SUPERGEN Bioenergy Hub – Bioenergy Systems
5th November 2014

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THE BIO-CAP-UK PROGRAMME

Impacts of Biomass Feedstock Properties on Air/Oxy Combustion with Carbon Capture

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Overview

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- Introduction to the Bio-CAP-UK Programme
- Work packages
- Fundamental fuel studies
  - fuel tests
  - preliminary results
- Pilot-scale trails at PACT using the 250 kW rig
- ICP-OES: Additional instrumentation
- Secondments

Introduction to Bio-CAP-UK

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- Two-year programme funded through UKCCSRC Call 1
- Brings together two ‘hubs’:

SUPERGEN Bioenergy Hub

UKCCS RESEARCH CENTRE

- Consortium includes three university partners:

THE UNIVERSITY OF EDINBURGH

TyndallManchester Climate Change Research

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- Research aim: to accelerate progress towards achieving **operational excellence for flexible, efficient and environmentally sustainable Bio-CCS** thermal power plants by developing and assessing fundamental knowledge, pilot plant tests, techno-economics and LCA

Summary of work packages

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WP1

fundamental studies and biomass characterisation

- fuel, char and ash characteristics and milling requirements
- torrefied biomass combustion rate, fuel ignition, burn-out and ash quality
- production of biomass database for subsequent WPs

WP2

pilot-scale plant campaign at UKCCSRC PACT

- air-biomass combustion with post-combustion amine capture
- solvent degradation studies with biomass-generated flue gases
- oxy-biomass combustion with flue gas recycling

WP3

power plant simulations for air-/oxy-biomass combustion

- process simulation linked to CFD modelling of the power plant
- virtual power plant simulations

WP4

bio-CCS value chains in the UK

- developing viable process configurations for different bio-CCS options
- full life cycle and techno-economic assessments

Fundamental fuel studies

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- Fundamental studies on fuel, char and ash characterisation
- Range of fuels to be tested but most detailed studies will be carried out on those intended for pilot-scale tests:
  - white wood pellets
  - El Cerrejon coal
  - a torrefied wood

- Other fuels used for comparison include:
  - Pittsburgh #8 coal
  - pine
  - white wood chips

Fundamental fuel studies

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- Fuel characterisation:
  - Proximate and ultimate analyses
  - Combustion behavior – in air and CO_2-O_2
  - Devolatilisation behavior– in N_2 and in CO_2

- Char characterisation:
  - Proximate and ultimate analyses
  - Reactivity
  - Morphology
  - Surface area

- Tests on ash residues:
  - Composition
  - Characteristic melting temperatures

ash fusion

Fundamental fuel studies

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Elemental Oxide (%)	White Wood Pellets	El Cerrejon Coal
SiO_2	25.4	46.1
Al_2O_3	4.4	23.6
Fe_2O_3	3.1	14.3
TiO_2	0.2	1.0
CaO	20.4	5.1
MgO	6.8	1.7
Na_2O	1.5	2.5
K_2O	14.8	0.9
Mn_3O_4	1.9	<0.1
P_2O_5	2.8	0.3
SO_3	2.9	3.2
Trace Metals (dry) mg/kg		
Arsenic	0.3	3.4
Cadmium	0.1	0.2
Chromium	4.7	5.1
Copper	2.8	5.0
Nickel	0.9	6.2
Lead	1.3	3.1
Vanadium	<0.6	11.5
Zinc	12.7	6.5

Pilot-Scale Trials at PACT

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- Technical assessment of up to 100% biomass firing using the UKCCSRC PACT National Core Facilities – by the investigation and comparison of:
  - dedicated biomass power
  - co-firing with coal
- 250 kW combustion rig:
  - air-mode firing with amine-based post-combustion carbon capture (combined with solvent degradation studies)
  - oxy-fuel combustion
- Provide information for subsequent modelling on:
  - operational experience
  - flue gas recycle, optimal burner settings and combustion efficiency
  - ash formation and composition (slagging, fouling, corrosion)
  - emissions measurements (including combustion gas analysis, as well as particulate matter, alkali metals, chlorine and sulphur)

250 kW_{th} Combustion Plant

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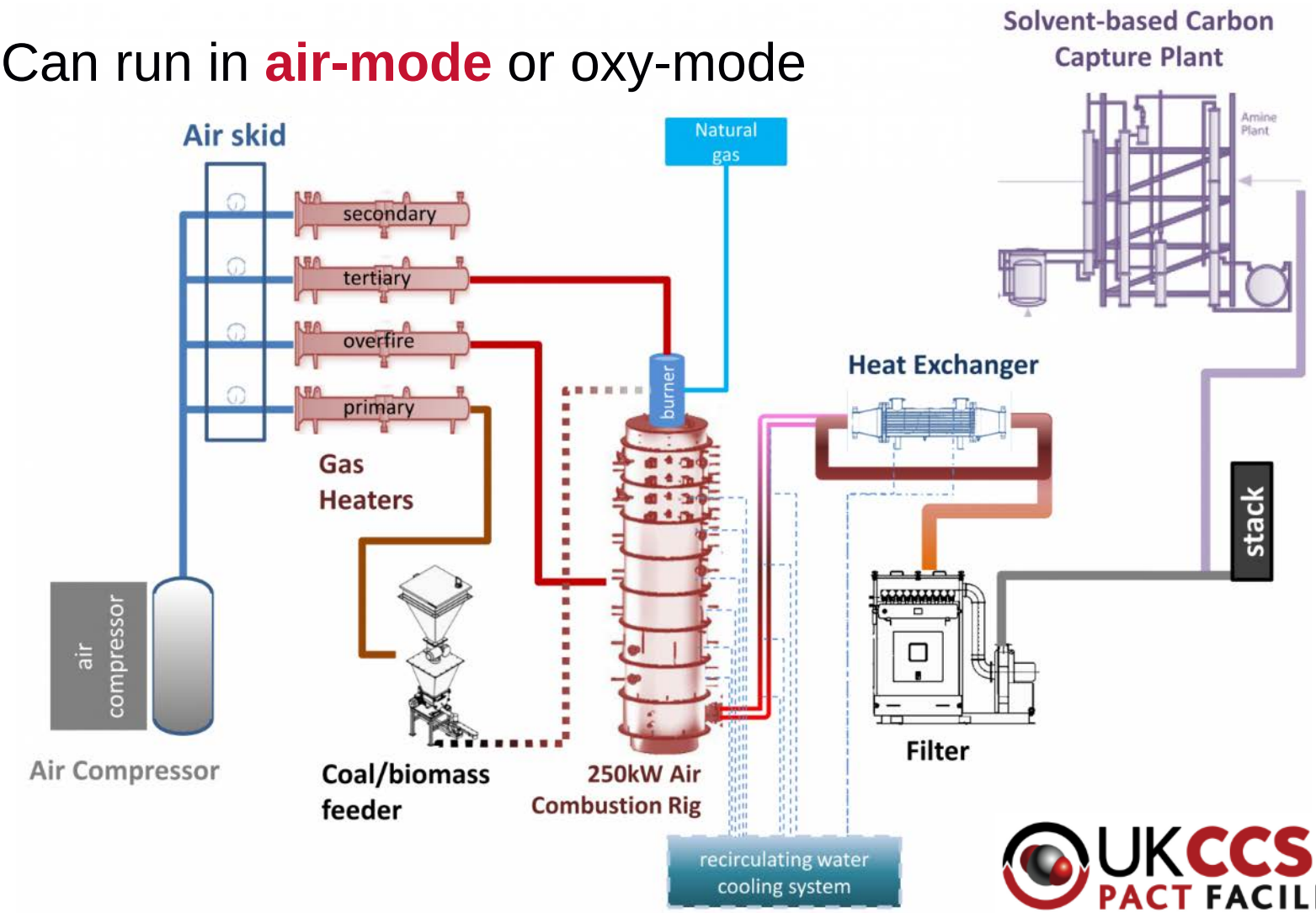
- Can run in **air-mode** or oxy-mode



UKCCSRC PACT FACILITIES

250 kW_{th} Combustion Plant

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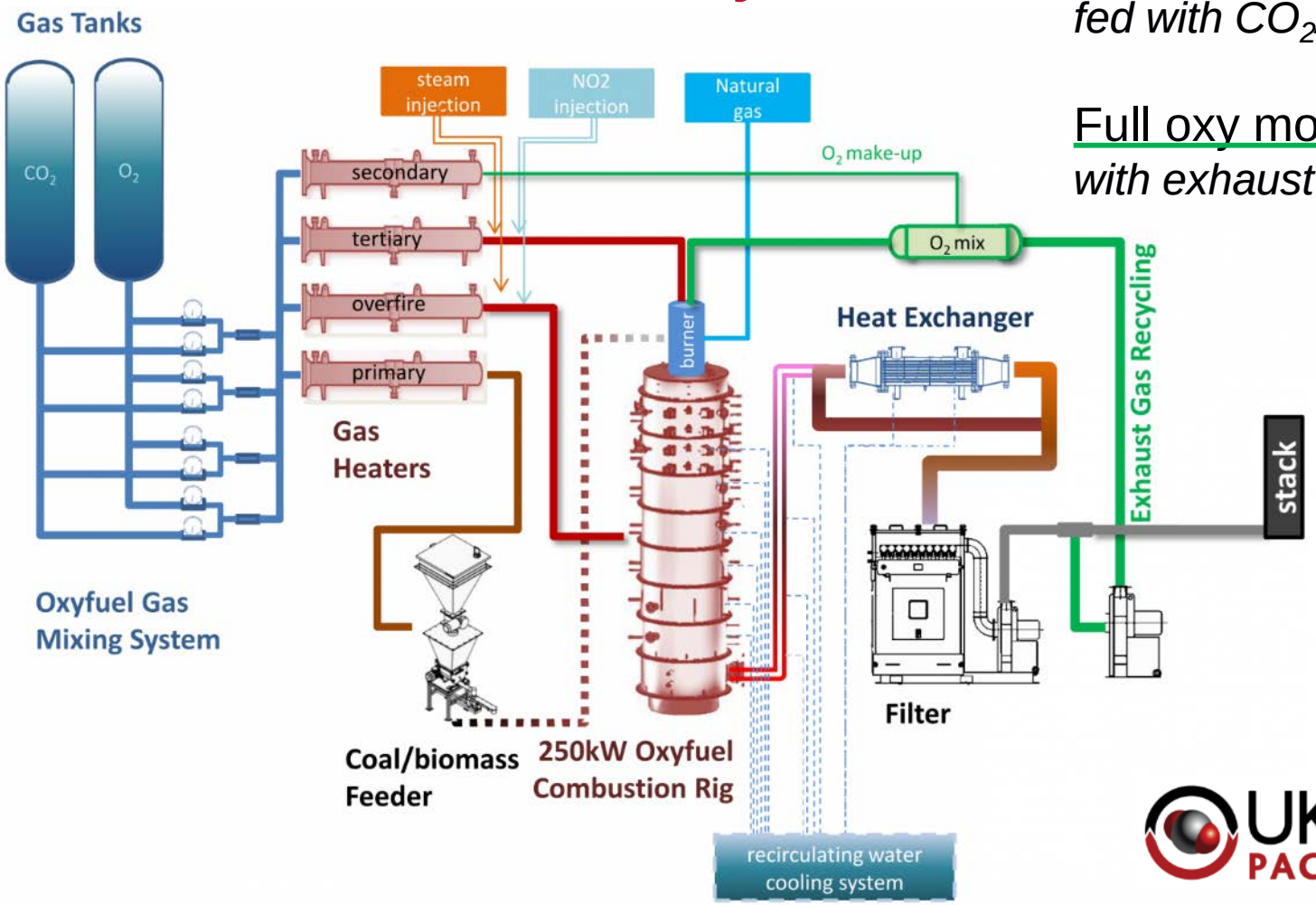
- Can run in air-mode or **oxy-mode**



Simulated oxy mode:
fed with CO_2/O_2 from skid

Full oxy mode:
with exhaust gas recycle

UKCCSRC PACT FACILITIES

250 kW_{th} Combustion Plant

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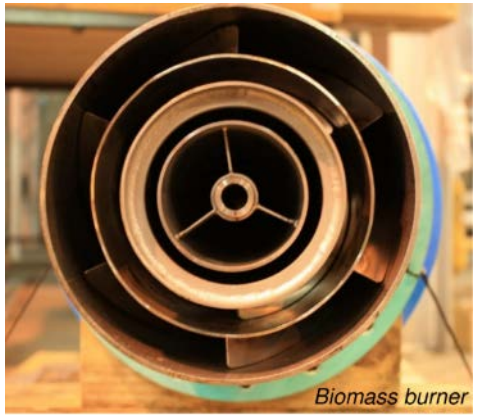
- Cylindrical design with a down-fired pulverised fuel system
- Has two interchangeable Doosan burners:
  - for coal and co-firing
  - for biomass



- Alstom are a project partner and have designed a new burner to be used for these tests

UKCCSRC PACT FACILITIES

ICP-OES Mobile Lab

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- Element fate and partitioning – fuel and ash analysis
- Mobile lab, which houses an **i**nductively **c**oupled **p**lasma – **o**ptical **e**missions **s**pectrometer for simultaneous multi-elemental detection of entrained metal aerosols and vapours
- Can identify the emissions spectra (spectral lines) of non-volatile metals and major, minor, trace and ultra-trace volatile elements – over 30 elements in total
- Focus on elements that:
  - are found in high concentrations (fuel specific)
  - cause operational issues (slagging, fouling, corrosion, solvent degradation) **K and Na**
  - are easily vaporised **Hg, Cd, Pb**
  - are toxic (heavy metals) **Hg, V, Cr, Cd and Pb**

ICP-OES Configuration

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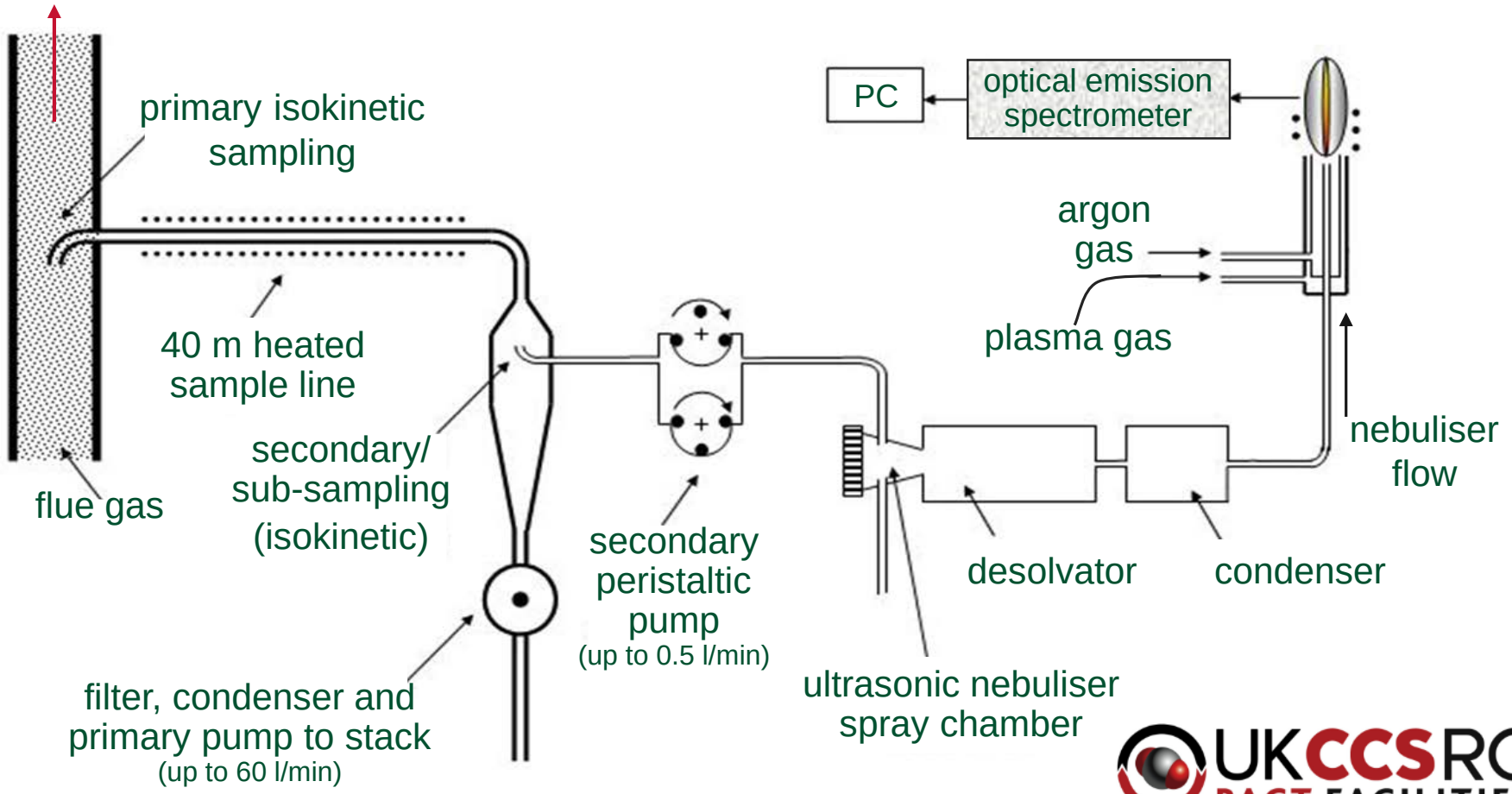
Spectro CIROS^{CCD}



UKCCSRC PACT FACILITIES

ICP-OES Configuration

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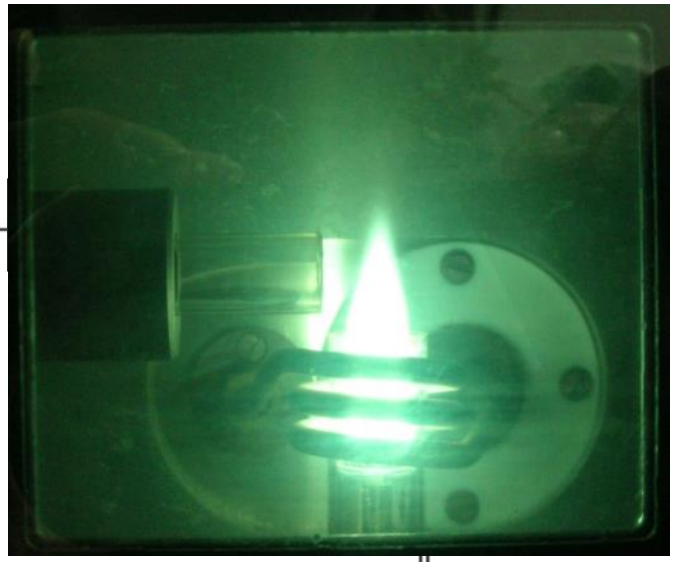

desolvator

condenser

ultrasonic nebuliser
spray chamber

Spectral Lines for Elements

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Element	Wavelengths (nm)
* Aluminium	309.271, 396.152
* Arsenic	189.042
Barium	455.404
* Cadmium	214.438, 226.502, 228.802, 361.051
* Calcium	315.887, 393.366, 396.847, 422.673
Carbon	193.091, 247.856
* Chromium	205.552, 283.563
Cobalt	230.786, 237.862, 238.892
* Copper	224.7, 324.754, 327.396
* Iron	259.941, 373.486
* Lead	261.418, 283.305, 405.778
Lithium	670.78
* Magnesium	279.553, 285.213
* Manganese	257.611, 403.076
Mercury	194.227, 253.652, 296.728, 435.835
* Nickel	221.648, 231.604, 305.082, 341.476
Nitrogen	174.525
Oxygen	130.485
* Potassium	404.721, 761.900, 766.491
* Silicon	251.612, 288.158 (plus others)
Silver	328.068, 338.289
* Sodium	588.995, 589.592
Tin	242.949, 303.412
* Vanadium	292.464, 309.311
* Zinc	202.548, 206.191, 213.856

** found in high concentrations in oxide form in the fuels*

** found as trace elements in the fuels*

Several lines for some elements . . .

. . . but none for Cl (cannot be monitored due to low sensitivity and high spectral interference from other elements)

Additional Funding: Secondments

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- Inward and outgoing HEFCE secondments:
  - Alstom to ETII (UoL) – Dr Rachael Hall to aid with ICP-OES analysis and modelling of bio-CCS
  - ETII (UoL) to Alstom – Dr Karen Finney to assess techno-economics of reducing metal loading in biomass combustion
- Awarding of project funding of ~£100,000 from EPSRC Impact Acceleration Account, plus a large in-kind contribution from Alstom

ALSTOM

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5th November 2014

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Thank you!

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