Why CCS Readiness and what does it look like?

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About the UKCCSRC

www.ukccsrc.ac.uk

The UK Carbon Capture and Storage Research Centre (UKCCSRC) leads and coordinates a programme of underpinning research on all aspects of carbon capture and storage (CCS) in support of basic science and UK government efforts on energy and climate change.

The Centre brings together over 290 of the UK’s world-class CCS academics from more than 40 UK universities and research institutes and provides a national focal point for CCS research and development.

Over 310 Early Career Researchers participate in an active capacity development ECR programme.

Initial core funding for the UKCCSRC is provided by £10M from the Engineering and Physical Sciences Research Council (EPSRC) as part of the RCUK Energy Programme. This is complemented by £3M in additional funding from the Department of Energy and Climate Change (DECC) to help establish new open-access national pilot-scale facilities (www.pact.ac.uk). Partner institutions have contributed £2.5M.

The UKCCSRC welcomes experienced industry and overseas Associate members and links to all CCS stakeholders through its CCS Community Network. https://ukccsrc.ac.uk/membership/associate-membership https://ukccsrc.ac.uk/membership/ccs-community-network
The Climate Problem
Cumulative total anthropogenic CO₂ emissions from 1870 (GtCO₂)

Temperature anomaly relative to 1861–1880 (°C)

RCP2.6, Historical, RCP4.5, RCP6.0, RCP8.5, 1% yr⁻¹ CO₂, 1% yr⁻¹ CO₂ range
The Paris Agreement

http://unfccc.int/paris_agreement/items/9485.php

Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

This implies Carbon Capture and Storage on all fossil fuel use, plus minimising other anthropogenic emissions e.g. from food production.
What do we need to achieve?

The prime climate objective is not to end the use of fossil fuels.

The prime objective is to develop and deploy 100% CCS in time to cap cumulative emissions of carbon at a safe level.

CO$_2$ EOR and other applications with partial overall capture should be seen as a stage in a path from zero CO$_2$ capture to 100% CCS.

They can be a move in the right direction from where we are now – emitting 100% of fossil carbon to atmosphere.

The key factor is the extent to which technologies and/or projects can readily be adapted to get higher fractions of CO$_2$ stored.
CCS and CCS readiness
CCS - Sequencing Deployment

BUILD ALL PLANTS CAPTURE READY

Overall effort also important to maintain continuity

SECOND TRANCHE Commercial & Regulatory Drivers

FIRST TRANCHE Demonstration

DEVELOPED MARKET CCS ROLLOUT

GLOBAL CCS ROLLOUT

Big prize is getting two learning cycles from two tranches of CCS projects before global rollout

14. We will work to accelerate the development and commercialization of Carbon Capture and Storage technology by:

(a) endorsing the objectives and activities of the Carbon Sequestration Leadership Forum (CSLF), and encouraging the Forum to work with broader civil society and to address the barriers to the public acceptability of CCS technology;

(b) inviting the IEA to work with the CSLF to hold a workshop on short-term opportunities for CCS in the fossil fuel sector, including from Enhanced Oil Recovery and CO₂ removal from natural gas production;

(c) inviting the IEA to work with the CSLF to study definitions, costs, and scope for ‘capture ready’ plant and consider economic incentives;

(d) collaborating with key developing countries to research options for geological CO₂ storage; and

(e) working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.
CO₂ CAPTURE READY PLANTS

Technical Study
Report Number: 2007/4
Date: May 2007

E.ON
Robin Irons
Doosan-Babcock
Gnanam Sekkappan
Academics
Mathieu Lucquiaud, Hannah Chalmers, Jon Gibbins
IEA GHG
John Davison

二氧化碳捕集预留发电厂

技术研究报告

报告编号：2007/04
日期：2007/05

为G8行动计划而写

中文报告仅供参考，请以英文资料为准

Chinese Translation
Li Jia, Liang Xi
UK-China (Guangdong) CCUS Centre

Available from:
www.captureready.com

Funded by DECC
CAPPCCO project
Chinese Advanced Power Plant Carbon Capture Options, 2007 to 2011
Carbon Capture Readiness (CCR)

A guidance note for Section 36 Electricity Act 1989 consent applications

http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/ccs/ccs.aspx
CCS retrofit is easier if the plant is carbon capture ready (CCR)

Basic Requirements for Capture Readiness (in order of importance):

• Build new plant in a location that will allow viable CO$_2$ transport to a secure storage site

• Leave space to install capture units and space for critical connections and ancillary equipment within the plant

• Deploy a CO$_2$ capture ready steam cycle design

• Build plants with higher efficiency (but not a critical factor)
PC Post-com Capture Ready Checklist

• Capture retrofit study with outline level plot plan
• Power Plant Location
• Space Requirements – equipment plus laydown and construction access
• Boiler Flue Gas System modifications
• DeNOx Equipment
• Particulate Removal
• Flue Gas Desulphurisation Unit
• Steam Turbine Generator and Auxiliaries – steam extraction
• Water - Steam - Condensate Cycle – thermal integration
• Cooling Water System - overall power plant cooling duty will increase
• Compressed Air System
• Raw Water Pre-treatment Plant
• Demineralisation Plant
• Waste Water Treatment Plant
• Electrical Supplies
• Chemical Dosing Systems and Steam Water Analysis System
• Plant Pipe Racks – space for additional pipework
• Control and Instrumentation
• Plant Infrastructure – including access during retrofit
Capture-ready steam turbine designs


• Throttled LP turbine

Simplest design, but losses in throttling valve. Initial pressure ~3.6 bar for amine, cannot be varied

• LP turbine taken out of service

Most efficient design, but cannot vary steam extraction flow. Initial pressure ~3.6 bar for amine, cannot be varied

• Floating IP/LP crossover pressure

Avoids all throttling losses at design extraction rate. Extraction pressure goes up with reduced flow rate 7 to 3.6 bar possible
Lignite fuel, ~ 1MtCO$_2$/yr being sold for EOR, Shell Cansolv amine capture technology, Looking for 30% reduction in capital costs in future projects
Boundary Dam Integrated Carbon Capture and Storage Demonstration Project

http://www.saskpowercarboncapture.com/projects/boundary_dam
Maasvlakte CCS Project
Capture: 250 MW; post-combustion
Storage: Offshore hydrocarbons field
Annual CO$_2$ captured & stored: 1.1m tons

European Energy Programme for Recovery
EEPR Budget: € 389 m, € 180 m from EU
EEPR Activities Start date: 1 January 2010
End date: 31 December 2014
Operational Flexibility

- We have done preliminary modelling of part load operation, and starts and stops

![Graph showing operational flexibility]

- CO₂ Capture
- Target operating window
CO₂ Capture-Ready Ultra Mega Power Projects, India

British High Commission, Mott MacDonald, April 2008

- An appropriate definition of a ‘capture-ready’ plant in the current India context is one that focuses on measures essential to remove barriers to later retrofit of CCS, does not entail any performance penalty prior to CCS retrofit and is flexible to integration with a range of possible future CO₂ capture equipment. While a 3 month dedicated outage for retrofit is conservatively assumed for the economic analysis in this study, retrofit of CCS should require no more than normal plant outages if timed to coincide with major plant maintenance.

- The definition of ‘capture-ready’ should also encompass the transport and storage of CO₂ and preliminary confirmation of feasible routes to CO₂ storage.

- The capital costs of preparing a plant as capture-ready are estimated at approximately 1% of reference plant CapEx for a 4,000 MW plant, with the key additional cost elements being studies, design time and balance of plant.

- A CO₂ abatement incentive of $33-42/tCO₂ is required for CCS.

- The economic performance of CCS retrofit is marginally improved by investment in the high-efficiency ultra supercritical coal plant for each site, although return on investment for retrofit projects is more sensitive to capture block efficiency, retrofit date, and retrofit outage period.

- The projected improvement in post-combustion CCS technology by 2020, is significant.
Preliminary estimates on the effect of original plant efficiency on the levelised cost of electricity with capture retrofit. All plants assumed to have same original COE, capture equipment capital costs ~ throughput\(^0.8\).
CAPTURING INDIA’S CARBON
THE UK’S ROLE IN DELIVERING LOW-CARBON TECHNOLOGY TO INDIA

A Christian Aid report based on the findings of research by the University of Edinburgh and the University of Surrey

Carbon capture and storage (CCS) has been hailed by many countries – including the UK, Canada and the USA – as an important way of reducing the global greenhouse gas emissions that cause climate change. It is seen as part of the way to ensure energy security in a time of climate crisis. Many believe it will allow countries to continue burning coal without increasing the threat of climate change.

It was a commitment of Barak Obama’s bid for the presidency of the United States. Launching the UK’s manifesto for the international climate talks in Copenhagen, Prime Minister Gordon Brown stated that ‘carbon capture and storage will be a vital new technology in reducing carbon emissions around the world’.

Capturing India’s Carbon: The UK’s role in delivering low carbon technology to India, Christian Aid, 2009
India needs assistance from other countries to ensure the security of its energy supply and to increase access to modern energy for millions of its people, without adding to global greenhouse gas emissions. Achieving a low-carbon future for India will require cooperation on a wide range of technologies, from improved cooking stoves to concentrated solar power. **Christian Aid believes that India’s priority should be a renewable and sustainable energy future, which will:**

- increase poor people’s access to power through decentralised renewable technologies
- increase energy security by using locally available resources
- achieve a low-carbon economy.
However, while coal remains ‘king’ in the Indian power sector – as suggested by the survey – India must be in a position to be carbon-capture ready and to develop CCS in the future as part of its low-carbon strategy. The UK and EU demonstration plants must deliver knowledge that is relevant to the Indian context. It is vital that the UK and EU reduce their own emissions and test technologies that can contribute to global emissions reductions, before urging them on developing countries such as India.

For India – and other developing countries – to adopt low-carbon technology as an integral part of its energy planning, certain incentives must be in place. These include:

- a clear international climate change regime
- industrialised countries taking the lead on demonstrating and implementing low-carbon technologies
- training and capacity building to allow India to choose and implement the low-carbon technologies that are right for the country
- assured financial support, both up front and into the future.
Tilbury artist’s impression with CCS

PCC option
- tower boilers
- use amines
- technology advances to reduce size
- two absorbers plus one desorber per 800 MW_e

Alternative options
- land area for oxyfuel similar
- look at alternatives to tower boilers

To make space for CCS
- close currently operating units, demolish, rebuild
- move the coal stock
- then build capture plant
E.ON scraps plans for Kingsnorth Power Station, threatening 200 jobs

The firm said it was withdrawing from a competition to build the UK's first carbon capture and storage site – which some consider the future of power generation for the country – which means the probable closure of the station in 2015.

E.ON said the economic climate had influenced its decision to abandon the plans. Company chief executive Paul Golby said: "It has become clear that the economic conditions are still not right for us to progress the project and so, simply put, we have no power station on which to build a CCS demonstration.

"As a group we still believe that carbon capture and storage is a vital technology in the fight against climate change, and will now be concentrating our efforts on our Maasvlakte project in the Netherlands, as we believe the lessons from that project can be brought back to the UK for future generation CCS projects."
Coal Capacity History and Forecast AEO’05

Will the Nation’s Industry be Prepared and Capable of Meeting This Coal Plant Forecast?
Summary

- Capture readiness a part of getting ready for CCS deployment
- Pragmatic interim solution to having to play catch-up on CCS
- Complements work on CCS technology development
- But must not displace CCS technology development
- Can avoid carbon lock-in, provided other factors enable retrofit
- Now becoming part of new plant permitting in EU
- New power plants in UK now must be CCR (NGCC permitted)
- UK approach based on ‘intelligent space’
- Not a rigid definition, can develop over time
- CCR steam turbine gives upgrade and operational flexibility
- Ongoing area for collaboration with China and India
- Additional work needed on CO$_2$ transport and storage
- Government role in pipeline networks and storage potential
Conclusions

Stages in all power plant clean-up technologies:

1. ‘It’s science fiction!’
2. ‘It’s impossibly expensive and complex!’
3. ‘It’s a major investment but necessary.’
4. ‘It’s obviously just a routine part of any power plant.’

CCS is now in early stage 3 and we are working hard to get it to stage 4 as quickly as possible.

CCS gives a critical option for achieving zero emissions

• Can expect $2^{nd}$ generation projects next that are based on $1^{st}$ generation projects and that benefit from learning-by-doing.
• But starting from nothing so still a small amount of activity globally.
• Capture readiness and developing CCS capacity gives countries the option to deploy CCS rapidly and at reduced cost in the future.
THE END
Overview of UK CCS roadmaps

At the time of writing the UK Government position on CCS roadmaps is as follows:

In November 2015, the Government chose to no longer make available capital funding to support the two CCS Competition projects and took the decision to close the CCS Competition in early 2016. The Government then commissioned Lord Oxburgh to establish a CCS Parliamentary Advisory Group which reported to Government on 12 September 2016. We will consider carefully the findings and recommendations made in Lord Oxburgh’s report and will set out a future approach to CCS in due course. We will continue to work with industry going forward, but the costs of CCS must come down if it is to play a part in the long-term decarbonisation of the UK’s economy.

…we will be launching a consultation on coal power stations, which will inform our policy development in this area.

…Industrial Carbon Capture Usage and Storage has been identified as a potentially important contributor to long term decarbonisation. As with CCS more generally, the Government will set out a future approach in due course.

The two official bodies that the above response relates to, the Committee on Climate Change (CCC) and the CCS Parliamentary Advisory Group (in the ‘Oxburgh Report’), have both released generally similar CCS deployment roadmaps and linked recommendations, with timelines requiring preparatory work to start as soon as possible following a Government CCS strategy decision.

The CCC published the illustrative timetable below, noting the following requirements:

‘Sufficient scale of targeted roll-out: a combination of industry and power plants is necessary to realise economies of scale and allow a build-up of skills, developer and financial interest. Our analysis suggests that an overall scale of 4-7 GW of power CCS and 3-5 Mt captured CO₂ from industrial plants by 2035 would be sufficient to commercialise CCS and facilitate subsequent wide-scale deployment.’

‘An initial focus on one or two strategic clusters: clusters in areas of industrial activity around storage sites that have been identified and successfully characterised.’

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1 Government response to the Committee on Climate Change ‘Progress on meeting carbon budgets’, October 2016
The Oxburgh Report notes that:

120. No more fundamental research is needed in order to begin a programme of least cost CCS deployment.

125. The component markets are in a state of maturity and transformative technologies are not anticipated to be available at scale in a timeframe or with a degree of certainty that justifies waiting.

126. Incremental improvements are already efficiently absorbed in the supply chains delivering the component technologies of CCS. Research should of course continue to support the long-term cost-effective development of this important strategic industry.

The CCC has identified a key role for CCS in delivering Paris targets:

**Carbon capture and storage (CCS)** is very important given its potential to reduce emissions across heavy industry and the power sector, open up new decarbonisation pathways (e.g. based on hydrogen) and remove CO\(_2\) when coupled to bioenergy. Estimates by the Committee and by the ETI indicate that the costs of meeting the UK’s 2050 target could almost double without CCS.

The CCC also notes in connection with the problem of residual emissions from sources fitted with CCS in 2050 and beyond:

**Industry** (excluding refining) contributes a remaining 27 MtCO\(_2\)e/yr. These are largely from fuel combustion, process emissions and residual CCS emissions from manufacturing. Although CCS can significantly reduce emissions from applications where there are few low-carbon alternatives, we assume it only captures up to 90% of emissions.

The CCC describe greenhouse gas removal (GGR) technologies (*negative emissions technologies*) as:

- options to actively remove CO\(_2\) and other greenhouse gases from the air. Developing and deploying GGR options globally and in the UK will be central to realising the Paris ambition of a balance between greenhouse gas sources and sinks, given the difficulty of removing all sources. Specific GGR technologies range from afforestation to ocean liming, direct air capture and storage (DACS), and alternative forms of cement.

On the importance of biomass energy with CCS (BECCS) the CCC states:

*Our UK scenarios to 2050 include up to 67 MtCO\(_2\)/yr removals from three GGR options: afforestation, BECCS and wood in construction. BECCS could become capable of reducing emissions at a comparable cost to other technologies in the 2030s. This would require the Government to implement an effective new approach to CCS development and development of sustainable bioenergy supplies without locking these into alternative uses. Our scenarios include up to 47 MtCO\(_2\)/yr removed by BECCS while generating energy.*