UKCCSRC PACT FACILITIES

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Biomass CCS Parallel Session

BIO-CAP-UK:

Air/Oxy Biomass Combustion with CO_2 Capture Technology, UK Study

Dr Karen N Finney

10th September 2014 – UKCCSRC Biannual, Cardiff

Overview

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- Project overview and aims
- Summary of work packages
- Fundamental studies – fuel characterisation
- Pilot-scale trails at PACT: 250 kW rig
- Addition of SUWICs mobile laboratory to PACT Facilities
- Secondments
- Modelling and plant simulations

Thanks to the project partners at Leeds, Manchester and Edinburgh – Ben Dooley, Leilani Darvell, Jenny Jones, Alan Williams, Patricia Thornley and Hannah Chalmers for their inputs

Project overview and aims

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- Two-year programme funded through UKCCSRC Call 1
- Consortium includes three university partners:

THE UNIVERSITY OF EDINBURGH

TyndallManchester
Climate Change Research

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- Brings together two ‘hubs’:

SUPERGEN Bioenergy Hub

UKCCS
RESEARCH CENTRE

- 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
- oxy-biomass combustion with flue gas recycling
- solvent degradation studies with biomass-generated CO_2

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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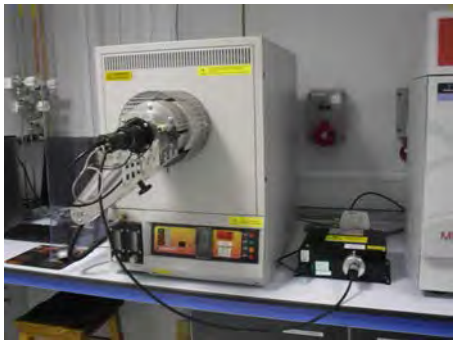
- Tests for fuel characterisation:
  - proximate and ultimate analyses
  - TGA combustion – in air and CO_2-O_2
  - TGA pyrolysis – in N_2 and in CO_2
  - DTF char preparation tests
- Tests on char:
  - proximate and ultimate analyses
  - TGA
  - SEM/EDX
  - BET SA
- Tests on ash residues:
  - XRF
  - XRD
  - AFT

ash fusion



Fundamental fuel studies

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Analysis	Provides data on:
Ultimate analysis	C, H, N, Cl and S for fuels and chars
Proximate analysis	moisture, volatile matter, fixed carbon and ash content
Thermogravimetirc analysis (TGA)	pyrolysis kinetics (in N_2 and CO_2), char combustion kinetics (in air and O_2-CO_2 mixtures) and char proximates
Drop tube furnace (DTF): char preparation and analysis	char reactivity, char kinetics and Na/K partitioning
BET and SEM (scanning electron microscopy)	char morphology, porosity characteristics and surface area
XRF metal analysis (X-ray fluorescence)	ash analysis, including K, Na, Ca, Al, Ti, Fe and Mg
AFT (ash fusion temperature)	ash melting behaviour at high temperatures

Pilot-Scale Trials at PACT

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- Technical assessment of up to 100% biomass firing using PACT facilities – investigation into:
  - dedicated biomass power
  - co-firing with coal

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- 250 kW combustion rig:
  - air-mode firing with amine-based post-combustion carbon capture
  - oxy-fuel combustion with flue gas recirculation
- Provide information for subsequent modelling on:
  - operational experience
  - flue gas recycle, optimal burner settings and combustion efficiency
  - ash formation and composition (slagging, fouling, corrosion)
  - heat flux/transfer
  - 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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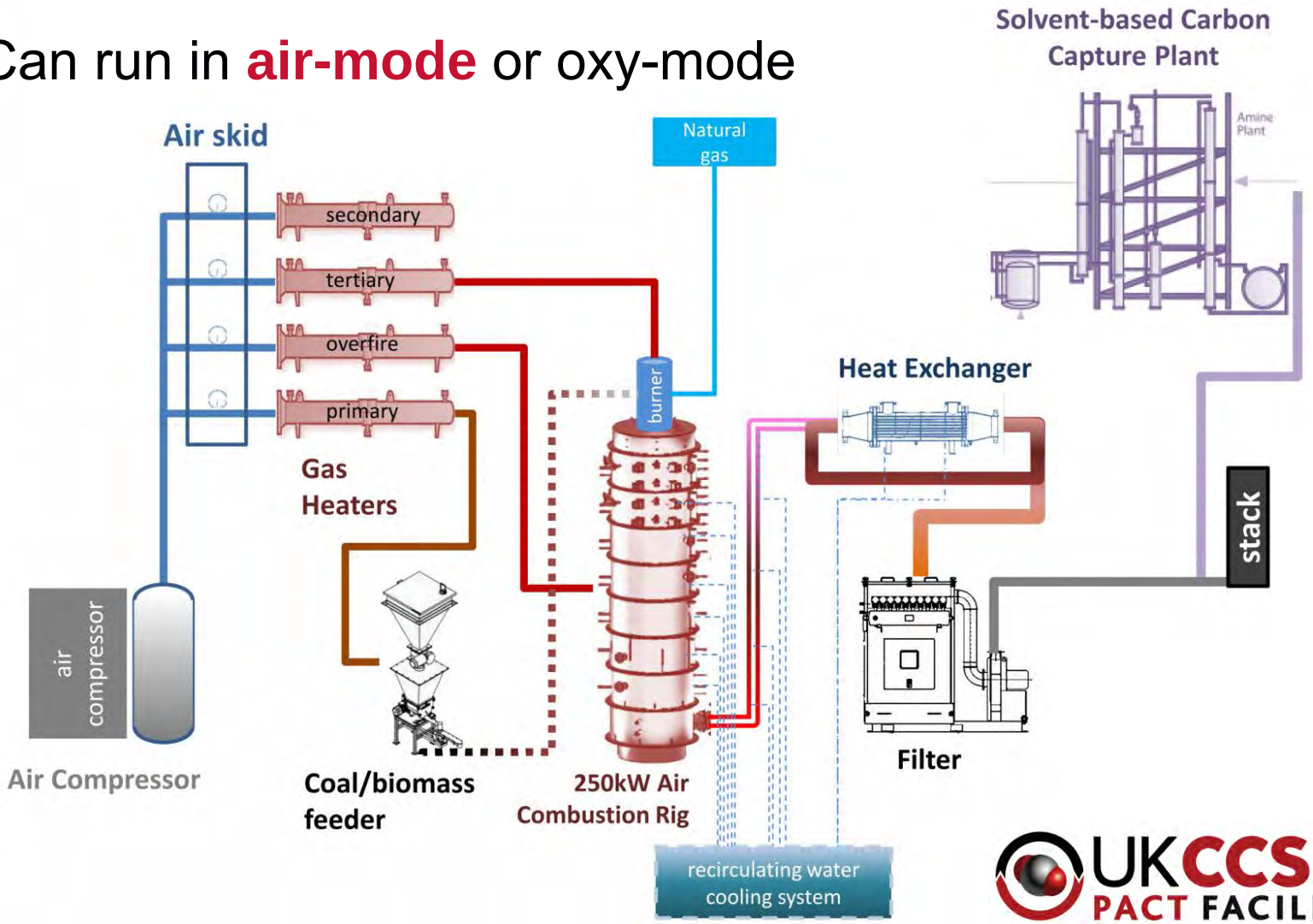
- Can run in **air-mode** or oxy-mode



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250 kW_{th} Combustion Plant

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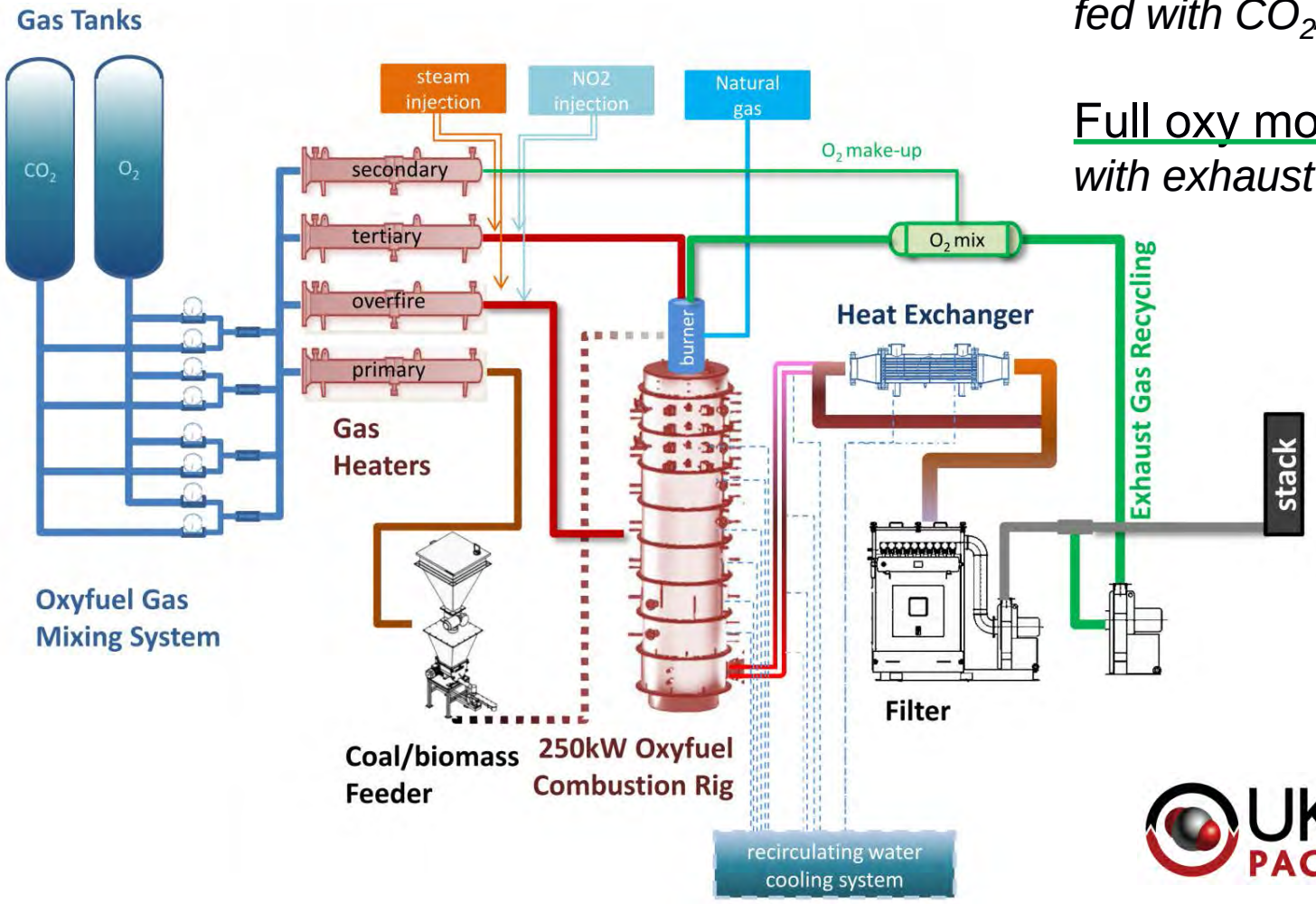
- Can run in air-mode or **oxy-mode**



Simulated oxy mode:
fed with CO_2/O_2 from skid

Full oxy mode:
with exhaust gas recycle

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250 kW_{th} Combustion Plant

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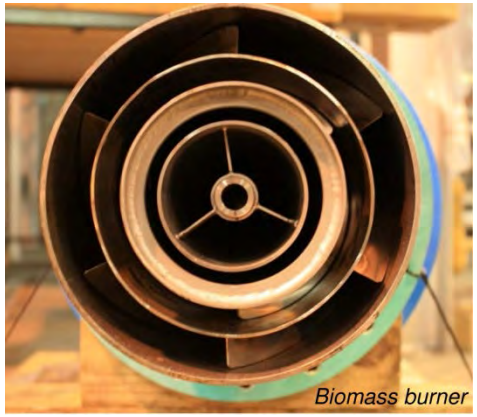
- Cylindrical design with a down-fired pulverised fuel system
- Has interchangeable burners:
  - for coal and co-firing

Coal burner*

  - for biomass



Biomass burner

- Also includes a dedicated air metering skid, gas heaters, steam skid, flue gas filter, heat exchanger and flow and temperature monitoring, water cooling system for the combustion vessel and flue ducts

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The CEML

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- The Continuous Emissions Monitoring Laboratory is a self-contained mini mobile laboratory
- It houses a Spectro ICP-OES: an **i**nductively **c**oupled **p**lasma – **o**ptical **e**missions **s**pectrometer for continuous online diagnostics of metal aerosol emissions
- Can identify the emissions spectra (spectral lines) of various non-volatile metals and major, minor, trace and ultra-trace volatile elements, including:
  - **sodium**, lead, zinc, boron, aluminium, barium, bromine, **calcium**, chromium, scandium, cadmium, iron, iodine, **potassium**, lithium, cobalt, copper, titanium, phosphorus, silicon, tin, **magnesium**, nickel, manganese, silver, thallium, sulphur, vanadium, antimony, cadmium, **mercury** and tin
- Looks for elements that cause of operational issues, toxic, easily vaporised, high concentrations, etc.

S.U.W.I.C

The CEML

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- The CEML is now part of the UKCCSRC PACT Facilities
- It has now been moved to PACT Core Facilities, Sheffield

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ICP-OES Configuration

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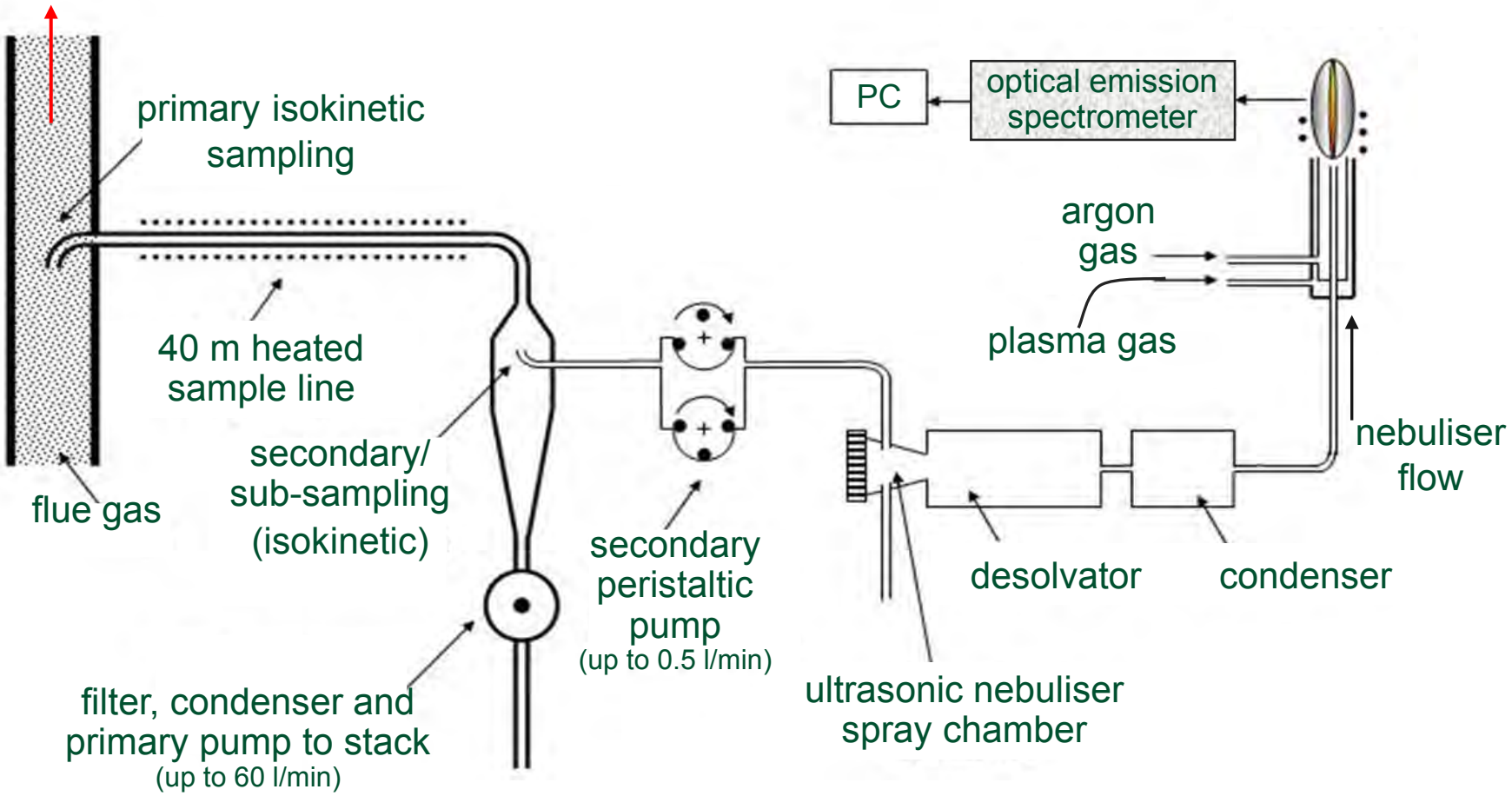

ICP-OES Configuration

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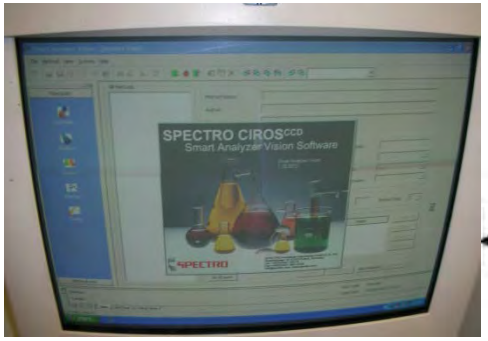

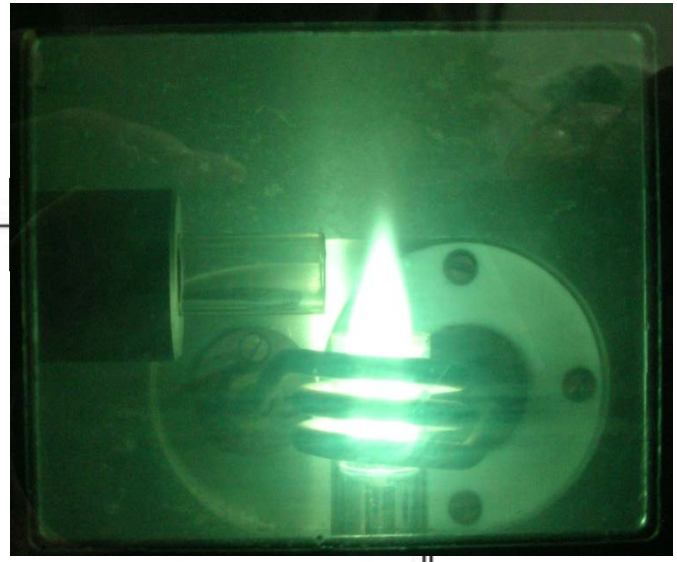

desolvator

condenser

ultrasonic nebuliser
spray chamber

Custom-built, radial, demountable plasma torch using inductively coupled argon plasma at ~6000K

Additional Funding: Secondments

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- Awarding of project funding of ~£100,000 from both the EPSRC Impact Acceleration Account and a large in-kind contribution from Alstom
- Inward and outgoing HEFCE secondments:
  - Alstom to ETII (UoL) – Dr Rachael Hall to aid with oxy-fuel combustion tests, 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
- Dr Rachael Hall started at Leeds in July 2014
- Dr Karen Finney will start at Alstom in September 2014

ALSTOM

Modelling and plant simulation

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- Improved fundamental modelling approaches to predict oxy-biomass plant transient performance to be developed
- Time-averaged and large eddy simulation (LES) modelling of the 250 kW oxy-fuel burner at PACT
- The simulation model (integrated gPROMs/ASPEN with CFD) will generate preliminary system designs specifying configuration for a range of plant sizes and applications
- Provide initial off-design operation estimates aimed at an early understanding of potential transient behaviour at start-up, shutdown and loss of load for air or oxy-biomass plant
- All data from WP1, WP2 and WP3 will feed into the life cycle and techno-economic assessments

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