Future oxycombustion systems

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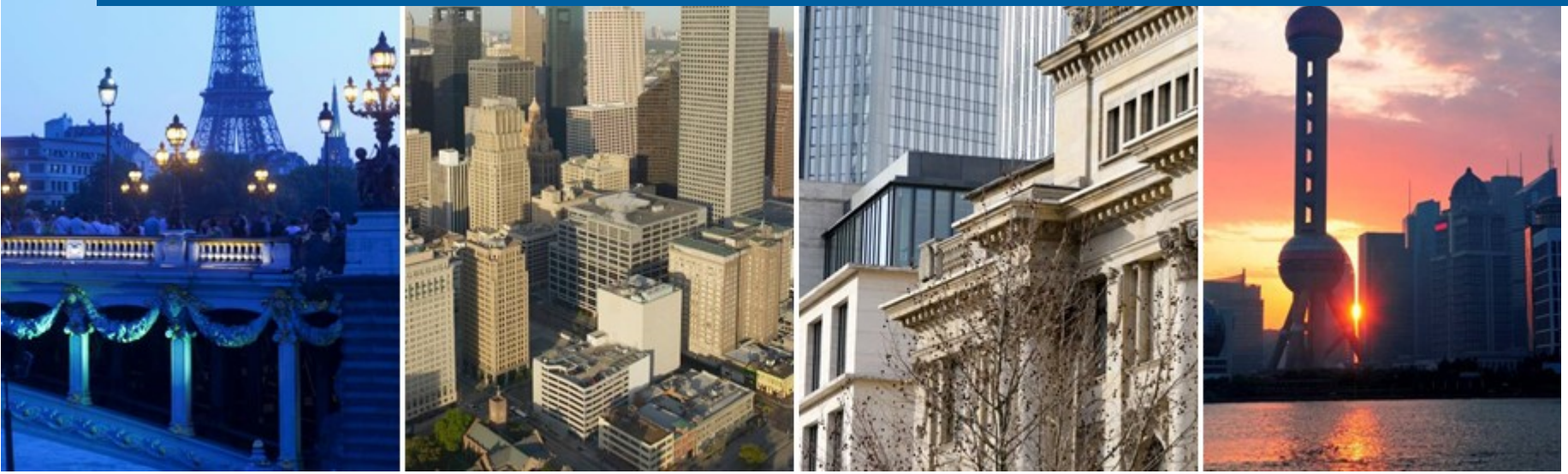

Agenda

- Introduction
- 2010 State-of-the-art plants
- Future oxycombustion systems
- Conclusion

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Air Liquide roadmap toward CO_2 capture

Air Liquide is highly involved in oxy-coal technologies development

AL is selected by DOE for the 1st **full-scale oxyfuel plant FutureGen 2.0** (200 MW_e)

2015

CPU pilot tested within the **CIUDEN** and **O_2GEN** projects in Spain (30 MW_{th} boiler)

2013

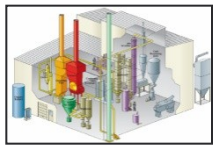
CPU pilot tested at **Callide** in Australia (100 MW_{th} bituminous coal plant)

2012

Joint studies with **Vattenfall** (1 GW lignite plant) and **B&W** (700 MW sub-bituminous coal plant)

2010

Near-commercial scale 30 MW_{th} **burner demonstration** with **B&W**

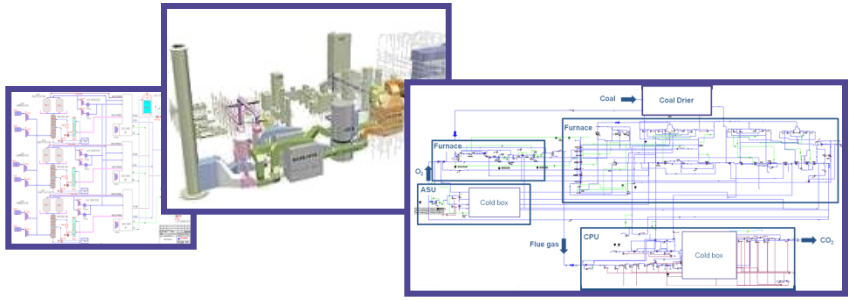


2007

Further improvement of oxycombustion systems

- Air Separation Unit (ASU) and CO_2 Processing Unit (CPU) have a strong impact on oxyfuel process efficiency

- There are some development opportunities in the 2015-2020 timeframe
  - ASU & CPU specific energy consumption reduction
  - Oxyfuel process optimization



- Scope of the study has been:
  - Large-scale Oxy-PC power plant
  - High CO_2 purity (>99.9 %-vol) and high capture rates (>90%)
  - Focus on overall plant efficiency improvement (no OPEX/CAPEX trade-off)

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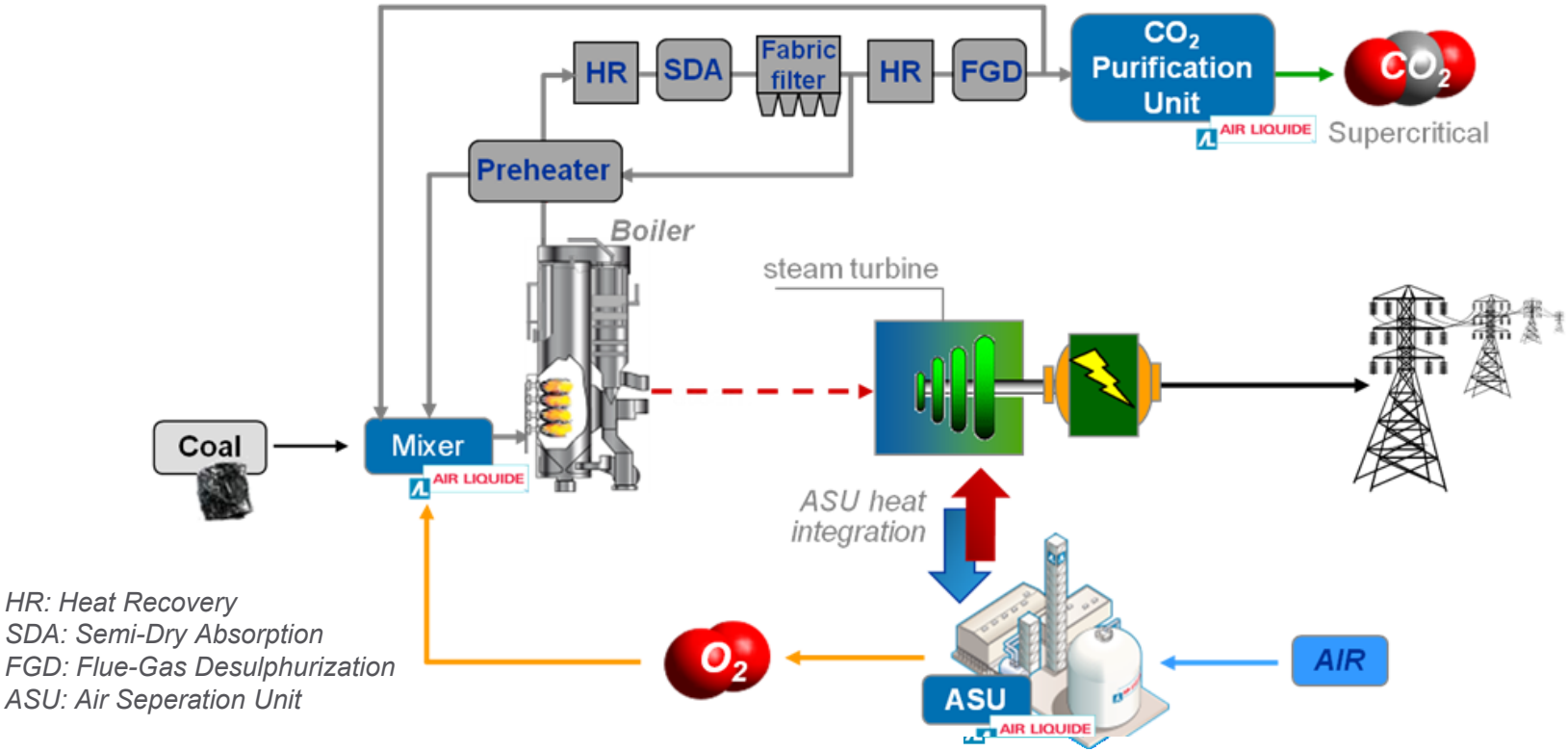
Reference plants design basis

- Air/Oxy reference plants: based on Vattenfall-Air Liquide 2010 study (1 GW gross)
- ASU & CPU designs based on '2010 technology' (Air Liquide commercial offer)
- 'High efficiency' plant design
  - Steam data: 280 bar/600°C/620°C
  - Pressurized steam lignite drier (+3-4 %-pts)
  - Heat recovery below acid dew point (+1 %-pts)

- Air-fired reference plant net LHV efficiency: 49.6%

Oxyfuel reference plant configuration

Oxyfuel reference plant simplified process flow diagram:



- Oxyfuel plant net LHV efficiency: 41.9% → Efficiency penalty of 7.7 %-pts

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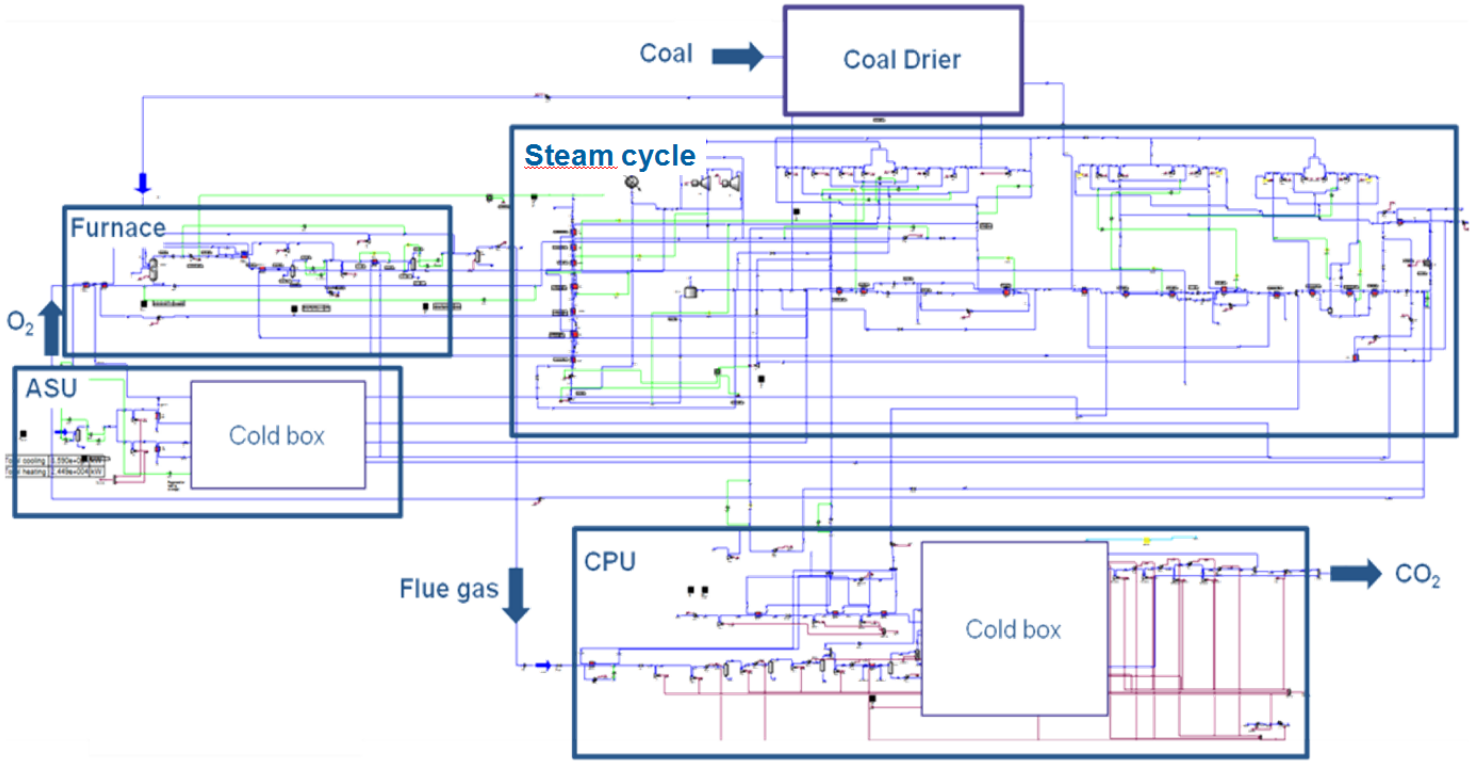
Process simulation basis

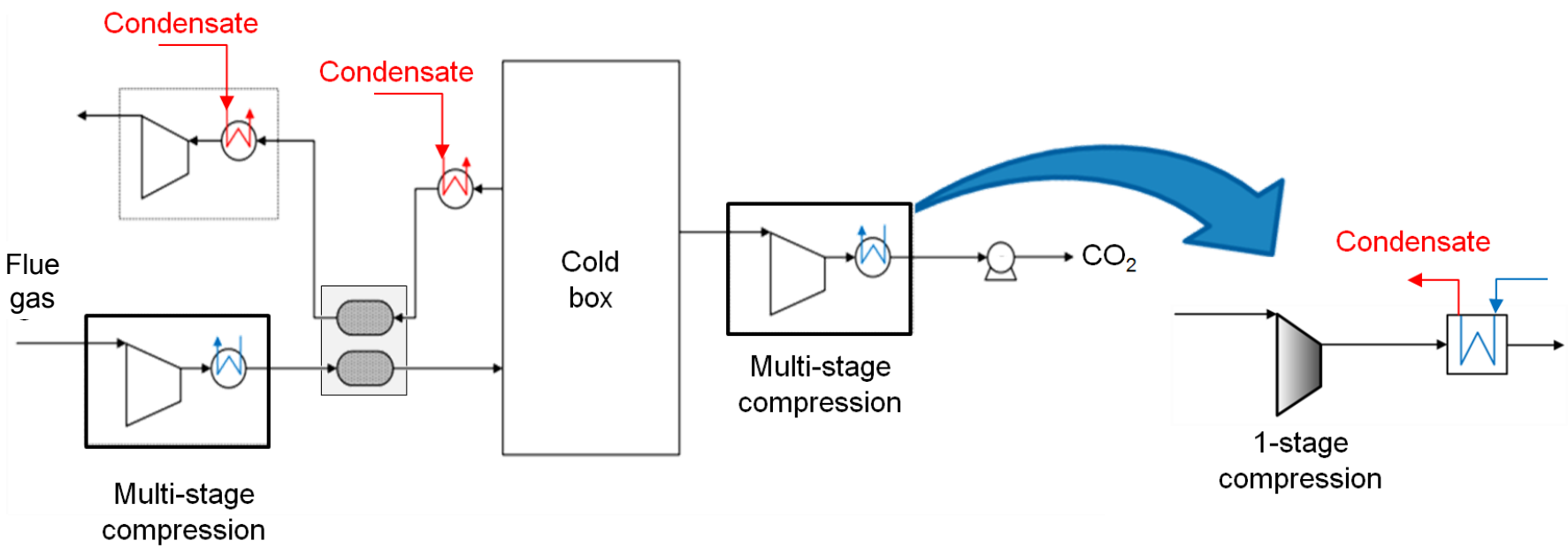
- Steady-state simulation of the overall plant (Aspen Hysys software)



CPU heat integration

- Concept 1: CPU heat integration on dry CO_2 compression
  - Use of CO_2 compression heat for steam cycle condensate preheating
  - CPU steam consumption reduction

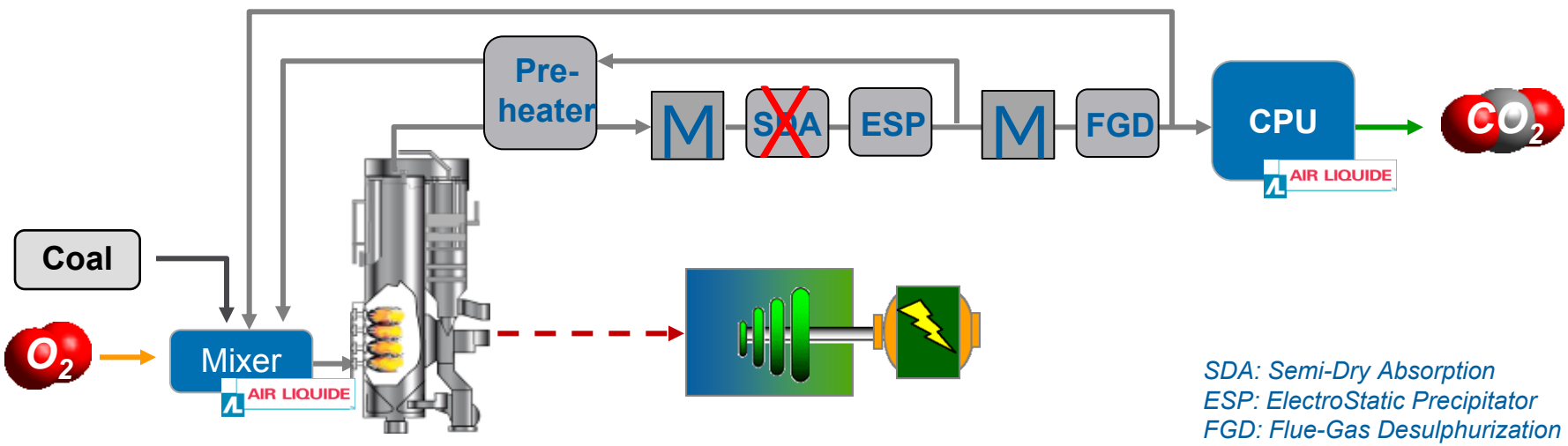
→ Plant net efficiency: **+ 0.2 pt**



Warm recycle

- Concept 2: Semi-Dry Absorption removal - Warm recycle
  - Alternative to SDA will avoid water injection quenching effect
    - Fully dry sulfur abatement technology
    - Low sulfur coal
  - Secondary recycle temperature increases
  - Heat recovery is increased by 40 MW_{th}

→ Net efficiency: **+0.5 pt**



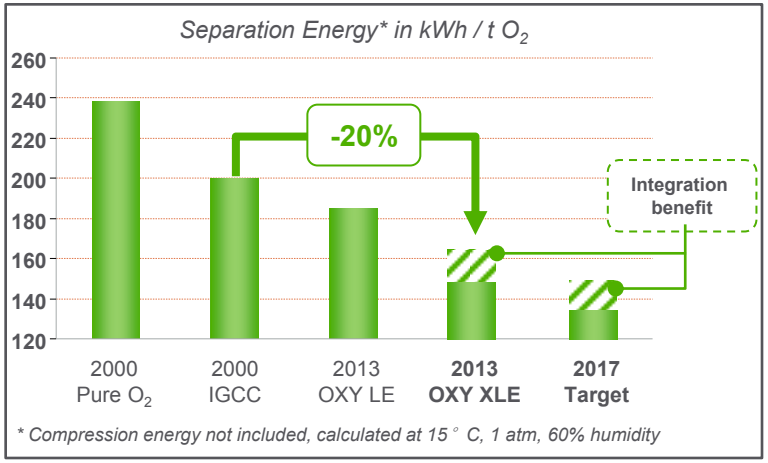
SDA: Semi-Dry Absorption
ESP: ElectroStatic Precipitator
FGD: Flue-Gas Desulphurization

ASU & CPU development

- Concept 3: ASU '2015-2020' design
  - Technology development
  - Advanced cycle design
  - Increased level of integration

2020 target: 145 kWh/t (w/o int. credit) → **+ 0.7 pt**

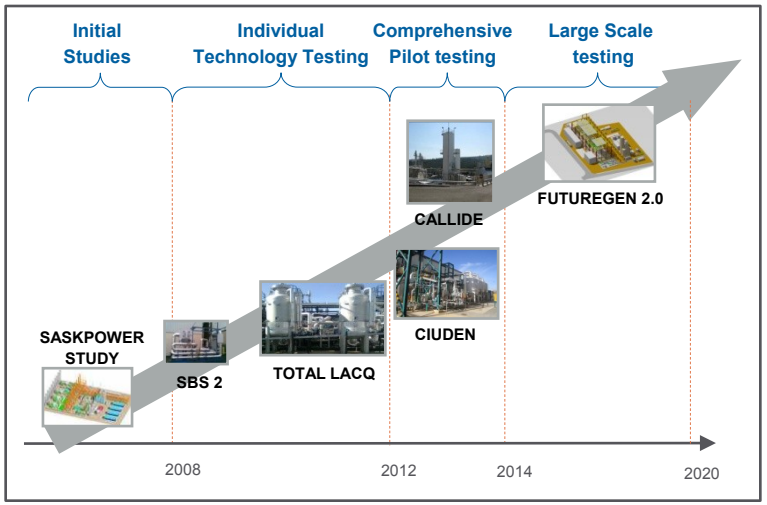
Air Liquide eXtra Low Energy ASU development



- Concept 4: CPU '2015-2020' design
  - Advanced CO_2 membranes
  - REX on Ciuden and Callide pilots
  - Improvement of drying and compression

2020 target at 90% capture: 120 kWh/t (w/o int. credit)
→ **+ 0.4 pt**

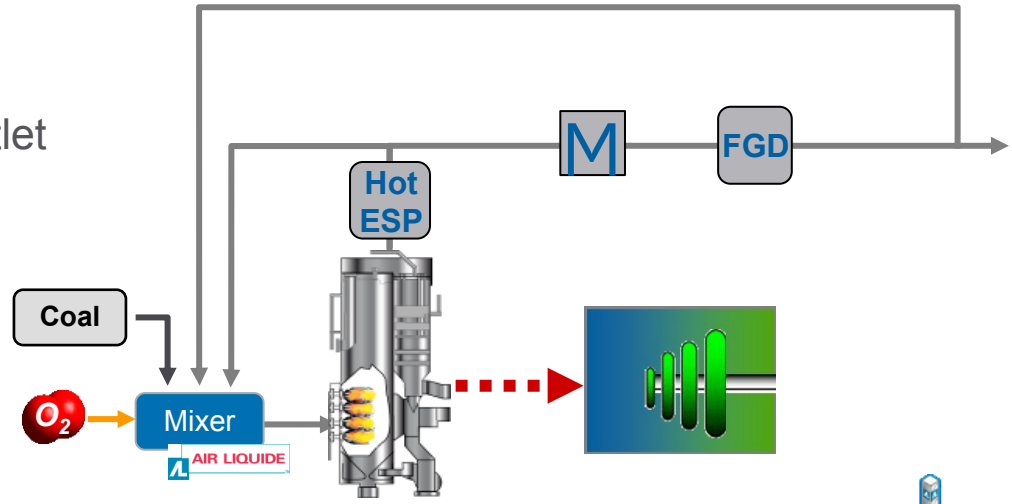
Air Liquide CO_2 purification unit roadmap



Hot recycle & Oxygen preheating

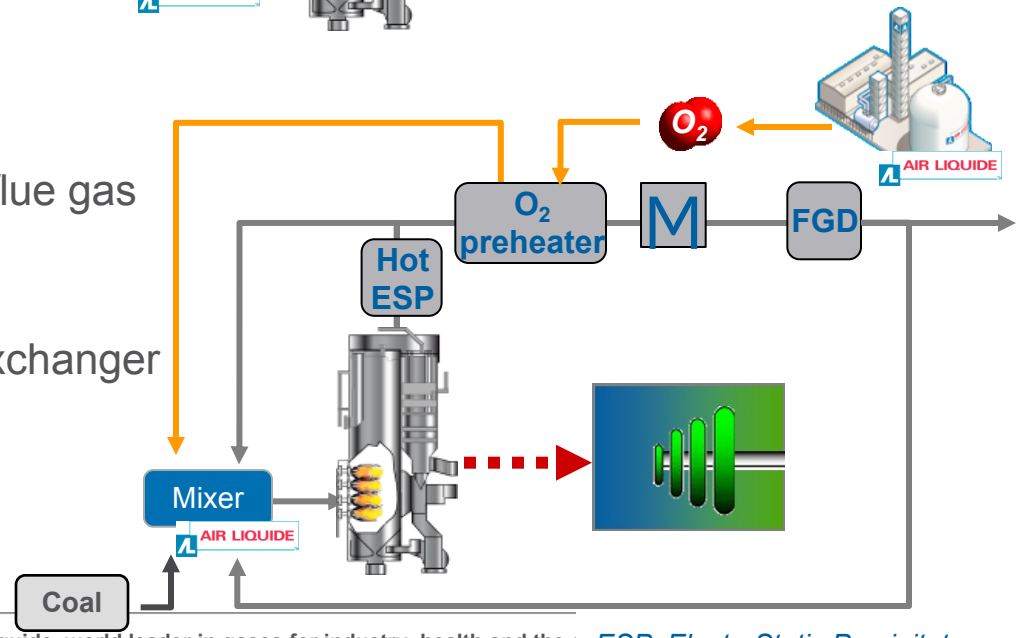
- Concept 6: Hot recycle
  - Secondary recycling at boiler outlet
    - Reduced heat recovery
    - Increased boiler power
  - Hot ESP technology

→ Net efficiency: **+ 0.2 pt**



- Concept 7: Oxygen preheating
  - O_2 preheating at ~300°C against flue gas
    - Reduced heat recovery
    - Increased boiler power
  - High temperature gas-gas heat exchanger

→ Net efficiency: **+ 0.2 pt**



ESP: ElectroStatic Precipitator
FGD: Flue-Gas Desulphurization

Influence of plant design

- No heat recovery below acid dew point
  - No acid corrosion risk
  - Efficiency reduction is higher for the air-fired plant (-0.7 pts) than for the oxyfuel plant (-0.2 pts)

→ **Without** heat recovery below acid dew point, air-oxy efficiency gap is reduced by **0.5 pt**

- Advanced steam cycle
  - Double reheat configuration
  - Ultra-Super Critical (USC) steam cycle

→ **With** advanced steam cycle, air-oxy efficiency gap is reduced by **0.1 pt**

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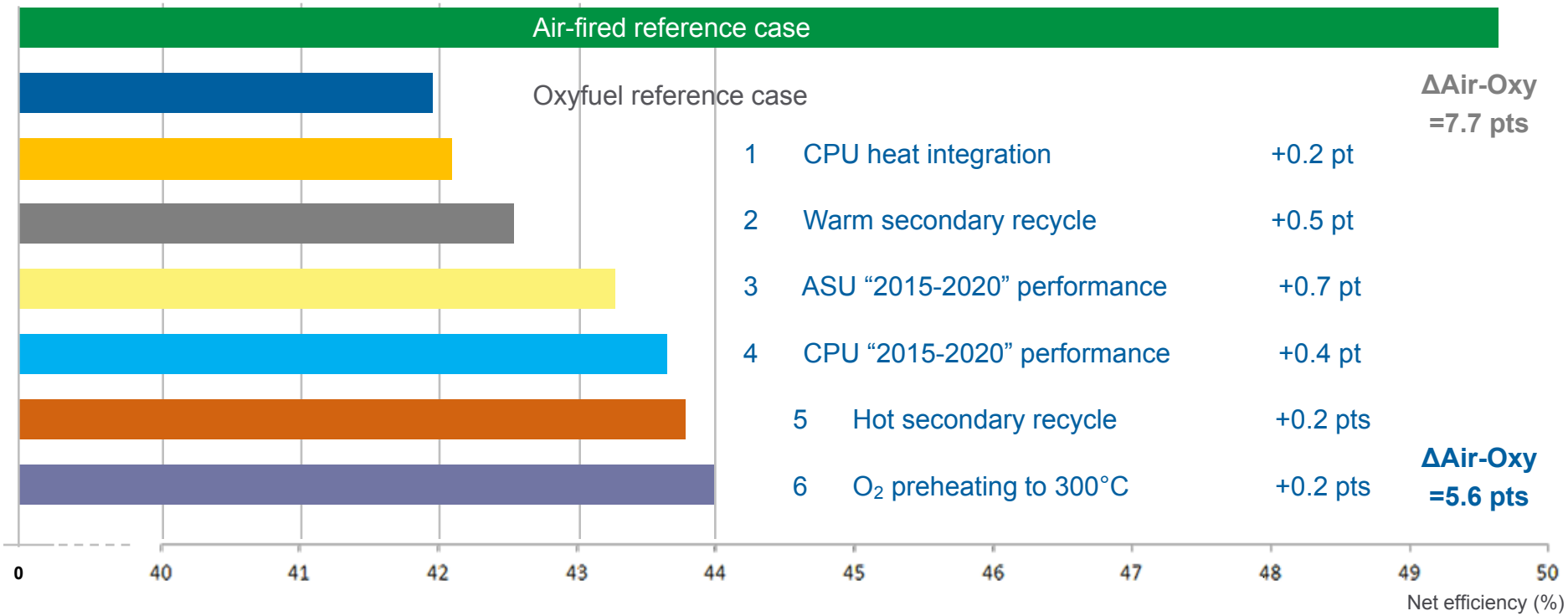
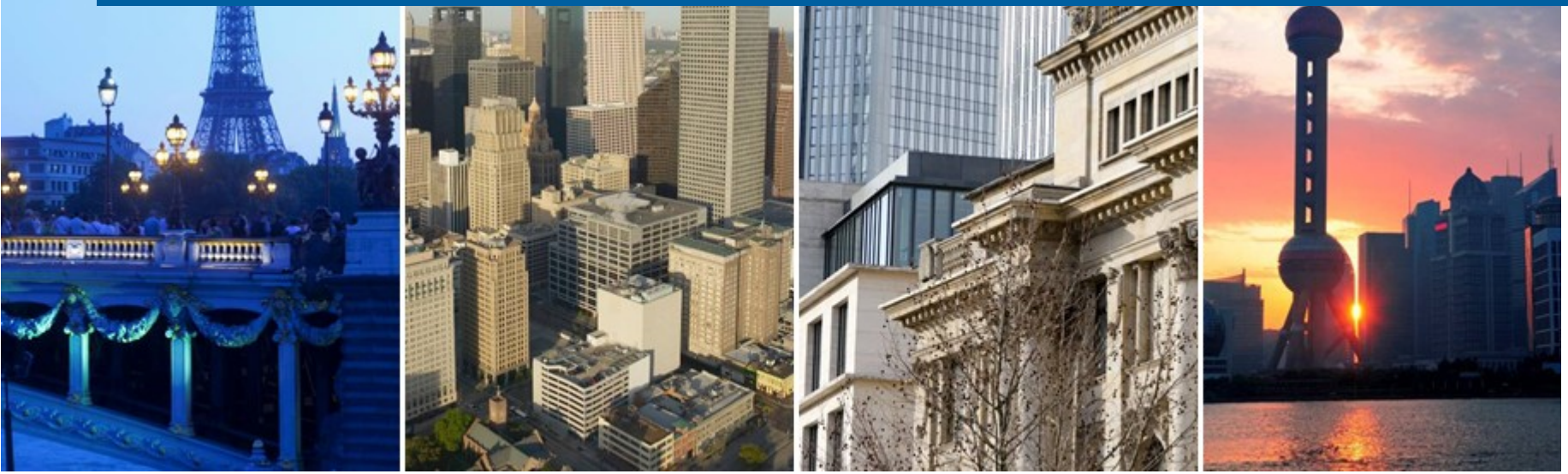
Conclusion



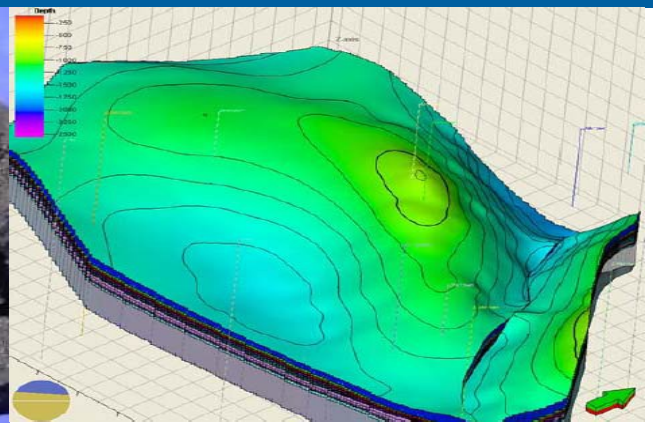
- High improvement potential: **+2 pts** on net LHV efficiency
- **ASU & CPU optimization** has strong impact on overall efficiency
- Efficiency penalty can be reduced **in the 5 pts range**

End of presentation
Thank you for your attention

Aknowlegments to Nicklas Simonsson, Vattenfall R&D AB



Design basis and boundary conditions



Power plant design

Parameter	Unit	Value
Main steam pressure	[bar]	280
Main steam temp.	[°C]	600
Reheat steam pressure	[bar]	60
Reheat steam temp.	[°C]	620
Final feed water pressure	[bar]	310
Final feed water temp.	[°C]	300
Condenser pressure	[mbar]	34

Ambient conditions	Annual average
Ambient air temp. [°C]	9,5
Relative humidity [%]	75,3
Ambient pressure [mbar]	1007,7
Cooling water supply temp. [°C]	16,4

Fuel specification

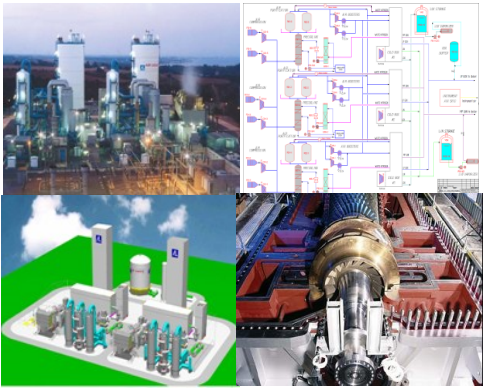
Elementary analysis (a.r.)	Unit	Design lignite
LHV	[kJ/kg]	8700
C	[%-wt]	26,3
H	[%-wt]	1,9
O	[%-wt]	9,5
N	[%-wt]	0,3
S	[%-wt]	0,8
Cl	[ppm]	90
F	[ppm]	30
Ash	[%-wt]	8,1
Moisture	[%-wt]	53,1

CO2 quality requirement

CO_2	> 99,9 %-vol.
O_2	< 10 ppmv
Ar	< 0,1 %-vol.[4]
N_2	< 0,1 %-vol.[4]
H_2O	< 5 ppmv
CO	< 5 ppmv[5]
NO	< 5 ppmv[5]
NO_2	< 5 ppmv[5]
SO_2	< 5 ppmv[5]
SO_3	< 5 ppmv[5]
HCl	< 5 ppmv[5]
HF	< 5 ppmv[5]
NH_3	-

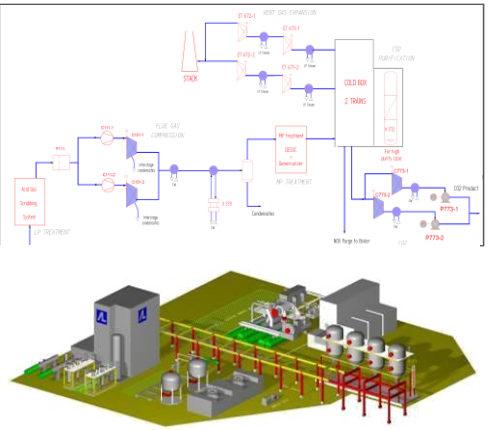
Oxyfuel reference plant - ASU & CPU

- ASU & CPU designs based on ‘2010 technology’ (Air Liquide commercial offer)



Air Separation Unit (ASU)

- 15,300 TPD Oxygen (3-trains)
- Compression heat recovered for BFW heating
- Oxygen preheating at ~200°C, 96.5 %-v purity
- Specific consumption (w/o integ. credit): 160 kWh/t



Cryocap™ CO_2 Processing Unit (CPU)

- 16,000 TPD CO2 (2-trains)
- CO_2 capture rate: 90%
- No heat integration
- 99,99 %-vol purity, 125 bars
- Specific consumption: 130 kWh/t