Technology Insight 1

University of Sheffield PACT facilities

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Bridging the gap between bench-scale R&D and large-scale industrial pilot trials

The University of Sheffield houses the UK's national research and development facilities for combustion and carbon capture research – the Pilot-scale Advanced CO_2 Capture Technology (PACT) facilities – which form part of the Carbon Capture International Test Centre Network and the European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL).

The university is procuring a broader range of facilities as part of the new ERDF-funded flagship, the Translational Energy Research Centre (TERC). The new centre will open in March 2021 and will focus on low-carbon energy research at a technology readiness level of 3-6. This is crucial for early stage research into proven, sustainable solutions, ready for commercial deployment in the UK and beyond.

The facility will operate under the Energy2050 initiative at Sheffield, which aims to develop a sustainable, affordable and secure energy supply focusing on advanced conventional power.

Access to cutting-edge facilities

The NEWEST-CCUS project will benefit from the use of some of the facilities at the Translational Energy Research Centre, including the grate boiler, carbon dioxide (CO_2) capture plant and analytical instruments described below.

Grate boiler

A 240 kWth Gilles HPKI-R grate-fired biomass boiler (Fig 1) can combust a range of chipped and pelletised biomass and bio-waste fuels. The high-temperature, post-combustion zone ensures optimum combustion with the introduction of secondary and tertiary air along the flue gas path.

The system is automated and has continuous automatic removal of combustion residues – bottom ash via an under-grate auger and fly ash via a built-in multi-cyclone. The boiler has been fitted with an array of additional ports in the combustion chamber and overpass sections for characterising in-furnace temperatures, gas composition, deposition, corrosion, etc. between different fuels and excess oxygen levels used.

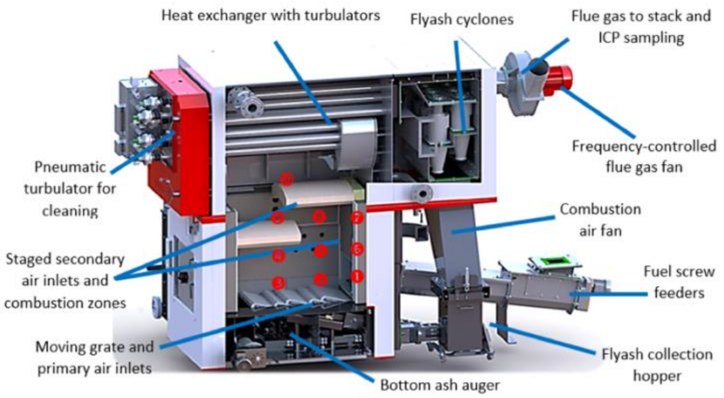


Figure 1: Grate boiler

Additional ports before and after the multi-cyclone allow for flue gas characterisation using a range of online analytical capabilities, including metal aerosol emissions analysis, flue gas composition and emissions characterisation and particle size classifications. Fly ash and bottom ash samples are collected to determine burnout and metal partitioning.

CO_2 capture plant

Figure 2: CO_2 capture plant

The solvent-based CO_2 capture plant (Fig 2) is integrated into the combustion facilities. The plant is equipped with two absorbers, stripper and water wash. Each of the absorbers has two packed bed sections – 3 metres each, packed with Flexipac 350Y, 12m total packed height – with solvent redistribution at each bed.

Each bed is equipped with six resistance temperature detectors for temperature profiling. The stripper and water wash are packed with IMTP25 random packing. The plant also has a carbon filter for solvent hygiene.

A separate flue gas desulphurisation section is available to capture sulphur from coal flue gases, which avoids sulphur contamination of the capture solvent.

Gas analyses are carried out at six locations using a Fourier Transform Infrared Spectrometer for full gas characterisation. Solvent analyses are performed at four different locations using online and offline analysers. The gas analysis suite, including those for entrained metals and PM1, can be incorporated into the capture plant to assess where such species become concentrated (e.g. in the pure stream of CO_2, in the CO_2-depleted flue gas, etc.).

Inductively Coupled Plasma Optical Emissions Spectrometer

Entrained metal concentrations are measured online by the Inductively Coupled Plasma Optical Emissions Spectrometer (ICP-OES), shown in Fig 3, a state-of-the-art diagnostics tool. This tool generates simultaneous data for multiple elements found as entrained aerosols in the sample gas.

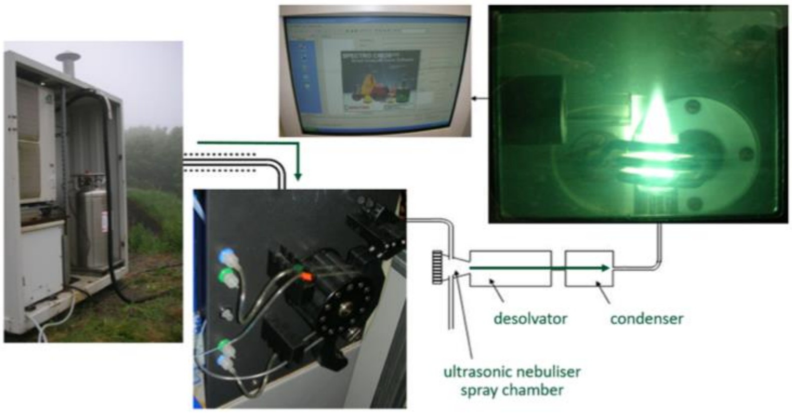


Figure 3: Inductively Coupled Plasma Optical Emissions Spectrometer (ICP-OES)

The gases are sampled isokinetically from the stack and transferred to the argon-based plasma torch operating at ~6000 K. The spectrometer can assess the spectral lines of a large number of elements, including over 30 volatile and non-volatile species – Pb, Na, Zn, B, Al, Br, Ca, Cr, Sc, Cd, Fe, I, K, Li, Co, Cu, Ti, P, Si, Sn, Mg, Ni, Mn, Ag, Tl, S, V, Sb and Hg.

A number of these are of special interest to power generators and carbon capture applications as they can cause operational issues, such as slagging, fouling or corrosion (K and Na) or are toxic (heavy metals Hg, V, Cr, Cd and Pb). The ICP-OES is capable of the quantitative determination down to ultra-trace levels.

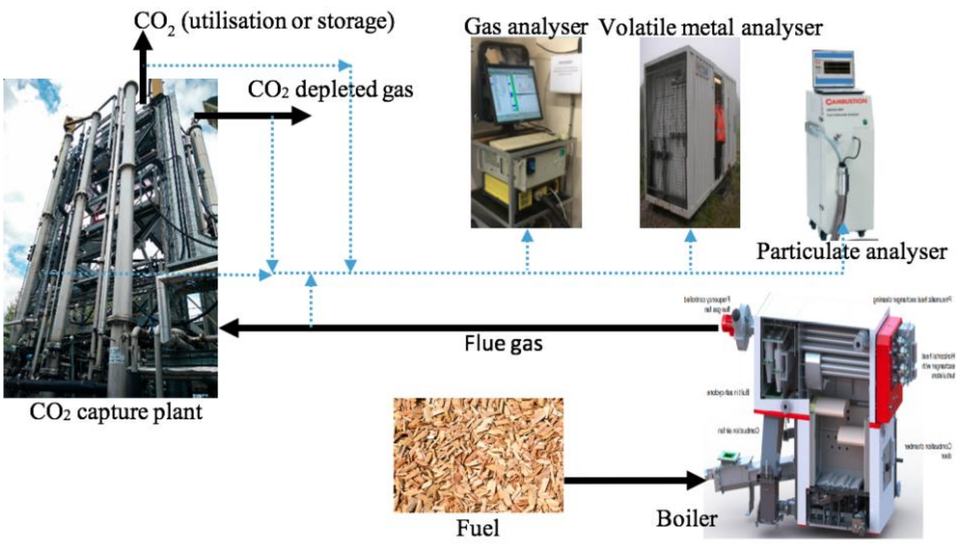
CAMBUSTION DMS500

The Rapid Response Particulate Analyser, CAMBUSTION DMS500 is used for submicron sized particle analysis in the flue gas. The instrument uses electrical mobility measurements of particles with sensitive electrometer detectors, and measures particle size, number and mass spectra in real time. The instrument's measuring range is 5nm to 1µm and its fastest response time is 200 ms.

The Translational Energy Research Centre's role

The research team in Work Package 4 will use the integrated grate boiler and CO_2 capture plant with analytical instruments. The test campaigns will be carried out with two different biomass fuels and two different solvents. Our experimental setup is shown in Fig 4. The test campaigns will quantify the impact of impurities in biomass on key performance indicators, including solvent degradation and reboiler duty, comparing a generic amine solvent (nominally MEA at 30wt% as the baseline case for benchmarking) with the proprietary solvent technology commercialised by CCSL for each fuel case study.

Figure 4: overall experimental set up



Fuels of interest that could be tested include waste wood of a variety of grades and/or graded non-woody fuels in the form of pellets and/or chips, which can also be pulverised, as appropriate.

Based on extensive fuel analysis, comprehensive characterisation of the flue gases will be conducted for each fuel. This includes standard combustion products (e.g. CO, CO_2, NOx, SOx, etc) in addition to entrained metal aerosols (via ICP-OES) and submicron particulates (using DMS500).

This will identity the key species and pollutants from the combustion process for each fuel and aid the determination of their impact on the solvents and operation of the carbon capture plant under waste-to-energy conditions.

Part of the PACT facility at the University of Sheffield. Credit: PACT

European Union
European Regional Development Fund

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Accelerating CCS Technologies

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