The Energy Innovation Process

http://www.energyresearchpartnership.org.uk/Innovation+Landscape

![Diagram of the Energy Innovation Process](image-url)
About PACT

- **Pilot-scale Advanced Capture Technology** facilities
  - Funded jointly by the EPSRC and DECC
  - Partners: Cranfield, Edinburgh, Imperial, Leeds, Nottingham, Sheffield
  - Part of the UK Carbon Capture & Storage Research Centre (UKCCSRC)

- **Scope**: Specialist national facilities for research in advanced fossil-fuel energy, bioenergy and carbon capture technologies
  - Comprehensive range of pilot-scale facilities
  - Specialist research and analytical facilities
  - Supported by leading academic expertise

- **Aim**: Catalyse and support industrial and academic research to accelerate the development and commercialisation of novel technologies

- **Objectives**
  - Bridge gap between bench-scale R&D and industrial pilot trials
  - Provide shared access to industry and academia
PACT Locations

• 3 Facility Sites
• PACT Office
Edinburgh PACT Facilities

• Advanced Capture Testing in a Transportable Remotely-Operated Mini-lab (ACTTROM)
• Integrated, mobile carbon capture media testing laboratory
• Designed for long-term on-site testing of CO₂ capture media on real flue/process gases with a possibility of multiple parallel tests
• Facility is transported to the test site and connected directly to onsite flue/process gases
• Remotely monitored and operated by University of Edinburgh
• **About to go on site at Peterhead**

• **ACTTROM**
  – Aids technology development and scale-up for technology developers
  – Provides site-specific operational data to operators, for example, in advance of the deployment of a specific capture system
Cranfield PACT Facilities

- PACT is part of new energy facilities at Cranfield
- 750kWth Burner Rig for Gas Turbine Hot Gas Path Research
- 350kWth Circulating Fluidised Bed Facility
- 50kWth Chemical/Calcium Looping Facility
- 150kWth Pulverised Fuel rig
- Dense-phase CO$_2$ Flow Loop Rig
PACT Core Facility components
Carbon Capture Plant
250kW Air Combustion Plant

- Air Compressor
- Coal/biomass feeder
- 250kW Air Combustion Rig
- Heat Exchanger
- Filter
- Natural gas
- Stack
- Recirculating water cooling
- Gas Heaters
- Secondary
- Tertiary
- Overtire
- Primary
- Amine Plant
250kW Air/Oxy Combustion Plant

Overview

• ~250kWth, 4.5m high; 0.9m radius, cylindrical, down-fired rig with 8 sections
• Fuel: Coal, Biomass, Co-firing, Gas (primarily preheating)
• 2 x (interchangeable) coal/biomass burners - scaled from Doosan Power Systems commercial low-NOx burners
• Dedicated, high precession air metering skid
• Flue gas candle filter ( >99% ash removal);
• Furnace pressure (negative) balanced by exhaust fan
• Temperature and flow monitored water cooling system for the combustion rig, flue gas duct and heat exchanger.
• SCADA operating system with internet monitoring
Air-coal 200 kW with preheated air

RANS, temp contour.
Air-coal 200 kW with preheated air
250kW Air/Oxy Plant - Analytical

3D laser diagnostics and thermal imaging

- In-flame temperature profiles using suction pyrometry
- Heat flux profiles using an ellipsoidal radiometer and total heat flux probes
- Laser Induced Fluorescence (LIF)
- In-flame and exhaust species profiles
- 3D Particle Image Velocimetry (PIV), Laser Doppler Velocimetry (LDV);
- Flame characterisation, including shape, luminosity, and frequency, using 2D and 3D flame imaging with photographs and videos as well as computer tomographic reconstruction of the flame in 3D
- Particle velocity profiles within the top section of the furnace (for both non-reactive and reactive species)
- 200kW_th air coal combustion (benchmark simulation)
- 2D flame imaging by Kent University

Experiments

<table>
<thead>
<tr>
<th>Flicker (Hz)</th>
<th>LES</th>
</tr>
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<tbody>
<tr>
<td>6 - 9</td>
<td>5.3</td>
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</tbody>
</table>

1Experimental Images and data courtesy of Kent University
Theoretical study of flame flicker for air & oxy at 250 kW_{th}

Flicker study

Temperature [K]
- 2000
- 1900
- 1800
- 1700
- 1600
- 1500
- 1400
- 1300
- 1200
- 1100
- 1000
- 900
- 800
- 700
- 600
- 500
- 400

Oscillation frequency (Hz)

air  oxy21  oxy25  oxy30

Theoretical study of flame flicker for air & oxy at 250 kW_{th}
Applications

• Testing & development of alternative solvents
• Benchmarking & energy requirements
• Solvent degradation & enhancement studies
• Real aged solvents assessment
• Plant and system modelling
• Assessment of plant flexibility and performance with different fuels (e.g. biomass) or other conditions
• Integrated systems modelling and control
• Validation of baseline economics
Key Simulation/Experimental Results

MEA Solvent, Flue Gas CO2 Level = 7%

<table>
<thead>
<tr>
<th>Lean Flow (kg/h)</th>
<th>Rich Flow (kg/h)</th>
<th>Lean Ldg (mol/mol)</th>
<th>Rich Ldg (mol/mol)</th>
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</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>Modelling</td>
<td>Experimental</td>
<td>Modelling</td>
</tr>
<tr>
<td>515</td>
<td>515</td>
<td>531</td>
<td>538</td>
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<td></td>
<td></td>
<td>0.25</td>
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<td>0.41</td>
<td>0.40</td>
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</table>

<table>
<thead>
<tr>
<th>CO2 Cap (kg/h)</th>
<th>CO2 Cap (%)</th>
<th>Reb Duty (MJ/kg CO2)</th>
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<tbody>
<tr>
<td>Experimental</td>
<td>Modelling</td>
<td>Experimental</td>
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<tr>
<td>16.45</td>
<td>16.45</td>
<td>76.3</td>
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</table>
Absorber Temperature Profile

ABSORBER Rate-Based Modeling - Interface Profiles Temperatures

Liquid Temperature
Vapor Temperature
Absorber Composition Profile

ABSORBER Rate-Based Modeling - Interface Profiles Compositions

Interface vap mole frac. H₂O vs. Interface vap mole frac. CO₂
• Carry out system assessment
• GHG balances
• Process Analysis of Bio-CCS Options

• Fundamental Experimental studies
• Pilot-Scale studies
• Virtual reality System Simulation

• Fundamental Experimental studies
• Pilot-Scale studies
• Process Simulation
Impact

• The project will remove some of the significant technical barriers to bio-CCS development.

• It will progress current understanding of the potential of bio-CCS for the UK energy system so that realistic projections of deployment, costs and achievable GHG reductions can be incorporated in policy development.

• The project will accelerate UK development of bio-CCS technology

• The project will consolidate the UK’s position as world-leaders in technology understanding for decarbonisation of existing coal based power generation infrastructure
Technical Challenges (1)

Case Study: Didcot Power Station A

Air Oxy25 Oxy30
Coal

Air Oxy25 Oxy30
Biomass

Temperature [K]

2200
2033
1866
1699
1532
1365
1198
1031
864
697
530
363
Gas Turbine System

Overview

• Two Turbec T100 Microturbines
• Consume 330kW of Natural gas
• Fuel: Natural gas, biogas, syngas, diesel, kerosene, methanol, LPC
• Generation 100kWe and 150kWth
• Overall efficiency up to 77% (33% electrical)
Gas Turbine System

GT + (amine) Solvent Based Carbon Capture Plant = Post combustion Capture from Gas Turbine System
• INVENSYS UKCCSRC-PACT partnership was signed 01/2014
  • Access to all their process simulation model including DYNSIM
  • Available for use for initial period of 3 years
Technical Challenges (2)

Case Study: Didcot Power Station A
Virtual Reality Power Plant Simulation
Analytical Facilities: Labs

- Analytical labs
- Unique Continuous Emission Monitoring mobile laboratory for solid-state detector based ICP-OES (SUWIC)
- Cambustion DMS500 Fast particulate analyser
- CHNS/O Elemental Analyser
- GC MS and TG-MS
- Thermogravimetric Analyser and TG-MS
- FT-IR and TG-IR
- Portable SERVOFLEX MiniMP gas analysers (CO$_2$ and O$_2$)
Overview & Contacts

• Comprehensive research capability and support
• Consolidating a wide range of facilities and supporting expertise
• Maximising equipment utilisation through shared access to industry and academia

Services
  – R&D Services
    • Collaborative research
    • Contract research
  – Analytical services
  – Technical consultancy
  – Training