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Theme A – Capture

WP AC1 Pilot Testing & Combined Systems and Capture

BECCS

Bioenergy with Carbon Capture and Storage

Bio-CAP-UK and Beyond

BECCS Research Under the New UKCCSRC-2017

PI: M Pourkashanian, Co-Is: Karen N Finney, Muhammad Akram & Lin Ma
[Energy 2050, Sheffield]

UKCCSRC AUTUMN 2017 BIANNUAL
September 2017, Sheffield

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Presentation Overview

- The importance of and evidence for BECCS
- Technical research challenges for BECCS
- Overview of Bio-CAP-UK
  - *aims and research outline*
  - *key results for potassium*
- New BECCS funding
- BECCS research under the new UKCCSRC grant
- Developments at PACT

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The Importance of BECCS

- Potential for net negative emissions
- IPCC: key CO_2 mitigation strategy – in the absence of such mitigation technologies, medium/long term costs can increase substantially
- CCC and EU Energy Roadmap 2050: BECCS is in need of vital demonstration projects
  - *negative emissions from using BECCS will reduce costs and risks of meeting carbon budgets"*
- European Biofuels Technology Platform and ZEP: clear need for carbon-negative solutions – BECCS is the only large-scale technology to remove CO_2 from the atmosphere

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Evidence for BECCS

- ETI: published evidence for deploying BECCS in the UK*
  - *BECCS could deliver ~55m t/a of net negative emissions by 2050*
  - *knowledge gaps have been addressed over the last 10 years*
  - *all major components have been demonstrated or 'proven' individually, de-risking the full-system deployment*
- Carbon Sequestration Leadership Forum now has a dedicated BECCS taskforce
  - *final report in Autumn 2017 will include commercial status; technology options and pathways; resource assessments and emissions profiles; economic analyses for BECCS concepts*
  - *Bio-CAP-UK has contributed to this – specifically on the technical challenges of bioenergy and integrated BECCS systems*

*ETI (2016) **The Evidence for Deploying Bioenergy with CCS (BECCS) in the UK**, Online: d2umxnkyjne36n.cloudfront.net/insightReports/The-Evidence-for-Deploying-Bioenergy-with-CCS-in-the-UK.pdf?mtime=20161107110603

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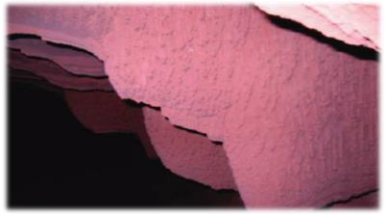
Technical Research Challenges for BECCS

- Characteristics that make it difficult to handle, mill, transport, feed, combustion and do CCS
- Inorganic constituents lead to plant issues:
  - *slagging indices are based on alumina-silicates*
  - *in most biomass materials, K is the dominant alkali metal, generally released by volatilisation*
  - *trace metal release in the gas phase can impact downstream processes/equipment (CO_2 capture)*
- To date, no estimates or measurements of the composition of CO_2 derived from BECCS in power plants are available



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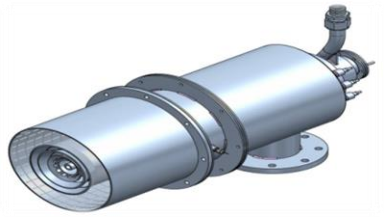
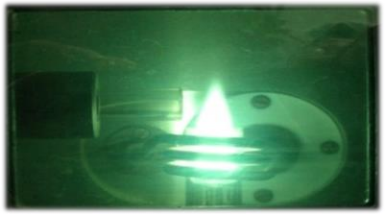
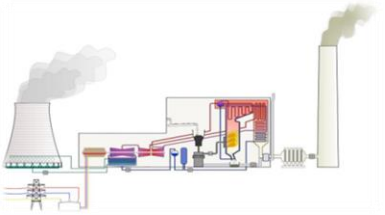
Bio-CAP-UK Project

- Jointly funded between the UK Carbon Capture and Storage Research Centre and the Supergen Bioenergy Hub
- Bio-CAP-UK: air/oxy biomass combustion with CO_2 capture technology – a UK study
- The project will **accelerate progress** towards achieving **operational excellence** for **flexible**, **efficient** and **environmentally sustainable** bio-CCS thermal power plants by developing and assessing fundamental knowledge in this area through, extensive pilot plant tests, techno economic studies and life cycle assessments







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Bio-CAP-UK Project

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TyndallManchester
Climate Change Research

University of Leeds
Leilani Darvell
Ben Dooley
Jenny Jones
Alan Williams

University of Edinburgh
Bill Buschle
Hannah Chalmers
Chih-Wei Lin
Mathieu Lucquiaud
Juan Riaza

University of Sheffield
Khalidah Al-Qayim
Karen Finney
Jon Gibbins
Lin Ma
Bill Nimmo
M. Pourkashanian
Katarzyna Stechly
János Szuhánszki
Xin Yang

University of Manchester
Temitope Falano
Sarah Mander
Laura O'Keefe
Patricia Thornley

e·on

BOC
A Member of The Linde Group

DOOSAN

drax

Progressive energy

sembcorp

PSE
The Advanced Process Modelling company

Industrial Panel: Greg Kelsall and Rachael Hall (GE), Ian Hibbitt (BOC), Robin Irons (EON), Chris Manson-Whitton (Progressive Energy), Alfredo Ramos and Penny Stanger (PSI), Scott Taylor (Sembcorp Industries), Stanley Santos (IEA)

Chair: Jim Swithenbank (University of Sheffield)

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SUPERGEN Bioenergy Hub

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Bio-CAP-UK Project

- Project aim:
  - *to address specific issues to deployment, remove some of the significant technical barriers to development and progress current understanding of its potential in the UK energy system, so that realistic projections of deployment, costs and achievable GHG reductions can be incorporated in policy development*

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TyndallManchester Climate Change Research

WP1: *fundamental studies and biomass characterisation*

WP2: *pilot-scale plant campaign at UKCCSRC PACT*

WP3: *power plant simulations for air-/oxy-biomass combustion*

WP4: *bio-CCS value chains in the UK*

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Bio-CAP-UK Project – Outputs

Ongoing academic projects (EPSRC)	Opening for New Fuels, Future Conventional Power
Ongoing commercial project	Torrefied biomass fuel combustion research
ETI-BIOFIB	Washed Biomass
Future commercial project	Proposal submitted for steam exploded biomass research
EPSRC-BioEnergy SuperGen Extension	BECCS Project
EPSRC-UKCCSRC-2	BECCS Project
PACT	300 kW biomass grate combustion boiler (£275K)
PACT	biomass gasifier – CHP 50 kWe + 100 kWth (£420K)
PACT	gas turbine modification to fire biogas (£75K)
Capacity Building	7+ PhDs, 7+ ECRs
Disseminations	9+ Journal Papers and 7+ joint journal papers 21+ conference presentations
Experimental data on oxidizing environment on release of light/heavy metals during coal/biomass combustion – database will have significant impacts on assessing influence of CO_2 impurities for transport/storage	National Database via BioEnergy SuperGen + UKCCSRC data repository

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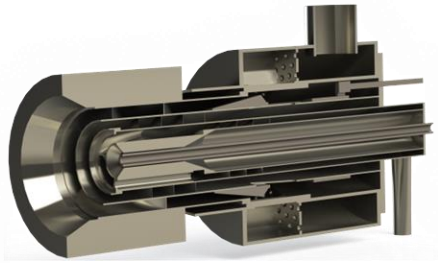
Bio-CAP-UK Project

- IAP comments:
  - *results generated are novel for this industry*
  - *produced good data and outputs for underpinning the science*
  - *assessed critical, industrially-relevant issues: plant performance, metal aerosol composition and particle size*
  - *overall, a successful programme that has opened up new research avenues*
  - *if everyone wants BECCS, what will we have to burn? is the same option always the best?*

coal firing baselines



biomass firing tests

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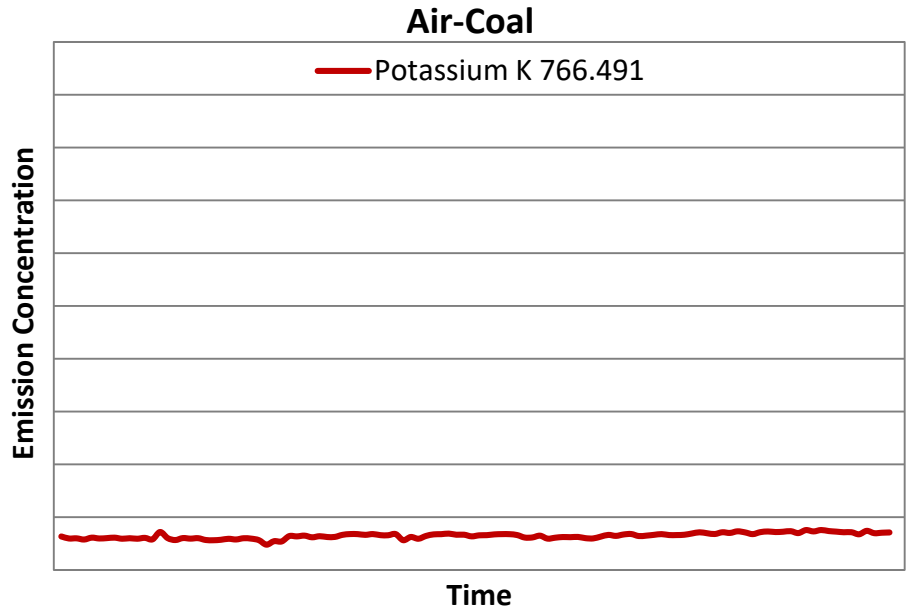
Bio-CAP-UK Project

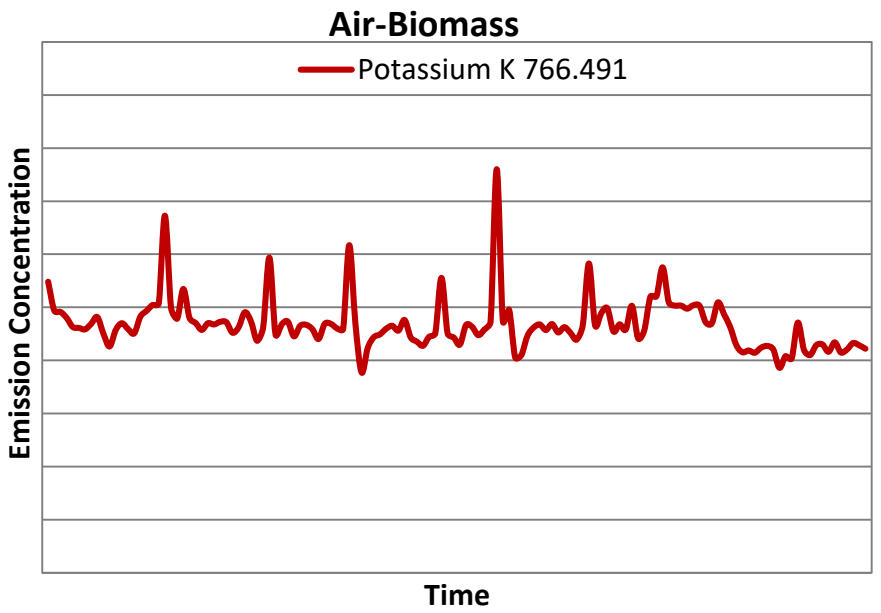
Fuel Analysis	Coal	Biomass
Potassium (as K_2O, %)	1.0	10.1

Biomass analysis from University of Leeds project partner

Relative Aerosol Emissions Ratio	Air-Coal		Air-Biomass		Oxy27-Coal		Oxy27-Biomass	
	average	max	average	max	average	max	average	max
Potassium K 766.491	1	1.80	6.53	10.41	0.31	0.35	26.42	36.04

All metal aerosol emissions are standardised relative to the average data for the air-fired coal baseline tests





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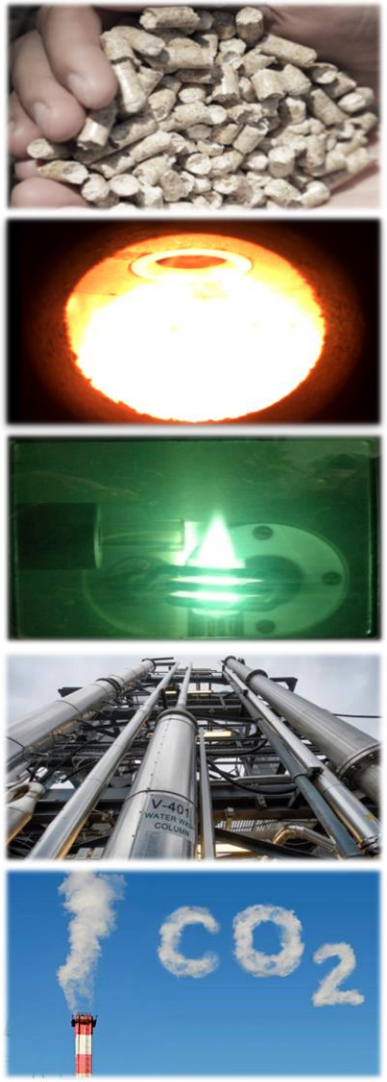
New BECCS Funding

- Extensive work covered under the new UKCCSRC
  - *fuel flexibility: fully instrumented 250 kW grate-fired boiler burning solid recovered fuel (SRF) with a 150 kW solvent-based post-combustion capture*
- SUPERGEN Bioenergy Hub extension granted
  - *BECCS is a key theme in the submission*
  - *Sheffield: range of biomass/recycled/waste fuels for testing impacts of bioenergy emissions on CCS*
- ETI project on biomass/waste combustion
  - *subject to ETI approval BIO-FIB project will be extended to cover CO_2 Capture*



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BECCS Research in UKCCSRC 2017 Grant

- The new grant has four key themes in the core research programme
  - *BECCS under 'Combined Systems and Capture' (WP AC1. BECCS)*
  - *BECCS within the energy system under the 'Systems and Policy' theme (WP CA1. BECCS)*

- This will provide underpinning research on future deployment for all aspects of BECCS
  - *next generation CO_2 capture technologies and processes*
  - *detailed modelling coupled with experimental data using the PACT facilities*
  - *examine 'social license to operate'*

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BECCS Research under UKCCSRC 2017

- **Combined systems and capture: BECCS**
  - *testing at PACT to demonstrate process integration at pilot scale (for retrofits) and the potential of oxy-fuel capture for increased waste fuel flexibility (greenfield applications)*
  - *combustion gases, metal aerosols and particulate formation will identify key species/pollutants from the combustion process and their impact on the capture plant and solvents*
  - *enable better understanding of element partitioning from the combustion of recycled/waste fuels under a range of realistic pilot scale conditions, leading to the formation of comprehensive and novel datasets on the fates of specific elements*

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BECCS Research under UKCCSRC 2017

- **Combined systems and capture: BECCS**
  - *data/samples from previous projects by the applicants (e.g. Supergen Bioenergy Hub, UKCCSRC/Supergen Bio-CAP- UK) will inform the tests under a range of real operating conditions (air/oxy-firing) to evaluate the impact of alkali/transition/heavy metals and other species on:*
    (i) the oxidative degradation and corrosion of CO_2 capture solvents, initiated and aggravated by transition metal carryover
    (ii) possible contamination of the high-purity captured CO_2 stream with a range of inorganic elements

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BECCS Research under UKCCSRC 2017

- **Systems and Policy: BECCS within the Energy System**
  - *seek to address some critical questions:*

    (i) what is the best (e.g. least cost per tCO_2 removed, most removed from the atmosphere) way to achieve BECCS?

    (ii) is the best option pulverised fuel thermal plant collocated and integrated with electrolysis (e.g. an oxy-CCS plant could use the H_2), or a BIGCC-CCS plant?

    (iii) what is the best use of carbon-negative H_2 (heating, transport, chemicals)?

    (iv) what are the technical constraints of injection into the gas network?

    (v) how can BECCS be integrated into a renewable energy system and how can plants best operate within a system that minimises time that they are idle?

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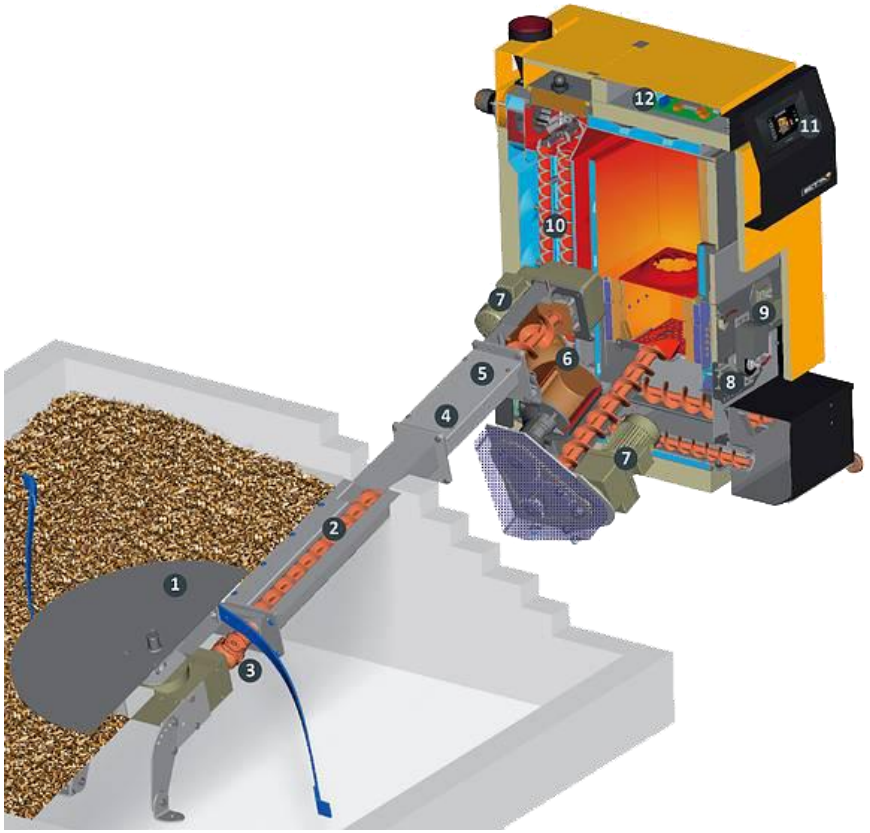
PACT Expansion Activities

- New multi-fuel, grate-fired combustor
  - *200 kW model to be installed at PACT*
  - *can burn a range of chipped or pelleted wood-based fuels*



energy 2050

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Wood chip boiler*

Stationary fuel cell power

Conventional / bioenergy Power*

Solar energy

Waste to energy Boiler

PACT-2
Heat Management
450 KWe
1180 KWth

Smart energy management module

CHP Biomass Gasifier-H2

Biogas CHP turbine

Energy storage

Liquid CHP Turbine*

CO2-Capture Membrane

Next Generation CO2 Capture

PCC CO2 Capture Plant

solvent analysis

ICP metal emissions

particle emissions

Natural Gas CHP Turbine*

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THANK YOU

Bio-CAP-UK and Beyond

BECCS Research Under the New UKCCSRC-2017

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