Research Councils UK Energy For a Low Carbon Future

Carbon Capture Technologies Scoping Workshop

The Cumberland Hotel, Marbel Arch, 15th August 2013

How can we develop the underpinning research in carbon capture technologies to act as strong foundations to accelerate CCS deployment?

Feedback Section 1

Prioritisation of Research Needs:

Participants discussed with their tables areas which either:

- Are not met by the current research landscape or
- Speculate which areas are being met but which may benefit from further inputs and development of next generation technologies.

Tables looked at clustering the outputs into similar themes and creating a group of outputs which were given an over-arching title which could be translated into a research challenge.

Environmental Implications:

- Development of environmental emissions monitoring instruments
- By-products of capture products and their environmental impacts (eg: gases)
- Instruments for process diagnostics and control.

Economic and Policy Barriers:

- Comparison of incentives for coal (cheaper per tonne) and gas (cheaper per kWh). How to accurately consider a realistic set of counter-facts for per tonne of CO_2 abated.
- Access impacts of policy in global environment – will we drive our industries overseas or price the UK out of the market?

Membranes:

- Membranes for post and pre- combustion. Mixed matrix membranes.
- Oxygen separation using novel membranes.
- Hydrogen purification with access to pilot plant testing.

Capture technology needs to be matched to the CO_2 source (acknowledging that different sources will co-exist in clusters):

- Integration and optimisation between a range of applications in a cluster.
- Capture from energy intensive industries – range of technologies are likely to be applicable.
- Capture from natural gas power plants – not just as an add-on, eg: fuel cell technologies, chemical looping and the Allam cycle.

Matching the technologies to the future generation fleet:

- New generation GTS optimised for CO_2 capture
- Pre-combustion pilots

CCS power plants that work well in the energy system:

- Important to be able to properly study links between capture and other things (transport, electricity systems)
- Measurement and online monitoring – novel solutions and configurations for new applications.
- Plant flexibility and control.
- Nitrosamines and other by-product issues with amines.
- Process development with proper power plant engineering and capture process development linked.

Process and Systems Integration:

- Low temperature and low fuel burning carbon capture
- Process integration and systems heat
- Integration of capture and utilisation in District Heating.
- Optimisation of full power plant and systems simulation.

System Engineering for CCS:

- Whole CCS systems analysis
- Operation, control and optimisation of carbon capture based on solvents
- How to improve dynamics of capture plant
- Combination of membrane with PCC solvents
- Scale-up of capture plants, especially in solvents.

Applying CCS to non-fossil-power systems:

- Underground coal gasification and integration with CCS
- Hybrid capture systems
- Transportation gap – static sources, industrial processes, mobile emitters
- Carbon bubble – CCS allowing the abatement of carbon sources.

Next generation capture technology:

- High pressure gas reactor
- Oxy-fuel
- Air based carbon capture
- Oxy-gas turbine
- Use gas turbine research and not just solvent research

Novel technologies

- Electrochemical desorption for chemical solvents
- Purification of CO_2 mixing of gases from different sources and impacts
- Link to transport – how best to achieve the gas specification required for transport

Linking with other relevant activities and portfolio areas in the energy programme etc:

- Access to pilot scale testing
- Building on progress and learning from success and other outcomes.

Basic research informed from practical past experience to achieve greater performance, cost and reliability:

- Need back from experience is essential to get the next generation of capture technologies
- Feedback from ALL applications – including non-capture and broader scope (materials)

what worked well with what?

Carbon "negative" materials:

- Bio-CCS
- Mineralisation of CO_2
- Funding of methods to create carbon negative materials
- Technology and environmental impacts of bio-CCS.

Pre-combustion:

- Adsorbents, membranes and processes
- Reliability versus integration
- Pre-combustion capture including hydrogen production
- Sorption and membranes – enhanced water gas shift.

Utilisation:

- CO_2 for plant growth
- Local CO_2 utilisation captured by industrial plant
- Integration of CO_2 capture and by-products into local economy – get nearby to avoid large transportation distances

Realistic and holistic assessment as early as possible to novel and unproven approaches:

- Inputs for novel technologies – realistic screening at an early stage, identifying show-stoppers is critical.
- Early assessment of environmental impacts for processes, eg: fugitive emissions, spent material disposal.

Environmental and Life Cycle Analysis:

- Creation of frameworks for establishing CO_2 disposal sites
- Environmental impacts and life cycle emissions (both environmental and economic) of CO_2 capture processes and solvents.
- Full scale and full variable analysis of the types of capture – environmental, economic etc.
- Inclusion of industrial CCS on the energy and policy
- Regular assessment of the air as a function of CO_2 capture
- CCS with water production for water constrained countries – technology development in UK.

Explaining, communicating and influencing carbon capture:

- The big picture pro's and con's – economic, environmental and communicating to the public.
- CCS vulnerability to policy changes
- Human impact of CCS – employment, fuel poverty and economic growth
- CCS implication for resources and domestic and industrial energy costs.

Scale:

- Technology of scale
- Inherent capture systems

From lab to process:

- Prove membrane technology from lab scale to process scale
- Process intensification
- Investigation of capture in "real" gases
- Effect of impurities on the capture process, eg: water, SOx and NOx etc.

Industrial Capture:

- Scale is smaller than in power plants
- Tailoring capture technologies for gas compositions and the process it is used in
- Retrofitting and plant matching with substantial variation
- Capture from industrial sources
- De-centralised carbon capture
- Air based carbon capture
- Industrial CCS will use the same basic technologies but will need flexibility of scale and flue gas composition.

Best Research Area Identification in a Systematic Way:

- Systematic identification of possible processes that are thermodynamically feasible but have not yet been discovered
- Non-solvent processes more thermodynamically efficient processes
- Physical methods for desorption from solvents eg: pressure, sound waves, cavitation and centrifugal force
- Mapping capture processes and technologies onto cost curves to enable identification of cheapest industries from which to capture CO_2 and specific best processed for those industries.
- Anything that would be immediately commercially viable eg: improved ways to capture CO_2 from source gas
- Combined capture and storage eg: producing a solid directly by interaction with CO_2 containing stream

Feedback Section 2

Participants were asked to choose an area to discuss as a group to work up into answering one of the research challenges

how would you address the research gap?

The challenge: **Systematic assessment of processes to identify future research areas**
How will this help to speed up the deployment of CCS?
There may be a better way we haven't identified because we haven't looked – cheaper, more efficient Identifying show-stoppers will reduce wasted time Optimisation of integration will be identified Whole systems impacts would be considered
What research is required to meet this challenge/need?
Process and systems – how to integrate and intensify Engineering scale-up of capture plant Integration of capture and utilisation Whole systems analysis and combining different technologies Optimise and integrate processes with a view to progressing commercial roll-out Model and calculate possible solutions that are thermodynamically feasible Publications outlining possible solutions which can be developed further
What disciplines are required to tackle the challenge?
Physical chemistry and chemical engineering including thermodynamics Chemical, mechanical and process Engineers Integration of disciplines including business, legal and commercialisation
What access to facilities is needed to help address this challenge? Are they currently available and where?
Research students Chemical and thermodynamics modelling systems Lab scale to pilot scale facilities
What is the estimated budget required?
Modelling software £? 20 masters' thesis' 5 PhD thesis'

The challenge:

Effective process and system integration

1)	How will this help to speed up the deployment of CCS?
	Ensuring that good ideas are brought through to being ready for use Cost reduction by getting the best out of original ideas
2)	What research is required to meet this challenge/need?
	Improved simulators with reliable validation Links between material developers and process simulation expertise Challenge can be to get new materials concepts to be "ready" for process studies but one aim here is to try to accelerate the use of processes Need to consider multiple timescales (hourly operation also variations in conditions over time – potentially including upgrades etc.)
3)	What disciplines are required to tackle the challenge?
	Multi-disciplinary – engineers, scientists, economists
4)	What access to facilities is needed to help address this challenge? Are they currently available and where?
	Access to facilities to provide validation data – detail depends on which technology being analysed Could link with DoE programmes?
5)	What is the estimated budget required?
	£1 – 2 M if pursuing with a 3 – 4 university consortium

The challenge: **Novel /Next generation capture technology and scale-up**
1) How will this help to speed up the deployment of CCS?
Bring next generation processes through to pilot scale and demonstration – foster when efficiency and cost savings have been identified Examples of processes: adsorbents, membranes, high pressure oxyfuel reactor, air-based capture
2) What research is required to meet this challenge/need?
Identify "show stoppers" in terms of: Real flue gas operations, materials supply, and general sustainability, life cycle analysis, plus overall process integration
3) What disciplines are required to tackle the challenge?
Chemistry, Chemical engineering, materials, general sustainability, life cycle analysis, system simulations, legal and business aspects – provide a real world perspective.
4) What access to facilities is needed to help address this challenge? Are they currently available and where?
Although "real" flue gas is important for novel capture technologies from a UK perspective we need to link with world leading international facilities for specific technologies.
5) What is the estimated budget required?
For a specific novel capture technology, a multi-partner project is required with necessary international links into world leading research groups and facilities, could be up to £1.5 million

The challenge:

Industrial CCS

1) How will this help to speed up the deployment of CCS?

Starting from a low base – there is a lot of growth potential
Facilitate translation
Build clusters
Mobilise industry support – powerful advocates
No alternative to CCS for some heavy industry emitters who need to decarbonise.

2) What research is required to meet this challenge/need?

Gas separation is different
Different resources – no steam available
Specific studies for specific industries
Cost and geographic challenges
Reduce cost of existing solutions
Economic modelling of proposed CCS processes
Pilot plant needed – lab scale testing may not be possible for all but may be for some….

3) What disciplines are required to tackle the challenge?

Many! Highly site-specific requirements
Process simulations and technicians – chemical modelling software
Industry professionals
Integrating the different disciplines – project management

4) What access to facilities is needed to help address this challenge? Are they currently available and where?

Access to industrial sites
Commercially sensitive data
Pipelines and disposal sites
If possible to test chemical processes, access to suitable testing facilities

5) What is the estimated budget required?

Work together – TSB, DECC, BIS and EPSRC
£1.5 – 2 M for a small consortium with post-docs working alongside similar industries.

The challenge:

Communication, Policy and the Environment

1) How will this help to speed up the deployment of CCS?

Planning permissions
Public acceptance and approval
Investment-investor confidence
Codes and standards – help to develop local and international deployment
LCA of capture from other areas – new opportunities
Feed into risk assessment and analysis – LCA to feed deployment
Environmental framework
Help scale-up approach
SAFETY = CONFIDENCE

2) What research is required to meet this challenge/need?

CBA full system
Global and local analysis of energy measures
Comprehensive / dynamic database from different capture plants
LCA
Risk register – technical and non-technical
Dispersion of by-products or impurities in environments
Response or application to development of fracking
Economic impact – energy consequences - research

3) What disciplines are required to tackle the challenge?

Multi-phase fluid dynamics
Risk (social, economic, environmental financial) analysis
LCA expertise
CCS footprints in relation to other activities
Energy/engineers
Policy or regulations experts
Communications

4) What access to facilities is needed to help address this challenge? Are they currently av and where?

Multi-disciplinary teams
Lab facilities – bioassays to test environmental framework
Data access
High performance computing
LCA software
Sigma-pro

5) What is the estimated budget required?

5 institutions ~1.5 million – 6 PhD studentships, 1 KT fellow, 10 research staff

The challenge:

Membranes for CCS

1) How will this help to speed up the deployment of CCS?
Potentially more energy efficient, smaller footprint and cheaper Builds on significant recent research and strong IP position
2) What research is required to meet this challenge/need?
Membrane materials, fabrication and process to optimise flux and selectivity for pre- and post- combustion feeds
3) What disciplines are required to tackle the challenge?
Chemistry, materials science, chemical engineering, multi-scale modelling process design – pilot scale testing (eg: ACTTROM)
4) What access to facilities is needed to help address this challenge? Are they currently available and where?
Facilities for long-term testing (not currently available) Facilities for long-term structural characterisation Facilities for lab-scale testing (eg: Diamond I11) Building membrane rigs – partially available Computational
5) What is the estimated budget required?
Consortium of 3 – 4 groups ~£1 – 2 million.

The challenge: Developing CCS technologies which "fit" in the energy system
1) How will this help to speed up the deployment of CCS?
Technology that is ready – deployment ready – more likely to adopted rapidly – don't have to delay to adapt to industry needs Broader use of CCS across range of applications more quickly if relevant underpinning thinking has been done
2) What research is required to meet this challenge/need?
Integrated, multi-scale studies – virtual power plant, dynamic simulator, links to studies of electricity system, CO_2 transport etc. Control and operations engineering – simulation and development of relevant monitoring processes and instruments Understanding of environmental impacts
3) What disciplines are required to tackle the challenge?
Engineers (mechanical, chemical and electrical) Environmental scientists for impacts Perhaps mathematicians for developing modelling codes Economics and social science in some of the "contextual" studies
4) What access to facilities is needed to help address this challenge? Are they currently available and where?
High power computing Pilot-scale facilities (eg: to test monitoring instruments and for validation) such as PACT Good links with full-scale power plant data and commercial scale plant would be helpful – perhaps SaskPower if progress in the UK is too slow…
5) What is the estimated budget required?
3 – 4 university consortium - £1.5 – 2 Million

The challenge: **Negative CO_2 Emissions**
1) How will this help to speed up the deployment of CCS?
To achieve CO_2 targets, maximise use of waste and biomass Move away from CO_2 neutral options – novel second generation biomass CO_2 utilisation Safety , risk analysis, social implications
2) What research is required to meet this challenge/need?
Drying, processing, feeding technologies Dealing with unusual impurities and properties of unconventional fuels Selection of technologies Life cycle analysis and simulations High pressure reactors Ash properties and use
3) What disciplines are required to tackle the challenge?
Chemical and mechanical engineers Mathematical modelling and simulation process models Business and commercialisation skills
4) What access to facilities is needed to help address this challenge? Are they currently available and where?
PACT facilities New technologies for high pressure applications
5) What is the estimated budget required?
Consortium-based research - £2 million

The challenge:

Gas turbines in CCS

1) How will this help to speed up the deployment of CCS?

Respond to the government strategy of deploying CCGT – CCS ready
Improved flexibility and/or economic performance
Better fit to power system needs and more affordable (so more likely to be accepted and supported by relevant stakeholders)

2) What research is required to meet this challenge/need?

Cycle optimisations
Process integration, production of capture
Novel cycles (HAT, OXY, high pressure systems)
Virtual dynamic systems simulations
Scale-up

3) What disciplines are required to tackle the challenge?

Mechanical engineering
Chemical engineering
System integration and control
Materials engineers
Chemistry, Physics and Mathematics

4) What access to facilities is needed to help address this challenge? Are they currently available and where?

Gas turbines
Capture plants
High pressure reactors
Some facilities are available at national PACT facilities

5) What is the estimated budget required?

Gas turbine research can be very expensive, however, use and exploitation of the current facilities the cost can be reduced… £1.5 million consortium of researchers.