Biomass and Recycled Wood Utilisation in the PACT CTF:

Experimental Characterisation and Comparison of Emissions

Presented by: M. Pourkashanian

K.N. Finney, J. Szuhanszki, K. Milkowski, M. Akram

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Biomass and Emission

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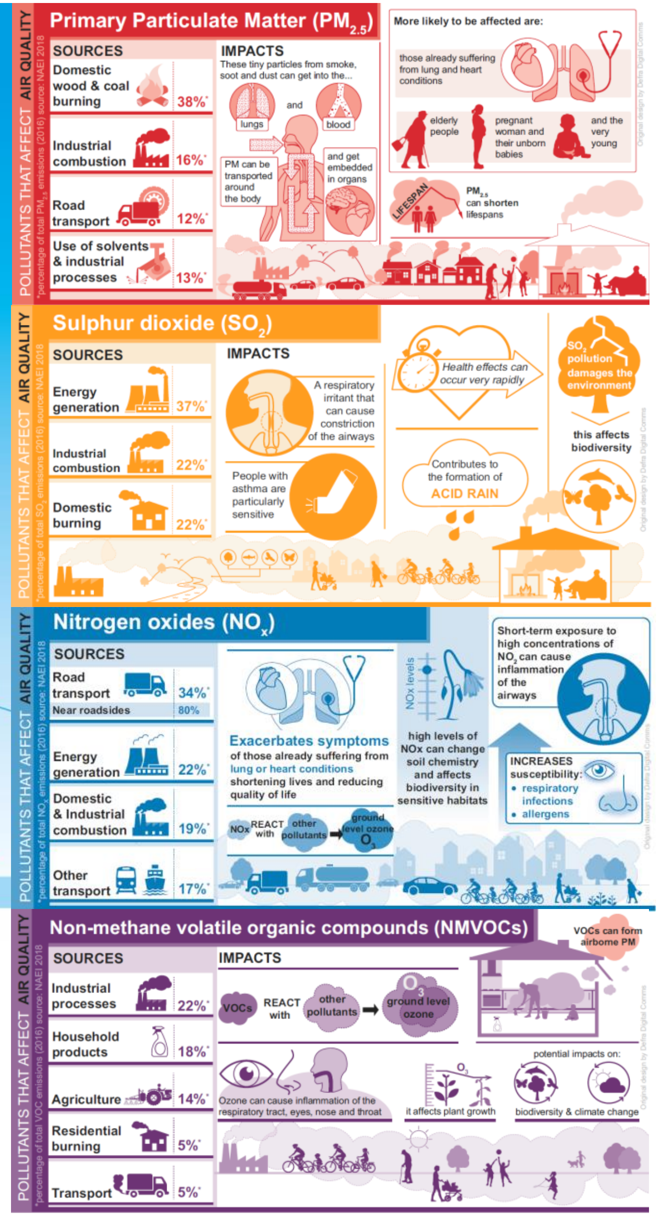
- Directly measured emissions
- Data and our understanding of the activities that produce air pollution



- **Particulate matter (PM)**
  - **impacts on the env.**
- **Open fires and wood-burning stoves as additional form of heating for many households in both urban and rural areas;**
- **Growth of biomass boilers for home heating.**
  - **an impact on our air quality**
  - **single largest contributor to our national PM emissions at 38%.**
- **Industrial combustion (16%) and road transport (12%).**

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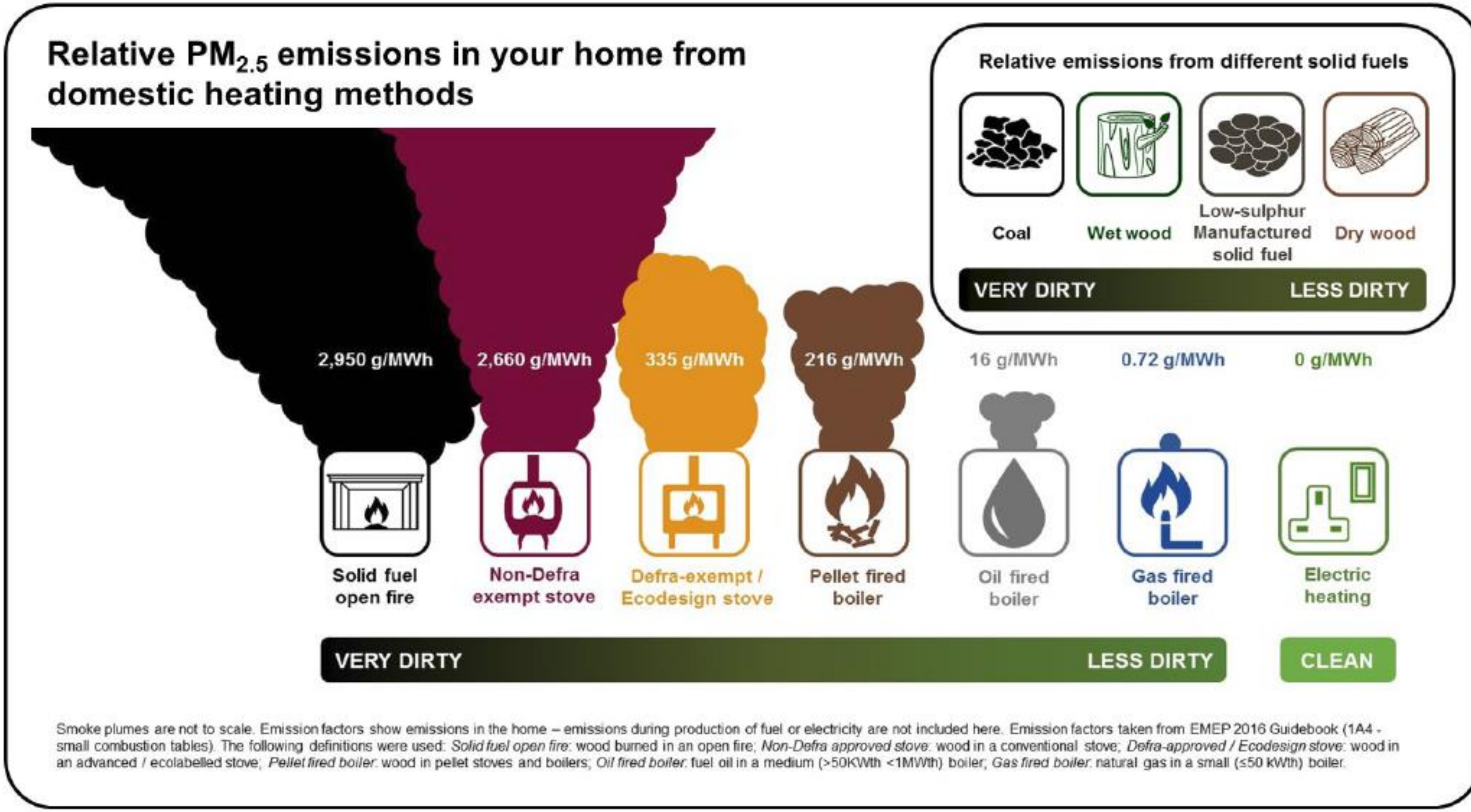
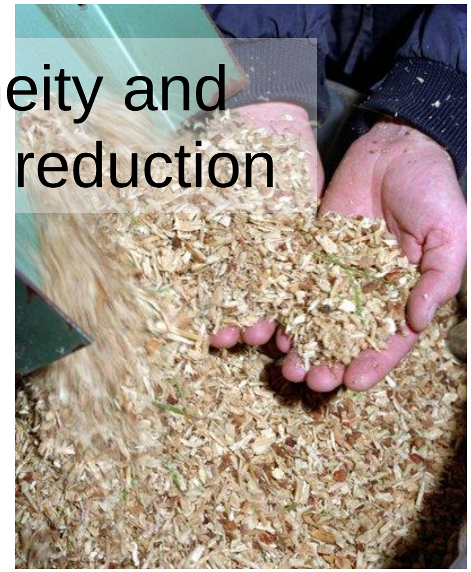
Reducing the impact of domestic burning



Challenges of biomass utilisation

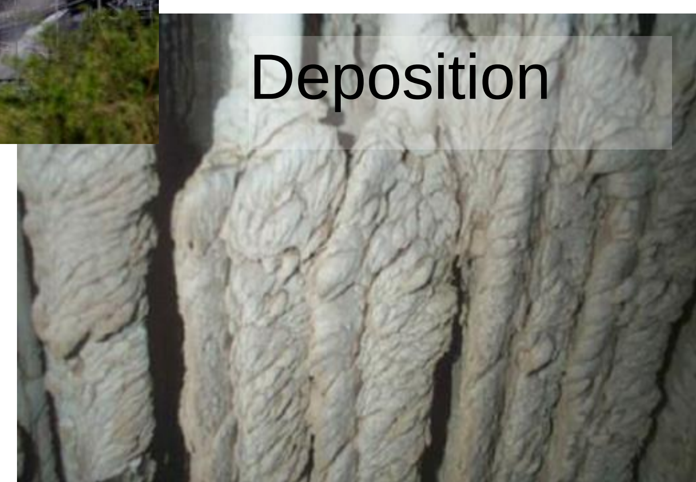
Mould during storage

Heterogeneity and particle size reduction



Fire and explosion risk

Deposition



Current Fuels Tested at PACT

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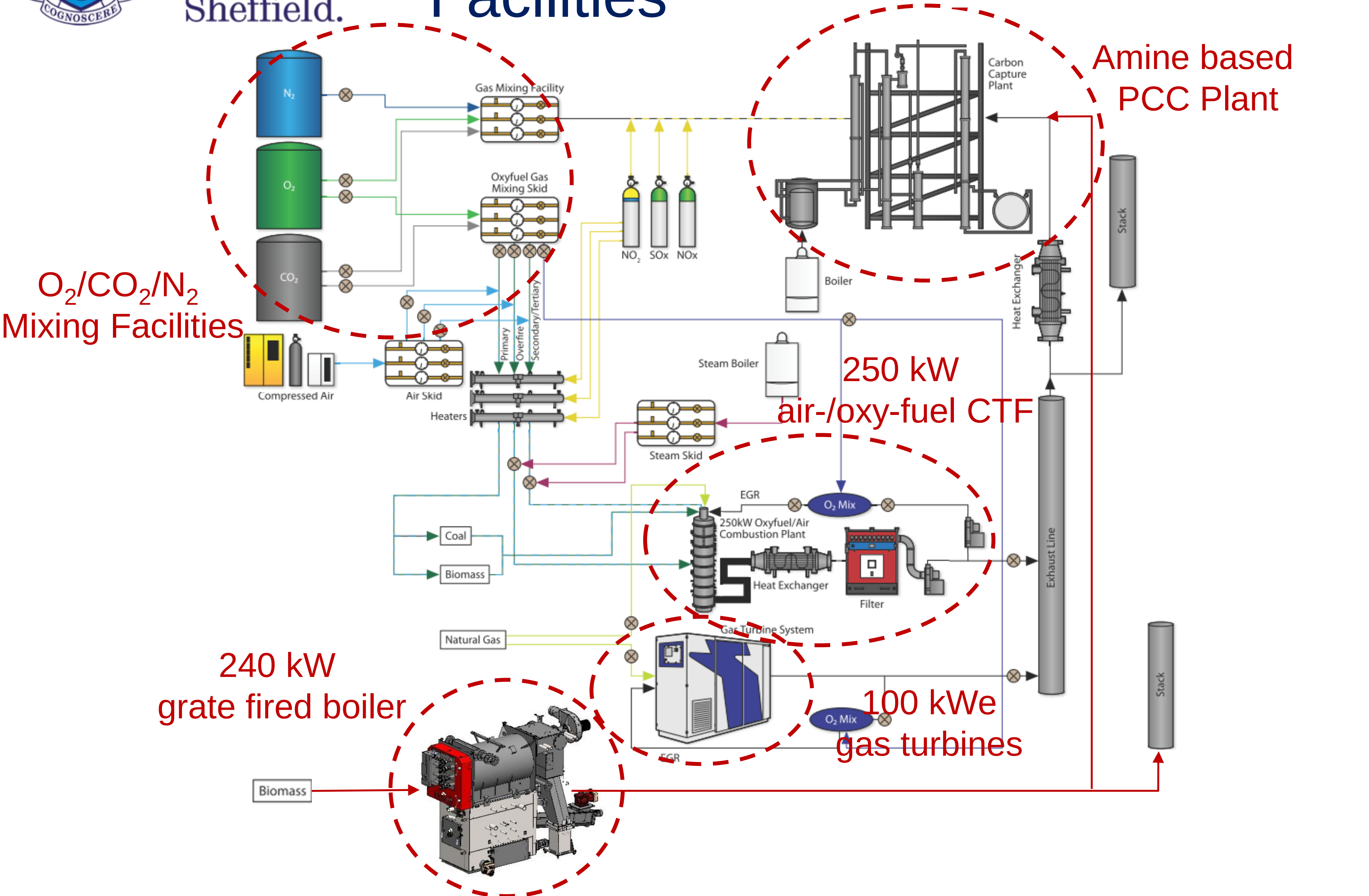
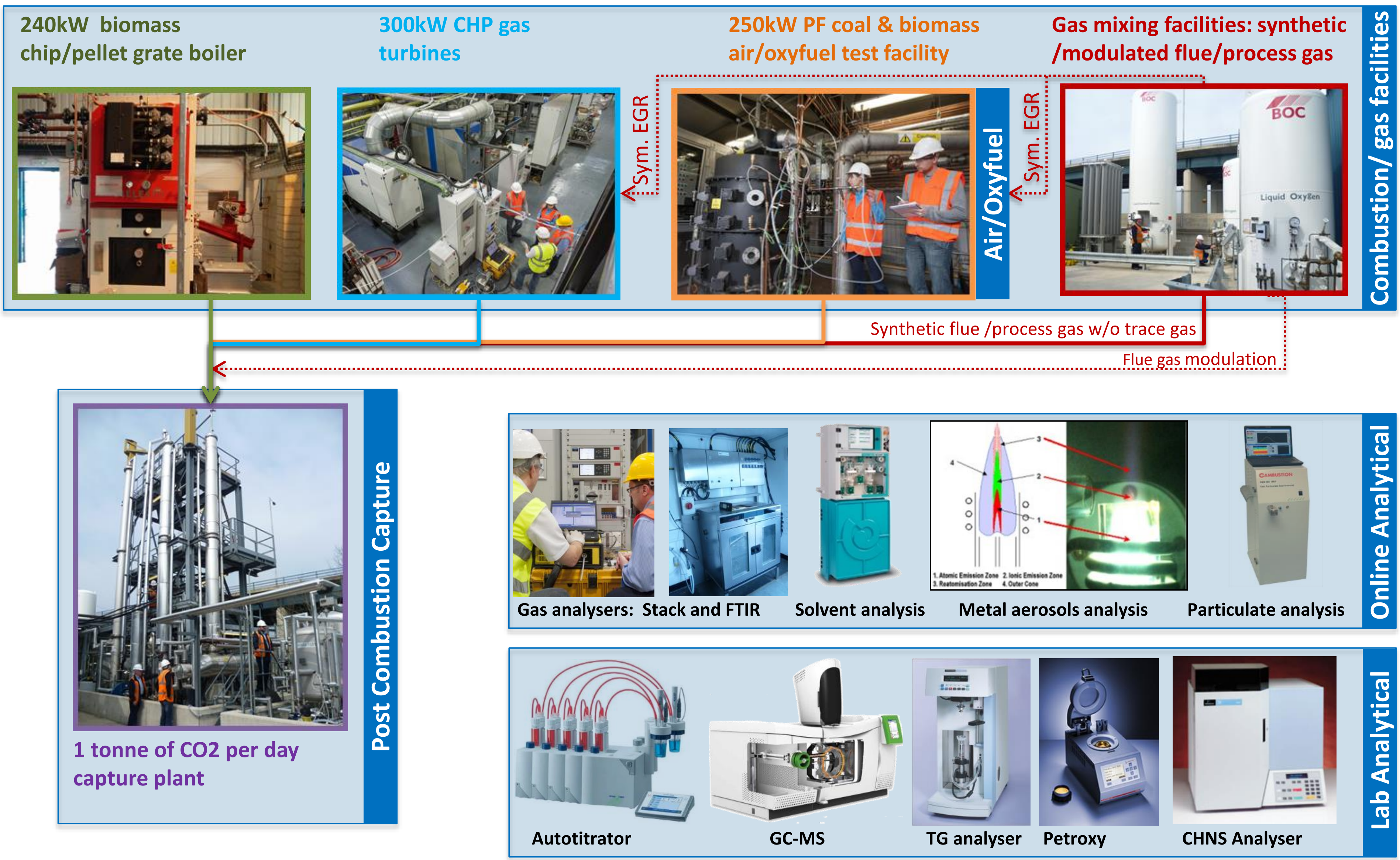
Virgin Wood (SCR Willow)

Grade A recycled wood

PACT Core Facilities

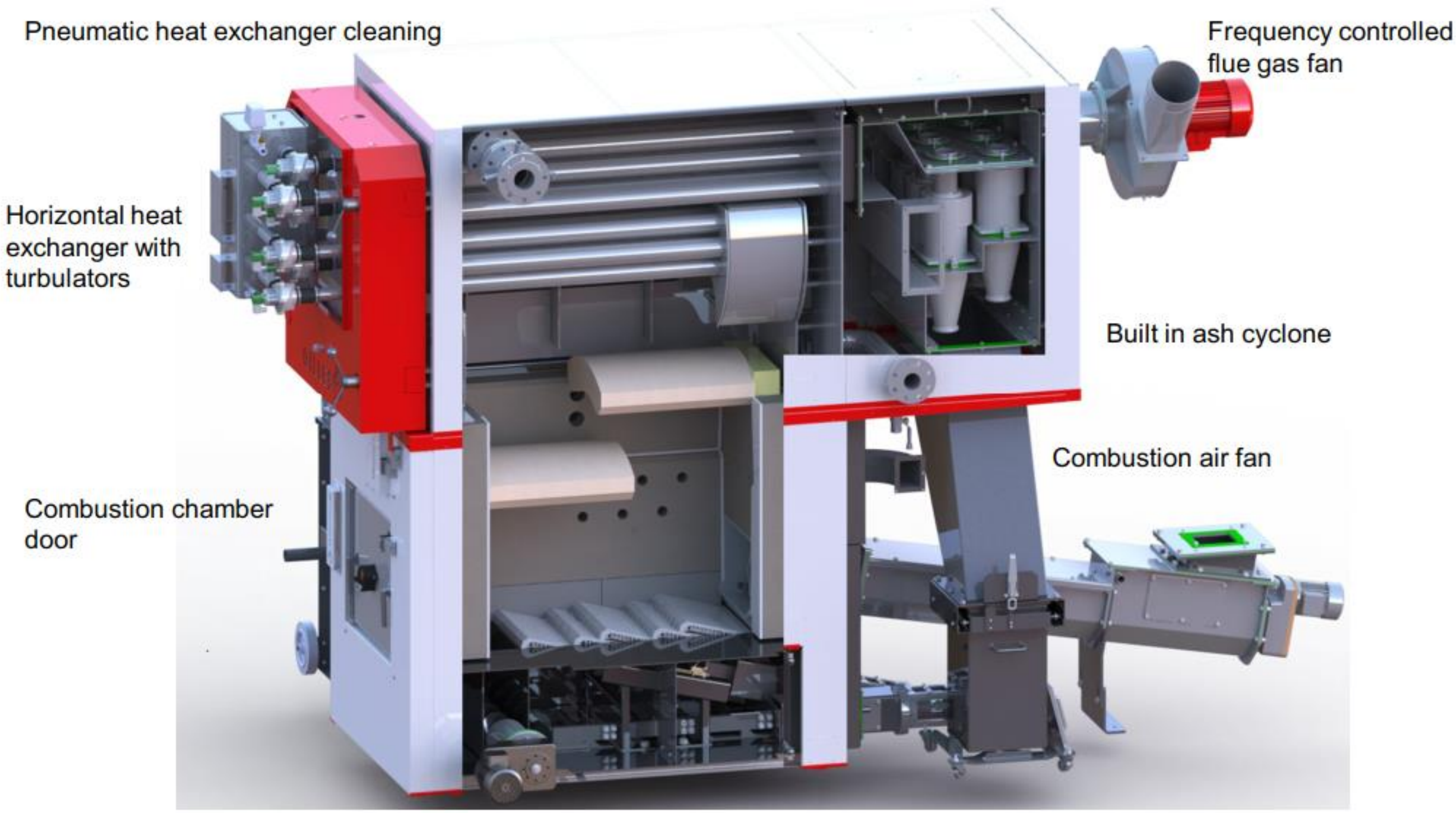


Integrated PACT facilities



Grate fired boiler

- Latest addition to the PACT rigs the 240 kW grate fired boiler
- Integration to post combustion capture plant (PCCP) for solvent research



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Current Fuels Tested at PACT

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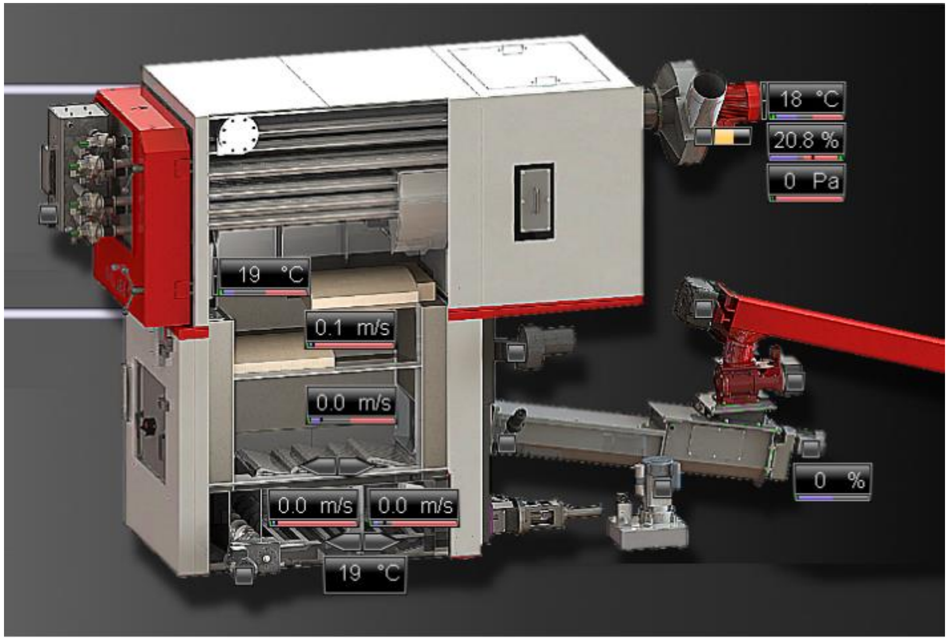
Proximate & Ultimate analysis (wt%, ar)		
	Willow	**Grade A**
Moisture	12.0	17.1
Volatiles	73.4	71.3
Fixed Carbon	13.9	11.3
Ash	0.70	0.3
C	43.63	41.81
H	5.06	4.80
N	0.32	0.12
S	0.04	0.02
Cl	0.02	0.03
O	38.23	35.82
GCV (MJ/kg)	17.36	16.86
NCV (MJ/kg)	15.96	15.39

Ash Fusion temperatures (°C)		
	Willow	**Grade A**
Initial deformation	>1500	1490
Softening	>1500	1500
Hemispherical	>1500	>1500
Flow	>1500	>1500

Key data sets

Combustion characterization

- In-furnace temperatures & gas compositions
- Deposition and corrosion probing
- Burnout & metal partitioning between bottom and fly ash streams
- Flue gas composition, metal aerosol and submicron particulates emissions



Capture Plant performance:
(future research)

- Flue gas and solvent flow rates
- Lean and rich loading
- Absorber temperatures and pressures
- Boiler duty
- CO_2 capture rate
- Emissions (metal aerosols, submicron particles, ammonia)

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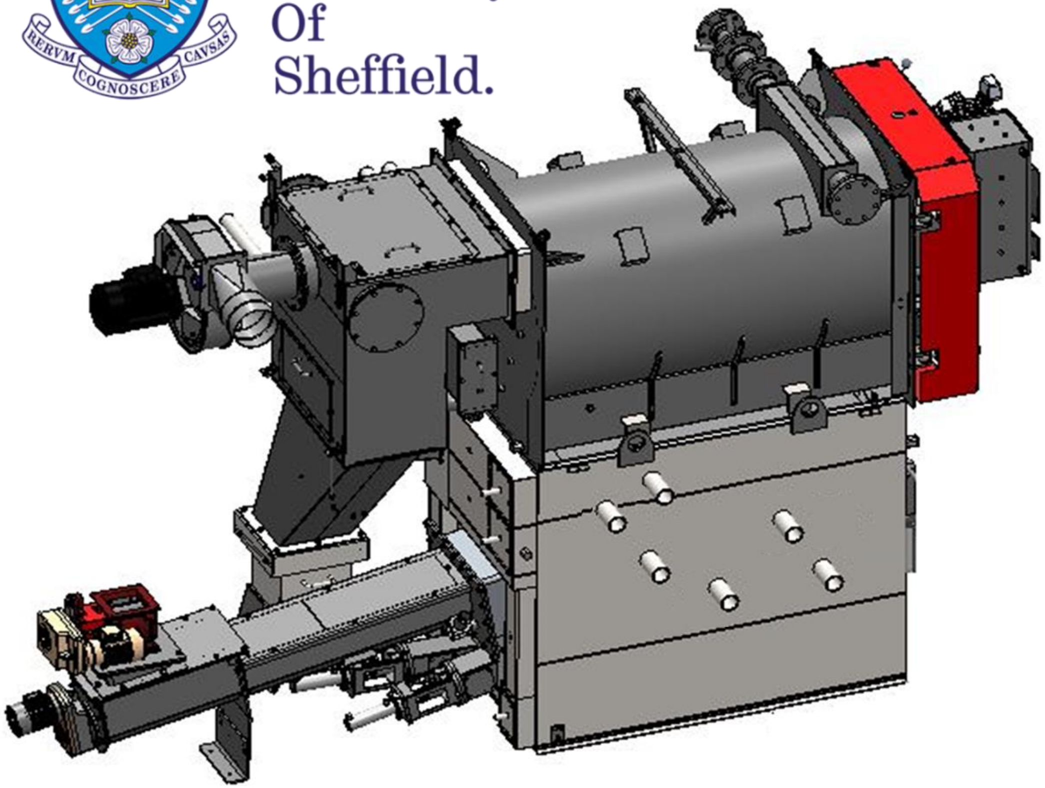
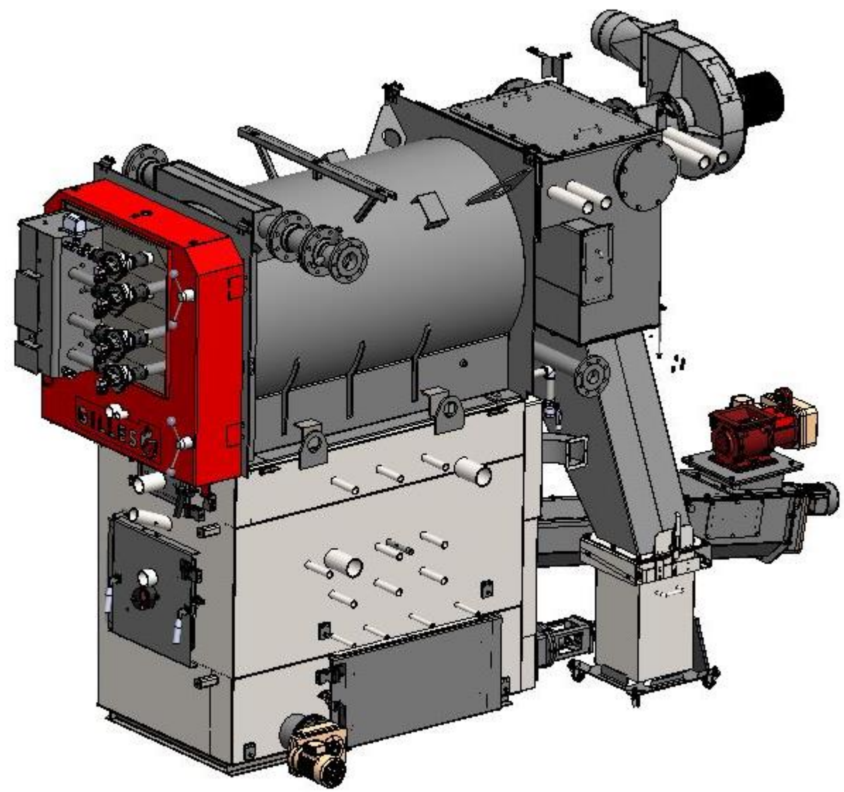


2” and 3” ports along boiler to enable comprehensive combustion characterisation



- 11 ports in the combustion chamber and overpass to the boiler (in-furnace temperature, gas composition, deposition, corrosion)
- 7 ports before and after the cyclones (flue gas composition, metals, particulate emissions)
- 16 fixed thermocouples

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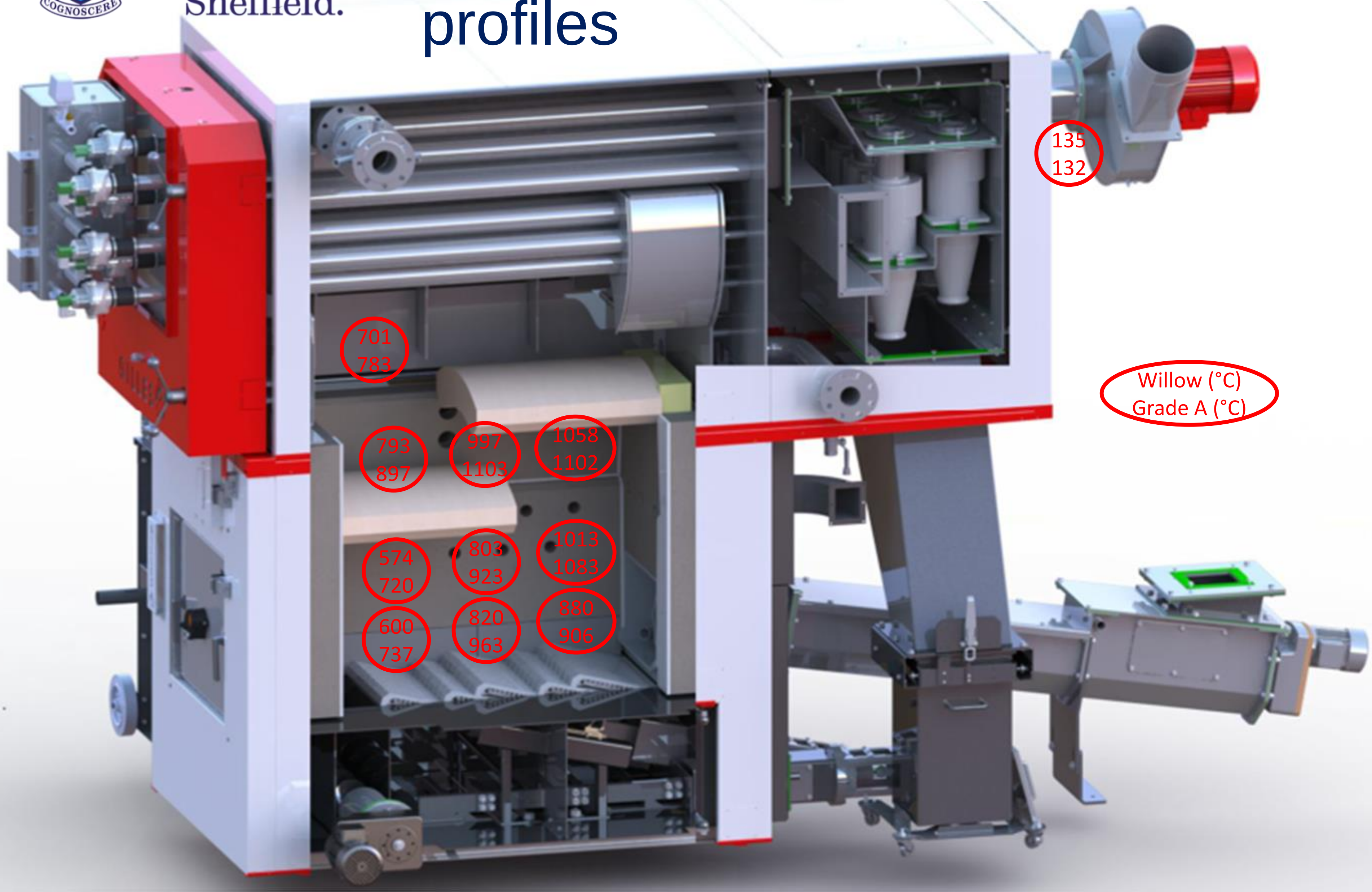
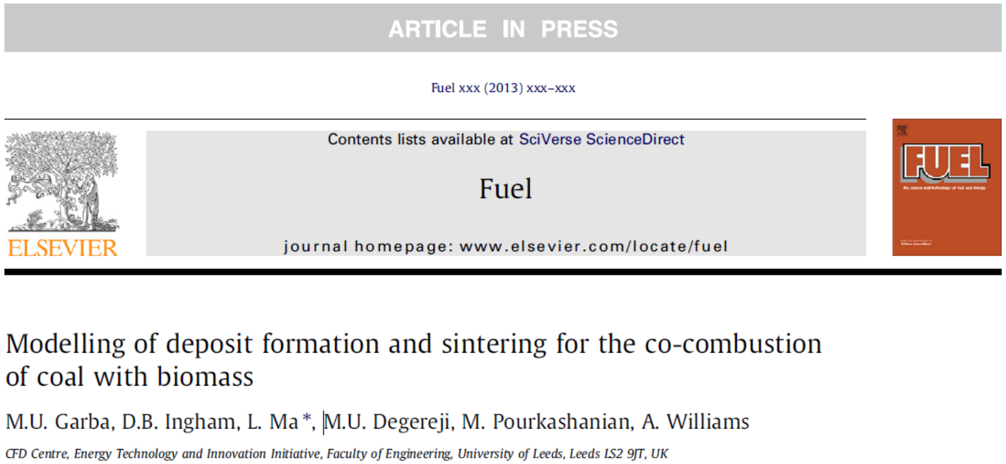
Temperature profiles



Deposition & Corrosion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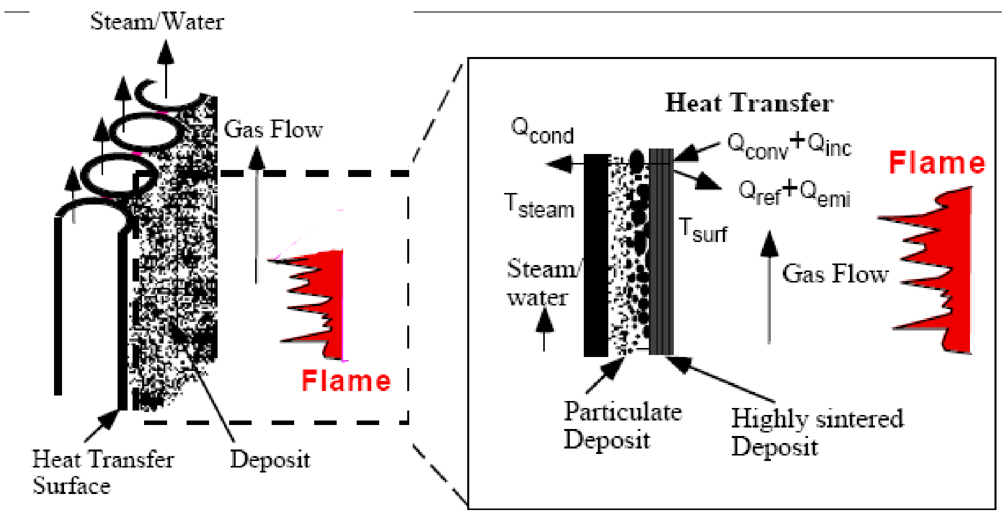
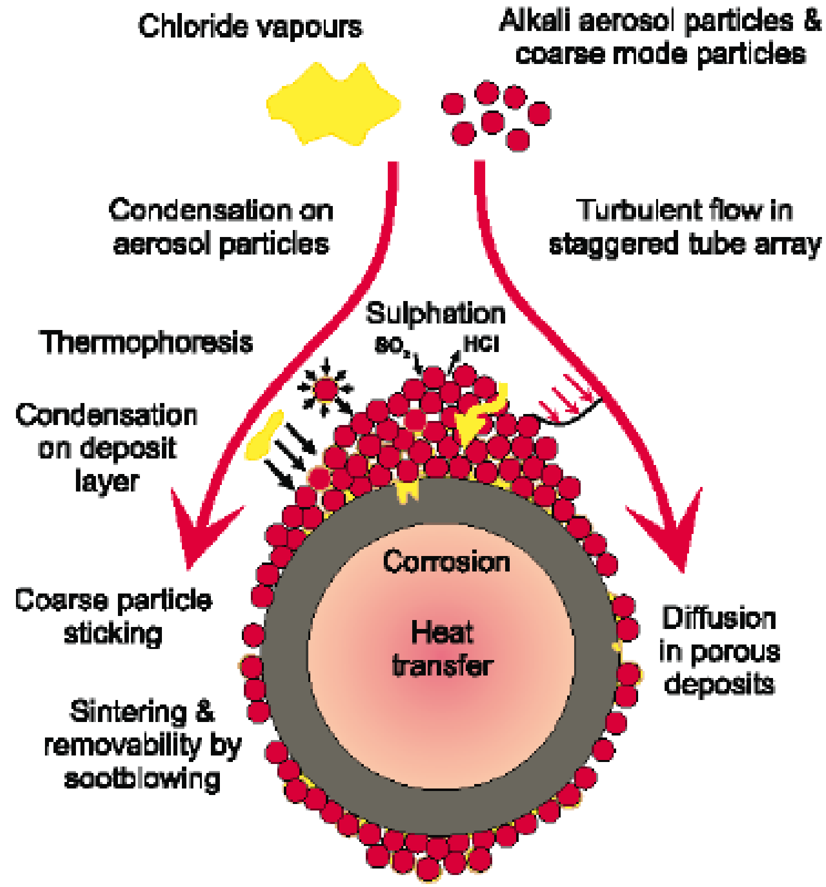
Modelling of deposit formation and sintering for the co-combustion of coal with biomass

M.U. Garba, D.B. Ingham, L. Ma *, M.U. Degereji, M. Pourkashanian, A. Williams

CFD Centre, Energy Technology and Innovation Initiative, Faculty of Engineering, University of Leeds, Leeds LS2 9JT, UK





- Deposition on boiler tubes impacts the overall boiler performance
- Reducing efficiencies and increasing maintenance requirement

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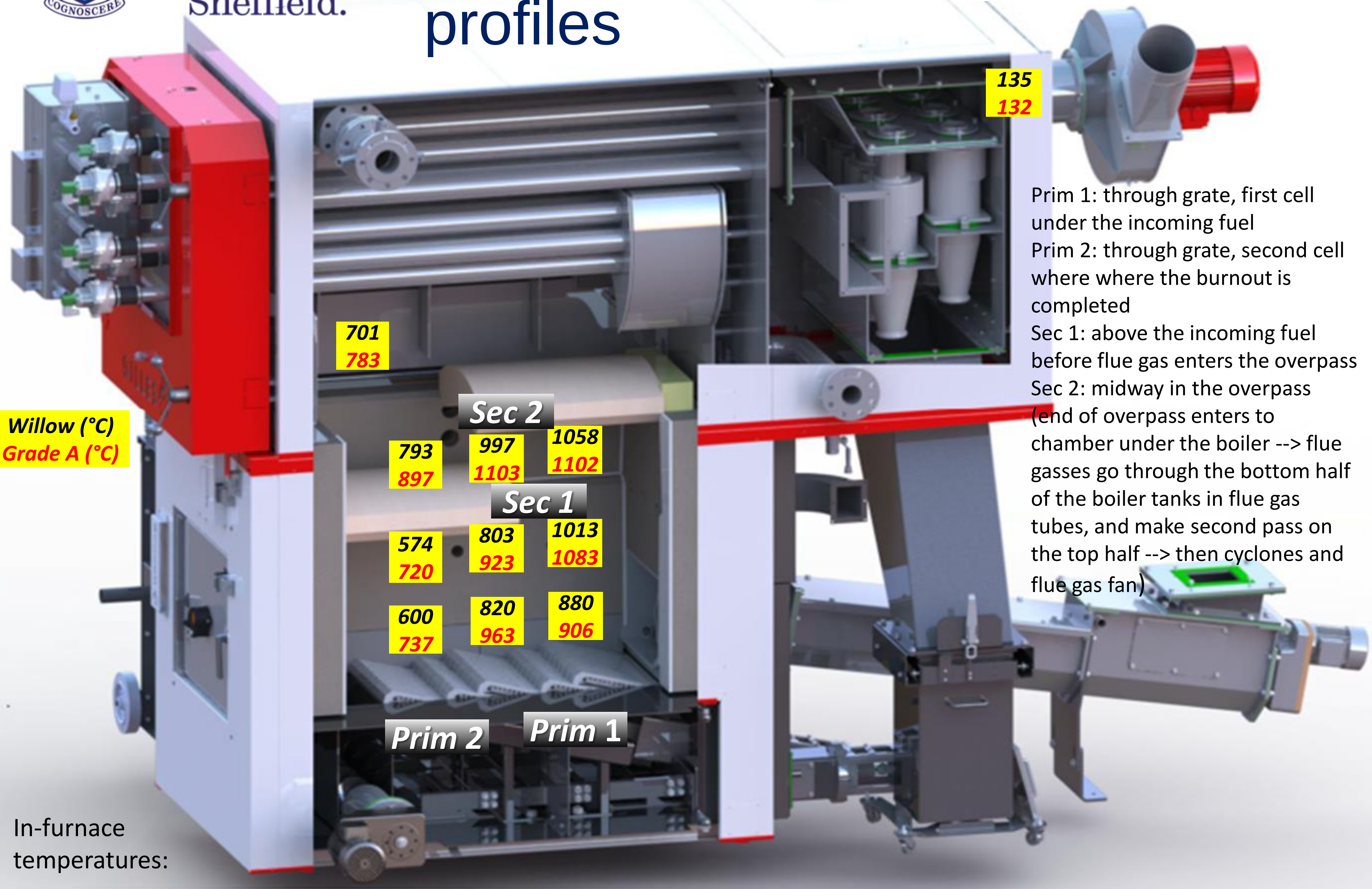
Temperature profiles



Prim 1: through grate, first cell under the incoming fuel
Prim 2: through grate, second cell where where the burnout is completed
Sec 1: above the incoming fuel before flue gas enters the overpass
Sec 2: midway in the overpass (end of overpass enters to chamber under the boiler --> flue gasses go through the bottom half of the boiler tanks in flue gas tubes, and make second pass on the top half --> then cyclones and flue gas fan)

In-furnace temperatures:

ICP-OES

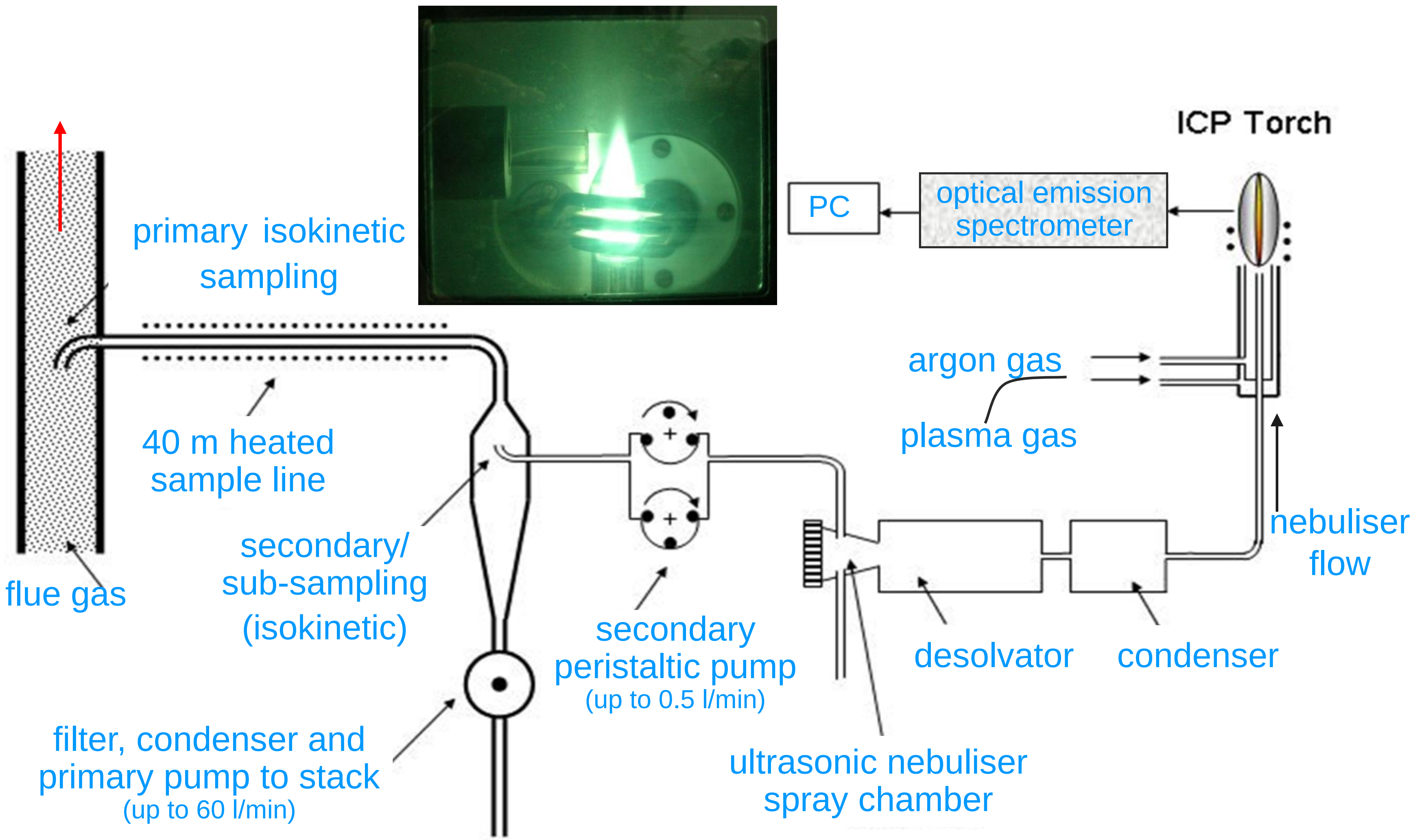
- The continuous metal emissions monitoring laboratory is a self-contained mini mobile laboratory to quantify levels of entrained metal aerosol emissions

- It houses a Spectro Ciros^{CCD} ICP-OES: an **i**nductively **c**oupled **p**lasma – **o**ptical **e**missions **s**pectrometer

- Emissions spectra of non-volatile/volatile elements:
  - ~ over 30 elements – Pb, Na, Zn, B, Al, Br, Ca, Cr, Sc, Cd, Fe, I, K, Li, Co, Cu, Ti, P, Si, Sn, Mg, Ni, Mn, Ag, Tl, S, V, Sb and Hg

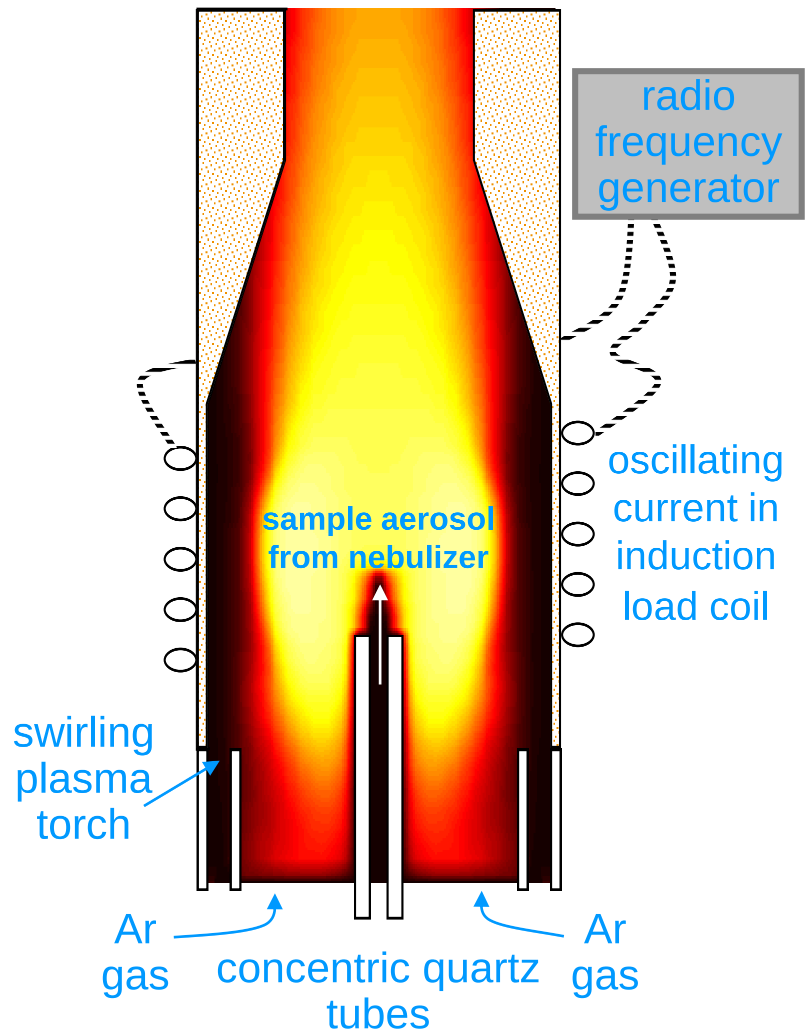
- Our tests will focus on elements that:
  - ~ cause operational issues (slagging, fouling, corrosion) **K and Na**
  - ~ are easily vaporised **Hg, Cd, Pb**
  - ~ are toxic (heavy metals) **Hg, V, Cr, Cd and Pb**

Sample system configuration



ICP Torch

- Custom-built, radial, demountable plasma torch
- Argon plasma heated to 6000K
- The plasma torch excites the sample to higher energy states. On relaxation, from these excited states, causes a release of photons. These photons have specific wavelengths directly corresponding to the transition in energy level, and it is this fingerprint wavelength that is used to identify the specific species present in the sample



ICP Data from Combustion Tests

Spectral Line	Lower Detection Limit (mg/m³)	Upper Line Range (mg/m³)	Correlation Coeff
Ag 328.068	0.00366	18.488	0.99996
Al 396.152	0.01450	16.500	1.00000
As 189.042	0.09120	18.488	0.99997
B 249.773	0.09440	16.394	0.99987
Ba 455.404	0.00031	18.488	0.99999
Ca 422.673	0.24900	16.500	1.00000
Cd 228.802	0.00306	18.488	0.99997
Co 228.616	0.00352	18.488	0.99996
Cr 267.716	0.00268	18.488	0.99996
Cu 324.754	0.00252	18.488	0.99994
Fe 259.941	0.00344	16.394	0.99999
Hg 253.652	0.10400	15.907	0.99949
K 766.491	0.07330	16.500	0.99993
Li 670.780	0.00192	18.488	0.99996
Mg 279.553	0.00114	16.394	0.99996
Mg 285.213	0.00183	16.394	0.99999
Mn 257.611	0.00052	16.394	0.99998
Mo 202.030	0.01060	16.394	0.99999
Na 589.592	0.03330	18.488	0.99996
Ni 231.604	0.01030	18.488	0.99995
Ni 227.021	0.01830	18.488	0.99996
Pb 220.353	0.05960	18.488	0.99999
Pb 261.418	0.01770	16.394	0.99997
Sb 206.833	0.05810	18.488	0.99999
Tl 190.864	0.13000	16.394	0.99987
V 292.464	0.00280	16.394	0.99996
Zn 213.856	0.00536	18.488	0.99994

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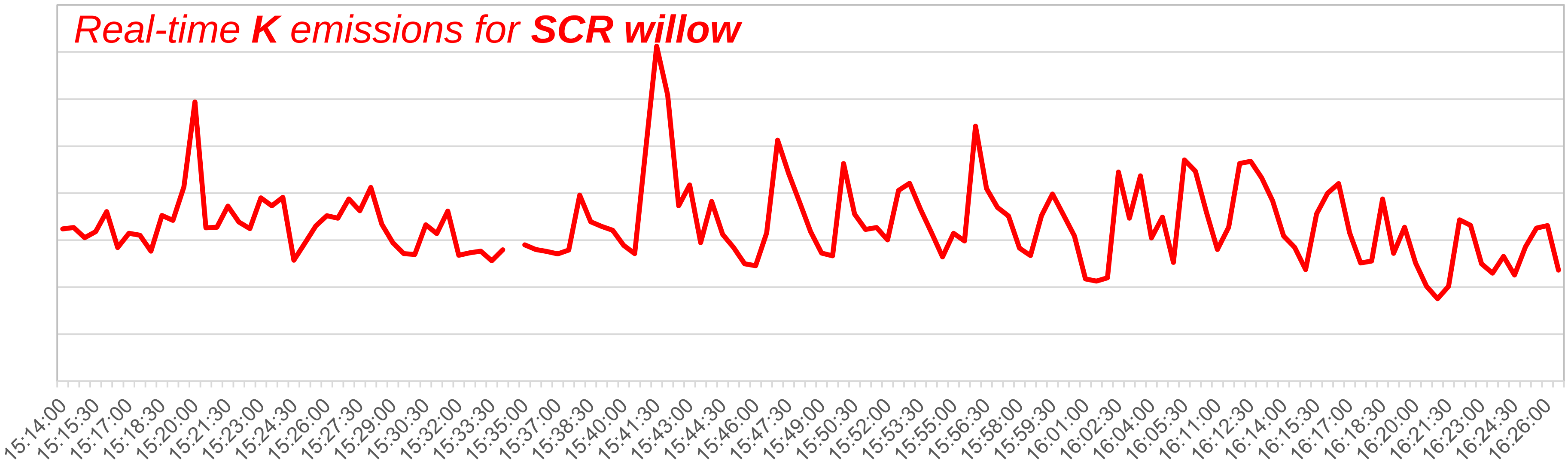
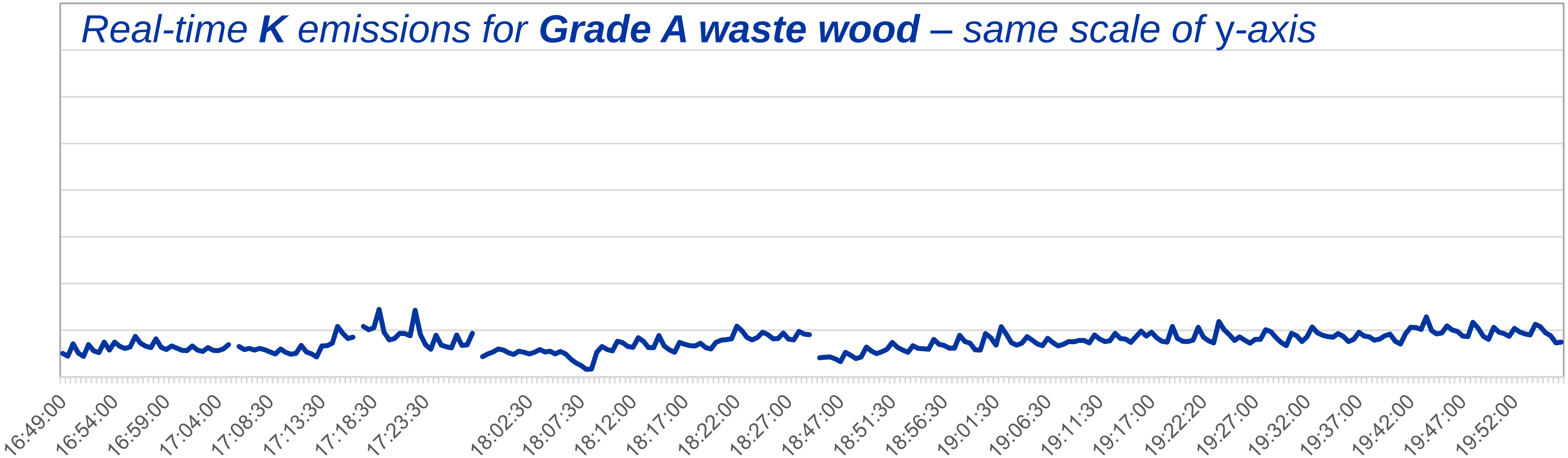
ICP Data from Combustion Tests





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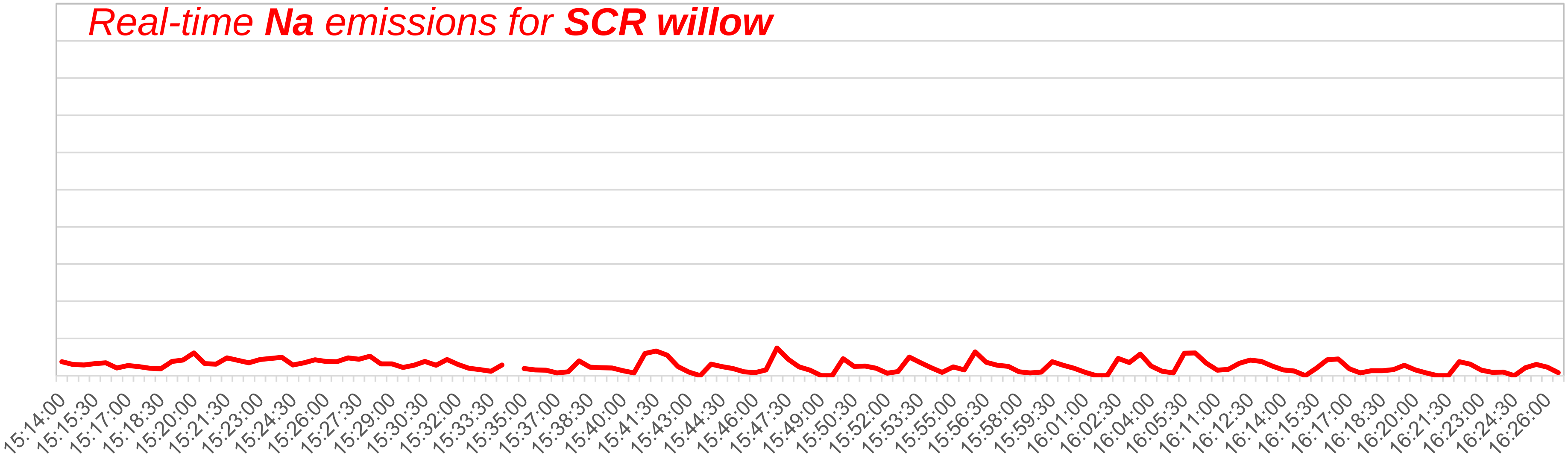

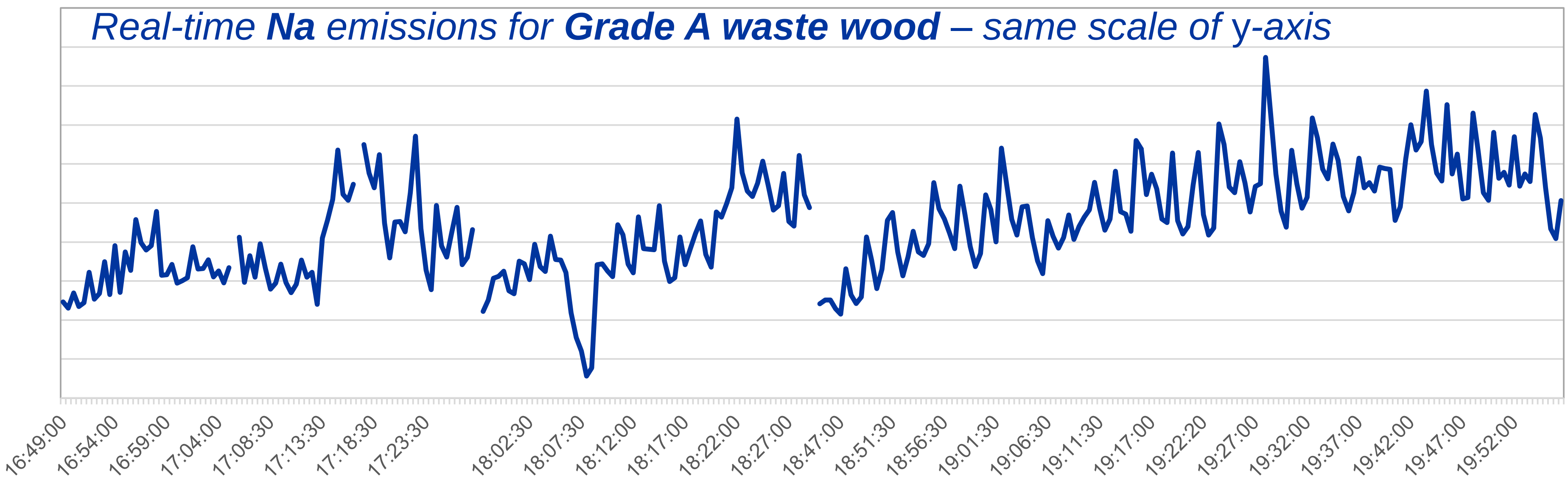

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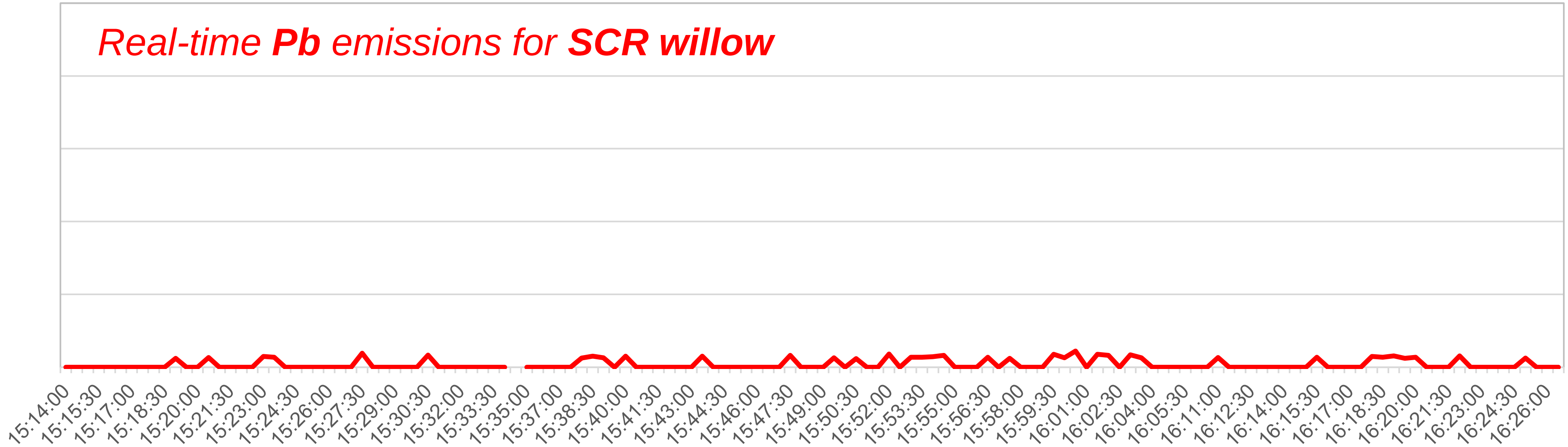

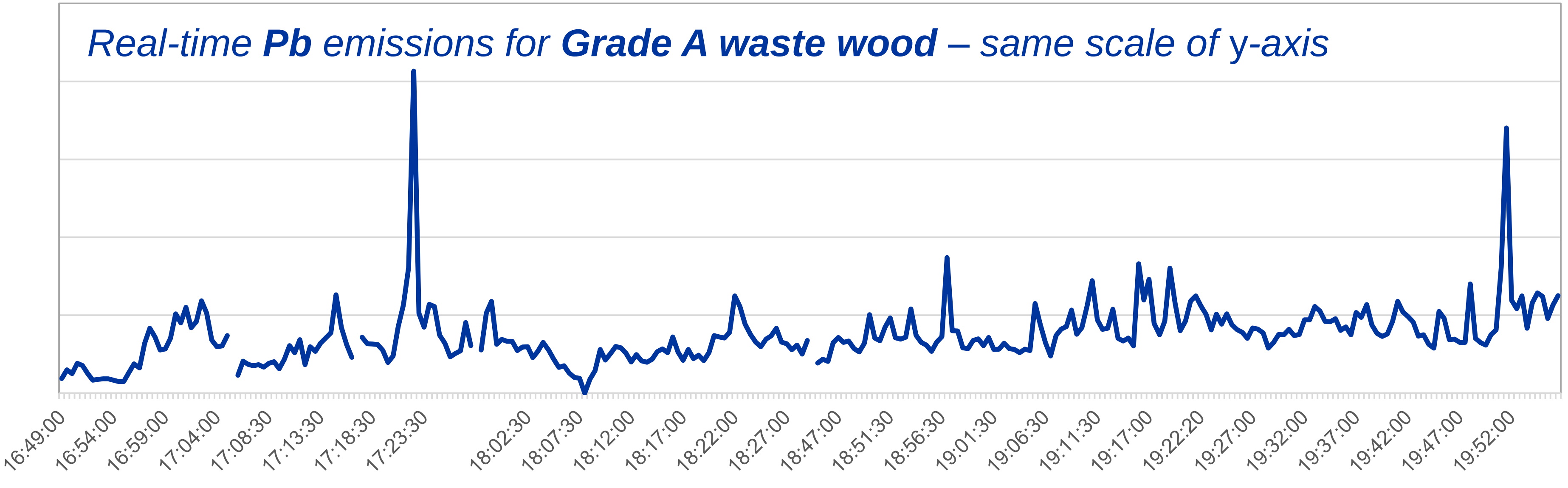

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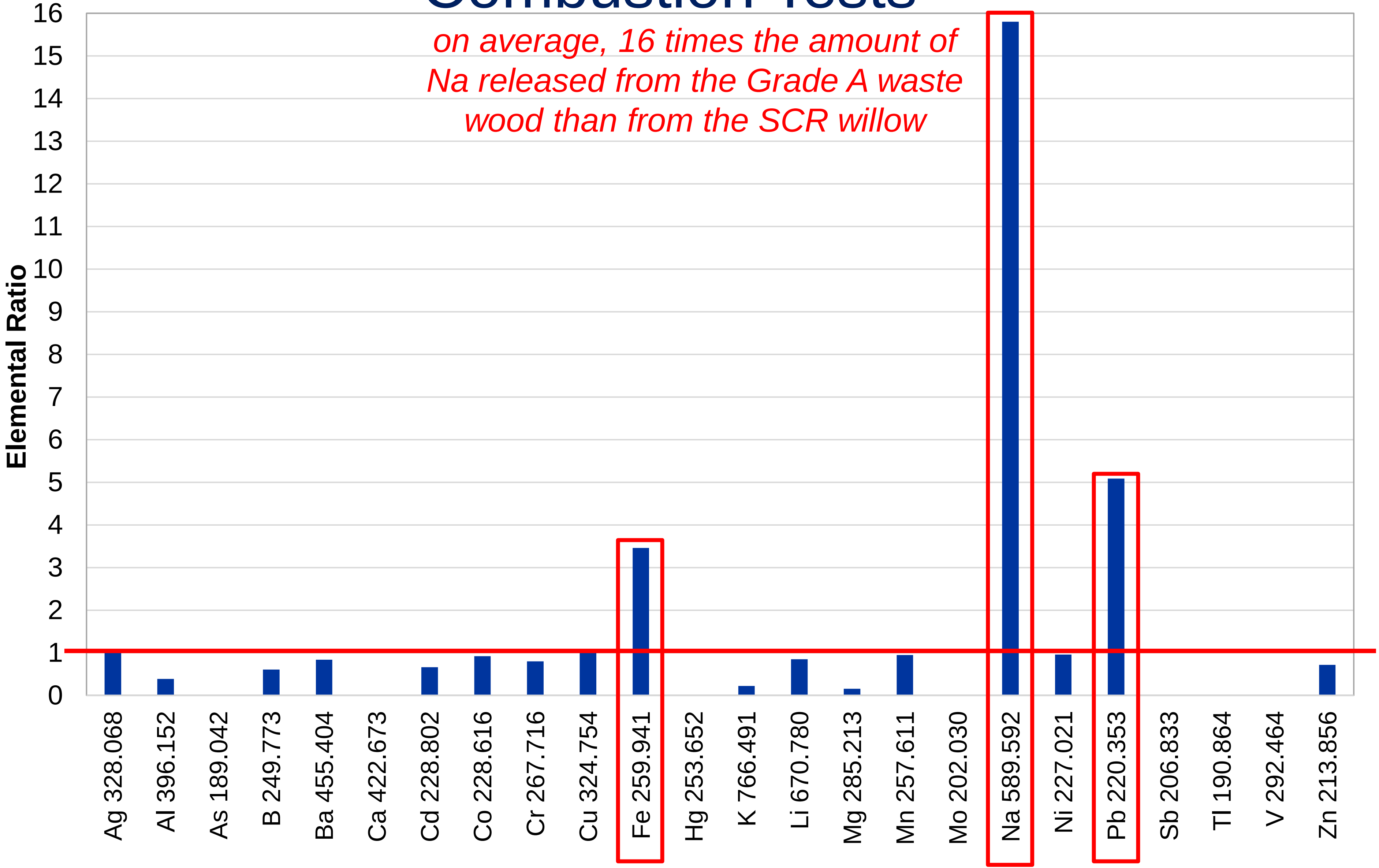
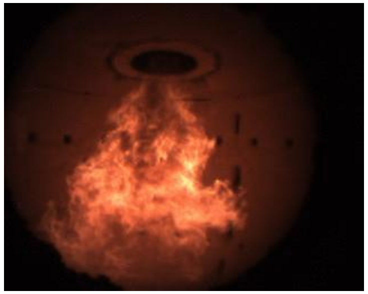
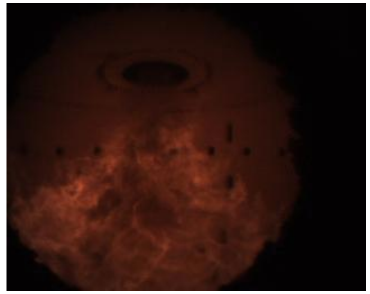


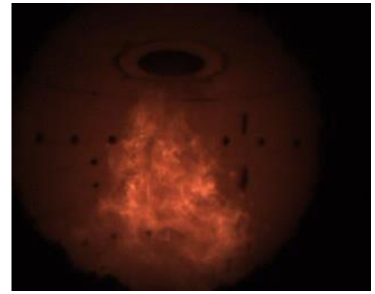
BECCS: fuel and oxidizer switching

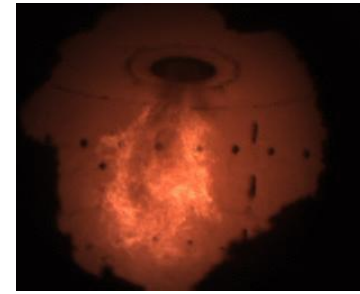
Experimental calculation of the oscillation frequency - BIOMASS

Original flame imaging

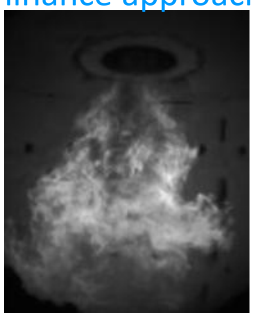

Air


Oxy24


Oxy27


Oxy30

Luminance approach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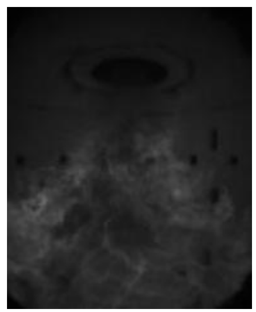
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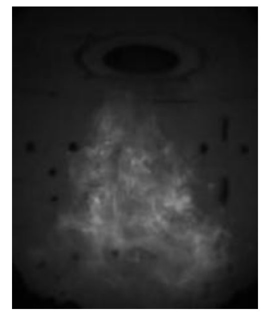
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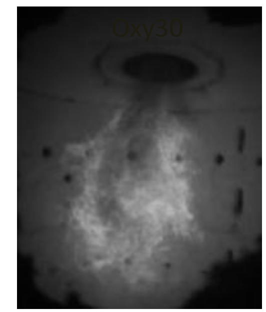
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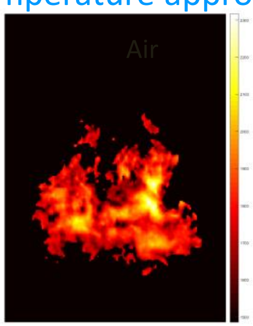
Temperature approach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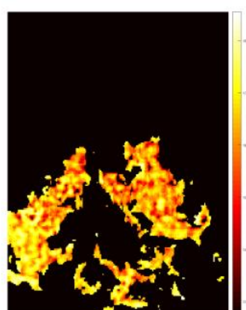
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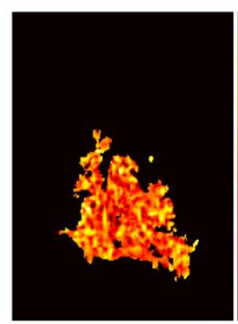
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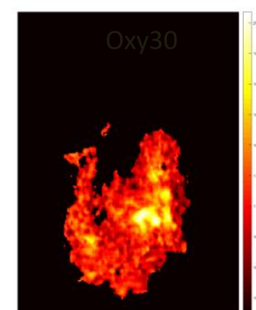
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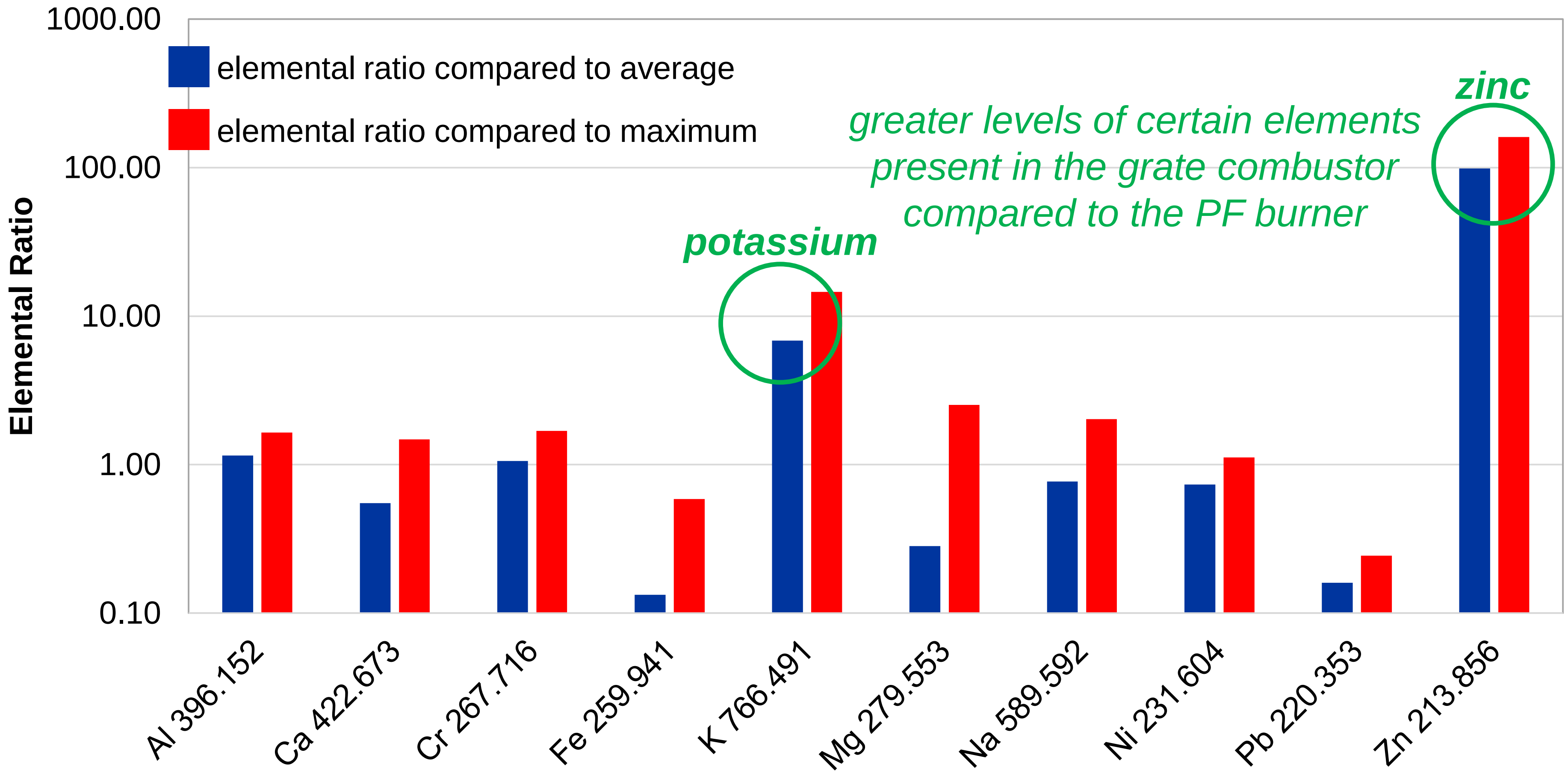
ICP Data from Combustion Tests

- Comparison of SCR willow combustion in the grate boiler to white wood combustion in a PF burner – elemental ratios



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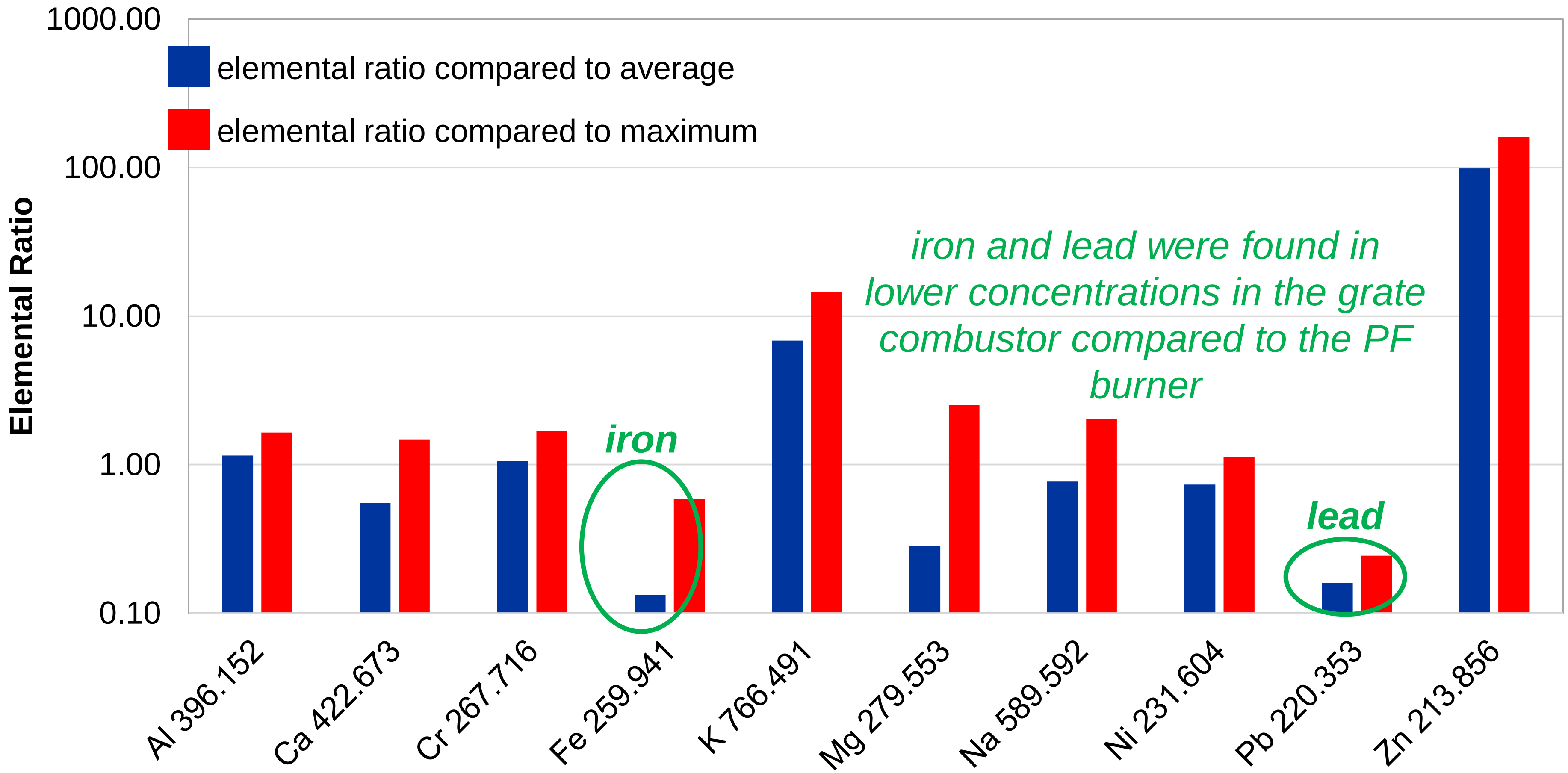
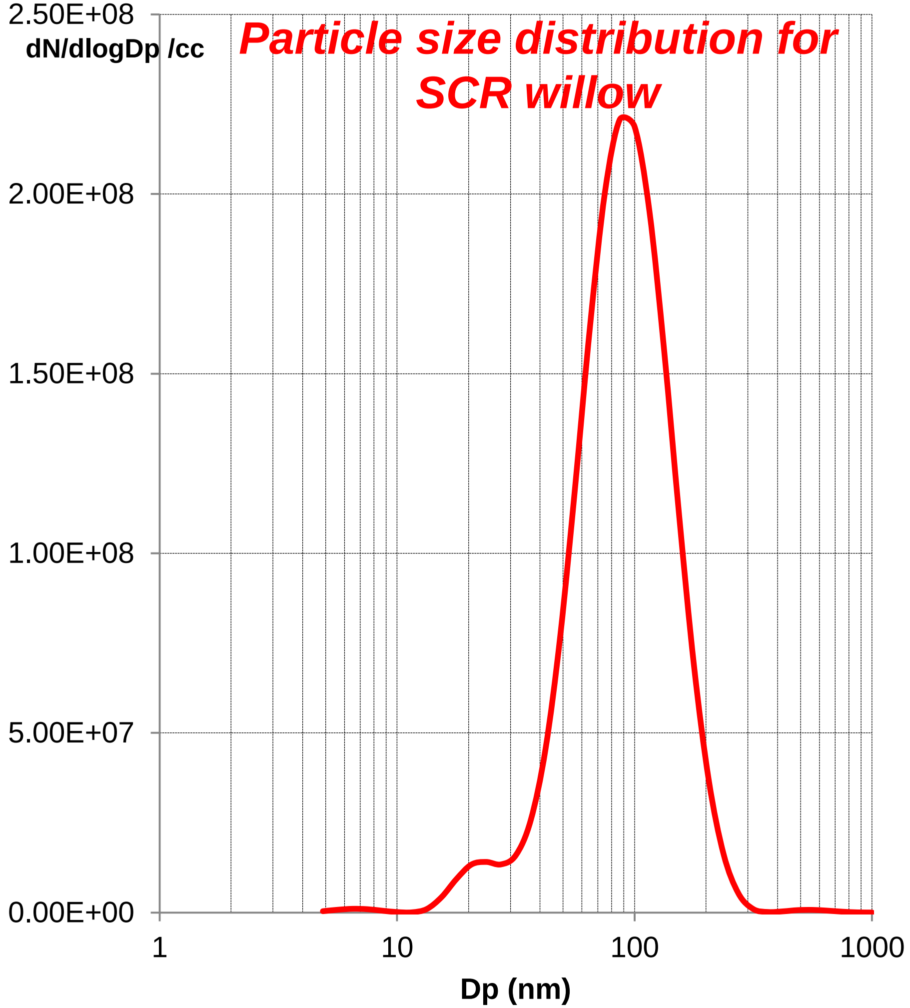
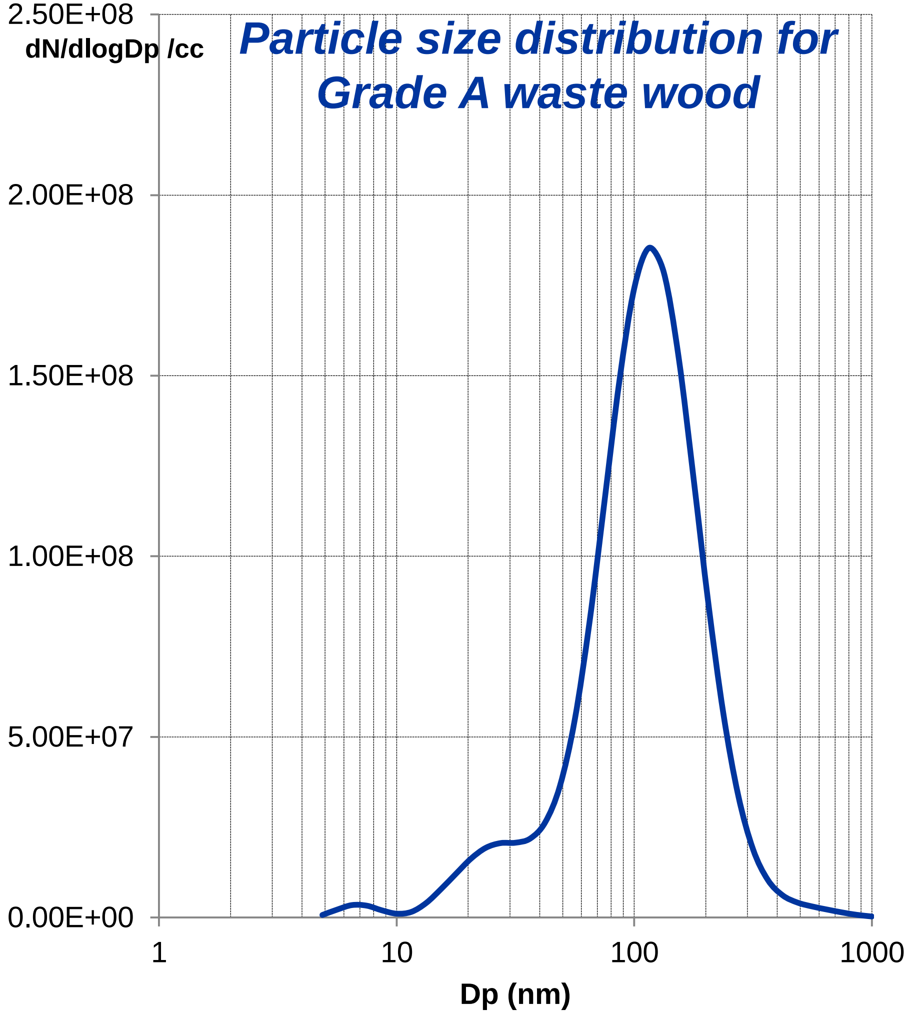


DMS data – submicron particle size distribution





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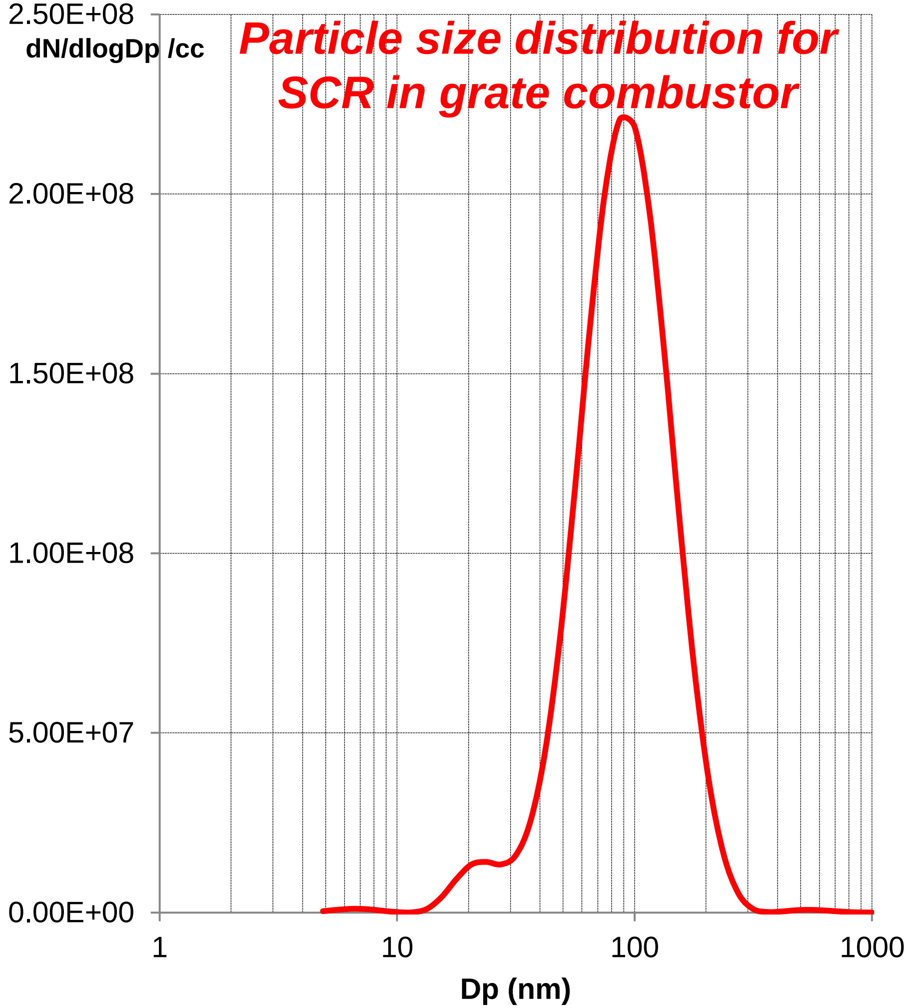

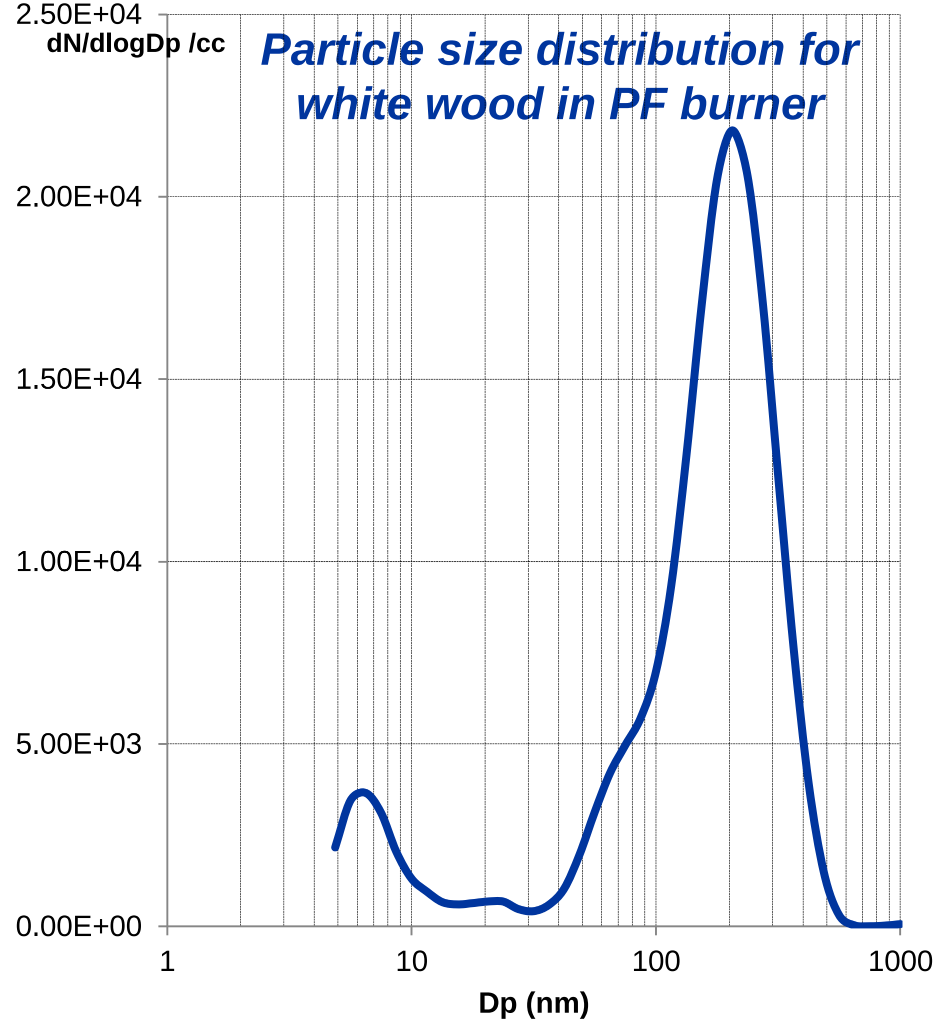

DMS data – submicron particle size summary

	Total Particle Concentration (N/cc)	Geometric Mean Diameter (nm)	Peak Size Concentration
SCR willow in grate combustor	107,637,062	86.5	peak 1: 20-30 nm peak 2: 86 nm
Grade A waste wood in grate combustor	100, 424,977	89	peak 1: 31 nm peak 2: 115 nm
air-fired white wood in PF burner	12,065	106.5	peak 1: 6-7 nm peak 2: 205 nm

ICP Data Summary

- Overall, relatively similar levels of different emissions were achieved for the SCR willow and Grade A waste wood combustion tests – the main difference was for alkali metals (potassium and sodium)
- For SCR willow, **potassium** was the most prominent element, with very high levels of entrained aerosol emissions in the flue gas
- For the Grade A waste wood, **potassium**, **sodium** and **zinc** were the dominant elements to come through as entrained aerosols – but were generally much lower in concentration than for the SCR willow with the exception of sodium
- Entrained aerosol emissions alkali earth metals were found in minimal concentrations in both flue gases, despite notable concentrations in the initial fuel samples
- **Mercury** was not detected in either flue gas; only very low levels of other heavy/toxic metal, such as **chromium**, **cadmium** and **lead** were seen for both fuels

Thank you!

Any Questions?

The work is part of the Opening New Fuels for UK Generation (EPSRC Grant: EP/M015351/1)