Coal Research Forum 23rd AGM and meeting of the combustion division

Drax power Ltd, Drax Power Station, Selby, North Yorkshire.
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An Overview of Oxyfuel Combustion Academic Programme for the UK (OxyCAP UK)

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Objective: “to develop academic research capability for oxy-fuel combustion in five key areas”:
1) New experimental techniques for oxy-fuel combustion.
2) Advanced computer modelling techniques (LES, integrated CFD/system)
3) Experimental data on coal ash/boiler material behaviour under oxy-fuel conditions.
4) UK capacity in oxy-fuel fluidised bed combustion (FBC).
5) Training & development new researchers.
Link and information flow between tasks-OxyCAP UK Project
**University of Cambridge**

**Task:** ST1-A, application of optical diagnostic techniques to particle laden flows

**Goals:**
- a) Create a database of turbulent combustion experiments with coal particles
- b) Analyze the difference between oxy-firing and air-firing and to
- c) Identify the limitations of optical diagnostic techniques to the coal combustion.

**Methodology:** Laser Doppler Velocimetry (LDV), Particle Image Velocimetry (PIV) and chemiluminescence imaging techniques to generate flow and scalar field measurements.

**Researchers:** Saravanan Balusamy, Alexander Schmidt, Simone Hochgreb, Stuart Scott, John Dennis.

Images/content courtesy of University of Cambridge
Goals: a) Study oxyfuel combustion  
    b) Ash transformation.  
    c) Ash deposition and corrosion studies.

Task: ST1-A (P.F. exp. Oxycomb), ST13-A & ST3-B

Methodology: Experiments in 150 kWh oxyfuel combustion with RFG. 
Analysis of morphology of the ash comparing different fuels.

Researchers: Nelia Jurado, Hamid Darabkhani, John E Oakey.

Images/content courtesy of Cranfield University
University of Edinburgh

**Task:** ST1-A (P.F. exp. Oxy-combustion), ST5-B (technical coordination).

**Goals:**

a) Determine safe levels of $O_2$ in $O_2/CO_2$ in FGR.

b) Mill safety.

c) Ignition/combustion fundamentals under oxyfuel conditions.

**Methodology:** Coal dust ignition tests under oxy-fuel conditions in 20 L and 200L bombs. Peak pressure and $dP/dt$. Analysis of char from ignition with TGA.

**Researchers:** Ignacio Trabadelo, Hannah Chalmers, Jon Gibbins.

Images/content courtesy of University of Edinburgh
**Goals:**

a) Improve understanding of oxy-combustion.

b) Model coal particles burning in oxy-combustion and other species.

**Task:** ST2-A (LES for Oxy-combustion).

**Methodology:**
LES, development of code from Eulerian-Eulerian to Eulerian-Lagrangian
Use LES for air combustion before oxy-combustion simulation.

**Researchers:** Benjamin Franchetti, Fabrizio Cavallo Marincola, Andreas Kempf.
University of Kent

**Task:** ST1-A (P.Fexp. Oxycomb), STI4 & ST5 (web)

**Goals:**
- a) 3D Flame imaging.
- b) Flow metering and on-line sizing of pulverised coal.
- c) Particle image characterization.

**Methodology:** The 3-D temperature distribution of flame cross-and longitudinal sections can be measured based on two-colour method.

**Researchers:** Y. Yan, G. Lu, M. M. Hossain and L. Gao.

Images/content courtesy of University of Kent
**University of Leeds**

**Task:** ST1-A, ST2A, ST2B, ST2C & ST5AB (financial & technical coordination.)

**Goals:**
- a) PF Oxy-combustion fundamentals (and fuel characterisation).
- b) LES, CFD and global plant simulation.

**Methodology:** Oxy/air solid fuels CTF 250 kW rig (PACT facilities).
Develop CFD sub-models and Large Eddy Simulation.

**Researchers:** János Szuhánszki, Sandy Black, Alessandro Pranzitelli, M. Pourkashanian, L. Ma, and B. Nimmo.

Images/content courtesy of University of Leeds
Task: ST1-A (P.F. Oxyfuel combustion)

Goals: 
a) Coal devolatilisation and subsequent char burnout characteristics
b) The effect of mineral matter and potential formation of carbonate species.
c) Coal/biomass oxy-cofiring + char analysis.
d) Water vapour content in FGR.

Methodology: Drop tube furnace (DTF) tests under conditions of different temperatures (up to 1500ºC), residences times (≥ 25 ms) and oxy-combustion atmospheres (+TGA)

Researchers: Colin Snape, Chenggong Sun and Donglin Zhao.

Images/content courtesy of University of Nottingham
Research and Pathways to Impact Delivery (RAPID)

- The RAPID process will run throughout the course of the UKCCSRC
- Led by the Research Area Champions and gathering input from a wide range of academic, industry and other stakeholders.
- Results summarised in a RAPID Handbook.
- The first draft of the Handbook will be published after an intensive 4 month exercise at the project outset
- Handbook will be updated annually.
Complete chains taking CO₂ from source to secure geological storage

Capture
Transport
Storage

Interfaces + Interactions + Interoperability

Post
Pre
Oxy
Industry
Pipeline
Ship
Hydro-carbon
Aquifer

Gas
Coal
Biomass
Solvent
Solid
Membrane

CO₂ processin
Oxygen productio

Hydrocarbons
Cement
Iron & steel
Low carbon energy
Gas phase
Dense phase

Long/short distance
Buffer storage
Buoy transfer
Monitoring
Capacity assessment
Injection engineering

Financial
Environment
Safety
Regulation

Public acceptance
Pathways to Impact

**Academic Impacts**

- Enhancing the knowledge economy
- Training highly skilled researchers
- Improving teaching and learning
- Improving health and well-being
- Wealth creation, economic prosperity and regeneration
- Enhancing the research capacity, knowledge and skills of public, private and third sector organisations
- Changing organisational culture and practices

- Worldwide academic advancement
- Innovative methodologies, equipment, techniques, technologies and cross-disciplinary approaches
- Contributing towards the health of academic disciplines

**Economic and Societal Impacts**

- Enhancing the effectiveness and sustainability of organisations including public services and businesses
- Attracting R&D investment
- Improving social welfare, social cohesion and/or national security
- Commercialisation and exploitation
- Enhancing cultural enrichment and quality of life

- Environmental sustainability, protection and impact
- Evidence based policy-making and influencing public policies
- Increasing public engagement with research and related societal issues

RESEARCH COUNCILS UK
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Environmental sustainability, protection and impact

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Increasing public engagement with research and related societal issues
CRF Research Needs - The key R,D&D challenges include:

- Improve the efficiency of coal fired power generation with effective removal of conventional pollutants such as SOx, NOx particulates and trace metals.
- Improve the use of more advanced steam cycles, for which the need to improve performance through materials selection is critically important.
- Improve plant integration, together with enhanced fuel and operational flexibility.
- Establish near zero emissions systems such that CO₂ can be prevented from being released to atmosphere, with any adverse technical impacts on such efficiency and environmental performance being minimised in as cost effective manner as possible. This will require large scale demonstrations of the first generation CO₂ capture systems and offshore CO₂ storage within a complete CCS chain.
- Improve effectiveness and costs of the first generation CO₂ capture systems and the development of second generation systems that will overcome some of the inherent disadvantages of the first.
- Gain a better understanding of the properties of CO₂ to ensure the provision of robust transport systems.
- Improve assessment and modelling of CO₂ storage capacity in various geological formations, together with the development of improved monitoring and verification techniques.
**THINGS THAT ARE NEEDED TO MAKE CCS HAPPEN**

- Perceived need for CCS
- Plans that include CCS
- Money to pay for CCS
- Legal cover for CCS
- Permitting, Regulation and Leasing
- Project liability protection
- Environmental sustainability
- Public acceptance
- Industry to produce and capture CO₂
- CO₂ transport systems
- CO₂ storage sites -
- CCS Hardware
- CCS-related Services
- Operating/Managing CCS systems in real time and day-to-day
- UKCCSRC + other research input

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**CCS IMPACT LANDSCAPE**

**IMPACTS FROM UNDERPINNING RESEARCH**

- Public acceptance
- Environmental sustainability
- Global climate change agreement
- Understanding role of CCS
- UK energy & climate policy
- Global climate change agreement
- Energy market planners –DECC, Ofgem, National Grid, utilities
- Financial instruments to support CCS – government grants, EMR, carbon price, clean energy standards etc.
- CCS safety regulators - HSE
- Plant permitting – EA, SEPA
- Crown Estates
- Offshore storage site permitting & leasing
- Onshore pipeline permitting
- Offshore pipeline routing and leasing
- Government participation in storage liability
- CCS project/process insurance
- Process emissions
- Lifecycle emissions
- Site impacts
- Remediation options
- Media
- Opinion formers
- Local groups
- Special interest groups
- Electricity utilities
- Steel with CCS
- Cement with CCS
- Refining with CCS
- Hydrocarbon extraction and processing with CCS
- Synthetic fuels with CCS
- National Grid
- Onshore pipeline developers and operators
- Offshore pipeline developers and operators
- Pipeline T&S project developers
- Shipping T&S project developers
- Storage site developers & operators
- CO₂ EOR developers & operators
- Oil & gas companies (many roles)
- Many stakeholders in technology ‘funnel’ - R&D doers, funders, VCs, OEMs etc
- Consultants: e.g. engineering, sub-surface, legal, environment
- EPC Contractors
- Electricity market operators
- T&S system operators – National Grid, utilities
- National Grid + others

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**UNDERPINNING RESEARCH ACTIVITIES**

- Research organisations & communities
- Ideas
- Facilities
- Evidence
- Impact support
- Engagement
- Know-how
- Skilled people

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**PROCESSES AND POSSIBLE EXAMPLES OF STAKEHOLDERS INVOLVED IN MAKING CCS HAPPEN**

- Global climate change agreement
- Understanding role of CCS
- UK energy & climate policy
- Global CCS development organisations: CSLF, GCCSI, IEAGHG, Clean Energy Ministerial CCUS
- Electricity market planners –DECC, Ofgem, National Grid, utilities
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**High-level --------- Very specific**

**Long term ----------- Immediate**

**Demonstrable ---------- Potential**

**Big --------------- Small**

**Multiple impacts --------- Focussed impact**

**Intentional --------------- Serendipitous**

**UKCCSRC involved -------------- 3rd party**

**Plan preceded ------------ Plan followed research**

**Research ---------------- Deployment impact**

**Tangible ---------------- Intangible vehicle**

**Publishable --------------- Confidential**

**Clear Attribution ---------- Debatable**