The Right Honourable Amber Rudd, MP
Secretary of State for Energy and Climate Change
Department for Energy and Climate Change
3 Whitehall Place
Westminster
London SW1A 2AW

6 July 2016

A strategic approach to Carbon Capture and Storage

Dear Secretary of State,

Carbon capture and storage (CCS) is of critical importance to meet the UK's carbon targets at least cost and to fulfil the ambition of the Paris Agreement. When the Committee wrote to you in January we noted the urgent need for a new approach following cancellation of funding for the Commercialisation Programme in the November 2015 Spending Review. As promised, this letter follows up with advice on the way forward for CCS in the UK.

Last week you agreed to set the fifth carbon budget at the level we recommended, which I commend. It is an important milestone for investors, businesses and the country more widely. Our advice on the fifth carbon budget strongly emphasised the need for CCS, as did our annual Progress Report that was laid before Parliament last week. We identified CCS as an important area requiring a new approach.

Despite the cancellation of the CCS competition, helpful progress was made and lessons were learnt during the process. These lessons have been clearly set out by the industry[1], supported by the *Key Knowledge Deliverables* you published last week. Understanding these lessons and progress to date allows a more strategic approach to be adopted. Importantly, the failings of the competition were in the design of the policy and the business case rather than technical problems with the projects or their planned storage sites.

Incorporating these lessons into a new approach would allow the development of CCS at a lower overall cost to consumers and taxpayers. It would also ensure that important domestic industries such as steel, chemicals and cement are able to compete in the low-carbon world that is the aim of the Paris Agreement.

[1] CCSA (June 2016) *Lessons and evidence derived from UK CCS programmes 2008-2015*

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The key elements we identify for a strategic approach to develop CCS at least cost are:

- **Separate the support for capture from the support for the transport and storage infrastructure** (often referred to as a 'part chain' approach). This is a key learning point from the cancelled competition where the 'full chain' approach was unsuccessful. It reflects the different technical and economic characteristics of the different parts of the chain: CO_2 pipes and stores are a separate shared infrastructure investment, whilst carbon capture is integrated to the power or industrial facility. Separate support ensures developers at each stage of the chain manage their own risks, without these being compounded by risks elsewhere, and reduces costs overall.

- **An initial focus on one or two strategic clusters:** clusters should be chosen in areas of industrial activity around storage sites that have been identified and successfully characterised during the Commercialisation Programme.

- **Suitable allocation of risks between the public and private sectors:** government is best placed to manage policy-related risk (e.g. the number of projects offered support and therefore the amount of CO_2 flowing to the transport and storage infrastructure). It may also have to underwrite long-term storage liabilities (i.e. similar to nuclear liabilities). The private sector is best placed to manage risks related to construction and operation. There are various policy options, business models and institutions that could deliver improved risk allocation, allowing access to lower costs of capital (see Annex).

- **Funding instruments for capture:** contracts for difference fill this role for power plants and a similar form of support will be needed for industrial CCS. Sufficient funding should be allocated for both sectors (whether from general taxation, consumer bills or elsewhere). Support should be allocated competitively where possible to minimise costs. In designing a new instrument for CCS, fuel price risks need to be taken into account.

- **Sufficient scale of roll-out:** deployment across both industry and power is necessary to realise economies of scale and allow a build-up of skills, developer and financial interest. There are various options for the order with which projects could be brought on line and learning used to reduce costs. Our analysis suggests that an overall scale of, for example, 4-7 GW of power CCS and 3-5 Mt captured CO_2 from industrial plants by 2035 would be sufficient to put the UK on track to meeting its commitments cost-effectively.

A strategy should be developed immediately, beginning with a clear signal of renewed commitment to a CCS industry in the UK. A review of ownership options and business models should be undertaken (by DECC or the National Infrastructure Commission), with the preferred

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approach and a new funding model for industry chosen as soon as possible. Funding should be allocated and the strategic locations chosen in the next 1-2 years, with the first capture contracts awarded during this Parliament. In principle, it would be possible to move more quickly: a number of capture projects are at the design stage, and a number of stores are well characterised and ready for development.

The conclusion of the detailed assessment and Expert Advisory Board commissioned by my Committee is that an effective approach will require an active UK programme. A 'wait and see' approach drawing on international learning and early-stage R&D will not be sufficient because the majority of the potential routes to reducing costs arise from UK deployment: learning from experience, economies of scale from larger plant size, development of the supply chain, developing and maintaining the interest and engagement of the financial community, and efficient sizing and sharing of transport and storage infrastructure.

The costs from such a strategic approach would be low in this Parliament and represent good value for consumers in the long run. The impact on the annual electricity bill for an average household would rise to around £7 per year by 2030 (see Annex). Government would have to underwrite or fund the initial infrastructure costs of about £0.6 billion in the early 2020s and continue to underwrite storage and cross-chain risk.

That is good value given the likely pivotal role of CCS in meeting the Paris Agreement's long-term objective of balancing sources and sinks of emissions, and the estimated doubling of the cost of meeting the UK's 2050 target if CCS is not available. This is because there are limited, if any, low-carbon alternatives to CCS in a number of applications in the 2030s, 2040s and beyond:

- it is the only current option available at large scale to reduce emissions from segments of important industrial sectors, including steel, cement and chemicals;
- combined with bioenergy it could deliver 'negative emissions' that will be needed to meet the longer-term objective from Paris of achieving "net zero" emissions;
- combined with gas-fired power generation it could allow for flexible 'mid-merit' power generation to help security of supply, with recoverable heat available for heat networks; and
- it currently appears to be the lowest cost route to low-carbon hydrogen, which could help to reduce emissions in difficult areas such as heating and HGVs.

Our analysis of the least cost pathways to 2050 imply deployment of CCS at scale from the mid-2020s and increasing thereafter. This will require UK action to start now. The Energy Technologies Institute has estimated that delaying CCS commercialisation for ten years would increase the cost

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of reducing GHG emissions by £1-2 billion per year throughout the 2020s, increasing to £4–5 billion per year in 2040[2].

A new programme would also provide opportunities for a range of UK businesses and jobs, including the oil and gas industry. Investment proposals for new gas-fired plants would be strengthened if suitably located near potential CCS clusters. If some of the captured carbon can be used, there may be opportunities for new industries and production processes to be developed in the UK. Such carbon capture and use opportunities are being actively explored by a number of companies in the UK and around the world.

The advice in this letter reflects updated assessments and a review of all the evidence since the announcement that the competition was to be cancelled. We have published the detailed work on our website and a summary is provided in the Annex.

As ever I would be very happy to discuss this advice further with you.

Yours,

Lord Deben
Chairman, Committee on Climate Change

[2] ETI (2016) *ETI analysis of the UK energy system design implications of delay to deployment of carbon capture and storage (CCS) in the UK*. Available at: http://www.parliament.uk/documents/commons-committees/energy-and-climate-change/ETI-letter-to-Chair-on-Future-of-CCS.pdf

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Annex

This annex provides further details of the analysis underpinning our advice and the options for implementation. It covers three areas:

(i) Analysis of a strategic approach to CCS

(ii) Advisory Board key messages

(iii) The value of CCS for UK decarbonisation and need for UK deployment

(i) Analysis of a strategic approach to CCS

We commissioned consultants Pöyry to identify elements of a strategic approach to developing CCS in the UK. This work builds on and updates a larger study that Pöyry and Element Energy carried out for the Committee last year, identifying the key elements of a cost-reduction strategy for CCS to balance effectiveness in cost reduction with minimised cost to consumers.

The executive summary of the Pöyry report is reproduced in Box 1. The possible business models Pöyry identified to separate support for carbon capture from carbon transport and storage are set out in Figures 1a and 1b. Figure 2 sets out the timeline for progress that Pöyry proposed.

Box 1: Executive Summary of "Strategic approach to CCS" (Pöyry, 2016)

Withdrawal of funding from the Commercialisation Programme in 2015 left the UK without any explicit funding mechanism for developing CCS in the UK. With CCS now facing a highly uncertain future the Committee on Climate Change (CCC) has commissioned Pöyry to provide a short report exploring the options for commercialising Carbon Capture and Storage (CCS) in the UK.

While CCS is one option for decarbonising the power sector, it is the only available option for decarbonising many industrial processes. In the longer term, CCS combined with biomass could be a source of negative carbon emissions, allowing cost savings by reducing the need to decarbonise elsewhere. Analysis by the CCC indicates that developing a CCS industry is essential to decarbonising the UK industrial sector, and work from the ETI suggests that CCS infrastructure needs to be in place by the late 2020s or early 2030s.

The Commercialisation Programme has left the UK with well characterised storage ready for development, a detailed appraisal of capture technologies and costs and a significant body of knowledge around the creation of successful commercial arrangements for CCS.
These assets create the opportunity for rapid development of CCS within the UK if appropriate support is put into place. Recent falls in expected UK gas prices also make CCS more cost-effective when compared to technologies that are not dependent on fuel prices.

In this report, we explore the key steps required to establish a CCS industry in the UK, and the costs of doing so. Critically, we consider that one of the most important lessons to learn from the commercialisation is the difficulty of funding CCS on a "full-chain" approach, where a single payment rewards the construction and operation of capture, transport and storage. We suggest that any cost-effective CCS strategy will require the Government to absorb cross-chain risks via "part-chain" funding mechanisms, where transport and storage are supported either via a second funding scheme, or a risk sharing arrangement.

Our broad view of how to achieve cost reductions is unchanged from our 2015 report to the CCC. Development should be focused around capture and storage hubs, reducing costs by sharing transport and storage infrastructure. As far as possible, and subject to cost targets, continuous rollout of CCS power generation will drive savings via lower financing costs and development of supply chains. Finally, optimal technology choice, location choice and knowledge transfer will be crucial to access learning by doing and risk reduction cost savings.

We consider that industrial CCS should be considered a critical part of the overall CCS strategy, but we do not believe that CCS should be developed around industry alone. The requirement for CCS for industry provides a framework for considering necessary investment that could drive the development of at least one CCS hub. Once a hub is in place, cost estimates suggest that power CCS is a valuable source of low-carbon generation, and immediate development of power CCS helps drive cost reductions and captures significant volumes of carbon that be used to securely drive the development of a transport and storage network.

Exploring timelines for the roll-out of CCS, we conclude developing low cost CCS by the early-2030s requires immediate progress on a new strategy for UK based CCS. Even with immediate development, we consider it very challenging to get CCS operating in the early 2020s, and expect that second generation power CCS would begin operation around 2030, around 5 years later than in our 2015 report. To drive this schedule, some key steps need to be taken:

- Making an early decision on a preferred region(s) from which capture facility bids will accepted, ideally accompanied by a decision on which storage facility to develop.
- Committing to making funding available for carbon capture units, provided that cost targets can be met.
- Choosing an initial business model to support transport and storage, with the Government absorbing a significant part of four key risks:

- Cross chain funding risks
- Carbon volume flow risks
- Long term storage liabilities
- Fuel price risk

- Allocating responsibilities within the business model to existing bodies where possible, and creating new bodies if required.
- Establishing a mechanism that will support the development of carbon capture from industrial processes.

In addition to exploring the objectives of a CCS strategy, and the steps required to meet them, we have updated the cost estimates from 2015 to take into account recent developments, and separation of funding for capture units from transport and storage.

Using fuel prices from the 2015 DECC Reference Scenario, and engineering estimates from the 2013 Cost Reduction Task Force we calculate that post-combustion gas CCS, commissioning in the mid-2020s, could be developed with a 15 year Contract for Difference (CfD) at around £115/MWh, and that once learning, development and economies of scale are taken into account, costs would reduce to £85-90/MWh in the 2030s.

Driving this investment, in addition to CfDs for capture units, will require the creation of a transport and storage network. A minimum transport and storage investment of around £600m is likely to be required, dependent on the geographical choice of the initial hub, and the storage facility used. At the high end of our rollout estimates, with significant support for CCS power generation and industrial capture, we estimate that around £2.5bn of investment by 2035 could support 7.5 GW of power generation and 5 Mtpa of industrial capture.

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Figure 1a - Business model and money flows for private funding of storage

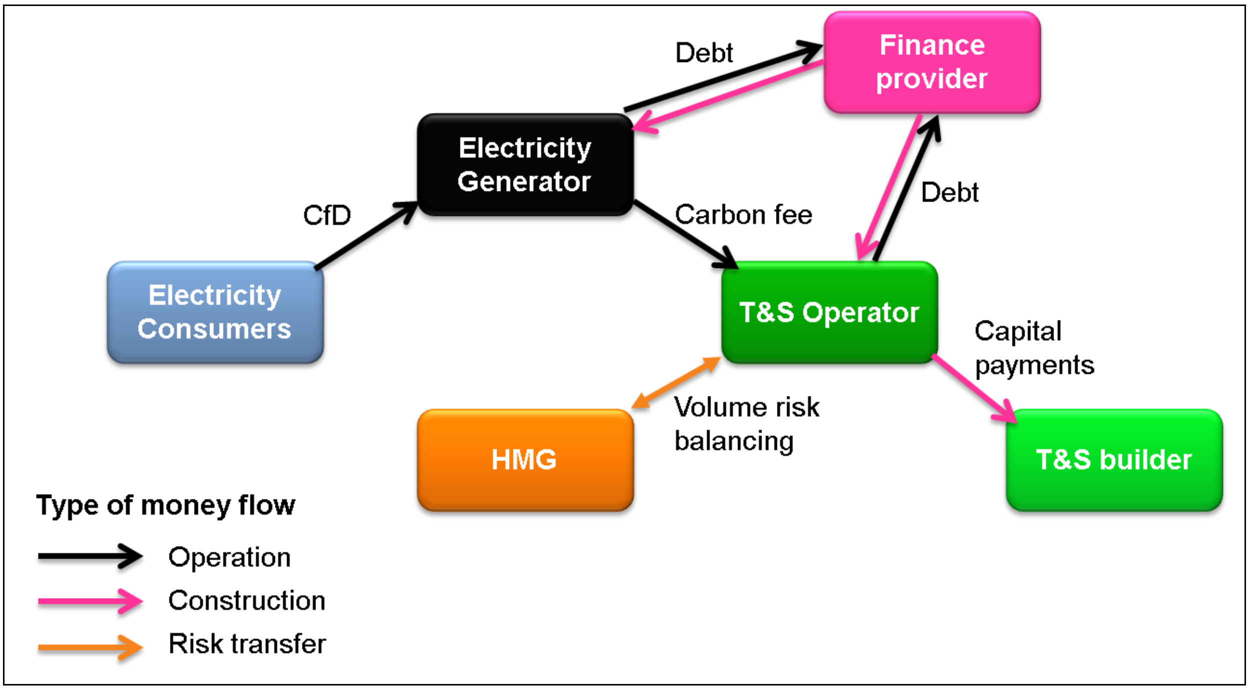

Figure 1b - Business model and money flows for grant funding of storage

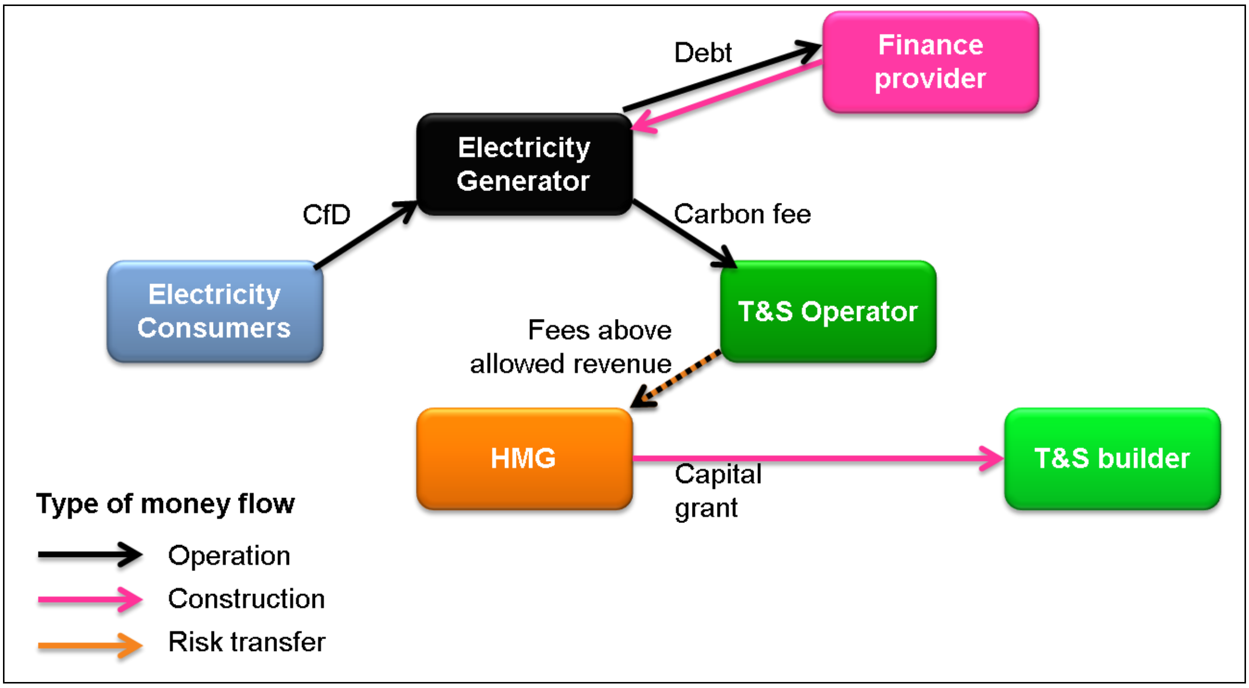

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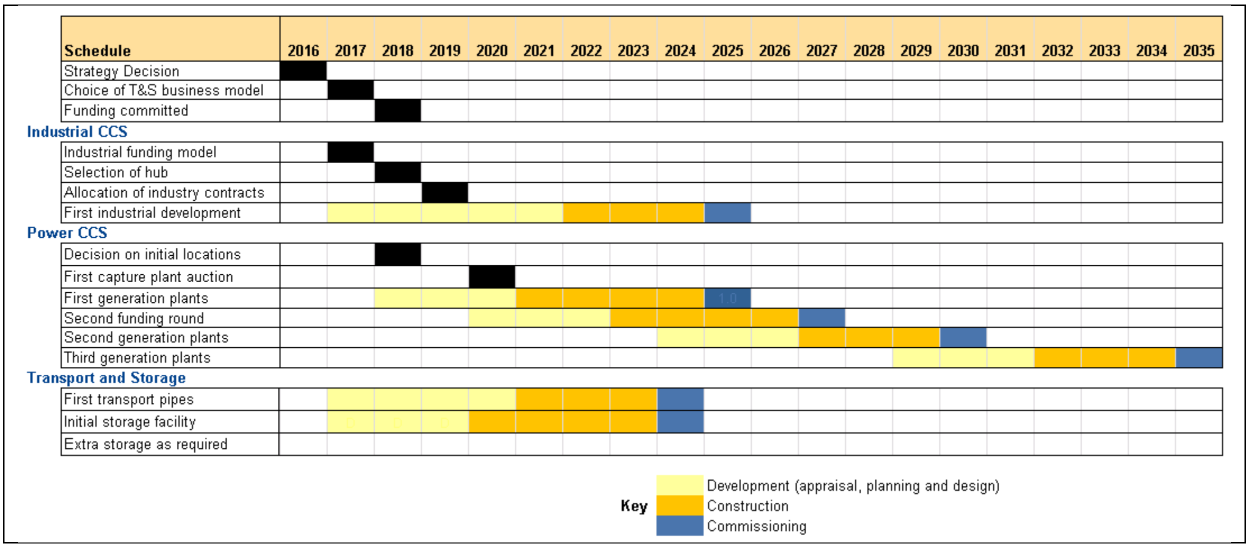
Figure 2 – Timescales for deploying industrial capture, power capture, transport and storage



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(ii) **Advisory Board key messages**

The Committee convened an expert Advisory Group to help scope, steer, oversee and comment on Poyry's analysis.[3] The Chair of the Advisory Group (Dr Robert Gross of Imperial College) produced a report summarising the Advisory Group's views on the consultants' work; the evidence base, key assumptions, methods, and areas for future work, and on the implications of this work for the CCC's advice to government on developing CCS in the UK. Box 2 reproduces the report summary.

Box 2: Summary from "CCS in the UK: A new strategy; Advisory Group Report"

The Committee on Climate Change (CCC) has commissioned expert input on policy, strategy and costs for carbon capture and storage (CCS). This analysis will inform the CCC in their advice to government on a strategy for CCS in the UK. The CCC commissioned Consultants Poyry to produce analysis of potential CCS costs and strategy. The CCC convened an expert Advisory Group to help scope, steer, oversee and comment on the consultants' analysis. This report provides a Chair's summary based upon the reflections of the Advisory Group. It comments on the report the consultants have produced and the wider issues associated with this crucially important topic.

The Group notes the importance of CCS as a flexible enabler of low carbon energy – whether through continued use of fossil fuels for electricity, or by enabling industrial decarbonisation and the production of hydrogen which can be used flexibly in a wide range of end uses. CCS has the potential to play an important role in the power sector, in enabling industrial decarbonisation, low carbon hydrogen (and syngas) production and, potentially, a pathway to negative emissions in combination with bioenergy (biomass gasification with CCS).

The Group finds that the analysis from Poyry is well-conceived and provides valuable new insights into policy and strategy to promote CCS during the 2020s. Detailed cost and strike price analysis from Poyry suggests that the levelised costs of gas-fired capture plants connecting to a well-utilised transport and storage infrastructure could be below £100/MWh. The Group believe that this is feasible under sensible assumptions, noting that estimates of future CCS costs are subject to considerable uncertainty and there is a wide range of estimates in the literature.

The cancellation of the planned CCS Commercialisation Programme is a significant set-back to the development of CCS in the UK. However, work undertaken in preparation for the cancelled Programme has however provided important information on technology costs and in the characterisation of stores. These are now considered ready for development and have generated developer interest in follow-on projects that could in principle be retained.

[3] The Group was: Shabana Ahmad and Ward Goldthorpe (The Crown Estate), George Day (ETI), Patrick Dixon (Independent Director, CCSA; former Expert Chair of OCCS), Emrah Durusut (Element Energy).

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The Group believes that there is a valuable opportunity to rethink strategy and policy to facilitate the creation of CCS infrastructure at lowest overall cost. The Group note the importance of separating the handling of contracting and risks for capture plants from the transport and storage (T&S) of CCS. There is substantial scope to improve the allocation of risks, ensuring they are allocated to the party best-placed to manage them, thus allowing industry participants to access lower costs of capital. Moreover, if T&S infrastructure is able to serve multiple sectors it may be possible to improve utilisation and increase economies of scale, which can also lower costs per unit of CO_2 stored.

There is a need for government to take steps during this Parliament to provide clarity over aspirations and objectives for CCS, both in terms of long term goals and development of early projects. The Group recommends that policy to allow development of a strategically planned CCS T&S infrastructure is given detailed attention by DECC and the National Infrastructure Commission.

Whilst international CCS developments and ongoing research and development (RD&D) are important to cost reduction they cannot substitute for developments in infrastructure and learning that are UK specific. Therefore there is a need for action on three main fronts: funding for near-term capture projects, an approach to risk allocation for CO_2 storage sites, and strategy and regulation to allow industry to invest in a future CCS T&S infrastructure.

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(iii) **The value of CCS for UK decarbonisation**

We estimate that CCS, including through production of hydrogen, can potentially contribute around 100-250 $MtCO_2$ of abatement across power, industry, transport and heat in 2050. Alternative options to deliver this abatement are expected to be significantly more expensive, and/or to require more dramatic social change such as dietary change and restrictions on aviation demand.

CCS is a crucially important technology in electricity generation and industry, enables negative emissions through bioenergy with CCS, and is the lowest-cost route to hydrogen production:

- **Electricity generation**. CCS is the only source of low-carbon electricity generating technology that can generate when needed to meet demand. Wind and solar output are inflexible, nuclear is very costly to run flexibly, and gas and other forms of fossil generation are too carbon-intensive to have more than a very small role in electricity generation by 2050. Further, CCS is the least capital-intensive low-carbon electricity generation technology, and therefore more economic to deploy at lower load factors, including to meet seasonal requirements. In particular, winter demand from heat pumps, if deployed at scale, could only be met in the absence of CCS with substantial deployment of capital-intensive alternatives that would not be required to operate during the summer months.
- **Industry**. No competing technologies to CCS to decarbonise a range of industrial heat and process applications are currently envisaged. We estimate that around 25 Mt (27%) of industrial emissions can be reduced through CCS in 2050. Alongside improved energy efficiency and some electrification of processes this would still leave significant emissions from industry. Should further emissions reductions be required, a further 30 Mt (31%) could be reduced through use of low-carbon hydrogen, also likely to require CCS to be cost-effective. Furthermore, the UK's large potential CO_2 stores close to areas of industrial activity could give UK industry a significant advantage in the production of low-carbon manufacturing.
- **Bioenergy with CCS**. Combustion of biomass, or conversion of biomass to liquid fuels, results in conversion of some or all of the carbon content of the biomass to CO_2. Capture and storage of that CO_2 (resulting in "negative emissions" if bioenergy is considered to be "low-carbon") is clearly preferable to release to the atmosphere. While estimates of the quantity of sustainable biomass likely to be available in 2050 are extremely uncertain, our scenarios assume around 200 TWh of sustainable bioenergy could be available to the UK. If used with CCS, this bioenergy could deliver around 45 $MtCO_2$ of abatement. If used

without CCS, it would deliver only 25 Mt, and the shortfall would need to be made up elsewhere.

- **Hydrogen from CCS**. At present, hydrogen appears the most viable solution to decarbonising freight transport, where heavy goods vehicles are too large, and distances travelled too great, for battery electric vehicles to provide adequate substitutes. Hydrogen is also the only viable solution for a range of applications in industry. Finally, repurposing of the gas grid for use of hydrogen to heat buildings is currently considered to be the most promising alternative to wide-scale deployment of heat pumps. Currently two routes to low-carbon hydrogen production are envisaged: pre-combustion CCS with steam methane reformation, and electrolysis. The International Energy Agency estimates that production through electrolysis is more than three times more costly than production through pre-combustion CCS[4].

Taken together, use of CCS in power, industry, with bioenergy and through hydrogen could provide around 100-250 $MtCO_2$ of abatement by 2050. If CCS is not available, therefore, this abatement will need to come from elsewhere. Alternative options to reducing emissions in the absence of CCS include full decarbonisation of heat in buildings, full decarbonisation of the transport freight sector, as well as more dramatic social change such as dietary change and restrictions on aviation demand.

Given these important potential roles for CCS and the lack of low-cost, or in some cases any, alternatives, we have estimated that the costs of meeting the UK's 2050 target (i.e. to reduce emissions by at least 80% compared to 1990) would approximately double without CCS. This is consistent with evidence from the Energy Technologies Institute[5].

In contrast, the costs of developing CCS in the UK are moderate. We estimate that a programme to develop 4-7 GW of power CCS would result in strike prices decreasing from around £120/MWh for the first demonstrator, to around £90/MWh for second- and third-generation plant. This level of deployment would be expected to raise retail electricity prices by around 0.3p/kWh in 2030, resulting in a roughly £7 (1.5%) increase in a typical household electricity bill in 2030[6].

[4] IEA (2015) *Technology Roadmap: Hydrogen and Fuel Cells*. Available at: www.iea.org/publications/freepublications/publication/TechnologyRoadmapHydrogenandFuelCells.pdf

[5] ETI (2016) *ETI analysis of the UK energy system design implications of delay to deployment of carbon capture and storage (CCS) in the UK*. Available at: www.parliament.uk/documents/commons-committees/energy-and-climate-change/ETI-letter-to-Chair-on-Future-of-CCS.pdf

[6] Cost impact estimated relative to gas-fired power generation, facing a market carbon price. Typical household assumed to consume 3,000 kWh per year (DECC (2014) *Energy Consumption in the United Kingdom*).

CCS may also deliver wider benefits, in addition to the abatement cost savings set out above. Development of CCS would provide significant levels of new investment in areas such as the North East of England and Scotland, and therefore help to sustain economic activity and employment in these areas, particularly in the oil and gas industry. This would also allow existing industries in these areas to compete in a low-carbon world that is the aim of the Paris Agreement, and could uniquely position the UK to earn revenues from storing CO_2 imported from other countries.

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