# OxyCoal UK Phase 2 successfully completed

**As we have previously reported, Vattenfall has participated in the OxyCoal 2 project led by Doosan Babcock, part of Doosan Power Systems. At its R&D Centre site in Renfrew, Scotland, the company has modified its existing test facility with the addition of equipment for oxyfuel combustion purposes. The Clean Combustion Test Facility (CCTF) has successfully demonstrated a coal-fired oxyfuel combustion system of a type and size applicable to new build and retrofit advanced supercritical oxyfuel plant.**

Having completed close to 100 individual tests, the firing trials in the CCTF have demonstrated the successful operation of the 40 $MW_t$ OxyCoal$^{TM}$ burner, both in air and in oxyfuel mode. Safe and stable operation has been achieved across a wide operational envelope. $CO_2$ concentrations of up to 85% (v/v dry) have been achieved at the economiser exit.

**Operating experience**
In the project, a lot of emphasis has been placed on gaining oxyfuel operation experience. Flame stability, load turndown, start-up, shutdown and the transition between air- and oxyfuel-firing have been thoroughly investigated and demonstrated.

Three different methodologies for the safe and smooth transition between the air and oxyfuel firing modes have been developed and proven. Turndown from full load to 40% load has been demonstrated. The flame was stable and well rooted across the whole load range, although the length decreased as the load decreased, as in air firing.

**Observations of flame and heat transfer**
The combustion efficiency has been investigated by analysing the amount of unburned carbon in ash samples and the amount of carbon monoxide in the flue gases. The analyses show that the combustion efficiency under oxyfuel firing is comparable to that under air firing.

The flame has been observed using both imaging equipment and viewing ports located along the furnace side wall. Flames produced during steady-state conditions were well rooted to the flame holder and similar in shape across a wide range of operating conditions for both air and oxyfuel firing. However, some differences between oxyfuel and air firing have been observed and they relate to the width of the flame. Oxyfuel flames in the OxyCoal$^{TM}$ burner are narrower than those observed under air firing, which is consistent with expectations based on the CFD modelling undertaken during the burner design phase of the project.

Results from heat flux measurements show that the oxyfuel flame radiates less heat to the walls in the first half of the furnace, in comparison to firing in air. In the second half of the furnace, the heat fluxes are similar. The differences in heat flux profiles are explained by a combination of the mass flow through the burner and dust concentration in the furnace under the different firing modes.

**Behaviour of $SO_x$ and $NO_x$**
It might be expected that $SO_2$ concentration under oxyfuel firing would increase relative to the air-firing value in the same ratio as $CO_2$ concentration increases, i.e. five or

greater. Air and oxyfuel-firing $SO_2$ values expressed as mg/MJ would then be coincident. However, analyses of the flue gas composition have shown that oxyfuel firing produces concentrations of $SO_2$ about three times higher than those produced when firing in air. Consequently, when $SO_2$ is expressed as mg/MJ the oxyfuel values are lower than the air-fired values, since $SO_2$ is removed from the process by adsorption in the fly ash and dissolution in the direct contact coolers.

Similarly, NO concentration under oxyfuel firing is approximately three times the value observed during air firing. Consequently, on a heat input basis (mg/MJ), the oxyfuel-firing economiser exit NO values are approximately one half of the values obtained during air firing. In both air and oxyfuel firing, there is a tendency for economiser exit NO concentrations to increase with increasing stoichiometric ratios. Effective NO formation under oxyfuel firing is reduced compared with air firing due to the elimination of thermal $NO_x$ formation and the fact that re-burn reactions reduce recycled NO.

**Pleased with the cooperation**

For Vattenfall, the tests in the CCTF at Renfrew are a good complement to the test activities in our own pilot plant at Schwarze Pumpe. We can make important comparisons and thereby be more certain about some of the findings. In the OxyCoal 2 project, bituminous coal has been used as fuel, which is an important difference compared to Schwarze Pumpe, where we use lignite as fuel. Nevertheless, comparisons regarding combustion and heat transfer can be made and similarities and differences are noted.

Göran Lindgren, CCS R&D Programme Manager, expresses his delight: “We really appreciate the cooperation and the dialogue that we have with Doosan Babcock and the other participants in the OxyCoal 2 project. Oxyfuel has yet again been validated on a large scale and we are convinced that it is a useful technology for a CCS demonstration plant.”

Besides Vattenfall, Scottish and Southern Energy, E-On UK, DONG Energy, EdF, Air Products, Drax Power, Scottish Power and UK Coal have sponsored the project. The University of Nottingham and Imperial College of London have contributed knowledge and research. DECC, the UK Department of Energy and Climate Change, has also given the project financial support.