International Energy Agency

IEA/CSLF Report to the Muskoka 2010 G8 Summit

CARBON CAPTURE AND STORAGE

Progress and Next Steps

prepared with the co-operation of the Global CCS Institute

2010

carbon sequestration leadership forum

INTERNATIONAL ENERGY AGENCY

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Key points on progress to date

Since 2008, significant progress has been made to address the high-level recommendations on carbon capture and storage (CCS) made by the G8 Leaders. CCS has advanced towards commercialisation, notably through the commissioning of CCS pilot plants, continued learning from plants already in operation and the development of legal and regulatory frameworks. Several governments have committed to provide over USD 26 billion in funding support for demonstration projects. International collaborative and public outreach activities have increased substantially. The mapping of suitable storage sites is underway in various countries and a guide for CCS-ready plant has been developed.

Critical to the deployment of CCS, however, is the experience to be gained from the operation of large-scale demonstration projects. While much progress has been achieved, the recommendation made by the G8 Leaders at the 2008 Hokkaido Toyako Summit that 20 large-scale CCS demonstration projects should be launched by 2010 remains a challenge and will require that governments and industry work in concert.

To measure progress against the goal of launching 20 large-scale CCS projects by 2010, the International Energy Agency (IEA), the Carbon Sequestration Leadership Forum (CSLF) and the Global CCS Institute reviewed government initiatives and developed a set of assessment criteria against which to review progress by industry. Over the past two years, governments have made significant commitments that will facilitate the launch of between 19 and 43 large-scale CCS integrated demonstration projects by 2020. This is very promising, as government support is vital to helping projects under development overcome the final hurdles. A study commissioned by the Global CCS Institute (2010) identified 80 large-scale integrated projects at various stages of development around the world. Notable efforts from both government and industry can be found in the United States, the European Union, particularly the United Kingdom, Canada and Australia. Five large-scale CCS projects[1] are in operation, all commissioned prior to the 2008 G8 Summit. From the pool of 80 projects, one new project, the Australian Gorgon project, has been launched and is proceeding to construction.

A strong momentum has been developed over the past two years. It is important that governments and industry intensify future collaboration to accelerate the pace of development for the full implementation of the G8 goals.

Next steps

Continued political leadership is essential at both national and international levels to achieve the G8 goal of broad deployment of CCS by 2020. This G8 commitment is achievable, but will be challenging. Heightened urgency on the part of all stakeholders is needed to realise the number of large-scale projects that constitute the critical first steps in the deployment of CCS. A broadly supported international agreement on a global response to climate change is required. A price on carbon emissions and new, revenue-generating uses for CO_2 will help offset the cost of

[1] In Salah (Algeria), Sleipner and Snøhvit (Norway), Rangely (US) and Weyburn-Midale (Canada/US).

capture and transport. To reduce global emissions, the engagement of developing countries through, for example, capacity building and mapping of storage potential, is vital.

Much greater effort will be needed to meet future deployment levels; according to the *IEA CCS Technology Roadmap* (IEA, 2009b), about 100 projects will be required by 2020, roughly half of them in developing countries. These projects and other mitigation priorities are needed to support the G8's recognition in 2009 of "the broad scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 °C".

To keep this effort on track, CCS must remain on the agendas of high-level energy and climate change discussions, *e.g.* those of the G8, the G20 and the Major Economies Forum (MEF).[2] Already, the MEF has been active in driving the CCS agenda. To support these activities across the different fora, the IEA and CSLF must continue their efforts to track and report on the progress of CCS development and deployment.

Following the 2005 G8 Summit at Gleneagles, eight high-level recommendations were advanced to accelerate the development and uptake of CCS. Table 1 summarises progress to date on these recommendations. To build on the achievements of the past two years, "Next steps" have been identified that will facilitate the deployment of a nominal 100 CCS projects by 2020, including a significant proportion in developing countries.

Table 1. CCS high-level recommendations: progress to date and next steps

Progress to date	Next steps
Demonstrating CO_2 capture and storage	
• By April 2010, collaboration between government and industry had led to: ➢ 80 large scale industrial projects at various stages of development ➢ over USD 26 billion in government support for the development of large-scale CCS projects ➢ government commitment to the launch of between 19 and 43 large-scale projects ➢ one new project launched and proceeding to construction.	• Greater effort is required to meet the G8 goal of broader CCS deployment by 2020. • Stakeholders must work together to demonstrate and deploy CCS, not only in the power sector and gas separation, but also in CO_2-intensive industries such as cement, chemicals, and iron and steel. • Progress on the development and deployment of large-scale CCS projects needs to be continuously monitored and reported on a regular basis. The IEA and CSLF should continue this process. • Increased efforts needed to support the development of CCS demonstration projects in developing countries.

[2] The Major Economies Forum was launched in 2009 to facilitate debate on climate change issues. It gathers the 17 largest economies of the world. In December 2009, the MEF issued its CCS technology action plan.

Progress to date	Next steps
Taking concerted international action	
• Much progress has been made in terms of international collaboration. These efforts gained increased momentum with the establishment of the Global CCS Institute in 2009.	• Governments and industry must forge partnerships to promote best practice and knowledge sharing from publicly funded CCS demonstration projects. • Stakeholders must continue to co-operate and co-ordinate their international CCS activities in the areas of capacity building and knowledge sharing. This is important for the effective use of resources, particularly in developing countries. • Governments must maintain their efforts to ensure that CCS is recognised by the UNFCCC in the incentive mechanisms under the post-Kyoto arrangements. Inclusion in the Kyoto Protocol's Clean Development Mechanisms (CDM) would represent an important first step. • Closer co-operation is needed with developing countries to achieve the indicative target of 100 demonstration projects by 2020.
Bridging the financial gap for demonstration	
• The financial gap[3] for CCS has not narrowed over the past two years, largely due to continued uncertainty on future international climate change architecture and insufficient carbon price signals. Despite this, efforts by governments to bridge the gap have increased. • The high capital cost escalation of the past few years, which has proven a major barrier to the development of CCS projects, has reduced.	• As long as the financial gap remains, governments will need to develop mechanisms to move CCS from demonstration to commercialisation. • According to the *IEA CCS Technology Roadmap*, an estimated USD 5 billion to USD 6.5 billion per year is required to address the additional investment needs of CCS over the next ten years. • The rate of private and public financial commitments needs to increase, particularly for projects in developing countries. • Multilateral mechanisms need to be put in place, particularly for developing countries.
Creating value for CO_2 for commercialisation of CCS	
• The current value of CO_2 emissions alone is insufficient to drive large-scale development and deployment of CCS to meet the required levels of CO_2 mitigation. Beneficial uses for CO_2 (*e.g.* enhanced oil recovery) have been shown to financially offset CCS implementation costs in some cases, but will not be universally applicable.	• Governments must co-operate to establish a mechanism that assigns a price for each tonne of CO_2 emitted, which must be high enough to drive deployment of low-carbon technologies, including CCS, and be applicable to both developed and developing countries. • In the power sector, mechanisms may be introduced that value the generation of carbon-free electricity.

[3] A financial gap exists as a result of the additional costs for CCS above a conventional plant being higher than the revenue from the relevant market plus the additional benefit from CO_2 reduction. This gap will decline as experience with the technology increases resulting in cost reduction, and as the revenue from the relevant market and the benefit for CO_2 reduction increases.

Progress to date	Next steps
Establishing legal and regulatory frameworks	
• Significant progress has been made on the development of legal and regulatory frameworks, most notably in Australia, the European Union and the United States.	• Governments must continue to develop, refine and finalise legal and regulatory frameworks in jurisdictions in which CCS will be deployed. • For jurisdictions that have started to develop their legal and regulatory frameworks, efforts to resolve outstanding issues must be a priority if near-term targets for demonstration are to be met. • Particular efforts should be made to ensure that licensing and foreseen procedures do not unduly hinder the development of CCS demonstration and, later, the commercial plant.
Communicating with the public	
• Experience from a number of regions has indicated that public perception is a major factor in the success of a project. • Several organisations have developed public outreach activities in support of CCS.	• Leadership from governments and collective action from stakeholders are required to inform the public about CCS and to build confidence in its role in the low-carbon energy technology portfolio.
Infrastructure	
• Work on mapping suitable storage sites is proceeding in developed countries, but progress in developing regions is limited. • Developing common transport infrastructure will be critical to ensuring that CCS can be delivered cost effectively. There has been limited progress in this area to date.	• Governments and the private sector must significantly step up efforts to identify and characterise suitable geology for the secure and environmentally safe storage of CO_2 which is potentially a major constraint on the rapid and widespread deployment of CCS. • Harmonised methodologies must be developed for the characterisation and measurement of CO_2 storage capacity. • Further joint planning of CO_2 transportation infrastructure is needed across all regions.
Retrofit with CCS capture	
• As a result of broad stakeholder engagement, the CSLF, the IEA and the Global CCS Institute have developed a CCS-Ready guide for governments to consider when formulating a nationally or regionally appropriate policy.	• Governments should consider tailoring the CCS-Ready guide to their local policy and regulatory circumstances to avoid the long-term lock-in[4] of CO_2 emissions.

[4] Fossil fuel power plants typically have an operating life of 20 to 40 years. If a plant's design or location impedes subsequent retrofitting of CCS, that plant will potentially "lock-in" decades of largely unconstrained CO_2 emissions.

Background

Analysis indicates that CCS is an essential component of a portfolio of technologies and measures to reduce global emissions and help avoid the most serious impacts of climate change (IPCC, 2005; Stern, 2006; IEA, 2008a, 2009a and 2010). Together with renewable energy technologies, nuclear energy and greater energy efficiency, CCS contributes significantly to the least-cost route of reducing and stabilising CO_2 emissions in the atmosphere. It has been estimated that, without CCS in the technology mix, the cost of climate stabilisation would increase by 70% (IEA, 2008a).

At the Gleneagles Summit in 2005, G8 leaders committed to "work to accelerate the deployment and commercialisation of Carbon Capture and Storage technology" and invited the International Energy Agency (IEA) and the Carbon Sequestration Leadership Forum (CSLF) to hold a workshop on short-term opportunities for CCS. In response, the IEA and the CSLF assembled a group of experts from around the world, who agreed on eight high-level recommendations in the following areas:

- Demonstrating CO_2 capture and storage.
- Taking concerted international action.
- Bridging the financial gap for demonstration.
- Creating value for CO_2 for commercialisation of CCS.
- Establishing legal and regulatory frameworks.
- Communicating with the public.
- Infrastructure.
- Retrofit with CCS capture.

Foremost among the recommendations was the launch of 20 large-scale CCS demonstration projects by 2010. In 2008, at the Hokkaido Toyako Summit, G8 leaders expressed strong support for this initiative, "… with a view to beginning broad deployment of CCS by 2020".

At the L'Aquila Summit in 2009, leaders reaffirmed this commitment and indicated they would "accelerate the design of policies, regulatory frameworks and incentive schemes; encourage greater involvement of developing countries; and work to identify sources of financing for CCS demonstration projects ...". The G8 welcomed the IEA's report on criteria to facilitate tracking of progress on these projects (Box 1) and invited the Global CCS Institute to actively co-operate with the activities of the IEA and the CSLF. (Annex A contains additional information on the G8 and CCS, as well as a timeline of events and decisions taken.)

The IEA and CSLF were asked to report back to the Muskoka 2010 G8 Summit in Canada on progress towards the eight high-level recommendations on development and commercialisation of CCS. Since its official launch in 2009, the Global CCS Institute has also been closely engaged in this work. (Annex B provides a short description of the IEA, the CSLF and the Global CCS Institute.)

Box 1. Criteria for the launch of large-scale CCS demonstration projects

1. Scale is large enough to demonstrate the technical and operational viability of future commercial CCS systems:
   - A coal-fired power project should capture on the order of 1 million tonnes CO_2 annually.
   - A natural gas-fired power plant, an industrial or natural gas processing installation should capture of the order of 500 thousand tonnes CO_2 annually.
2. Projects include full integration of CO_2 capture, transport (where required) and storage.
3. Projects are scheduled to begin full-scale operation before 2020, with a goal of beginning operation by 2015 when possible.
4. Location of the storage site is clearly identified:
   - Primary site is identified with site characterisation underway.
   - Preferred CO_2 transport routes, linking the capture site and the storage site, have been identified.
5. A monitoring, measurement and verification (MMV) plan is provided.
   - This plan provides a high level of confidence that sequestered CO_2 is stored securely.
6. Appropriate strategies are in place to engage the public and to incorporate their input into the project.
7. Project implementation and funding plans demonstrate established public and/or private sector support.
   - Major milestones are identified and adequate funding is in place to advance the project to operation.

Details of progress

The following pages detail progress towards the eight high-level recommendations and "next steps" are identified to move forward and advance towards CCS commercialisation and deployment.

Demonstrating CO_2 capture and storage

Recommendation to G8 in 2008: The G8 must act now to commit by 2010 to at least 20 fully integrated industrial-scale demonstration projects for the broad deployment of CCS by 2020.

Progress to date

- **By April 2010, collaboration between government and industry had led to:**
  - **80 large-scale industrial projects in various stages of development**
  - **over USD 26 billion in government support for the development of large-scale CCS projects**
  - **government commitment to the launch of between 19 and 43 large-scale projects**
  - **one new project launched and proceeding to construction.**

Review of planned industry projects

In the first half of 2009, the Global CCS Institute commissioned a survey of the status of CCS projects worldwide. The survey was updated in April/May 2010 to ensure that this report included the most recent data available to track progress towards the G8's 2010 and 2020 goals. The survey identified 80 currently active or planned large-scale, fully integrated projects for assessment against a set of criteria developed by the IEA, the CSLF and the Global CCS Institute. The criteria, shown in Box 1, were used to measure progress against the goal of launching 20 large-scale projects by 2010. (Annex C contains the list of projects prepared by the Global CCS Institute.)

These projects are located primarily in developed countries with the majority in Europe and the United States, as well as in Australia, Canada and Korea. It is encouraging to note that seven of the projects are in developing countries – four in China, two in the Middle East and one (in operation) in Algeria. As the larger developing economies have turned to coal to fuel their growth, so CCS must be a key technology for these economies to embrace in the future. Of the four projects in China, three are in the power sector, where they plan to demonstrate CCS with integrated gasification combined cycle technology. Approximately two-thirds of the 80 projects identified are in the power generation sector. Industrial projects are well represented, though many of them are associated with separation of CO_2 from natural gas. There are projects related to the cement, aluminium and iron and steel industries, but more need to be developed. More than 40% of the projects plan to use the CO_2 for enhanced oil recovery (EOR).

Box 2. Commercial CCS projects in operation

Five fully-integrated, large scale CCS projects are in commercial operation today. Four projects – Sleipner, In Salah, Snøhvit and Rangely – inject CO_2 from a natural gas production facility where it is separated from the natural gas sent to market. In the first three cases, the CO_2 is injected into saline aquifers, while in the fourth it is used for EOR. A fifth project captures CO_2 at the Great Plains Synfuels Plant and transports it for EOR to the Weyburn-Midale project. All five are contributing to the knowledge base needed for widespread CCS use.

Sleipner. The Sleipner project began in 1996 when Norway's Statoil began injecting more than 1 million tonnes a year of CO_2 under the North Sea. This CO_2 was extracted with natural gas from the offshore Sleipner gas field. In order to avoid a government-imposed carbon tax equivalent to about USD 55/tonne, Statoil built a special offshore platform to separate CO_2 from other gases. The CO_2 is re-injected about 1 000 metres below the sea floor into the Utsira saline formation located near the natural gas field. The formation is estimated to have a capacity of about 600 billion tonnes of CO_2, and is expected to continue receiving CO_2 long after natural gas extraction at Sleipner has ended.

In Salah. In August 2004, Sonatrach, the Algerian national oil and gas company, with partners BP and Statoil, began injecting about 1 million tonnes per year of CO_2 into the Krechba geologic formation near their natural gas extraction site in the Sahara Desert. The Krechba formation lies 1 800 metres below ground and is expected to receive 17 million tonnes of CO_2 over the life of the project.

Snøhvit. Europe's first liquefied natural gas (LNG) plant also captures CO_2 for injection and storage. Statoil extracts natural gas and CO_2 from the offshore Snøhvit gas field in the Barents Sea. It pipes the mixture 160 kilometres to shore for processing at its LNG plant near Hammerfest, Europe's northernmost town. Separating the CO_2 is necessary to produce LNG and the Snøhvit project captures about 700 000 tonnes a year of CO_2. Starting in 2008, the captured CO_2 is piped back to the offshore platform and injected in the Tubåsen sandstone formation 2 600 metres under the seabed and below the geologic formation from which natural gas is produced.

Rangely.[5] The Rangely CO_2 Project has been using CO_2 for enhanced oil recovery since 1986. The Rangely Weber Sand Unit is the largest oilfield in the Rocky Mountain region and was discovered in 1933. Gas is separated and reinjected with CO_2 from the LaBarge field in Wyoming. Since 1986, approximately 23-25 million tonnes of CO_2 have been stored in the reservoir. Computer modeling suggests nearly all of it is dissolved in the formation water as aqueous CO_2 and bicarbonate.

Weyburn-Midale. About 2.8 million tonnes per year of CO_2 are captured at the Great Plains Synfuels Plant in the US State of North Dakota, a coal gasification plant that produces synthetic natural gas and various chemicals. The CO_2 is transported by pipeline 320 kilometres (200 miles) across the international border into Saskatchewan, Canada and injected into depleting oil fields where it is used for EOR. Although it is a commercial project, researchers from around the world have been monitoring the injected CO_2. The IEA Greenhouse Gas R&D Programme's Weyburn-Midale CO_2 Monitoring and Storage Project was the first project to scientifically study and monitor the underground behavior of CO_2. Canada's Petroleum Technologies Research Centre manages the monitoring effort. This effort is now in the second and final phase (2007-2011), of building the necessary framework to encourage global implementation of CO_2 geological storage. The project will produce a best-practices manual for carbon injection and storage.

Source: Adapted from Greenhouse Gas R&D Programme IA (2008b).

[5] Though Rangely uses CO_2 for EOR, it is considered a CCS project insofar as it follows an MMV plan that satisfactorily assesses the viability of the long-term storage of the CO_2.

Nine of the 80 large-scale integrated projects are in operation, while the rest are in various stages of development and planning. Five of the nine operational projects are considered integrated CCS projects, the other four being EOR projects that do not have complete monitoring systems to assess the viability of the long-term storage of the CO_2.

The five integrated CCS projects in operation (Box 2) were commissioned prior to the G8 Hokkaido Toyako Summit.

Review of government activity

Over the past two years, a number of governments (Australia, Canada, Japan, Norway, the Republic of Korea, the United Kingdom and the United States) as well as the European Commission have committed substantial funding to and are actively facilitating the deployment of large-scale CCS demonstration projects.

As of April 2010, public funding commitments were in the range of USD 26.6 billion to USD 36.1 billion. Moreover, governments have announced a commitment to launch 19 to 43 large-scale integrated projects before 2020. In many jurisdictions, a significant portion of economic stimulus spending has focused on developing, demonstrating and deploying clean energy technologies such as CCS. These commitments, however, are generally contingent on industry taking a full and active role.

Table 2. Funding and project announcements from governments and international organisations[6]

Country	**Funding committed to date (billion USD)**	**Number of projects committed by 2020**
Australia	2 to 6	3 to 5
Canada	3.5	up to 6
European Commission[a]	4 to 6	6 to 12
Japan	0.1	1 to 2
Norway	1	1 to 2
Korea, Republic of	1	1 to 2
United Kingdom[b]	11 to 14.5	4[c]
United States	4	5 to 10
TOTAL	**26.6 to 36.1**	**19 to 43**

Notes: a This includes the 300 million permits that are set aside under the EU-ETS for demonstration of CCS and of innovative renewable energy, and EUR 1 billion from the EC energy recovery package.

b UK funding includes operational support for 10 to 15 years of CCS operations. Note that UK funds may be used in conjunction with EC funds.

c Within the "TOTAL" range, the lower number considers 2 of these 4 projects as counted within the EC figure; in the larger number, they are all considered additional to EC projects.

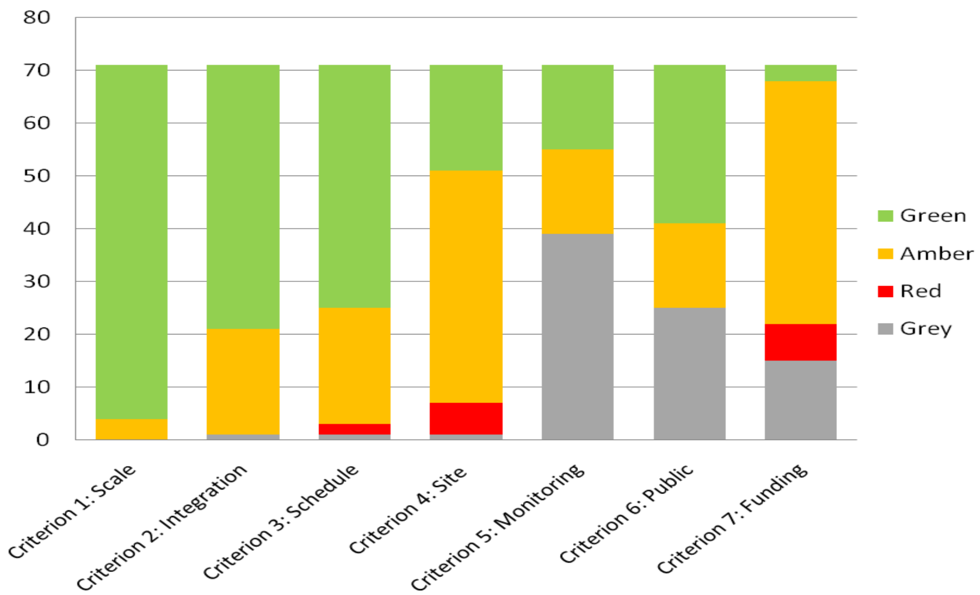
[6] Based on information available in the public domain as of 28 April 2010.

The G8 goals

After reviewing industry and government developments, one of the 80 projects, the Australian Gorgon project, was found to be launched and proceeding to construction. Closer examination reveals that while this one project meets all 7 criteria, 7 projects meet 6 or more, 19 meet 5 or more, and a total of 36 meet 4 or more of the criteria. This represents significant progress and suggests that many more projects could advance rapidly to the construction and operational stages. However, it does not necessarily imply that a project meeting more criteria will proceed to construction and operation faster than a project meeting less.

Figure 1 shows the performance against each criterion of the 71 projects not yet operational. For many of the projects, it is clear that funding remains a challenge. Impending closure on funding is a key stage in the life of a project. It increases the prospect of other criteria being met. The development of an MMV plan is often made a precondition of public funding. The development schedule is likely to be firmer. Site location and access is likely to be expedited prior to funding closure. Public engagement would also become more important.

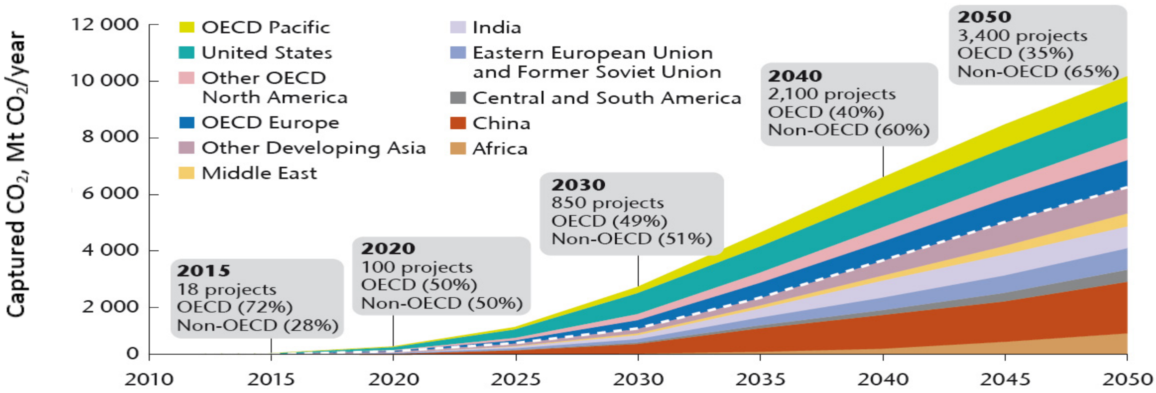
Figure 1. Analysis of projects not yet in operation



Note: Green shows that a criterion has been met
Amber shows that some progress has been made
Red shows that very little or no progress has been made
Grey shows the information was either insufficient or not specified.

Looking into the near future, the G8 commitment to "beginning broad deployment of CCS by 2020" is achievable but it will be challenging. Increased urgency from all stakeholders is essential to realise the first critical steps that these projects represent. According to the *IEA CCS Technology Roadmap*, about 100 projects will be required by 2020, 850 by 2030 and 3 400 by 2050. And, while CCS development will begin in the industrialised countries, it is expected to rapidly shift to developing countries after 2020. The dashed white line in Figure 2 indicates separation of OECD and non-OECD regions. The amount of CO_2 captured in non-OECD countries accounts for 50% in 2020, rising to 65% by 2050.

Figure 2. Global deployment of CCS 2010-2050 by region



Next steps

- **Greater effort is required to meet the G8 goal of broader CCS deployment by 2020.**
- **Stakeholders must work together to demonstrate and deploy CCS in the power sector and gas separation, and in CO_2-intensive industries such as cement, chemicals, and iron and steel.**
- **Progress on the development and deployment of large-scale CCS projects needs to be continuously monitored and reported on a regular basis.**
- **Increased efforts needed to support the development of CCS demonstration projects in developing countries.**

Taking concerted international action

Recommendation to G8 in 2008: G8 governments, international financial institutions and the private sector should foster international action to partner, financially support, build capacity and share information on large-scale CCS demonstration projects and near-term opportunities to accelerate wider deployment of CCS in developed and developing countries. An early priority should be to include CCS in the Clean Development Mechanism (CDM).

Progress to date

- **Much progress has been made in terms of international collaboration. These efforts gained increased momentum with the establishment of the Global CCS Institute in 2009.**

Capacity building

The CSLF published its Capacity Building Program in October 2009. The purpose of this programme is to assist all CSLF members to develop the information, tools, skills, expertise and institutions to implement CCS demonstration projects and move rapidly into commercial operation. Programme initiatives include disseminating practical information; building capacity in emerging economies; assisting government and regulatory agencies; and building academic and research institutions for CCS. CSLF members and the Global CCS Institute have provided both funding and in-kind resources to carry out these activities. In addition, the CSLF commissioned the Asian Development Bank to prepare a financial roadmap for developing countries. The CSLF also had engagement from developing countries at its 3rd Ministerial Meeting (London, October 2009), including attendance by ministers from China and South Africa.

In 2009, the IEA hosted a series of CCS Roundtables in Brazil, China, Poland, South Africa and Indonesia to expand its co-operation with emerging and developing economies on this topic. The goal of the Roundtables was to collect detailed information about the technology, legal, financial, public awareness and international collaboration issues associated with CCS in regions that are important to its development. The Roundtables included a group of key CCS stakeholders from government, industry, non-governmental organisations and academia to discuss the current status and future development of CCS in these regions.

The Global CCS Institute has partnered with and is contributing to a number of organisations and initiatives in CCS capacity building. To date, these organisations include the Asian Development Bank, the World Bank and the CSLF Capacity Building Program.

Knowledge sharing

Knowledge sharing has been identified as central to a CCS demonstration programme for accelerating technology development and driving down costs. The know-how and learning from this first wave of demonstration projects should be disseminated in order to reduce challenges for the next generation of CCS projects.

The European Commission has developed a Project Network for sharing knowledge arising from European CCS demonstration projects. Canada is developing a knowledge-sharing framework and is collaborating with the United States under the Clean Energy Dialogue. The Asia-Pacific Partnership on Clean Development and Climate has also established two knowledge-sharing networks. The Global CCS Institute is commissioning a knowledge-sharing programme to communicate lessons learned from demonstration projects. In co-operation with the IEA and the CSLF, this programme will develop knowledge-sharing principles and protocols. (See Annex D for principles that can be applied to knowledge sharing.) To accelerate global deployment of CCS, the programme will also link the emerging national and regional networks in the European Union, the United States, Australia and Canada.

CCS in international climate change arrangements

Discussions are underway on the inclusion of CCS in the Clean Development Mechanism (CDM) or any post-2012 climate change arrangements. Without such a framework (which includes financial mechanisms), it is unlikely that the deployment of CCS will expand at the pace required in developing countries.

Formation of the Global CCS Institute

In September 2008, as a direct result of the G8 declaration to launch 20 demonstration projects by 2010, the Australian government announced the formation of the Global Carbon Capture and Storage Institute (Global CCS Institute) and committed USD 90 million in annual funding for four years of operation. The central objective of the Institute is to accelerate the commercial deployment of CCS projects. (See Annex B for more information on the Global CCS Institute.)

Next steps

- **Governments and industry must forge partnerships to promote best practice and knowledge sharing from publicly funded CCS demonstration projects.**
- **Stakeholders must continue to co-operate and to co-ordinate their international CCS activities in the areas of capacity building and knowledge sharing. This is important for the effective use of resources, particularly in developing countries.**
- **Governments must maintain their efforts to ensure that CCS is recognised by the UNFCCC in the incentive mechanisms under the post-Kyoto arrangements. Inclusion in the Kyoto Protocol's Clean Development Mechanisms (CDM) would represent an important first step.**
- **Closer co-operation is needed with developing countries to achieve the indicative target of 100 demonstration projects by 2020.**

Bridging the financial gap for demonstration

Recommendation to G8 in 2008: Together with the private sector, governments should address the financial gap and risks facing early CCS projects, recognising that market mechanisms alone will not be sufficient for early deployment of CCS.

Progress to date

- **The financial gap for CCS has not been narrowed over the past two years, largely due to continued uncertainty on future international climate change architecture and insufficient carbon price signals. Despite this, efforts by governments to bridge the gap have increased.**
- **The high capital cost escalation of the past few years, which has proven a major barrier to the development of CCS projects, has reduced.**

A financial gap exists as a result of the additional costs for CCS, above a conventional plant, being higher than the revenue from the relevant market plus the additional benefit from CO_2 reduction. This gap will decline as experience with the technology increases resulting in cost reduction, and as the revenue from the relevant markets and the benefit for CO_2 reduction increases. Recently, the price level in CO_2 markets was in the range of USD 15 to USD 35 per tonne of CO_2, which is insufficient to make CCS competitive employing today's technology. As with any new technology, early CCS projects face an array of technical and commercial risks that require the sharing of costs and risks between public and private sectors. The investment disincentives and risks associated with "first-of-their-kind" projects, coupled with an uncertain regulatory landscape, will require that governments take an active role to facilitate most early projects.

In September 2009, the IEA, via its Working Party on Fossil Fuels, the CSLF and the Global CCS Institute, convened a meeting of experts that provided seven priorities for government action:

1. Develop project implementation partnerships with industry.
2. Encourage first-movers by moderating investment risks.
3. Provide adequate public funding.
4. Accelerate storage exploration and pipeline infrastructure development.
5. Conduct community outreach.
6. Work with industry to promote best practices, knowledge sharing and regulatory framework development.
7. Support demonstration projects in developing countries.

The CSLF Task Force on Financing CCS Projects held two meetings in January and April 2010 in conjunction with the Global CCS Institute. At the meetings, the Task Force determined that public-private partnerships involving appropriate sharing of costs and risks will be required for early projects. As the technology matures, this type of financing should be replaced with mechanisms that create value for the CO_2 emission reductions achieved by CCS.

Next steps

- **As long as the financial gap remains, governments will need to develop mechanisms to move from demonstration to commercialisation.**
- **According the *IEA CCS Technology Roadmap*, an estimated USD 5 billion to USD 6.5 billion per year is required to address the additional investment needs of CCS over the next ten years.**
- **The rate of private and public financial commitments needs to increase, particularly for projects in developing countries.**
- **Multilateral mechanisms need to be put in place, particularly for developing countries.**

Creating value for CO_2 for commercialisation of CCS

Recommendation to G8 in 2008: Governments should provide long-term policy certainty. This could be achieved through such measures as the introduction of appropriate regional national instruments to create a value for CO_2 through emissions trading, tax treatment or other mechanisms by 2010, along with incentives for research, development and demonstration.

Progress to date

- **The current value of CO_2 emissions alone is insufficient to drive large-scale development and deployment of CCS to meet the required levels of CO_2 mitigation. Beneficial uses for CO_2 (*e.g.* enhanced oil recovery) have been shown to financially offset CCS implementation costs in some cases, but will not be universally applicable.**

In 2008, the EU Emissions Trading System (EU ETS) began its second phase. Prices have been volatile with a range of USD 15 to USD 35 per tonne of CO_2. This price alone is not sufficient to make CCS projects commercially viable. In addition, other trading systems have been slow to emerge.

Norway introduced a carbon tax (approximately USD 55 per tonne) in 1991. This tax provided a major incentive for the construction of both the Sleipner and Snøhvit CCS facilities.

The CSLF has developed a comprehensive catalogue of incentives *(CSLF Incentives Registry)* such as carbon taxes, tax credits and government funding for both research and development and for large-scale projects.

EOR provides an important source of revenue for CCS projects; when the source of CO_2 is from natural gas processing (where capture costs tend to be low), it can make these projects commercially viable. Other applications in which CO_2 may provide a revenue stream include fertilizer production and food processing. While CO_2 re-use or conversion is not expected to make a significant impact on total CO_2 emissions, it may provide a transitional or localised opportunity to respond to the costs of capturing CO_2.

Next steps

- **Governments must co-operate to establish a mechanism that assigns a price for each tonne of CO_2 emitted, which must be high enough to drive deployment of low-carbon technologies, including CCS, and be applicable to both developed and developing countries.**
- **In the power sector, mechanisms may be introduced that value the generation of carbon-free electricity.**

Establishing legal and regulatory frameworks

<u>Recommendation to G8 in 2008</u>: By 2010, it is essential that governments in countries with major CCS potential, working with relevant international bodies, have established the appropriate legal and regulatory frameworks needed for safe large-scale geological storage of CO_2. For early projects, solutions for storing CO_2 should be developed drawing on the various experiences where CO_2 was used for enhanced oil recovery or experiences from scientific programmes.

Progress to date

- **Significant progress has been made on the development of legal and regulatory frameworks, most notably in Australia, the European Union and the United States.**

In the European Union, the Directive on the Geological Storage of CO_2 and the EU Emissions Trading Scheme Directive provide a framework for legislation and regulation of CCS within the region, which must be transposed into individual member state law by 2011. In Australia, comprehensive CCS legislation has been put in place at the federal level to cover CCS offshore and, in a number of states, to cover CCS onshore. In the United States, a number of states have implemented CCS legislation in parallel with the ongoing work at the federal level by the Environmental Protection Agency. In addition to these early movers, a number of other countries have begun the process of reviewing and amending legislation including Canada, Japan and Norway (implementing the EU legal guidelines).

To support this process, both the IEA and the Global CCS Institute have continuing work programmes focused on CCS legislation and regulation. The IEA International Regulators' Network, which provides a forum for CCS regulators, policy makers and other stakeholders to share updates and views, is central to this activity. As part of the Network, the IEA will be producing a bi-annual Review of CCS Legal and Regulatory Development and is developing a Model CCS Legal and Regulatory Framework as a tool for countries drafting their own CCS legislation. The Model Framework is expected to be published in July 2010.

In 2009, the Global CCS Institute completed a comprehensive analysis of regulatory regimes supporting CCS to identify gaps in regulatory frameworks that need to be overcome for project deployment. *Policies and Legislation Framing Carbon Capture and Storage Globally* (Global CCS Institute, 2009) resulted in a number of key recommendations to facilitate the development of comprehensive and effective CCS regulatory frameworks.

Next steps

- **Governments must continue to develop, refine and finalise legal and regulatory frameworks in jurisdictions in which CCS will be deployed.**

- **For jurisdictions that have started to develop their legal and regulatory frameworks, efforts to resolve outstanding issues must be a priority if near-term targets for demonstration are to be met.**
- **Particular efforts should be made to ensure that licensing and foreseen procedures do not unduly hinder the development of CCS demonstration and, later, the commercial plant.**

Communicating with the public

Recommendation to G8 in 2008: Public outreach is critical to CCS deployment. Thus, communication and understanding should be fostered. Stakeholders, including governments, must dedicate resources to disseminate information.

Progress to date

- **Experience from a number of regions has indicated that public perception is a major factor in the success of a project.**
- **Several organisations have developed public outreach activities in support of CCS.**

The Global CCS Institute has developed a comprehensive approach to advancing both project and regional public-engagement strategies. The Institute's approach is based on advancing social research, practical project support and improving regional communications.

The CSLF has developed a communications plan that will focus its outreach efforts on the global aspects of CCS as an important CO_2 mitigation technology. The purpose of this programme is to build public confidence in the viability of using fossil fuel resources to meet increasing future energy needs while reducing CO_2 emissions through CCS.

The IEA has taken steps to increase understanding of the role of CCS by publishing the *IEA CCS Technology Roadmap* (IEA 2009b), which outlines milestones for research, development, demonstration and deployment. The IEA Greenhouse Gas R&D Programme (IEA GHG) operates a communications research network.

The IEA GHG Weyburn-Midale CO_2 Monitoring and Storage Project has developed, in partnership with the Canadian CCS Network and Natural Resources Canada, a comprehensive national website[7] as a tool for communication with and outreach to the public on CCS.

In January 2010, the National Energy Technology Laboratories (US Department of Energy) issued its *Best Practices for: Public Outreach and Education for Carbon Storage Projects*.[8] These guidelines were developed from the experiences of the seven US Carbon Regional Sequestration Partnerships.

[7] www.CCS101.ca
[8] Available at: www.bigskyco2.org/files/pdfs/BPM_PublicOutreach.pdf.

Next steps

- **Leadership from governments and collective action from stakeholders are required to inform and educate the public about CCS and to build confidence in its role in the low-carbon energy technology portfolio.**

Infrastructure

Recommendation to G8 in 2008: Perspectives for the availability of a CO_2 transportation infrastructure are key to developing markets for CCS in power production and industrial applications. Plans need to be in place before pilot plants with CCS become operational. Trans-boundary effects need to be taken into account.

Progress to date

- **Work on mapping suitable storage sites is proceeding in developed countries, but progress in developing regions is limited.**
- **Developing common transport infrastructure will be critical to ensuring that CCS can be delivered cost effectively. There has been limited progress in this area to date.**

Storage capacity

The status of data availability and evaluation of CO_2 storage potential varies significantly around the world and is potentially a major constraint on rapid widespread CCS deployment. A concerted effort will be required to identify source and potential storage regions before pipeline networks can be identified. This work should have a long-term perspective that takes into account expansion from demonstration to commercialisation.

Several countries (Australia, Canada, Japan, Mexico and the United States, as well as the European Union) have started to map storage potential and create storage capacity databases in order to align CO_2 sources and storage sites. Through the North Sea Basin Task Force, Germany, the Netherlands, Norway and the United Kingdom are working together to evaluate their sub-seabed storage potential and undertake source-sink analysis.

Canada, Mexico and the United States are collaborating to produce a North American Carbon Storage Atlas of major CO_2 sources, potential storage reservoirs and storage estimates in all three countries, based on compatible mapping and data-sharing methodologies. The Atlas will be used to develop a comprehensive understanding of the potential for carbon capture and safe storage in North America.

The Global CCS Institute is collaborating with the IEA Greenhouse Gas R&D Programme (IEA GHG) to develop a global storage resource gap analysis. This analysis will alert policy makers to the scale, cost and timing of storage resource assessment tasks.

CO_2 transportation

There are approximately 3 400 miles of existing CO_2 pipeline in the United States, which have been operating for over four decades. The Government of Canada and the Province of Alberta announced that they would provide approximately USD 500 million for the first phase of a pipeline project (the Enhance project noted in Annex C) to link oil sands and petro-chemical operations with EOR opportunities in Alberta. In the United Kingdom, Yorkshire Forward is co-ordinating the development of plans for a CO_2 pipeline hub system in the northeast of England.[9] Other pipeline networks are under development in the European Union, such as the Rotterdam Harbour system. However, to enable large-scale deployment of CCS, more joint planning of CO_2 transportation infrastructure is required globally.

Next steps

- **Governments and the private sector must significantly step up efforts to identify and characterise suitable geology for the secure and environmentally safe storage of CO_2, which is potentially a major constraint on rapid and widespread CCS deployment.**
- **Harmonised methodologies must be developed for the characterisation and measurement of CO_2 storage capacity.**
- **Further joint planning of CO_2 transportation infrastructure is needed across all continents.**

Retrofit with CO_2 capture

<u>Recommendation to G8 in 2008</u>: The IEA believes that any developer of a new fossil fuel power station should have regard to what might be required for retrofit with CCS and should avoid steps that might make this unnecessarily difficult. Some developers already have such a product policy. The IEA Greenhouse R&D Programme (IEA GHG) has provided a technical study on capture and storage readiness.

Progress to date

- **As a result of broad stakeholder engagement, the CSLF, the IEA and the Global CCS Institute have developed a CCS-Ready guide for governments to consider when formulating a nationally or regionally appropriate policy.**

[9] www.co2sense.org.uk

Much progress has been made on this issue since a key workshop was held on the subject in Calgary in 2007.[10] The engagement of a wide range of stakeholders has enabled the CSLF, IEA and Global CCS Institute to provide a guide for CCS ready that can be adapted to meet the needs of particular regional or national circumstances (see Annex E). This guide includes a CCS-Ready definition that builds on work previously done by the IEA GHG. Follow-up is now required to apply this definition at a national or regional level taking account of local circumstances.

The concept of capture-ready has also been incorporated in new legislation, notably in the 2009 EU Directive on CO_2 Storage, and in the United Kingdom and South Africa.

Next steps

- **Governments should consider tailoring the CCS-Ready guide to their local policy and regulatory circumstances to avoid the long-term lock-in of CO_2 emissions.**

[10] IEA/CSLF 3rd Workshop on Near-term Opportunities for CCS, November 2007.

Annex A: G8 commitments on CCS

In 2005, G8 leaders issued the *Gleneagles Plan of Action on Climate Change, Clean Energy and Sustainable Development*. It included the following statement on carbon capture and storage:

> *We will work to accelerate the deployment and commercialisation of Carbon Capture and Storage technology by:*
>
> *... inviting the International Energy Agency to work with the Carbon Sequestration Leadership Forum to hold a workshop on short term opportunities for carbon capture and storage, including from Enhanced Oil Recovery and removal of CO_2 from natural gas production.*

In response, the IEA and the CSLF assembled a group of experts from around the world. They agreed on eight high-level recommendations, foremost among them the launch of 20 large-scale CCS demonstration projects by 2010.

In 2008, at the Hokkaido Toyako Summit, G8 leaders affirmed:

> *We strongly support the launching of 20 large-scale CCS demonstration projects globally by 2010, taking into account various national circumstances, with a view to beginning broad deployment of CCS by 2020.*

In 2009, at the L'Aquila Summit, G8 leaders reaffirmed:

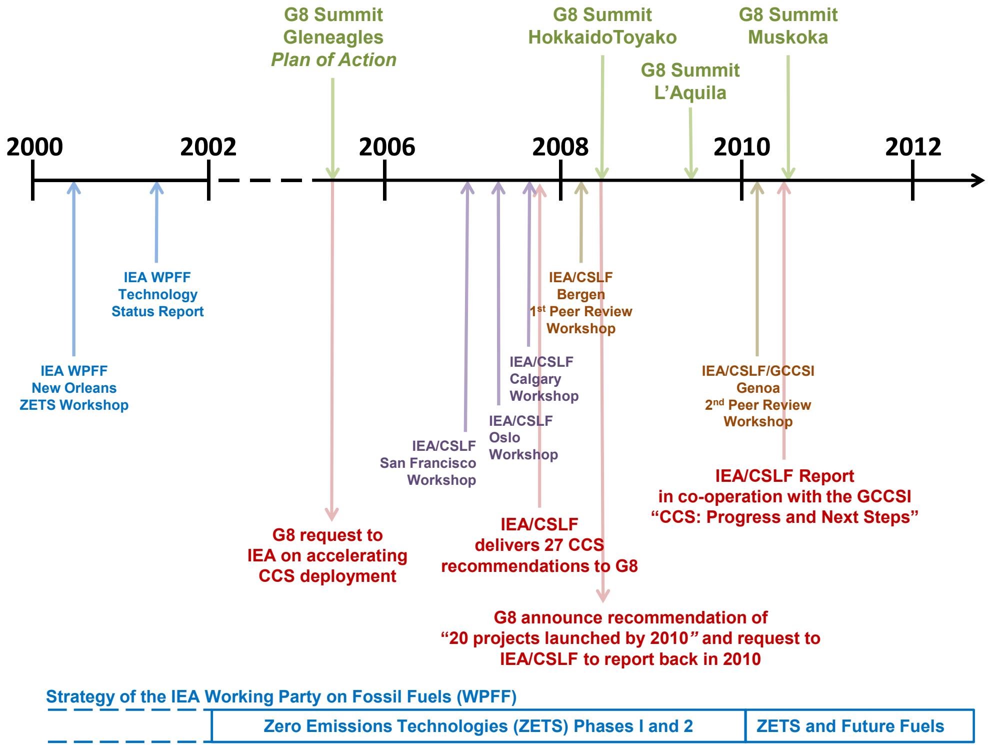
> *…the commitment made in Toyako for the launch of 20 large-scale Carbon Capture and Storage demonstration projects globally by 2010.*

And specifically, they recommended action be taken to:

- *accelerate the design of policies, regulatory frameworks and incentive schemes*
- *encourage greater involvement of developing countries*
- *work to identify sources of financing for CCS demonstration projects*
- *welcome the work on criteria by the IEA to facilitate tracking of progress on these projects*
- *invite the Global Carbon Capture and Storage Institute to actively co-operate with the ongoing activities of the IEA and the CSLF.*

The IEA and the CSLF have been working with the G8 on this issue since 2005. The Global CCS Institute has been involved since 2008.

Timeline of CCS activities of the IEA and the G8



Annex B: Information on the IEA, CSLF and Global CCS Institute

International Energy Agency

The International Energy Agency (IEA) is an autonomous body established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. It carries out a comprehensive programme of energy co-operation among 28 of the 31 OECD member countries. The basic aims of the IEA are to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations, and to assist in the integration of environmental and energy policies. The Agency maintains and improves systems for coping with oil supply disruptions, and operates a permanent information system on the international oil market. It also aims at improving the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use, and promotes international collaboration on energy technologies.

More information: www.iea.org

Carbon Sequestration Leadership Forum

The Carbon Sequestration Leadership Forum (CSLF) is a Ministerial-level international climate change initiative focused on the development of improved cost-effective technologies for the separation and capture of carbon dioxide (CO_2) for transport and long-term safe storage. The mission of the CSLF is to facilitate the development and deployment of such technologies via collaborative efforts that address key technical, economic and environmental obstacles. The CSLF will also promote awareness and champion legal, regulatory, financial and institutional environments conducive to such technologies. The CSLF is currently comprised of 24 members, including 23 countries and the European Commission.

More information: www.cslforum.org

Global Carbon Capture and Storage Institute

The Global Carbon Capture and Storage Institute (Global CCS Institute) is a bold new initiative aimed at accelerating the worldwide commercial deployment of at-scale CCS. Announced by the Australian government in September 2008, the Global CCS Institute was formally launched in April 2009. Recognising the important contribution CCS can make in ameliorating climate change, the Australian government has committed AUD 100 million annual funding for the Global CCS Institute. The Institute will play a pivotal role in facilitating the development and deployment of safe, economic and environmentally sustainable commercial-scale CCS projects. The Institute currently has 226 members. The cross-cutting membership comprises national governments, industries, research organisations and other interested stakeholders.

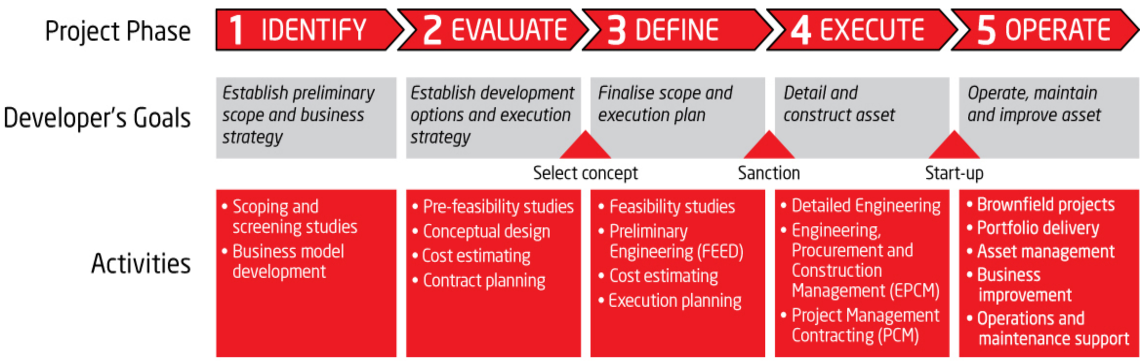
More information: www.globalccsinstitute.com

Annex C: Application of G8 criteria to large-scale integrated CCS projects

This appendix compares the current status of large scale, fully integrated CCS projects against the seven criteria developed by the International Energy Agency (IEA), the Carbon Sequestration Leadership Forum (CSLF) and the Global CCS Institute, as endorsed by the G8.

Projects are categorised into the major phases of development that a CCS project will undergo. The phases and their attributes are defined below.

Figure 3. Asset Lifecycle Model



Source: WorleyParsons, 2009

In addition to the Asset Lifecycle Model, a traffic-light system was used to assess each large scale integrated project against the G8 criteria. The traffic-light system simply allocates a green, amber or red designation to show a project's level of progress by criteria. In general, green shows that the criteria has been achieved, amber shows that some progress has been made but is not yet complete, and red shows that little or no progress has been made to date. The colour grey was used to highlight that the information was either not specified by project proponents or not enough information was provided.

Together, the Asset Lifecycle Model and the traffic-light system were applied to each large-scale integrated CCS project to provide a basis for assessing their progress towards being launched by the end of 2010.

Best endeavours were used to secure, verify and organise the data collected in the global survey of CCS projects. Numerous primary and secondary data sources have been used to collect and validate the data. It should also be noted that this assessment represents the status of projects as of April 2010.

	Project name	Country	Phase	1. Large scale	2. Full integration	3. Projects operation schedule	4. Storage site and transport definition	5.Monitoring, measurement and verification	6. Public engagement	7. Established public/private sector support
1	Coolimba Power Project	Australia	Identify	2 Mtpa power	Integated	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	No
2	Jänschwalde	Germany	Identify	2.7 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Intended	Yes
3	Immingham CCS Project	England, UK	Identify	4-7 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Insufficient information provided
4	NW Bohemia Clean Coal Project	Czech Republic	Identify	1.6 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Insufficient information provided
5	Barendrecht Shell	Netherlands	Identify	0.4 Mtpa industrial	Integrated	2012	Yes	Yes	Yes	Yes
6	Eemshaven RWE	Netherlands	Identify	0.2/0.3-1.2 Mtpa power	Integrated, with agreements still being pursued	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	No
7	Rotterdam CGEN	Netherlands	Identify	2.5 Mtpa industrial	Integrated, with agreements still being pursued	2014	Very little definition around site or transport routes	Insufficient information provided	Intended	Insufficient information provided
8	Belchatow CCS project	Poland	Identify	1.8 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Intended	Yes	Yes
9	Chemical Plant, Yulin	China	Identify	5-10 Mtpa industrial	Integrated	2015	Very little definition around site or transport routes	Intended	Yes	Insufficient information provided
10	Wandoan Power IGCC CCS Project	Australia	Identify	2.5 Mtpa power	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Yes	Yes	Yes
11	Dongguan Taiyangzhou IGCC with CO_2 capture project	China	Identify	0.1-1 Mtpa power	Integrated	2015	Very little definition around site or transport routes	Insufficient information provided	Yes	Insufficient information provided
12	Lianyungang IGCC with CO_2 capture project	China	Identify	0.1-1 Mtpa power	Integrated, with agreements still being finalised	2016	Limited definition of storage and/or transport	Yes	Yes	Insufficient information provided
13	Lake Charles Gasification	US	Identify	4 Mtpa industrial	Integrated, with uncertainty over agreements	No date established	Yes	Intended	Insufficient information provided	Yes
14	Air Products Project	US	Identify	1 Mtpa industrial	Integrated, with uncertainty over agreements	2015	Limited definition of storage and/or transport	Intended	Intended	Yes
15	CEMEX CO_2 Plant	US	Identify	1 Mtpa industrial	Integrated	2015	Very little definition around site or transport routes	Insufficient information provided	Intended	Yes

16	The Northern California CO_2 Reduction Project	US	Identify	1 Mtpa Industrial	Integrated, with uncertainty over agreements	2015	Limited definition of storage and/or transport	Insufficient information provided	Intended	Yes
17	Mississippi Gasification SNG	US	Identify	4 Mtpa industrial	Integrated, with uncertainty over agreements	2015	Yes	Intended	Yes	Yes
18	Battelle Memorial Institute	US	Identify	0.7 Mtpa industrial	Integrated	2015	Very little definition around site or transport routes	Intended	Intended	Yes
19	University of Utah	US	Identify	1 Mtpa industrial	Integrated, with uncertainty over agreements	2015	Yes	Insufficient information provided	Intended	Yes
20	Victorian CarbonNet CCS Project	Australia	Identify	4-10 Mtpa power and industrial	Integrated with dependency on partners	Planned for between 2015-2019	Yes	Intended	Yes	Yes
21	The Collie South West Hub Project	Australia	Identify	2.5-7.5 Mtpa power and industrial	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Intended	Yes	Yes
22	Integrated Project Carbon Mine Sulcis	Italy	Identify	2 Mtpa power	Integrated	2015	Yes	Insufficient information provided	Insufficient information provided	Insufficient information provided
23	Rotterdam CCS Network – Independent Storage Assessment	Netherlands	Identify	5 Mtpa power and industrial	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
24	Korea-CCS2	Republic of Korea	Identify	1.5 Mtpa-2.5 Mtpa power	Integrated, with uncertainty over agreements	2019	Limited definition of storage and/or transport	Intended	Yes	Yes
25	Spectra Fort Nelson CCS Project	Canada	Evaluate	1.2 Mtpa industrial (demo 2010-2017) 2.2 Mtpa industrial	Integrated	2010	Yes	Developed	Insufficient information provided	Yes
26	Tenaska Trailblazer Energy Center	US	Evaluate	5.75 Mtpa power	Integrated, with agreements still being pursued	2016	Limited definition of storage and/or transport	Insufficient information provided	Yes	Insufficient information provided
27	Antelope Valley Station	US	Evaluate	1 Mtpa power	Integrated, with agreements still being pursued	2012	Limited definition of storage and/or transport	Intended	Yes	Yes
28	FutureGen Clean Coal Project	US	Evaluate	1 Mtpa power	Integrated	2018	Limited definition of storage and/or transport	Intended	Intended	Yes
29	AEP Mountaineer	US	Evaluate	1.5 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Intended	Yes
30	Mongstad	Norway	Evaluate	1 Mtpa power	Integrated	2018	Limited definition of storage and/or transport	Intended	Intended	Yes

31	Bow City Power Plant CO_2 Capture	Canada	Evaluate	1 Mtpa power	Integrated	2014	Limited definition of storage and/or transport	Intended	Yes	No
32	RWE Goldenbergwerk (Huerth)	Germany	Evaluate	2.6 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	Insufficient information provided
33	Faustina Hydrogen	US	Evaluate	1.5 Mtpa industrial	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Yes
34	Indiana Gasification	US	Evaluate	1 Mtpa industrial	Integrated, with agreements still being finalised	2015	Yes	Insufficient information provided	Intended	No
35	Lockwood Gasification Plant	US	Evaluate	2 Mtpa industrial	Integrated, with agreements still being pursued	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	No
36	Pioneer Project	Canada	Evaluate	1 Mtpa power	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Yes
37	GreenGen IGCC Project	China	Evaluate	2 Mtpa power	Integrated, with agreements still being pursued	2013	Very little definition around site or transport routes	Insufficient information provided	Yes	Insufficient information provided
38	ZeroGen Commercial Scale Project	Australia	Evaluate	2 Mtpa power	Integrated	2015	Yes	Developed and approved	Yes	Yes
39	Southern California Edison IGCC Project	US	Evaluate	2.5 Mtpa power	Integrated	2017	Limited definition of storage and/or transport	Insufficient information provided	Intended	Yes
40	Karsto Full Scale	Norway	Evaluate	1 Mtpa power	Integrated with dependency on partners	By 2020	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
41	Kedzierzyn	Poland	Evaluate	2.4 Mtpa power	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Developed	Intended	Yes
42	Swan Hills	Canada	Evaluate	1.46 Mtpa industrial	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
43	Summit Texas Clean Energy CCS Project	US	Evaluate	2.7 Mtpa power	Integrated with dependency on partners	2012	Yes	Developed	Yes	Yes
44	Shell Mississippi CO_2 Project	US	Evaluate	1 Mtpa industrial	Integrated, with agreements still being pursued	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	No
45	Sweeny Gasification	US	Evaluate	3 Mtpa power	Integrated, with agreements still being pursued	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Yes
46	Praxair CO_2 Project	US	Evaluate	1 Mtpa industrial	Integrated, with agreements still being pursued	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Yes
47	Project Viking	US	Evaluate	1.2 Mtpa power	Integrated with dependency on partners	2013	Yes	Developed and approved	Yes	No

48	Cash Creek	US	Evaluate	2 Mtpa power	Integrated with dependency on partners	2015	Insufficient information provided	Insufficient information provided	Insufficient information provided	Insufficient information provided
49	Masdar CCS Project	UAE	Define	4.3 Mtpa industrial	Integrated with dependency on partners	2013	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
50	Compostilla Project	Spain	Define	1.1 Mtpa power	Integrated	2015	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Yes
51	SaskPower Boundary Dam	Canada	Define	1 Mtpa power	Integrated	2013	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
52	North East CCS Cluster (Teesside)	England, UK	Define	7.5 Mtpa power	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Developed	Intended	Yes
53	Hydrogen Energy California Project (HECA) IGCC	US	Define	1.8 Mtpa power	Integrated with dependency on partners	2015	Yes	Developed	Yes	Yes
54	FINNCAP - Meri Pori CCS Project	Finland	Define	1.25 Mtpa power	Integrated with dependent partners	2015	Yes	Developed and approved	Yes	Yes
55	Hydrogen Power Abu Dhabi (HPAD)	UAE	Define	1.7 Mtpa power	Integrated with dependent partners	2014	Limited definition of storage and/or transport	Insufficient information provided	Yes	Insufficient information provided
56	Kingsnorth Demo Plant	England, UK	Define	2 Mtpa power	Integrated	2016	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
57	ULCOS Florange	France	Define	1 Mtpa industrial	Integrated	2015	Limited definition of storage and/or transport	Developed	Yes	Yes
58	Rotterdam Afvang en Opslag Demo	Netherlands	Define	1 Mtpa power	Integrated with dependency on partners	2015	Yes	Developed	Yes	Yes
59	Hatfield Power Park	England, UK	Define	4.75 Mtpa power	Integrated with dependency on partners	2014	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes
60	Porto Tolle	Italy	Define	1 Mtpa power	Integrated	2015	Yes	Insufficient information provided	Intended	Yes
61	Eemshaven NUON (Nuon Magnum)	Netherlands	Define	1.3 Mtpa power	Integrated, with uncertainty over agreements	2015	Limited definition of storage and/or transport	Insufficient information provided	Yes	Insufficient information provided
62	Browse LNG Development	Australia	Define	3 Mtpa industrial	Integrated	2017	Limited definition of storage and/or transport	Insufficient information provided	Insufficient information provided	Insufficient information provided
63	Quest CO_2 Capture and Storage Project	Canada	Define	1.2 Mtpa industrial	Integrated, with uncertainties over agreements	2015	Yes	Developed and approved	Yes	Yes

64	Southern Company IGCC Project	US	Define	2.5 Mtpa power	Insufficient information provided	2014	Limited definition of storage and/or transport	Insufficient information provided	Yes	Yes but postponed
65	Longannet Clean Coal Power Station	Scotland, UK	Define	2 Mtpa power	Integrated, with uncertainties over agreements	2014	Yes	Insufficient information provided	Intended	Yes
66	Taylorville Energy Center (IGCC)	US	Define	1.9 Mtpa power	Integrated with dependency on partners	2014	Limited definition of storage and/or transport	Intended	Yes	Yes
67	Enhance Energy EOR Project	Canada	Define	1.8 Mtpa industrial	Integrated with dependency on partners.	2012	Yes	Intended	Yes	Yes
68	Lost Cabin Gas Plant Capture Project	US	Define	1 Mtpa industrial	Integrated with dependency on partners	2015	Limited definition of storage and/or transport	Developed	Insufficient information provided	Insufficient information provided
69	Korea-CCS1	Republic of Korea	Define	1.5 Mtpa power	Integrated	2017	Limited definition of storage and/or transport	Intended	Yes	Yes
70	Gorgon Carbon Dioxide Injection Project	Australia	Execute	3.4 Mtpa industrial	Integrated	2014	Yes	Developed and approved	Yes	Yes
71*	Occidental Gas Processing Plant	US	Execute	8.5 Mtpa industrial	Integrated with dependency on partners	2010	Yes	Insufficient information provided	Insufficient information provided	Yes
72	In Salah CO_2 Injection	Algeria	Operational	1.2 Mtpa industrial	Integrated	2007	Yes	Developed, approved and implemented	Not specified	Yes
73	Sleipner CO_2 Injection	Norway	Operational	1 Mtpa industrial	Integrated	1996	Yes	Developed, approved and implemented	Not specified	Yes
74	Snøhvit CO_2 Injection	Norway	Operational	0.7 Mtpa industrial	Integrated	2007	Yes	Developed, approved and implemented	Not specified	Yes
75	Weyburn Operations	Canada	Operational	3 Mtpa industrial	Integrated with dependency on partners	2000	Yes	Developed, approved and implemented	Not specified	Yes
76*	Salt Creek Enhanced Oil Recovery	US	Operational	2.4 Mtpa industrial	Integrated with dependency on partners	2004	Yes	MMV for permanent storage not specified, but CO_2 injection is measured	Not specified	Yes
77*	Enid Fertilizer	US	Operational	0.675 Mtpa industrial	Integrated with dependency on partners	2003	Yes	MMV for permanent storage not specified, but CO_2 injection is measured	Not specified	Yes
78*	Sharon Ridge EOR	US	Operational	1.3 Mtpa industrial	Integrated with dependency on partners	1999	Yes	MMV for permanent storage not specified, but CO_2 injection is measured	Not specified	Yes
79*	Rangely Weber Sand Unit CO_2 Injection Project	US	Operational	1 Mtpa industrial	Integrated with dependency on partners	1986	Yes	MMV for permanent storage not specified, but CO_2 injection is measured	Not specified	Yes
80*	Coffeyville Resources Nitrogen Fertilizer Plant	US	Operational	0.585 Mtpa industrial	Integrated with dependency on partners	2000	Yes	MMV for permanent storage not specified, but CO_2 injection is measured	Not specified	Yes

* Projects capturing CO_2 from anthropogenic sources for the purposes of enhanced oil recovery (EOR), with a lack of information to indicate that MMV exists for the purposes of managing CO_2 for permanent storage.

Annex D: Knowledge-Sharing Principles

The purpose of knowledge sharing between large-scale CCS demonstration projects is to:

- de-risk CCS with regard to scaling up to commercial size;
- accelerate deployment of safe and commercially viable CCS;
- increase the understanding of and confidence in CCS by the wider public;
- support capacity and capability building in the global CCS community; and
- inform future policy making.

Knowledge sharing is of particular importance to derive additional value for the public good where large sums of public money are involved. To this end, the following points present a set of high-level guidelines or principles to help governments design and implement effective knowledge sharing structures which maximise the spill-over benefits and the public good of publicly-funded large-scale CCS demonstration programmes.

Noting that jurisdictions will deliver CCS demonstration programmes in accordance with their specific policy landscape, consideration of these Knowledge-Sharing Principles should be made in the context of the appropriate legislative and regulatory regimes of the implementing jurisdiction. Wherever possible, implementing arrangements for knowledge sharing should be consistent with systems in other jurisdictions in order to facilitate knowledge sharing between regions.

- A position of extensive knowledge sharing should be default, except where a valid and clear commercial infringement is apparent. Such infringement concerns should be serious, legitimate and substantiated. Nevertheless, minimum requirements for knowledge sharing should be established that will deliver the policy objectives.
  - Negotiations on the type and detail of knowledge to be shared should be established by the relevant jurisdiction in line with their policy objectives and legislative instruments. Outcomes sought should consider relevant negotiations with equivalent demonstration projects.
- Project reporting should be in a standardised format and should address consistent criteria in order to effectively monitor the project's progress over the support period.
  - Project reporting should be in addition to knowledge sharing through activities such as project network events.
  - Data and relevant project reports should be made available in a timely manner to ensure quality, veracity and accuracy.
- Knowledge sharing between projects should be co-ordinated to ensure that value is added to contributing parties.
  - Jurisdictions, acting where possible in regional groupings, should promote the formation of project networks to facilitate knowledge sharing among projects.
  - Jurisdictions should consider whether there is a need to differentiate between knowledge that can be widely disseminated and that which is exchanged only between projects in order to maximise the extent of sharing and generate useful aggregated information for communicating to stakeholders.

- Jurisdictions should retain the option to establish sub-groups of projects working on similar issues or on a similar basis in order for sharing to occur more openly and/or effectively.
- Participation in knowledge-sharing activities should be actively promoted and trust should be engendered among members of project networks through mutual benefit and reciprocity, as far as is practicable.

- Knowledge-sharing arrangements within a network should have clear and transparent governance arrangements to support knowledge content and information channels.
  - Clear and transparent governance arrangements are required to support trust and establish opportunities for knowledge exchange
  - In designing knowledge-sharing networks, activities should be proactive rather than reactive in order to capture current issues and drive demonstration forward. Wherever practicable, stakeholders, such as government and communities, should be engaged in programme activities and provided with the opportunity to give input.

- Projects receiving public funding support should be tasked with specifying and empowering personnel to deliver knowledge-sharing requirements.
  - The purpose of knowledge sharing should be transparent and responsible personnel should be fully aware of the desired outcomes.

Source: Knowledge-sharing information from the Ad-hoc Inter-Governmental Knowledge-Sharing Working Group set up at the 2010 GCCSI Knowledge Sharing workshop in Ottawa, Canada.

Annex E: Carbon capture and storage ready

Definition of carbon capture and storage ready (CCSR)

A CCSR facility is a large-scale industrial or power source of CO_2 which could and is intended to be retrofitted with CCS technology when the necessary regulatory and economic drivers are in place. The aim of building new facilities or modifying existing facilities to be CCSR is to reduce the risk of carbon emission lock-in or of being unable to fully utilise the facilities in the future without CCS (stranded assets). CCSR is not a CO_2 mitigation option, but a way to facilitate CO_2 mitigation in the future. CCSR ceases to be applicable in jurisdictions where the necessary drivers are already in place, or once they come in place.

Essential Requirements of a CCSR facility

The essential requirements represent the minimum criteria that should be met before a facility can be considered CCSR. The project developer should:

- Carry out a site-specific study in sufficient engineering detail to ensure the facility is technically capable of being fully retrofitted for CO_2 capture, using one or more choices of technology which are proven or whose performance can be reliably estimated as being suitable.
- Demonstrate that retrofitted capture equipment can be connected to the existing equipment effectively and without an excessive outage period and that there will be sufficient space available to construct and safely operate additional capture and compression facilities.
- Identify realistic pipeline or other route(s) to storage of CO_2.
- Identify one or more potential storage areas which have been appropriately assessed and found likely to be suitable for safe geological storage of projected full lifetime volumes and rates of captured CO_2.
- Identify other known factors, including any additional water requirements that could prevent installation and operation of CO_2 capture, transport and storage, and identify credible ways in which they could be overcome.
- Estimate the likely costs of retrofitting capture, transport and storage.
- Engage in appropriate public engagement and consideration of health, safety and environmental issues.
- Review CCSR status and report on it periodically.

Definition application

These essential requirements represent the minimum criteria that should be met before a facility can be considered CCSR. However, a degree of flexibility in the way jurisdictions apply the definition will be required to respond to region- and site-specific issues and to take account of the rapidly changing technology, policy and regulatory background to CCS and CCSR, both globally and locally. More specific or stringent requirements could be appropriate, for instance, in jurisdictions where the CCSR regulator is working on the assumption that CCS will need to be retrofitted to a particular facility within a defined time frame.

Source: CCS-ready information from the Ad-hoc CCS-Ready working group set up at the 2010 IEA/CSLF/GCCSI CCS Ready workshop in Ottawa Canada.

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