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MINIMIZING THE ENERGY AND ECONOMIC PENALTY OF CCS POWER PLANTS THROUGH WASTE HEAT RECOVERY SYSTEMS

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INTRODUCTION

Implementation of currently considered and available CCS technologies into fossil power plants brings inevitable technical, energy and economic penalty. This is getting even larger when fossil fuels such as low rank coal are being utilized. All three generally considered CCS technologies were modelled – oxyfuel combustion and ammonia based post-combustion (subcritical power plant with fuel drying) and pre-combustion (IGCC with Rectisol wash for CO2 separation).

CCS technologies generally produce significant amounts of waste heat, more than traditional plants do. Here is suggested its partial utilization by modular units with unit cost comparable to the whole plant and which work independently on the rest of the system thus positively affecting also flexibility when compared to sophisticated recovery into the whole plant.

WASTE HEAT RECOVERY SYSTEMS

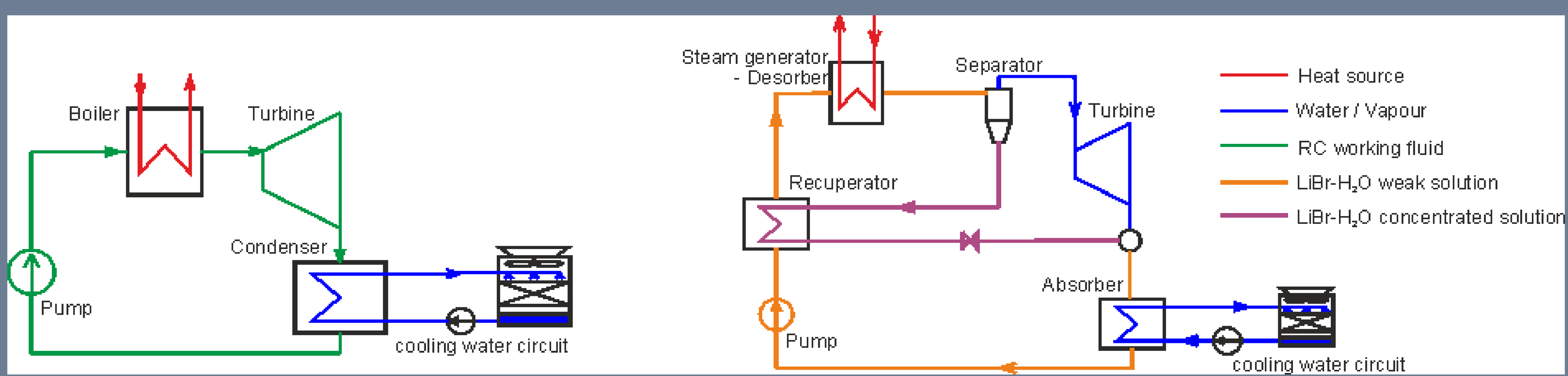
- Available as regularly supplied as nearly plug and play modular systems.
- Standalone units have advantage of higher flexibility of the whole system.
- Modules directly adjacent to the heat source

Rankine Cycles

- Steam cycle is a standard technology for larger scale and temperatures – steam microturbine
- Low T, power – Organic Rankine Cycle (ORC), best option in 300-150°C
- Currently industrial standard
- Modular simple system with series production allows low cost
- Poor feasibility at temperature <120°C due to very high irreversibility
- Available with / without recuperator

Absorption power cycles

- Changing temperature along boiling and condensation – low exergy loss
- Perspective of higher efficiency than ORC for **T < 120°C**
- Known for NH3-H2O, here novel concept using H2O-LiBr (from cooling)
- Potential for very high turbine efficiency even for very low power
- Perspective for modularity as ORC
- Potential disadvantages in corrosion risk, operation entirely in vacuum



POWER PLANTS AND PROCESSES FOR WASTE HEAT RECOVERY

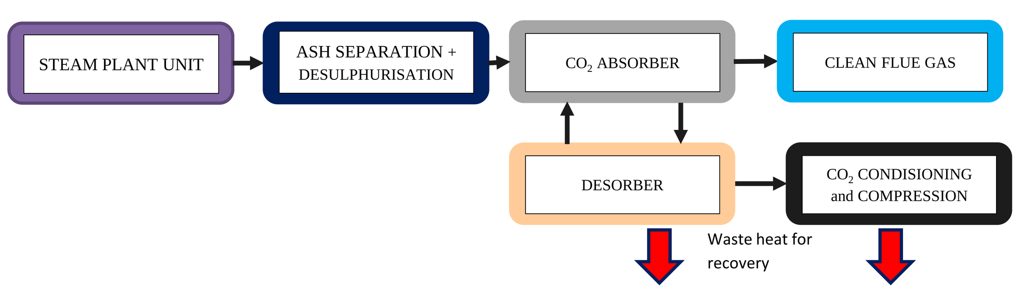
REFERENCE CASES AND MODEL INPUTS

- Lignite fired coal plant
- Approx. 250 MW capacity
- CO2 capture ratio 90%
- Capture technology by available industrial technology

CCS system	Oxyfuel	Post - combustion	Pre-combustion
Power cycle	Subcritical PC plant (575°C/580°C,18.3/3.6 MPa)		IGCC (515°C,12.5 MPa)
Fuel LHV	9.75 MJ/kg		16.5 MJ/kg
W^r / A^d / S	~ 31% / ~ 41% / ~ 3%		~ 27% / ~ 18% / ~ 1.7%

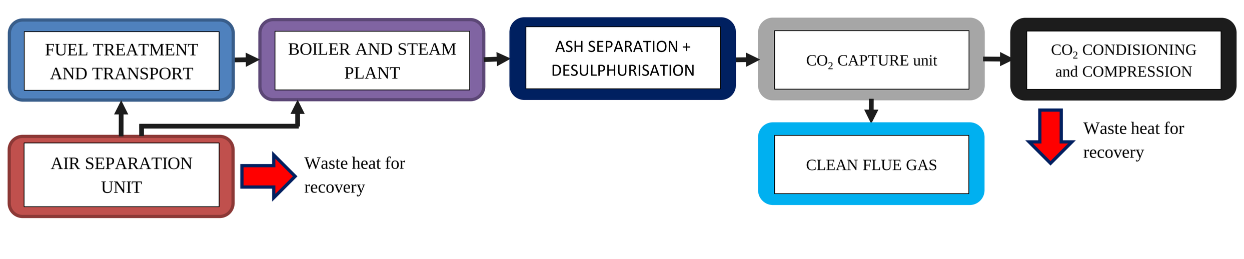
POST-COMBUSTION CCS SYSTEMS

- Wet ammonia scrubbing method
- Waste heat recovery potential low
  - Desorbed CO2 cooling
  - CO2 compressors cooling



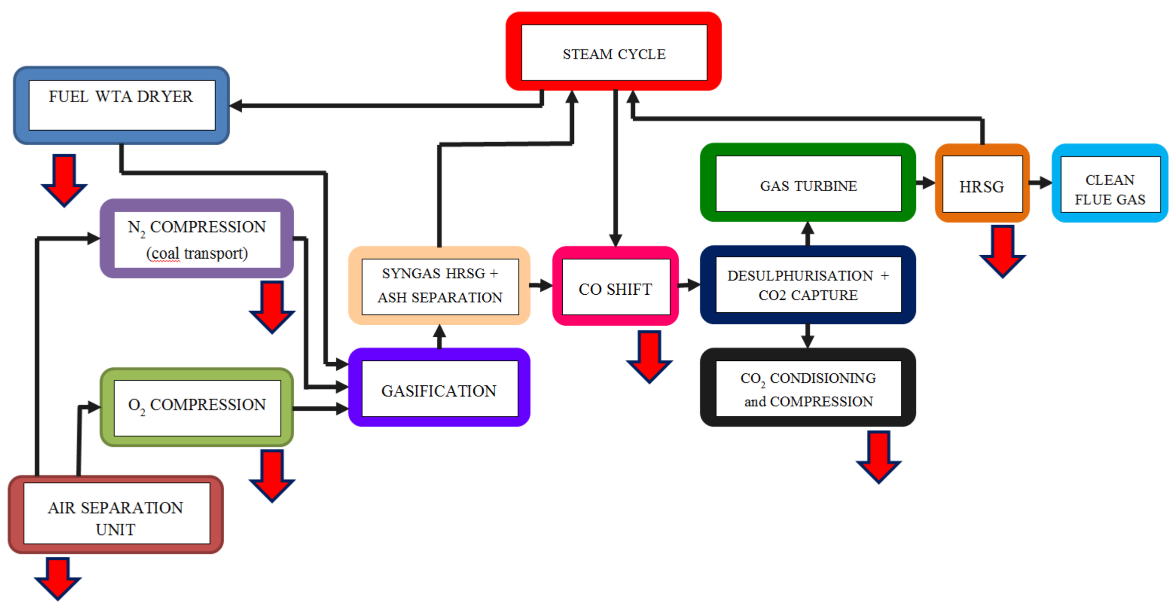
OXYFUEL CCS SYSTEMS

- Most significant potential for WHR in compressor cooling
  - ASU compressors cooling
  - CO2 compressors cooling



PRE-COMBUSTION CCS SYSTEMS

- Most complex system with large number of utilizable waste heat streams
  - Coal drying
  - ASU compressors cooling
  - O2 compressors cooling
  - N2 compressors cooling
  - Syngas cooling
  - CO2 compressors cooling
  - Aftercooling of flue gas (very low flue gas dew point)



TECHNICAL RESULTS OF WHR APPLICATION

POST-COMBUSTION CCS SYSTEMS

- Only **3.6 %** of fuel heat content in utilizable streams, low temperature
- Positive effect nearly negligible

Waste heat stream	Temperature [°C]	Heat flow (% of LHV input)	WHR unit type	Power increase (% of LHV input)
CO2 compression IC/AC	102 (cooling fluid)	1.3	LiBr APC	0.03
Desorber heating outlet	115	2.3	Isohexane ORC	0.05
Saved cooling power	-	1.2	-	0.001

OXYFUEL CCS SYSTEMS

- WHR potential associated especially with largest parasitic load – ASU
- Already potential for 1.3 percentage point (p.p.) power increase

Waste heat stream	Temperature [°C]	Heat flow (% of LHV input)	WHR unit type	Power increase (% of LHV input)
ASU air compressors IC/AC	234 (cooling fluid)	9.0	Isohexane ORC	1.13
CO2 compression IC/AC	105 (cooling fluid)	7.1	LiBr APC	0.17
Saved cooling power	-	10.5	-	0.01

PRE-COMBUSTION CCS SYSTEMS

- IGCC itself (w/o CCS) has already a significant potential for WHR
- CCS integration limits standard utilization of several waste heat streams and increases heat flow in them

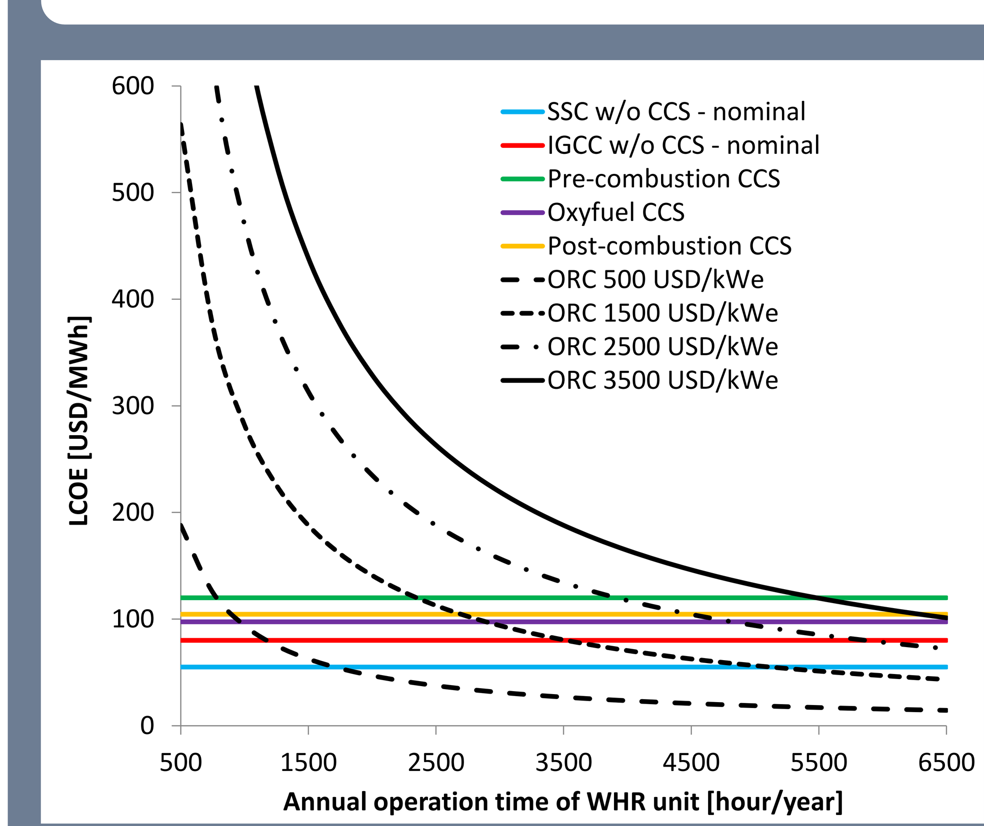
Waste heat stream	Temperature [°C]	Heat flow (% of LHV input)	WHR unit type	Power increase (% of LHV input)
ASU air compressors IC/AC	234 (cooling fluid)	3.2	Isohexane ORC	0.40
Gasifier O2 compressors IC/AC	246 (cooling fluid)	1.1	Isohexane ORC	0.12
Gasifier N2 compressors IC/AC	201 (cooling fluid)	0.3	Isohexane ORC	0.02
Coal dryer outlet vapours	110	3.3	LiBr APC	0.14
Syngas cooling (CCS / no CCS)	252 / 125	13.2 / 2.6	Isohexane ORC	3.19 / 0.11
CO2 compression IC/AC (CCS only)	113 (cooling fluid)	3.8	LiBr APC	0.09
Flue gas aftercooler (CCS / no CCS)	110 / 110	6.0 / 7.3	LiBr APC	0.18 / 0.20
Saved cooling power (CCS / no CCS)	-	31.9 / 10.6	-	0.03 / 0.01

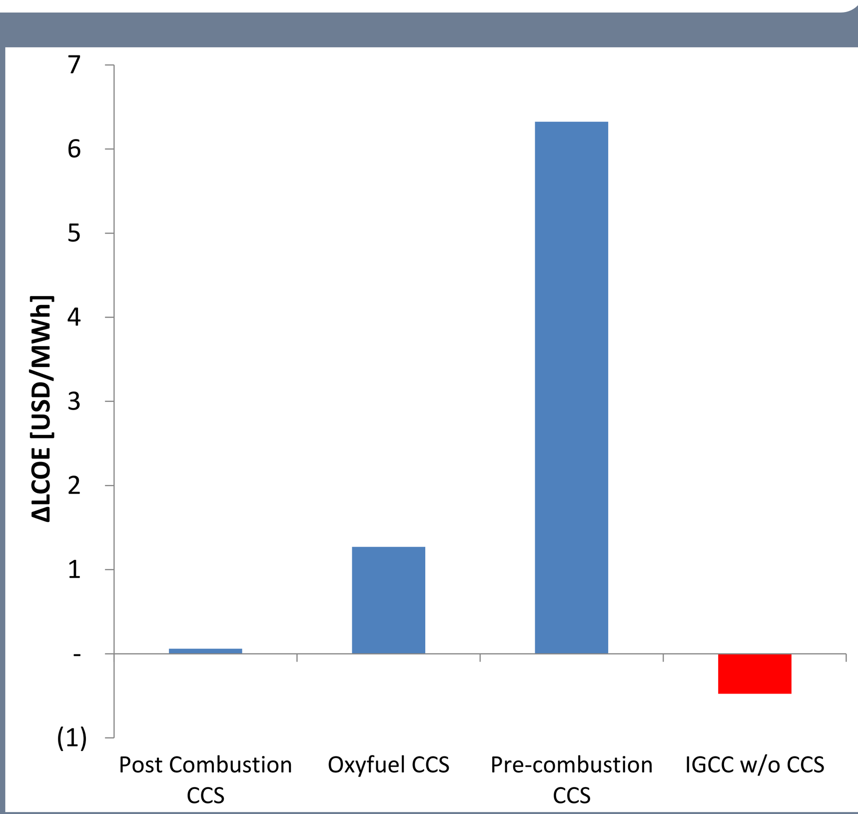
OVERAL RESULTS

	PC Plant	PC plant - Oxyfuel	PC plant – post combustion	IGCC	IGCC - CCS
Original efficiency [%]	38.99	31.13	28.12	43.18	31.27
Efficiency with WHR [%]	38.99	32.44	28.20	44.18	35.45
Efficiency increase [p.p.]	0	1.31	0.08	1.01	4.18

ECONOMIC RESULTS OF WHR APPLICATION

- LCOE define by Cost Estimation Methodology for NETL Assessments of Power Plant
- Nominal capacity factor 65% for IGCC and 75% for PC plant
- Typical cost of ORC units around 1600 - 4000 $/kWe (based on power output)
- Fuel price 2.5 USD/GJ (PC plant), 2.75 USD/GJ (IGCC plant)
- Discount rate 8%, annual price rates 1-4%
- Highest feasibility comes for most expensive power plant (IGCC) with CCS
- Lowest (negative) feasibility comes for IGCC plant without CCS





CONCLUSION

A number of processes in some CCS systems with recoverable low temperature heat are significant. Largest technical potential for WHR is in pre-combustion, where it can be utilized both in reference case and with CCS.

In case of CCS systems without WHR the IGCC efficiency comes out very similar to the oxyfuel, with WHR systems is the IGCC better in efficiency by 3 p.p.

Included baseload only into calculations. Taking into account start-ups and shutdowns may come better, especially for the IGCC without CCS.

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