Oxycombustion

Oxy-combustion of Coal/Biomass Mixtures in a 100kWth Combustor

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AIM

To understand the possible compensation in the heat transfer through the use of blends of coal and biomass in a retrofitted pilot plant for the fact that the properties (higher heat capacity and emissivity) of the gases in the oxy-combustion process differ from the air-firing case

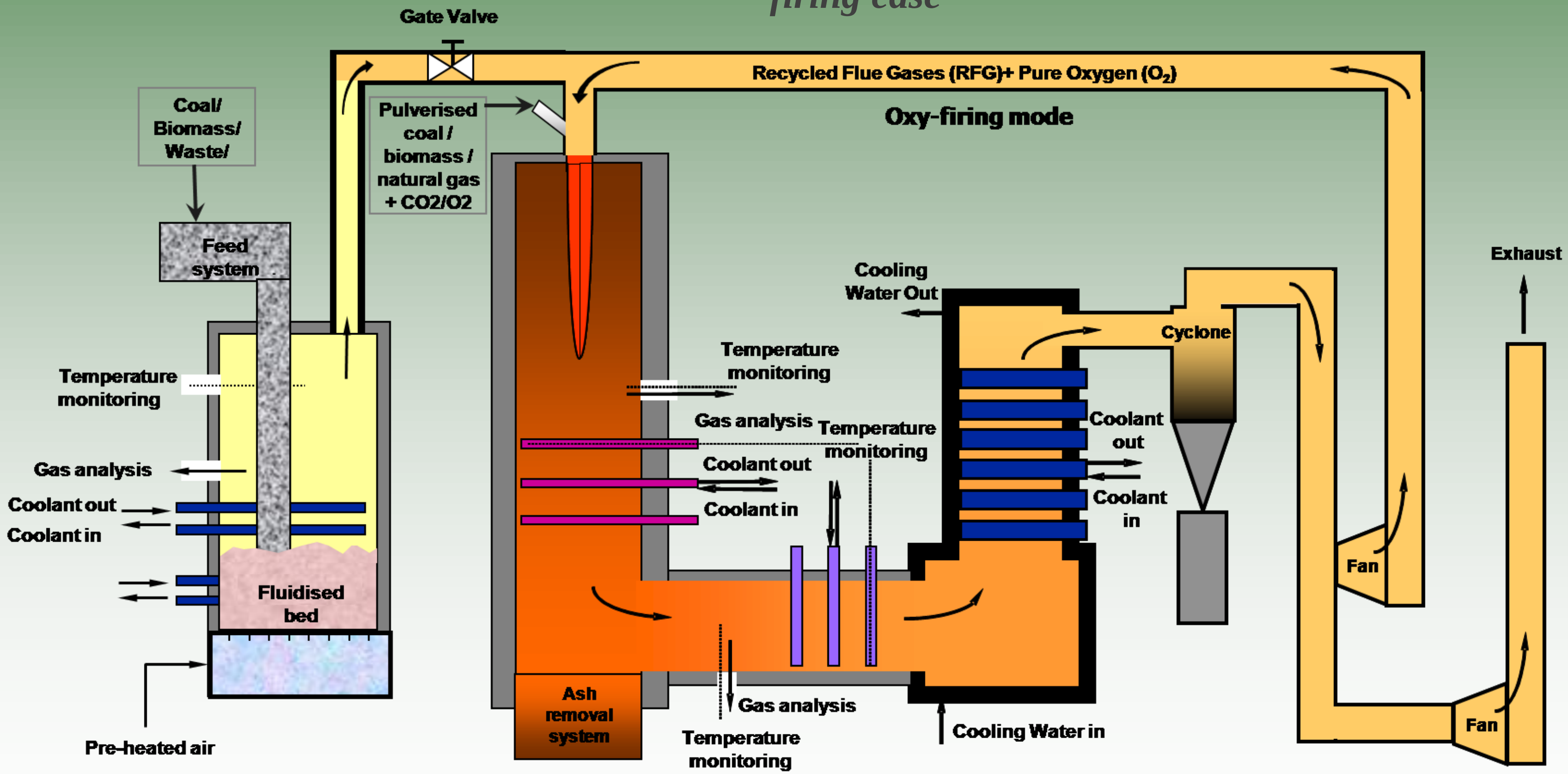

Diagram of Multi-fuel Combustion Rig at CERT

RETROFITTING OF THE EXISTING AIR-FIRING FACILITY

- **Swirler of the Burner**

- **RFG System**
  - ✓ **Gas tight fans**
  - ✓ **Thermal conditioning of the RFG**
- **New layout of the pipelines**
  - ✓ **Oxygen injection**
    - **Primary**
    - **Secondary**
  - ✓ **CO_2 supply**
- **New Fuel Feeder**

NEXT STAGES

- **CO_2 Purification**
  - ✓ **SOx Removal**
  - ✓ **Water Removal**
- **CAPCIS System's Installation: Acid Dew Point measurement**

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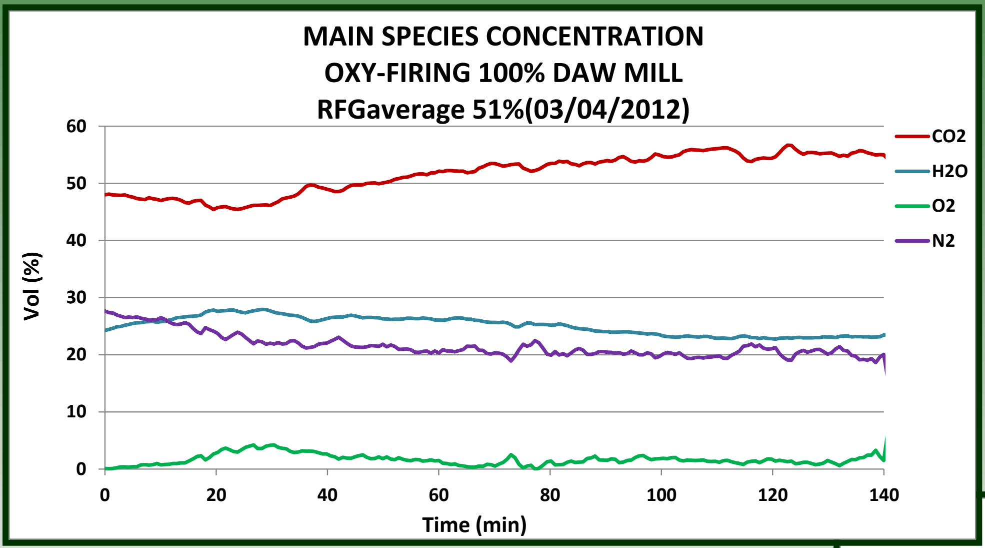
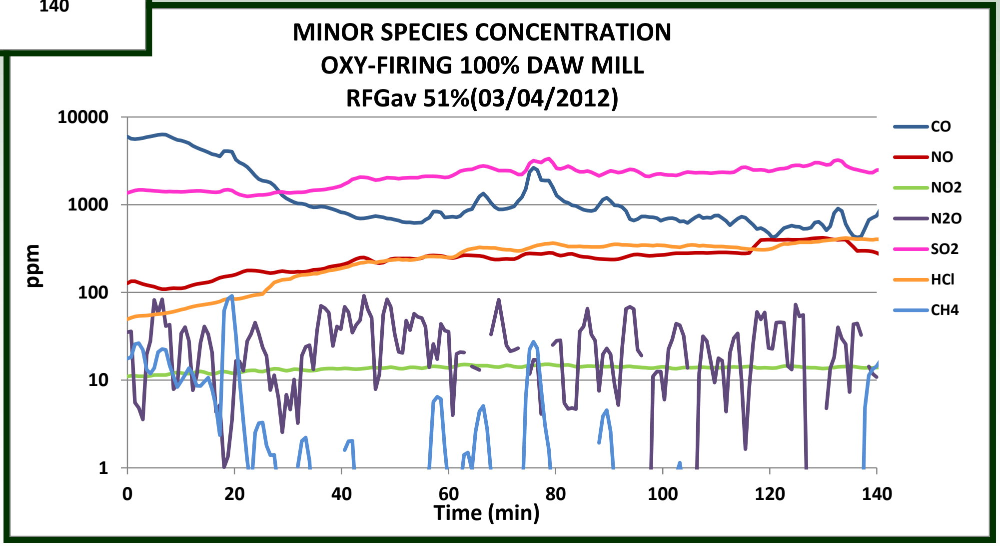
Experimental Results : GAS COMPOSITION
Daw Mill Coal 100%



- Maximum CO_2 : 56.7 % (v/v) (w. b.)
- H_2O ~ 23% (v/v)
- O_2~ 1.5% (v/v)

Stable operation



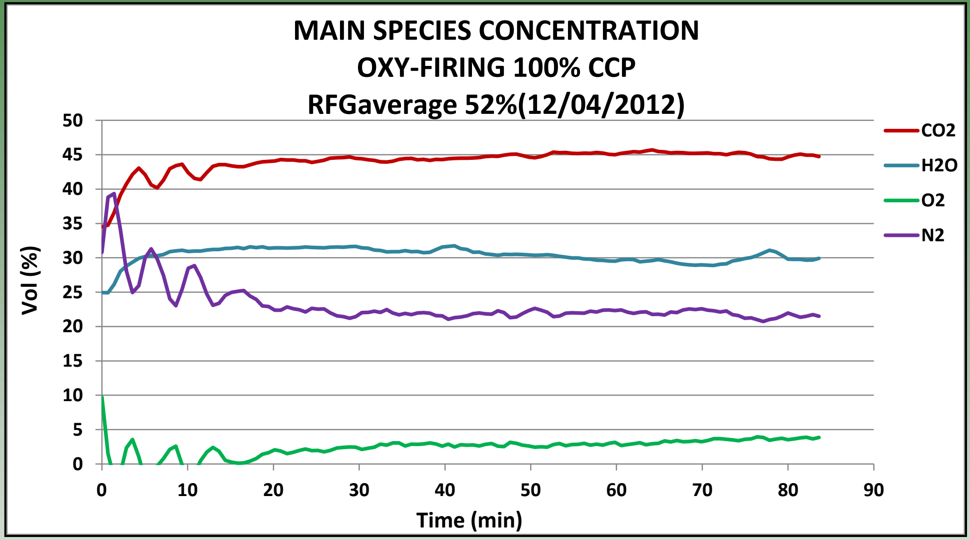
Average values:
SO_2 ~ 2000ppm
CO ~ 1000ppm

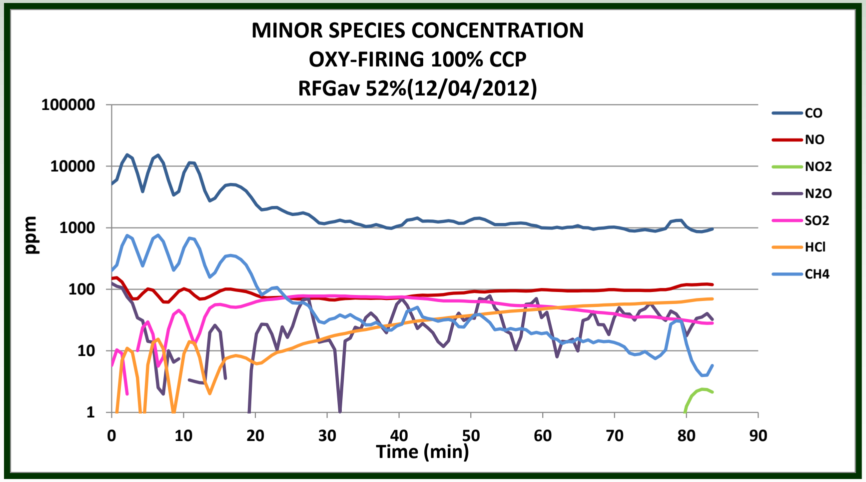
Experimental Results : GAS COMPOSITION
Cereal Co-Product 100%

CO_2 **maximum : 45.7% (v/v) (w. b.)**

H_2O **~ 30%**
O_2 **~ 3%**

SO_2 **average~ 100ppm**
CO average ~ 1200ppm





The high content of water vapour in the exhaust gas can result in operation problems (condensation occurred in the conducts associated with the pressure measurement devices)

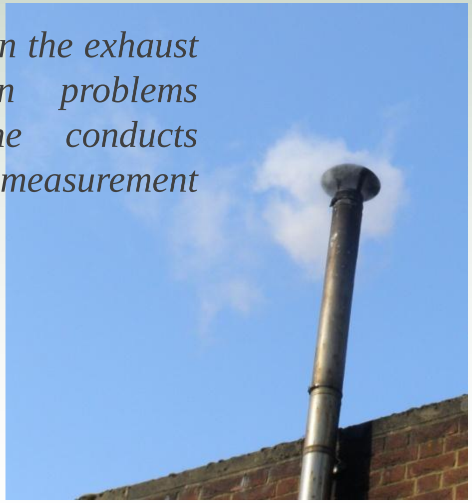
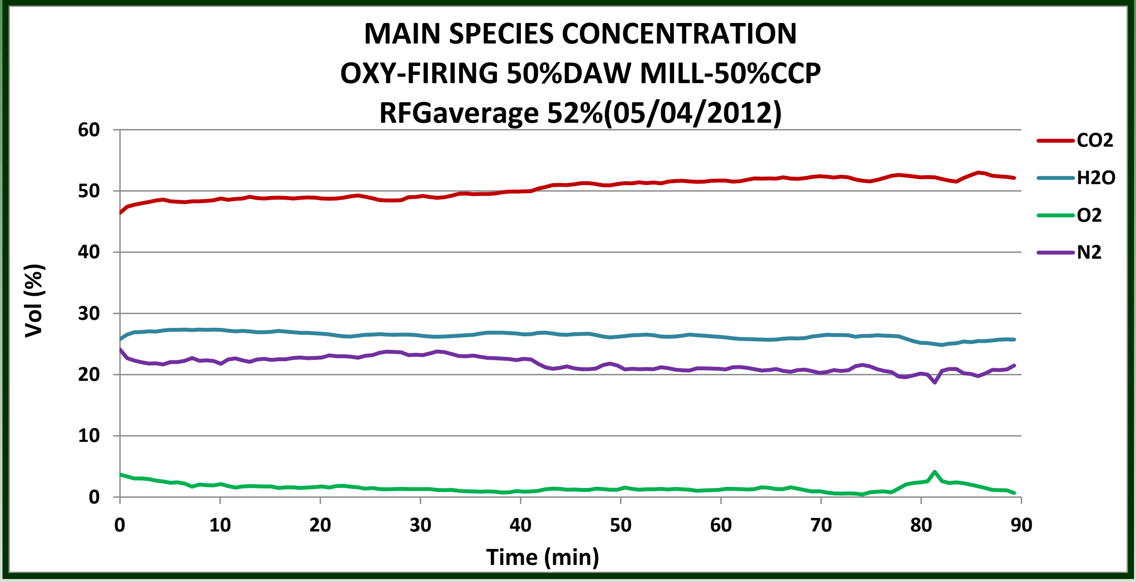
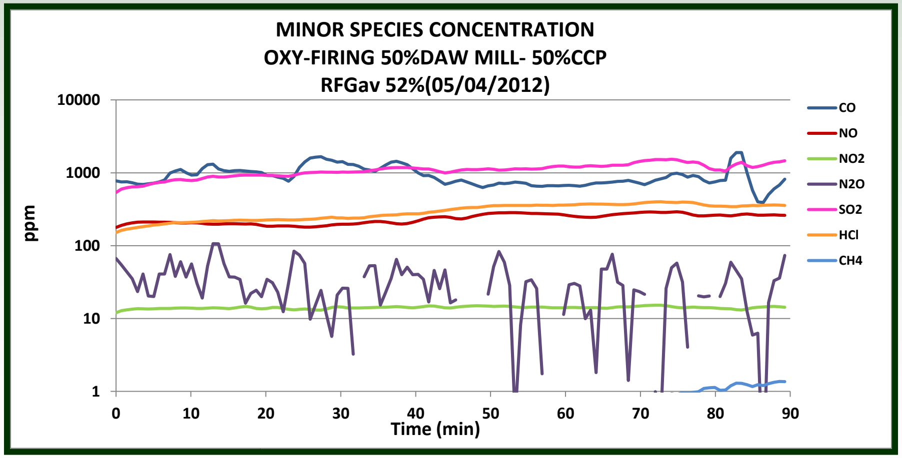


Photo made during the Test using CCP 100%

Experimental Results : GAS COMPOSITION
Daw Mill 50%- Cereal Co-Product 50%





CO_2 maximum : 53% (v/v) (w. b.)

H_2O ~ 26.4%
O_2 ~ 1.5%

SO_2 average~ 1500ppm
CO average ~ 900ppm

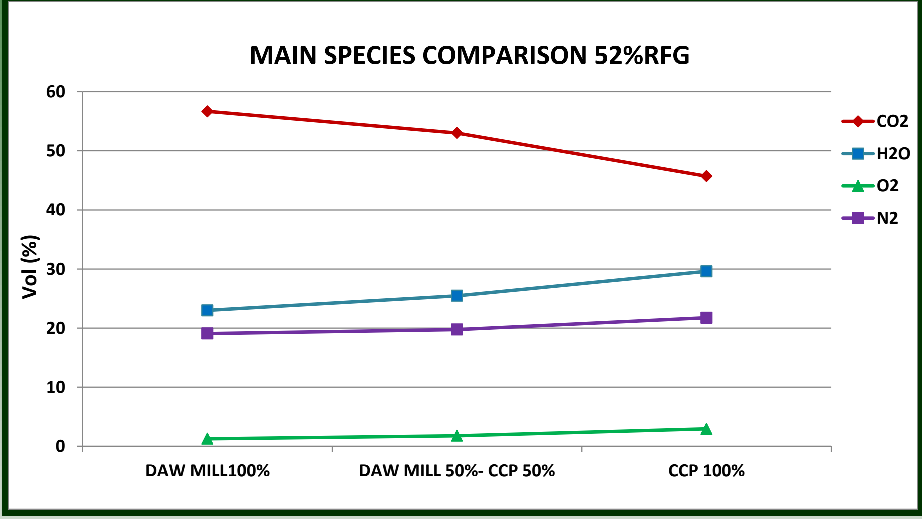
Experimental Results : GAS COMPOSITION
Fuel Comparison

MAIN SPECIES

- Maximum CO_2 when burning coal
- The water vapour concentration increases with the percentage of CCP in fuel

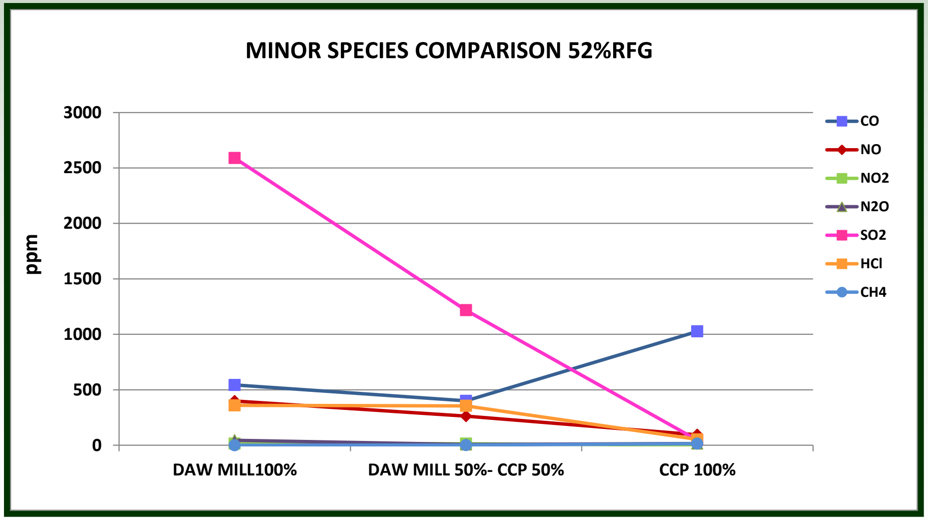
MINOR SPECIES

- SO_2 concentration dramatically decreases by adding more CCP into the fuel mixture
- CO increased in the last case due to not as good combustion as for the others cases



Fraction of total flue gas recycled	Sulphur concentration in flue gas
0.7	3110
0.6	2370
0.5	1920
0.4	1650
0.3	1390
0.2	1230
0.1	1080
0	1000

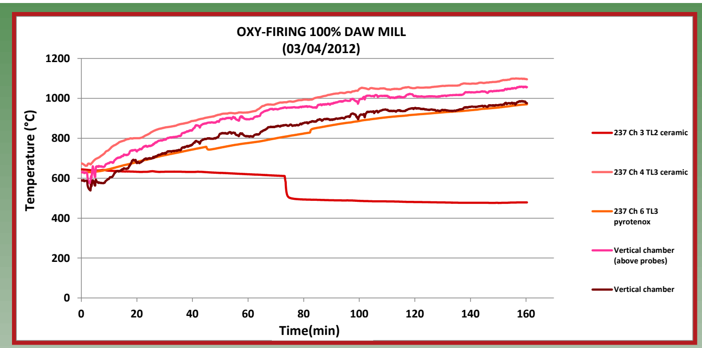
Example of the effect of recycle strategy on SO_2 concentration in the flue gas, based on 1000 ppmv without recycle. Data taken from Buhre *et al.*, (2005)

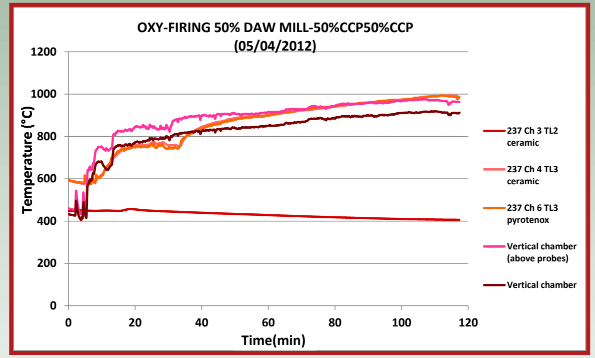


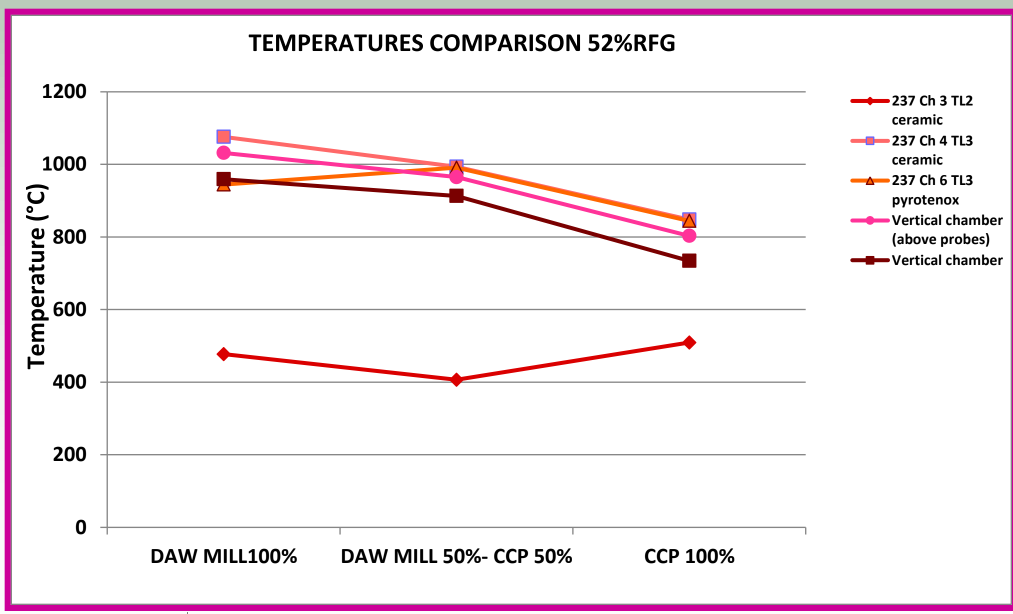
Experimental Results : TEMPERATURE
Fuel Comparison

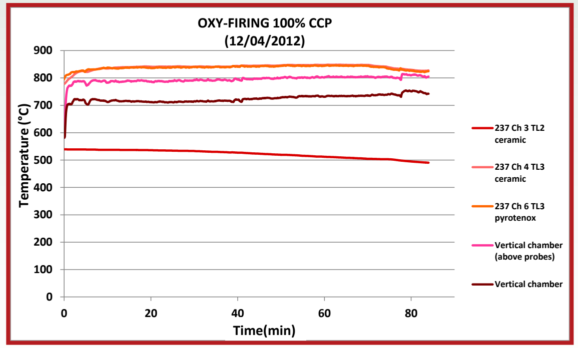
Maximum Temperatures

- Daw Mill 100% : 1100°C
- Daw Mill 50% - CCP 50% : 993°C
- CCP 100%: 848°C





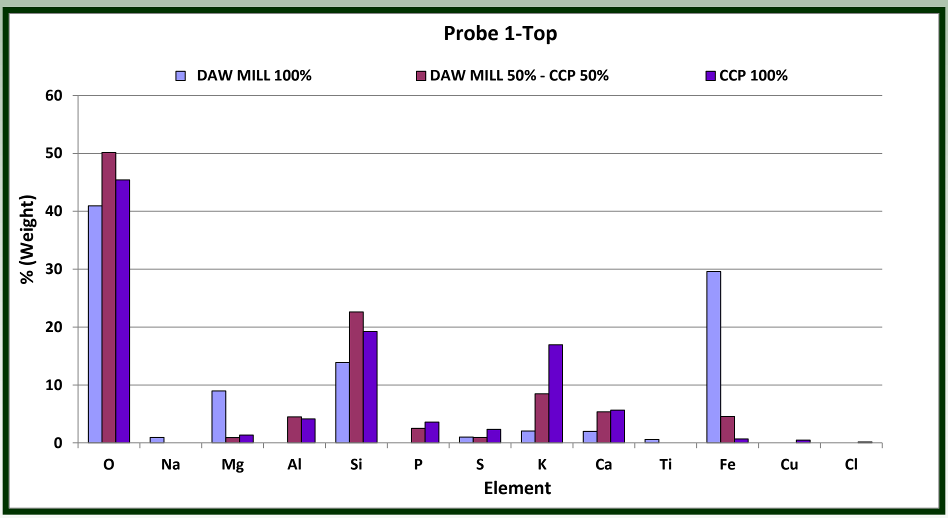




Experimental Results : ASH DEPOSITION
Fuel Comparison

Following the trend of the previous analysis:
- **K: Increases with the percentage of biomass**
- **Fe, Ti : Increases with the percentage of coal**

Exceptions:
- **O, Si, Mg: Not clear pattern**
- **Ca: Opposite behaviour to expected**



Ash Deposit Probe Daw Mill 50%-CCP 50%

Ash Deposit Probe CCP 100%

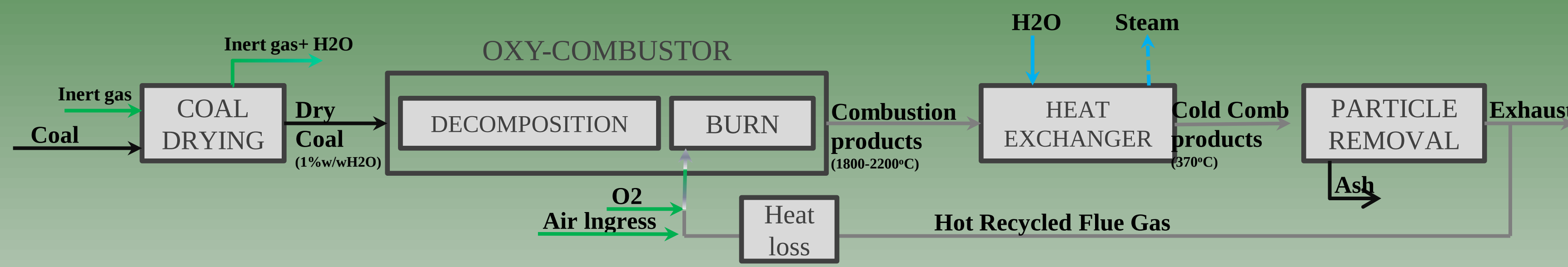
Different morphology of the ash comparing different fuels

	SiO2	Al2O3	Fe2O3	TiO2	CaO	MgO	Na2O	K2O	Mn3O4	P2O5	SO3	BaO
DAW MILL	36.8	23.9	11.2	1.1	12	2.5	1.5	0.5	0.4	-	-	-
CCP	44.36	2.79	2.47	0.12	7.78	3.96	0.36	24.72	0.1	12.04	-	0.05

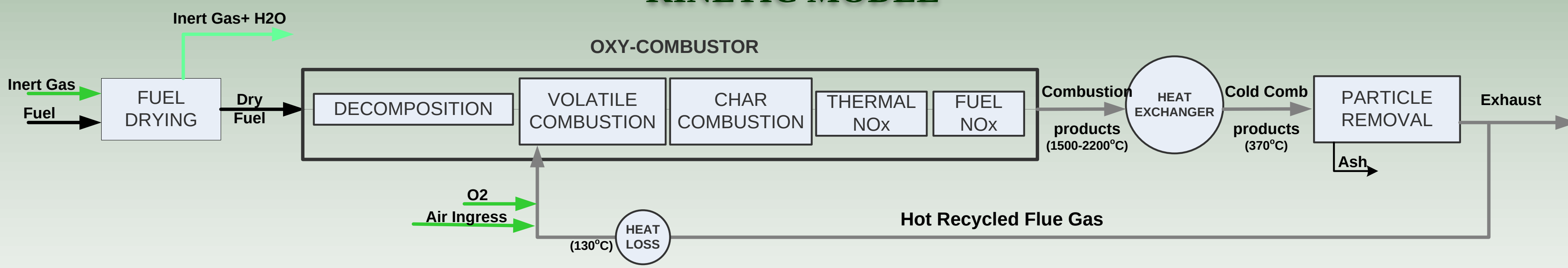
Previous ash Previous ash analysis supplied by EON

Simulation Results using Aspen Plus®:
OXY-FUEL COMBUSTION MODEL

EQUILIBRIUM MODEL



KINETIC MODEL



	STAGE 1 Air-firing case	STAGE 2 Oxy-firing case with Wet Recirculation	STAGE 3 Oxy-firing case with Wet Recirculation and Heat Loss	STAGE 4 Oxy-firing case with Wet Recirculation, Heat Loss and Air Leakage	STAGE 5 Air-firing case (KINETIC MODEL)	STAGE 6 Oxy-firing case with Wet Recirculation, Heat Loss and Air Leakage (*KINETIC MODEL*)
AIR/OXY-FIRING	Air -firing	Oxy -firing	Oxy -firing	Oxy -firing	Air -firing	Oxy -firing
%RFG	--	60,65,70	60,65,70	60,65,70	--	55,60,65,70
% O_2 Exc (v/v)	21	0,10,21	0,5,10	0,5,10	21	0,5,10
T_{RFG} (^oC)	--	370	130	130	--	130
Air Leakage	--	--	--	1.7% of Total Gas	--	1.7% of Total Gas
Fuel	Coal	Coal	Coal	Coal	Coal	Coal(El Cerrejon, Daw Mill), Biomass(Cereal Co-Product, Miscanthus), Blends of Coal and Biomass

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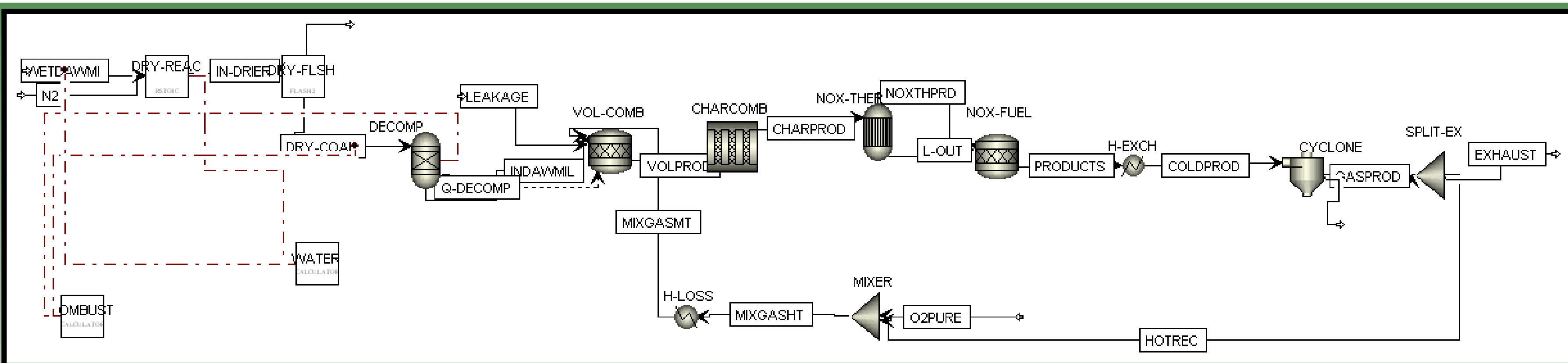
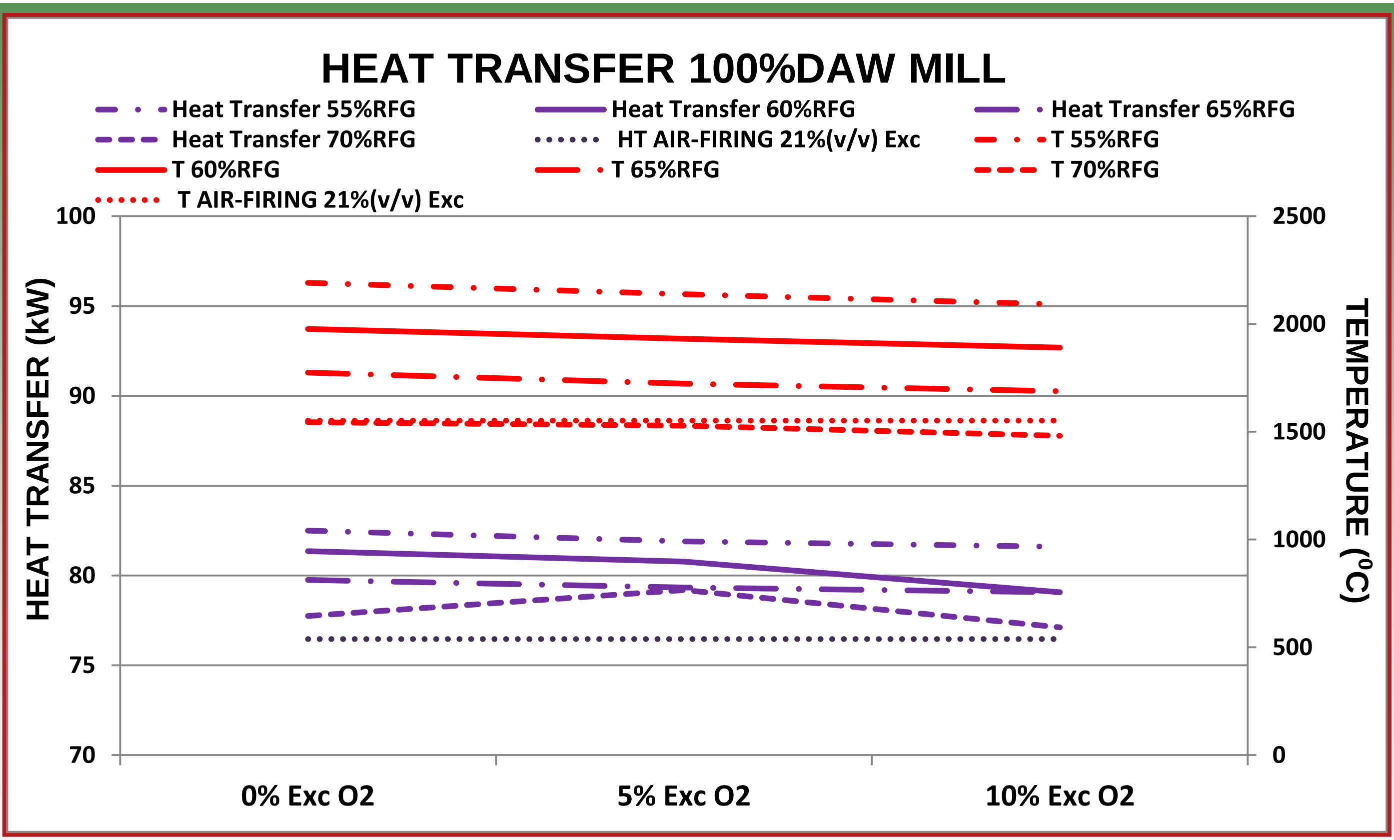
Simulation Results using Aspen Plus®:
OXY-FUEL COMBUSTION KINETIC MODEL



Reactor's Name	Type of Reactor	Reactions	Aspects to Highlight
DECOMP	**RYIELD**		
VOL-COMB	**RSTOICH**	**CO + 0.5O2→CO2** **S+ O2→SO2** **H2+ 0.5O2→H2O**	Xc =VM-H-S Proposed by to Sotudeh-Gharebaagh et al., (1998)
CHARCOMB	**RPLUG**	**C(s) + 0.5O2→CO** **C(s) + CO2→2CO** **C(s) + H2O→CO+H2** **CO + 0.5O2→CO2** **H2+ 0.5O2→H2O**	Kinetic reaction's parameters taken from Vascellari and Cau,(2009) modified to match with the dimensions required by Aspen Plus ® . For this modifications, bulk and real density of the char particle, total gas flowrate fed to the combustor and particle ratio have been taken into account.(Initial dimensions: kg_C /m^2·s·Pa .vs. Final dimensions: $kmol_C$ /m^3·s·Pa)
NOX-THERM	**REQUIL**	**0.5N2(air)+0.5O2→NO** **0.5N2(air)+0.5O2→NO2** **N2+0.5O2→N2O**	
NOX-FUEL	**RSTOICH**	**0.5N2(Fuel)+O2→NO2**	

Simulation Results: KINETIC MODEL
Daw Mill Coal 100%

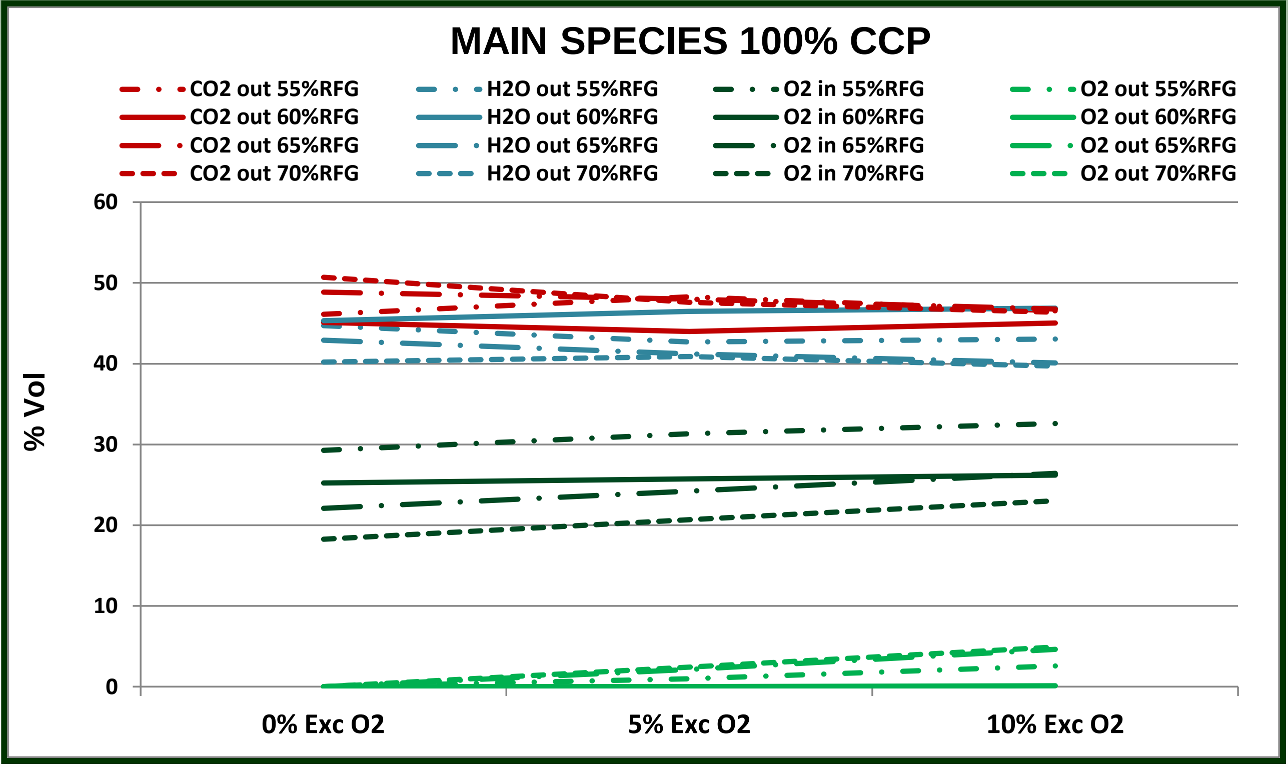


- **Heat Transfer:** - Values close to the reference case (air-firing 21%exc O2)
  - Case-study more similar: 70% RFG
  - Increases when the percentage of RFG is reduced
- **Temperature:** - The 70% RFG case matches up with the reference case

Simulation Results: KINETIC MODEL
Cereal Co-Product 100%

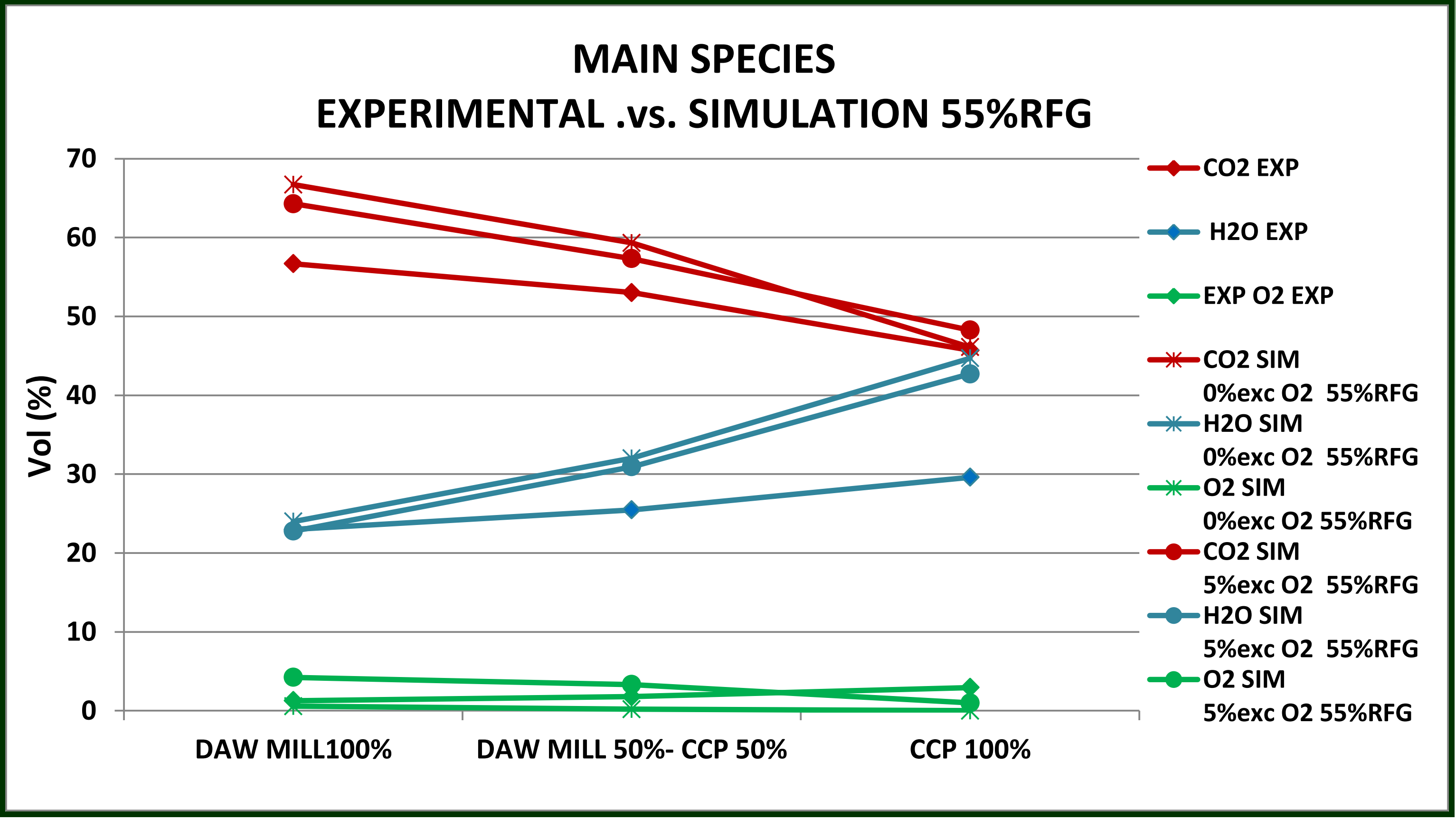
- **CO_2: Rises when the RFG percentage increases**
- **H_2O : decreases when the RFG percentage increases**
- **O_2 : Between the limits proposed with the exception of the 0% excess of oxygen cases**
- **$O_{2,\ FED}$: Out of range for the 55% RFG cases**

Similar values reached for CO_2 and H_2O



Experimental and Simulation Results:
KINETIC MODEL Fuel Comparison

- **CO_2: Better prediction when higher percentage of biomass in the fuel**
- **H_2O : Better prediction when higher percentage of coal in the fuel**



Summary and Future Work

SUMMARY

- Significant improvement in the Oxy-Combustor's performance as a result of the new fuel feeder installation
- Maximum concentration of CO_2 : 56.7%(v/v) (Wet basis)
- Kinetic Simulation Model has been developed with acceptable accordance with experimental results
- There is still some Air Ingress into the process
- Difficulties to have an excess of O_2 in the exhaust gas while keeping the O_2 in the entrance under 28% (v/v)

Future work

- Experimental tests using a wider variety of coal-biomass' blends
- Re-sealing of the burner and combustor to minimise air leakage
- Implementation of SO_x and H_2O removal in the Pilot Plant
- Further development of the simulation model:
  - Including equipment for CO_2 purification (SO_x and H_2O removal)
  - Combining wet and dry recycle

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