# Integration of Oxy Combustion in a Large Size USC PC Plant for a Competitive Solution

Thierry POURCHOT

Bénédicte PRODHOMME, François GRANIER,

Patrick MÖNCKERT, Olaf STALLMANN

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Oxyfuel Combustion Conference 3

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# Alstom Power Sectors
# Technologies adapted to all thermal energy sources

Gas

Coal

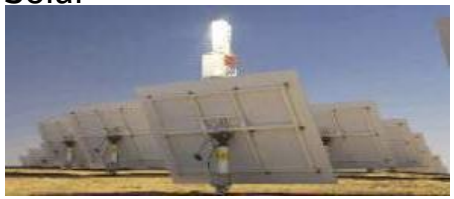
Oil

Hydro

Nuclear (turbine island)

Wind

Solar



Geothermal

Biomass

… for new power plants and the installed base





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# Alstom Plant Integrator™ concept

## Creating value for customers

Components

Integrated Systems

EPC

Operation & Maintenance

**Plant Integrator™**

**OPTIMISED** SOLUTIONS
ADDED **VALUE**

### Customer's business objectives

- Increased cash flow –lowest cost of electricity
- Higher power output
- Increased installation efficiency
- Reduced fuel consumption
- Increased operational flexibility
- Minimal environmental impact

**Working to achieve customer's business objectives**





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# Reference Plant 900MW Class cycle C

- The reference plant benefits from feedback experience of many tendered and executed large supercritical plants, as for example in Europe:

Belchatow in Poland: 1x900MW supercritical

Sostanj in Slovenia: 1x600MW supercritical

RDK8 in Germany: first project based on RP900

Neurath in Germany: 2x1100MW supercritical

Niederaußern in Germany: 1x1000MW supercritical





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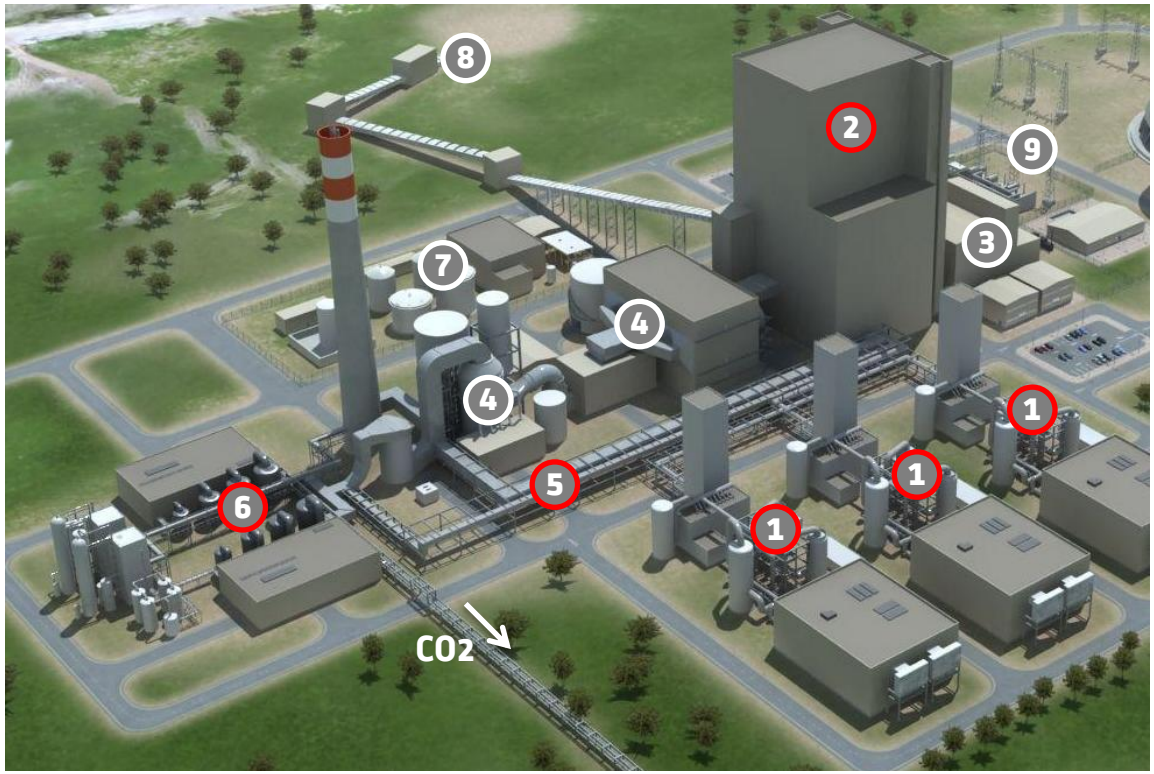
# Oxy-PC CO2 Capture Reference Plant
# Main Plant Scope

**Full turnkey steam plant 1 x 900 MW class (gross) including oxy extra features:**

1. Air Separation Units (ASU) - 3x33%
2. Once-through Oxy-Boiler Pulverised Coal
3. Turbine hall
4. Air quality Control Systems
5. Flue Gas Recycle ducts
6. Gas Processing Unit (GPU)
7. Balance of plant
8. Fuel storage & Handling Plant
9. Electrical Systems




... and Oxy Integration Systems!

Oxy PC Reference Plant developed on basis of RP 900MW Class Cycle C Product





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# Oxy-PC CO2 Capture Reference Plant
# Oxy-Combustion Integration Qualitative Benefits

- The integrated approach is key to integrate at best new oxy systems
- Strong and multiple interconnections with conventional plant components
- Main areas for integrations are :
  - Oxy Process / Flue Gas Path integration: optimum balance between ASU, Oxy Boiler, Flue Gas Recycle & GPU parameters
  - Heat Integration: optimum recovery of heat of Flue Gas Coolers & Condensors, ASU & GPU compressors in the W&S Cycle
  - Plant arrangement / Mechanical integration: optimal layout, study of alternative compressor drive solutions
  - Operation & Control / Electrical integration: global plant load & transient operation control, dynamic behaviour simulation.
- This integration approach should therefore be started very early in a project development to maximise its benefits.

An integrated approach will allow minimizing cost of electricity.





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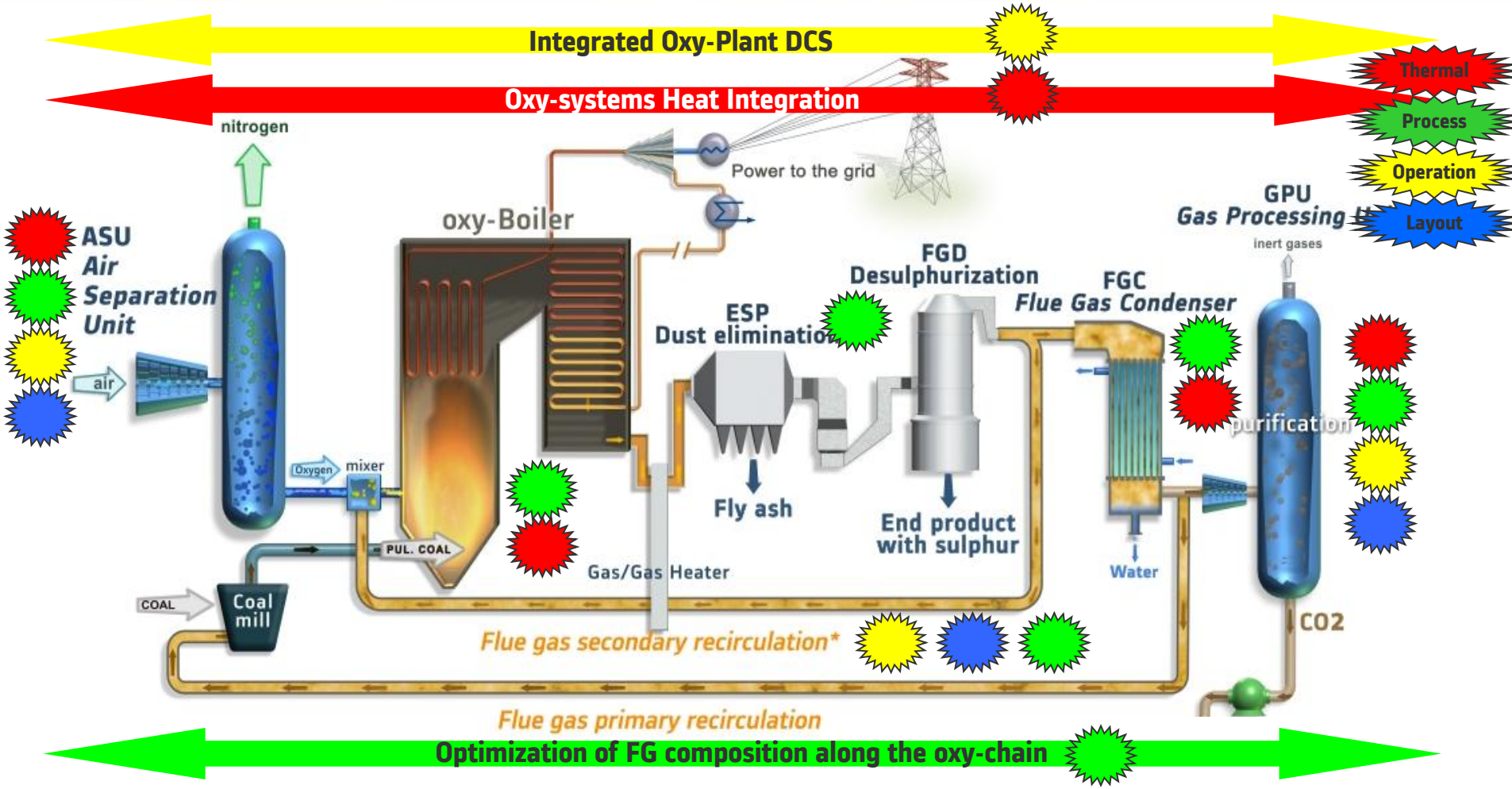
# Oxy-PC CO2 Capture Reference Plant
# Oxy-Combustion Integrated Approach




Multiple options and areas of integration evaluated for Oxy PC Reference Plant





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# Oxy-PC $CO_2$ Capture Reference Plant
# Oxy-firing Integration Assumptions

## DESIGN BASIS

- Oxy-Combustion Power Plant 900 MW class (90% $CO_2$ capture)
- Steam Cycle : 600  C / 620  C / 275 bara
- Bituminous Coal
- Direct cooling (power plant, ASU, GPU)
- $CO_2$ Specification for storage in a Saline Aquifer ( $CO_2$ > 95% vol, $O_2$ < 3% vol)
- Base load operating regime
- Flexibility in oxy-mode down to 40%
- Grid code compliance: 5% primary response in 30s at 90% load
- Parity factor for integration: 5300 €/kW

## ESTIMATED PLANT PERFORMANCE (BASELINE FOR INTEGRATION)

| | Net Eff. (LHV) | Net Output (MW) |
|---|---|---|
| Conventional Air-Fired Plant (No Capture) | 46.2% | 836 MW |
| Oxy Capture Plant - Not Integrated | 33.4% | 606 MW |

Not- integrated Oxy Plant efficiency ~13% pts below Non-Capture Plant





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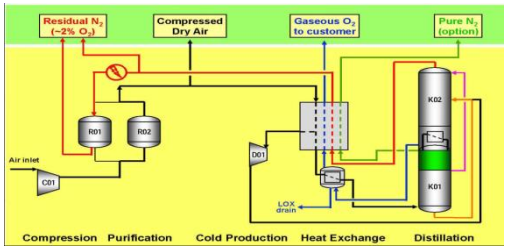
# Oxy-PC CO2 Capture Reference Plant
# Air Separation Unit Integration

## DESIGN BASIS – Non-Integrated Baseline

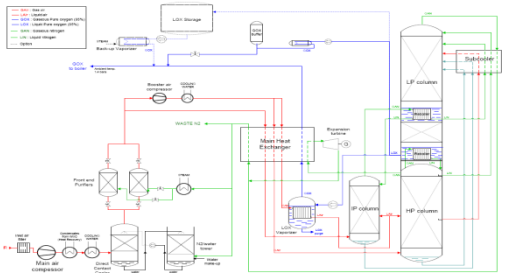
- 3 x 4400 tpd ASU trains (max. size today)
- 95% O2 Purity
- Low-pressure O2 production (~1.3 bara)

- State-of-the-art double-column Process
- In-line Centrifugal MAC (P/R ~5)




## OXY-INTEGRATED HIGH EFFICIENCY ASU

- Low-energy process (triple-column, multiple LP reboilers)
- Axial MAC (P/R ~3) & Heat Exchangers for Integration
- GOX & LOX storage for Plant Operability & Flexibility



## ESTIMATED HIGH EFFICIENCY ASU INTEGRATION VALUE*

| | ASU Power (MW) | Power Value (M€) |
|---|---|---|
| Non-integrated ASU | ref | ref |
| Oxy Integrated ASU | - 13.3 MW | +71 M€ |

**Value of Power Gain for High efficiency ASU >> Expected ASU Cost Increase**

*excluding heat integration





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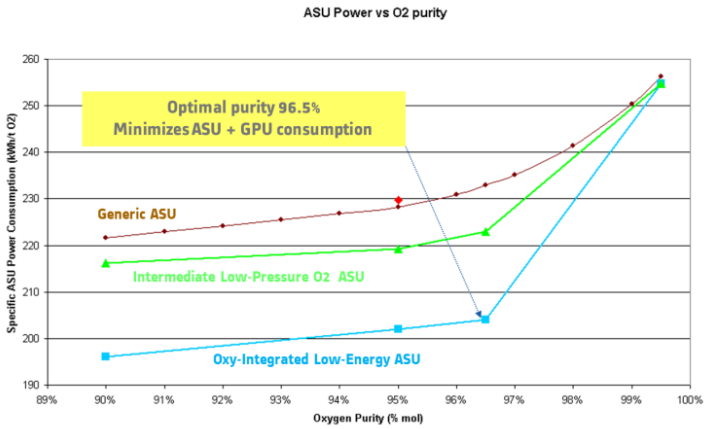
# Oxy-PC CO2 Capture Reference Plant
# Flue Gas Path Integration – ASU Oxygen Purity

## DESIGN BASIS

- 95% O2 Purity (conventional "low purity" Oxygen)
- Maximum 96,5% O2 purity capability for « Low Energy » ASU process (avoidance of Argon distillation)
- GPU multi-flash process for Saline Aquifer storage




Typical ASU Consumption versus O2 Purity

## OPTIMAL O2 PURITY

- 96.3% O2 purity:
  - slight increase of ASU consumption (<+1 %)
  - significant decrease of GPU Consumption (~-3%)

## ESTIMATED O2 PURITY INTEGRATION VALUE

| | ASU+GPU Power (MW) | Power Value (M€) |
|---|---|---|
| 95% O2 purity | ref | ref |
| 96.3% O2 purity | - 1.4 MW | +7 M€ |

**O2 Purity Optimisation Provides Added Value at no (or negative) Additional Cost**





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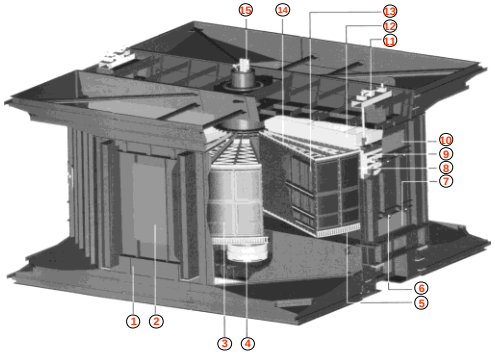
# Oxy-PC CO2 Capture Reference Plant
# Flue Gas Path Integration – FG Recycle, O2 Injection & RGH

## DESIGN BASIS

- AQCS: ESP + WFGD – Flue Gas Condenser (FGC)
- Secondary Recycle after ESP & Primary after FGC
- O2 Injection after Recycle Gas Heater – standard RGH
- Operation up to max. 1,5% S in coal (design 0,6%)

## FLUE GAS PATH RECYCLE & O2 INJECTION OPTIMISATION

- 6 Flue Gas Recycle topologies evaluated, 9 Evaluation criteria: SO2 concentration, Flue Gas & Recycle Gas Temperatures, etc
- 3 Injection options evaluated, 6 Evaluation criteria: RGH O2 limit, O2 & Coal consumptions, etc.
- RGH : Optimization of leak rate – purging & pressurized sealing



## ESTIMATED FG RECYCLE OPTIMISATION VALUE

| | Net Power (MW) | Power Value (M€) |
|---|---|---|
| Base Case | ref | ref |
| Best Topology | + 9.8 MW | +52 M€ |

**Optimization of recirculation provides Fuel/Operation Flexibility and Power Value**





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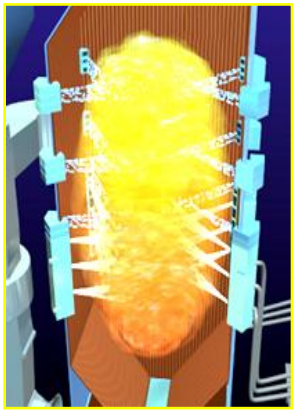
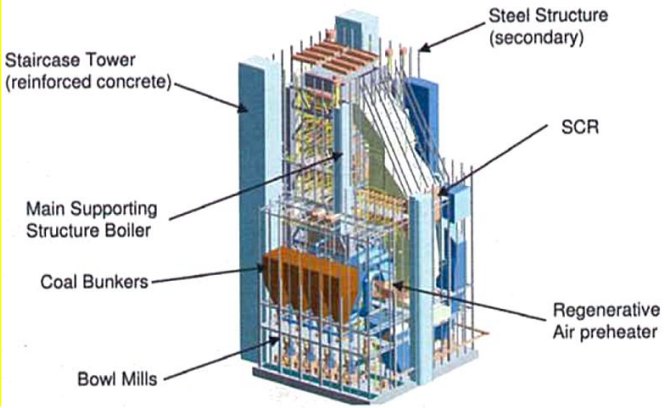
# Oxy-PC CO2 Capture Reference Plant
# Flue Gas Path Integration – Oxy-PC Boiler

## AIR-FIRED DESIGN BASIS

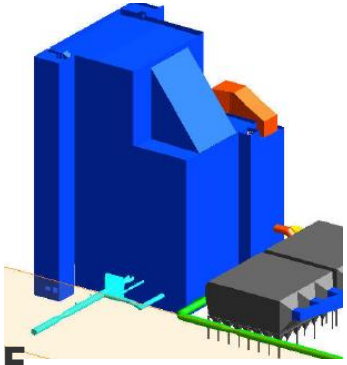
- ALSTOM USC PC Tower-type Boiler, 900 MW class
- ~700 kg/s air intake, ~3% air in-leakage






## OXY-PC BOILER

- ALSTOM USC Oxy-PC Boiler, Same rating/size as air-fired
- Improved sealing



## ESTIMATED REDUCED AIR-INLEAKAGE INTEGRATION VALUE

| | Net Power (MW) | Power Value (M€) |
|---|---|---|
| Conventional sealing | ref | ref |
| Oxy improved sealing | + 7.6 MW | +40 M€ |

**Reduced Oxy-Boiler Air In-leakage provides High Value at Low Cost**





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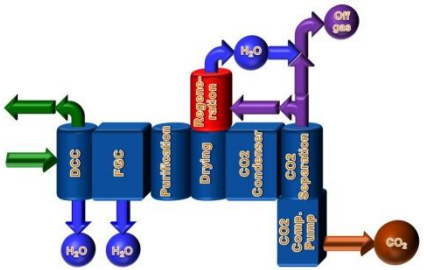
# Oxy-PC CO2 Capture Reference Plant
# Flue Gas Path Integration – Gas Processing Unit

## GPU DESIGN BASIS

- 90% CO2 Capture Rate, 110 bar CO2 product pressure
- Saline Aquifer CO2 specification (CO2 > 95%, O2 < 3% vol.)
- Vent Gas Emission: NOx < 150 mg/Nm3 (air fired basis)

## GPU FLUE GAS PATH INTEGRATION

- Energy optimisation
- Maximized CO2 content
- Direct Cooling integration




## ESTIMATED GPU COOLING INTEGRATION VALUE

| | GPU Power (MW) | Power Value (M€) |
|---|---|---|
| No cooling integration | ref | ref |
| GPU direct cooling | - 4.7 MW | +25 M€ |

**Integrated GPU Cooling provides High Value at Low Cost**





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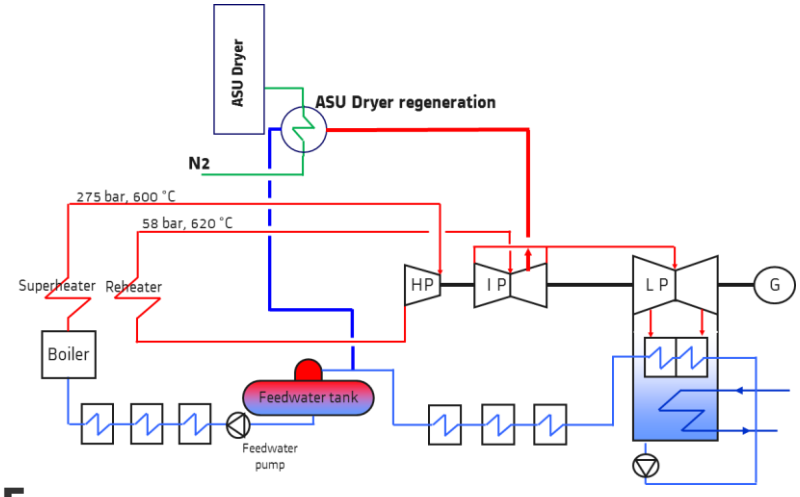
# Oxy-PC CO2 Capture Reference Plant
# Process Heat Integration - Air Separation Unit Dryer

## DESIGN BASIS – "STAND-ALONE" ASU

- 3 x 4400 tpd ASU trains
- Molecular sieve dryers
- Heat needed for periodic ASU Dryer regeneration
- Electrical heating,

## ASU DRYER REGENERATION INTEGRATION

- Steam heating supply from W&S cycle




## ESTIMATED ASU PROCESS HEAT INTEGRATION VALUE

| | NET Power (MW) | Power Value (M€) |
|---|---|---|
| Electrical heating | ref | ref |
| Steam Integrated heating | +5.1 MW | +27 M€ |

**High Value of Dryer Heating Integration at Low Cost**





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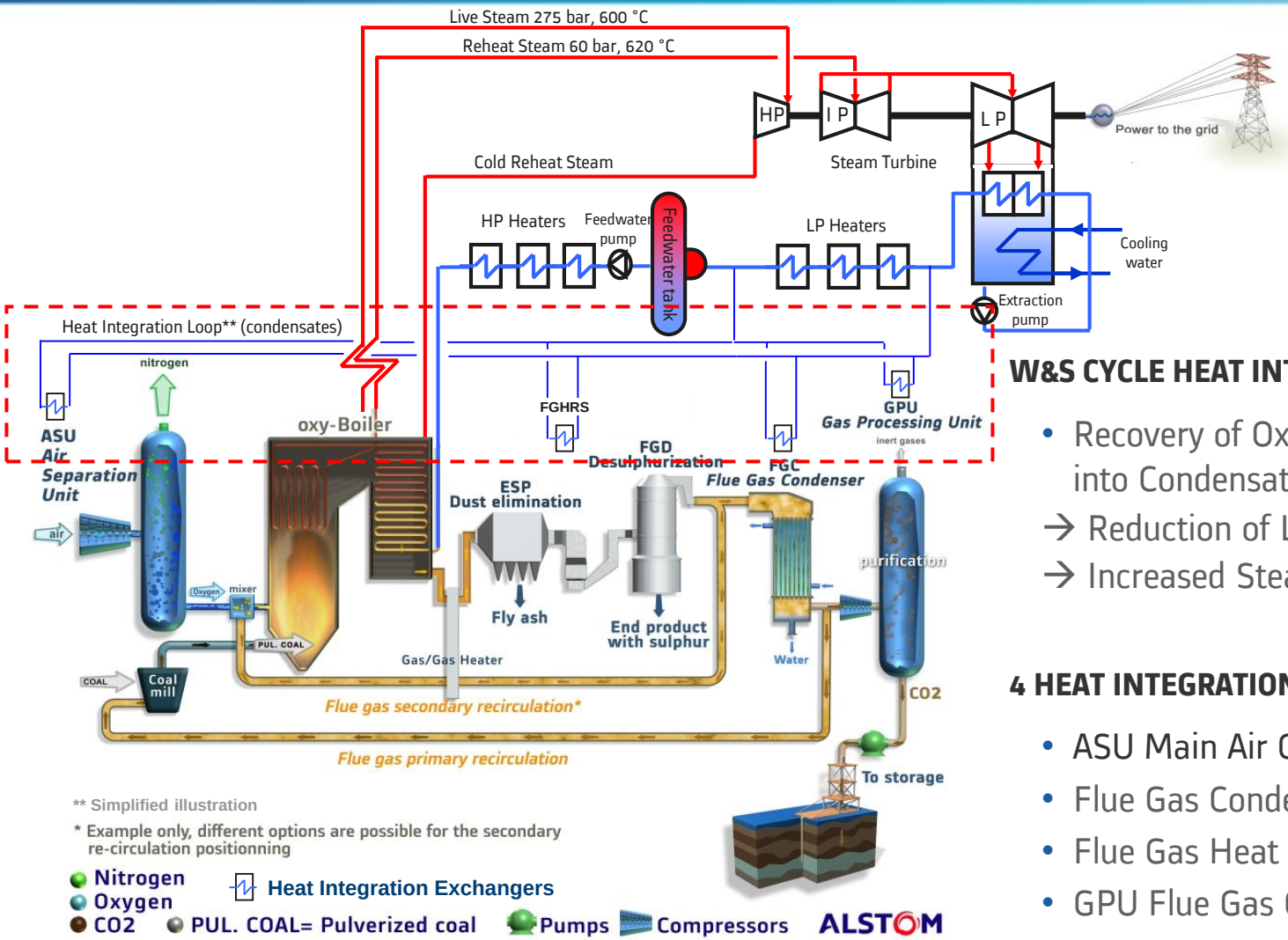
# Oxy-PC CO2 Capture Reference Plant
# Heat Integration - Water&Steam Cycle & Flue Gas Path




## W&S CYCLE HEAT INTEGRATION

- Recovery of Oxy-systems available Heat into Condensate Loop

→ Reduction of LP Heaters extraction

→ Increased Steam Turbine Power

## 4 HEAT INTEGRATION SOURCES

- ASU Main Air Compressor
- Flue Gas Condenser
- Flue Gas Heat Recovery
- GPU Flue Gas Compressor





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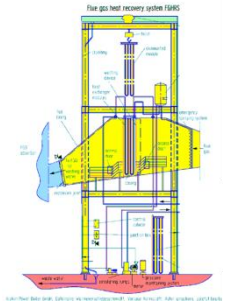
# Oxy-PC CO2 Capture Reference Plant
# Heat Integration

| | Power delta |
|---|---|
| **ASU MAIN AIR COMPRESSOR** | |
| Axial MAC & Coil-wound HX | > 8.5 MW |
| **FLUE GAS CONDENSER INTEGRATION** | |
| Direct Contact Cooler after WFGD | > 1.2 MW |
| **FGHRS INTEGRATION IN OXY PLANT** | |
| Flue Gas Cooling upstream WFGD | > 7.1 MW |
| **GPU FLUE GAS COMPRESSOR** | |
| Axial-radial compressor | > 4.5 MW |




## OPTIMIZED WATER AND STEAM CYCLE CONFIGURATION

- Optimal cycle design, to take in account Performance, Operability, Process control and Reliability
- 7 configurations evaluated

## ESTIMATED HEAT INTEGRATION VALUE

| | NET Power (MW) | Power Value (M€) |
|---|---|---|
| Total Heat Integration | + 25,7MW | 136 M€ |





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# Oxy-PC CO2 Capture Reference Plant
# TOTAL INTEGRATION VALUE

## ESTIMATED TOTAL INTEGRATION VALUE

| | Net Power (MW) | Net Efficiency (%) | Power Value (M€) |
|---|---|---|---|
| Not Integrated Oxy | ref | ref | ref |
| High efficiency ASU | +13.3 MW | +0.7% | +71 M€ |
| Integrated Flue Gas Path | +23.5 MW | +1.3% | +125 M€ |
| ASU Dryer Steam Supply | +5.1 MW | +0.3% | +27 M€ |
| Optimal Heat Integration | +25.7 MW | +1.4% | +136 M€ |
| **Total Oxy Integration** | **+67.7 MW** | **+3.7%** | **+359 M€** |

## ESTIMATED INTEGRATED PLANT PERFORMANCE

| | Net Eff. (LHV) | Net Output (MW) |
|---|---|---|
| Conventional Air-Fired Plant (No Capture) | 46.2% | 836 MW |
| Oxy power Plant - Not Integrated | 33.4% | 606 MW |
| Oxy power Plant – Integrated | 37.1% | 673 MW |

Total Integration provides 3.7% pts Efficiency Improvement and High Power Value
Integrated Oxy Plant efficiency ~9% pts below Non-Capture Plant





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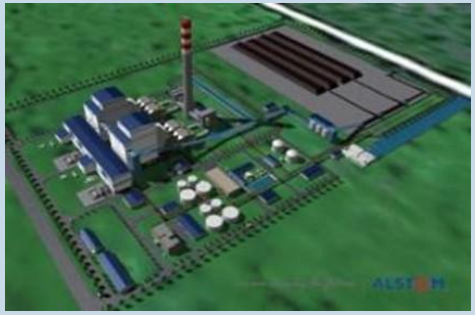
# Alstom Cost of Electricity study on CCS

13 pilots, several demo projects in development


## CCS experience

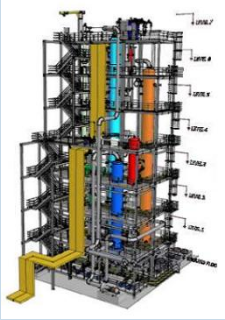
Global supply of turnkey power plants

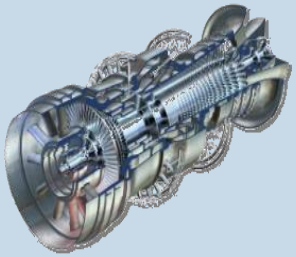


## Plant Integration experience

## Robust CCS-CoE study built on Alstom know-how

## Key component OEM





- **Independent Validation of methodology and hypothesis;**
- **Update of asumptions every year**





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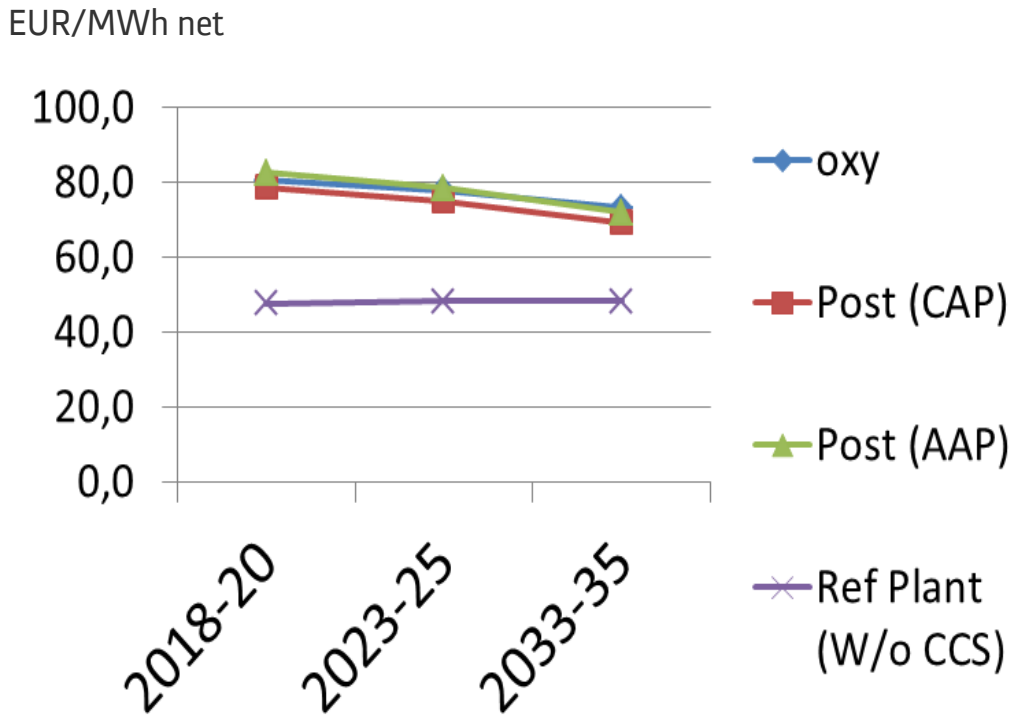
# Results for bituminous coal Europe LCoE (No $CO_2$ price)




*Source : Alstom cost of electricity study 2013*

Coal price = 70,9 EUR/t

All technologies are in the same cost range : differences will be site-specific





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Thank you!

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