

REPORT OF THE “CLEAN COAL AND CARBON CAPTURE AND STORAGE WORKSHOP”

Meeting Report, 2-3 February 2006,
London

Event organised and sponsored by:



*Ambasciata d'Italia
Londra*



THE UK ENERGY RESEARCH CENTRE

The UK Energy Research Centre's (UKERC) mission is to be the UK's pre-eminent centre of research, and source of authoritative information and leadership, on sustainable energy systems.

UKERC undertakes world-class research addressing the whole-systems aspects of energy supply and use while developing and maintaining the means to enable cohesive research in energy.

To achieve this we are establishing a comprehensive database of energy research, development and demonstration competences in the UK. We will also act as the portal for the UK energy research community to and from both UK stakeholders and the international energy research community.

The Meeting Place

The Meeting Place provides for the Centre's networking activities and brings together academics and stakeholders from different disciplines and professions.

The core objectives of the Meeting Place are to:

- bring together members of the UK energy community and overseas experts from different disciplines, to learn, identify problems, develop solutions and further the energy debate
- promote interdisciplinary working and engagement of stakeholders of various professions working in energy-related areas
- provide a forum for collaborative projects addressing key issues
- develop new synergies between different strands of energy research
- build up the strengths of the research community

Background

This workshop was coordinated and sponsored by the Italian Embassy and the UK Energy Research Centre (UKERC), in association with the UK Carbon Capture and Storage Consortium (UKCCSC).

The aim of the workshop was to strengthen UK/Italian collaboration as a basis for submitting joint projects under the EU's 7th Framework Programme, and in general to further international cooperation on carbon capture and storage.

Three specific work areas were identified:

- a) Coal gasification and hydrogen production
- b) Coal combustion with carbon dioxide capture
- c) Geological storage

Following a networking lunch, the first day of the workshop involved a half day of keynote presentations. These covered the state-of-play with respect to carbon mitigation and technology strategies at EU, Italian and UK levels, legal issues, research collaborations and opportunities, future research requirements and the potential of clean coal and carbon capture and storage technologies. The second day began with presentations on the opportunities that a hydrogen economy and China might provide for deployment of clean coal and carbon capture and storage technologies, as well as other investment opportunities. Participants then split into three groups covering:

- a) Coal gasification and hydrogen production
- b) Coal combustion with carbon dioxide capture
- c) Geological storage

Each working group was required to:

Review current activities and active UK-Italy collaborations
Identify common research interests
Prioritise opportunities for future collaborations
Note any potential barriers to joint working

This report, documents relating to the workshop and all presentations given at the workshop can be downloaded from the UKERC website:

<http://www.ukerc.ac.uk/content/view/220/115>

Day 1 – Keynote presentations

The workshop was opened with a welcoming address from the **Ambassador of Italy, H.E. Giancarlo Aragona**. This was followed by a presentation from **Sir David King, Chief Scientific Adviser to the UK Government**, titled “Potential of CCS as part of global climate change mitigation strategy”. Sir David began by setting out the global dimensions of the carbon mitigation problem and set out his arguments as to why carbon capture and storage has a critical role to play in addressing this problem, both within the UK and globally. He discussed the capacity and potential of CCS to deliver carbon reductions and the opportunities for the application of CCS technologies within the UK and abroad, most particularly in China. To realise these opportunities, Sir David pointed out some of the barriers that need to be overcome, in particular the need to incorporate CCS within the EU emissions trading scheme, to reduce costs, to bring about public acceptance and to put in place appropriate regulations and policies. To enable incorporation within EU ETS, more information is needed on the reliability of long-term storage. For the successful deployment of all carbon mitigation technologies and measures, it is necessary to establish greater certainty within markets. This can be achieved through the establishment of longer term and more stable policy at all levels, which underlines the importance of stable long-term international agreements. There is also a significant skills gap to address.

Sir David mentioned the various UK initiatives recently established to encourage realisation of the potential of clean coal and CCS technologies. These include the set up of the Carbon Capture and Storage Association, the UK Carbon Capture and Storage Consortium, the Energy Research Partnership (ERP), and the Dti's Carbon Abatement Technologies Strategy (CATS).

In the discussion that followed Sir David King's talk, the issue of permanence of carbon capture and storage was raised. To what extent must this be proved and over what timescale? A participant pointed out that it would be ideal to be reassured that carbon dioxide can be stored safely and securely for millennia but such proof might only be achieved over a lengthy timescale – with global warming already upon us, we can not afford to wait. Sir David King acknowledged the dilemma but stressed that demonstration projects were absolutely necessary.

Mr Angel Perez-Sainz, Head of the Unit for Energy Production and Distribution Systems, DG Research of the European Commission, gave a presentation on “Zero emission strategies for coal at EU level”. Angel began with setting out the issues and challenges facing the EU in mitigating carbon emissions and improving security of supply. He gave an overview of activities the Commission had undertaken in previous Framework programmes within the field of carbon capture and storage. Framework Programme 6 witnessed a step change in funding support compared to the previous programme, with 5 times more funding committed – a total of some 70m Euros. Angel talked about the various projects currently taking place under FP6 as well as other initiatives such as the

ZEP Technology platform, ERA-NET (FENCO) to improve co-ordination of Member States and the Carbon Sequestration Leadership Forum to further international cooperation. Clean coal technologies and CO₂ capture and storage technologies for zero emission power generation are priorities under Framework Programme 7. With input from the Member States, the Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) consists of an Advisory Council and a Coordination Group, both supported by a Secretariat, to develop a Strategic Research Agenda and a Deployment Strategy for carbon capture and storage technologies. Angel also talked about initiatives to improve EU and international cooperation including the DYNAMIS project, ERA-NET (FENCO), the IEA framework, CSLF membership and bilaterals.

Angel concluded his presentation by explaining that to consolidate its leading position in Clean Power Generation, Europe needs to:

- Boost investment on research and technology development
- Continue to integrate fragmented, private and public (national, European) efforts
- Work together towards a vision shared by all relevant stakeholders, including European society, economy and governments
- Face jointly as Europeans the challenges and opportunities of international cooperation and competition
- FP6 has provided a solid basis

The Commission has set up the Zero Emissions Technology Platform and FP7 in order to address these needs outlined above in the months and years to come.

In the discussion that followed Angel's talk, the topic of a common EU energy policy surfaced. Angel said that he believed sufficient political momentum now existed which would make it possible to set up a Working Group to enable Member States to put forward their ideas – this could lead to a Green Paper for open debate. The issue of slow policy development was raised. Angel felt that decision-makers are currently short on information but with adequate scientific input the policy process would be accelerated. A participant questioned whether the Commission's pluralist decision-making process was a hindrance to progress. Angel responded that indeed it was sometimes difficult to work with the involvement of so many stakeholders but he stressed that structures and the input of the stakeholder community were essential for successful policy development.

The final point raised by the audience related to the question of including carbon capture and storage within the EU ETS. The participant argued that it would be sensible to put regulations or standards in place, ahead of having technologies or systems proven, and these standards would drive industry to deliver solutions. An example of this approach is in California where automobile emissions regulations

were put in place ahead of catalytic converters being available. Angel agreed this approach seemed sensible but pointed out this is not always the approach with policy-making.

Professor Sergio Garibba, Director General of Energy and Minerals Resources of the Italian Ministry of Productive Activities, gave a presentation on “The Role and Perspective of Coal in Power Generation in Italy”. Sergio introduced the audience to Italy’s current energy mix for power generation, related issues and policy trends.

Sergio summarised:

Short-term: increasing coal use for power generation

- Switching from oil to clean coal technology
- Reducing carbon intensity and pollutants
- Maintaining existing power plants in operation

Long-term: transition to near-zero emissions

- Advanced materials
- Ultra-high efficiency systems
- CO₂ capture and storage

Sergio set out some new issues that Italy is now facing: emissions trading and National Allocation Plan at EU level (Directive 2003/87/EC); development of a long-term energy strategy (to 2030); development of a new technology roadmap for coal combustion and zero emissions. Energy security is high on Italy’s agenda – the importance of security was highlighted recently when Italy suffered as a result of the reduced gas supply from Russia to the Ukraine.

Sergio outlined the R&D situation in Italy, pointing out the problem of high fragmentation of R&D activities within Italy. He suggested a need for improved cooperation between universities, institutes and industries within Italy as well as improved cooperation at EU and international levels. The issue of funding is also of great importance. Sergio also set out the elements of the Sardinian coal initiative.

There was some discussion on the US FutureGen Project, a \$1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant. The question was raised whether the EU should work with the US on this and if so, whether this should be on an EU basis or on a national bi-lateral basis. Key questions would be when, what, where and how to build.

Steven Koonin, BP's chief scientist, gave a talk titled, "The Challenge of Carbon Mitigation". Steven began his presentation by pointing out that our energy future will be determined by: demand growth; environmental constraints; energy supply challenges; security of supply issues; and technology. Global demand is projected to increase by just over 50% over the next 25 years. Conventional reserves of coal are so plentiful they could easily meet this increase in demand and could indeed meet demand for a couple of hundred years. Much of this coal is located in the Former Soviet Union, North America and Asia Pacific.

Steven pointed out some key facts on global warming – with a key message being that global emissions would have to be reduced by more than 50% to counteract the projected increase in demand and to stabilise CO₂ concentrations at 550ppm. Modest reductions can only delay the growth in concentration i.e. buy time. 21st century emissions will be more important from the developing world than the developed world, with total emissions of the developing world surpassing those of the industrialised world between 2015-2025. At this turning point, a 10% emissions reduction from the industrialised world would be offset by less than 4 years growth in the developing world. With GDP so closely correlated to per capita CO₂ emissions, Steven argued that technology would have to be central to the solution.

Steven explained that future options were likely to be shaped by two major axes of concern: carbon mitigation and security of supply. The emphasis on these two axes varies from country to country. Carbon capture and storage and clean coal technologies are likely to be favoured by countries where security of supply is a major concern. Steven believes there are only two technologies which offer a realistic chance of achieving the major carbon reductions necessary: nuclear and carbon capture and storage. He also argued that it would more economically efficient to pursue the power sector ahead of the transport sector for carbon mitigation. However, transport's dependence on oil gives rise to security of supply concerns which may turn out to be the main driver for technological development in this sector.

In the discussion following Steven's talk, questions were raised about the amount of conventional reserves remaining. Koonin explained that the estimation of reserves can often be more of an art than a scientific assessment. A participant pointed out that with continued growth, particularly in China, production rates of oil will have to be very high in the future, and this may cause problems if supply can not satisfy demand despite reserves being available. Steven responded that increased production to meet demand would depend on adequate infrastructure being in place, and there is likely to be an increase in the production of biofuels and the transformation of coal or gas to liquid. Another query was raised about the extent to which we can trust government estimates of government-owned reserves. Steven responded that in the case of Saudi Arabia, estimates could probably be trusted as officials are well informed.

Day 1 – Research Challenges and Responses

Plenary Presentations

Starting off the afternoon session on research challenges and responses, **Ing. Pietro Barbucci of ENEL** gave his talk on “Research needs in coal power generation”. Pietro's overview covered the research areas of efficiency, environment, hydrogen and carbon reduction, capture and storage. Pietro stressed that clean coal would play an increasingly important role in the future, coupled with a reduced dependence on oil and gas. The future of coal-fired generation would depend on continuous improvements in thermal efficiency. This would require new materials and manufacturing compatibilities and significant process efficiency improvements. Process efficiency improvements would come from: ultra supercritical pulverised fuel USC-PF; circulating fluidised bed combustor CFBC; integrated gasifier combined cycle IGCC; external fired combined cycle EFCC . Pietro set out the development requirements for each of these processes.

Research relating to the environment included the development of low-NOx combustion systems. Tightening EU regulations will require solutions to radically reduce micro-pollutants with health effects e.g. volatile organic pollutants, ultrafine particles; and heavy metals. Pietro discussed the importance of understanding the chemistry of these pollutants. He also talked about the different technologies capable of treating the different types of pollutant and how research is looking at the synergistic action of various technologies on these pollutants.

Pietro explained that research into carbon capture and storage is part of a wider strategy aiming to reduce CO₂ emissions in all ways possible including: process residues utilisation; biomass co-combustion; improved efficiency. He also pointed out that a sustainable future for coal could only be achieved with the development of near zero emissions technologies. Together with efficiency increases, cost effective carbon abatement technologies must be developed to support future power generation together with the proof of safe long-term storage and acceptance. This requires developments in: post-carbon capture; oxy-firing to enhance CO₂ capture; multi-function IGCC - hydrogen production.

Nick Otter, Director of Technology and External Affairs at Alstom, gave a presentation titled, “Emission reduction options for coal combustion power plants”. Nick began by giving an overview of the market situation today. Developing countries, most particularly the upsurge in China and Asia, will significantly shape the future outlook. In the long term it is clear that there will be a continuing reliance on fossil fuels, especially in countries like China and India. Over 25% of world-wide capacity is more than 30 years old and much of this is in the developed world. As China is set to overtake the US as the biggest CO₂ emitter by 2015, it is important that the developed world properly engage

emerging market economies in negotiations and agreements to reduce CO₂ emissions.

The implications of these trends and issues are that the clean use of fossil fuels will become more important. Incentives and a stable financial and regulatory framework will be needed to accelerate the deployment of clean fossil fuel technologies as well as other technologies. A broad balanced portfolio approach is needed from policy makers – as there is unlikely to be a single winning technology. Markets and investors also need much more certainty about the future value of CO₂ and the operation and impact of the EU ETS. The engagement of emerging economies will require the use of high efficiency technologies, retrofitting of highly efficient coal plants for CCS and ensuring new plants are capture ready. In the discussion that followed Nick's talk, the need for incentives to encourage the building of 'capture ready' plants was raised. Nick pointed out there is a premium on ensuring plants are capture ready but the cost depends on the type of plant.

Nick emphasised the need for an integrated approach to enable coal combustion systems to achieve non-CO₂ emissions reductions as well as CO₂ reductions, favourable economics and effective operability. Nick argued that such a strategy should work to the long term (2030 and beyond), should consider the needs of different markets and countries and that technologies should be 'in tune' with markets to engage investors. The strategy must contain the overall approach of: increased efficiency, fuel flexibility and re-powering; near zero-emission with CO₂ capture and storage; and links to hydrogen issues or long term sustainable vision. It should also include aspects of research and technology development; component and system validation; demonstration/lighthouse projects; and deployment mechanisms.

Nick then went into the details of various coal combustion technologies for the following:

- Supercritical & Ultra-Supercritical Steam Conditions
 - o Increase efficiency
- Circulating Fluidized Bed (CFB) and "advanced CFBs"
 - o Low costs, low emissions, fuel flexibility
- Emissions Controls
 - o For new and existing, and integrated and post-combustion
- Zero Emission and CO₂ Capture
 - o Post-combustion capture
 - o Oxyfuel (O₂/CO₂ recycle) combustion capture
 - o Chemical Looping

Dr Nick Riley (British Geological Survey – BGS) and Ing. Sergio Persoglia (Istituto Nazionale Oceanografia e Geofisica Sperimentale) gave a joint presentation on “Geological Storage of CO₂ – examples of UK/Italian research collaboration”. Italy has many geographic locations where CO₂ is naturally leaking through the ground. Research institutions across the EU have been using this natural leakage to develop and test new technologies. The BGS has co-ordinated much of this research. The European Commission has enabled much of this work through FP5 and FP6. The three major projects are called: NASCENT (complete); WEYBURN Phase 1 (complete); CO₂GeoNet (ongoing).

Nick and Sergio outlined various aspects of these projects, including partners, content, timetables and findings. Packages under the ongoing CO₂GeoNet project include: conceptual model of gas migration in a leaking CO₂ natural analogue; development of advanced seismic modelling capabilities; ecosystem responses to CO₂ leakage, model approach; geochemical monitoring for onshore gas releases at surface; monitoring of submarine CO₂ fluxes and ecological impact; testing remote sensing technologies for potential CO₂ leaks.

Nick reported that the public tend to be much more concerned about the prospect of CO₂ leakage rather than the building of a nearby power station. However, he pointed out that the project had identified some locations in Italy with dramatic leakage rates where people were still happy to live in these locations as the problem was manageable.

The presentation was concluded with a series of recommended next steps. Nick stressed that more UK government support would be needed, for example, through the Research Councils. He pointed out that EU countries have different geological conditions and there are many locations experiencing natural leakage which would be worth looking at. There is a need to build on further work and then to develop strategies to accelerate the deployment of technologies. Suggested next steps were:

- form a legal entity (EEIG)
- more stakeholder involvement and partners
- develop strategy for FP7 and Europe
- think big and transform from being a network in to a fully integrated Research Centre for Europe
- this will require financial backing of partner governments in order to gear FP7 funds.

The issue of monitoring was raised during the discussion following Nick and Sergio's talk. Nick pointed out that it will be necessary to monitor many sites very closely at first up until handover to the state/government. Monitoring will involve high costs. Nick also pointed to the major challenges posed by the UK's marine

environment as most storage in the UK is likely to be in the seabed. Research and development efforts will need both funds and infrastructure.

Brian Morris, Head of the Carbon Abatement Technologies Unit, UK Department of Trade and Industry (Dti), gave a presentation titled, “A programme for developing CATS for fossil fuels use: The way forward and delivery”. CAT is short for ‘carbon abatement technologies’. Dti’s CAT strategy is largely focussed on CO₂ capture and storage which has the potential to achieve a 90% CO₂ reduction, improved combustion efficiency which could deliver a 15-20% reduction and fuel switching, which could offer 5-10%. Brian pointed out that it would be necessary to apply CO₂ capture and storage technologies to highly efficient power plants in order to achieve zero or near zero emissions.

Dti has carried out analyses of different scenarios, with and without nuclear, to investigate the use of CO₂ capture and storage in the long term future. Details of this analysis “The role of fossil fuel carbon abatement technologies (CATs) in a low carbon energy system – a report on analysis undertaken to advise the Dti’s CAT strategy” can be found at

<http://www.dti.gov.uk/energy/coal/cfft/cct/pub/pdfs/r301.pdf>

The CAT strategy proposed is a ten year industry-led programme, covering all fossil fuels, industrial uses as well as power, and involves demonstration as well as R&D. The strategy includes support for demonstration, aims to strike the right balance between technical and non-technical areas for action and emphasises international collaboration. The strategy sets out ten tasks. A Technology Strategy Board will be responsible for the key strategic task, ‘support research, development and demonstration of CATs’. The other nine tasks are the responsibility of the Cleaner Fossil Fuels Technology Unit with support from an expert contractor. The nine tasks are:

- Support the demonstration of CO₂ –capture ready plant.
- Support the demonstration of CO₂ storage.
- Facilitate international collaboration in UK-based CAT development and demonstration projects.
- Facilitate and support UK collaboration in CAT development and demonstration projects based in other countries.
- Examine possible measures to encourage the initial commercial deployment of CCS
- Facilitate the acquisition and transfer of knowledge and know-how.
- Lead in preparing the national and international regulatory frameworks and market systems
- Increase public awareness and stimulate an informed debate on the role of CATs

- To develop and maintain a route map for the development of CATs in the UK.

The Dti is looking to allocate demonstration funding of £25m for CATS, £7.5m for hydrogen and £7.5m for fuel cells. These three areas could be integrated in some cases. The detailed design of programmes and criteria for assessing proposals is to be discussed with industry and other stakeholders. Brian outlined possible assessment criteria.

In the discussion that followed the issue of leakage was raised. Brian informed that the permanency of carbon removal from the atmosphere was a major concern for the government. He also added that a communication strategy would be essential to bring about acceptance.

Day 2 – Opportunities for clean coal use and CCS

Plenary Presentations

Ing. Pierpaolo Garibaldi from Italy's Ministry for Environment and Territory gave a talk on "The hydrogen economy in Italy". Pierpaolo began by making clear to the audience that Italy would be looking at a post-Kyoto future dominated by decarbonised energy sources – coal with carbon capture and storage is likely to be very important. With fossil carbon capture and storage, the options are post combustion (retrofitting), pre-combustion (new units) and oxyfuels (new units). Pierpaolo informed that pre-combustion seemed most promising for a hydrogen economy. He discussed the options for producing hydrogen and how different countries would be adopting different options according to their national resources and interests. Italy's vision is based on producing hydrogen mainly from fossil carbon capture and storage, but also to a lesser degree from biomass and solar energy. The hydrogen would be used for power production (gas turbine), distributed energy production (fuel cell) and automotive applications (fuel cell). The options for Italy need to be assessed alongside criteria such as economics, competitiveness, social impact, environmental impact etc but Pierpaolo stressed that selection of the options was no longer a technical problem in need of further R&D but rather an energy policy decision matter. Although the barriers to future progress are not technical, Pierpaolo pointed out that there are still R&D needs including:

- geological survey for CO₂ storage
- CO₂ long term safe storage in aquifers and natural gas depleted reservoirs
- gasification technology improvement
- high temperature raw gas cleaning technology
- water shift improvement (membrane reactor)
- cheaper O₂ production technology
- overall complex investment reduction
- H₂ combustion in turbines
- automotive and stationary fuel cells
- hydrogen and CO₂ logistic technology development
- scale effect for combines electricity and hydrogen
- best site selection
- overall economics

In the discussion that followed Pierpaolo mentioned the problem of widespread opposition to producing hydrogen from coal within both technical and economic circles. But he emphasised that to deliver significant carbon reductions in the region of 50 or 60% the only promising and realistic solutions are nuclear and/or clean coal. He added it would be important to get this message across to the public, in order to bring about acceptance of the technological solutions.

The title of **Professor Luigi Marsullo's - President of Finpublic SpA** – talk was “Investment opportunities in the Italian market”. Luigi began by presenting an overview of Italy’s socio-economic context. Luigi then went on to identify the features and trends of Italy’s energy markets and government policy which are shaping the energy investment outlook in Italy. Most recently in Italy the energy policy debate has focussed on: diversification of energy sources and increase of efficiency; secure timely investment in energy-related infrastructure; and clarity of the responsibilities of the regions and the central Government.

Luigi estimates that the total investment requirement for energy infrastructure in Italy over the period 2005-2008 is expected in the range of 10-15 billion Euros and 15 billion Euros for the period 2009-2015. About 10% of the above investment is expected to origin from renewable resources.

He discussed financing through Public Private Partnerships (PPP) and Project Financing (PF), and argued that all the energy investments could be delivered through PF. Luigi concluded that the Italian energy market may present significant opportunities to new investments and that fair competition and transparency are providing companies with a level playing-field. In addition, the financial and business environment looks friendly towards renewed and strengthened enterprise collaboration and partnerships.

During the discussion following the presentation, questions on the importance of the impact of the distribution of political power between the regions was raised. Luigi had mentioned that clarification of the roles and competences of central government and the regions was part of Italy’s energy strategy. It was pointed out by a participant that the UK may require such clarification of governmental roles as the country has an interesting structure with Westminster/central government, the Scottish Executive, the Welsh Assembly and local governments holding power. There are issues to be considered with respect to the roles/responsibilities of these bodies and the development and implementation of energy policy. It was suggested these issues might be raised and clarified through the upcoming Energy Review.

The final plenary presentation was given on Day 2 by **Bill Senior of the UK’s Department for Environment, Food and Rural Affairs (Defra)**. The presentation, “Addressing the Challenge of Coal Use in China through Carbon Capture and Storage”, focussed on issues relating to the deployment of clean coal and carbon capture and storage technologies in China and UK/EU/China cooperation. Today, China is the world’s number 1 producer and consumer of coal. China’s coal consumption is set to double in 25 years. The message is clear that we can not mitigate global climate change without China’s engagement.

There are many key questions that need to be answered in relation to CCS deployment in China: Is CCS viable?; At what scale?; Is there enough capacity?;

How soon might it be used?; How can we build in-country expertise and capacity?; How might it be financed?. The answers to these questions are of more importance to the industrialised world than in China – carbon abatement is currently a low priority in China. Bill explained the rationale behind the UK/EU's desire to cooperate with China to deliver zero emissions coal-fired power production. The commitment to cooperate follows on from the G8 Gleneagles Summit and Plan of Action and is part of the EU-China Summit's Joint Declaration on Climate Change and Energy. The latter commitment involves developing and demonstrating in China and the EU advanced near-zero emission coal technology through carbon capture and storage. Work has already begun to put this project in place – it is expected to involve three Phases, which are expected to complete within 8 years. The UK is planning a Call for Expressions of Interest and is hoping that industry will enhance the available funding. The UK government has allocated £3.5m to this project.

Working Group Outputs

Working Group 1 focussed on coal gasification and hydrogen production. The group reviewed current activities and active UK-Italian collaborations:

- Large-Scale IGCC Demo
 - Sarroch (CH)
 - AGIP
 - Falconara
- CO₂ Separation
 - membranes
- O₂ Production
- Cycle Studies
- Fundamental Understanding
- Gas Turbines
 - diluted syngas
- Ash Disposal

Common research interests identified included:

- 3rd Generation IGCC
 - CO₂ capture ready
 - Reduce cost
 - Increase availability\flexibility (load and fuel)
- Gas turbine
 - dilution
 - ASU integration
 - advanced GT
- CO₂ Separation
 - membranes\ adsorption (solid PSA) / Low high Temp
 - chemical looping

- integration with CO shift
- High Temp Desulphurisation
- General Gas Cleaning
- Soft Issues
 - Public Perception
 - Incentives
- Novel Cycles
- Establish Protocols
- Materials
 - Gas Turbine
 - Catalysts
 - Absorbants

Opportunities to pursue these joint interests might be provided by FP7, EU/China cooperation, joint government funding or the scientific research community. The group also identified potential barriers to joint-working: limited funds; co-ordination of funds; intellectual property rights; CO₂ trading scheme; UK university full economic costing; 'timeline'; further development of EU ETS and inclusion of CCS.

Working Group 2 concentrated on coal combustion with CO₂ capture. The group identified a number of common research interests:

- UK and Italy have similar long term targets on fuel mix e.g. in Italy - CCGT 20%; Coal 50%; RE 30%). UK has a similar emphasis on coal, with some nuclear as well. Different starting position but common target and therefore similar issues to address
- General agreement that the deployment of technologies is now required.
- Necessary to see the deployment of oxyfuel firing and/or CO₂ capture from coal plant for demonstration purposes.
- Research interests/collaboration have to be complimentary to other FP6 and FP7 projects.
- Deployment of appropriate coal combustion and CO₂ capture technologies should be considered necessary within 10 years retrofit of the technology. This could be an area where the UK and Italy could collaborate, identifying a suitable plant and the appropriate technologies. (1 possible Project)
- Discussion then turned to the building of new plants and the need to ensure that, in accordance with the twin track approach discussed yesterday, new plants should be designed to be 'capture ready' (readily converted at a later date to CCS) (2nd possible Project area)
- There is a lot on ongoing work in Italy on the characterisation and control of emissions (particulates, mercury, etc). These technologies might be the basis for further project (to be investigated). Full scale rig demonstration of oxyfuel burner
- Continuing R&D work in all areas, such as

- ASU (cryogenics is an interesting area),
- Materials development for oxyfuel firing and boiler design
- Way forward was seen as the establishment of a working group to develop the ideas and put together the basis of possible projects.
- Priorities were considered to be
 - Demonstration project (oxyfuel and/or CO₂ capture). in the first instance by a retrofit
 - Design of a capture ready plant with the associated R&D
 - Oxyfuel burner

The potential barriers to joint working identified by the group included:

- Italy's lack of a clear coal firing energy strategy (compared to UK's CATs Strategy), was seen as a barrier to define common interests. group agreed that if a Working Group would be set up, this could be analysed further.

Working Group 3 covered clean coal technologies and carbon capture and storage. The group agreed that current active collaboration in CO₂ storage research and demonstration is strong:

- EU Framework Programmes: CO₂Geonet, CO₂Remove, IncaCO₂, Geocapacity, CO₂net, Weyburn 2
- – Collaboration started in FP5, involves RTD organisations, industry and government
- ZEFFPP Technology Platform
- IPCC Special Report on CCS
- Common and complementary research interests were identified, based around:
 - Italy's unique position as a natural laboratory for CO₂ storage and leakage
 - Leakage, migration, monitoring, health and environmental impacts
 - UK's position as major North Sea country with infrastructure, storage sites and upcoming demo projects
- Possible funding sources/mechanisms identified included:
 - EU Framework Programmes are a very important source mechanism
 - Funding mechanisms exist for exchange of students between universities e.g. Erasmus
 - Other niche opportunities: INGV has fund for innovative continuous monitoring programme
- Strong national programmes are essential for fostering scientific exchange and bilateral/international cooperation
- Stable economic and regulatory framework is essential for private sector investment

Closing Remarks

Speaking from the Italian perspective, Roberto Amendolia of the Italian Embassy pointed out that bilateral meetings would help strengthen multilateral meetings, especially those involving decision-making processes as starting out with 25 member states can be difficult. This meeting was also useful in scoping out UK/Italian research priorities which may help inform the EU with respect to allocation of research funds. This meeting has also highlighted the importance of emerging economies, most particularly China, and the need for UK/Italian/EU cooperation with these economies was highlighted. This meeting also assisted with the important task of identifying the barriers to research developments and further collaboration. Roberto suggested that the meeting should not be a one-off and that it would benefit from follow up.

Speaking from the UK perspective, Jim Skea, Research Director of UKERC, stressed the importance of talking about RDD&D (research, development, demonstration and deployment) rather than R&D. This meeting had achieved this - facilitating useful discussion on demonstration and deployment as well as research and development. Jim noted that some discussions were particularly strong on policy incentives for deployment. This is naturally a sensitive area and the interface between science and policy on the issue of fossil carbon capture and storage is sure to increase in the future. Jim thought it clear that industry and academics would need to work closely together and with government to make the innovation chain work. On the topic of the usefulness of bilateral meetings – Jim felt that it may appear from the outside to be inefficient but the message was clear that bilateral operations are not a hindrance to EU processes but rather, can help lubricate them as dealing with 25 member states can indeed be challenging. Jim suggested continuing with bilateral meetings and proposed having a follow-up meeting to this workshop in Italy next year.