Air operation
  - Oxyfuel operation to atmosphere
  - Oxyfuel operation to CO2-process
  - CO_2 evaporation from on-site storage tanks

  (effortful in realization and regulation)
- 3 parallel I&C systems

  (ASU, conventional part, CO2-plant)
- Sulfur-rich flue gas recirculation
- Series connection of 5 fans/compressions
- FGD: external oxidation and high sulfur removal
- Flue gas condensation and high aerosol precipitation
- Fuel transport with air and/or flue gas
- More extensive safety requirements to media (CO_2, O_2, NH_3) and systems

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Status of the Oxyfuel Pilot Plant

- Commissioning of all components and systems finished (Aug. 2008).
- Security and function test by technical authority (TÜV) finished (Sept. 2008).
- Permission for regular operation by technical authority granted (Sept. 2008 for air operation, Oct. 2008 for Oxyfuel operation).
- Optimization and verification of warranted characteristics finished.
- Functionality of the Oxyfuel process is verified in pilot scale.
- Until beginning of January 2009
  - > 700 hours of Oxyfuel operation
  - separation and liquefaction of > 800 t CO_2
- After first measurement campaigns in November 2008, start of the test program in January 2009.

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Experiences with boiler

- Proven start burners (propane) having problems in Oxyfuel atmosphere due to high dust loads (Flame guards and installation situation had to be optimized)
- Authority demand: Individual burner examinations for all operating states
- Good flame stability in Oxidant at O_2 > 27%(w)
- 25 -30 % humidity in hot recirculation

- Supplying of pure O_2 and mixture in the burner possible
- Use of only a burner influences the burning behavior and the waste gas values
- Different burner swirls necessary for air and oxyfuel operation

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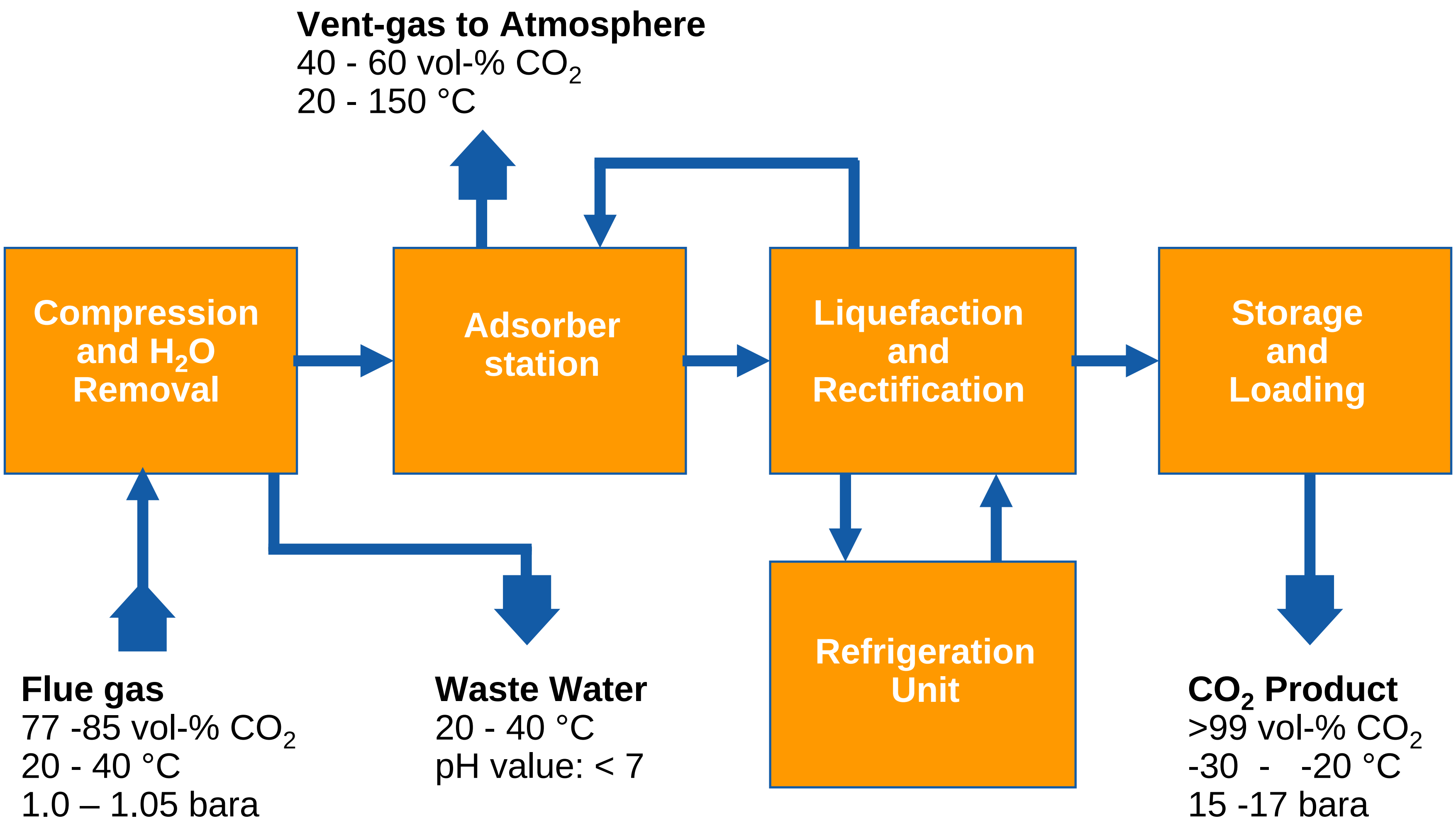
Requirements on flue gas scrubbing

Component	Composition	Reduction from*	Reduction to*	Capture rate
ESP	Ash	11.200 mg/m^3	< 20 mg/m^3	> 99 %
FGD	SO_2	11.500 mg/m^3	< 100 mg/m^3	> 99 %
	SO_3	50 mg/m^3	< 20 mg/m^3	> 50 %
	Ash	20 mg/m^3	< 10 mg/m^3	> 50 %
FG-Condenser	H_2O	30 vol-%	4 vol-%	> 85 %
	SO_2	100 mg/m^3	< 20 mg/m^3	> 80 %
	SO_3	20 mg/m^3	< 5 mg/m^3	> 75 %
	Ash	10 mg/m^3	< 1 mg/m^3	> 90 %

All design data are fulfilled !

* all mg/m^3 in Norm (dry)

Simplified CO_2 Liquefaction Process



CO_2- plant in detail

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Attainable CO_2 purities

Composition CO_2, liquid	Oxyfuel pilot plant (Technical CO_2)	Comparison to Food quality
CO_2	> 99,7 %	> 99,99 %
N_2+Ar+ O_2	< 0,3 %	< 30 ppm
H_2O	< 50 ppm	< 50 ppm
SO_2	< 2,5 ppm	< 1 ppm
SO_3	< 0,5 ppm	-
CO	< 10 ppm	< 10 ppm
NO	< 5 ppm	< 2,5 ppm
NO_2	< 15 ppm	< 2,5 ppm

Transport concept for pilot phase

- Transport with trailers (22 ton CO_2)
- Max. 7 to 9 trailer per day
- Distance: approx. 350 km
- Storage in depleted gas field

EGR project Altmark

"CO2Sink" Ketzin

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Outlook on test program

- Variation of coal quality
  (moisture, sulphur content, particle size).

- Tests of special measurement technique for flue gas composition and CO_2 monitoring.

- Material tests for demo plants and 700°C technology under Oxyfuel atmosphere.

- Testing of different burners.
- Tests with bituminous coal.

- $DeNO_X$ tests at the boiler and for the vent gas stream from the CO_2 plant.
- Test of an integrated dry lignite ignition burner.

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Summary

- Oxyfuel works in pilot scale, emission limits are kept.
- Successful integration of plant components from chemical engineering (ASU, CO2 plant).
- Gained experiences from permission process and implementation of secondary clauses for CCS power plants.
- CO_2 monitoring over the whole technology chain (capture – transport – storage) developed for the first time world wide.
- World-wide first application for participation in emission trading for a CCS plant.
- First steps towards full scale CCS plants is successfully done.

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Vision of the next generation power unit

Concept 1
<u>Oxyfuel boiler</u>

Concept 2
<u>Post combustion capture</u>

Thank you for your attention !