An insights report by the
Energy Technologies Institute

Carbon capture and storage
Building the UK carbon capture and storage sector by 2030 – Scenarios and actions

In partnership with: element energy | PÖYRY

Contents

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The ETI welcomes both feedback on this report and further engagement with stakeholders around actions enable efficient CCS sector development

Introduction

The ETI's work has shown that a successful UK Carbon Capture and Storage (CCS) sector could save tens of billions of pounds (something like 1% of GDP) from the annual costs of low carbon energy by the 2040s: a huge potential saving by any standards. Apart from providing low carbon electricity, CCS can capture industrial emissions, help deliver low carbon gas and deliver 'negative emissions' in combination with Bioenergy.

The first two key projects (Peterhead and White Rose) are currently being taken forward under the Government's CCS Commercialisation Programme. But what else is needed to build a substantial CCS sector by 2030? What practical steps are needed on the ground, and how much will it cost?

This report summarises work that we have done to examine these questions. It extends our previous modelling-based analysis, using three ambitious but deliverable scenarios to illustrate how we can build the CCS sector by 2030.

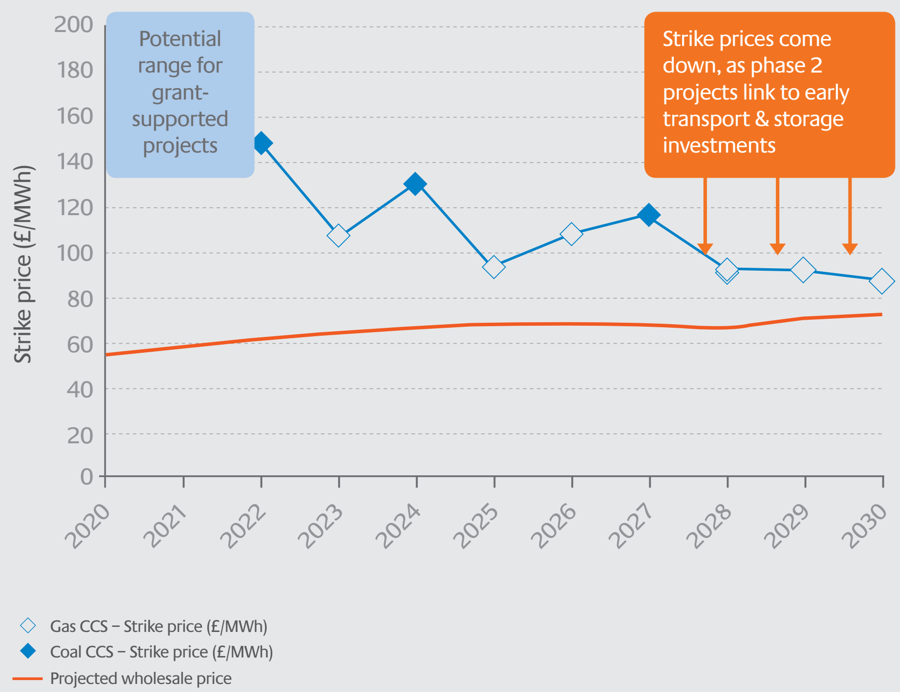
Key headlines

- Successfully deploying CCS would save billions of pounds – capturing industrial emissions at low cost, providing low carbon energy for industry, transport & heat and delivering negative emissions combined with Bioenergy
- To deliver these savings requires around 10GW of capacity by 2030 - needs capital investment around £21-31bn[1] – based on efficient sharing of infrastructure and co-ordinated cluster/hub development
- Early investments in transport and storage infrastructure can unlock future unit cost reductions and strategic build out options. Strike prices below £100 per MWh are achievable in the 2020s
- 10GW scale deployment is achievable and affordable, capturing and storing around 50 million tonnes of CO_2 per annum from power and industry by 2030
- Developing capture technology options and diversifying geographical location can deliver reduced risk
- Success or otherwise in deploying CCS determines key aspects of the UK's energy infrastructure architecture
- Delay increases reliance on nuclear and offshore wind – increasing system risk and costs before and after 2030

[1] All figures are quoted in 2014 prices.

Potential development of strike prices

(Concentrated scenario)



Context

The UK has an opportunity to build a CCS sector capable of reducing the costs of meeting its carbon targets by tens of £billions, while exploiting the UK's unique offshore engineering capabilities and safeguarding the future of key energy-intensive industries.

This report identifies the practical steps needed over the period to 2030 to build a UK CCS sector that can:

- Move rapidly towards cost competitive low carbon electricity generation during the 2020s
- Deliver low cost emissions reductions to efficiently meet the 4th and 5th carbon budgets, and
- Put the broader UK energy system on a trajectory towards its long term objectives of affordable and secure low carbon energy

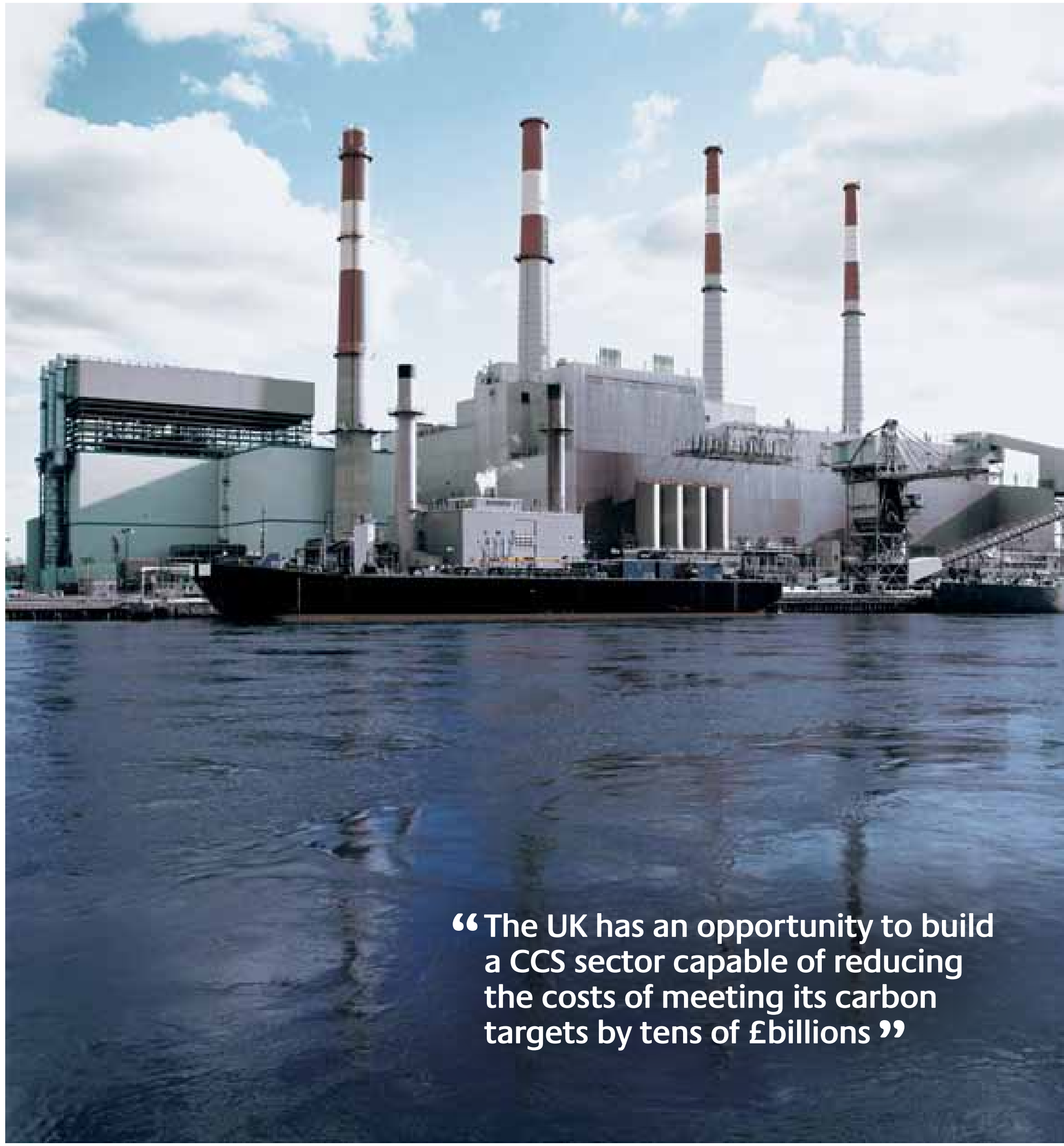
The analysis uses three ambitious but deliverable sector scenarios for the UK CCS sector to 2030. The sector scenarios are tools to identify challenges and the steps required to overcome these in the context of real geographies and dependencies, plausible potential projects, existing and potential power generation and industrial sources of CO_2, realistic decision timelines and developing project economics.

Over a period of six months, and with significant input from many stakeholders, the project has developed three realistic sector scenarios to 2030. This extends previous modelling-based analysis of the potential role of CCS (based for example on ETI's energy system modelling, analysis of the UK Continental Shelf geological storage resource and modelling of transport and storage infrastructure)[2]. It also builds on the UK government's stated "CCS Commercialisation Outcome":

- Private sector electricity companies can take investment decisions to build CCS equipped fossil fuel power stations, in the early 2020s, without Government capital subsidy, at an agreed contract for difference (CfD) strike price that is competitive with the strike prices for other low carbon generation technologies.

The project team does not seek to recommend a particular scenario – indeed the specific development path of the CCS sector could mix elements of all three scenarios presented. However the outcomes of the analysis and identified actions are intended to inform policy makers and industry participants alike.

[2] ETI evidence submitted to Environment and Climate Change Committee inquiry on CCS;
A picture of CO_2 storage in the UK: learnings from the ETI's UKSAP and derived projects;
Optimising the location of CCS in the UK; Potential for CCS in the UK.
(all available on the ETI website www.eti.co.uk/programme/carbon)



Why develop CCS at scale in the UK?

ETI's analysis of the UK energy system points to the central importance of CCS in enabling the UK to meet its carbon budgets efficiently. ETI's energy system modelling is based on robust engineering analysis and cost evidence and suggests that successfully deploying CCS would save tens of billions of pounds (up to circa 1% of GDP by 2050) from the annual cost of meeting UK Climate Change targets, compared with alternative approaches to reducing emissions which do not deploy CCS. Apart from its role in power generation, CCS can capture industrial emissions at low cost; provide flexible low carbon energy for industry, transport and heat through gasification; and deliver high value negative emissions (in combination with Bioenergy).

Enabling CCS to realise its potential and play this key role in UK decarbonisation will require developing around 10 GW of capacity by 2030. This level of ambition is consistent with DECC's Electricity Market Reform (EMR) delivery Plan (which included up to 13 GW of CCS by 2030), and with the Committee on Climate Change's (CCC) scenarios for curbing power sector emissions to 50g CO_2/kWh by 2030. Capital investment required would be around £22 – 31 billion to build the sector over the period to 2030, equivalent to around 10 to 12% of total power sector investment estimated by the Committee on Climate Change. Delaying development of this level of capacity beyond 2030 would expose the UK to substantial cost and deployment risks in meeting carbon budgets.

Overview of 2030 Sector Scenarios

On this basis the three scenarios summarised below represent distinct and plausible pathways to developing a 'close to cost optimal' 10 GW of CCS capacity by 2030

Scenario	Costs	Strike prices	Benefits / issues
Concentrated			
Concentrated around the first 2 projects; dominant role for gas CCS with Southern North Sea (SNS) storage.	» £14 bn CfD cost to 2030 » £2.1 bn CfD cost per annum in 2030 » £21 bn total capex spend to 2030	» Early Phase 2 projects below £100 / MWh by 2025 » Below £90/ MWh in 2030	» Fast cost reduction, but limited optionality and / or some infrastructure costs deferred to 2030s.
Enhanced Oil Recovery (EOR) led			
Wood report-style push; market pull for CO_2 for EOR supported by e.g. tax incentives.	» £14 bn CfD cost to 2030 » £2.2 bn CfD cost pa in 2030 » £27 bn capex spend to 2030	» Both coal and gas plants below £100/ MWh by late 2020's » Assumes £20/t CO_2 price to EOR	» North Sea jobs & revenues » Oil & gas revenues reduce net costs of policy support (CfDs) » Oil price risk exposure
Balanced			
Multiple regional clusters, fuels and capture technologies.	» £18 bn CfD cost to 2030 » £3.2 bn CfD cost per annum in 2030 » £31 bn total capex spend to 2030	» New gas-fired plants below £100 / MWh in 2030 as 3rd gen of plants developed	» Greater optionality for 2030s roll out » Store & technology diversity = risk reduction

Notes: The CCC projections suggest that total annual LCF spend could be around £10 bn per annum by 2030 (CCC projections in Energy prices and bills – impacts of meeting carbon budgets, Dec 2014)
All figures are in 2014 prices

Key conclusions emerging from the scenarios

- Developing a 10 GW scale CCS sector by 2030 is feasible and affordable through a number of different pathways, based on co-ordinated cluster/hub development
- Early 'phase 2' projects can make use of the stores and transport infrastructure developed under the commercialisation programme, delivering strike prices at or below £100 per MWh by 2025, with potential further cost reductions by 2030
- A 10 GW scale CCS sector would be affordable in terms of the demand on levy control framework funds (an annual support cost of around £1.1 to £1.3 billion by 2025) and efficient in terms of cost per tonne of CO_2 reduction
- This scale of CCS deployment could capture and store around 50 million tonnes of CO_2 emissions per annum from power and industry by 2030, enabling CCS to develop in the 2030s to the optimal scale suggested by longer term analysis of the UK energy system
- This outcome can be delivered by creating a supportive policy environment with early action on critical issues to bring forward timely investment

"This scale of CCS deployment could capture and store around 50 million tonnes of CO_2 emissions per annum"

Three scenarios based on key drivers and policy backdrop

CCS growth

1

Concentrated

- Geographic concentration around the two competition projects to reduce transport and storage costs and barriers
- Dominant role for SNS storage and gas CCS

2

Enhanced Oil Recovery (EOR) led

- Implement Wood's recommendations to coordinate UKCS oil production and increase commercial attractiveness
- High CO_2 - EOR policy support (e.g. tax incentives)
- CO_2 has a value due to demand from CO_2-EOR projects – reduces net costs of policy support (CfDs)

3

Balanced

- Push on all fronts to win support from diverse stakeholders
- A variety of regional source clusters
- Multiple fuel sources and capture technologies

Key requirements for CCS sector development

1. **Timely implementation of both CCS Commercialisation Programme projects:**

   The scenarios point clearly to the value of both Commercialisation Programme projects (Peterhead in Scotland and White Rose in Yorkshire) in developing vital transport and storage infrastructure which unlock later unit cost reductions and strategic build out options. Failure to develop two projects to open up two CCS hubs would constrain options and increase the risk of failure to develop a CCS sector at scale by 2030.

2. **Early investment in physical appraisal to expand the promising 5/42 and Captain aquifer stores and appraise further sites**

   All scenarios require suitable sinks for subsequent phases of project to be developed early, given long lead times for developing storage sites, and the need for clarity to underpin investment decisions. This means that, in addition to the vital storage development under the Commercialisation Programme, immediate investment to expand capacity is needed, either tax payer funded or by creating sufficiently strong incentives to bring forward private investment.

3. **Enable early investment decisions by 'phase 2 projects' (the first tranche of projects which follow the Commercialisation Programme) by awarding a further 3 appropriately designed CfDs by 2020**

   All three scenarios depend on enabling at least three early follow on projects to reach final investment decision by 2020, in effect requiring the award of three further power sector CfDs ahead of commissioning of the Commercialisation Programme projects.

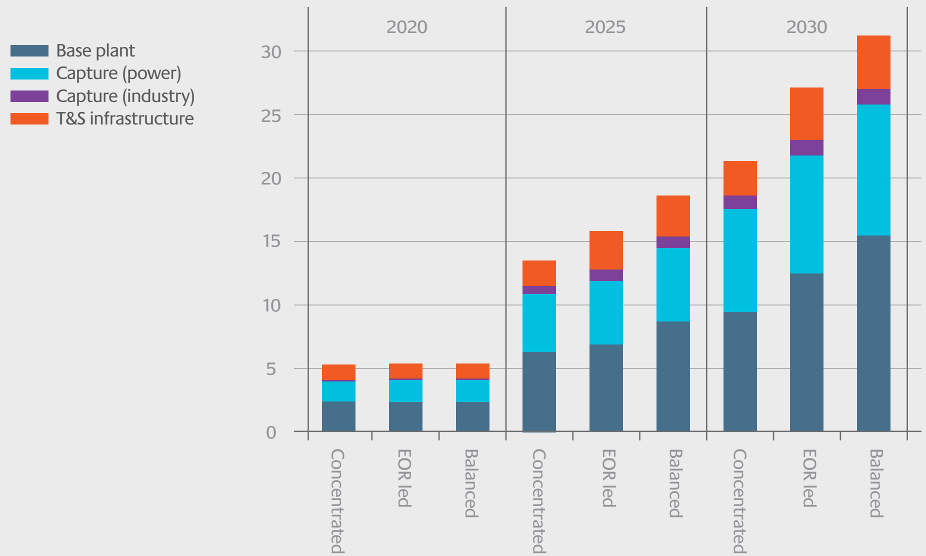
   This is a key challenge for the current policy framework, requiring early commitment of levy control framework resources, and potentially bespoke contractual design to bring forward sufficient private sector investment while maintaining incentives for cost-efficiency.

4. **Stimulate a robust project development pipeline by delivering clear signals to investors and project developers about the scale and strength of policy (levy control framework support) commitment to developing CCS:**

   All of the scenarios require a robust pipeline of developing projects throughout the 2020s. Stimulating a sufficiently project pipeline will require significant strengthening of current policy and market signals, and resolution of uncertainties for investors.

   The scenarios point clearly to the need to achieve 5 or 6 CfD awards by 2020, (i.e. 3 or 4 follow-on projects, in addition to the 2 commercialisation programme projects) committing around £1.1 – £1.3 billion annually of the LCF to CCS by 2025. A consistent pipeline of projects will be needed through the 2020s, resulting in support costs around £2-3bn per annum by 2030 (or around 20 to 30% of expected annual low carbon support costs) Investors and project developers will require clearer signals about this scale and strength of commitment.

Cumulative capital expenditure by scenario (£bn)



Other issues to be resolved

The scenario analysis also suggests that a range of other issues will need to be resolved to support the rapid development of the sector during the 2020s, including:

» **Governance for infrastructure sharing:** Efficient sharing of infrastructure is central to the strategic value and cost reductions achievable in all scenarios, but the most effective associated arrangements for governance or regulation, and for charging will need to be clarified. A purely negotiated incremental cost approach would have very different strike price and risk management implications to a more regulated network charging framework.

» **Strategy for capture readiness:** Developing a more robust strategy for capture readiness, the location of new thermal plant and retro-fitting needs greater attention if, as seems likely, a wave of investment in unabated gas-fired capacity is required early in the 2020s (ahead of CCS sector development) to bolster energy security / supply margins.

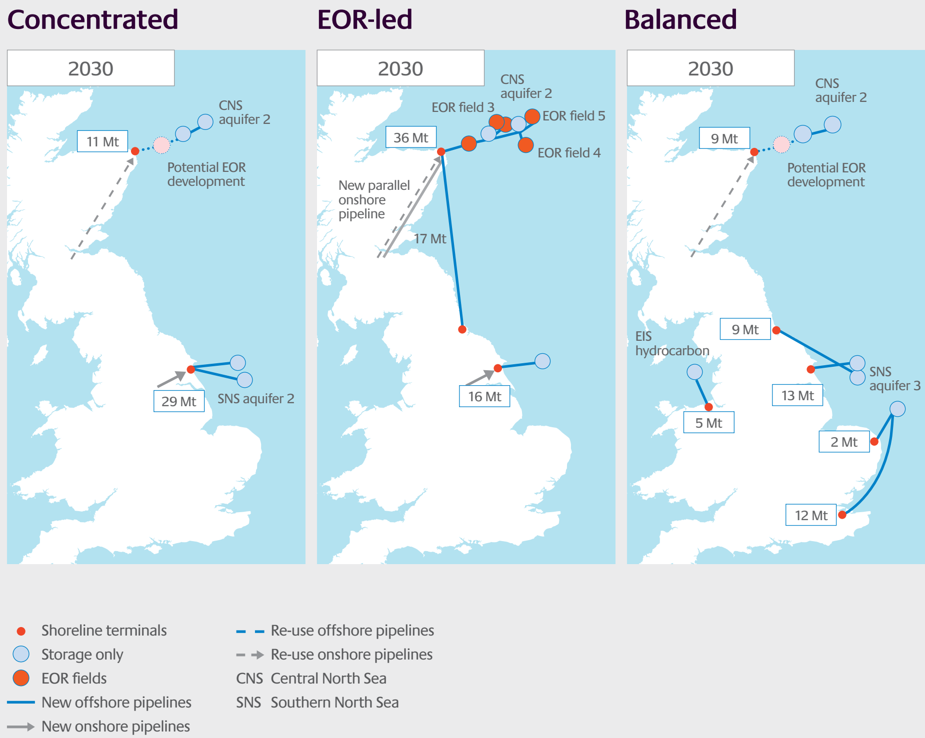
» **Financial incentives for industrial CCS:** All scenarios demonstrate the clear potential for CO_2 capture from major industrial sites before 2030; but realising this will require early resolution of financial incentives to support capture of industrial process-related emissions with CCS.

» **Management of load factor risk for CCS power projects:** The potential load factors achievable by CCS power plants in the medium and long term will depend on the broader generation mix. Given the lifetime of CCS projects, investors may require greater clarity on this, or a contract which is different from CfDs, with rewards not based entirely on delivered output.

» **Risk management and governance for EOR:** The degree of reliance on EOR (and associated incentives) in financing and leading the development of the sector and its infrastructure will need to be clarified, as it will be an important influence on the pipeline of projects. Investments in northern / Scottish capture and CO_2 infrastructure would become more attractive along with coal-based capture projects to provide CO_2 volumes. However, an EOR-led approach would also need to manage oil-price risks to the viability of EOR; address greater complexity in cross-sector co-ordination; and clearly demonstrate how it delivers value in ultimately reducing emissions.

» **Reflecting strategic value in CfD allocation decisions:** The scenario modelling showed that developing a range of capture technology options and more diversity in geographic location can deliver reduced risk and increase optionality for future CCS development. But this looks likely to come at some added financial cost. While there is no clear case for government to pick technologies, policy on CfD allocation will need to clarify how these issues will be taken into account.

Comparison of the scenarios: transport and storage networks in 2030



What if CCS sector development is delayed?

- Delay in developing a UK CCS sector of around 10 GW scale by 2030 will increase the risks of higher costs in meeting carbon budgets, both before and after 2030
- This is because slower development of CCS (e.g. a 5 year delay) would require advancing other potentially more costly and risky ways of cutting emissions (e.g. a substantial move away from gas heating in the 2020s)
- Avoiding the cost and risks of delay, by investing in 10 GW of CCS by 2030 therefore delivers high value to the UK.

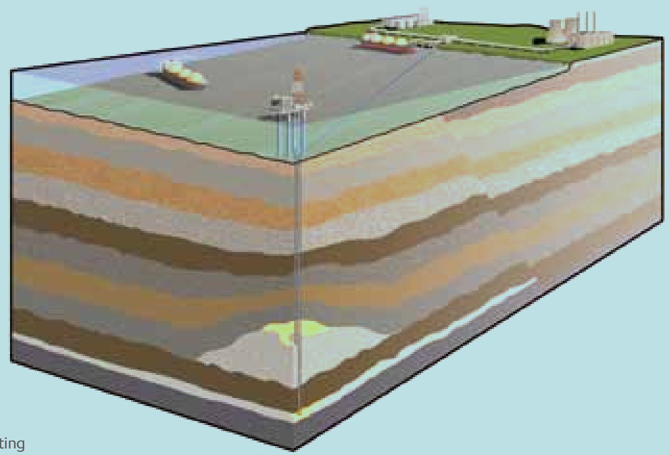
If delay were to permanently stunt the growth of CCS in the UK, ETI's analysis points to a substantial increase in the economic burden of meeting carbon targets, arising from the need to deploy higher cost technologies to cut emissions, particularly in heat and transport. A complete failure to deploy CCS would imply close to a doubling of the annual cost of carbon abatement to the UK economy from circa 1% to 2% of GDP by 2050 (or roughly an extra £1000 on annual average household bills for energy and transport services). ETI's analysis suggests that success or otherwise in deploying CCS determines key aspects of the UK's energy infrastructure architecture (e.g. different infrastructure choices depending on the extent of decarbonisation of heat and transport required to meet carbon budgets).

Scenario analysis and historical experience suggests that creating momentum in the sector to stimulate a robust project development pipeline will be important to deployment and realising cost reductions in practice. So delay in building the sector will increase the risk that CCS fails to deliver a significant contribution to either the power sector or broader decarbonisation, in turn creating broader risks of higher costs, heavy reliance on other technologies or potential failure to meet carbon budgets.

A shorter 5 or 10 year delay in developing the CCS sector would still increase costs and risks across the UK energy system and make infrastructure decisions required in the 2020s more challenging, given uncertainty in the role of CCS. There is an argument that delay would enable the UK to take advantage of technology cost reductions delivered by CCS investment elsewhere globally. But many of the costs and risks of early CCS deployment are UK-specific and early cost reduction opportunities depend on early infrastructure investments, achieving scale and capacity utilisation in the UK sector.

Containing the cost impacts of a 5 year delay would require both rapid (and risky) 'catch up' development of CCS during the 2030s and accelerated early uptake of a range of other low carbon technologies during the 2020s to fill the gap left by CCS (e.g. rapid replacement of gas heating during the 2020s as well as very rapid growth of biomass value chains to serve both heat and industrial energy needs).

More realistically, if broad strategy remains focused on early decarbonisation of the power sector, delay to CCS would lead to greater reliance on nuclear and offshore wind, with associated pressure to deliver very demanding deployment. Even with successful unit cost reductions, this would increase system risk and costs both before and after 2030.



CCS System Modelling Toolkit
ETI has invested in the creation of a modelling toolkit capable of simulating the operation of all aspects of the CCS chain from capture and transport to storage and maintenance.

> "A complete failure to deploy CCS would imply close to a doubling of the annual cost of carbon abatement to the UK economy"

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Glossary of terms

CfD
Contracts for Difference
A new form of fixed price contract available for low carbon generation under the government's electricity market reform

EMR
Electricity Market Reform
A programme of reforms introduced under the Energy Act 2013 to promote investment in affordable, reliable low carbon electricity, including new contracts for low carbon generation and a carbon price floor

SNS
Southern North Sea

EOR
Enhanced Oil Recovery
A range of techniques to increase the amount of crude oil that can be extracted from an oil field, including the injection of CO_2

T&S
Transport & Storage
CCS involves compression of CO_2 and transport by pipeline or ship for injection into geological storage sites, either depleted oil or gas fields, or saline aquifer rock formations

UKCS
UK Continental Shelf
The region of waters surrounding the UK in which it claims mineral rights

5/24 and Captain Aquifer Stores
Where are these located?
5/42 is located in the southern North Sea approximately 70 miles off Flamborough Head, the Captain aquifer is located below the Moray Firth in the Central North Sea approximately 65 miles to the north east of Peterhead

FID
Final Investment Decision
The final decision to construct a project following a period front end engineering and design

LCF
Levy Control Framework
A tool used by government to monitor and control the costs of energy policies and schemes on consumers' energy bills

The ETI gratefully acknowledges the valuable assistance and insights provided by all the steering group members who gave substantial amounts of their time to help deliver this project. We would also like to thank a broader group of stakeholders who attended the project workshop in October 2014, and who otherwise assisted the project.

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