10 February 2016

UK R&D priorities for Carbon Capture and Storage (CCS)

Introduction

The UK Government announced on 25th November 2015 that it was withdrawing the £1 billion of funding earmarked for its CCS Commercialisation Programme, effectively bringing an end to a competitive process that saw two projects bidding for Government support. Despite its decision to not proceed with either the White Rose or Peterhead projects under the CCS Competition, Secretary of State for Energy and Climate Change, Amber Rudd, and Energy Minister, Andrea Leadsom, have since made it clear that CCS remains a crucial tool for reducing UK emissions in the longer term.

Although future UK policy on CCS is currently uncertain, it is clear there remains a case for undertaking further R&D activities in order to reduce costs and risks associated with CCS project deployment. This paper brings together the views of the CCS industry (represented by the CCSA and APGTF) with the research community (represented by the UK CCS Research Centre and the Coal Research Forum) to identify near-term priority areas for UK R&D.

Whilst R&D can help to reduce the component costs of CCS projects, R&D alone cannot deliver cost-reductions of sufficient magnitude to make CCS cost-competitive with the current 'least-cost' technologies, e.g. 'unabated' gas-fired (i.e. without CCS) and nuclear generation. These cost reductions can only be delivered with UK deployment of CCS, which establishes essential carbon dioxide (CO_2) transport and storage infrastructure, enables economies of scale and helps to reduce the cost of capital. The Committee on Climate Change (CCC) recently concluded that up to 75% of cost reductions for CCS projects can only be achieved through local deployment and cannot be bought in on the back of international deployment. CCS R&D activities should therefore be undertaken in support of a clear and coherent UK deployment strategy.

To maximise the effectiveness of CCS R&D and deliver outcomes relevant to near-term projects in the UK, consideration should be given to strengthening the process for setting R&D priorities in order to ensure that the limited available funding is delivered to those projects likely to deliver the maximum benefits to UK consumers. This paper proposes that greater emphasis should be placed on industry's perspective on R&D priorities in order that R&D can most usefully contribute to the broader delivery of CCS.

Whilst much effort has been put into defining research priorities for CCS (e.g. by APGTF, the International Energy Agency, and the Carbon Sequestration Leadership Forum, etc.), these exercises tend to yield lists that cover R&D in its broadest sense but do not steer funding towards those projects that could have the greatest impact in terms of delivering against the 'Outcome' for of the CCS Commercialisation Programme[1]. Although the Outcome is assumed obsolete in light of the Government's decision on 25th November 2015, the

[1] The 'Outcome' of the CCS Commercialisation Programme is defined: *"As a result of the intervention, 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 CfD Strike Price that is competitive with the strike prices for other low carbon generation technologies"*

principle of prioritising R&D actions on their potential contribution towards near-term cost reductions remains valid, as do the recommendations presented in this paper.

Methodology

To bring stakeholder groups together and identify priority R&D areas, the UKCCSRC and CCSA jointly hosted a workshop on industry-relevant R&D in November 2014 to scope out the highest priority areas for R&D following the DECC CCS Policy Scoping Document. The meeting sought to identify priority opportunities for CCS R&D and led to the conclusion that: a) CCS R&D priorities need to be better articulated both in terms of priority areas and outcomes sought; and, b) that timeliness/relevance to 'Phase 2' (see below for definition) projects and potential for cost reduction should be better-integrated into the process of determining which research proposals are awarded funding. These proposals on priorities were tested on a much wider audience through consultation with CCSA and APGTF members and then presented to a Workshop of around 120 experts on 15th October 2015 organised by the CCSA, APGTF, UKCCSRC, CRF and the Knowledge Transfer Network. The tables of priorities included below have taken account of the comments at the Workshop.

The list of priorities has been mapped against current funding opportunities in an attempt to help identify and highlight any particular funding gaps that might need to be addressed by funders. General comments on current funding routes are given in Appendix 1.

Under the heading 'Timing' the likely relevance to a Phase 1, 2 and 3 of CCS roll-out is indicated. This was based on Phase 1 consisting of the two CCS Competition projects, a second phase which utilises this common infrastructure, and a third phase following-on when CCS is commercially viable. As indicated in the appendix below there is ample scope for low-TRL R&D including academic research in support of Phase 1, 2 or 3 projects.

R&D on wholly new technologies is likely only to be relevant to Phase 3 projects and would need to show significant cost benefit to overcome the higher risk penalty that would apply.

R&D priorities for whole-system CCS

Area	*Theme*	*Timing*	*Type of project / budgets*	Relevance of current funding
Business models for CCS in power sector (e.g. CFD terms/allocation, liabilities, visibility on the market, access to infrastructure, European market, insurance, alternative costing models to LCOE, assessing the risk/benefit trade-off of pre-investment in enabling T&S infrastructure, possible revenue streams from CO_2 utilisation, etc.)	Whole systems	Phase 2	University/research institute projects 2 or 3) with power sector involvement, each £100-300K, 100% funded	EPSRC (+NERC and ESRC)
Role of CCS in energy markets and industry, 'polygeneration' (includes sustainable hydrogen production), CCS for shale gas, large-scale hydrogen storage in caverns, etc., including studies to establish future full-scale projects	Whole systems	Phase 2	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded Industry-led studies, each £100-250K, co-funded	EPSRC (+NERC) DECC/Scottish Government ETI
Stimulus for (capture) transport and storage business	Whole systems	Phase 2	University/research institute projects (1 or 2) with industry involvement, each £100-400K, 100% funded	EPSRC (+NERC)
Dynamic operation and logistics of an industrial (clustered) network	Whole systems	Phase 2	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded Industry – led project (s) each £250K, publically funded	EPSRC Innovate UK or DECC Energy Entrepreneurs Fund (appropriate where IP developed) DECC or BIS EC – Horizon 2020 (LCE 29)

Area	Theme	Timing	Type of project / budgets	Relevance of current funding
Business models for CCS in industrial process applications (e.g. possible incentive mechanisms, possible revenue streams from CO_2 utilisation, markets, avoidance of carbon leakage, costing models, clustering, etc.)	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded	EPSRC (+NERC and ESRC)
Dynamic operation of the UK energy market including the need/ impact of flexible operators	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded	EPSRC EC – Horizon 2020 (LCE 28)
Optimised network for security of supply/benefits of balanced energy portfolio	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded	EPSRC DECC
Opportunities/issues arising from experience at the SaskPower Boundary Dam #3 project (Canada) and other large-scale projects (including the FEED stage of UK Commercialisation projects)	Whole systems	Phase 2/3	University/research institute projects (3 or 4) with industry involvement, each £300-500K, 100% funded Industry-led projects, each £100-250K, co-funded	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS
Flexibility in CCS systems operation (i.e. a combination of flexible capture, transport / buffer storage, injection and storage)	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded Industry-led projects, each £100-250K, co-funded	EPSRC DECC EC – Horizon 2020 (LCE 28)
Public perception and acceptance (e.g. demonstrable safety, emissions, etc.)	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each	EPSRC DECC

Area	Theme	Timing	Type of project / budgets	Relevance of current funding
			£100-300K, 100% funded	
Inherent safe design of CCS systems	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded Industry-led projects, each £100-250K, co-funded	EPSRC DECC EC – Horizon 2020 (LCE 28)
End-of-life issues and 'ABANDEX' costs for CCS systems (e.g. closing wells; dismantling and removing platforms; decommissioning, dismantling and removing process equipment; salvaging equipment; site remediation and restoration; on-going monitoring; etc.)	Whole systems	Phase 2/3	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded Industry-led projects, each £100-250K, co-funded	EPSRC DECC EC – Horizon 2020 (LCE 28)

R&D priorities for CO_2 capture

Area	*Theme*	*Timing*	*Type of project/ budgets*	Relevance of current funding
Capture process intensification/ optimisation (including new/alternative solvents for PCC; optimised regeneration of PCC solvents and managing/mitigating against solvent degradation; oxy-firing for gas and biomass; pre-combustion decarbonisation; O&M; etc.) and optimised integration of capture plant with power plant or industrial process (and linked to storage capacity)	Capture	Phase 2/3	University/research institute projects (3 or 4) with industry involvement, each £300-500K, 100% funded. Industry-led projects, each £100-500K, co-funded	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS
Reducing the energy penalty of CO_2 capture by reducing electricity load of auxiliary equipment (e.g. improved ASU processes and designs for oxy-firing and pre-combustion decarbonisation; advanced compressor technology; etc.)	Capture	Phase 2/3	University/research institute projects (3 or 4) with industry involvement, each £300-500K, 100% funded. Industry-led projects, each £100-500K, co-funded	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS
Optimum and advanced materials for construction and operation (including concrete to withstand amines for absorber and regenerator towers; plastic packing for towers; steels; polymers; etc.)	Capture	Phase 2/3	University and research institute projects (3 or 4) with industry involvement, each £300-500K 100% funded. Industry-led projects	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS
Waste stream minimisation and water use	Capture	Phase 2/3	University and research institute projects (3 or 4) with industry involvement, each £300-500K 100% funded. Industry-led projects	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS

Area	Theme	Timing	Type of project/ budgets	Relevance of current funding
Fundamental understanding and research to address feedback/feed-forward issues (e.g. problems identified from demo projects where answers are needed); water-energy-food 'nexus'; etc.	Capture	Phase 2/3	University/research institute projects (as necessary) with industry involvement, each £100-300K, 100% funded	EPSRC (+NERC and ESRC as appropriate)
Advanced/novel capture processes and cycles (e.g. solid absorbents, membranes, ionic liquids, metal-organic frameworks, pre-combustion decarbonisation in polygeneration cycles, etc.)	Capture	Phase 3	University/research institute projects (3 or 4) with industry involvement, each £300-500K, 100% funded. Industry-led projects, each £100-500K, co-funded	EPSRC DECC, Innovate UK or Energy Entrepreneurs Fund (where IP developed) EC – Horizon 2020 (LCE 24), RFCS

R&D priorities for CO_2 storage and monitoring

Area	*Theme*	*Timing*	*Type of project/ budgets*	**Relevance of current funding**
Flexibility in 'reservoir' response (including geology and installed infrastructure and measurement, monitoring & verification (MMV) baselines) to different CO_2 stream properties (composition, impurities, phase state) to allow use of Phase 1 storage sites. Urgent R&D need to identify risk of 'lock-out' for, or creation of major cost barrier to follow-on Phase 2a projects	Injectivity & Dynamic Capacity	Phase1 and 2a	University/research institute projects (1 or 2) with industry involvement, each £100K -1M, 100% funded. Industry-led projects to carry out early-stage appraisal of specific storage sites that are likely to be used in Phases 1+2	EPSRC, Crown Estate, National Grid, ETI DECC/ETI
R&D activities to support testing of storage site core samples to enable early follow-on projects.		Phase 2a, 2b and 3	University/research institute projects (1 or 2) with industry involvement, each £100-400K, 100% funded	EPSRC, Crown Estate, National Grid, DECC, ETI EC - Horizon 2020 (LCE 30)
Refining of methodologies for much quicker site characterisation with variable data quality and quantity (UK but much also generic) and cost-effective operation and management of two or more injection sites in an extensive storage formation or in stacked and overlapping storage formations	Inj. & Dyn. Cap.	Phases 2 and 3	University/research institute projects (1 or 2) with industry involvement, each £100-400K, 100% funded.	EPSRC, Crown Estate, National Grid, Scottish Government, Scottish Enterprise, EC - Horizon (LCE 27)

R&D priorities for CO_2 storage and monitoring (cont.)

Area	*Theme*	*Timing*	*Type of project/ budgets*	Relevance of current funding
Water production: (1) testing of regulatory landscape, e.g. quality and quantity of produced water (high- or low-salinity, trace oil) and its effect on the environment, storage versus enhanced oil recovery (EOR) legislation on producing water in UK offshore (cf. 30 ppm oil currently permitted when 'overboarding' from fixed or moving vessels); (2) design of water production systems e.g. well spacing, power needs, effects on capacity, injectivity, storage optimisation, pressure control and reduction of pressure and brine interactions with other subsurface activities; (3) How to deal with produced brine	Inj. & Dyn. Cap.	Phase 1 and 2a	(1) University/research institute projects (1 or 2) with industry involvement, each approx £300K, 100% funded. (2) Industry-led projects (£250k plus)	NERC, EPSRC InnovateUK, Crown Estate, National Grid, DECC/ETI EC - Horizon 2020 (LCE 30)
New methods for monitoring, including low cost continuous 'alarm' type systems that would trigger more expensive surveys as and when appropriate and improving predictive capabilities			University/research institute projects (1 or 2) (£200K+)	EPSRC/NERC, Crown Estate, National Grid, ETI
De-risking numerical modelling (better methodology in conditioning and constraining models for Bunter or portions of Captain sandstones using R&D under Injectivity, Containment, and Dynamic Capacity headings below)		Phase 1 and 2a	University/research institute projects (1 or 2) with industry involvement, each £100-300K, 100% funded	EC - Horizon 2020 (LCE /30), Crown Estate, EPSRC, National Grid

R&D priorities linked to strategic CO_2 storage sites: Goldeneye, Captain aquifer and Endurance (5/42) aquifer

Area	***Theme***	***Timing***	***Type of project/ budgets***	**Relevance of current funding**
Injectivity: • Quality of stream; • Proving long term injectivity testing; • Injection into underpressured reservoir (e.g. Rotliegend), risk of flashing & Joule Thompson cooling, etc.; • Pressure management and the need for de-pressurised reservoir remedies pre-heating of CO_2; • Compressor issues; • Fluid displacement in saline aquifers; • Reservoir compartmentalisation, sealing or conducting fracture networks; • Induced seismicity; • Well monitoring; • Qualification testing of lower injection wellbore materials choices for the expected acidic, chloride rich, trace oxygen containing environment, including: o Better understanding of safe, viable and low-cost downhole materials choices (both metallic and non-metallic) for multi-impurity CO_2 stream injection service; and, o Chemical rate data availability and reliability in relation to geochemical modelling of aquifer storage sites and seals	Inj.	Phases 2a, 2b and 3	University/research institute projects (1 or 2) with industry involvement, each £100-500K, 100% funded	EC - Horizon 2020 (LCE 30)

R&D priorities linked to strategic CO_2 storage sites: Goldeneye, Captain aquifer and Endurance (5/42) aquifer (cont.)

Area	*Theme*	*Timing*	*Type of project/ budgets*	Relevance of current funding
Containment: Characterisation of the under and overburden, fault flow properties under variable stress, geomechanical fracture pressure, stress regimes, underburden & sealing systems; mechanical response (cf. analogues like Decatur/Aquistore microseismicity). Wellbore integrity. Site specific surface monitoring strategies to increase efficiency/accuracy. Experimental, long duration, geochemistry of cap rock and storage formation		Phase 2a, 2b & 3	University/research institute projects (1 or 2) with industry involvement, each £100-500K, 100% funded	EC - Horizon 2020 (LCE 30), EPSRC, NERC
Dynamic Capacity: Hydraulic connectivity of aquifer, geological heterogeneity e.g. (shallow marine, aeolian, lacustrine facies, etc., fault-zone transmissibility	Dyn. Cap.	All	University/research institute projects (1 or 2) with industry involvement, each £100-500K, 100% funded	EC - Horizon 2020 (LCE 30), EPSRC, NERC

Notes:

1. It is possible that storage and monitoring of early Phase 2 projects ('Phase 2a') would be geographically co-located with Phase 1 sites (i.e. at or near Goldeneye and 5/42 of, respectively, Peterhead and White Rose). However it was noted that to cluster all storage for Phase 2 (or even Phase 2a) to only these sites may not be an acceptable risk profile; there may well be viable projects that emerge in Phase 2 which, due to geographic location and/or composition of CO_2 'waste' stream, would have lower risk if alternative sites were employed. There are generic R&D elements that would be applicable to large parts of storage and monitoring in UK waters (and globally). Goldeneye and 5/42 are diverse in terms of reservoir and environmental characteristics and, as case studies, provide a good representation of regional variability.
2. The group adopted a framework of three key areas of storage: Injectivity, Containment and Dynamic Capacity. Monitoring (MMV) spans all three.
3. In May 2015, ETI commenced work on a project funded by DECC to down-select and advance the appraisal of five sites.

Improving the project selection process

A typical process for determining which research projects are awarded funding is based on five main stages:

1. R&D needs are identified based on e.g. the APGTF RD&D Technology Strategy (see http://apgtf-uk.com/index.php/publications/publications-2014) and/or the UKCCSRC 'Research and Pathways to Impact Delivery (RAPID' document (see https://ukccsrc.ac.uk/research/research-and-pathways-impact-delivery-rapid).
2. Calls for proposals. These often reference the APGTF priorities and/or the UKCCSRC RAPID reference and include assessment criteria and questions for assessors.
3. Proposals are submitted by applicant(s).
4. Assessors/evaluators score projects against specified criteria.
5. A panel of moderators ranks the applications in terms of total score and then awards funding down the list until the total budget has been allocated.

Notably, proposal assessment processes do not explicitly consider the overall objective for Government intervention, i.e. to commercialise CCS, and therefore doesn't consider factors such as timeliness (relevance to Phase 1 or 2) or potential for cost reductions (again, by relevance to phase of deployment).

To improve the project selection process, participants at the November 2014 workshop suggested the following:

1. Quality of research, leverage of other work and breadth of application, impacts, impact commitments and user support should be used as stage gate criteria, pre-requisite to a project securing funding.

2. The list of assessment criteria provides greater emphasis on timeliness and cost reduction. Proposed new criteria could include:

Relative weighting	**Criteria**
Highest weighting	Cost reduction potential relative to projects within scope of funding call.
	Risk reduction potential relative to projects within scope of funding call. Appropriate metrics would need to be determined.
Medium weighting	How well the project meets the subset of more specific priorities identified.
	Contribution towards longer term CCS objectives (i.e. to Phase 3 and beyond).
	Immediacy of impact, e.g. to Phase 1, Phase 2 and/or Phase 3.
	User support

3. Funding bodies should pre-determine the balance sought between longer-term and shorter-term impacts and separate money should be allocated to each 'pot'. Scores should be weighted to put more emphasis on timeliness and projects with an immediate impact, i.e. those that can contribute towards achieving the Outcome, should receive a greater share of the available funding.

4. More specific industry collaboration should be required to ensure that R&D projects meet the needs of industry.

5. Given the absolute priority afforded by Government to CCS cost-reduction, participants at the Workshop were broadly in agreement that the academic and research community – as well as industry – should demonstrably be seen to support both the narrative and delivery of CCS cost-reductions and the imperative of commercial deployment.

Recommendations

1. Each portfolio of funding for future CCS R&D needs to prioritise support for projects directly relevant to potential Phase 1 and 2 projects in order to maximise the potential impact of the funding. This remains the case irrespective of the 25th November decision.

2. An additional element of funding should support longer-term R&D of a more general or more speculative nature. The recommendations here-in are complemented (for longer-term R&D) by the UKCCSRC RAPID Handbook.

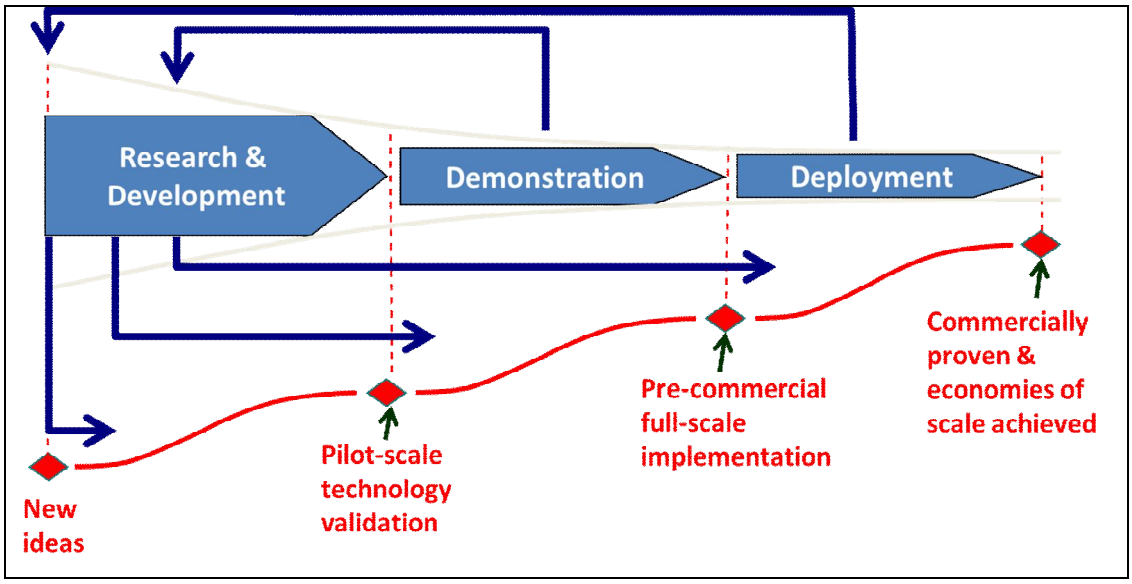
3. Some support may be gained by EU funding where priority topics can be fitted into the larger EU projects but these are likely to more generic than specific. There would be value if the EU were to design the future NER400 modalities around the specific needs and nature of CCS projects, including activities to support early deployment.

4. Representatives of the CCSA, APGTF and UKCCSRC should meet with representatives of DECC, Innovate UK, ETI, Crown Estate and the Research Councils to review the above on a semi-regular basis. Such discussions should include how work of the types that have hitherto been supported by UKCCSRC and ETI might be supported in future. The objective of the discussions would be to ensure that there is a realistic potential funding route for each critical type of work. The discussions should include the role for loans in place of grants for Innovate UK's portfolio.

Appendix: Funding for CCS R&D

As was reported in the 2014 APGTF Strategy, there has been significant funding support for CCS R&D over the last decade along the 'innovation chain' (see Figure 1). Support has been provided at Technology Readiness Levels (TRLs)[2] 1 to 6 by the Research Councils (led by EPSRC), Innovate UK (formerly the Technology Strategy Board), ETI and DECC (see Figure 2). The Crown Estate is also actively supporting storage-related work and National Grid has its own programmes, including COOLTRANS, an £8m project which was supported by the EC under the European Energy Recovery Package – EERP – as part of the Don Valley project. Companies, research institutes (including BGS, PML, NOC, SAMS, TUV NEL, etc.) and universities have also gained funding from the EU Framework programmes, most recently Horizon2020 programme, which runs 2014-2020, the EU Research Fund for Coal and Steel (RFCS) and European Structural Funds.

Figure 1: Technology innovation chain



The support models (and the associated proportion of public funding and ownership of results) vary across these funding agencies, with the highest levels of funding (near 100%) at the lowest TRLs and the lowest (~25%) at the highest TRLs. The proportion of public funding is highest for universities and research institutes, and for industry is greater for micro- and small-enterprises than for medium-sized and larger companies. With its unique public-private funding arrangements the ETI is able to fund up to 100% of costs for TRL 3-6 projects. ETI has recently commissioned a high-TRL project funded by DECC. Industry has provided the balance of R&D funding, estimated overall at about half of the total, justified within the companies by the commercial benefits which were expected to accrue from demonstration/commercialisation projects and future CCS deployment.

[2] TRL 1 to 3: "In the lab" research and feasibility.
TRL 3 to 6: "At scale" technological development.
TRL 6 to 7: Technology is demonstrated with commercial prototypes.
TRL 8 to 9: Describes technology once it is "in service."

It is very important to recognise that whilst CCS at the overall system level may be considered to be at TRL 6 or 7, there is ample scope for R&D which is at much lower TRL levels, including fundamental research at TRLs 1 and 2.

Current funding support

The Research Councils (predominantly EPSRC, with some support from NERC) supports research institute and university research, including research projects coordinated through the UKCCSRC (including in collaboration with the Research Council of Norway). Generally, Research Council funding is directed at projects which are at the low TRL levels both through targeted, specific 'calls' and via its more responsive 'standard mode'. Nevertheless, they encourage projects which are supported financially or in-kind by industry and seeks to emphasise the importance of the probable 'impact' of the research. In the context of the present exercise, it is important to stress that low-TRL work and exciting cutting edge R&D which supports fundamental understanding of the technologies likely to be implemented in Phase 1 or Phase 2 projects will maximise the potential impact in the next 10-15 years. EPSRC is most relevant Research Council in terms of capture and transport research, with NERC most relevant for storage research and ESRC for social science and economics research. In all three areas of activity some projects have been coordinated by the EPSRC-funded UKCCSRC.

Innovate UK (formerly the Technology Strategy Board) supports industry-led R&D which will lead to UK competitive advantage. Recently Innovate UK has supported:

- Feasibility studies, typically £100-150K SME-led (100% funded) activity;
- Large, mid-stage, business-led collaborative projects, typically £500K to £3M (70% funding for micro- and small-SMEs, 60% for medium-SMEs, 50% for larger companies); and
- Larger, late-stage, business-led collaborative projects, typically £1-10M (25% funding).

The pre-condition that the R&D must have a route-to-market within a 5-8 year timescale has restricted Innovate UK's activities in the CCS field.

DECC has supported CCS projects through:

- Significant funding (£28 million to support the development and demonstration of CCS components and next generation technologies, £35 million for pilot-scale projects to bridge the gap between research and commercial-scale deployment). Industry-led projects in these categories were eligible for 25-50% funding.
- the Energy Entrepreneur's Fund, but recent projects have been limited to one-year duration.
- A storage-related project commissioned and delivered by ETI (£2.5M funding).

DECC recently announced £1.7M of support along with £2.5M from the Scottish Government for industrial research and feasibility work for a proposed full–chain 570MW_e CCS coal-gasification power station located in Grangemouth, Scotland.

ETI invests in R&D in CCS in order to develop relevant technology and IP, including next-generation capture technologies, storage appraisal and MMV, system modelling and hydrogen systems. It has also carried out very valuable studies of the future UK energy system which have demonstrated the crucial role to be played by CCS in power and industry.

EC Horizon2020 Energy. The first (2014-2015) and current (June 2015) *draft* EC Horizon2020 Energy 2016-17 Work Programme includes a number of CCS topics under the theme "Enabling the decarbonisation of the use of fossil fuels during the transition to a low-carbon economy": Note that the June 2015 Work Programme covers 2016 and 2017. The parts of the Work Programme that relate to 2017 are provided at this stage on an indicative basis. Such Work Programme parts will be decided during 2016.

- LCE 15 – 2014/2015: Enabling decarbonisation of the fossil fuel-based power sector and energy intensive industry through CCS. With two key challenges 'Geological storage' and 'Application of CCS to industrial sectors other than power, including bio-CCS'
- LCE 24 - 2016: International cooperation with South Korea on new generation high-efficiency capture processes
- LCE 25 - 2016: Utilisation of captured CO_2 as feedstock for the process industry
- LCE 26 - 2016: Cross-thematic ERA-NET on Applied Geosciences
- LCE 27 - 2017: Measuring, monitoring and controlling the subsurface containment of CO_2 and natural gas
- LCE 28 – 2017: Highly flexible and efficient fossil fuel power plants
- LCE 29 - 2017: CCS in industry, including Bio-CCS
- LCE 30 - 2017: Geological storage pilots.

Individual Horizon2020 projects might be ~15 MEuros in total, but they would have a wider scope than the priority projects identified here.

EU Research Fund for Coal and Steel. Two of the six 'Coal Priorities' of the RFCS Programme for 2015 potentially allow CCS projects:

- 1.5 Technological improvements targeting load flexibility AND environmental performance of coal-fired power plants
- 1.6 Pilot projects validation of emerging AND innovating technologies leading to efficiency improvements AND CO_2 emission reduction.

27.2% of the total budget of 55MEuros/year (i.e. 14.96MEuros) is available for coal-related R&D, and there are 6 priority topics. Projects seeking around 1MEuros over three years could be viable candidates.

EC 'Other actions' from first Horizon2020 call. Studies to support the formulation, implementation, communication and monitoring of sustainable energy policy, including its research and innovation dimensions, awarded through public procurement, grants to named beneficiaries or through administrative arrangements with the Joint Research Centre (JRC):

- B.2: Competitive low-carbon energy technologies:
  - B.2.3.: Support to Research and Innovation Policy in the areas of Renewable Energy, Carbon Capture and Storage and Clean Coal (public procurement)
  - B.2.7.: Energy Storage Mapping and Planning (public procurement)
  - B.2.8.: Energy Policy support on CCS (public procurement).

Some international CCS organisations also fund CCS research. One such example is the IEA Greenhouse Gas R&D Programme (IEAGHG), which may publish a call for research, such as the IEAGHG 2014 call for 'Review of offshore monitoring techniques'.

Letters of support, in-kind or financial support from industry for proposals led by academic organisations will promote the need for the research in the review and award process.