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Explosibility characteristics of wood biomass dust, torrefied biomass, coal and coal/biomass mixtures

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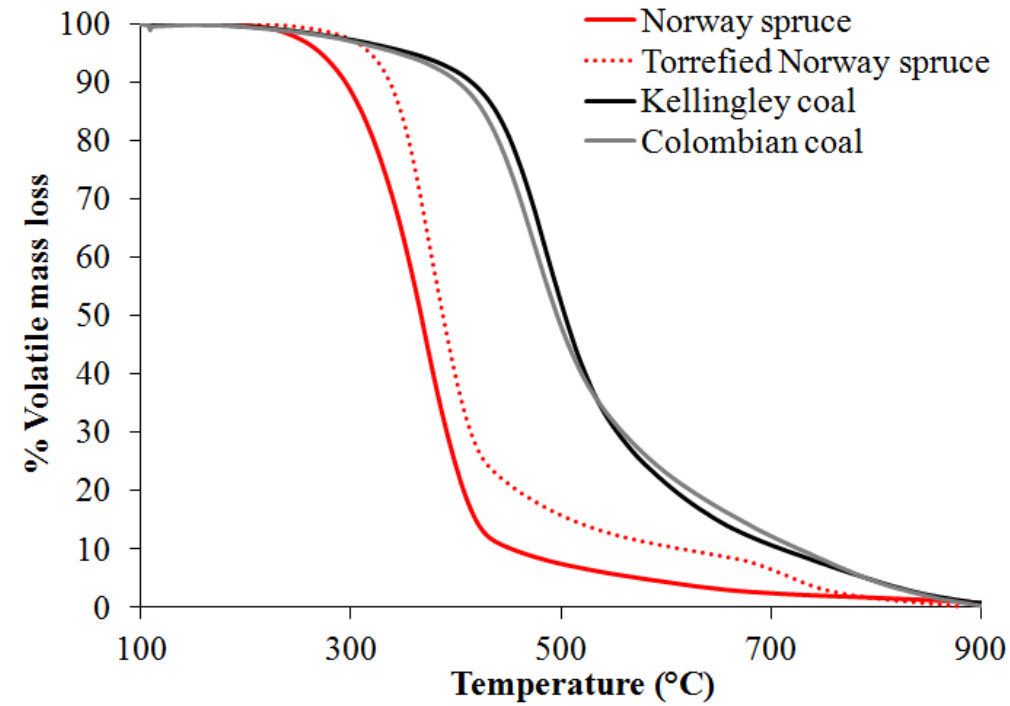
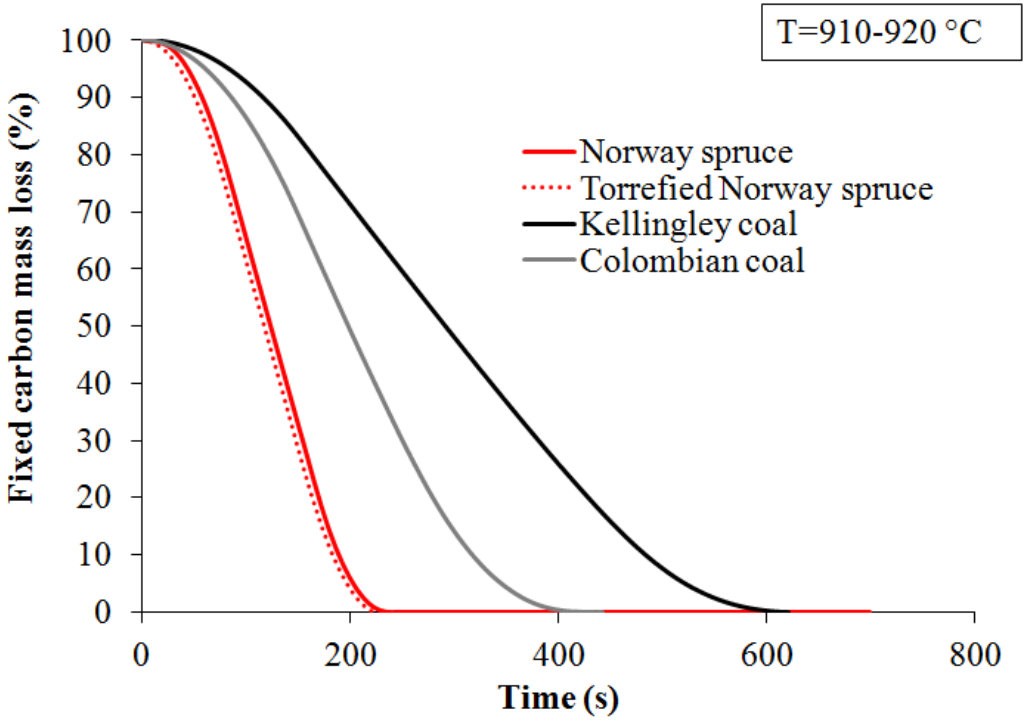
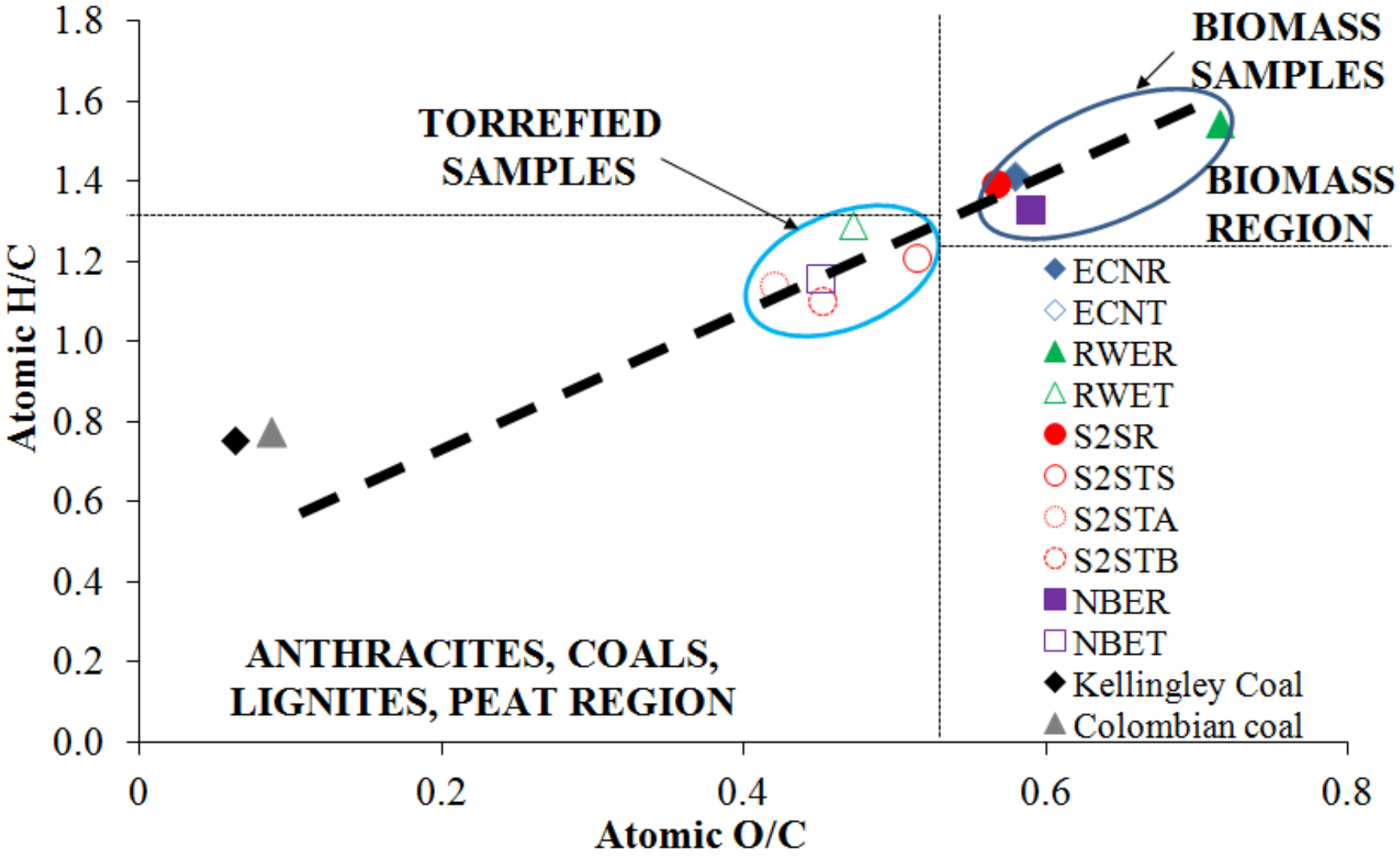
Introduction

- Coal: Generates 41% of the world's electricity
- Biomass: CO_2 neutral
- **Torrefied biomass**: upgraded biomass
- 200-300°C in the absence of oxygen for a certain residence time
- End product is similar to low rank coals: Increased CV, more easily ground, hydrophobic
- **Mixtures Coal/biomass or torrefied biomass**

	Southern Pine	Torrefied Southern pine	Kellingley Coal	Colombian coal
Elemental Analysis (wt%)^{ar}				
C	48.4	54	65	66.6
H	5.4	5.2	4.1	4.3
O*	38.1	32.5	5.5	7.8
N	0.6	0.7	2.4	2.1
S	0	0	2.2	0.7
Proximate Analysis (wt%)^{ar}				
Moisture	5	3.3	1.7	3.2
VM	78.5	70.3	29.2	33.7
FC	14	22.1	50	47.8
Ash*	2.5	4.3	19.1	15.3
VM/FC	5.6	3.2	0.6	0.7
A/F	6.3	7.2	11.3	11.1
A/F^{daf} (g/m^3)	190	166	106	108
GCV^{daf} (MJ/kg)	21	23.4	33.8	33.5
Bulk density (kg/m^3)	268.4	415.4	443	407.4


Norway spruce
Torrefied Norway spruce
Kellingley coal
Colombian coal
% Volatile mass loss
Temperature (°C)
100
90
80
70
60
50
40
30
20
10
0
100
300
500
700
900


T=910-920 °C
Norway spruce
Torrefied Norway spruce
Kellingley coal
Colombian coal
Fixed carbon mass loss (%)
Time (s)
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800


BIOMASS SAMPLES
TORREFIED SAMPLES
BIOMASS REGION
ANTHRACITES, COALS, LIGNITES, PEAT REGION
ECNR
ECNT
RWER
RWET
S2SR
S2STS
S2STA
S2STB
NBER
NBET
Kellingley Coal
Colombian coal
Atomic H/C
Atomic O/C
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
0
0.2
0.4
0.6
0.8

Coal sample	K_{St}	P_{max}	MEC
Morwell coal	220	7.6	-
Brown coal	151	10.0	-
Yallourn dark	91	6.7	-
Prince mine coal	44	6.5	70
Phalen mine coal	30	6.0	120
Lingan mine coal	44	7.0	90
Russian anthracite	68	5.0	-
Sulcis lignite	162	6.8	-
South African coal	81	6.0	-
Polish coal	135	6.8	-
Snibston coal	149	6.5	-
Spanish lignite	107	8.8	90
German lignite	105	8.7	60
Pittsburgh coal	41	6.7	65
Pocahontas coal	31	6.5	80
Sebuku coal	114	6.6	63

K_{St}=30-220 barm/s

P_{max} =5-10 bar

MEC= 60-120 g/m^3

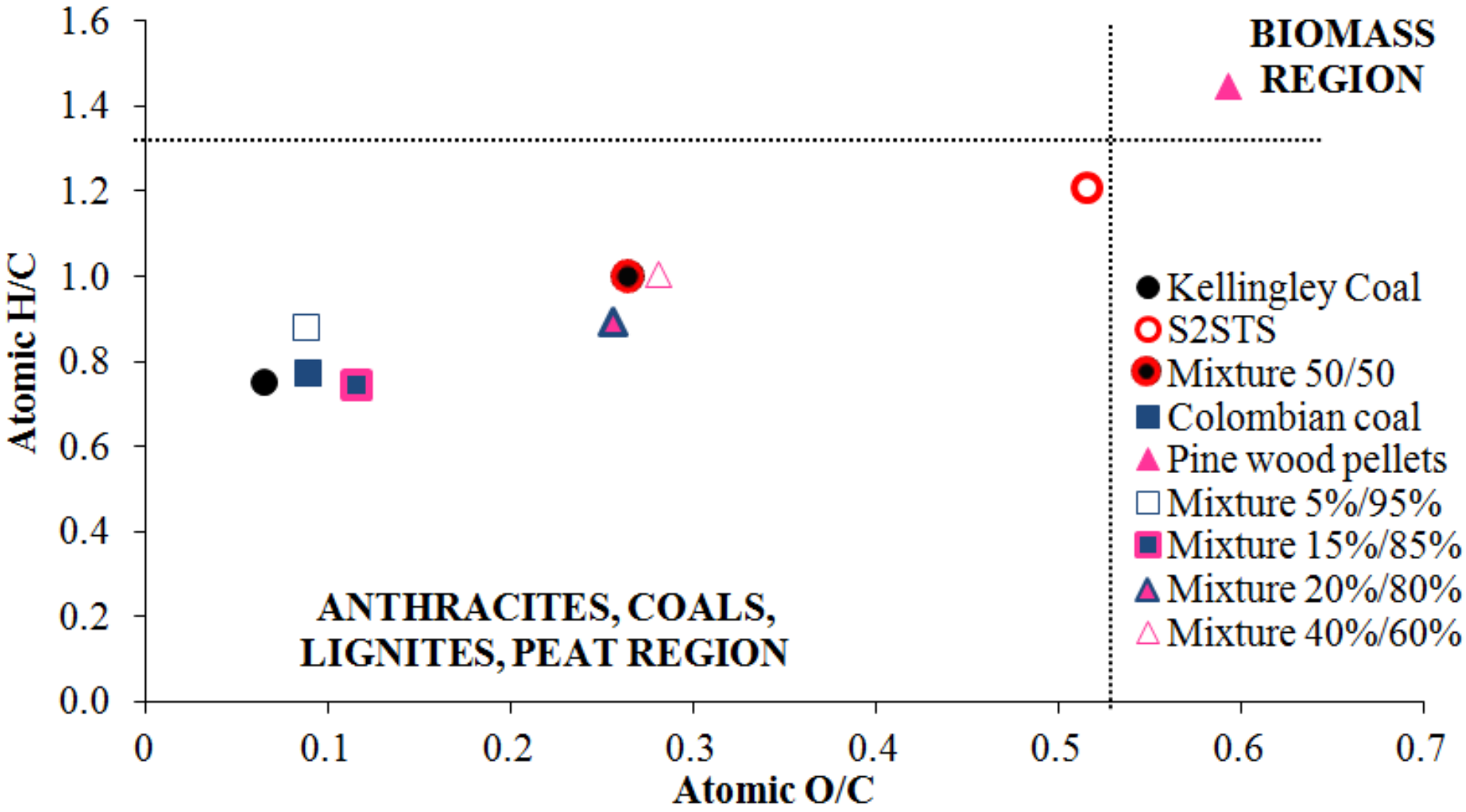
Fuel	K_{St} (barm/s)	P_{max} (bar)	MEC (g/m^3)
Cork	179	7.2	40
Walnut shells dust	105	9.4	70
Pine nut shells dust	61	8.9	-
Pistachio shells dust	82	9.3	90
Wood	115	8.6	30
Bark	132	9.0	30
Forest residue	87	8.6	60
Spanish pine	44	7.7	90
Barley straw	72	7.9	90
Miscanthus	53	7.8	120
Sorghum	41	7.3	120
Rape seed straw	23	6.7	210
Wood dust (beech and oak mix)	136	7.7	-
Forest residue (bark and wood)	92	9.1	20
Wood dust	87	7.8	-
Wood dust, chipboard	102	8.7	60
Wheat grain dust	112	9.3	60
Olive pellets	74	10.4	125
Cellulose	66	9.3	60
British Columbia wood pellets	146	8.1	70
Nova Scotia wood pellets	162	8.4	70
Southern yellow pine wood pellets (USA)	98	7.7	25
Wood dusts	208	9.4	-
Fibrous wood	149	8.2	20
Sawdust	115	9.0	-

K_{St}=23-208 barm/s

P_{max} =6.7-10.4 bar

MEC= 20-210 g/m^3

$$Y\ (wt\%) = x_{biomas}\ Y_{biomass}\ (wt\%) + x_{coal}\ Y_{coal}\ (wt\%)$$

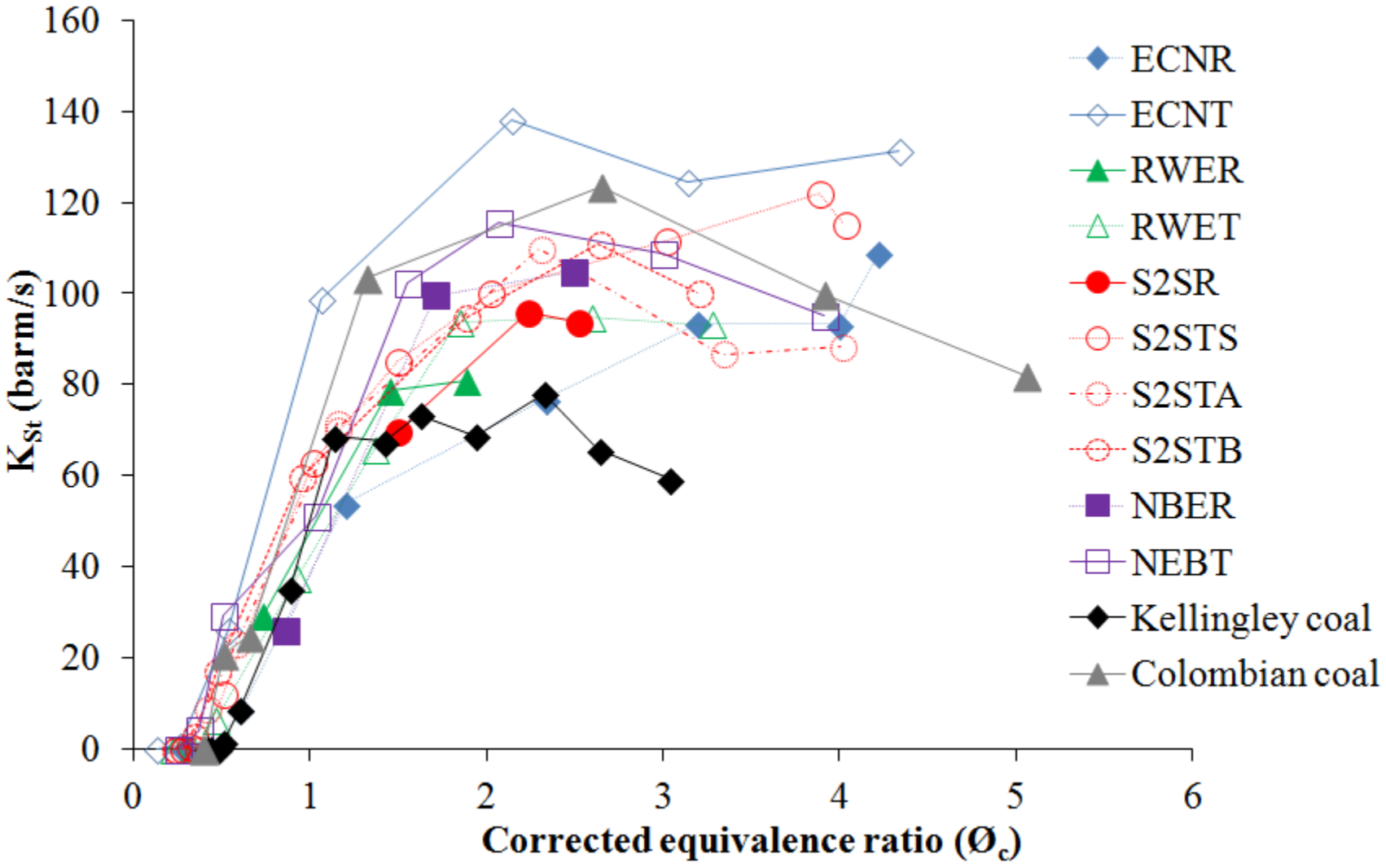


Fuel	K_{St} (barm/s)	P_{max} (bar)	MEC (g/m^3)
Wood dust	115	8.6	30
German Lignite	146	8.6	60
Mixture (25/75)	111	8.4	90
Barley straw	72	7.9	90
Spanish lignite	164	8.6	90
Mixture (25/75)	137	8.4	150
Wood dust	87	7.8	-
Black lignite	105	7.7	-
Mixture (25/75)	104	8.8	-

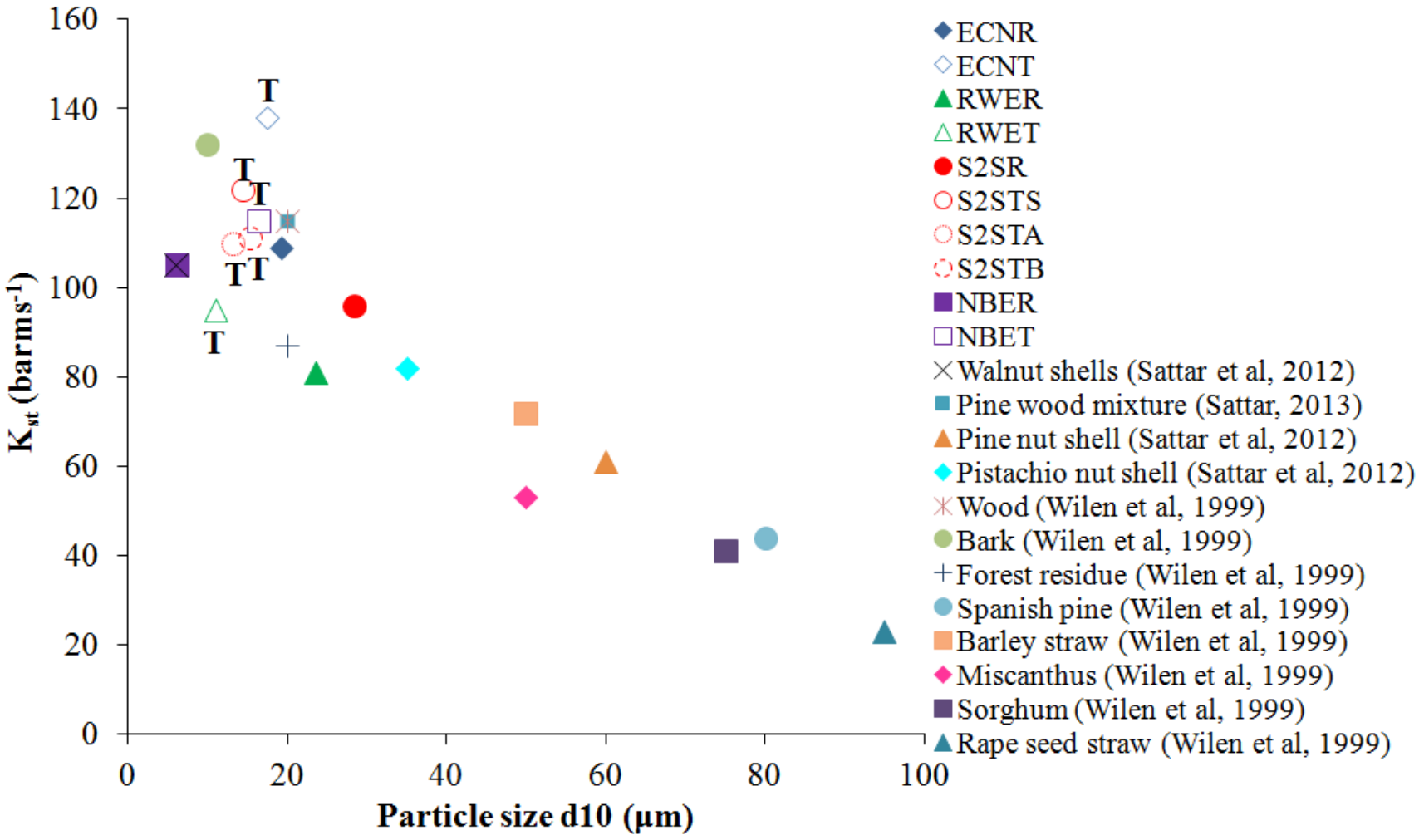
Objectives

- Determine explosion characteristics K_{St}, P_{max} (Dust size <63 μm)
- Determine combustion properties: flame speeds, burning velocities, heat release rates
- Determine the changes in combustion/explosion properties induced by torrefaction and by mixing of fuels

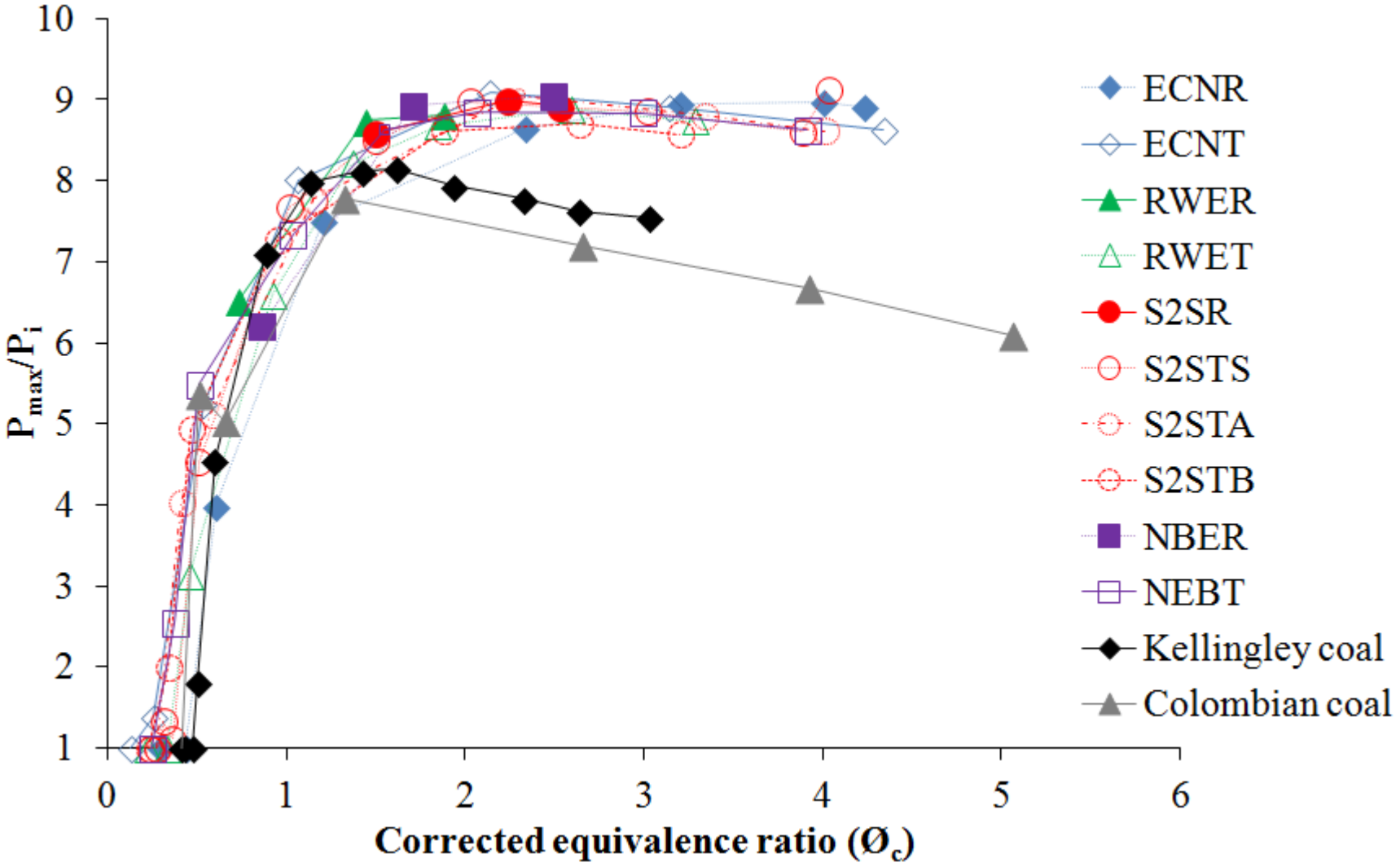
K_{St}


160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
K_{St} (barm/s)
Corrected equivalence ratio ($Ø_c$)
ECNR
ECNT
RWER
RWET
S2SR
S2STS
S2STA
S2STB
NBER
NEBT
Kellingley coal
Colombian coal

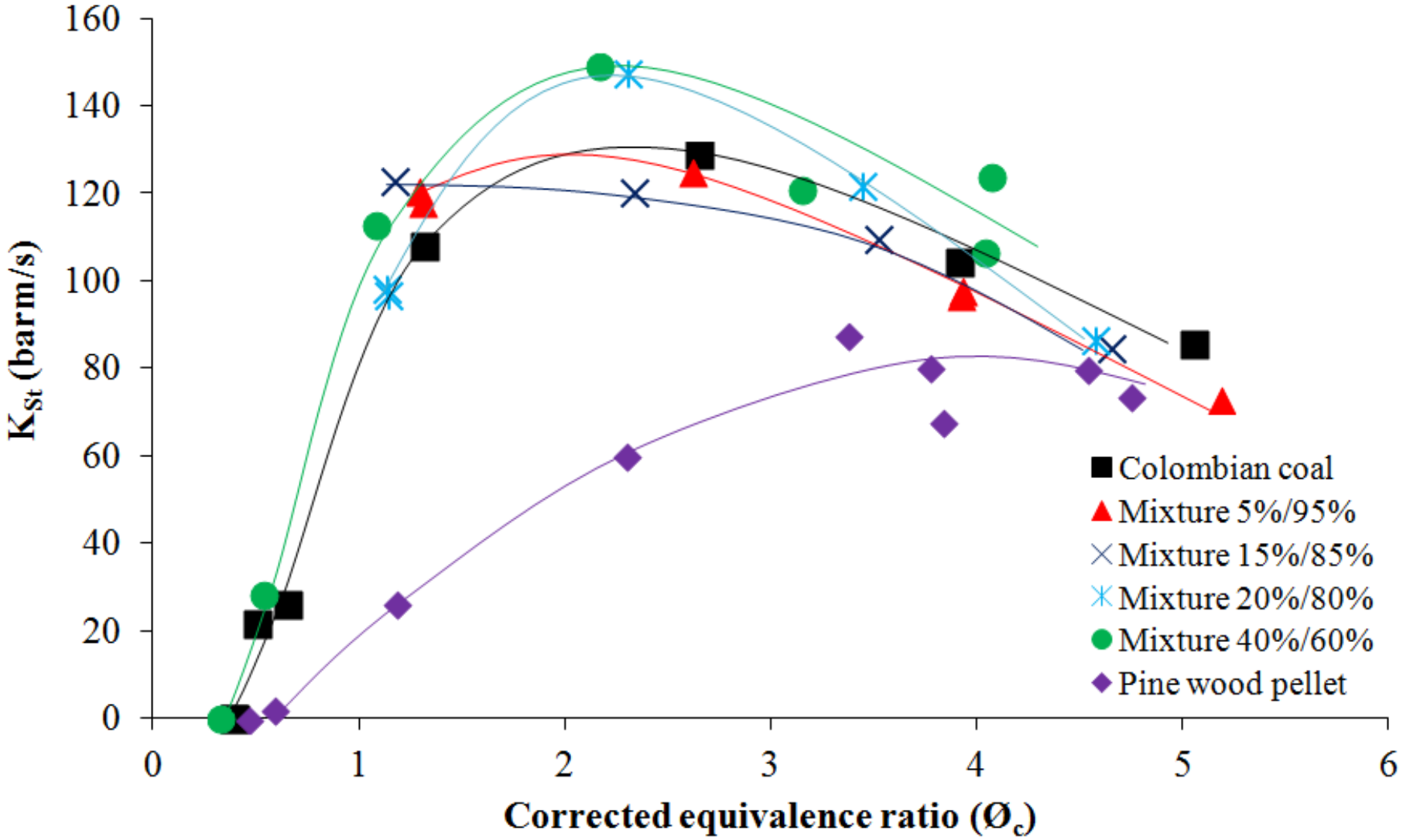
Correlation of K_{St} and fraction of fines



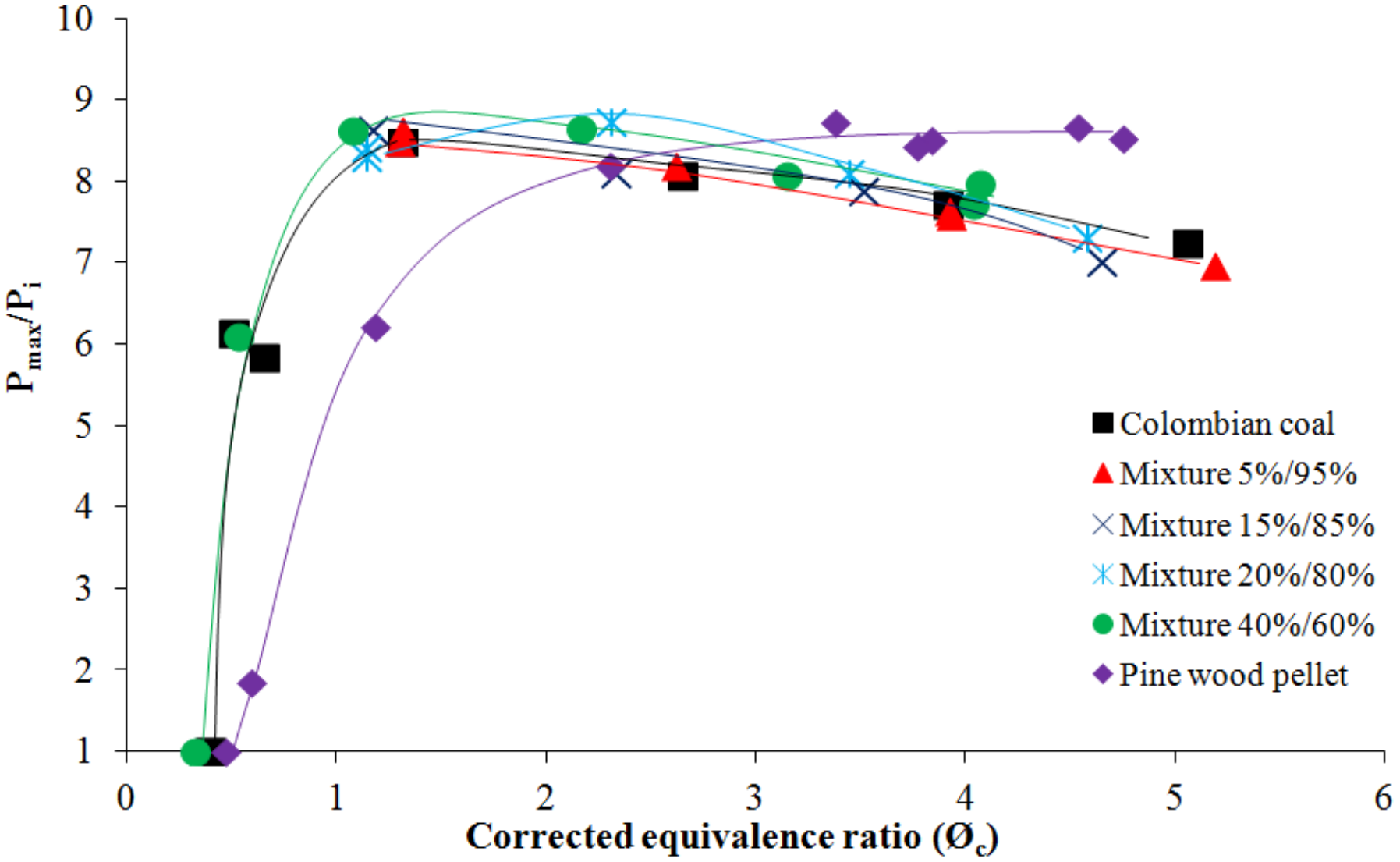
P_{max}/P_i


10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
P_{max}/P_i
Corrected equivalence ratio ($Ø_c$)
ECNR
ECNT
RWER
RWET
S2SR
S2STS
S2STA
S2STB
NBER
NEBT
Kellingley coal
Colombian coal

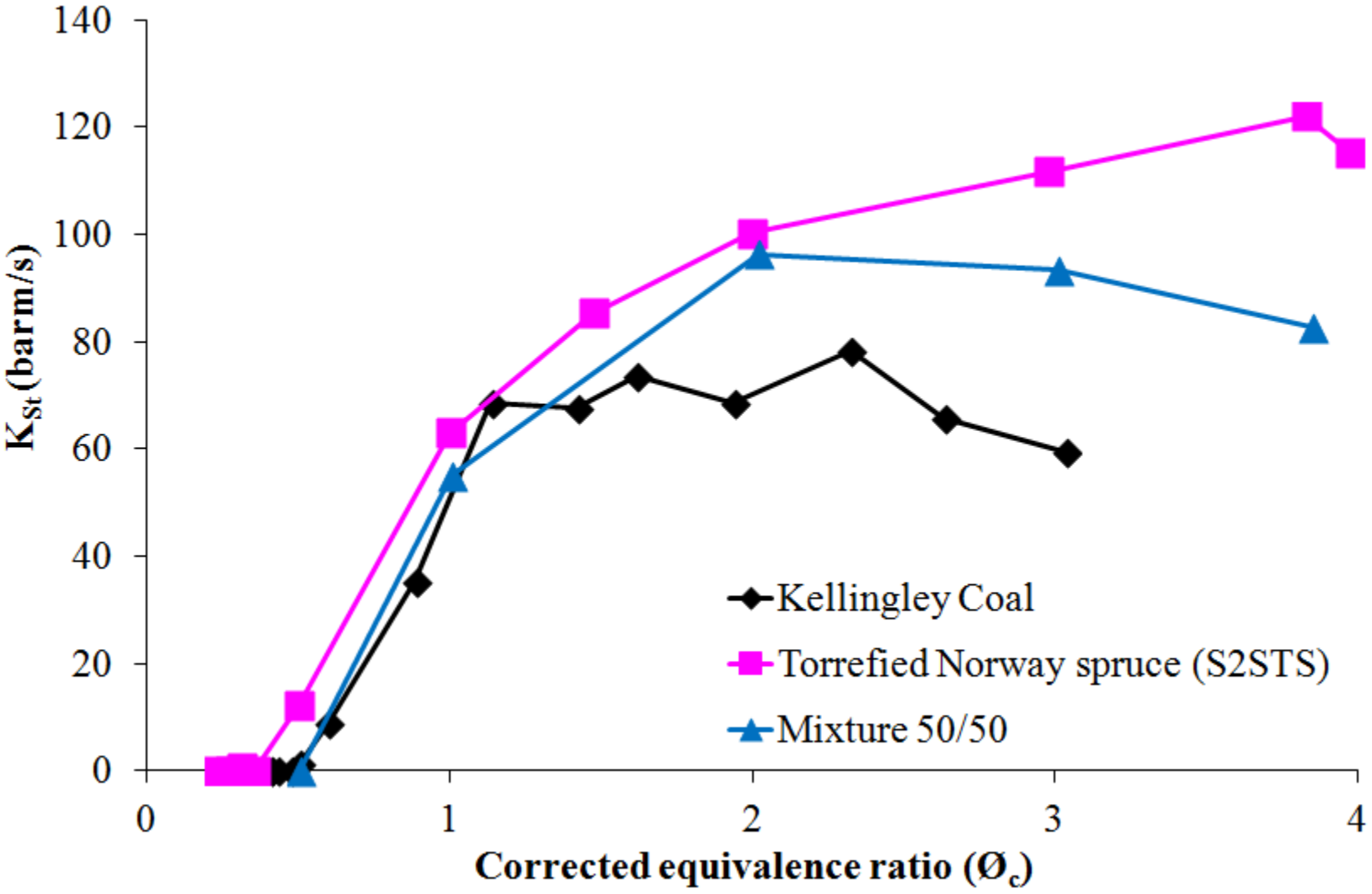
K_{St} Biomass/coal mixtures



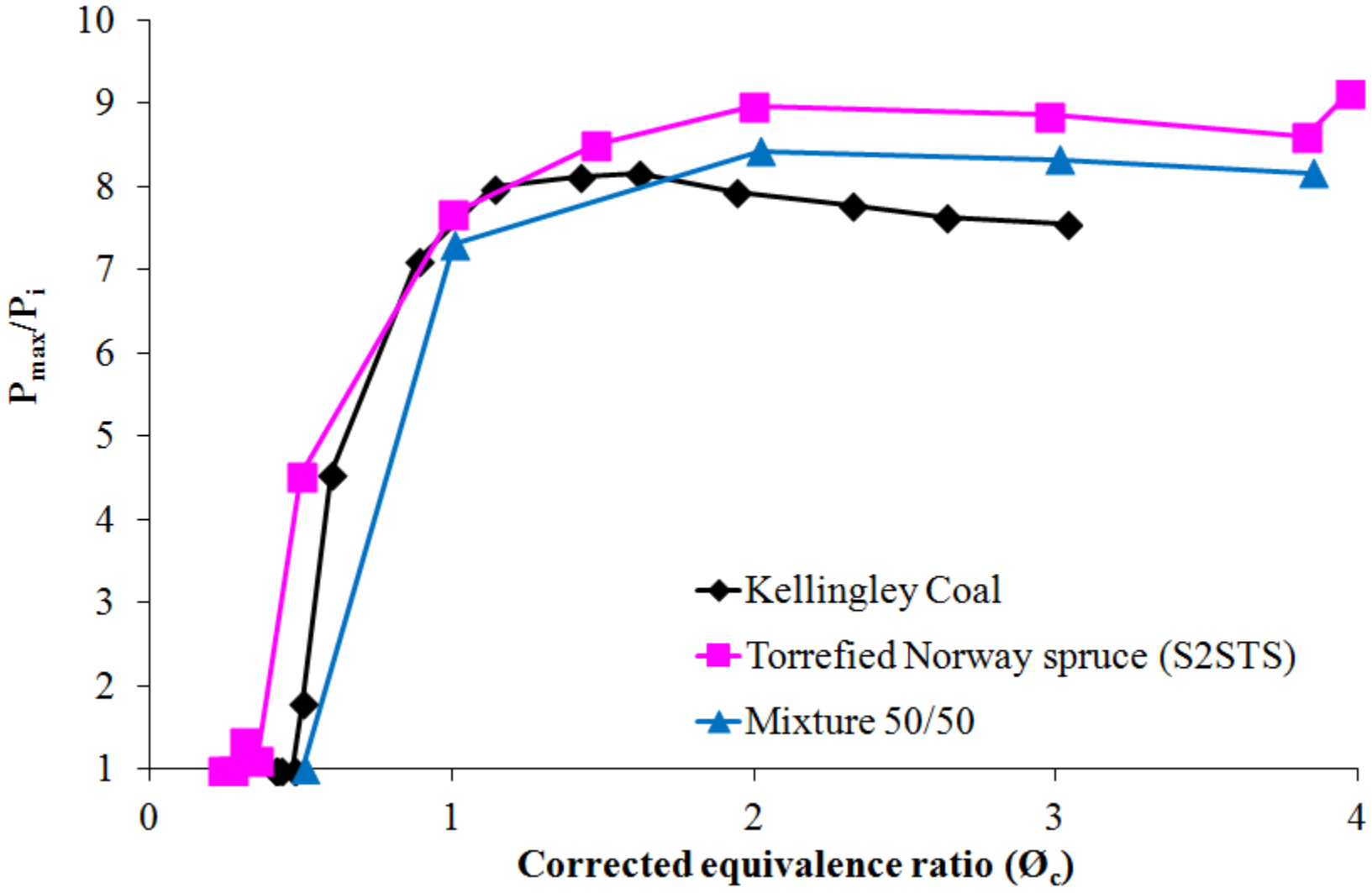
P_{max}/P_i: Biomass/coal mixtures



K_{St} Torrefied biomass/coal mixtures



P_{max}/P_i: Torrefied biomass/coal mixtures



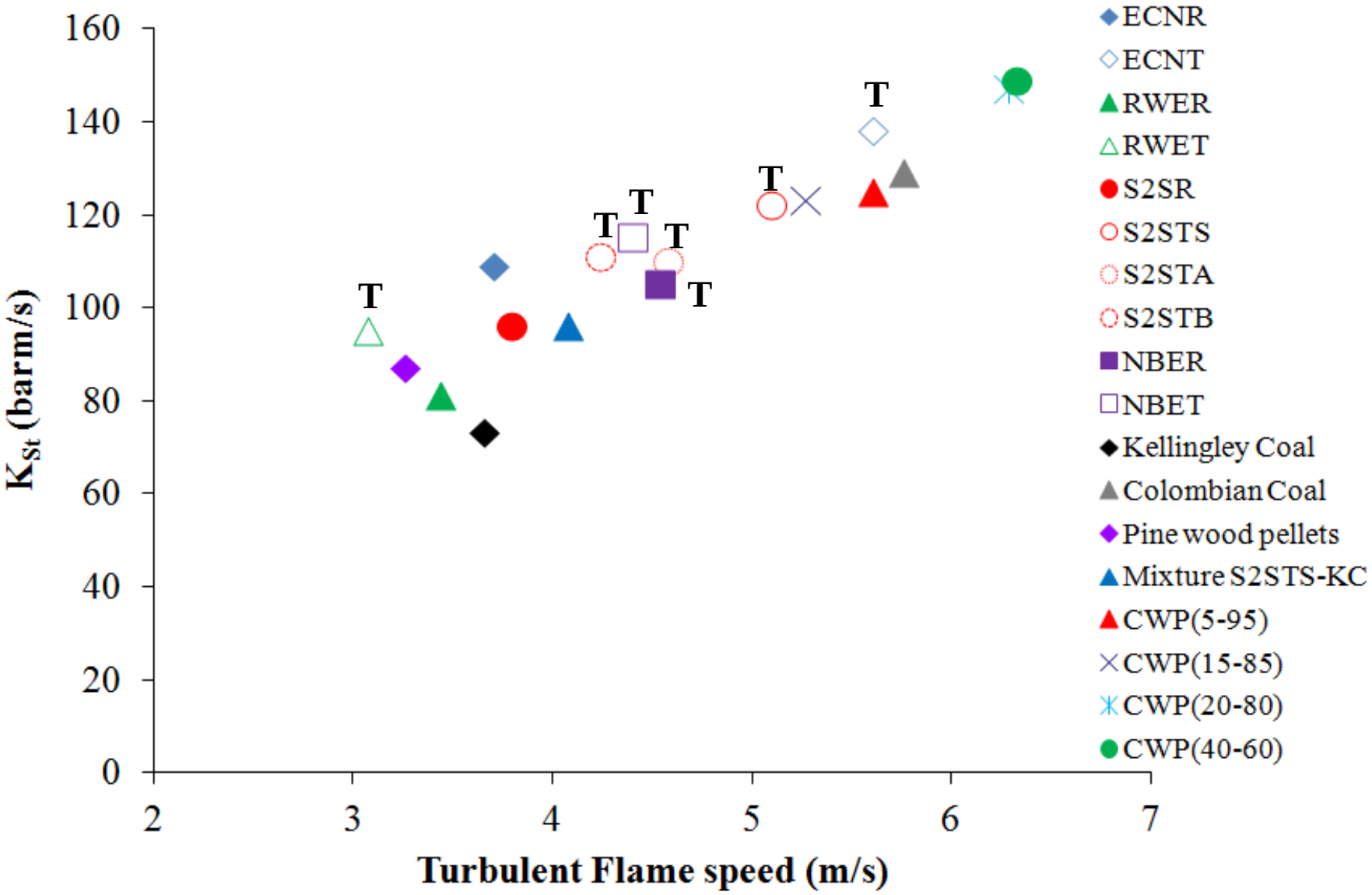
Summary Explosion characteristics

	K_{St} (barms^{-1})	P_{max}/P_i	S_{FT} Turbulent Flame Speed (m/s)	S_L Laminar burning velocity (m/s)
ECNR	109	9.0	3.7	0.10
ECNT	138	9.1	5.6	0.15
RWER	81	8.8	3.4	0.10
RWET	95	8.9	3.6	0.10
NBER	105	9.0	4.5	0.12
NBET	115	8.8	4.4	0.12
S2SR	96	9.0	3.8	0.10
S2STA	110	9.1	4.6	0.12
S2STB	111	8.7	4.2	0.12
S2STS	122	9.0	5.1	0.15
Kellingley Coal	78	8.2	3.7	0.12
MIXTURE (by mass)				
Kellingley Coal+TM8S (50/50)	96	8.4	4.1	0.12

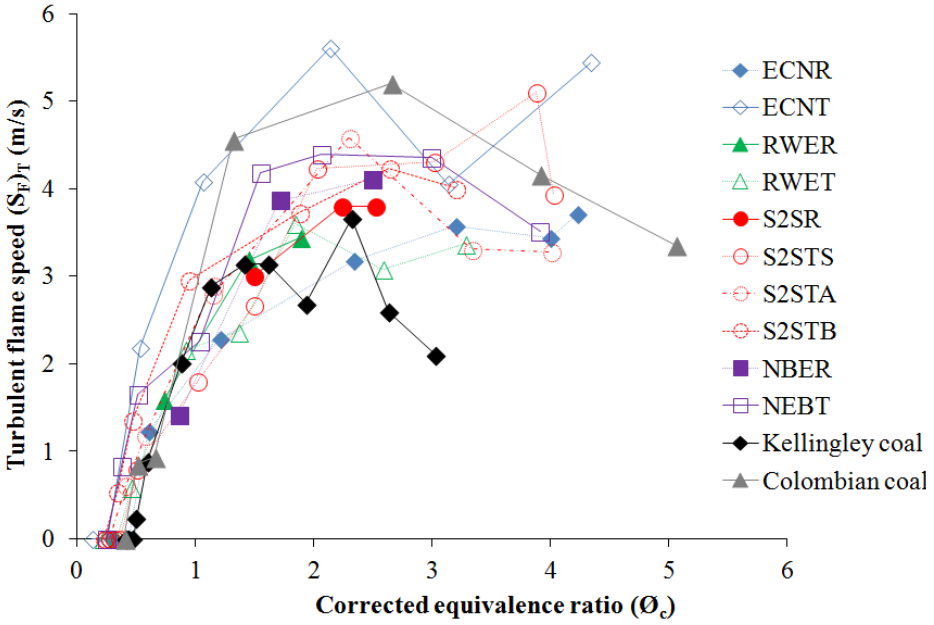
Summary explosion characteristics

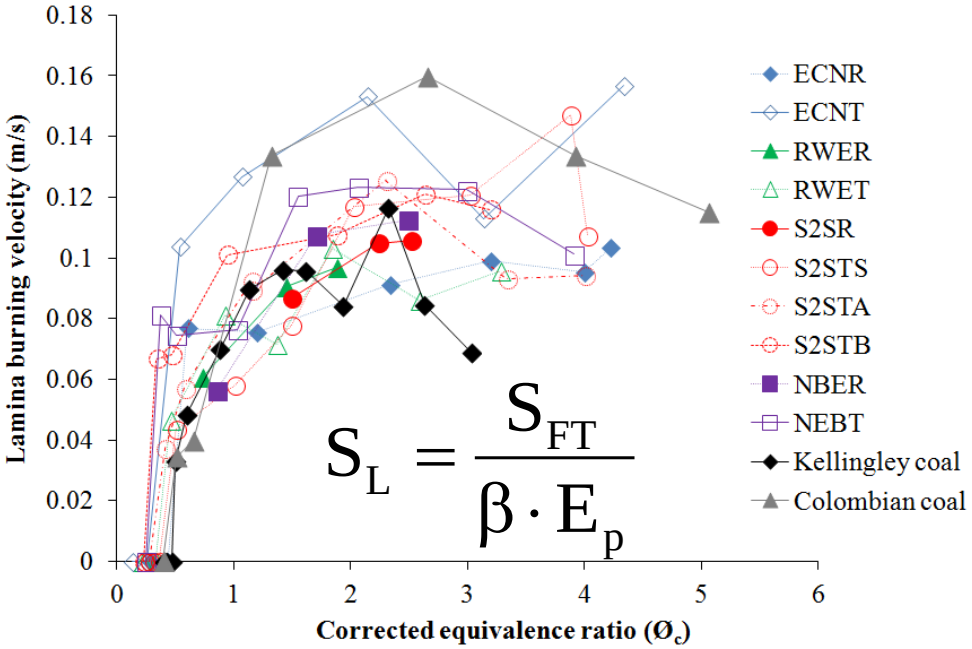
	K_{St} (barm/s)	P_{max}/P_i	S_{FT} Turbulent Flame Speed (m/s)	S_L Laminar burning velocity (m/s)
Colombian Coal	129	8.5	5.2	0.16
Pine wood pellets	87	8.7	3.4	0.1
MIXTURES (by mass)				
Mixture A (5% PWP, 95% CCB)	125	8.6	5.6	0.17
Mixture B (15% PWP, 85% CCB)	123	8.6	5.3	0.16
Mixture C (20% PWP, 80% CCB)	147	8.7	6.3	0.18
Mixture D (40% PWP, 60% CCB)	149	8.6	6.3	0.18

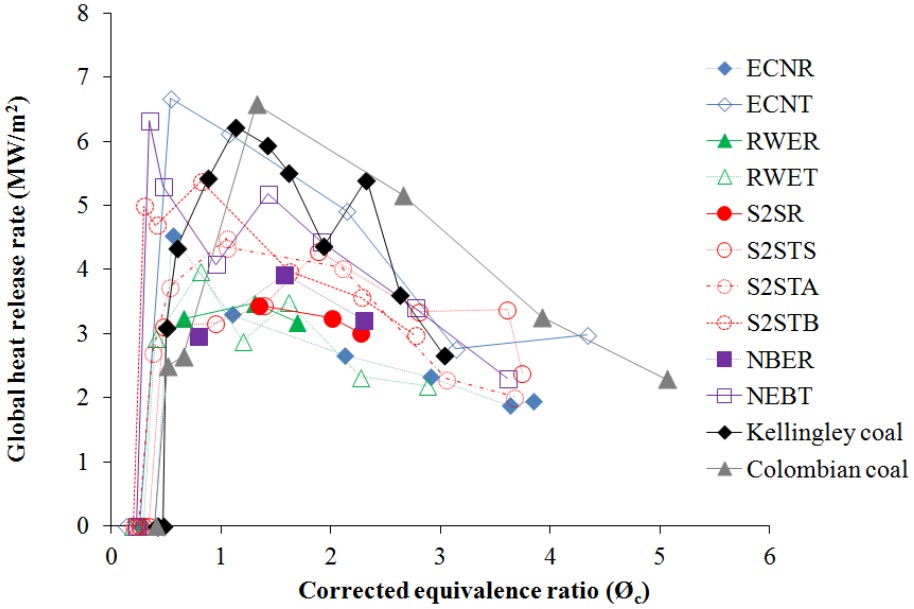
Correlation of Flame speeds and K_{St}



Flame speeds, burning velocity and HRR







Conclusions

- Torrefied biomass showed higher K_{St} and P_{max} than raw parent biomass
- Occasional synergistic effect in mixtures
- Linear relationship S_F and K_{St}
- Factors affecting reactivity related to rate of reaction (particle size, surface area)

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