CanmetENERGY

Leadership in ecoInnovation

Co-firing of Coal and Biomass in a Pilot Scale Oxy-fuel CFBC

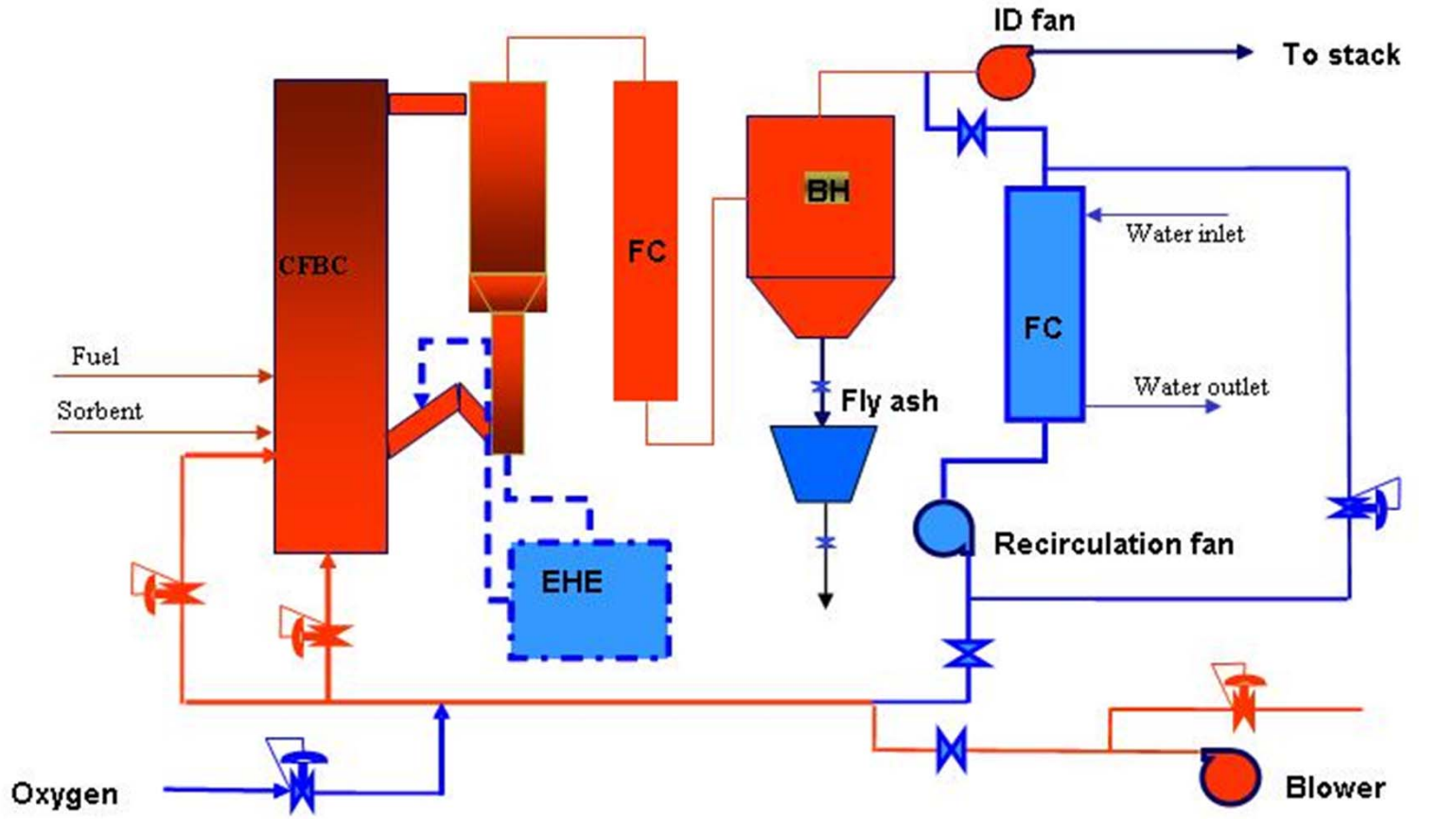
L. Jia, Y. Tan, Y. Wu and E.J. Anthony

CanmetENERGY, 1 Haanel Drive, Ottawa, Ontario, Canada, K1A 1M1

Introduction

- Oxy-fuel CFB is a promising CCS technology
- Oxy-fuel CFB retains the fuel flexibility of CFB
- Co-firing biomass with CCS will have negative CO_2 emission levels
- Canada has vast biomass reserves

0.8MW$_{th}$ oxy-fuel pilot scale CFBC



Fuel properties (as analyzed, wt%)

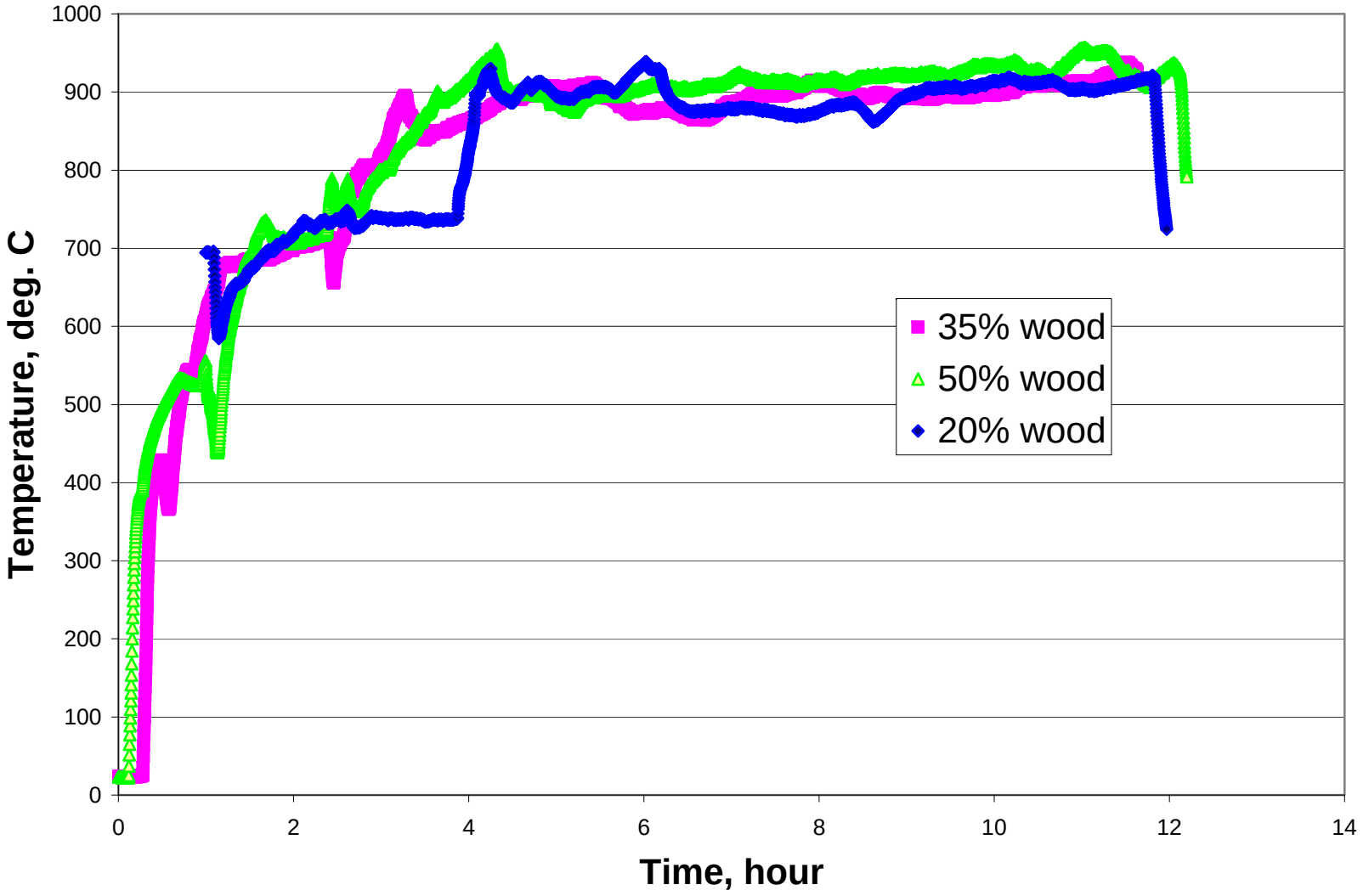
	Wood pellet	Boundary Dam	Bituminous	Genesee
Proximate analysis				
Moisture	**9.52**	**13.23**	**6.7**	**6.08**
Ash	**0.38**	**11.33**	**14.18**	**24.72**
Volatile	**76.46**	**33.86**	**25.10**	**26.87**
Fixed carbon	**13.64**	**41.58**	**54.02**	**42.33**
Ultimate analysis				
Carbon	**44.7**	**54.6**	**66.34**	**52.2**
Hydrogen	**5.36**	**3.50**	**3.64**	**3.05**
Nitrogen	**0.12**	**0.81**	**1.59**	**0.79**
Sulphur	**<0.05**	**0.63**	**0.56**	**0.30**
Oxygen (diff)	**39.91**	**15.92**	**7.00**	**12.85**
LHV, MJ/kg	**17.49**	**20.74**	**25.28**	**19.98**

Test conditions

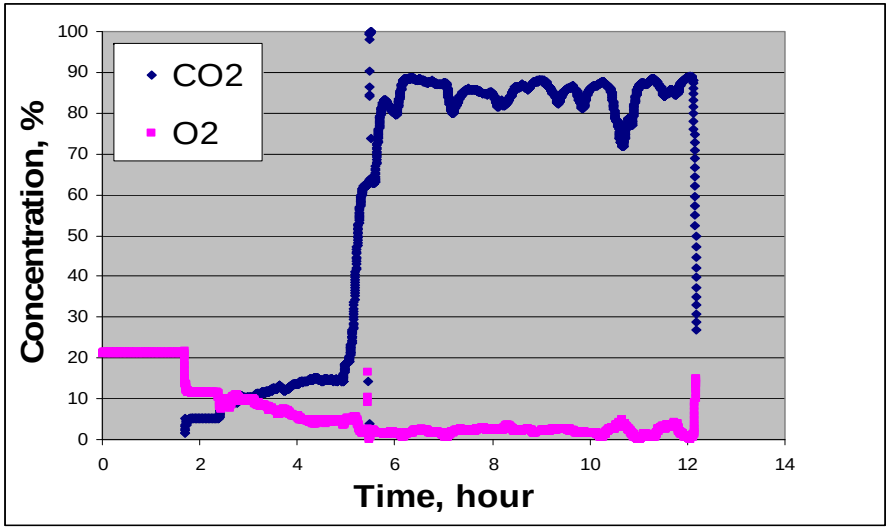
- Nominal free board temperature: ~910°C
- Wood pellet to coal weight ratio: 20/80, 35/65 and 50/50.
- Velocity: ~4 m/s
- Nominal Ca/S = 3

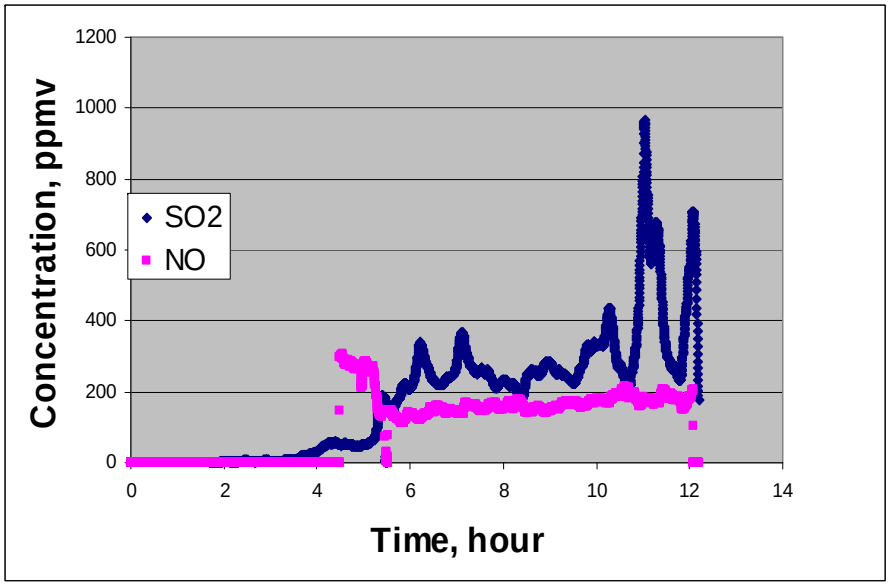
Co-firing of wood/bituminous coal

	20 wood/80 coal	35 wood/65 coal	50 wood/50 coal	Coal only
Average riser temp., °C	894 ± 17	901 ± 13	921 ± 20	909 ± 7
Average bed temp., °C	884 ± 19	880 ± 10	928 ± 15	878 ± 11
Fuel rate, kg/h	64.0 ± 6.8	73.8 ± 3.4	80.1 ± 4.8	54.9 ± 3.7
Oxygen, kg/h	100.8 ± 4.7	117.7 ± 5.0	118.3 + 4.6	101.3 ± 4.6
Nominal Ca/S	3	3	3	3
Velocity, m/s	3.24 ± 0.35	3.71 ± 0.40	3.94 ± 0.45	3.28
O_2, %	1.2 ± 0.7	2.46 ± 1.1	2.0 ± 0.8	3.32 ± 0.46
CO_2, %	80.0 ± 6.2	86.0 ± 3.7	85.0 ± 3.1	89.0 ± 3.3
CO, ppm	2564 ± 560	1316 ± 590	1639 ± 649	1888 ± 245
SO_2, ppm	362 ± 96	304 ± 99	309 ± 134	643 ± 65
NO_x, ppm	117 ± 17	150 ± 20	162 ± 19	236 ± 23
Recycle ratio	0.663	0.668	0.661	0.701
Sulphur capture, %	76.1	76.7	69.6	69.3
Fuel N to NO_x, %	1.2	1.8	2.3	1.74

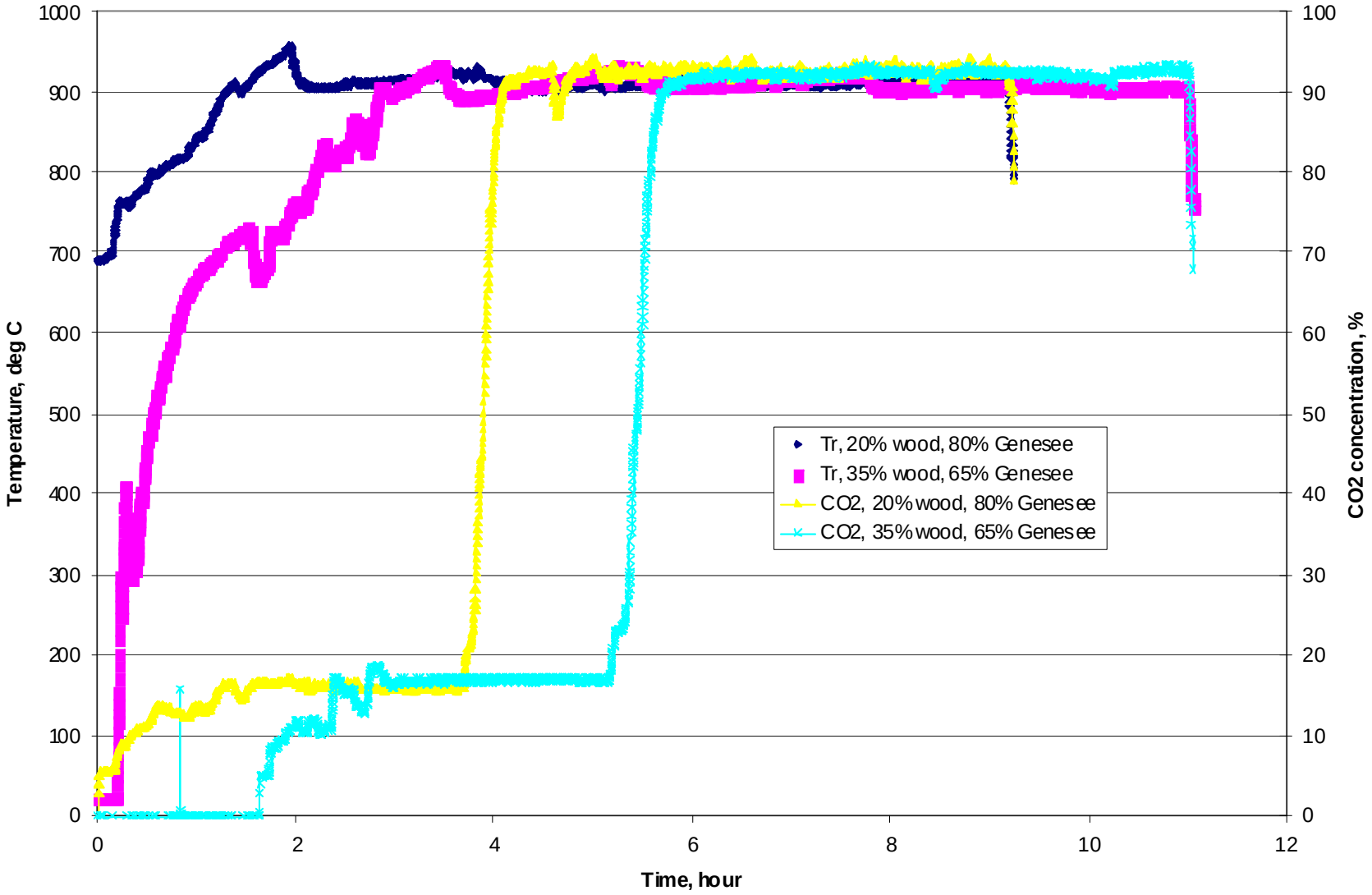


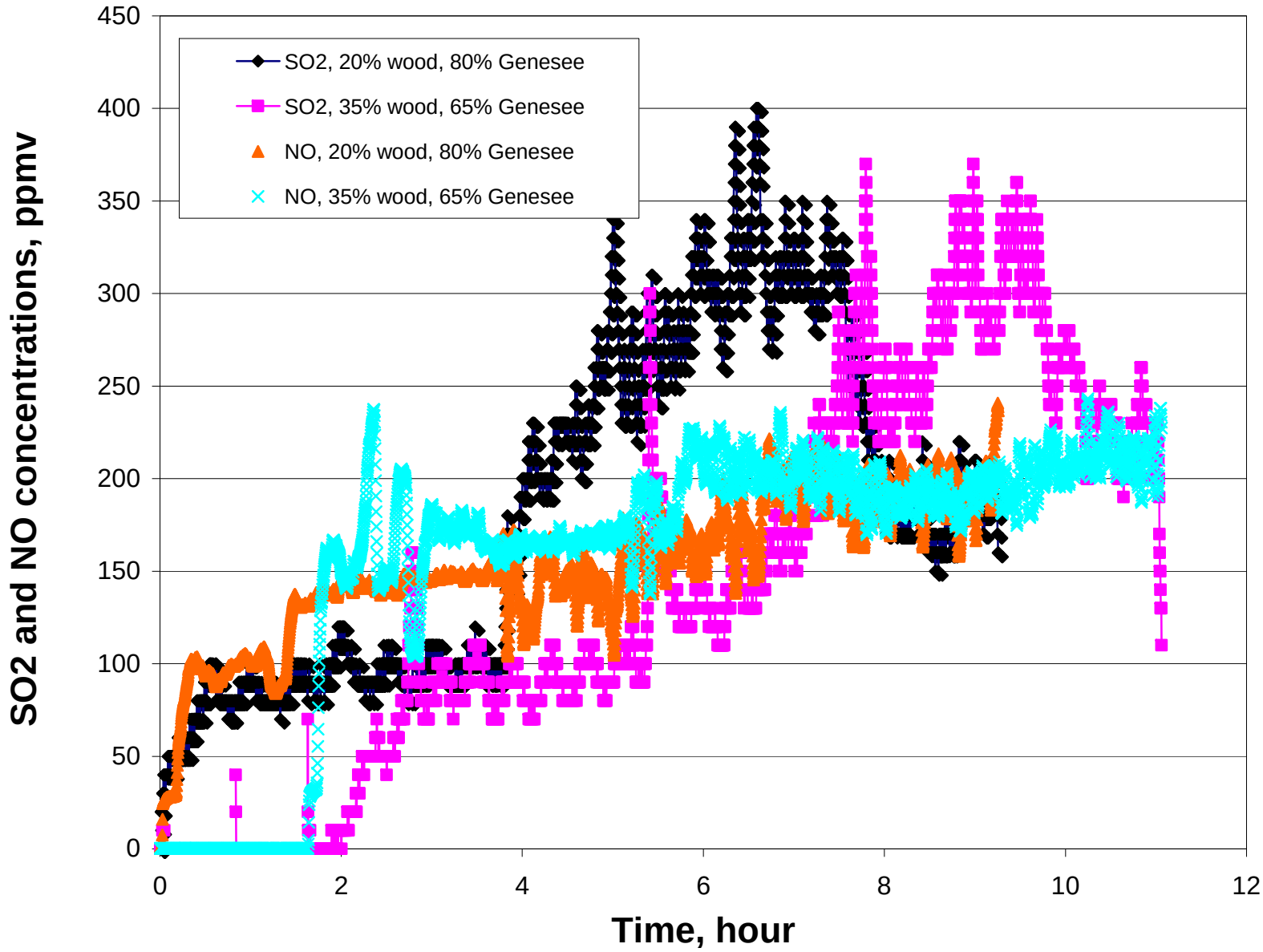
Average freeboard temperatures, oxy-fuel CFB co-firing of wood pellets and bituminous coal





Oxy-fuel CFBC of 50% wood pellets /50% bituminous coal.


Temperature, deg C
CO2 concentration, %
Time, hour
Tr, 20% wood, 80% Genesee
Tr, 35% wood, 65% Genesee
CO2, 20% wood, 80% Genesee
CO2, 35% wood, 65% Genesee
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12


SO2, 20% wood, 80% Genesee
SO2, 35% wood, 65% Genesee
NO, 20% wood, 80% Genesee
NO, 35% wood, 65% Genesee
SO2 and NO concentrations, ppmv
Time, hour
0
50
100
150
200
250
300
350
400
450
0
2
4
6
8
10
12

SO_3 concentrations in the exhaust flue gas

Bituminous coal	
20% wood / 80% bituminous coal	<0.16 ppmv
35% wood / 65% bituminous coal	2.23 ppmv
50% wood / 50% bituminous coal	1.12 ppmv
Genesee (lignite)	2.27 ppmv
20% wood / 80% Genesee lignite	2.76 ppmv
35% wood / 65% Genesee lignite	1.86 ppmv

Metals in the flue gas for co-firing of wood/bituminous coal, dry basis *(µg/m³)*

Wood/bituminous	20/80	35/65	50/50	0/100
Al	80.6	< 57	< 53	17.2
Sb	< 2.5	< 2.8	< 2.6	< 1
As	< 2.5	< 2.8	< 2.6	< 1
Ba	< 15	< 17	< 16	< 5
Be	< 0.5	< 0.6	< 0.5	< 0.5
B	148	144	167	50.6
Cd	1.8	1.4	0.92	< 1.1
Ca	400	362	250	< 215
Cr	< 1	< 1.4	< 1.3	< 5
Co	< 0.5	< 0.6	< 0.5	< 0.5
Cu	< 2	< 2.8	< 2.6	< 5
Fe	< 150	< 170	< 158	237
Pb	< 1.2	< 1.4	< 1.3	2.04
Mg	99.4	56.8	< 26	57.0
Mn	< 2	< 2.8	16325	< 2
Mo	< 2.5	< 2.8	< 2.6	< 1.1
Ni	7.4	2.9	< 2.6	< 1.1
P	< 25	< 28	< 26	< 108
K	< 200	< 227	12178	< 215
Se	< 5	< 5.7	< 5.3	2.37
Ag	< 1.2	< 1.4	< 1.3	< 0.11
Na	250	206	165	118
Sr	< 1.5	< 1.7	< 1.6	< 1.1
Tl	< 2.5	< 2.8	< 2.6	< 0.1
Ti	4.4	7.2	4.1	< 32
U	< 2.5	< 2.8	< 2.6	< 1.1
V	< 2.5	< 2.8	< 2.6	< 108
Zn	18.1	15.6	< 2.6	17.2
Hg	0.25	0.29	0.11	0.79

Concentrations of elements, dry Basis *(µg/m³)*, co-firing of wood pellets and Genesee coal

Element	Genesee coal only	20% wood pellets / 80% Genesee	35% wood pellets / 65% Genesee
Al	< 14	< 6	< 12
Sb	< 1.4	< 0.6	< 1.2
As	< 2.7	< 1.2	< 2.4
Ba	< 5	< 2	< 5
Be	< 1.4	< 0.6	< 1.2
B	294	382	477
Cd	0.4	0.3	< 0
Ca	< 545	< 231	< 487
Cr	< 14	< 6	< 12
Co	< 1.4	< 0.6	< 1.2
Cu	< 3	< 1	< 2
Fe	< 272	< 116	< 243
Pb	< 1.4	< 0.6	< 1.2
Mg	< 136	< 58	< 122
Mn	< 5	< 2	< 5
Mo	< 2.5	< 2.5	< 2.5
Ni	< 2.7	< 1.2	< 2.4
P	< 272	< 116	< 243
K	< 545	< 231	< 487
Se	< 5	< 2	< 5
Ag	< 0.3	0.14	< 0.2
Na	< 272	< 116	< 243
Sr	< 2.7	< 1.2	< 2.4
Tl	< 0.1	< 0.1	< 0.1
Ti	< 14	< 6	< 12
U	< 0	< 0	< 0
V	< 0	< 0	< 0
Zn	< 1	< 1	< 1
Hg	1.80	3.87	3.46

VOCs concentrations for co-firing wood/bituminous coal, dry basis *(µg/m3)*

Wood/bituminous	20/80	35/65	50/50	0/100
Dichlorodifluoromethane (FREON 12)	< 0.3	< 0.3	< 0.3	< 0.35
Chloromethane	6.25	3.29	5.84	22.0
Vinyl Chloride	0.24	< 0.2	< 0.2	< 0.2
Bromomethane	1.07	4.85	3.45	1.94
Chloroethane	0.22	< 0.15	< 0.15	< 0.16
Trichlorofluoromethane (FREON 11)	< 0.15	< 0.16	< 0.17	< 0.18
Acetone (2-Propanone)	< 0.67	2.12	0.87	1.23
1,1-Dichloroethylene	< 0.15	< 0.16	< 0.17	< 0.2
Iodomethane	< 0.22	2.58	0.96	0.35
Carbon Disulfide	13.5	4.31	3.48	4.75
Methylene Chloride(Dichloromethane)	< 0.3	< 0.32	< 0.33	< 0.35
1,1-Dichloroethane	< 0.18	< 0.19	< 0.2	
trans-1,2-Dichloroethylene	< 0.15	< 0.16	< 0.17	
cis-1,2-Dichloroethylene	< 0.15	< 0.16	< 0.17	
Chloroform	< 0.16	< 0.18	< 0.18	< 0.18
1,2-Dichloroethane	< 0.1	< 0.11	< 0.12	< 0.1
Methyl Ethyl Ketone (2-Butanone)	< 0.54	< 0.58	< 0.59	< 0.7
1,1,1-Trichloroethane	< 0.21	< 0.23	< 0.23	< 0.2
Carbon Tetrachloride	< 0.24	< 0.26	< 0.26	< 0.35
Benzene	1360	55.8	45.6	31.1
1,1,2-Trichloroethane	< 0.24	< 0.26	< 0.26	< 0.16
1,2-Dichloropropane	< 0.16	< 0.18	< 0.18	< 0.4
Trichloroethylene	< 0.16	< 0.18	< 0.18	< 0.5

VOCs concentrations for co-firing wood/bituminous coal, dry basis *(µg/m3)*

Wood/bituminous	20/80	35/65	50/50	0/100
Dibromomethane	< 0.15	< 0.16	< 0.17	1.94
Bromodichloromethane	< 0.16	< 0.18	< 0.18	< 0.2
cis-1,3-Dichloropropene	< 0.15	< 0.16	< 0.17	< 0.35
trans-1,3-Dichloropropene	< 0.1	< 0.11	< 0.12	< 0.2
Dibromochloromethane	< 0.13	< 0.15	< 0.15	< 0.4
Methyl Isobutyl Ketone	< 0.3	< 0.32	< 0.33	< 0.2
Methyl Butyl Ketone (2-Hexanone)	< 0.45	< 0.49	< 0.5	< 0.4
Toluene	42.6	4.59	2.10	< 0.18
Ethylene Dibromide	< 0.15	< 0.16	< 0.17	< 0.2
Tetrachloroethylene	< 0.27	< 0.29	< 0.3	< 0.1
Chlorobenzene	< 0.16	1.20	0.40	< 0.16
1,1,1,2-Tetrachloroethane	< 0.15	< 0.16	< 0.17	< 0.4
Ethylbenzene	< 0.21	< 0.23	0.28	< 0.5
m / p-Xylene	< 0.22	0.79	0.69	1.94
Styrene	< 0.18	< 0.19	< 0.2	< 0.2
o-Xylene	< 0.22	< 0.24	< 0.25	< 0.35
Bromoform	< 0.21	< 0.23	< 0.23	< 0.2
1,1,2,2-Tetrachloroethane	< 0.21	< 0.23	< 0.23	< 0.2
1,2,3-Trichloropropane	< 0.22	< 0.24	< 0.25	< 0.2
1,3-Dichlorobenzene	< 0.3	< 0.32	< 0.33	< 0.4
1,4-Dichlorobenzene	< 0.3	< 0.3	< 0.3	< 0.2
1,2-Dichlorobenzene	< 0.3	< 0.3	< 0.3	< 0.4

Conclusions

- Oxy-fuel CFB co-firing of wood pellets and coals presented no difficulties.
- Stable oxy-fuel operation with CO_2 concentrations reaching 80 - 90% .
- Effect of co-firing on freeboard temperature insignificant

Conclusions, cont.

- NO_x was lower as wood has lower nitrogen content, although fuel N conversion ratios were comparable as firing coal only.
- Metals and VOCs emissions levels will most likely pose no barrier for the adaptation of the oxy-fuel CFB co-firing biomass and coal.