Carbon Capture and Storage Inquiry

Energy and Climate Change Committee

This is an Engineering the Future response to the Energy and Climate Change Committee Carbon capture and storage inquiry.

The development of this response has been led by:

- **The Institution of Engineering and Technology**

The response has been written with the assistance of and endorsed by:

- The Energy Institute
- The Institution of Chemical Engineers
- The Institution of Mechanical Engineers
- The Royal Academy of Engineering

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For further information please contact:

Thomas Man, Manager Professional Engineering Forum, The Royal Academy of Engineering

thomas.man@raeng.org.uk 020 7766 0654

Engineering the Future is a broad alliance of engineering institutions and bodies which represent the UK's 450,000 professional engineers.

We provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy.

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1. Engineering the Future (EtF) is a broad alliance of engineering institutions and bodies which represent the UK’s 450,000 professional engineers. We provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy. This evidence is submitted on behalf of Engineering the Future and its development has been led by the Institution of Engineering and Technology and it is supported by The Energy Institute, The Institution of Chemical Engineers, The Institution of Mechanical Engineers and the Royal Academy of Engineering.

Executive Summary

2. A largely decarbonised electricity sector consisting of nuclear, renewables and CCS, combined with energy storage and demand response is technically achievable. Without CCS, the UK would need a lot more nuclear if it is to meet greenhouse gas (GHG) targets.

3. There are three main components to CCS: capture, transport and storage. All three components use proven technologies that have been demonstrated independently in different industries. The three have not yet been implemented together in an end-to-end system in the power sector.

4. In this submission, we have concentrated on CCS in the context of power generation because that is the scope set out by the ECC Committee in its call for evidence. Once proven, CCS will be applicable to industries other than power generation, thus allowing cuts in CO_2 emissions that could not readily be achieved otherwise.

5. All of the CCS technologies currently available will impose an efficiency penalty, effectively requiring approximately 10-15% more fuel to be burned in gas-fired power plants and 20-25% in coal-fired power plants to produce the same amount of electricity.

6. The key barrier for CCS technology is that, to date, there have been insufficient economic reasons for companies to develop and implement it or even to undertake the demonstrations necessary to bring the technology to maturity.

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What types of CCS technology are currently being developed and how do they differ from one another?

7. The three main components of CCS are capture, transport and storage. All three use proven technologies that have been demonstrated independently in different industries. The three have not yet been implemented together in an end-to-end system in the power sector.

Carbon Capture Technologies

8. There are three principal methods of carbon capture:

- Pre-combustion: carbon is removed from the fuel prior to combustion so that the exhaust is essentially carbon-free;
- Post-combustion: carbon dioxide is removed from the plant exhaust after combustion;
- Oxy-fuel: the fuel is burnt in pure oxygen resulting in a high concentration of carbon dioxide in the exhaust so it can be removed more easily. (If the fuel is burnt normally in air, the exhaust contains a large amount of nitrogen from the air, meaning that there is a greater volume of gas to treat, making removal more difficult.)

9. Pre-combustion processes are suitable for new construction, which fits the situation for coal generation in the UK, where new plants would replace existing coal plants that are all quite old and relatively inefficient by modern standards. Post-combustion (and potentially oxy-fuel) is suitable for retrofit to existing coal and gas plants as well as new build. There are numerous available reports that provide additional details on these three technologies, providing a comparison of costs, efficiencies and trade-offs.[1]

10. It is important to note that all of the technologies currently available will impose an efficiency penalty, effectively requiring approximately 20-25% more coal or 10-15% more natural gas to be burned to produce the same amount of electricity. The reason for this is the high energy consumption of the carbon capture stage of the process at the power station site. Approximately twice as much CO_2 is produced and therefore has to be captured per unit of electricity generated when using coal compared with using gas.

11. Each technology has a number of potential variations and there are a number of promising refinements. For example, alternative absorption materials for post-combustion capture may offer significant future reductions in the inherent efficiency penalty associated with CO_2 capture.

12. We would suggest that narrowing the UK focus to one particular technology (either pre- or post-combustion, or oxy-fuel) would not be beneficial, as different generation plants will benefit from different capture technologies: new construction is likely to be most relevant for coal in the UK, while natural gas plants, if built in quantity to meet a shortfall in generation, could have more potential for retrofit.

Transport and Storage Technologies

13. Carbon dioxide transport is a mature technology following decades of operation for enhanced oil recovery (EOR) applications in the US and more recently for offshore storage

[1] See, for example, the CCS Cost Reduction Task Force Report, May 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/201021/CCS_Cost_Reduction_Taskforce_-_Final_Report_-_May_2013.pdf

in the North Sea. Onshore CO_2 transport has been principally for EOR away from centres of population. There are potential concerns over safety should a pipeline rupture occur close to a population centre and these need to be addressed and managed (See Question 5 for further discussion of safety).

14. Long-term storage is less well developed with only a small number of reference sites. For example, Norway has been injecting approximately 1mt of CO_2 a year into the North Sea at Sleipner since 1996. We would suggest that exploration and proving trials for offshore UK storage sites are accelerated to ensure that this part of the chain is fully developed.

What contribution could CCS make towards the UK's decarbonisation targets? Are the UK Government's expectations reasonable in this regard?

15. Providing all the decarbonised electricity required to meet the carbon reduction targets for the electricity sector using a combination of renewables and nuclear power alone would be logistically demanding and costly, even with significant demand reduction through energy efficiency and the active management of peak demand. All these technologies carry development and deployment risk, as well as economic risk, which makes a wider portfolio of options highly desirable.

16. In all global scenarios and modelling through to 2050 that we have seen, fossil fuel generation sources will be essential to meet overall energy demands. In order to meet EU and UK carbon reduction targets and global needs to reduce greenhouse gas emissions, we believe fossil fuel generation will need to decarbonise through the application of CCS.

17. The 2010 Royal Academy of Engineering report *Generating the Future*[2] outlined four energy scenarios that could meet the 2050 emission reduction target. In all scenarios there is contribution from CCS in order to meet the UK's 80% reduction target. Only the "high demand reduction" scenario shows a limited deployment of CCS and the report did not recommend implementing a policy based on this scenario. The report highlighted the urgent need to progress a full suite of low carbon technologies if we are to meet the targets.

18. The government's expectations to achieve a largely decarbonised electricity sector by 2050 are reasonable as a largely decarbonised electricity sector, consisting of nuclear, renewables and CCS, combined with energy storage and demand response, is technically achievable. It is difficult to estimate the cost of achieving this and we may find over the timeframe we are reviewing, one or two new technologies appear and/or existing technologies achieve a step change in cost/performance. In addition, technologies currently favoured may hit barriers in development or deployment and become less significant than currently predicted.

19. The DECC July 2013 levelised cost forecasts for generation technology projects commissioning around 2025[3] show coal and gas generation equipped with CCS and renewables to be at a similar cost (within margins of error to be expected over this planning horizon). There are some indications that the cost of renewables will fall below the estimates of coal and gas with CCS towards the end of the 2020s but this is difficult to predict and depends on fuel price expectations and anticipated advances in the efficiency of renewables delivery. We believe that CCS could potentially become economically viable over this period alongside other low carbon technologies, assuming demonstration proves successful and decarbonisation targets are not relaxed.

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[2] Royal Academy of Engineering, March 2010, "Generating the Future", www.raeng.org.uk/gtf
[3] DECC, "Electricity Generation Costs 2013" https://www.gov.uk/government/publications/decc-electricity-generation-costs-2013

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20. There are further potential CCS applications in industry (such as refining, cement, iron and steel production) that could materially contribute to the UK meeting decarbonisation targets.

21. In the longer term, once CCS has been developed and proven, it has the potential to create “negative” carbon emissions by being applied to power stations fuelled by biomass from sustainable sources. This is potentially an important capability because it could theoretically be used to offset the carbon emissions from applications where it is hard to imagine replacing unabated fossil fuels, such as aviation. A number of respected analysts including the Energy Technologies Institute see this as an important part of decarbonising by 2050.

Are there any potential benefits (e.g. the ability to export CCS technology abroad) of successfully developing CCS to the UK economy and, if so, what are they?

Commercial benefits:

22. The main benefit of CCS is that it offers a means of decarbonising fossil fuels, which are a stable, reliable and proven generation source. On a global basis, fossil fuel generation will continue to be a major part of the energy mix. Recent trends show the developing economies of the world largely powering their economies through coal and gas fired electricity generation, and fossil fuels for transportation.

23. There exists the opportunity for the UK to design, develop and implement world-leading CCS projects. Research is underway at UK universities that may lead to valuable IP which could be exploited on a global scale. However, much of the work to be done is industrial, moving from pilot scale, through to demonstration in large-scale projects. This could provide commercial opportunity for a number of UK companies involved, some of which are conducting world-leading large pilot demonstrations, such as Doosan Babcock at Renfrew, Glasgow. We would expect to see economic value throughout the supply chain and the creation of jobs that would have value, but this would depend on the UK’s success in this activity versus global competitors.

24. Successful demonstration of CCS in the UK could kick start the technology elsewhere and create first mover advantage. We would however caution that a number of countries have also invested in CCS research, development and deployment, particularly Canada, the USA, Norway and China, and first mover advantage will need effort to be gained and sustained. One area where the UK may be more likely to gain competitive advantage could be the application of CCS on gas-fired plant, which seems likely to be a major part of the UK’s requirements. Most other countries are focusing on CCS on coal-fired plant.

25. The potential benefits of exporting know-how does, however, depend on a continuing and increasing global response to addressing climate change, which is not certain at this stage.

Diversity and flexibility:

26. CCS power generation offers advantages as part of a diverse energy mix in that it could be deployed at scale with an established fuel supply chain. CCS can be combined with flexible generation plant (such as combined cycle gas turbine (CCGT)), which is needed for grid balancing. Once proven, it is likely that CCS-equipped power stations would evolve

to be specified for flexible operation to obtain the greatest benefit from the technology. Most analysts believe that such power stations would be cost-competitive with nuclear and renewables once deployed at scale, subject to demonstration and continued commitment to carbon targets and supporting price/regulatory mechanisms.

Disadvantages:

27. The disadvantages are the continued dependence on fossil fuel (and therefore world fuel prices), concerns over security of supply, and integrity of the permanent storage. In the shorter term, a further disadvantage is the large adverse impact on power station thermal efficiency which, in today's world of low carbon prices, makes CCS appear only to add cost and degrade performance. However, this situation should not last if the world becomes serious about abating climate change.

What are the main barriers (e.g. economic, political, regulatory, scientific and social) to developing large-scale integrated CCS projects in the UK and internationally? How can they be overcome?

Economic

28. The key barrier for CCS is that a mechanism is required to create an economic driver as CCS adds costs without any direct economic benefit. In the UK, we have legislated for our 2050 GHG targets and as a consequence have developed economic incentives to ensure that these are achieved. These comprise the carbon price floor which penalises plant that emits carbon and therefore will give CCS technology a cost advantage. However, the main mechanism is a long term Contract for Difference (CfD) which would need to be negotiated with government. We support the recommendations from the CCS Cost Reduction Task Force Report[4] that we need make progress here to ensure that funding mechanisms are fit-for-purpose and that the contracts are bankable.

29. It is difficult to comment internationally other than the same principles would need to apply, i.e. GHG targets supplemented by incentives to ensure they are achieved.

30. Please see also the response to Question 1.

Political

31. Government action to fund the first project as soon as possible would strengthen the UK's pathway to decarbonising its fossil fuel generation (and assist with decarbonisation of other heavy industry outside of power generation) in order that CCS can be proven and applied to the rest of the fossil fuel generation mix (and other industrial sources). Without it, it is difficult to see how the UK will decarbonise its electricity system and industrial sectors to meet the targets. The danger in not having demonstration projects operational that prove the technology is that commitment to achieving the country's carbon reduction targets may begin to erode.

[4] CCS Cost Reduction Task Force Final Report, 2013 www.gov.uk/government/uploads/system/uploads/attachment_data/file/201021/CCS_Cost_Reduction_Taskforce_-_Final_Report_-_May_2013.pdf

Regulatory

32. There are safety risks in the construction and operation of CCS, as there are with any large-scale enterprise, which will require analysis, mitigation and the development of appropriate regulation. These are discussed further in our response to Q5.

33. The UK has not yet addressed the legal framework around CO_2 disposal and sequestration offshore but it is a significant issue. A key issue will be to put in place an effective commercial and regulatory structure. These (and more) questions need to be answered before investors would start to invest:

- Will a monopoly CO_2 network be a regulated industry, like National Grid?
- Will the reservoirs be owned by a monopoly state organisation or will there be a competitive market in which reservoir owners bid to power stations to take their CO_2?
- Who will regulate this market?
- What is the role of The Crown Estate? Who will issue licences to sequester carbon?

Scientific

34. The storage component has some geological integrity risks to be addressed. We are not able to comment on the permanent integrity of geological sequestration for saline aquifers or depleted oilfields, but would suggest opinion is best sought from the British Geological Survey and academic researchers in that area.

Technology

35. The greatest technology challenges are around improving the efficiency of the capture process, which typically requires 10-15% (for gas) and 20-25% (for coal) more fuel to be burned for the same electrical output. The cost associated with this is the largest contributor to the overall cost of CCS. The process will typically sequestrate 85% of the CO_2 typically produced, rising to 90% predicted by 2020. There is opportunity for technology development to improve that level, which if coupled with a high carbon price, could also improve the economics. There are technologies in the research stage that show promise in these areas.

36. The other key challenges are pulling together several technologies, all of which may have been demonstrated in different applications but which have yet to be integrated with a large power station (either new or being retrofitted), a network of new CO_2 pipelines and various storage reservoirs – probably mainly offshore. The systems engineering and project engineering of all this and its control systems, while essentially routine, is distinctly “non-trivial” and is something that is likely to be developed over the first half-dozen projects.

Social

37. There is further work to do on public outreach to ensure the safety and storage integrity components are fully understood by key stakeholders. Considerable public resistance to CCS has been seen in Europe, but there the permanent underground CO_2 storage was planned to be onshore. The UK’s intention to store CO_2 in saline aquifers offshore should ease the public concern. We suggest thorough public engagement on the benefits and risks of CCS.

38. As with other new low-carbon technologies, costs will be higher than for current systems and public acceptance of this will be crucial.

Are there any safety issues associated with capturing, transporting and storing carbon dioxide? How could they be overcome? Who should have responsibility for ensuring these activities are safe?

Capture

39. Capture plant is standard industrial process technology. There are significant safety management issues but they should be wholly within the capabilities of a competent operator and would be regulated by the HSE in the normal way.

Transport

40. CO_2 is inert but heavier than air, and in the event of an escape it will tend to settle at ground level and potentially expose people and animals in the area to risk of suffocation. There are thus safety risks associated with accidental or malicious pipeline ruptures that will need to be addressed and managed. The Energy Institute has produced technical guidance[5] on how to manage the transport of CO_2 safely where there is increased population density.

41. Safety will be the prime responsibility of the asset owner, regulated by the HSE. Risks associated with a properly maintained and regulated CO2 pipeline transmission network should be seen in the context of other potentially hazardous operations such as transporting natural gas and ethylene, which are routinely carried out in the UK.

Storage

42. Storage facilities for the UK will be offshore, and will carry risks of offshore working as for offshore oil, but these should be manageable by a competent operator. Studies of reservoir integrity will be an important part of the development of sequestration sites, and we would not expect either seepage or sudden release of CO_2 from properly designed storage reservoirs. Safety will be regulated by the HSE as for other offshore activities.

How have other countries incentivised CCS development? How successful have they been? How do they compare to the UK's efforts?

43. The Global CCS Institute (GCCSI) maintains a list of global projects and their status.[6] In power generation applications there are demonstration projects in the 'execute' stage in USA and Canada. Those at the 'Define and Evaluate' stage include Europe (10), US (5) and Canada (1). In the US and Canada projects, the CO_2 will be used for enhanced oil recovery (EOR) rather than permanent storage. There are indications that China now has a major programme at the 'identify and evaluate' stage. See Figure 1 for more details.

[5] Energy Institute and the Global Carbon Capture and Storage Institute "Technical guidance on hazard analysis for onshore carbon capture installations and onshore pipelines"
http://www.energyinstpubs.org.uk/cgi-bin/moreinfo/moreinfo.cgi?articleid=1302

[6] http://www.globalccsinstitute.com/projects/browse

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Figure 1: Status of CCS Projects for Power Generation

	Operate	Execute	Define	Evaluate	Identify
UK	0	0	3 (Geo) 1 (EOR)	1 (Geo)	1 (EOR)
Europe (other than UK)	0	0	4 (Geo)	1 (Geo)	0
USA	0	1 (EOR)	1 (Geo) 3 (EOR)	1 (EOR)	0
Canada	0	1 (EOR)	1 (EOR)	0	0
China	0	0	0	2 (EOR)	1 (Geo) 3 (EOR)
Korea	0	0	0	1 (Geo)	1 (Geo)
Australia	0	0	0	2 (Geo)	0
Middle East	0	0	1 (EOR)	0	0

Source: Derived from large-scale integrated CCS projects identified by the Global CCS Institute.
http://www.globalccsinstitute.com/projects/browse
Website viewed on 21 August 2013

Key:
Geo = Permanent Geological Storage
EOR = Enhanced Oil recovery

44. We believe projects that are for end-to-end power generation application will be directly funded by governments, and potentially smaller projects linking in industrial sources of CO_2 to the existing networks will be too. Those projects capturing CO_2 from a power plant and using the CO_2 for EOR have some government funding to support the commercial value of the CO_2.

45. We do not believe that other countries have developed or implemented incentives or mechanisms that specifically encourage private sector development and deployment of CCS. This represents an opportunity to take a leadership position by progressing models to ensure the first commercial full scale CCS project takes place in the UK.

Is the UK Government's approach, set out in its CCS Roadmap, likely to incentivise development of CCS in the UK?

46. The roadmap is a welcome demonstration of the government's intention to see CCS become a commercial reality, especially including the cost reduction activity which is underway to identify and promote cost reduction efforts.

47. Since the report was published in April 2012, key milestones appear to be slipping. We believe a decision on granting the £1bn funding and additional EMR support to the first project will now not be made until mid-2015, whereas the plan indicated that would be mid-2014. We believe it would be possible to take this decision as early as late 2013 for some projects given the voluminous work and FEED studies that have already been undertaken.

These slips emphasise the industry's concern as to whether CCS will become a commercial reality.

48. The key is to have the first project operational as soon as possible in parallel with clear development of the regulatory framework and commercial model.

49. Progress towards a demonstrator is currently constrained more by the terms and requirements of public competitions than by the capability to develop and construct the plant.

Could the successful development of CCS improve international efforts to mitigate climate change? What role could UK CCS play in this?

50. An affordable and reliable decarbonised electricity sector, broadening in time to encompass heavy industry, would demonstrate the UK's ability to deliver leading edge energy projects. Should economies around the world similarly aspire to achieve a decarbonised energy sector, then the UK would be in an ideal place to seize on those opportunities. At least as important as the technologies will be the economic and regulatory environment that creates the platform for investment.

51. CCS offers one of those areas where UK expertise could be exported as we expect that the majority of the world to have a fossil fuel-based electricity sector for the foreseeable future. Additionally, the carbon intensity of other major industrial processes (such as cement production) can be improved through the application of CCS on their processes.

52. Mitigating fossil fuel emissions has potential for significant large scale impact on a global scale, providing a pathway for developing countries to meet CO_2 reduction targets whilst utilising readily available fuel resources.

53. We would add, however, that for CCS to make real impact there needs to be a stronger global consensus on carbon emissions reduction, with rich countries (including the UK) being prepared to bear the costs of carbon emissions abatement on a large scale, and a way found to bear the costs in developing countries. This seems challenging in the present economic climate, and given reduced public interest in climate change globally, but this needs to be viewed in the context of developments taking place over several decades.

What are the consequences of failing to develop CCS and what alternatives are available for decarbonisation if CCS fails?

54. If CCS is not taken forward at sufficient scale, additional measures and/or technologies would need to be implemented if we are to meet the carbon reduction target.

55. The primary alternative technology is probably new nuclear. Without CCS, there would be a need for a much larger UK nuclear build programme than currently envisaged. This is deliverable from an engineering perspective, but would require large amounts of capital and the substantial expansion of UK and global supply chains. From a risk perspective it leaves a significant exposure to the costs of nuclear, especially in a market with relatively few approved vendors and fuel sources.

56. Alternatively, or additionally, a greater capacity of reliable renewable generation would need to be developed. In the case of offshore wind, expansion on a scale to replace the potential role of thermal power stations equipped with CCS would probably be unfeasible given the need to manage generation intermittency on such a large scale. To support this, we would need very large scale and potentially long term energy storage and/or

interconnection across Europe and potentially beyond. Such scenarios have been explored in models, but carry substantial development and deployment risks, which again emphasise the value in the optionality of CCS.

57. Time of use tariffs and demand response techniques could be developed to reduce and adjust the timing of energy usage. However, given the scale of the deployment of these techniques that would be needed to meet the targets, in the absence of CCS and/or nuclear at the right scale, the impact on the electricity and energy system would be profound, and would probably challenge the limits of public acceptance.

58. At the moment it is difficult to foresee a power generation sector that does not include fossil fuel generation being available in time to meet climate reduction targets. Failing to progress CCS in time could therefore create political pressure to reduce those targets to avoid the risk of supply shortage.

59. Finally, there are a number of industrial sources of CO_2 such as cement and iron and steel manufacture, where CO_2 is intrinsically produced as part of the process, and there are no currently feasible substitutes for the product. Failure to develop CCS will have significant knock-on effects for decarbonisation of these sectors too.