Economic Commission for Europe
Committee on Sustainable Energy

Expert Group on Cleaner Production of Electricity from Fossil Fuels
Eleventh session
Geneva, 30 October 2015
Item 7e of the provisional agenda
Task Force on Capture Readiness

Status on Global Carbon Capture and Storage Readiness (CCSR) Discussion

Prepared by a task force of experts in response to paragraph 16(d) of the report of the Expert Group on Cleaner Electricity Production from Fossil Fuels Tenth Session[1]

1. Background

Carbon Capture and Storage (CCS) technologies are of major importance because they prevent CO_2 emissions into the atmosphere and therefore directly contribute to the mitigation of climate change and global warming consequences. The process of CCS can be generally divided into the following stages: 1) capturing CO_2 (through post-combustion, pre-combustion and oxyfuel processing), 2) CO_2 transport, and 3) CO_2 storage. Capturing and storing CO_2 requires additional equipment and decreases the electrical output for a given fuel input to a power generation facility. In order to minimize the impacts of deploying CCS and encourage its use worldwide, the international community and researchers from around the world are working to reduce the costs and optimize the performance of CCS technologies.

While mainstream deployment of CCS today faces considerable economic, technical, administrative, environmental, and social difficulties, new fossil-fuel plants and industrial facilities still continue to be constructed in large numbers. This raises the prospect of 'locking-in' future CO_2 emissions from these fossil-using assets unless they are retired early or CCS can be retrofitted. Designing, and possibly locating, the plants to facilitate CCS retrofits, without requiring extensive modifications or interruption in operation, increases the probability that the latter option will be attractive and at an earlier date.

2. Need for flexibility as CCS experience is still developing

The principles for making a plant 'CCS Ready', CCSR (also sometimes expressed as 'capture ready' or CCR) have been refined by CCS experts over the last decade and an internationally-agreed summary is given below. Practical details for suitable CCSR plant designs will, however, follow CCS deployment experience and so are likely to be developing for some time and will also be project-specific in many details. Similarly, the details of prospective secure storage sites still need to be explored in many cases. The establishment of effective regulatory frameworks to include CCSR in member states' project permitting processes must therefore allow for an ongoing process of developing amendments and clarifying definitions in order to respond to the recent advances and continuous update of knowledge related to both CCS, and CCSR practice and policy. As stated by the

[1] Report can be found at:
http://www.unece.org/fileadmin/DAM/energy/se/pdfs/clep/ge10/ECE.ENERGY.GE.5.2014.2_Report.pdf

Global CCS Institute in its 'CCS Ready Policy and Regulations' review, being overly prescriptive may result in technology lock-in, will certainly increase administrative and assessment costs, and may also prove unresponsive to technology evolution[2].

3. CCSR Principles

In order to broaden the understanding of the term "CCS Ready" the Global CCS Institute, the International Energy Agency (IEA) and the CSLF, with input from industry and non-government organizations, jointly developed the definition of CCSR principles below, which was published as part of a report to the G8 in 2010[3]:

> ***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:*
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> - *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 CO2.*
> - *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*

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[2] CCS ready policy and regulations: the state of play. Progress towards the implementation of CCS ready policy and regulatory frameworks. Published: 23 Aug 2012, p. 44
http://decarboni.se/sites/default/files/publications/44161/ccsreadydraftfinal10aug.pdf
[3] https://www.iea.org/publications/freepublications/publication/ccs_g8.pdf

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.

The definitions of CCSR provided by the Global CCS Institute, CSLF and IEA above serves as a useful entry points, but as noted, regulators have to be receptive and flexible as the newest information becomes available. The importance of a proper balance between the interests of plant developers and the need for a sufficient degree of prescription should be also taken into account while establishing the legal basis for CCSR.

4. Translating CCSR principles into practice

Although the cost of making a new power plant CCSR has been assessed as less than 1% of capital investment for a coal fired unit[4], building a CCSR plant is likely to face challenges related to uncertainties about the future cost of carbon emissions, possible regulation changes, long-term CO_2 emissions targets, ownership liability for any stored CO_2, and the still-evolving development of carbon capture technologies[5].

These risks should be integrally considered from a plant developers' perspective, as they are the core element of the comprehensive CCSR policy implementation. From the point of view of a plant developer, pre-investment in making a plant CCS Ready has to be weighed against the costs of future mitigation of GHG emissions for a business-as-usual (BAU) plant. The uncertainties are, however, being reduced by CCS deployment at scale, such as the Boundary Dam project, in markets where CCS is already supported. Such existing large-scale CCS projects, including those under construction, can provide the substantial knowledge that will subsequently act to reduce costs and reinforce investor and stakeholder confidence.

Finally, as the Global CCS Institute highlights, the needed efforts from a plant developer to implement a CCSR policy could also divert the attention from other, short-term GHG mitigation options. In this case CCSR policy is often considered as a supplementary tool along with other existing mechanisms such as emission trading schemes (ETS) and emission performance standards (EPS). Continued attention to the development of the drivers to move from CCS Ready to actual CCS deployment/retrofit is also required to ensure that emission reductions eventually occur. Publicly stating that a fossil-using facility is CCSR does, however, largely remove any grounds for objections to subsequent retrofit once CCS use becomes more widespread.

5. Recommendations for UNECE role

Taking into account that fossil fuels will remain the key source for meeting energy demands in the foreseeable future, which has been repeatedly forecasted by various credible organizations such as the International Energy Agency (IEA), strong, sustainable and coherent emission reduction policies able to encourage CCS are desperately and urgently needed.

The United Nations Economic Commission for Europe has a long-standing and well-recognized history of providing a neutral platform for an exchange of views and policy debate amongst UNECE and non-UNECE member States. A key advantage of UNECE lies in its capacity to address the diversity of emerging climate change risks with all parties concerned and in its ability to convey

[4] https://ukccsrc.ac.uk/system/files/publications/ccs-reports/DECC_CCS_52.pdf
[5] CCS Ready Policy: Considerations and. Recommended Practices for Policymakers. 17 February 2010. P. 1 http://www.cslforum.org/publications/documents/CCS_Ready_Policy_Considerations.pdf

recommendations, when appropriate, to the attention of the governments of Member States, the Economic and Social Council and the General Assembly.

The UNECE Secretariat can bring closer all stakeholders to achieving an important understanding on the basic principles and parameters of the best technically and economically sound practices to provide a complete transition to CCS and resource-efficient and environmentally clean technologies in the longer term. As part of this transition the UNECE CEP Expert Group is suggested to promote effective CCSR application to assist with subsequent commercial-scale deployment of CCS.

Although respected methodical literature on CCS and CCSR in particular is available, further guidance on the latest actual CCS and CCSR regulatory and industrial experience through facilitated interaction between regulators, industry and other stakeholders in member states at various stages in CCS and CCSR implementation is strongly needed, especially for countries with economies in transition. Such knowledge is clearly vital and beneficial to achieve the desirable environmental outcomes with the use of the most appropriate and cost effective CCSR policy approach.

Appendix 1 – Selected CCSR reports

A1.1 Gleneagles Communique and IEA/IEAGHG report on capture readiness

The G8 2005 Gleneagles Plan of Action[6] initiated work on CCS, including capture readiness, as detailed below:

> *14. We will work to accelerate the development and commercialization of Carbon Capture and Storage technology by:*
>
> *(a) endorsing the objectives and activities of the Carbon Sequestration Leadership Forum (CSLF), and encouraging the Forum to work with broader civil society and to address the barriers to the public acceptability of CCS technology;*
>
> *(b) inviting the IEA to work with the CSLF to hold a workshop on short-term opportunities for CCS in the fossil fuel sector, including from Enhanced Oil Recovery and CO_2 removal from natural gas production;*
>
> *(c) inviting the IEA to work with the CSLF to study definitions, costs, and scope for 'capture ready' plant and consider economic incentives;*
>
> *(d) collaborating with key developing countries to research options for geological CO_2 storage; and*
>
> *(e) working with industry and with national and international research programmes and partnerships to explore the potential of CCS technologies, including with developing countries.*

In response to item 14(c) the IEAGHG undertook a study that included engineering aspects of making coal plants capture ready for post-combustion capture and oxyfuel[7]. This has subsequently also been translated into Chinese with UK Department of Energy and Climate Change funding. It also forms the basis of UK CCSR regulations for power plant permitting (see A2.1 below).

[6] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48584/gleneagles-planofaction.pdf
[7] http://ieaghg.org/docs/General_Docs/Reports/2007-4%20Capture%20Ready.pdf

A1.2 CSLF report, 2010

Further, significant work in the field has been undertaken by the Carbon Sequestration Leadership Forum (CSLF) that brings together the efforts of 23 members, including 22 countries and the European Commission. The CSLF represents an important forum for international collaboration in the sphere of the development and deployment of CCS technologies, addressing a wide range of issues and seeking solutions to key technical, economic and environmental challenges in CCS global domain.

In conjunction with ICF International, the CSLF has proposed in 2010 a definition of CCS readiness that reflects three main CCS components. In particular, a plant, which intends to be regarded as CCS Ready, needs to be Capture Ready, Transport Ready, and Storage Ready. All these phases are highly interconnected and cannot be considered in isolation because their successful implementation requires an integrated approach.

The proposed international definition for CCS Ready by ICF & CSLF was included in the summary report entitled "*CCS Ready Policy: Considerations and Recommended Practices for Policymakers*" and published in 2010. The full text of the definition as an extract from the report is presented below:

Proposed International Definition of CCS Ready[8]

Capture Ready Plant

A CO_2 Capture Ready plant satisfies all or some of the following criteria:

1) Sited such that transport and storage of captured volumes are technically feasible;
2) Technically capable of being retrofitted for CO_2 capture using one or more reasonable choices of technology at an acceptable economic[9] cost;
3) Adequate space allowance has been made for the future addition of CO_2 capture-related equipment, retrofit construction, and delivery to a CO_2 pipeline or other transportation system;
4) All required environmental, safety, and other approvals have been identified;
5) Public awareness and engagement activities related to potential future capture facilities have been performed;
6) Sources for equipment, materials, and services for future plant retrofit and capture operations have been identified; and
7) Capture Readiness is maintained or improved over time as documented in reports and records.

Transport Ready Plant

A CO_2 Transport Ready plant satisfies all or some of the following criteria:

1) Potential transport methods are technically capable of transporting captured CO_2 from the source(s) to geologic storage ready site(s) at an acceptable economic cost;

[8] CCS Ready Policy: Considerations and. Recommended Practices for Policymakers. 17 February 2010. Prepared by: ICF International. Prepared for: The Global Carbon Capture and Storage Institute. Submitted by: ICF International
http://www.cslforum.org/publications/documents/CCS_Ready_Policy_Considerations.pdf

[9] Note: "Economically acceptable" means that, during the operating life of the plant, a reasonable probability exists that the plant can be retrofitted and operated with CCS at a total cost comparable to the GHG mitigation costs borne by other plants in the jurisdiction. The plant's total cost for capture, transport, and storage would include costs for planning, construction capital, and operating costs, including the time value of money. "Technically feasible" or "technically capable" means that technologies exist that can be applied to capture, transport and store a significant portion of the CO_2 emitted from the plant, while substantially preserving the original functionality of the plant.

2) Transport routes are feasible, rights of way can be obtained, and any conflicting surface and subsurface land uses have been identified and/or resolved;
3) All required environmental, safety, and other approvals for transport have been identified;
4) Public awareness and engagement activities related to potential future transportation have been performed;
5) Sources for equipment, materials, and services for future transport operations have been identified; and
6) Transport Readiness is maintained or improved over time as documented in reports and records.

Storage Ready Plant

A CO_2 Storage Ready plant satisfies all or some of the following criteria:

1) One or more storage sites have been identified that are technically capable of, and commercially accessible for, geological storage of full volumes of captured CO_2, at an acceptable economic cost;
2) Adequate capacity, injectivity, and storage integrity have been shown to exist at the storage site(s);
3) Any conflicting surface and subsurface land uses at the storage site(s) have been identified and/or resolved;
4) All required environmental, safety, and other approvals have been identified;
5) Public awareness and engagement activities related to potential future storage have been performed;
6) Sources for equipment, materials, and services for future injection and storage operations have been identified; and
7) Storage Readiness is maintained or improved over time as documented in reports and records.

A1.3 Feasibility study for CO_2 Capture-Ready Ultra-Mega Power Projects, (UMPP) India

This study[10], which is cited because cost estimates were produced, was undertaken in 2008 by a team led by consultants Mott MacDonald (MM) on behalf of the British Government[11]. It combined new information available from three other first-of-kind studies, to identify and evaluate options for making a proposed 4000MW UMPP "CO_2 Capture-Ready".

The report builds in particular on a parallel MM study of advanced supercritical technologies[12], incorporating learning from operating plant in India, and on two studies commissioned by the IEA Greenhouse Gas R&D Programme (IEA GHG) – on capture-ready plants globally and on CO_2 storage opportunities in the Indian subcontinent[13]. The study makes new recommendations on the suitability of proposed coal-fired capacity in India for capture-ready design.

For a UMPP with estimated initial capital costs of USD 5 billion, the additional capital expenditure for design of a capture-ready plant is limited to 1% of the initial cost i.e. USD 50 million. Assuming these modifications are made, it was estimated (at the time of the study in 2008) that one of the selected projects could be made fully CCS operational, including a new generation unit to maintain net power output levels, for a further investment of USD 2.1 billion. Retrofit of CCS to a UMPP of 4,000 MW gross capacity will capture 18.8-19.5 Mt/year, at an 85% capture rate. The resulting abatement cost, taking into account conservative improvements in capture technology by an assumed retrofit date of 2020, is calculated at approximately USD 33/tCO_2. Due to the significant economies of scale available at a UMPP, such an abatement cost is comfortably within the range of expected future incentives for CCS globally – so that design of a UMPP as capture-ready would be a commercially attractive proposition.

[10] https://ukccsrc.ac.uk/system/files/publications/ccs-reports/DECC_CCS_52.pdf

[11] Foreign and Commonwealth Office (FCO) under their Global Opportunities Fund Climate Change and Energy Programme

[12] MM, "UMPP Risk Analysis", April 2008

[13] IEA GHG, "CO_2 Capture Ready Plants", Report 2007/4, May 2007; IEA GHG, "An Assessment of the Potential for CO_2 Storage in the Indian Subcontinent", S Holloway, A Garg, M Kapshe *et al*, Report 2008/2, April 2008

Appendix 2 Examples of existing CCSR regulations and guidelines

Constructing a plant as CCSR implies that the consenting authority has concluded at the time the consent was granted that it will be technically and economically feasible to retrofit CCS to that power station in the future.

Some examples of guidance on the evidence that has to be presented to support consenting are given below.

A2.1 EU CCSR regulations

The 28 countries of the European Union fall within the ambit of the CCS Storage Directive 2009/31/EC including Article 33 – Amendment of Directive 2001/80/EC, which is the specific CCSR provision. As the Directive applies to all the EU Member States, it is mandatory that they fully and accurately transpose it into their national law. However, governments still have enough policy space to address their particular national requirements. For instance, in UK and France a plant is only permitted where there is a positive assessment for CCSR feasibility and in the Rotterdam area in the Netherlands all new plants are required to be fully CCSR.[14]

The Directive states:

> *1. Member States shall ensure that operators of all combustion plants with a rated electrical output of 300 megawatts or more for which the original construction license or, in the absence of such a procedure, the original operating license is granted after the entry into force of Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide, have assessed whether the following conditions are met:*
>
> - *suitable storage sites are available,*
> - *transport facilities are technically and economically feasible,*
> - *it is technically and economically feasible to retrofit for CO2capture.*
>
> *2. If the conditions in paragraph 1 are met, the competent authority shall ensure that suitable space on the installation site for the equipment necessary to capture and compress CO_2 is set aside. The competent authority shall determine whether the conditions are met on the basis of the assessment referred to in paragraph 1 and other available information, particularly concerning the protection of the environment and human health.*

A2.1 UK guidelines

A comprehensive approach to CCSR and transposition of the EU regulations is demonstrated by the UK where CCSR requirements apply to all new build generation (i.e. biomass and natural gas as well as coal) of over 300 MW capacity[15]. Because an EPS now operates alongside the CCSR regulations any coal plant would have to be built with CCS from the outset rather than as CCSR, but a number of CCSR natural gas combined cycle projects have been permitted or are being considered. The UK government detailed guidance is based on the 2007 IEAGHG report. The UK also operates a CCS Commercialization Program with up to GB£1 billion in capital funding and support through a Feed in

[14] http://hub.globalccsinstitute.com/sites/default/files/publications/44161/ccsreadydraftfinal10aug.pdf
[15] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/238627/7605.pdf

Tariff with a Contract for Difference under the Electricity Market Reform arrangements is being provided to support CCS low carbon electricity projects.

An important feature in UK CCSR regulations is that the Government takes into account the current level of development in CCS technology and national infrastructure by considering applicants' assessments with a "no barriers" approach. Applicants are asked to demonstrate that there are no known technical or economic barriers which would prevent the installation and operation of their chosen CCS technologies. The UK Government also does not intend to prescribe the detail of how CCS technology is applied in individual cases, but does expect that applicants will follow best practice as far as this knowledge is available and provide a reasoned justification of their choices.

The UK guidelines are summarized as follows:

As part of their application for Section 36 consent applicants will be required to demonstrate:

- *That sufficient space is available on or near the site to accommodate carbon capture equipment in the future;*
- *The technical feasibility of retrofitting a potential carbon capture technology;*
- *That a suitable area of deep geological storage offshore[16] exists for the storage of captured CO_2 from the proposed power station;*
- *The technical feasibility of transporting the captured CO_2 to the proposed storage area; and*
- *The likelihood that it will be economically feasible within the power station's lifetime, to link it to a full CCS chain, covering retrofitting of capture equipment, transport and storage.*
- *Applicants must make clear in their CCR assessments which CCS retrofit, transport and storage technology options are considered the most suitable for their proposed development. In addition, if applicants' proposals for operational CCS involve the use of hazardous substances, they may be required to apply for Hazardous Substances Consent (HSC). In such circumstances, they should do so at the same time as they apply for Section 36 consent.*

If granted consent, operators of the power station will be required to:

- *retain control over sufficient additional space on or near the site on which to install the for the carbon capture equipment, and the ability to do use it for that purpose;*
- *submit reports to the Secretary of State for DECC as to whether it remains technically feasible to retrofit CCS to the power station. These reports will be required within 3 months of the commercial operation date of the power station (so avoiding any burden on the operator with an unimplemented consent) and every two years thereafter until the plant moves to retrofit CCS.*

2.3 Canadian Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations

Canadian regulations issued for new coal plants[17] in 2012 include a temporary exemption to 2025 from meeting an EPS of 420 tCO_2/GWh if it can be shown that the plant will be able to fit CCS by

[16] Offshore storage is required in UK regulations since the overwhelming majority of UK storage capacity is in offshore geological structures and so a route to prospective offshore regions is essential. Offshore storage is also expected to have greater public acceptability than onshore storage in the UK.

that time. Because of the relatively short time period and fixed cut-off date this approach might be regarded as staged CCS implementation rather than CCS readiness. In the latter case time to retrofit is typically uncertain and plants would be designed and built with the objective of being able to use the best CCS system that will be available for the base plant technology at the time, bearing in mind that it is very likely that the capture system that will eventually be fitted is not known in detail when the new capture ready plant is designed.

Currently there are no new coal power plants or old plant upgrades being proposed in Canada that would apply these guidelines.

Regulatory requirements for a temporary exemption from the EPS require that:

> *(1) A responsible person for a new unit or an old unit may apply to the Minister for a temporary exemption from the application of* [the EPS] *in respect of the unit if*
>
> *(a) in the case of a new unit, the unit is designed to permit its integration with a carbon capture and storage system; and*
> *(b) in the case of an old unit, the unit may be retrofitted to permit its integration with a carbon capture and storage system.*
>
> *(2) The application must indicate the unit's registration number and include the following supporting documents and information:*
>
> *(a) a declaration that includes statements indicating that*
>
> > *(i) based on the economic feasibility study referred to in paragraph (b), the unit, when operating with an integrated carbon capture and storage system is, to the best of the responsible person's knowledge and belief, economically viable, and*
> > *(ii) based on the technical feasibility study referred to in paragraph (c) and the implementation plan referred to in paragraph (e), the responsible person expects to satisfy the requirements set out in section 10 and, as a result, to be in compliance with subsection 3(1) by January 1, 2025;*
>
> *(b) an economic feasibility study that demonstrates the economic viability of the unit when it operates with an integrated carbon capture and storage system and that*
>
> > *(i) provides project cost estimates, with their margin of error, for the construction of the integrated carbon capture and storage system, and*
> > *(ii) identifies the source of financing for that construction;*
>
> *(c) a technical feasibility study that establishes …. that there are no insurmountable technical barriers to carrying out the following activities:*
>
> > *(i) capturing a sufficient volume of CO_2 emissions from the combustion of fossil fuels in the unit to enable the responsible person to comply with* [the EPS]*),*
> > *(ii) transporting the captured CO_2 emissions to suitable geological sites for storage, and*
> > *(iii) storing the captured CO_2 emissions in those suitable geological sites;*

[17] http://www.gazette.gc.ca/rp-pr/p2/2012/2012-09-12/html/sor-dors167-eng.html

(d) a description of any work that has been done to satisfy the requirements set out in section 10, along with the information referred to in Schedule 3 with respect to that work; and

(e) an implementation plan that provides a description of the work to be done, with a schedule for the steps necessary to achieve the following objectives:

(i) satisfaction of the requirements [for a specified timeline for CCS implementation – see below], *and*
(ii) compliance of the responsible person with [the EPS] *by January 1, 2025 when the unit is operating with an integrated carbon capture and storage system that captures CO_2 emissions from the combustion of fossil fuels in the unit in accordance with the laws of Canada or a province that regulate that capture and that transports and stores those emissions in accordance with the laws of Canada or a province, or of the United States or one of its states, that regulate that transportation or storage, as the case may be.*

The specified timeline that projects would have to follow to ensure CCS implementation by the required date is:

- Front end engineering design study by January 1, 2020;
- Purchase any major capture equipment purchase by January 1, 2021;
- Contract for the transportation and storage of CO_2 by January 1, 2022;
- Ensure performance by January 1, 2024.

There is also an annual reporting requirement on progress towards these milestones.