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Capturing carbon, tackling climate change:
A vision for a CCS cluster in the South East

Introduction

There is global desire to reduce greenhouse gas emissions, and in particular carbon dioxide (CO_2) from the power industry and other large industrial emitters, to mitigate climate change. Climate change is important, must be addressed and should be part of a co-ordinated vision for the future. Government and industry need to work together to achieve this.

The UK is responding to the challenge of climate change and is set to do this at a time when it has a significant need to replace its ageing power generation assets. It therefore has an ideal opportunity to provide modern, leading technology power plant within the full portfolio of fuels (renewable, fossil and nuclear) necessary to maintain a balance between security of supply and cost of electricity, and to achieve the reduction in carbon dioxide emissions.

In the case of fossil fuel, and in particular coal, there is a chance to link new plant to equipment to capture carbon dioxide emissions. The combination of new more efficient power stations and carbon capture and storage (CCS) is a significant opportunity to improve the carbon footprint of the UK power industry.

The demonstration of carbon capture should be done quickly and hence provide evidence that the UK supports carbon capture. The expertise gained from a demonstration plant can be used to enable other facilities to introduce the clean coal technologies to make decarbonisation of the energy industry a reality.

On new power stations, the transportation of captured carbon dioxide can be on a case by case basis or in a group by linking a number of locations together, in effect forming a 'cluster' for the added benefit of carbon collection and transportation, allowing new facilities to connect quickly to a carbon transportation system, much like the way they connect to National Grid for gas supplies or electricity transport today.

A Thames Cluster is the perfect enabler to allow the energy and other industries in the South East to de-carbonise. The creation of a collection and transportation system in the area of UK with the highest electrical demand offers a world leading opportunity.

The area around London, essentially the Thames and Medway estuaries, offers the opportunity, firstly through the proposed new coal-fired power plant at Kingsnorth, and then through other proposed projects, to make a dramatic difference to the energy generation industry and to the emissions in the UK.

Summary

This review highlights the significance for the Thames Cluster to collect CO_2 from major emitters in the Thames and Medway Estuaries. The review recommends that the collected CO_2 is combined into a pipework network that links the area to depleted gas fields, such as the Hewett Field. There is sufficient storage to absorb over 60 years of CO_2 emissions from the Thames Cluster. There is additional storage available in other gas and oil fields and further storage in aquifers.

It is most cost effective to start a CCS cluster by capturing CO_2 from the largest emitters first. These provide the flow rates to justify a pipeline network. In the area of the Thames Estuary there are eight sites (seven power plants and a refinery) which each emit over 1 million tonnes (Mt) of CO_2 per year. The potential for a CCS cluster from these sites combined is around 28 Mt CO_2 annually.

The two planned coal-fired power projects at Kingsnorth and Tilbury would be capable of capturing a combined 16 Mt of CO_2 per annum that would cover over half of the total emissions within the Thames and Medway Estuary area.

The preferred storage locations for CO_2 are depleted oil and gas fields. The long history of hydrocarbons being held underground there for millennia demonstrates their suitability and longevity. This has also been demonstrated by numerous projects around the world where CO_2 has been injected deep underground. There is the added advantage that the CO_2 can be used in recovering additional fossil fuel as it is injected into the fields, a process known as Enhanced Oil Recovery (EOR) and Enhanced Gas Recovery (EGR) for oil and gas respectively.

It is important to minimise the environmental effects for the construction of the new pipework. This can be achieved by installing the majority of pipework offshore. This has the added benefit of reducing the impact on environmentally sensitive and residential areas.

There is a window of opportunity to provide early implementation of CCS by combining the transportation and storage of CO_2 from the two proposed large coal-fired projects that are located in close proximity. The pipework network could then be easily extended in the future to incorporate additional power stations in the region.

Carbon capture and storage

Carbon capture and storage (CCS) was considered in the Stern Review (Stern [2006]) to be essential in providing a lower carbon future globally. Fitted to large point sources of CO_2, CCS will allow continued use of fossil fuels through carbon abatement until replacement low carbon processes can come to maturity.

CCS is the technology to capture CO_2 from the combustion process, compress it to a liquid and deliver it by pipeline to a suitable storage or sequestration location where it can be permanently stored.

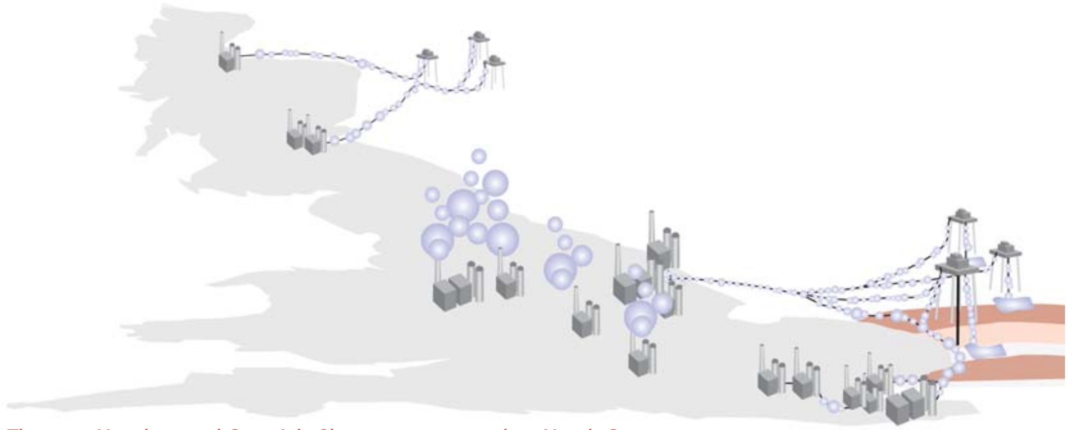
The post combustion CCS process starts by separating the CO_2 from the flue gases. This is achieved by dissolving it in a solvent in an absorber. This amine based solvent is then heated in a stripper column to recover the CO_2. The recovered CO_2 is compressed and transported to a geological storage location. In the UK the preferred locations are the depleted oil and gas fields in the North Sea.

The UK has a number of areas that have high concentration of energy use and electricity generation as in the Thames and Medway estuaries. Therefore the UK is well situated to create a pipework network akin to a grid that allows different producers to connect into. This would combine the CO_2 from different emitters together and pipe it to multiple depleted gas fields.

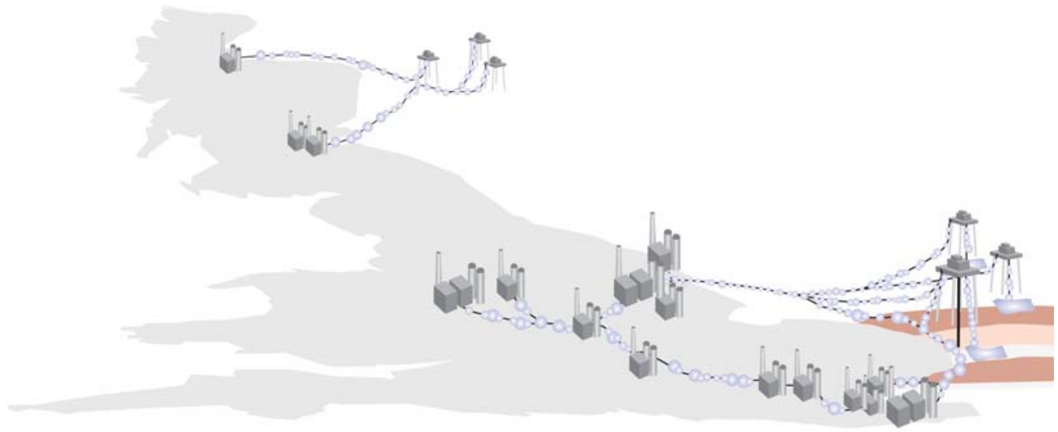
Phased development of CCS for the UK

Current position: all power stations emitting CO_2

Kingsnorth CO_2 emissions stored in North Sea



Thames, Humber and Scottish Clusters connected to North Sea

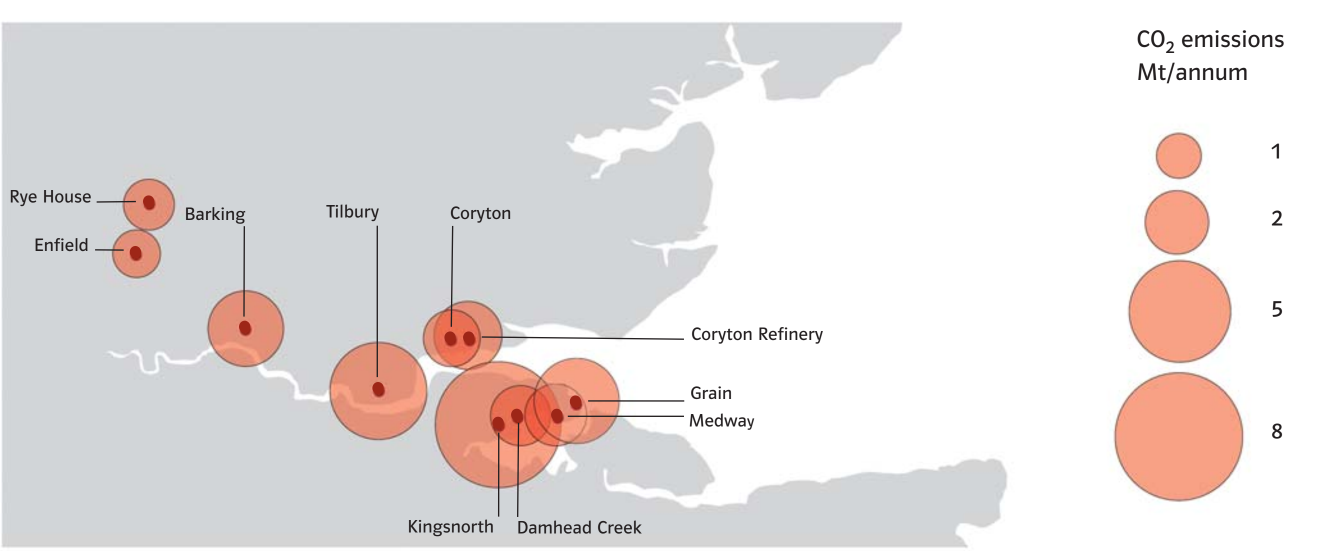


Inland power stations connected to pipeline network

The Thames Cluster

The Thames and Medway Estuaries have a significant number of power stations, with two proposed large power stations planning to incorporate CCS in the future. These two projects can be the start of a cluster (the "Thames Cluster") delivering CO_2 into the North Sea at an early opportunity. Others are added later as per Figure 1.

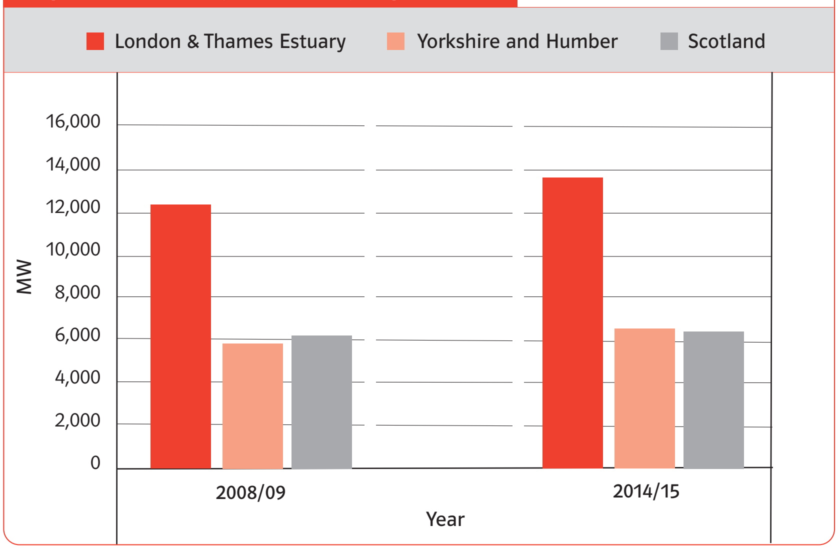
Figure 1: Thames Cluster



Electricity demand

The Greater London Area is the largest consumer of electricity[1] in the UK, growing to a projected demand in 2015 of 13,500 MW. The bar chart below compares this to the whole of Scotland and to the Yorkshire and Humber area. See also Figure 3 showing the clusters in relation to the oil and gas fields. Locating power stations close to demand minimises transmission losses.

Figure 2: Electricity demand by region



[1] 2008 Seven Year Statement, National Grid, (http://www.nationalgrid.com/uk/Electricity/SYS)

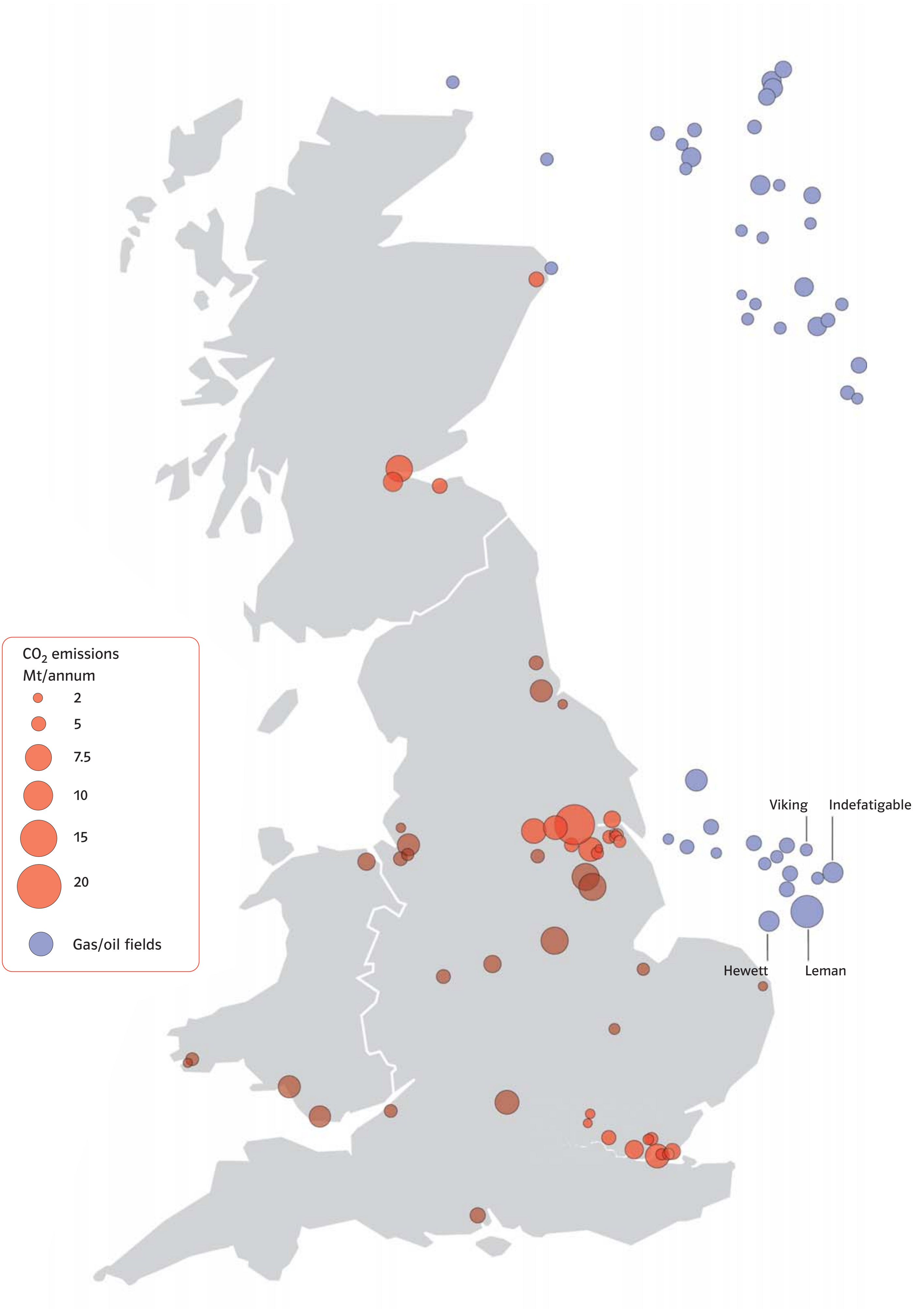


Figure 3: Diagram of energy clusters in relation to oil and gas fields

The main power stations

This review has concentrated on the largest power plant CO_2 emitters that are capable of emitting over 1 Mt per annum. These are listed in a table in Appendix 1 that are the most feasible for CCS in terms of available carbon dioxide and technical viability.

An assessment has been made to identify power plants that are likely to be in operation in 2020 by which time it is expected that large scale CCS will be available. This takes into consideration power plants known to closing by 2016 in accordance with the Large Combustion Plant Directive (LCPD).

Table 1: Major fossil-fuelled power stations in Thames Cluster

Power station	Potential CO_2 capture post 2016 Mt/annum	Initial assessment for space for CCS plant	Planned declared CO_2 capture Mt/annum
Kingsnorth	**8.0**	Yes	**8.0**
Tilbury B	**8.0**	Yes	**8.0**
Barking	1.1	Yes	
Medway		Yes	
Damhead Creek	3.1	Yes	
Coryton	1.8	Yes	
Rye House	1.7	Yes	
Grain CHP	3.1	Yes	
Enfield	1.0	Yes	
Littlebrook		Yes	
Total	**27.9**		**16.0**
Coryton Refinery*	1.2		

Note: Capture rates are based on IEA [2007] Table 2. Typically 85-90% of CO_2 emitted
* It has been assumed for this report that only 50% of CO_2 emissions can be captured

The major power plants in Table 1 currently emit a total of 30 Mt of CO_2 per annum. It is expected that this will decline to the conservative 28 Mt of CO_2 per annum after 2016 as expected developments are implemented and older power stations are decommissioned. This figure may increase as the development plans for Littlebrook and Medway power stations are publicised. If all the identified plants were fitted with the appropriate CCS technology, this emission level would reduce to 4 Mt of CO_2 per annum. If the two declared projects are built at Kingsnorth and Tilbury, they would capture 16 Mt of CO_2 per annum.

An initial assessment has been made from satellite pictures and historical knowledge of each site to verify whether it will be possible to retrofit a CCS plant. This is summarised in Table 1. For sites that will have new power plant installed it has been confirmed by the developer that they will all be constructed to allow for a future retrofit of a CCS plant.

Pipe routes

A number of pipe routes have been reviewed for transporting the CO_2 from The Thames Cluster to the Hewett Gas Field. One option is overland to Bacton and then out to sea using the existing offshore pipeline routes. The second option is a short overland route with the significant run offshore off the eastern coast of England. It will be possible to identify a route which takes due consideration of:

- Shipping lanes
- Offshore wind-farm developments
- Installed pipelines
- Minimising impact on coastline

The size and number of the pipelines will depend on the amount of CO_2 to be transported to the depleted oil and gas fields as more power stations are built and retrofitted with CCS technology. It is a significant challenge to route the pipe overland ensuring minimisation of the impact on environmentally sensitive areas, crossing infrastructure and rivers and avoiding residential areas. The offshore route will avoid some of these pitfalls and is likely to prove preferable.

Figure 4: Route of CO_2 pipeline from Thames Cluster to Hewett Gas Field

The offshore pipe route would also allow Great Yarmouth Power Station, to feed its CO_2 emissions into the network.

There exists significant experience in designing, constructing and maintaining large pipework conveying gas as can be demonstrated for natural gas. Thus the installation of an offshore pipeline for CO_2 is practical. An initial study has indicated that such a pipeline would have a length of about 270 km from Kingsnorth to Hewett.

North Sea oil and gas fields – CO_2 storage

Oil and gas fields are regarded as prime potential sites for CO_2 storage for the following reasons:

- They have a proven seal which has retained buoyant fluids, in many cases for millions of years
- A large body of knowledge about their geological and engineering characteristics has been acquired during the exploration and production phases of development.
- In some cases there may be economic benefits to be gained from enhanced oil or gas recovery (EOR or EGR respectively) in conjunction with CO_2 storage.

British Geological Survey (BGS) has completed a study to identify the most suitable fields for CO_2 storage (BGS [2005]) using the following criteria:

- Degree of water invasion – The ingress of water will limit the storage of CO_2 and cause injection problems.
- Permeability – Improved permeability means it is easier to recover gas and inject CO_2. It will also reduce the number of wells.
- Compartmentalisation – Occurs when the reservoir is divided into multiple compartments as a consequence of faults or other barrier that has the potential for each compartment to behave independently of each other. Increases potential for more wellheads.
- Availability of field for storage – This is assumed to be the case when the field reaches depletion. It is advantageous that the field is not abandoned as this will usually mean that the field infrastructure may have been removed.
- Size of the field for storage.

The next section summarises the key findings for the best fields identified:

- Hewett Field (initial field for proposed Thames Cluster CO_2 storage)
- Viking Field (selected for Humber Cluster by Yorkshire Forward)
- Leman and Indefatigable (additional good storage sites for Thames and Humber Clusters)

Other clusters

Yorkshire Forward proposed a cluster commonly known as the Humber Cluster for the collection of CO_2 and storage in the Viking Field. This included a number of old coal-fired power stations including Drax (YF [2008]), large and small industrial CO_2 emitters. Older coal-fired power plants such as Drax (which alone emits 20.5 Mt/year (DTI[2006])) are large emitters, but they are unlikely to be suitable candidates for CCS in their current form due to the age of the existing plant. Substantial refurbishment or re-planting would be required. The Yorkshire Forward report quoted two planned CCS projects at Ferrybridge and Hatfield.

Scotland has three large power stations on the eastern coast that could together form a "Scottish Cluster". There are no specific plans in place to construct CCS plants and unfortunately the pre-combustion CCS project at Peterhead has been halted.

As the CCS technology becomes accepted, these clusters should all be developed and their CO_2 emission stored permanently.

Hewett Field

The main L Bunter Field has a capacity of 237 Mt CO_2 with a potential of 383 Mt CO_2 storage by also using the U Bunter and Zechstein fields. This equates to a total storage capacity for Kingsnorth and Tilbury of about 24 years.

This main field is well suited for gas storage because there is little water drive where water would encroach on the reservoir The other fields have potential due to their location. Note the Leman field is at a further distance of only 24 km with a potential storage of 1203 Mt CO_2.

Viking Field

The Viking Field is the preferred field for the Humber Cluster put forward by Yorkshire Forward. It has a capacity of 221 Mt. The field is at greater distance from the Thames Cluster and also further away from the coast.

There is an encroaching aquifer in one of the southern compartments. The water flowing into the field may cause injection problems and reduce storage capacity. It is unlikely that all the invading water can be flushed out by CO_2 injection. The site has low permeability in some pools making it more difficult to inject CO_2.

Indefatigable and Leman

The Indefatigable field combines good permeability, low compartmentalisation and depletion drive with excellent capacity (357 Mt). Leman also has excellent potential. It has the advantages of having a significantly larger storage capacity of 1203 Mt and being closer to the coast than Indefatigable.

Note that the Indefatigable and Leman fields are already connected to Bacton and are in close proximity to the Hewett field and thus accessible once the Hewitt field has been filled. This makes them the obvious choice for expansion.

Table 2: Available CO_2 storage capacity for selected fields

Field name	Gas initially in place billion cubic metres (bcm)	CO_2 storage capacity (x 10^6 tonnes)
Hewett L Bunter	59.5	237
Hewett U Bunter	38.4	122
Hewett Zechstein	11.9	24
Total	**109.8**	**383**
Viking	84.7	221
Indefatigable	158.6	357
Leman	397	1203

(Extract from 4.1 from DTI [2006])

Comparison between Hewett and Viking

Table 3: Comparison between Hewett and Viking fields

	Hewett	Viking
Storage capacity	237 – 383	221
Water depth	37m	23m
Depth to crest	1227m	2480-2740m
No. of compartments	No compartmentalisation	11 separate compartments
Availability	2010-2015	2013-2018
Proximity to terminal	Bacton (28km)	Theddlethorpe (170km)
Proximity to Leman	24 km	27 km
Proximity to Indefatigable	63 km	66 km

It is anticipated that the Hewett field will only require a single wellhead to inject CO_2 into the field because it is not compartmentalised. The Viking field will require multiple wellheads. This reduces significantly the cost at the wellhead for development at Hewitt prior to CO_2 injection. It has a large storage capacity and simple expansion to include additional fields. This makes it the preferred field for the Thames Cluster.

Storage capacity

It is important to prove sustainability to ensure that sufficient storage is available for the projected life of the power stations. Table 5 summarises this for the Thames Cluster. Phase 1 includes the two proposed initial projects for the Thames Cluster. Phase 2 includes all power plants that are believed will be in operation beyond 2020 and that are expected to contribute CO_2 to the Thames Cluster.

Table 5: Storage capacity of gas fields

Field name	Storage capacity Mt	**Phase 1** Kingsnorth + Tilbury	**Phase 2** Major power plants in Thames Cluster	
Hewett	359	22 years	12 years	
Indefatigable	357		64 years	Combination of all three fields: Hewett, Indefatigable and Leman
Leman	1203			

The Hewett field will provide storage for over 20 years storage for the Phase 1 CCS projects. The addition of Indefatigable and Leman allows easy extension of storage capability that should provide storage capacity beyond the life of the power plants that form the Thames Cluster. Note that the total identified storage in UK gas fields is 5100 Mt as detailed in DTI [2006]. There is therefore significant potential to allow for all sequestrated CO_2 to be added to these fields including the Humber Cluster and other power stations located further north.

Conclusion

The south east is the largest area of electricity consumption in the United Kingdom. There is consequently a high incentive to continue to replace ageing electricity generating plant and to expand generating capacity in the Thames and Medway Estuaries area. This study has identified 9 existing significant sites for electricity generation there that in 2016 will be emitting about 28 Mt of CO_2 per annum. These sites are located within an area of about 700 km^2, making it feasible to collect the CO_2 emissions for onward transportation to a suitable storage facility.

There are two projects for new coal-fired power stations at Kingsnorth and Tilbury that afford the opportunity to capture 16 Mt of CO_2 per annum as Phase 1 of the proposed Thames Cluster. It is believed both projects are significantly advanced and would enable early capture and storage of CO_2 in the North Sea. This would allow the United Kingdom to lead the large scale implementation of this technology. It may have the added benefit of recovering additional fossil fuels from depleted fields.

The pipeline distance from the Thames Cluster to Hewett field is not dissimilar to other proposals, but has the significant advantage of limited new pipework installation overland. The Hewett and closely located Indefatigable and Leman fields will provide a storage capacity of over 60 years for the identified total CO_2 emissions identified from the major power stations which could be included in the Thames Cluster. There is significant additional capacity for the Humber Cluster and for other clusters to be added as CCS projects come on stream.

The provision of new power stations closer to demand in the south east reduces the transmission losses and pressure on the existing transmission infrastructure that currently exports electricity from the North to the South.

The Humber area is currently the largest generator of electricity. The power stations there are spread over an area of approximately 1400 km^2. However, the larger coal-fired power stations are located inland and currently the planned CCS projects are not as advanced as those in the south east. The plan to export CO_2 to the Viking field would therefore require a more extensive pipework system than for the Thames Cluster and would take longer to develop. However, it is critical that this area also implements CCS and adds its CO_2 into the North Sea storage facilities.

There are two significant coal-fired power plants in Scotland that have publicly declared an interest in CCS technology. The challenge is to form an identifiable cluster for Scotland when power stations are up to 200 km apart. However their presence on the east coast or an estuary provides an opportunity to provide a network out to the North Sea.

The Thames Cluster is the area that is the most likely to have early availability of significant CCS projects. The CO_2 would be transported predominately by offshore pipeline to the depleted Hewett field off the coast near Bacton. Future expansion of the Thames Cluster would allow electricity generation and usage to be kept closely together, reducing transmission losses, while providing a sustainable solution for CO_2 storage.

Appendix 1

Main power station CO_2 emitters for Thames Cluster	Owner	Power station capacity MW	Loss in capacity	Future or additional capacity MW	Build year	Closure date/ Capacity loss	Date for new capacity
Kingsnorth	E.ON	1940	1940	1600	1973	2015	2014
Tilbury B	RWE	1428	1063	1600	1968	2012	2015
Barking	Barking Power	1000	1000	470	1995	2019	2013
Medway	Scottish & Southern Energy	688	688		1995	2020	
Damhead Creek	Iberdrola	792		500	2001		2016
Coryton	Intergen	732			2002		
Rye House	Iberdrola	715			1993		
Grain	E.ON	1350	1350			2015	
Grain CHP	E.ON			1270			2010
Enfield	E.ON	400			1999		
Littlebrook D	RWE	1370	1370	TBC	1980s	2015	

Appendix 2

Comparison between Thames Cluster, Humber Cluster and Scotland Cluster	Electricity demand (2008-09) MW	Current CO_2 emissions from power stations Mt pa	Potential CO_2 capture from planned CCS projects	Direct distance between planned CCS projects km	Direct distance to coast km	Estimated distance from power plant to field km
Thames Cluster	12,355	30	16	20	On estuary	270
Humber Cluster	5,920	55	6	20	90	>260
Scotland Cluster*	6,103	15	14	200	On estuary/coast	>250

*Longannet, Peterhead and Cockenzie

References

DTI [2006] Industrial Carbon Dioxide Emissions and Carbon Dioxide Storage Potential in the UK, S. Holloway et al, BGS, DTI October 2006

IEA [2007] CO_2 Capture, IEA Greenhouse Gas R&D Programme, D Adams & J Davison, May 2007

NG [2008] 2008 Seven Year Statement, National Grid, 2008 (http://www.nationalgrid.com/uk/Electricity/SYS)

Stern [2006], Stern Review: The Economics of Climate Change, HM Treasury, 2006

YF [2008] A Carbon Capture and Storage network for Yorkshire and Humber, (http://www.yorkshire-forward.com/sites/default/files/documents/Yorkshire%20%20Humber%20Carbon%20Capture%20%20Storage%20Network.pdf)

E.ON UK plc
Westwood Way
Westwood Business Park
Coventry
CV4 8LG
United Kingdom

T +44 (0) 2476 424000
F 44 (0) 2476 425432
eon-uk.com

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