Oxyfuel
Combustion
Conference 3

3rd Oxyfuel Combustion Conference

Conference Summary

Ponferrada, Spain.

9th - 13th September 2013

Evaluating technology options to mitigate greenhouse gas emissions

Introduction


Museo Nacional de la Energía

The Oxyfuel Combustion Network was set up in 2005 with the aim of providing an international forum for organisations with an interest in the development of Oxyfuel Combustion technology. The meetings soon gathered momentum and support from a niche community within the capture fraturnity. The meetings soon became very well attended with so much new information potentially to be shared, that the decision was made after only the 3rd workshop to take the series to a conference level. This enabled a much larger gathering of experts from both industry and academia to reap the benefits of having new information and results presented in parallel sessions. No events of this size and significance had previously been available to the Oxyfuel community. The technical expertise, experience and passsion of the Steering Committee has guaranteed the integrity and excellence of the series, establishing it as the go-to event in the oxyfuel world.

The third in the Oxyfuel Combustion Conference series was held in Ponferrada, in the North West corner of Spain. The area is home to the conference hosts Fundación Ciudad de la Energia' (CIUDEN). Both the Foundation, IEAGHG and the OCC series share the ethos of collaboration to drive forward essential technologies to help reduce anthropogenic greenhouse gas emissions making them perfect partners to create an exciting and significant conference.
CIUDEN's Technology Development Centre for CO_2 Capture (es.CO_2) is located close to Ponferrada and a visit to the facility where the main capture process is oxycombustion, provided a fitting climax to the conference.

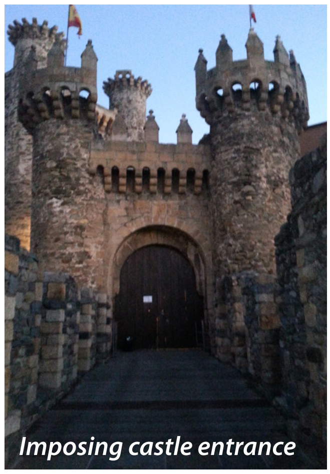
Ponferrada itself has a history long history of mining dating back to the Roman era where gold was the major mined resource and in 1918 the Ponferrada Mining, Iron and Steel Company was founded. The Spanish National Energy Corporation (ENDESA) was founded later in 1944 and in 1949 it opened Spain's first coal-fueled power plant in Ponferrada. This plant has now been fully restored to it's former glory and was the very apt location of the welcome reception (sponsored by Foster Wheeler).

New to the OCC Series, was the addition of two mini-workshops on high temperature corrosion and oxy-FBC development as well as a special session on industrial applications of oxyfuel combustion technology. As before OCC3 also hosted the 5th Oxyfuel Working Group (OFWG) Capacity Building Course.

The venue for the conference was split over two locations each within a 3 minute walk of the other. The opening, keynote speeches, plenary and closing sessions were held in the Bergidum Theatre with the auditarium able to accommodate the 312 delegates. It was then a short walk to the 12th century Castillo de los Templarios (Templar Castle) for the 4 streams of the techncial sessions.

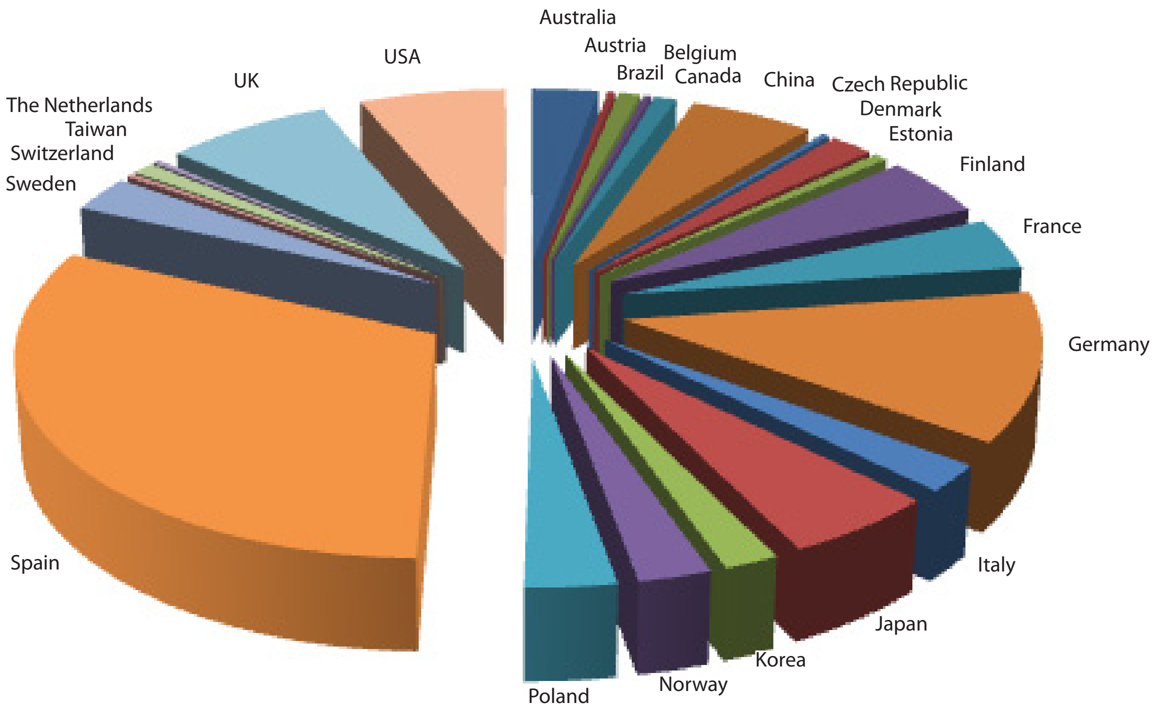

Keynote speech in the Bergidum Theatre


The old Chapel in the Castle hosted Stream A


Imposing castle entrance

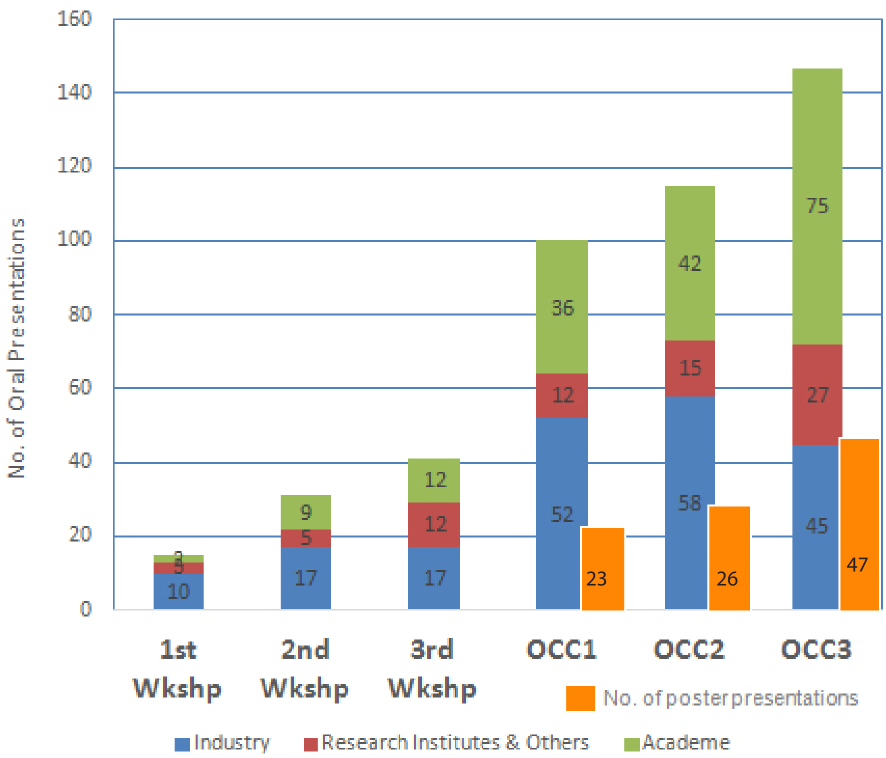
Conference Statistics

The conference was the largest to date and was attended by some 312 delegates representing 24 countries , with 120 coming from industry, 105 from academe and the remaining 87 from research institutes & others.



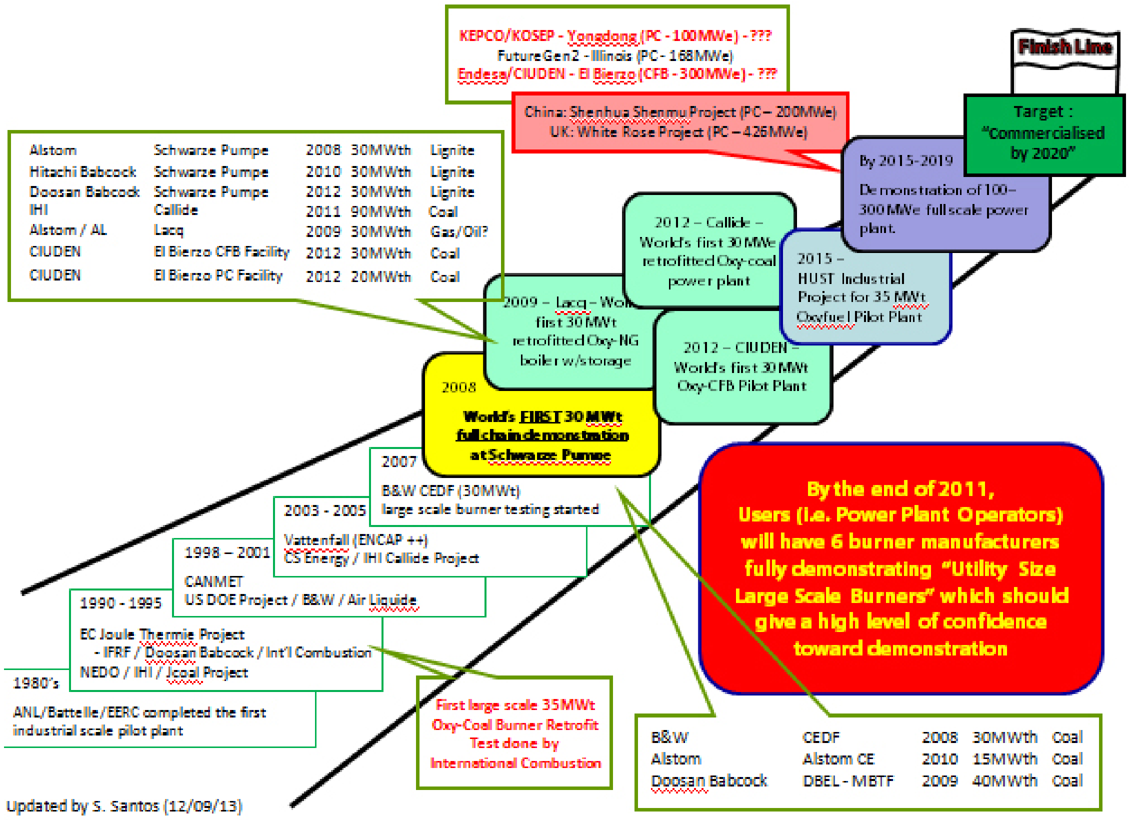
Delegate by country representation

The graph to the right shows the growth of the abstract submissions and number of presentations and posters throughout the oxyfuel workshops and OCC conferences. OCCC3 received 191 abstract for consideration and each of these were peer reviewed by two subject experts resulting in 147 being allocated to oral presentations. These were given as two plenary sessions, six technical sessions, each with 4 parallel streams to include the two mini-workshops and special session on oxyfuel in industry. In addition 47 abstracts were allocated as poster presentaitons, the two hour dedicated poster session held within the central courtyard of the Templar Castle provided the perfect backdrop to dislpay the posters and attendance to the session was high with much intense conversation in evidence.



Oxyfuel Combustion Technology – Challenging Road to Demonstration & Commercialisation

The enormous investment in R,D&D over the past 10 years has born its fruit and made a significant contribution to the maturity of the oxyfuel combustion technology for power plants with CO_2 capture. Work has been done in all aspects of operation which include the fuel preparation, air separation unit, oxyfuel burners and boiler, flue gas processing, and CO_2 processing unit. One of the key messages from the different stakeholders who attended the OCC3 is that this technology is ready for demonstration. How to achieve the goal to build an oxyfuel combustion power plant with CO_2 capture and storage is an important priority in the next 5 years. Failure to achieve this goal means losing the progress made during the last decade. The figure below presents the challenging road to demonstration and commercialisation – some of the key milestones achieved so far are briefly described.



Today, the Callide Power Station retrofitted with oxyfuel combustion technology and equipped with two trains of ASU and one of CPU processing a part of the flue gas and capturing about 20% of the total CO_2 emitted from this plant, is now the largest operating oxyfuel power plant in the world. This could be classified as mini-demonstration plant rather than a large scale pilot plant. We are continuously learning from this project and a message from this technology demonstration is that oxyfuel combustion can be retrofitted. Operating Callide Oxyfuel Power Plant reliably and achieving a cumulative 10,000 operating hours by November 2014 will be its biggest achievement and contribution to the development of this technology. OCC4 will give a platform for CS Energy to share their operational experiences.

Total's Lacq project is unique in such a way that a natural gas boiler has been successfully retrofitted with oxyfuel combustion. The operation of the Lacq boiler, from July 2009 to March 2013, providing steam to the natural gas processing plant was also able to cumulatively capture and transport >50K tonne of CO_2 and inject it at the Rousse depleted gas reservoir. One of the key achievements of this project is demonstrating that dried CO_2 with 5-7% O_2 and small amount NOx (<0.1%) could be transported using carbon steel pipe and injected into a depleted gas reservoir without any cause for concern. Post-injection monitoring at Rousse storage is now on-going. This provides an opportunity to learn and develop storage guideline methodology for oxyfuel combustion technology.

Another important milestone in the development of oxyfuel combustion is CIUDEN's 30MWth oxy-CFB test facility. This is the largest operating oxy-CFB boiler worldwide and has contributed significantly to the design validation and optimisation of the first generation CFB boiler for demonstration and development of next generation boilers. Work is on-going with an aim to develop collaborative programme for long term reliability testing and evaluation of other fuels including biomass and petcoke.

Europe once led the development of oxyfuel combustion technology. The Compostilla and Janschwalde Demonstration Projects have showcased the readiness of this technology and could have provided a very good platform to demonstrate to the world the viability of oxyfuel technology in the commercial environment. The experiences in developing these projects has established that equipment manufacturers and engineering companies are now ready to build these plants and provide performance guarantees. The shelving of both projects is a considerable set back. It should be noted that show stoppers are not due to technology barriers emphasising again that this technology **is** ready for demonstration.

The future of the technology…

Vattenfall has significantly contributed to the development of this technology and successfully brought this technology to its current maturity. As a result of this investment – the 30MWth Schwarze Pumpe pilot plant was built and operated to evaluate various suites of technology options for oxyfuel combustion power plants. Together with CIUDEN's test facility – both assets have achieved their objectives of validating the design of the first of a kind (FOAK) oxyfuel combustion power plant for large scale demonstration.

Both facilities still have important roles in supporting future development of large scale demo projects. It is important to highlight the need to maintain these facilities to support any work for further oxyfuel combustion power plants with CCS.

The progress of FutureGen2 was reported during the conference. Major accomplishments include the:

- Purchase of the Ameren assets by the Alliance,
- Power purchase agreement signed,
- CO_2 liability management addressed,
- Environment impact statement issued.
- Lean financial arranger in place.

The final investment decision for FutureGen2 projects to proceed will be taken in 2014. This project has really given hope that this technology will be demonstrated before the end of this decade.

In the UK, the White Rose project is gathering pace, this will be a state of the art new build coal-fired power station fully equipped with CCS technology. It will be built at the existing Drax power station in Northern England and plans to capture 90% of emissions. The 426MW oxy-combustion demonstration project has been selected as one of two preferred bidders in the UK Governments CCS Commercialisation Programme and is now at the Front End Engineering and Design (FEED) phase. Two million tonnes of CO_2 captured by the project will be transported by the National Grid pipeline for permanent storage under the North Sea. The project is led by Alstom, Drax, BOC and National Grid.

Three different large scale Chinese projects were presented during OCC3 in detail. Work is on-going to build two pilot plants with size equivalent to 30-40MWth and are an important indication of interests by Chinese power companies and equipment suppliers to catch up with the development of this technology. The development of 200MWe demonstration by Shenhua Guohua Power Co. is clearly the right direction for the future.

A final thought…

"OCC3 has clearly showcased how far we have come on the development trail. It is important that planned large scale FOAK demonstration projects to go ahead. These are important steps in the next five years to come in order to gain the confidence of this technology"

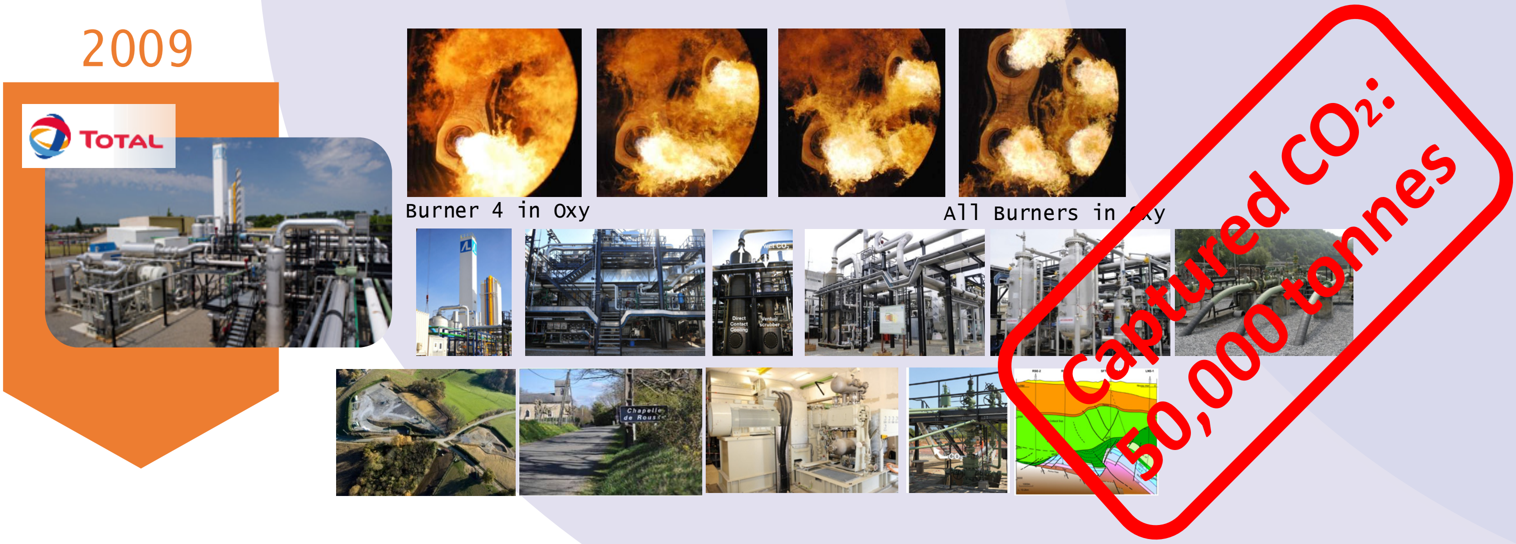
The Value of Large Scale Demo and Pilot Plants in the Development of Burner and Boiler Technologies for Oxyfuel Combustion

Vattenfall hosting OCC1 (2009); Callide Oxyfuel Projects hosting OCC2 (2011) and CIUDEN hosting OCC3 (2013).

A common denominator across our conference hosts is that they have each spearheaded the development of oxyfuel combustion technology for power plants with CCS worldwide. Together with Total's Lacq project – they have shared with the oxyfuel community their experiences gained in building and operating these large scale pilot plants that has helped this technology to mature and become ready for demonstration.

Sharing of Technical knowledge....

Experience in CO_2 Storage.....



Top compliation: Vattenfall's Schwarze Pumpe CO_2 capture plant. Images repoduced with kind permission from Alstom, Babcock & Wilcox, Doosan Babcock and Hitachi Power
Bottom compliation: Total's Laq project. Images reproduced with kind permission from Air Liquide and Total

Industrial facilities for technological development and technical training ....

2011

A real demonstration plant.....

2012

The Conference Sponsors

GOBIERNO DE ESPAÑA | MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO | ciudad de la energía

FOSTER WHEELER

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Top compliation: CIUDEN's Technology Development Plant. Images repoduced with kind permission from CIUDEN
Bottom compliation: CS Energy Callide Plant. Images reproduced with kind permission from Air Liquide and Total

ASU: Meeting the Oxygen Demand of the Oxy-fuel Combustion Power Plant

The air separation unit (ASU) is a century old technology with the wealth of experience that comes with it. Despite being a mature technology, its application of providing the oxygen to the oxyfuel combustion power plants has provided challenges where the ASU technology needed to evolve and meet the future demand of its customers in terms of cost reduction, operation flexibility and efficiency improvement.

Various presentations from OCC3 have reported that today's REFERENCE 1000MWe oxyfuel coal fired power plant will require at least 3 trains of 5000mtpd class ASU. However, in the commercial future of oxyfuel combustion technology, industrial gas companies should be able to deliver at least 2 trains of 8000 mtpd class ASU for the same amount of oxygen needed.

It is important to realise that today's current state of the art and largest operating single train ASU only delivers ~3900mtpd of O_2. These are typically seen in GTL/CTL, IGCC and other energy applications; and are classed as large ASU's. In this regard, for oxyfuel combustion power plants, development of a new class of ASU was required – i.e. the "very large ASU".

Development of Mega ASU's for oxyfuel combustion coal fired power plant have been designed and customised for the specific requirement of delivering oxygen with low pressure (< 1 barg), low purity (95-97% O_2) and high energy efficiency.

In terms of energy efficiency improvement, several cycles based on dual reboilers or triple columns have been presented. This has been reported since OCC1(2009). Similarly, discussion on the operation flexibility has been analysed based on the number of ASU trains and the arrangement of the number of compressors per train. Additionally, concepts of using liquid air or liquid oxygen has been presented to provide wider flexibility and energy storage concepts. These are introduced in OCC2 (2011).

In OCC3, refinement of the different concepts introduced in the past conferences were presented. These include more detailed discussion and assessment on the use of cold compression technology together with liquid storage concept, liquid swapping for flexible operation, and recuperative vapour recompression distillation cycle. It can be concluded that the ASU could be designed to operate flexibly achieving between 3-5%/min of load changes even without the liquid storage incorporated. The use of the liquid storage concept to provide better energy management with a wider range of flexibility is strongly dependent on the cost of electricity to be sold in the market.

Just as important an area of development is the integration of the ASU to the power plant and CPU, this was also comprehensively discussed during the conference. Integration will play an important part in reducing the energy penalty of producing oxygen. In summary, industrial gas companies could deliver an ASU today with ~160 kWh/t O_2 (ISO conditions). In the future, with integration, it is aimed to deliver an ASU with 130-140 kWh/t O2 (ISO conditions) by 2020.

What's new in OCC3 is the introduction of the concept of "high pressure oxygen supply". This is an important development to meet the increasing interest in the development of oxyfuel fired gas turbine. What was missing in OCC3 were the presentations related to new novel oxygen production which include the OTM, ITM and CARS.

The ASU development has played an important role in the demonstration and commercialisation of oxyfuel combustion power plant with CCS. It could be concluded from various presentations of the OCC series that industrial gas companies have developed several technical solutions to meet the demand of the customers for oxyfuel combustion power plant. The ASU delivering the oxygen at lowest cost, reduced energy penalty and capable of flexible operation will remain a major focus for discussion in the near future.

Poster session

Closing session

José Carlos de Dios Director of the CO_2 Geological Storage Programme CIUDEN

CPU – The New Frontier in the Development of Oxyfuel Combustion Power Plant

From the very first day of the OCC3 conference, delegates heard that the CO_2 processing unit or the CPU should be designed to handle any flue gas generated by the oxyfuel combustion boiler…

Looking at it in detail, the CPU consists of two parts, the warm and the cold. The warm part consists of the flue gas condenser, compression of the flue gas, removal of NOx/SOx, flue gas drying, and Hg/trace elements removal. Whilst the cold part consists of the cold box (mainly the HEX, flash and distillation column), the final compression and handling of the CPU vent.

The learning at OCC3 showed that several vendors have developed or implemented many different solutions to meet the challenge of flue gas handling… Several pilot plants have been evaluated and it have shown that all solutions work! Since OCC2, the cumulative number of operating hours of CPUs has increased tremendously. This includes development work implemented at the mobile CPU units of Alstom, Air Products, Praxair and CANMET; and pilot plants built and operated at Schwarze Pumpe (Air Products and Linde), Lacq (Air Liquide), CIUDEN (Air Liquide), and Callide Power Plant (Air Liquide).

Major achievements over the past decade of CPU developments include

- Following the first publication by Air Products regarding the NOx/SOx reaction during compression; several vendors have developed a suite of technology options to handle both NOx and SOx in the flue gas. These include:
  - Sour Compression Process developed by Air Products
  - LICONOX process developed by Linde
  - Sulfuric Acid Wash or Activated carbon process developed by Praxair
  - CryoCap process developed by Air Liquide
- Refrigeration cycles operating near the triple point of CO_2 using impure CO_2 is currently the most favoured technology to remove the non-CO_2 components in the cold box. We have learned that very high purity of CO_2 could be achieved with minimal impact to the CAPEX or OPEX using this method.
- Solutions to achieve a CO_2 capture rate of greater than 98% is possible by capturing the remaining CO_2 from the CPU vent using either membrane, PSA or VPSA technology.

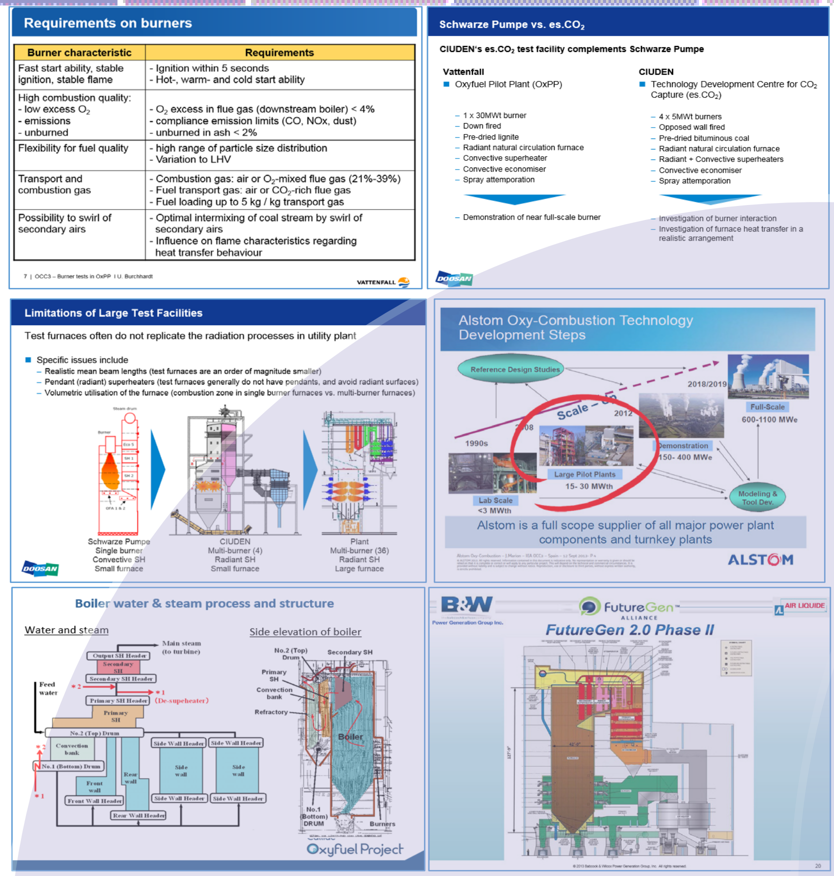
What are the remaining challenges?

- NOx chemistry and its behaviour in the CPU will remain an important topic of discussion in the near future.
- Specification for CO_2 purity remains an open topic. It is not to be expected that this will be resolved until we have gained knowledge and experience from various demonstration plants. The pilot plants have demonstrated that equipment vendors are ready to face the challenges of meeting these specifications. Questions remains if a high purity CO_2 is a necessity to operate CCS safely and reliably.

The most imminent challenge is how to bring the CPU development forward. In conclusion, it is how to build on from the gains of operating the different pilot plants to reduce the CAPEX and OPEX; and this can only be achieved by bringing the technology to a demonstration scale power plant.

Dinner on the final day

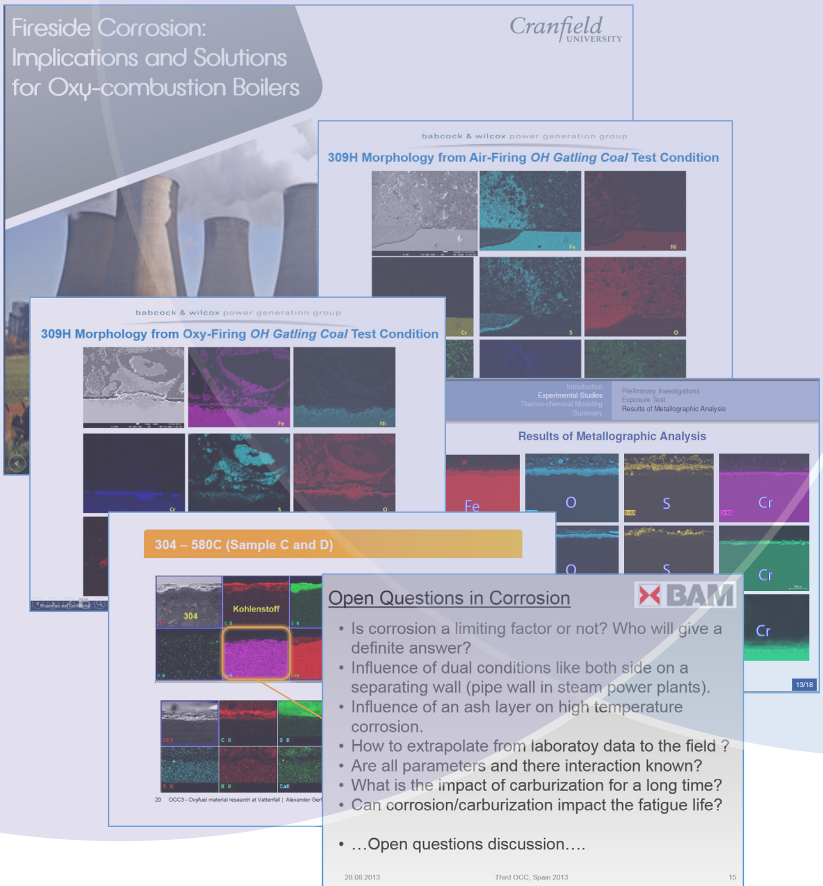
Key Highlights from OCC3

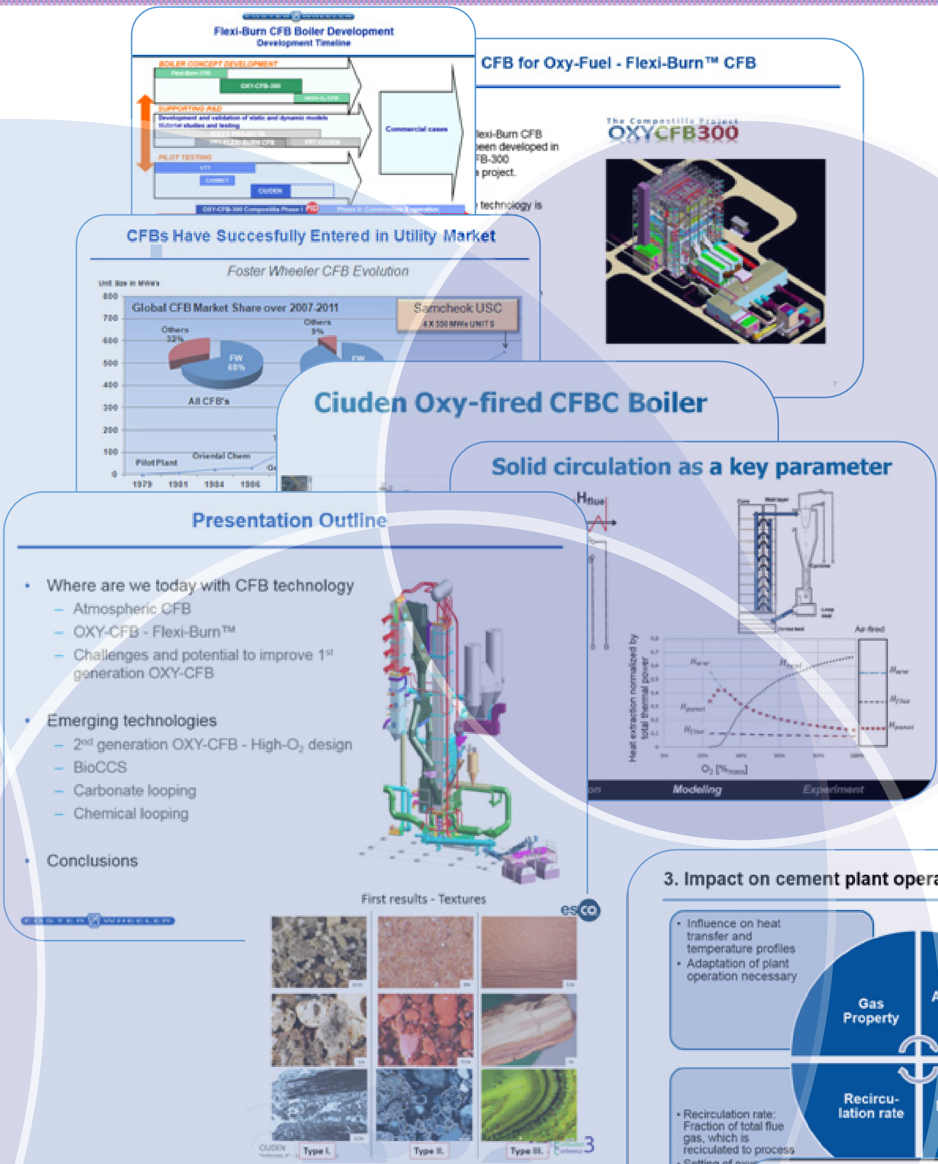


The very heart of oxyfuel combustion research since the 1980's is the burner and boiler development. What have various large scale pilot facilities accomplished? – they have successfully developed the guidelines in the design and operation of burners and boilers for oxyfuel combustion. Future work will require the improvement in modelling tools to allow good predictability of the combustion behaviour and heat transfer phenomena of a full scale utility boiler.

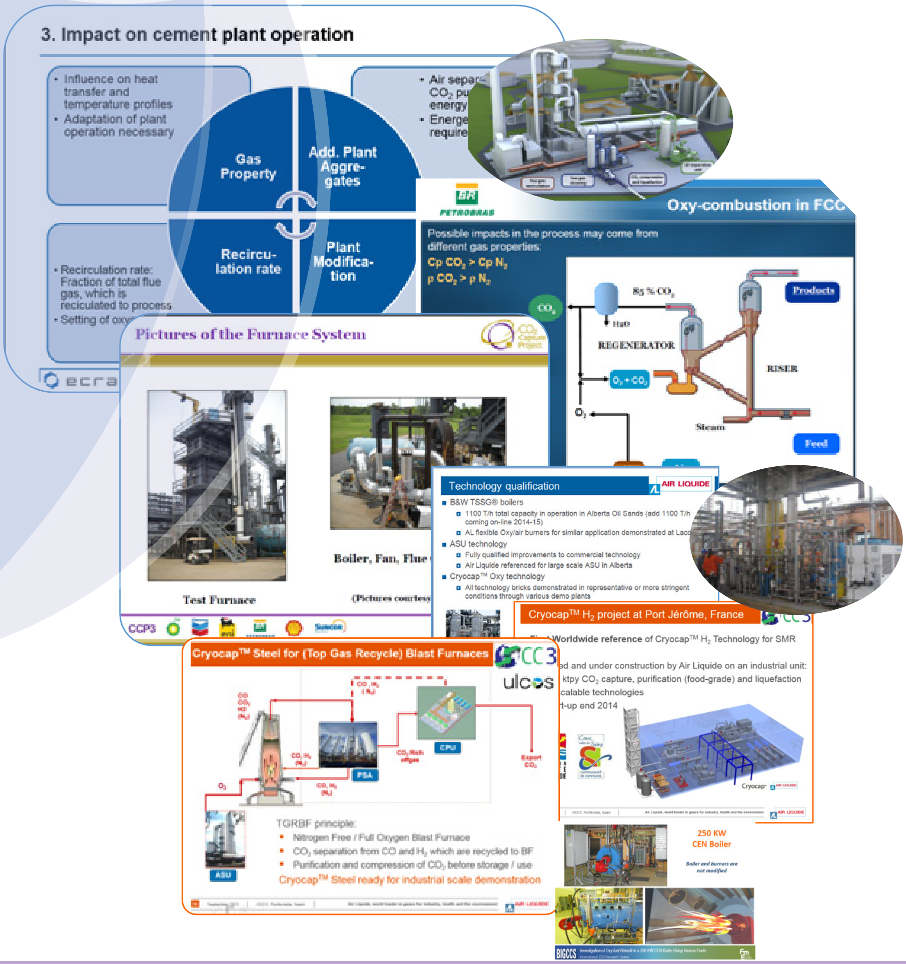
The importance of materials selection and understanding the corrosion phenomena were highlighted in the Corrosion Workshop during OCC3. Most work is focused on the development of advanced materials suitable for advanced USC boilers for oxyfuel combustion.

A follow up to this workshop will be held in 2014





One of the main objectives of OCC3 was to look onto the progress and development of oxy-FBC technologies. Thus, in collaboration with CIUDEN – the 3rd Oxy-FBC Workshop was included in the programme. The development of FBC has also reached the same level of maturity as compared to its oxy-PC counterpart. Current generation will be designed to be flexible in both air and oxy mode. One of the emerging developments in this area includes the use of high O_2 oxidant.



The importance of industry CCS was highlighted at OCC3…

Various aspects (boiler, ASU and CPU) to the development of oxyfuel combustion are also considered for other industries.

- Kiln (cement & lime industry)
- FCC (oil refining industry)
- Fired heater (oil refining industry)
- OTSG/boiler (oil refining industry)
- SMR (H2 industry)
- OBF (steel industry)

5th OFWG Capacity Building Course

A Successful Course

With approx. 60 delegates, representing 13 countries, drawn from universities and power stations, the 5th Oxyfuel Capacity Building Course was considered a complete success. The staff from CIUDEN and in particular Ms Sandra María Ramos Vigo, were integral to the success of the course and must be thanked for their efforts. Congratulations to all of the excellent lecturers out of Industry and Academia from Australia, China, Europe & US who kindly donated their time for the course. Their presentations can be found through the following link: http://www.ifk.uni-stuttgart.de/allgemeines/Veranstaltungen/Oxy-Fuel_Capacity_Building_Course_2013/index.html

Attendees and presenters at the OFWG Capacity Building Course

Panel discussion during the course

The 5th Oxy-fuel Capacity Building Course was held on the days prior to the 3rd Oxyfuel Combustion Conference in Ponferrada, Spain (September 8th/9th, 2013) and was coordinated by Joerg Maier from IFK, University of Stuttgart, Germany. The course was free, but delegates had to cover their travel and accommodation costs.

The Oxyfuel capacity building course was first launched first in 2009 and has since then been held in Daejeon, Korea, Beijing, China, Yeppoon, Australia and Tokyo, Japan. The course is designed as stand alone, covering status, theory and practice, and to provide background knowledge to delegates new to oxyfuel technology for carbon capture and storage. The target audience for the course is engineers from power generation industries and university research students. When coupled with the OCC3 conference, students get a solid introduction to oxyfuel combustion before attending the full conference where more detailed infomation will be presented.

This 5th OFWG Capacity Building Course was funded by IEAGHG from the budget of the OCC3 with the support of CIUDEN, Foster Wheeler, Vattenfall, Alstom and Air Liquide

Summary of the 5th OFWG Capacity Building course provided by Joerg Maier, University of Stuttgart, IFK, Germany

University of Stuttgart
Germany
ifk

Site Visit

To conclude a successful OCC3 Conference, CIUDEN organised a site visit to the Technology Devolopment Centre for CO_2 Capture (es.CO_2) on Friday the 13th. During this tour the attendees had the opportunity to visit the largest oxy-FBC pilot plant operating in the world and check first hand some of the issues discussed during the technical sessions.

Due to site restrictions, the maximum number of attendees for the visit was limited to 50 people in each group. Four buses transferred the attendees from hotels to es.CO_2 Centre throughout the day. Once in the Centre, each group of 50 was split into three groups of 16 to17, this ensured ample opportunity to ask the guides questions and to receive a more personal tour to include the control room.

The site began operation in 2011 as a not-for-profit facility allowing research by any company or institution and is currently hosting a biomass gasifier, a 3km CO_2 transport rig in addition to the oxy-FBC plant.

The site also hosts the Pilot Plant for CO_2 Injection in Soils (PISCO$_2$) and delegates were able to visit the installation which is curently monitoring bioindicators which are sensiitive to CO2. Small amounts of CO_2 are injected into controlled areas containing a variety of soils and the effects on bacteria, fungi, insects and plants are recorded.

Delegates being shown the control Room

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