Carbon capture and storage in Europe

Carbon capture and storage (CCS) is an important component of many national, European and worldwide strategies to tackle climate change. CCS can reduce greenhouse gas emissions by capturing the carbon dioxide (CO_2) generated by large point sources before it is released to the atmosphere, and then transporting it to a secure underground storage facility.

The European Academies Science Advisory Council (EASAC) established a working group in October 2011 to examine the challenges that must be addressed to secure CCS as a viable component of strategies to mitigate climate change, and consequently to consider what contribution it may make in Europe up to 2050. This report presents the findings and recommendations of that EASAC study.

The three main technologies for **CO_2 capture** – post-combustion capture, pre-combustion capture and oxy-fuel combustion – are considered technologically feasible, but integrated operation on commercial-scale power stations remains to be demonstrated. They have broadly similar costs, adding around 50% to the levelised cost of electricity when applied to coal- or gas-fired power stations. Present and anticipated developments should bring this penalty down to 30–45% over the next 20 years, and further incremental improvements may be expected beyond that timescale. More substantial improvements based on radically new technologies and configurations are speculative at the present time.

Transport of CO_2 may be by pipelines or ships, the latter potentially being favoured for small and/or remote offshore locations or where flexibility is required, particularly in start-up phases. For ship transport, scale-up to commercial capacities in the context of CCS needs to be demonstrated. For pipelines, further research, development and demonstration work over a period of 5–10 years should provide the necessary confidence in their economic and safe design and operation in light of anticipated impurities in the CO_2 and variable load operation of the CO_2 sources. The development and operation of an integrated, cross-border CO_2 transport infrastructure in Europe, linking large networks of capture and storage sites, represents a major institutional and logistical challenge. However, there are no insurmountable technical problems facing pipeline transport.

The processes of **CO_2 storage** are broadly understood, but significant uncertainties remain which will need to be addressed to provide sufficient confidence to regulators and the public that CO_2 storage will be safe over the long term. The precise levels of confidence that will eventually be required in respect of the various issues impacting on the long-term safety of CO_2 storage, and the consequent degree of resolution of these uncertainties that will be expected, will emerge from an iterative process of confidence building between developers and regulators, in which publics should play an active part. Acceptable levels of confidence and resolution of uncertainties will be influenced by the urgency of action to mitigate climate change on the one hand, and by liability issues, public concerns, and the long time periods over which CO_2 must be safely stored on the other.

The rate at which uncertainties can be resolved, and knowledge gained, will be constrained by the need to observe geological processes, some over periods of years to build sufficient understanding, but others (for example CO_2 migration and retention processes, and borehole seal integrity) potentially over decades. Similarly, characterisation of a candidate storage site to achieve sufficient confidence to commit to CO_2 injection may take several years, and generally more for saline aquifers, where the major part of estimated storage capacity rests, than for mature and depleted oil and gas fields given their previous characterisation. These factors will be an important influence on the rate at which CCS can be deployed in Europe. An early priority is to develop a better characterisation of Europe's potential CO_2 storage sites.

Public perceptions will have an important bearing on the progress of CCS in Europe and there is a case for more concerted initiatives at European Union (EU) and national levels to debate the value of CCS in the context of climate change mitigation strategies, and consequently to build awareness and acceptance of the potential of CCS as an option for climate change mitigation. The social setting for CO_2 storage facilities may need to be given greater weight, alongside the suitability of the geological setting and location in relation to capture sites, in deciding where to locate CO_2 storage facilities.

Consideration has been given to **alternatives** to 'mainstream' CCS such as biochar, use of biomass with CCS, waste carbonation, algae cultivation and CO_2 utilisation in chemical processes, which have already reached the pilot and demonstration stage. It is concluded that for the near term, there seem to be no feasible alternative approaches capable of making a major contribution to climate change mitigation, although there are several interesting concepts being developed that could provide some modest additional means for reducing greenhouse gas emissions in the future.

With regard to the **current position of CCS in Europe**, a picture emerges of delays in, and downsizing of, the first steps (in particular the proposed set of demonstration plants), of continuing challenges to the economic viability of CCS and of difficulties of public acceptance, which may constrain the possible locations and rates of development of transport and storage infrastructures. Confidence in the safety and permanence of CO_2 storage is likely to build relatively slowly.

Looking forward to the **prospects for CCS in Europe**, an outcome at the lower end of the ranges considered by the European Commission in establishing the CCS Directive, and more recently in the Roadmap 2050 exercise, may be a more realistic central case. The core of this contribution would lie in CCS applications with favourable juxtapositions of sources, sinks and public acceptance. From an electricity systems point of view, it would focus on situations where CCS enables fossil-fired power stations to play a key role in balancing supply and demand in an electricity system having close-to-zero greenhouse gas emissions and relying primarily on renewable energy sources, and possibly nuclear power. Positioning CCS in this way may help to overcome opposition founded on a belief that pursuit of CCS will be at the expense of developing renewable sources.

At present, the financial and policy conditions are not in place in Europe to attract private investment in CCS. Initial enthusiasm for CCS appears to be waning under the harsh spotlight of funding demonstration plants and the first-generation commercial facilities that should follow. Unless decisive policy actions are taken to address this issue, and to provide investors with sufficient confidence in returns

over the lifetime of projects, this situation looks set to continue. If CCS is to make a significant contribution in Europe to climate change mitigation, technologies, capacity and infrastructure need to be developed steadily and with greater urgency than currently prevails. CCS is not a tap that can simply be turned on, if and when suitable financial conditions emerge or future policy makers decide that CCS is a crucial component of Europe's energy strategy.

Recommendations from the study concern the **financial viability** of CCS, **storage issues**, **CCS technology development**, **CO_2 transport** and **public engagement**.

For the **financial viability** of CCS, consideration should be given to additional funding mechanisms to augment EU allowances from the EU Emissions Trading Scheme, such as feed-in tariffs or 'contracts for difference', to tip the economics in favour of CCS deployment, and to the appropriate division of risks between governments and commercial developers. The Emissions Trading Scheme should be extended to include alternative technologies such as the use of biomass with CCS, carbonation and CO_2 utilisation under the condition that the mitigation effect from the life cycle of these options (especially in the case of CO_2 utilisation) is significant, and can be measured and proven.

Achieving adequate funding of the capital and operating costs of EU demonstration plants is an immediate priority: current rules for funding the demonstration projects may need to be revisited. Although funding constraints may limit the initial number of demonstration plants to three or four, a second tranche of demonstration plants should be planned for and financed to demonstrate an adequate range of technologies and application options.

Care must be taken in pushing forward CCS that carbon-intensive industries are not driven to other regions where there are fewer restrictions ('carbon leakage') through well-designed packages of regulatory and financial measures. The EU should continue to influence developments globally to secure the introduction of similar levels of environmental protection elsewhere.

On **storage issues**, it is recommended that a strong focus be placed on activities to accelerate confidence building on the permanence and safety of CO_2 storage, including clarifying and elaborating regulatory frameworks, and fast-tracking several storage facilities through the complete regulatory process to minimise associated uncertainties as the volumes of stored CO_2 accumulate. The demonstration plants are essential to provide data at large scale and should be developed as soon as possible. They should be complemented by more pilot-scale injection test sites, perhaps five or six in total, which may be able to be implemented and deliver useful results on shorter timescales.

An early, and major, strategic investment should be made to locate and characterise Europe's CO_2 storage capacity, so that a significantly more confident picture is developed than is available now, and to enable an integrated approach to the development of Europe's CCS infrastructure.

The report has identified the research and development activities necessary for **CCS technology development** which are appropriately funded at an EU level through mechanisms that ensure results are made publically available, subject to not compromising commercial incentives. Demonstration plants should be set up to have sufficient flexibility to test a range of options.

A strategic and pan-European approach should be taken to developing Europe's **CO_2 transport** infrastructure, both pipelines and ships, which should be on a par with critical developments in Europe's electricity grid and natural gas pipeline networks for policy attention, EU support and enabling mechanisms. Ship transport of CO_2 should be fully incorporated into the provisions of the CCS Directive.

An enhanced emphasis should be placed on **public engagement** and debates about the role of CCS in mitigating climate change at EU and national levels compared with other options, to increase awareness and to put decisions to proceed with CCS on a firmer footing. These debates should enable a better understanding to be developed of publics' attitudes to CCS and why they are formed.

The full report is available from the EASAC website: www.easac.eu.

EASAC

EASAC – the European Academies Science Advisory Council – is formed by the national science academies of the EU Member States to enable them to collaborate with each other in providing advice to European policy-makers. It thus provides a means for the collective voice of European science to be heard.

Its mission reflects the view of academies that science is central to many aspects of modern life and that an appreciation of the scientific dimension is a pre-requisite to wise policy-making. This view already underpins the work of many academies at national level. With the growing importance of the European Union as an arena for policy, academies recognise that the scope of their advisory functions needs to extend beyond the national to cover also the European level. Here it is often the case that a trans-European grouping can be more effective than a body from a single country. The academies of Europe have therefore formed EASAC so that they can speak with a common voice with the goal of building science into policy at EU level.

Through EASAC, the academies work together to provide independent, expert, evidence-based advice about the scientific aspects of public policy to those who make or influence policy within the European institutions. Drawing on the memberships and networks of the academies, EASAC accesses the best of European science in carrying out its work. Its views are vigorously independent of commercial or political bias, and it is open and transparent in its processes. EASAC aims to deliver advice that is comprehensible, relevant and timely.

For more information about EASAC and for copies of all our previous publications, please visit our website www.easac.eu.

EASAC Secretariat
Deutsche Akademie der Naturforscher Leopoldina
German National Academy of Sciences
Jägerberg 1, D-06108 Halle (Saale), Germany
Tel: +49 (0)345 4723 9833 fax: +49 (0)345 4723 9839
email: secretariat@easac.eu

EASAC Brussels Office
Royal Academies for Science and the Arts of Belgium (RASAB)
Hertogsstraat 1 Rue Ducale, B-1000-Brussels, Belgium
Tel: +32 (2) 550 23 32; fax: +32 (2) 550 22 05
email: brusselsoffice@easac.eu
web: www.easac.eu