Sixth International Conference on Clean Coal Technologies CCT2013

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Simulation of Oxy-combustion co-firing Coal and Biomass with ASU and Steam Turbine using Aspen Plus

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Scope and Aims

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Study the oxy-combustion process, co-firing blends of coal and biomass, through a rate-based simulation model.

The validated model will be used as a tool to select future test parameters

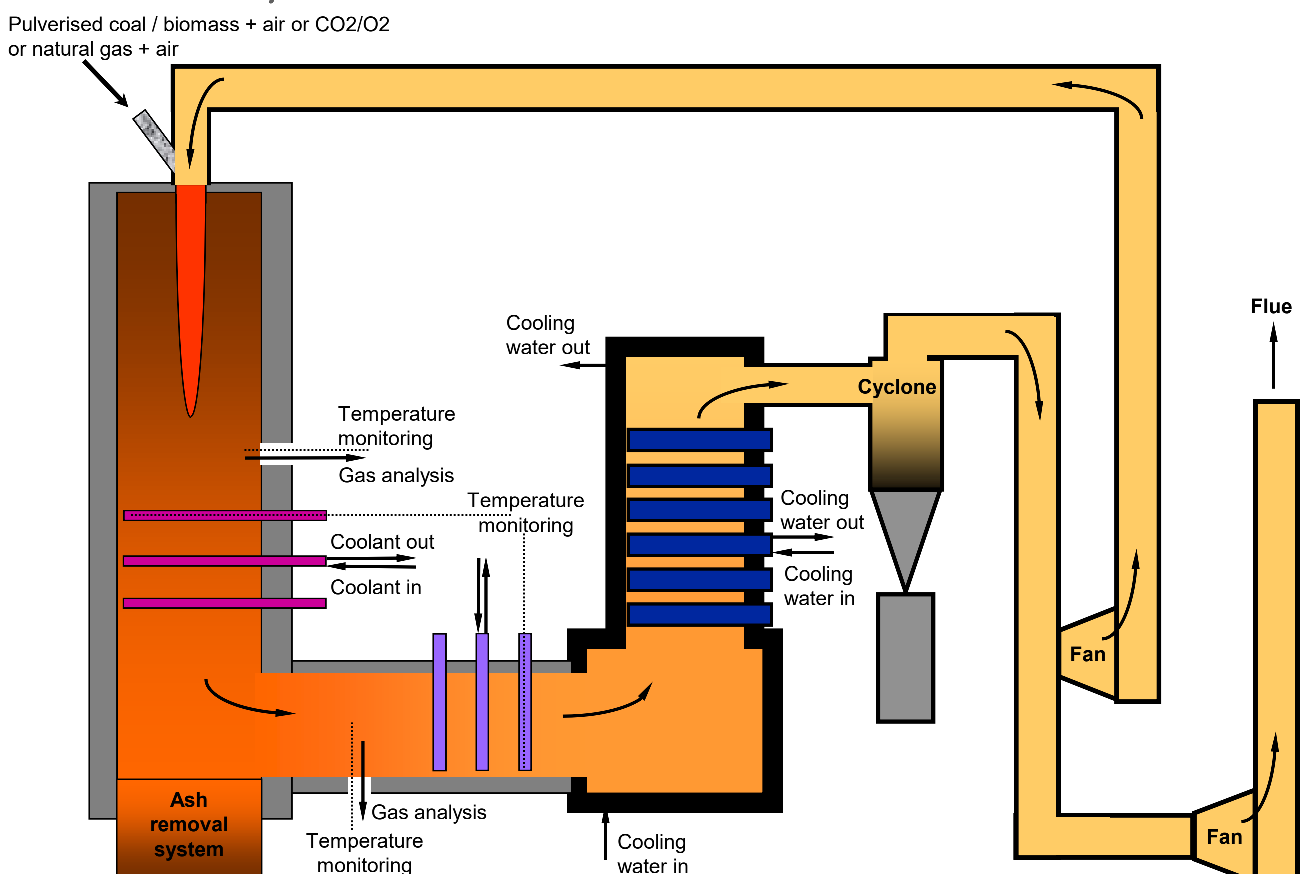

Diagram of 100kWth Multi-fuel Oxy-Combustor at CERT

Simulation Process
BASICS

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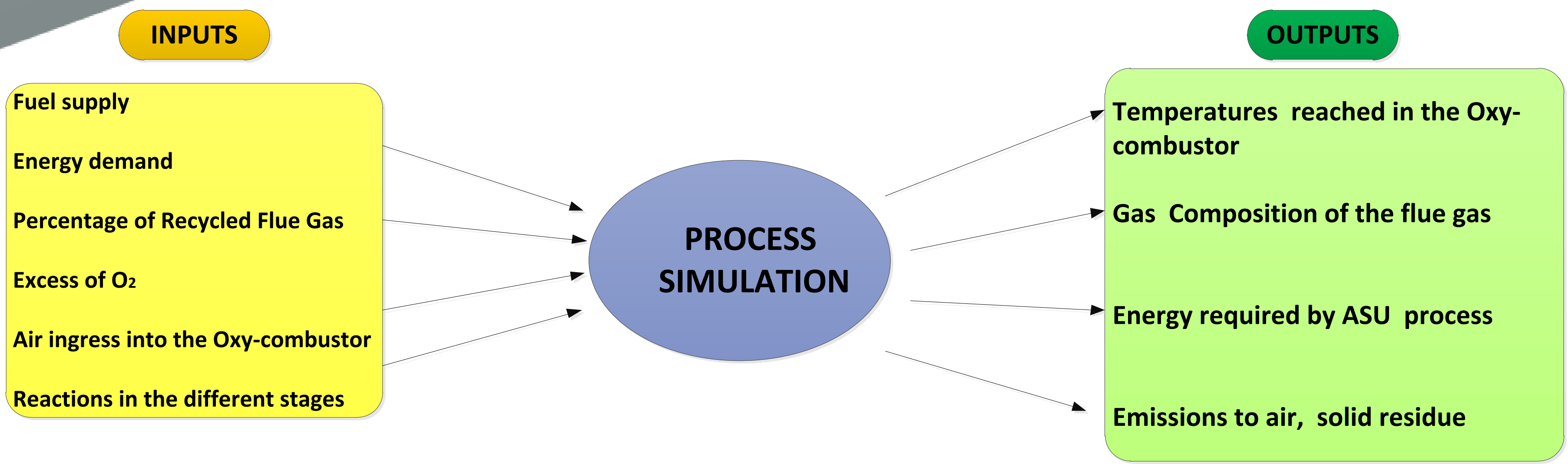

Limitations of Aspen Plus

- ✓ **Prediction of adiabatic flame temperature (without considering composition of the gas for the heat transfer)**
- ✓ **Solid residue same composition as ash defined as input (inability to simulate reaction involving solid phase)**

Simulations using Aspen Plus®
STAGES

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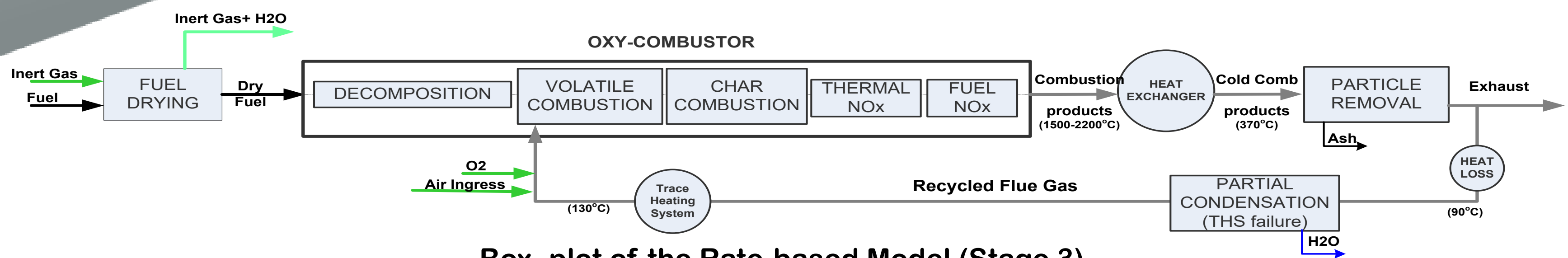
KINETIC MODEL

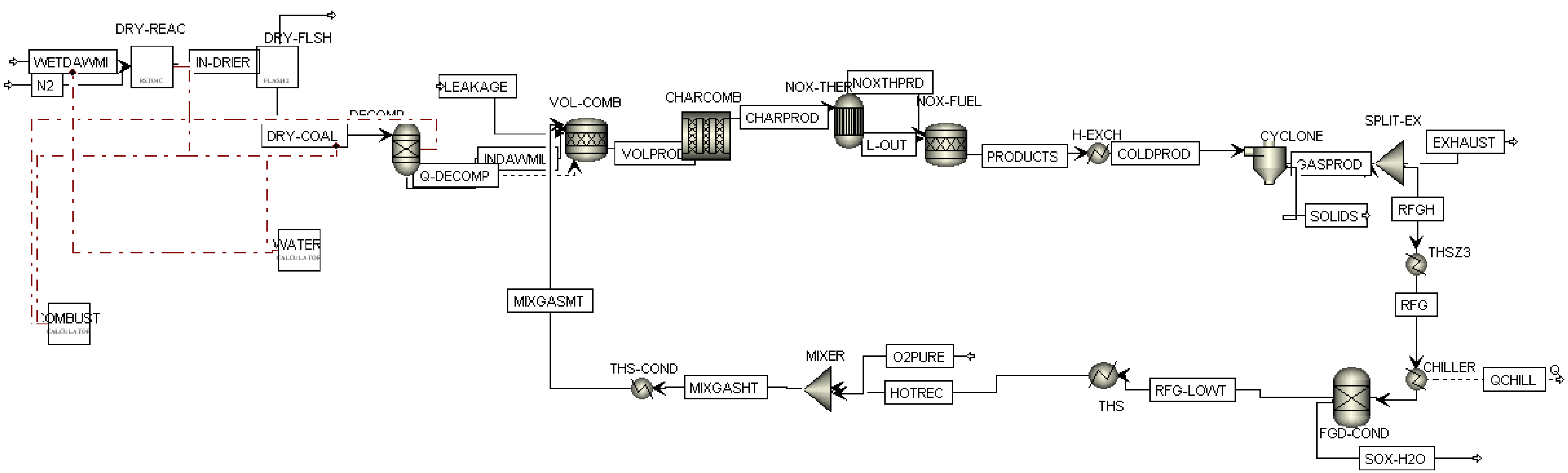
	STAGE 1 Air-firing case	STAGE 2 Oxy-firing case with wet recirculation, heat loss and air leakage	STAGE 3 Oxy-firing case with partial condensation in RFG, heat loss and air leakage	STAGE 4 Oxy-firing case with dry recirculation, heat loss, air leakage	STAGE 5 Air-firing case with power generation unit	STAGE 6 Oxy-firing case with dry recirculation, heat loss, air leakage, ASU and power generation unit
AIR/ OXY-FIRING	Air -firing	Oxy -firing	Oxy -firing	Oxy -firing	Air -firing	Oxy -firing
RFG (%)	--	55, 60, 65, 70	55, 60, 65, 70	55, 60, 65	--	55, 60, 65
O_2 Exc (%) (v/v)	21	0,5,10	0,5	0,5	21	0,5
T_{RFG} (ºC)	--	130	75,90	130	--	130-200
Air Leakage (% of Total Gas fed)	--	1.7	0, 2, 10, 18	10	--	10
Fuel	Coal	Coal (El Cerrejon, Daw Mill), Biomass(Cereal Co-Product, Miscanthus), blends of coal and biomass (75/25; 50/50; 25/75)	Daw Mill coal, Cereal Co-Product biomass, blends of coal and biomass (75/25; 50/50; 25/75)	El Cerrejon coal, Cereal Co-Product biomass, blends of coal and biomass (75/25; 50/50; 25/75)	Coal	El Cerrejon coal, Cereal Co-Product biomass, blends of coal and biomass (75/25; 50/50; 25/75)
RFG Purification	Particle removal	Particle removal	Particle removal	Particle removal, acid species and water vapour condensation	Particle removal, acid species and water vapour condensation	Particle removal, acid species and water vapour condensation

- ✓ Establish reference cases (Stages 1 and 5)
- ✓ Validation of the model by applying similar conditions to experiments (Stage 3)
- ✓ Simulations with condenser implemented to include dry RFG (Stage 4)
- ✓ Simulation of the entire system including ASU and steam turbine (Stage 6)

Simulations using Aspen Plus®:
MODEL VALIDATION



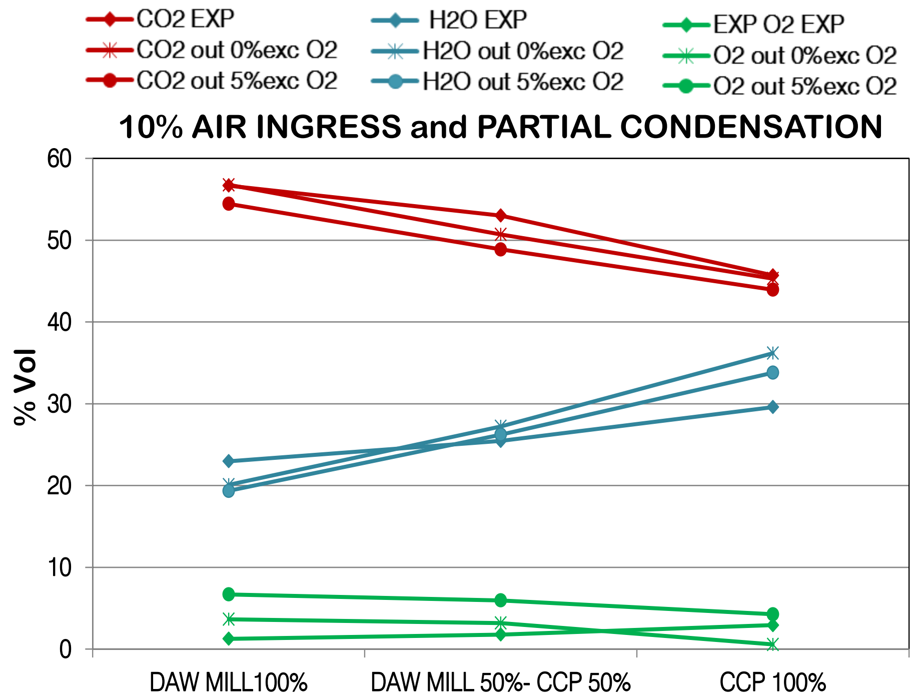
Box- plot of the Rate-based Model (Stage 3)

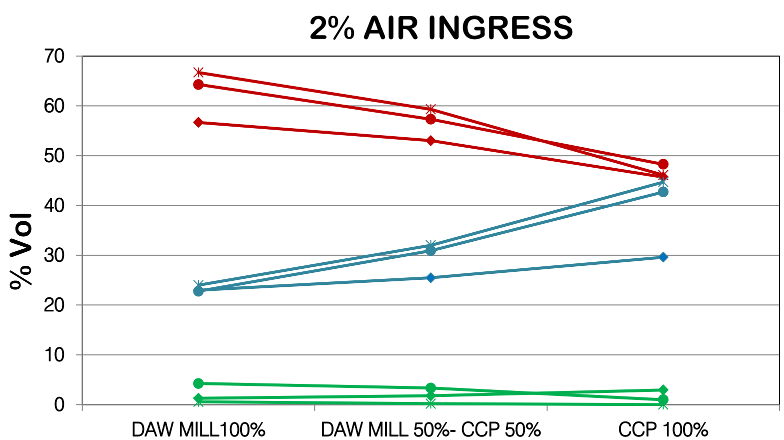


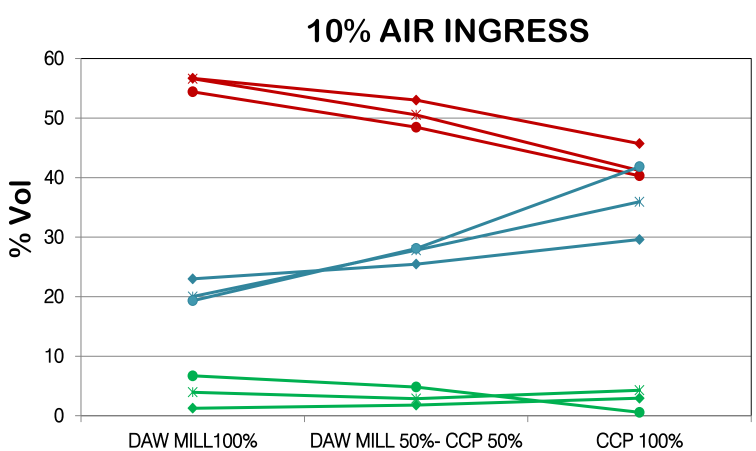
Interface of the rate-based model with partial condensation on the RFG in Aspen Plus (Stage 3)

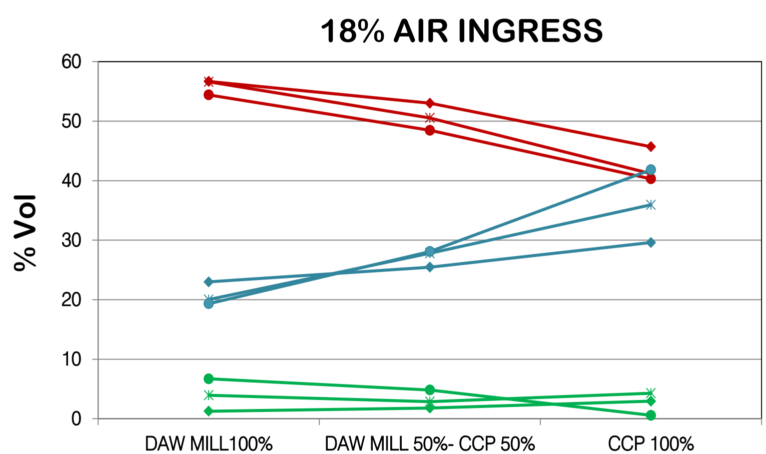
Simulations using Aspen Plus®:

AIR INGRESS COMPARISON









On-going modifications in the Pilot Plant:

WATER AND ACID SPECIES REMOVAL

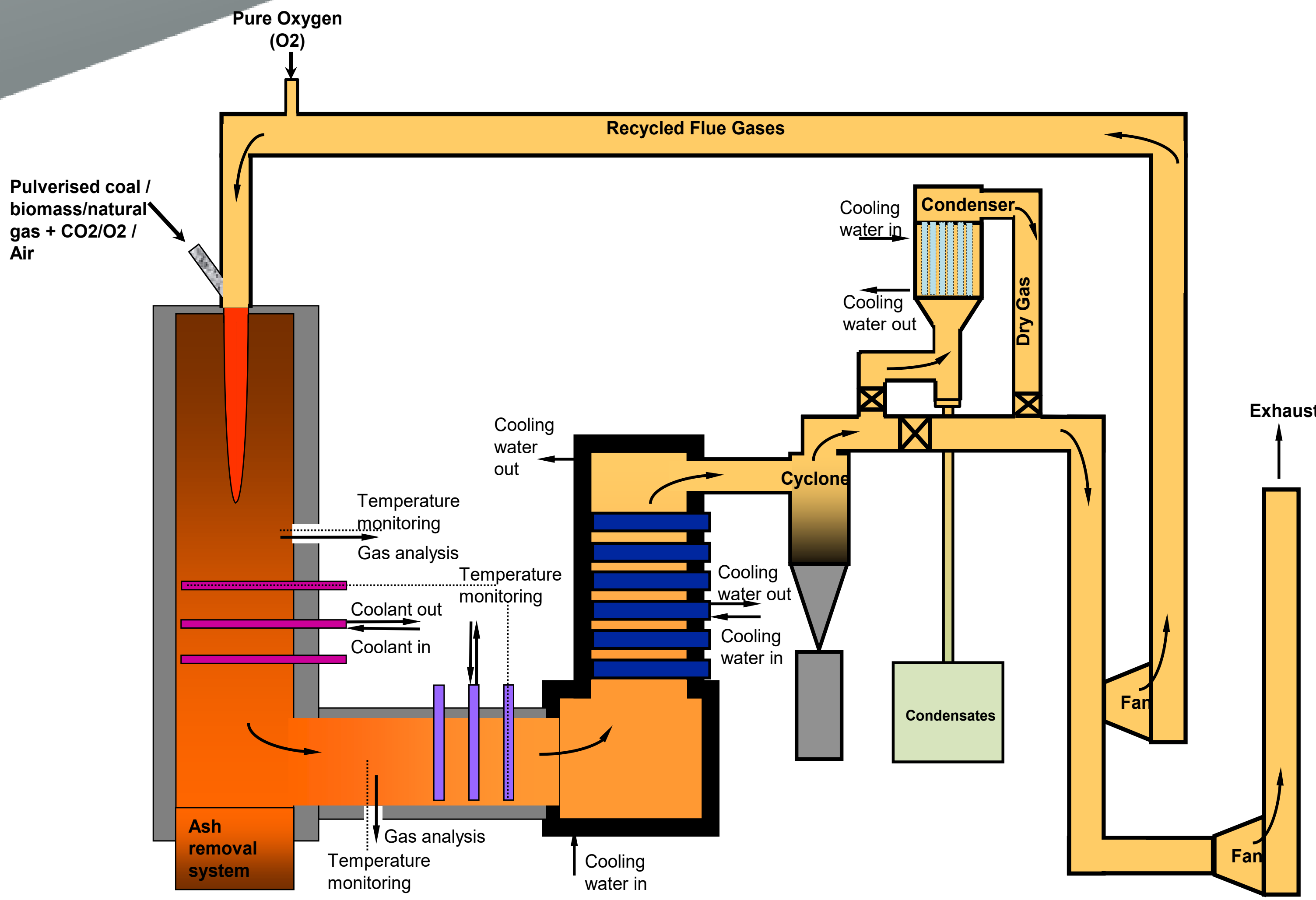
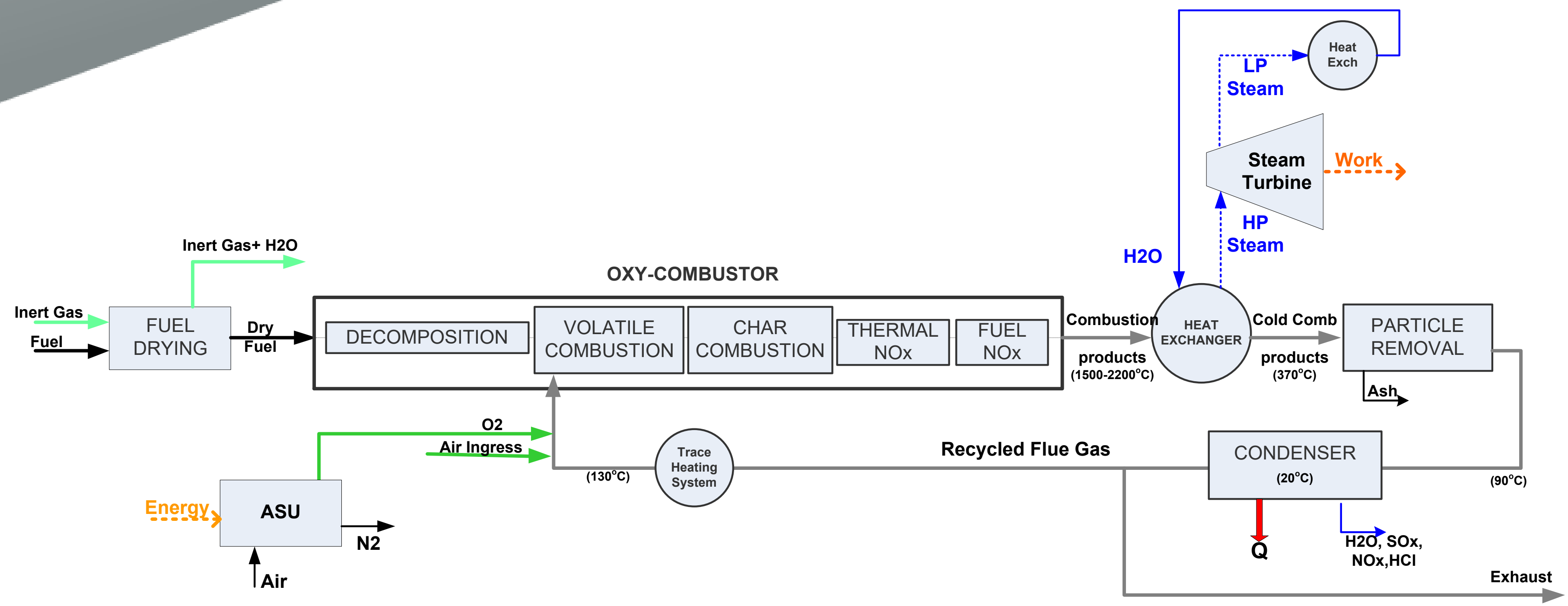


Diagram of 100kWth Oxy-Combustor with Condenser

Simulations:
OXY-COMBUSTION PLANT



Box-plot of the ASU, oxy-combustor and steam turbine (Stage 6)

Simulations:

OXY-COMBUSTION PLANT

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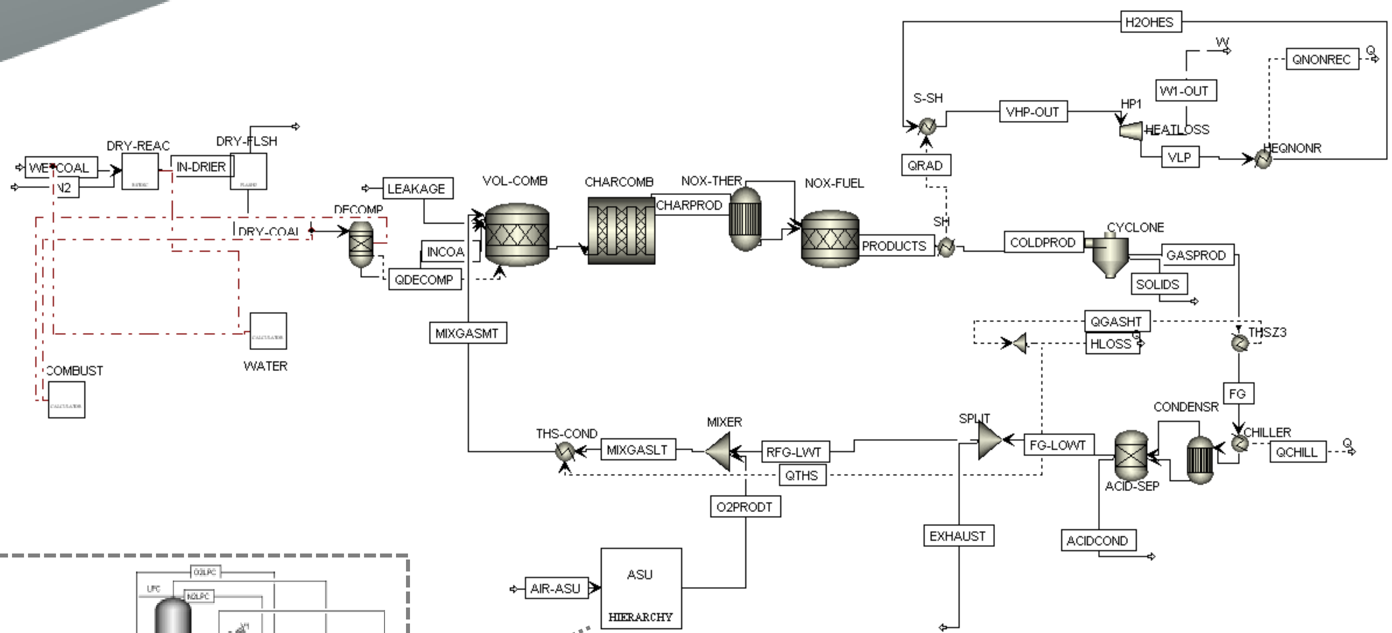
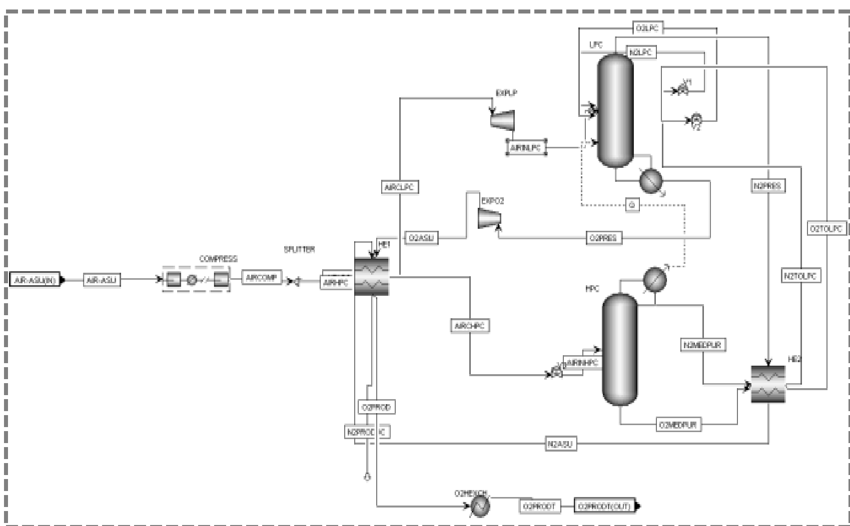


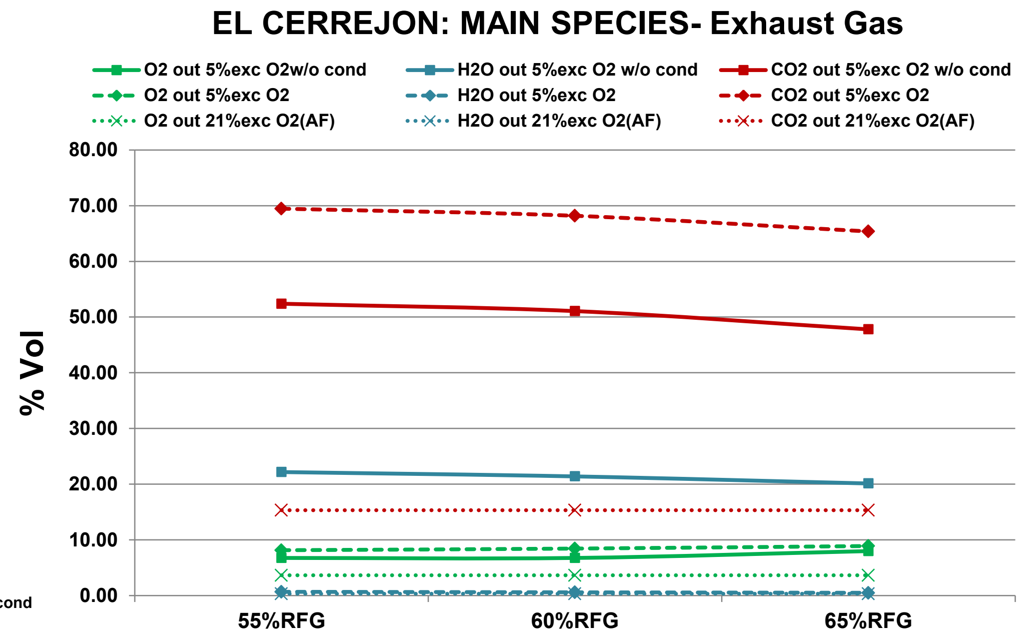


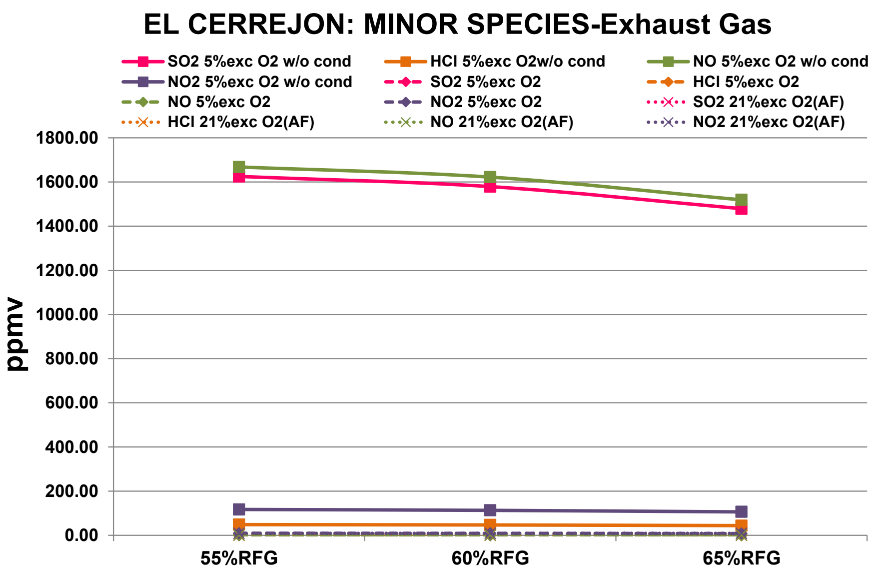
	Air-firing	Oxy-firing
Power generated (kW)	24.01	25.07
Power consumed ASU(kW)	--	8.06
Net power generated (kW)	24.01	17.01
Net fuel input (kW)	100	100
O_2 stoichiometric (kmol/h)	0.8973	0.8973
O_2 excess supplied (%)	21	5
Raw air to ASU (kmol/h)	--	4,70

Simulation results for air and oxy-firing base case

Dry recycle flue gas
EFFECT ON THE EXHAUST
EL CERREJON COAL

- CO_2 increases 20% (v/v) as consequence of implementation of the condenser
- H2O decreases at the same proportion to the increase of CO_2
- All minor species drop to near zero content in the exhaust gas, in the cases where the condenser was used





	CO_2 (%)	H_2O (%)	O_2 (%)
El Cerrejon (CC)	15.32	0.32	3.64
El Cerrejon (OC)	68.18	0.58	8.43
El Cerrejon50%-CCP50% (OC)	66.12	0.85	8.54
Cereal Co-Product (OC)	72.46	1.48	3.47

Dry recycle flue gas

EFFECT ON COMBUSTION PRODUCTS

FUEL COMPARISON

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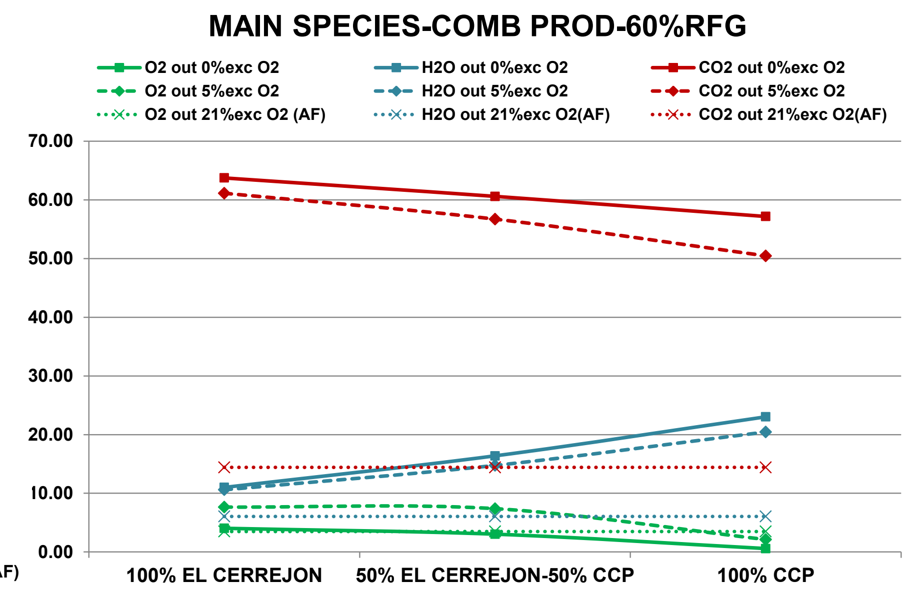
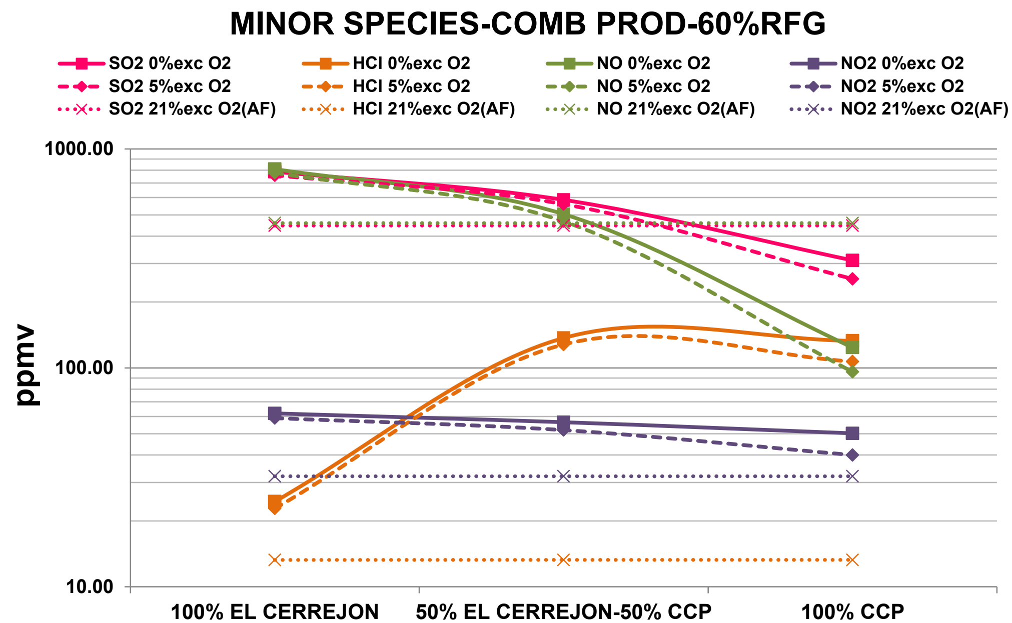
- Max. CO_2 decreases in the combustion products with higher content of biomass oxy-fired
- H_2O content when burning CCP increases:
  - ✓ By 10% comparing to oxy-firing 100%coal
  - ✓ By 14%comparing to air-firing case





- Marked decrease for SO_2 and NO contents when increasing the percentage of biomass
- Increase in the HCl content as result of the higher content of Cl in the elemental analysis of the biomass (0.17% (w/w) in CCP vs 0.02 % (w/w) El Cerrejon)
- No significant variation for NO_2 contents

Power generation

FUEL COMPARISON

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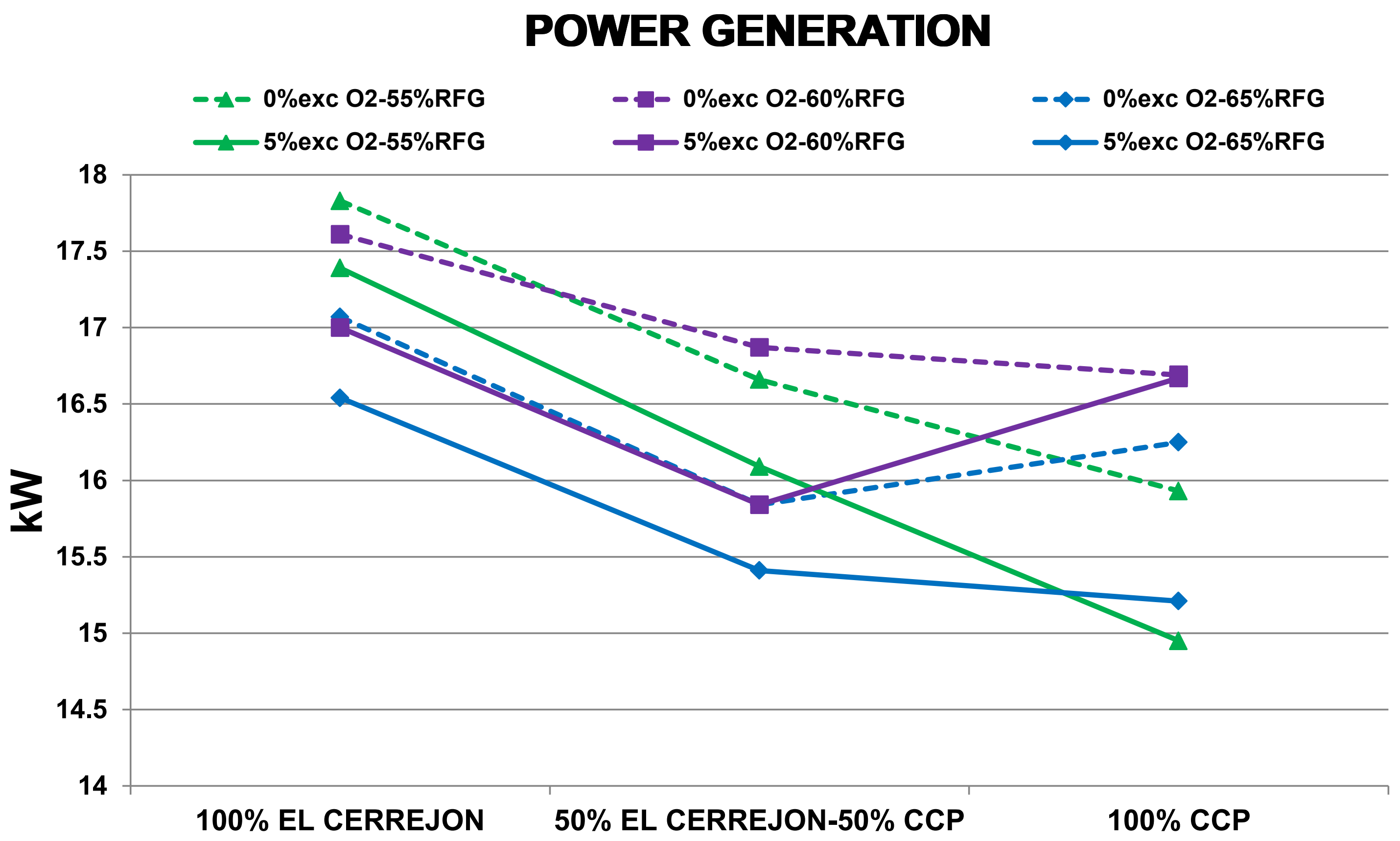
- ✓ Power generated decreases generally with higher content of biomass (exception: 60% RFG and 5%exc O_2)
- ✓ Power generation is enhanced when a lower %RFG is used
- ✓ Higher power levels achieved when burning without excess of oxygen



Summary

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- Kinetic Simulation Model has been developed with acceptable agreement with experimental results
- Model validation has been carried out and helped to deduce the amount of air ingress into the process (10% of the total flue gas fed to the combustor)
- Simulation model including equipment for CO_2 purification predicts remarkable increase of the %CO_2 contents
- Last step fulfilled for simulations: delivering of kinetic model including dry RFG, ASU, and steam turbine. Study the effects caused by the variation of the fuel and %RFG on the power generated

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Thanks for your attention

Any questions?

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