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GLOBAL STORAGE RESOURCES GAP ANALYSIS FOR POLICY MAKERS

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GLOBAL ANALYSIS OF STORAGE RESOURCES AND RECOMMENDATIONS TO POLICYMAKERS TO MEET CCS DEPLOYMENT OBJECTIVES

Executive Summary

The IEA Greenhouse Gas R&D Programme (IEAGHG), on behalf of the Global CCS Institute, commissioned Geogreen to undertake a study reviewing the current global portfolio of operational and announced CO₂ geological storage projects, in the context of key CCS deployment targets for 2020: 20 operational sites stipulated by the G8; and 100 operational sites as described in the 2009 IEA CCS Roadmap ‘Blue’ scenario (limiting atmospheric CO₂ concentrations to 450ppm).

The Geogreen study included detailed modelling of the timescales and resources required for storage sites to achieve bankable status, whereby final investment decisions can be made in advance of site construction, commissioning and operations. Building on this analysis, the study showed that the current CCS project portfolio could allow the G8 target to be reached provided that adequate resources are made available for a large proportion of the proposed projects and that storage associated with CO₂-EOR can be included.

However, the analysis also showed that the IEA Roadmap target for 2020 is effectively unattainable. Project lead times are long – up to 15 years for deep saline formation storage sites, accompanied by significant risks of project failure due to both technical (e.g. geological) and non-technical (e.g. financing, public acceptance) issues. Based on current projections and assuming adequate funding, Geogreen estimated that approximately 50 sites could be operational by 2025 or, with the inclusion of CO₂-EOR projects, 100 sites by 2028. The latter will require up to 6 billion Euros of total investment to achieve the requisite number of storage bankability assessments, not including site construction and operational costs.

Hence the gap between the current global portfolio of CCS projects and roadmap deployment targets to mitigate greenhouse gas emissions is wide, being especially stark in non-OECD countries where only a small fraction of required project numbers have been announced. In the absence of adequate funding to resource storage site exploration and incentivise CCS, this gap will continue to widen as CCS falls further behind climate science – driven targets.



Background to the Study

Establishing access to an adequate bankable CO₂ geological storage resource is a prerequisite for investment in the construction of commercial-scale CO₂ capture and storage (CCS) projects. In this context, the term bankable refers to storage sites that have been evaluated such that sufficient confidence exists in technical and cost elements, to support final investment decisions. Regional mapping, exploration and characterisation of storage resources provides a critical technical, cost and timing element in the development of initial CCS projects that will pave the way for subsequent commercial deployment.

Geogreen was commissioned by the IEA Greenhouse Gas R&D Programme (IEAGHG), on behalf of the Global CCS Institute to undertake an analysis of requirements to realise bankable storage resources, in the context of existing global projects and key CCS deployment targets.

Scope of Work

The primary objective of the study was to alert policymakers to the scale, cost and timing of the storage resource assessment tasks to enable deployment of the 20 commercial-scale CCS projects by 2020 envisaged by G8 Leaders in 2008, and the 100 projects by 2020 as targeted in the 2009 IEA CCS Roadmap. In practice the challenge is to have sufficient bankable storage sites by 2015, so that CCS projects can be operational by 2020.

The study, comprising a literature review and desk based assessment, aimed to identify and prioritise the key storage resource gaps for each of the world's main carbon-intensive regions, and to outline the work programs (including time and costs) that would be required to fill those gaps to enable sufficient bankable storage sites to be defined to support the widespread commercial-scale deployment of CCS. These issues were considered both in the context of the G8 target and the 2009 IEA CCS Roadmap. Consideration was also given to subsequent wider deployment required over longer timescales (e.g. 2050) in order to make a significant contribution to mitigation of greenhouse gas emissions.

The existing evaluation of storage resources in developed countries, and the identification of the gaps in those countries, provided a reference framework for reviewing the evaluation status and gap analysis of storage in developing countries. The report summarised the status of storage resource evaluation in major world regions, identifying the distinctive challenges and key storage resource assessment tasks of each region in the timeframe aligned with 2020 targets.

A key objective was assessment for each region of the phasing and costs of the exploration and characterisation activities required to provide the bankable storage resource platform needed to support the CCS development outlined in the 2009 IEA CCS Roadmap, thus providing policy makers with reliable estimates of the corresponding phasing of resources that will be required to develop CCS in line with 2020 targets.



Findings of the Study

Review of Regional Storage Resource Assessments

The first stage of the study comprised a review of existing levels of deep subsurface geological knowledge. Largely dependent on exploration and production activities from the oil and gas industry, this knowledge level allowed qualification of the probability, cost and timescale for development of bankable storage resources.

The starting point for the assessment was the 2005 IPCC map of global storage prospectivity. Geogreen updated and expanded this map using information from subsequent storage research publications, and internal knowledge of global oil and gas exploration activities. Figure 1 presents a summary map of this work, used in the subsequent analytical sections of the report.

Development of Bankable Storage Resources

Geogreen developed workflows to identify the main project tasks required to achieve bankable status for commercial scale storage projects (100Mt CO₂ total capacity) in deep saline formations (DSF), depleted oil and gas fields (DOGF) and CO₂ enhanced oil recovery (CO₂-EOR) schemes. Each project task was assigned probabilistic values for timescale and associated costs, with regional variations where appropriate. This information allowed probabilistic modelling of project time and resource requirements to achieve bankable status and formed the core of the subsequent analysis of current progress against key CCS deployment targets. An example workflow for DSF is shown in Figure 2 below.

The analysis needed to allow for project failure rates, which could be broadly related to either technical or non-technical factors. Technical factors would be mainly geological in nature and could include unsuitable reservoir characteristics, inadequate caprocks or unacceptable leakage risks; Geogreen allowed for technical project failure rates of between 10% and 40%, based partly on industrial analogues such as natural gas storage.

Non-technical project failures could be due to such factors as financing, public acceptance or regulatory requirements and the report noted that prediction of non-technical failure rates is relatively subjective. For this reason, non-technical failure rates were not specifically modelled within the bankability assessment workflows.



Figure 1. Global Suitability for CO₂ Geological Storage

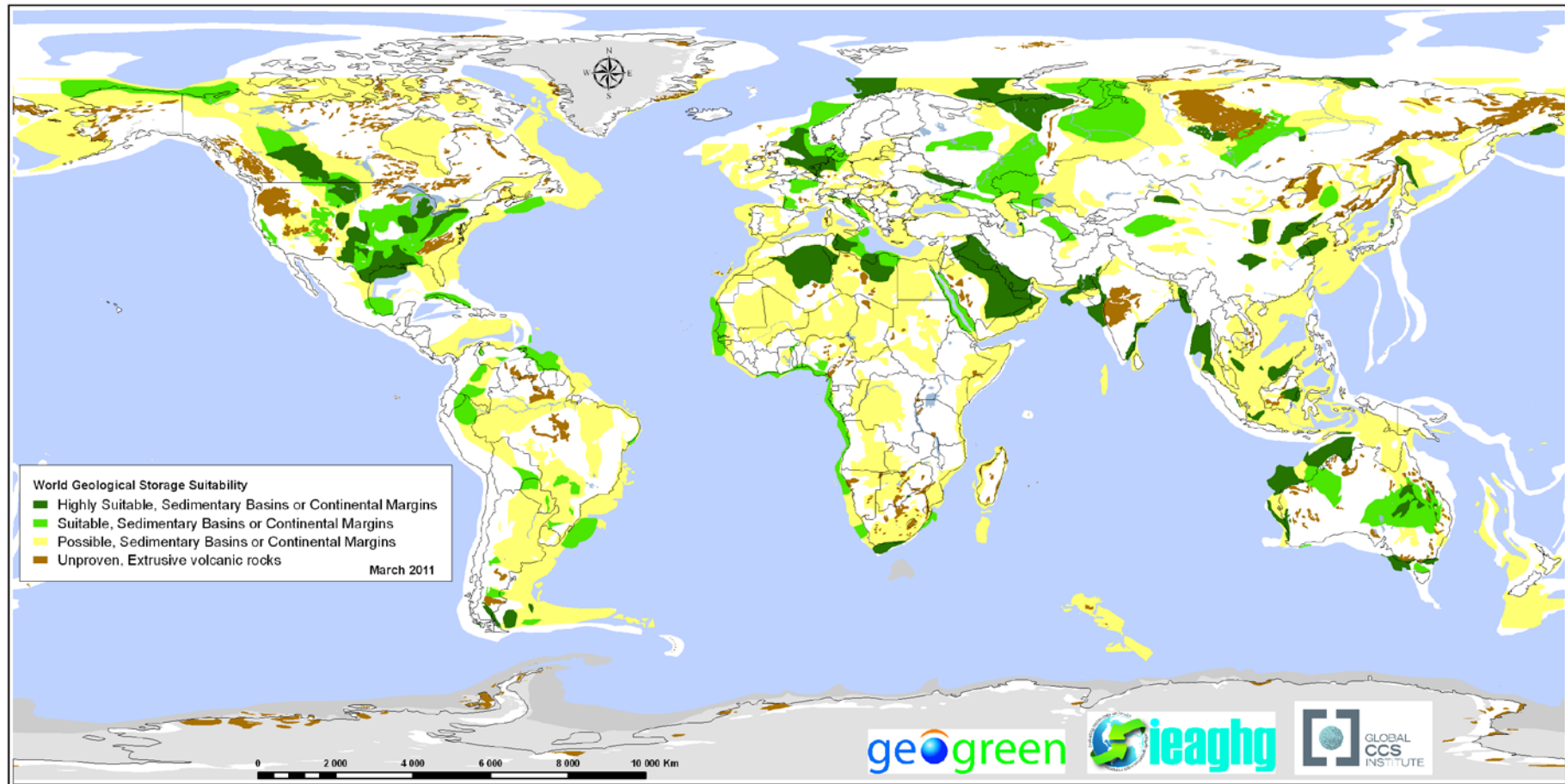




Figure 2. Project Phasing for Onshore Deep Saline Formations

Type of study	Phase	Major costs items
National based <i>Non exclusive surveys</i>	Phase 0 Screening	First desktop studies
Project based <i>Exclusive surveys</i>	Phase 1 Desk Based assessment	Desktop studies, where possible seismic reprocessing and existing wells logs analysis (including communication on project)
	Licensing Exploration Permit	Administrative engineering and follow-up
	Phase 2 Site confirmation & characterization	Studies and engineering for this phase (including monitoring actions, equipments and monitoring (soil, gravimetric, Insar)) Seismic acquisitions 2D Seismic acquisitions 3D (on CO ₂ future plume only) Civil Engineering Drilling CO ₂ well with rotary rig (including 20% contingency including Mob/demob)
	Licensing Injection test	Injection test permitting
	Phase 2 Injection Test	Studies and monitoring Injection test duration CO ₂ injection cost
Bankable		

Development of the workflows and subsequent analyses inevitably involved a wide range of other assumptions being made on technical, cost and time factors. Full details of the assumptions made in the modelling are detailed in the Geogreen report.

Key messages reported from the development of the bankability workflows can be summarised as follows:

- Considerable time periods are required for most projects to achieve bankable status – up to 15 years for DSF and DOGF, partly due to the sensitivity of licensing and environmental issues;
- The level of pre-existing geological knowledge can also have a major bearing on timescales and associated costs;
- Lead times to bankable status for CO₂-EOR schemes could be shorter, typically 1 to 3 years, but the number of these opportunities could be constrained by geographical, safety and production issues.

Assessment of Key Targets for CCS Deployment by 2020

The study considered bankable storage requirements to achieve key CCS deployment targets, in the context of currently operational and announced projects. Geogreen created a database using a variety of online information sources, including IEAGHG, and identified a total of 124 relevant projects. Further screening of these projects due to scale and other criteria reduced the total relevant number to 54; in addition, projects which have already achieved



operational or bankable status (e.g. Weyburn-Midale, Sleipner, In-Salah, Gorgon etc) are automatically regarded as contributing to the key deployment targets.

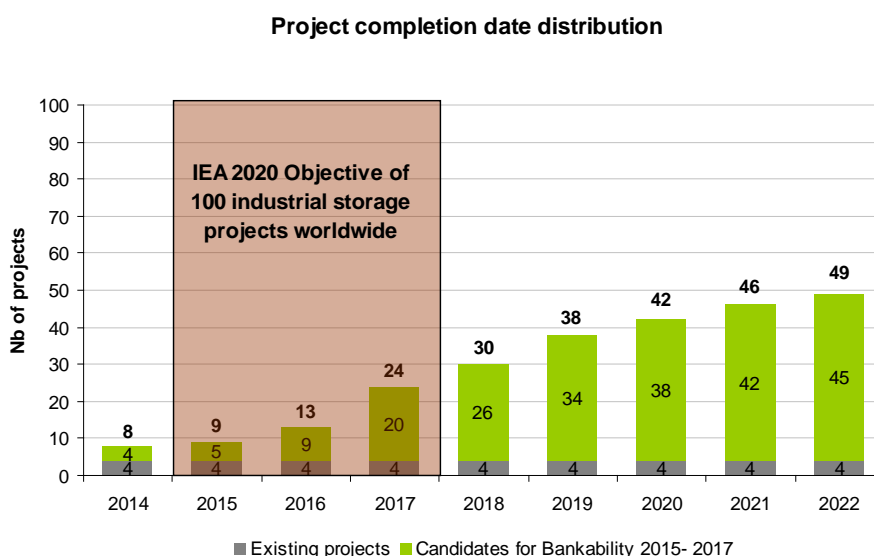
The workflow assessments for bankability described above allowed for technical failure rates for projects. Non-technical failure whilst not modelled was also discussed in the report; the study postulated that based on recent experiences of CCS proposals, between 14 and 24 of the current 54 announced projects considered by the study, could be cancelled due to non-technical factors, although inclusion of CO₂-EOR projects in this context could reduce this failure rate.

2020 Deployment Targets – Excluding CO₂-EOR

A key assumption made by the study was that all 54 announced projects would be able to proceed towards deployment. This assumption may of course be at odds with existing funding mechanisms, but provides a valid reference point for the analysis in the context of 2020 targets.

Figure 3 below shows the analysis of timescales required for current announced/operational DSF/DOGF projects to achieve bankable status. Note the gap between achieving bankable status and commencement of operations (for construction and commissioning) could be anticipated as typically 3 to 5 years, 2020 deployment targets require bankable status to be achieved between 2015 and 2017. Figure 3 shows that allowing only for technical failures, there *may be* sufficient DSF/DOGF projects announced to meet the G8 target of 20 projects – but the number of projects falls way short of the IEA Roadmap target of 100 operational projects by 2020. Rather, by 2025 only about half the target 100 sites might be operational.

Figure 3. Projected Timescales for Currently Announced DOGF/DSF Projects Achieving Bankable Status – Allowing for Technical Failure Rates





The Geogreen report included a regional analysis showing that whilst the number of announced DSF projects in OECD countries could theoretically achieve their required contribution to a 100 projects global target by 2025, non-OECD countries collectively fall far short of the same benchmark.

The study also reported the projected total cost of the bankability assessments described in Figure 3 as between 1.2 and 2.8 billion Euros, with a mean estimate of 2 billion. These costs relate to the achievement of bankable status and do not include site construction, commissioning and operational costs.

In order to achieve a total of 100 bankable projects by 2022 to 2025 (operational by 2028), Geogreen estimate an additional 60 projects would need to be announced by 2012. The total cost of achieving 100 bankable storage sites would be between 2.5 and 5.9 billion Euros.

The above analysis does not allow for non-technical project failures, which could be due either to public/regulatory acceptance or financing issues. Quantitative assessment of likely failure rates due to these factors is problematic, due to the immaturity of commercial scale CCS and difficulty in finding meaningful industrial analogues. Geogreen conclude that non-technical failures may effectively more than double the failure rate from the 15% modelled for technical failures, *giving an overall project failure rate of 30% to 40%*. These higher failure rates serve to widen the gap between the number of current project announcements and key CCS deployment targets – achievement of the G8 target would become far more uncertain, whilst achievement of 100 bankable sites even by 2025 (operational by 2028) would require 85 new project announcements by 2012.

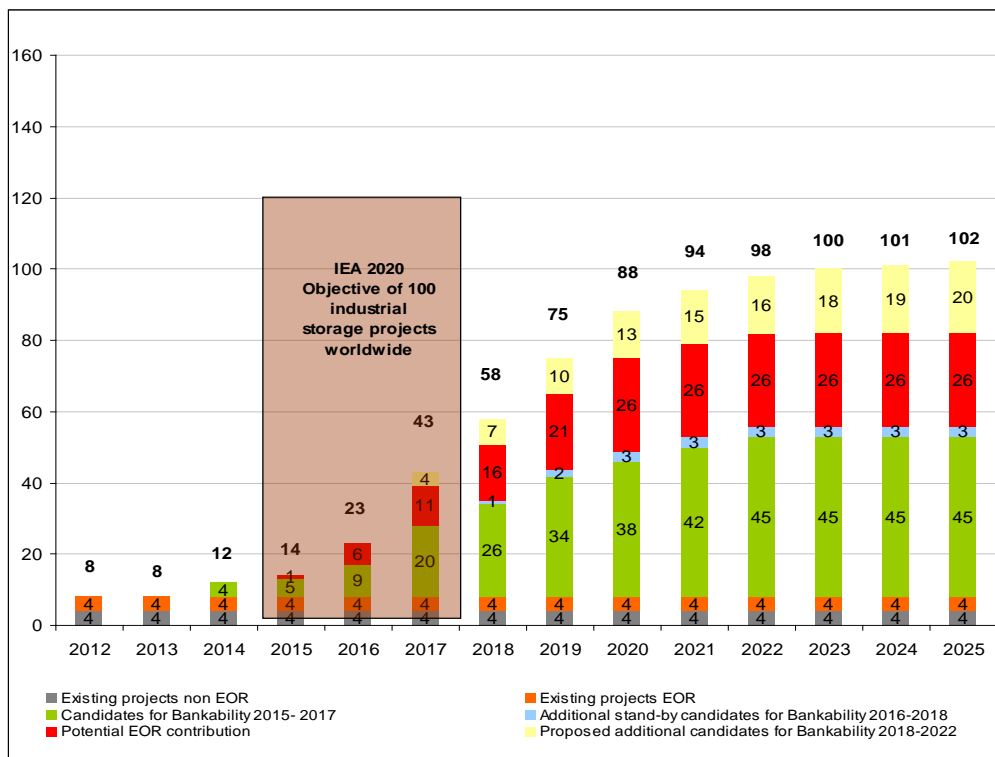
Potential Contribution of CO₂-EOR

The report discusses some key issues relating to the inclusion of CO₂-EOR projects in CCS deployment targets; CO₂-EOR projects must utilise anthropogenic CO₂ sources and be accompanied by an appropriate MMV plan to satisfy storage regulations. In the context of current or near-future CCS projects, inclusion of CO₂-EOR could increase by approximately 75%, the number of bankable CCS projects by 2018.

Therefore, as a result of including CO₂-EOR projects in the analysis, achievement of the G8 target by 2020 becomes likely, non-technical issues notwithstanding; whilst the gap between announced projects and achieving 100 bankable sites by 2025 is narrowed or even closed. This is summarised in Figure 4 below, which provides direct comparison to Figure 3 and therefore does not include non-technical failure rates.



Figure 4. Projected Timescales for Storage Projects Including CO₂-EOR Achieving Bankable Status – Allowing for Technical Failure Rates



2050 Deployment Targets

The 2009 IEA Roadmap states a target of 3,400 operational projects by 2050 in order that CCS provides the required share of emissions reduction measures to stabilise atmospheric concentrations of CO₂ at 450ppm, with approximately 150Gt of storage needing to be achieved by that date.

The study included a short, qualitative assessment of project needs for this 2050 goal. Geogreen noted that anticipated long term trends could include a decrease in project failure rates as practical experience of CCS operations is gained, and a gradual reduction in the proportion of storage in CO₂-EOR projects. The study estimated that 3,750 sites might need to achieve bankable status prior to the 2050 date to reach the target, with an associated cost exceeding 100 billion Euros. The long term viability of CCS may also require the development of distribution networks linking multiple sources and sinks, and the resolution of any cross border issues.

Expert Review Comments

Expert comments were received from 6 reviewers representing industry and including corporate sponsors of IEAGHG. The overall response was positive and highlighted a significant contribution the study could make to this area of storage policy research.



Key suggestions made by reviewers and incorporated into the final report included clear statements of all significant assumptions made in the modelling and assessment, and the inclusion of CO₂-EOR as an important storage option.

Conclusions

Compilation of detailed workflows for commercial scale storage sites (100Mt CO₂ storage capacity) to achieve bankable status – whereby final investment decisions can be made – has facilitated probabilistic assessment of development timescales and associated costs for projects utilising DSF, DOGF and CO₂-EOR storage sites. This modelling has demonstrated long lead times for bankable status, typically 5 to 15 years for DSF and influenced by factors such as the level of pre-existing site characterisation, environmental risks and permitting requirements. Lead times for storage projects associated with CO₂-EOR are typically shorter at between 1 and 3 years.

The study considered current operational and announced CCS projects in the context of key CCS deployment targets. Geogreen identified, in addition to 8 operational/imminent projects, a further 54 announced CCS projects that could progress to commercial operations. Technical failure rates of these proposed projects (e.g. due to geological factors) were assumed in the study to average 15%. Non-technical failure rates (e.g. public acceptance, financing) were not explicitly modelled, although the study suggested such factors could increase the overall project failure rate to between 30% and 40%.

The analysis showed that the current operational/announced global CCS project portfolio has the potential to achieve the G8 target of 20 operational projects by 2020, ***provided adequate funding for all projects is available*** and particularly if CO₂-EOR projects are included. Conversely, the 2009 IEA CCS Roadmap target of 100 operational sites by 2020 ('Blue' scenario, charting progress required for stabilisation of atmospheric CO₂ at 450ppm) is extremely unlikely to be achieved without a large number of additional and immediate project announcements; the current portfolio of announced global projects is more likely to deliver approximately 50 operational projects by 2025, given adequate funding. A more realistic target date for 100 operational projects of 2028 could be achieved, aided by the inclusion of CO₂-EOR projects and again notwithstanding financial and other non-technical issues. The gap between current efforts and deployment targets is most marked in non-OECD countries.

The 2009 IEA Roadmap also includes a target of 3,400 operational projects by 2050, with a cumulative 150Gt of CO₂ stored by that date. The study estimated an additional 3,750 sites would need to achieve bankable status between 2025 and 2050 to achieve this target, with likely long term changes including a proportional decline in the importance of CO₂-EOR for storage and a decrease in proposed project failure rates as the CCS industry matures.

The study has also reported a range of modelled costs for storage sites to reach bankable status in the context of deployment targets. These costs effectively relate to site characterisation, assessment and permitting but do not include site construction,



commissioning and operations. Progression of the current set of 54 announced projects towards bankable status could require between 1.2 and 2.8 billion Euros, whereas achievement of 100 bankable sites would require between 2.5 and 5.9 billion Euros. Long term achievement of 3,400 operational sites by 2050 would require investment of over 100 billion Euros just for bankability assessments.

Recommendation

Key messages derived from the study should be communicated widely to policymakers, regulators and other stakeholders in CCS deployment. These messages can be summarised as follows:

- Proposed projects will be subject to both technical (e.g. geological) and non-technical (e.g. financing) risks of failure; consequently, it is important to have a large enough portfolio of proposed projects to achieve deployment targets;
- The long lead times for storage sites to reach bankable status and subsequently, operational status require storage assessment to be commenced at an early stage in relation both to individual CCS projects and deployment targets;
- Only if funding is available to many or all currently announced projects and/or storage associated with CO₂-EOR is included, can the G8 target of 20 operational commercial CCS projects by 2020 be realised;
- The gap between the 2009 IEA CCS Roadmap milestones and projected progress of the existing global portfolio of announced CCS projects, especially in the context of current resourcing/funding, highlights that CCS deployment is falling behind targets to mitigate greenhouse gas emissions. This gap is especially stark in non-OECD countries.