



# Global best practices in assessment and readiness for CCS retrofit

Final report

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# Global best practices in assessment and readiness for CCS retrofit

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## Executive summary

The objective of this study is to identify global current best practice on carbon capture and storage (CCS) readiness, drawing both on practical experience from jurisdictions around the world, and on industry literature written since the Directive 2009/31/EC on the geological storage of carbon dioxide (CCS Directive) was adopted in 2009. The lessons learned from these sources are synthesised and their relevance to EU Member States is evaluated.

A review of international CCS readiness legislation confirmed that the most comprehensive policy and regulatory coverage on CCS readiness requirements is found within the EU. However, potentially relevant findings were identified through a review of legislation and CCS roll out experience in Canada, United States of America (USA), Australia, China and Norway, which are summarised below:

### Canada

- In recent years, Canada has delivered large-scale CCS projects driven by CO<sub>2</sub>-enhanced oil recovery (EOR) and Canada's federal and provincial governments' commitment to CCS.
- Canadian regulations for coal power plants include a temporary exemption from meeting an emissions performance standard (EPS), if it can be shown that the plant will be able to be retrofitted with CCS. This temporary exemption requires power plant developers to submit regular progress reports, in addition to the initial information that must be submitted, to demonstrate the plant will be able to be retrofitted with CCS.
- Alberta's Regulatory Framework Assessment suggests promotion of efficient and fair development of CCS, by encouraging CCS project proponents to work together and allowing power plants to apply for access to other operator's pipelines or storage sites.
- Learnings from the Boundary Dam Project suggest that, in addition to technical feasibility of the power plant, some important financial and market considerations must be taken into account, including potential market for any by-products such as CO<sub>2</sub> for enhanced oil recovery.

### United States

- Deployment of CCS in USA is primarily motivated by enhanced oil recovery opportunities and government incentives at both the federal and state level.
- USA has taken considerable steps toward "storage readiness", with the market and infrastructure for CO<sub>2</sub> sequestration largely developed and assessed.
- Although there is no legislation on CCS readiness in the US, lessons can be taken from the recent Carbon Pollution Standards for New, Modified and Reconstructed Power Plants. In addition to the newly constructed power plants, the Carbon Pollution Standards apply to some of the existing units, which are modified or reconstructed. EPA also introduced different emissions standards for natural gas and coal power plants.

### Australia

- The proposed CCS Readiness standards in Australia (which never went into force) had similar guidelines as in Article 33. It provided a list of six specific requirements and noted that the primary one was the assessment of likely costs of CCS being eventually deployed on the CCS ready plant, when CCS was deemed commercially ready.
- The proposed standards required project developers to provide an annual report to the administering authority on their power plant's compliance with the CCS Readiness standards.
- The Australian Government proposed that it would be mandatory for the power plants to implement the CCS retrofit within four years and complete the construction within seven years of the commercial availability of CCS being declared by the Government. The Australian Government proposed to conduct a review every two years to test the commercial viability of CCS, based on the technical, operational and commercial considerations.

## China

- The recent Asian Development Bank report provides explicit and separate guidelines for each element of CCS: capture, transport and storage. These guidelines provide specific requirements for project developers to follow. It suggests that all coal power plants of above a threshold size (2 GW or higher) should be sited within 200 kilometres of a major EOR field or geological storage formation. The report also suggests that developers should be encouraged to explore the option of a pipeline network that links various large CO<sub>2</sub> point sources to reduce unit costs.
- The ADB report recommends that a mechanism allowing power plant developers to recover CCSR costs by introducing a tariff for electricity from a CCS Ready power plant be introduced. It is also suggested that plant developers be required to maintain CCS Ready planning documents for defined time periods and to report periodically on the CCS Ready status of plants.
- Finally, the report suggests that the government could consider including CCS Ready requirements in the approval process of energy-intensive industry in addition to power plants.

## Norway

- Norway has increased “national storage readiness” by establishing CCS legislation, developing a detailed CO<sub>2</sub> Atlas and gaining experience from operational CO<sub>2</sub> storage projects.
- Norway has already established policy that all new coal-fired generation incorporate CCS from the time of commissioning and operation. This shows that strong CCS policies or regulations (e.g. requiring all new fossil fuel-fired power plants to install CCS) may make CCS readiness requirements redundant.

In addition to the country-specific best practices, further key learnings were identified through a review of academic and institutional reports on CCS readiness. These are explained in detail in the report.

The following conclusions have been developed from the information collated during this review:

### 1. Increasing storage readiness in the EU

Storage readiness is a key component of CCSR, but the identification and assessment of potential storage sites is beyond the scope of project developers. Article 33 requires that all combustion plants with a rated electrical output of over 300 megawatts ensure that suitable storage sites are identified. To achieve this, developers of such projects in the EU will rely on storage data developed by the Member States. It is important that detailed data on storage capacity is available.

EU Member States could move toward storage readiness by:

- carrying out collaborative multi-country storage assessments;
- developing CO<sub>2</sub> storage datasets;
- appraising storage units;
- enabling deployment of pilot and/or commercial CO<sub>2</sub> storage projects; and
- addressing legal challenges of cross-border CO<sub>2</sub> transport and storage.

These requirements are already called for in Article 4(2) of the CCS Directive.<sup>1</sup>

### 2. Identifying locations of potential CO<sub>2</sub> capture and storage clusters and feasible CO<sub>2</sub> pipeline routes within the EU

CCS clusters are expected to be developed within the EU, in order to minimise transport and storage costs. Locations of potential clusters could be assessed as part of the CCS readiness

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<sup>1</sup> The CCS Directive has the following requirement in Article 4(2): “Member States which intend to allow geological storage of CO<sub>2</sub> in their territory shall undertake an assessment of the storage capacity available in parts or in the whole of their territory, including by allowing exploration pursuant to Article 5. The Commission may organise an exchange of information and best practices between those Member States, in the context of the exchange of information provided for in Article 27.”

assessments. To qualify as CCS ready, power plants could be required to be located close to potential onshore CO<sub>2</sub> capture clusters and/or shoreline hubs. Plans for developing these potential clusters could be developed by the EC and/or Member States by considering potential CO<sub>2</sub> transport routes from onshore CO<sub>2</sub> clusters to shoreline hubs / ports.

Where plant developers can demonstrate the feasibility of CO<sub>2</sub> capture and transport to a nearby potential cluster (which will likely be connected to storage sites through a large-scale CO<sub>2</sub> transportation network or shipping), requirements to identify specific storage sites for their projects could be relaxed.

### **3. Requiring increasing levels of CCS readiness, in the context of Article 33**

Member States can increase CCS readiness requirements, as part of Article 33 implementation, as the CCS market develops to reduce the risk of stranded assets and 'carbon lock-in'

As an illustrative example a power plant commissioned before 2020 might be required to meet a minimum readiness threshold; while a plant commissioned after 2020 might need to meet a more stringent standard. An even more stringent regulation would require all fossil fuel-fired power plants commissioned beyond some future date to install CCS from the time of their commissioning.

### **4. Requiring regular progress reports as part of Article 33 compliance**

EU power plants developers could be required to submit regular (e.g. every 5 years) update reports on the CCS readiness status of their plants, taking into account:

- developments in CO<sub>2</sub> capture technology, especially the technical and economic feasibility of capture given any cost reductions achieved;
- new transport opportunities, based on, for example, nearby over-sized transport infrastructure;
- storage availability based on the latest assessments; and
- relevant market factors, such as fuel and carbon prices, and government incentives.

### **5. Extending CCS readiness requirements to emissions intensive industry**

Overall industrial emissions need to be cut significantly in order to meet the 2050 CO<sub>2</sub> reduction target. Analogous CCS Readiness requirements for energy and emissions intensive industrial subsectors, such as cement, chemicals, refining, and steel could be developed and rolled out by the EC. New industrial facilities could then be required to be CCS ready, and the costs and benefits of retrofitting existing plant could also be assessed.

### **6. Examining CO<sub>2</sub> utilisation opportunities and government incentives**

Economic feasibility assessments required from project developers to demonstrate CCS readiness could consider all available incentives as well as the potential market for CO<sub>2</sub> by-products, including carbon dioxide enhanced hydrocarbon recovery (CO<sub>2</sub>-HER), also referred to as enhanced oil recovery (EOR). Although the EU ETS carbon price remains relatively low, potential government incentives and/or potential market for any by-products including CO<sub>2</sub>-EHR may improve commercial viability of CCS in the EU.

# 1 Introduction

The objective of this study is to identify the current best practice on CCS readiness based on practical experience from jurisdictions around the world and international guidance documents. These diverse approaches are evaluated for lessons learned and their applicability to EU Member States.

- Section 2.1 presents country-specific progress on CCS readiness in Canada, United States, Australia, China and Norway. The process to identify these relevant countries and other project-specific case studies are also explained in the section.
- Section 2.2 presents the generic definition of CCS readiness, and key learnings from other case studies and reports published by key international organisations.
- Section 3 summarises the key lessons learned and best practices based on the materials reviewed and examines the applicability of the best practices to the EU Member States.

## 2 Global progress on CCS readiness

### 2.1 Country-specific progress

#### 2.1.1 Identification of relevant countries outside the EU

Relevant countries outside the EU have been identified based on the following criteria:

- **CCS project development** is based on the number of large-scale CCS projects, which are in “Operate”, “Execute”, “Define”, “Evaluate” and “Identify” stages<sup>2</sup> and number of notable pilot and demonstration CCS projects.<sup>3</sup> This criterion is included as key learnings for CCS retrofit can be identified from practical experience in project development outside the EU. The ranking has been assigned as follows:
  - **High:** Countries with more than one large-scale CCS project.
  - **Medium:** Countries with one large-scale or at least two notable CCS projects.
  - **Low:** Countries with fewer than two notable CCS projects.
- **National storage readiness**<sup>4</sup> is based on an assessment carried out by GCCSI in 2015, which considered storage potential, standard of country storage assessment, maturity of the assessment, pilot/commercial projects, and knowledge dissemination. The ranking has been assigned as follows:
  - **High:** Prepared for wide-scale storage
  - **Medium:** Well advanced
  - **Low:** Making progress or just starting
- **Inherent CCS interest**<sup>5</sup> illustrates potential interest countries may have in reducing emissions from fossil fuel sources by developing CCS based on global shares of fossil fuel production and consumption. Countries with high inherent interest in CCS are expected to have made progress in development of CCS legislation. It should be noted that this metric does not perfectly represent countries’ existing interest in CCS. Norway’s CCS interest rating has therefore been increased to “High” in this report.

<sup>2</sup> Large-scale CCS projects: <http://www.globalccsinstitute.com/projects/large-scale-ccs-projects> (accessed on 9 March, 2016).

<sup>3</sup> Notable projects: <http://www.globalccsinstitute.com/projects/notable-projects> (accessed on 9 March, 2016).

<sup>4</sup> Global CCS Institute, 2015, Global Storage Readiness Assessment



- **The Constituent Policy Index<sup>5</sup>** is based on the relevant policy measures available in the country (i.e. direct support for CCS, carbon pricing, etc.). For both inherent CCS interest and constituent policy index, ranking has been assigned as follows:
  - **High:** Upper Tier
  - **Medium:** Upper-mid Tier
  - **Low:** Lower-mid Tier or Lower Tier
- **Legal and regulatory indicator<sup>6</sup>** of the country based on the national legal and regulatory CCS frameworks. Countries with more advanced CCS frameworks are expected to provide learnings for CCS Readiness requirements.
  - **High/Band A:** CCS specific laws or existing laws that are applicable across most parts of the CCS project cycle
  - **Medium/Band B:** CCS specific laws or existing laws that are applicable across parts of the CCS project cycle
  - **Low/Band C:** Very few CCS specific or existing laws that are applicable across parts of the CCS project cycle

**Table 2.1: Scoring criteria to identify relevant countries**

Ranking	CCS project development			National storage readiness	Inherent CCS interest	Constituent Policy Index	Legal and regulatory indicator	Score
	Large-scale CCS projects (number)	Notable CCS projects (number)	Rating					
<b>High</b>	More than 1	-	High	Prepared for wide-scale storage	Upper Tier	Upper Tier	Band A	2
<b>Medium</b>	1	or at least 2	Medium	Well advanced	Upper-mid Tier	Upper-mid Tier	Band B	1
<b>Low</b>	0	and less than 2	Low	Making progress	Lower-mid Tier	Lower-mid Tier	Band C	0

The relevant countries have been ranked based on the criteria above. Table 2.2 summarises the assessment of these countries against the criteria. USA, Canada, Australia, China and Norway, which have the highest scores, are selected and assessed in more detail in the following sections.

<sup>5</sup> Global CCS Institute, 2015, Carbon Capture and Storage Policy Indicator (CCS PI) 2015 Update

<sup>6</sup> Global CCS Institute, 2015, Global CCS Institute CCS Legal and Regulatory Indicator – A Global Assessment of National Legal and Regulatory Regimes for Carbon Capture and Storage

**Table 2.2: Assessment of countries outside the EU**

Country	CCS project development			National storage readiness	Inherent CCS interest	CCS policy, legal and regulatory development		Total score
	Large-scale CCS projects (number)	Notable CCS projects (number)	CCS project development			Constituent Policy Index	Legal and regulatory indicator	
<b>USA</b>	12	17	High	High	High	High	High	10
<b>Canada</b>	6	4	High	High	High	High	High	10
<b>Norway</b>	2	0	High	High	High	Medium	Medium	8
<b>Australia</b>	3	5	High	Medium	Medium	Medium	High	7
<b>China</b>	9	9	High	Medium	High	Medium	Low	6
<b>South Korea</b>	2	2	High	Low	Medium	Medium	Medium	5
<b>Japan</b>	0	7	Medium	Low	Medium	Medium	Medium	4
<b>Brazil</b>	1	1	Medium	High	Medium	Low	Low	4
<b>Mexico</b>	0	0	Low	Low	Medium	Low	Medium	2
<b>India</b>	0	1	Low	Low	High	Low	Low	2
<b>Indonesia</b>	0	0	Low	Low	High	Low	Low	2
<b>Russia</b>	0	0	Low	Low	High	Low	Low	2
<b>Saudi Arabia</b>	1	0	Medium	Medium	Low	Low	Low	2
<b>UAE</b>	1	0	Medium	Medium	Low	Low	Low	2
<b>New Zealand</b>	0	0	Low	Low	Low	Low	Medium	1
<b>South Africa</b>	0	0	Low	Low	Medium	Low	Low	1

## 2.1.2 Canada

### 2.1.2.1 Background

In recent years, Canada has delivered large-scale CCS projects driven by CO<sub>2</sub>-enhanced oil recovery (EOR) and Canada's federal and provincial governments' commitment to CCS.<sup>7</sup>

- Over 25 million tonnes of CO<sub>2</sub> have been stored during the CO<sub>2</sub>-EOR operations in the Weyburn and Midale oilfields since 2000. CO<sub>2</sub> has been sourced from a gasification plant in North Dakota and transported to Saskatchewan, Canada.<sup>7</sup>
- The world's first operational large-scale power plant CCS project, the Boundary Dam Carbon Capture Project, was launched in 2014 in Canada. Most of the captured CO<sub>2</sub> is used for enhanced oil recovery operations and the remaining CO<sub>2</sub> is injected into a saline formation. In 2015, the Boundary Dam Project achieved the significant milestone of one year of operation.<sup>8</sup> IEAGHG has recently published the key learnings from the Boundary Dam Project.<sup>9</sup> The box below summarises the key considerations that must be taken into account to be able to transfer the business model to a different jurisdiction. See Annex 1 for a checklist developed by SaskPower for the next coal power plant retrofit.
- The Quest Project, world's first commercial-scale CCS project in an industrial processing facility storing more than one million tonnes of CO<sub>2</sub> per year, was launched in 2015.<sup>10</sup> The captured CO<sub>2</sub> is stored in a deep saline formation.

#### Box 2.1 Boundary Dam Project

##### Learnings from the Boundary Dam Project

A recent IEAGHG report summarises the experience and learnings of SaskPower from the Boundary Dam project. The report suggests that the following considerations must be taken into account in order to transfer the business model from Boundary Dam to a different power plant and jurisdiction. Although these considerations are more focussed on CCS deployment in general, economic assessments to demonstrate CCS readiness in the EU may also include these important issues.

- **Financial:** carbon tax, Government grant, Government incentives, financing, fossil fuel price forecasts, redundancy
- **Market:** potential demand for CO<sub>2</sub> (e.g. enhanced oil recovery), potential market for any by-products, electricity price forecasts
- **Technical design:** engineering, technology choice, reliability, operational forecasts, risk tolerance of organisation, optimising plant efficiency, modular construction
- **Construction:** Availability of skilled labour, internal experience, experienced construction or EPC firms, modularisation yards within reasonable transportation distance

### 2.1.2.2 CCS regulation

Canada's 2012 *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations* requires all coal power plants to be refitted with CCS to achieve a certain performance standard or retire after 50 years of operation.<sup>7</sup> Temporary exemptions

<sup>7</sup> GCCSI, 2014, Global Status of CCS

<sup>8</sup> GCCSI, 2015, Global Status of CCS – Summary Report

<sup>9</sup> IEAGHG, 2015, Integrated Carbon Capture and Storage Project at Saskpower's Boundary Dam Power Station

<sup>10</sup> Shell, 2015, The Quest for Less CO<sub>2</sub>: Learnings from CCS Implementation in Canada

are offered until 2025 if the plant can be retrofitted with a carbon capture and storage system by then.<sup>11</sup> This temporary exemption is similar to the CCS Readiness requirements in the EU and is examined in more detail in the next section.

In order to ensure that the required regulations are in place, the Government of Alberta initiated the Regulatory Framework Assessment (RFA) in 2011<sup>12</sup>, which examined in detail the technical, environmental, safety, monitoring and closure requirements of a CCS project. The RFA process, which was concluded in December 2012, included 71 individual recommendations, 9 conclusions and 25 actions for the Government of Alberta. Although the RFA did not specifically examine CCS readiness, learnings can be withdrawn from some of the recommendations for “Applications, Approvals and Regulatory Framework”, in particular, requirements for plant operators to:

- *“Define the roles and responsibilities of each regulator of CCS operations and create clear industry guidance documents;*
- *Require monitoring, measurement and verification (MMV) plans and closure plans to accompany all CCS related applications to the regulator and all tenure applications to the Department of Energy;*
- *Promote efficient and fair development of CCS by:*
  - *Encouraging CCS project proponents to work together,*
  - *Allowing proponents to apply for access to another operator’s pipelines or sequestration site(s) if private negotiations have failed and established conditions have been met, and*
  - *Changing tenure agreements to enable tenure to be revoked if it remains unused.”*

In British Columbia, the Ministry of Natural Gas Development is developing a regulatory policy framework for CCS, which is currently under consultation; the regulations for CCS are found in the Oil and Gas Activities Act (OGAA) and the Petroleum and Natural Gas Act (P&NG Act). Other elements are expected to be added to this regulatory regime for CCS projects.<sup>13</sup>

### **2.1.2.3 Legislation for CCS readiness**

As explained above, Canadian regulations for coal power plants include a temporary exemption from meeting an emissions performance standard (EPS) if it can be shown that the plant will be able to be retrofitted with CCS. Although not an explicit regulation on CCS Readiness, the requirements are relevant. To be able to be eligible for a temporary exemption, the project developer should submit the following information:

- An economic feasibility study that provides project cost estimates and identifies the source of financing to demonstrate the economic viability;
- A technical feasibility study demonstrating that there are no technical barriers for capturing the required amount of CO<sub>2</sub>, transporting the captured CO<sub>2</sub> to a suitable storage site, and storing the captured CO<sub>2</sub>;
- An implementation plan that provides a description of the work to be done, which is a staged implementation of CCS, with the following requirements:
  - Front-end engineering design study to be carried out by the 1<sup>st</sup> January 2020
  - Major equipment to be purchased by the 1<sup>st</sup> January 2021
  - Contract for CO<sub>2</sub> transport and storage to be in place by the 1<sup>st</sup> January 2022

<sup>11</sup> Government of Canada, Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations (SOR/2012-167) - Regulations are current to 2016-02-03 and last amended on 2015-07-01

<sup>12</sup> Alberta Energy, 2013, Carbon Capture and Storage Summary Report of the Regulatory Framework Assessment

<sup>13</sup> Province of British Columbia Ministry of Natural Gas Development, 2014, Carbon Capture and Storage Regulatory Policy - Discussion and Comment Paper

- Permits and approvals to be obtained by the 1<sup>st</sup> January 2022
- Plant to be able to capture CO<sub>2</sub> by the 1<sup>st</sup> January 2024

In addition to the initial documents submitted in order to be granted a temporary exemption, project developers must submit an implementation report that contains the following information each year following the grant of the temporary exemption:

- Steps taken in that year to construct the required elements of the CCS projects and to integrate these elements with the unit;
- Requirements satisfied in that year;
- Any changes to the proposed engineering design for the CCS project; and
- Description of the steps needed to meet all the remaining requirements and to complete the project by the 1<sup>st</sup> January 2025.

#### **2.1.2.4 Key learnings and best practices**

- Learnings from the Boundary Dam Project suggest that in addition to technical and economic feasibility of the power plant, some important financial and market considerations must be taken into account, including government incentives and the potential market for any by-products such as CO<sub>2</sub> for enhanced oil recovery. Economic feasibility assessments carried out by the project developers in the context of Article 33 may also include these important elements of financial and market considerations and viability of government incentives and value of by-products in the future.
- Alberta's Regulatory Framework Assessment suggests promotion of efficient and fair development of CCS by encouraging CCS project proponents to work together and allowing power plants to apply for access to other operator's pipelines or storage sites. As CCS clusters are expected to be developed in the EU to minimise transport and storage costs, member state competent authorities and governments can support Article 33 implementation by providing guidance on locations of potential clusters in the country-level CCS readiness assessments.
- The Canadian regulations on temporary exemption from meeting an EPS requires power plant developers to submit regular progress reports, in addition to the initial information that must be submitted, to demonstrate the plant will be able to be retrofitted with CCS. Project developers in the EU could be required to submit regular progress reports on the plant's compliance with the CCS Readiness standards, in addition to the initial application documents submitted to qualify as CCSR.

## 2.1.3 United States of America

### 2.1.3.1 Background

The Department of Energy (DOE) considers CCS as a key technology to meeting USA climate targets while ensuring energy security; it therefore provides significant federal funding support for projects to test capture technologies under the Clean Coal Power Initiative, and has awarded \$6.1bn to CCS and clean coal projects to date<sup>14</sup>.

A range of the proposed industrial scale projects are shown in Table 2.3. Government typically provides between 25% and 75% of the total funding of these schemes. Smaller scale grants are available from subsidiary bodies, such as the National Energy Technology Laboratory (NETL) which awarded eight smaller schemes awarded a total of \$25m in September 2015<sup>15</sup>.

**Table 2.3: Large Scale USA CCS Projects in Development**

Project	Description	DOE Funding	EOR	CO <sub>2</sub> storage
<b>Texas Clean Energy Project</b> <sup>16</sup>	Associated with a new build IGCC plant, the engineering studies have been completed and contractual arrangements are under discussion.	\$450m with a further \$637m in tax credits.	Yes	2.4 Mt/year
<b>Petra Nova CC Project, Texas</b> <sup>17</sup>	Associated with the retrofit of unit 8 of the W.A. Parish power plant near Houston, this will be the world's largest post-combustion capture project at a power station when it is launched in late 2016.	\$167m	Yes	1.4 Mt/year
<b>Illinois Industrial</b> <sup>18</sup>	Expected to begin in 2016, this will be the world's first large-scale bio-CCS project, at the Archer Daniel Midlands corn-to-ethanol facility in Decatur.	\$141m	No	1.0 Mt/year
<b>Kemper County Energy Facility</b> <sup>19</sup>	When operational in late 2016, this IGCC plant be the largest CCS power project in the by volume of CO <sub>2</sub> captured. Already over 2 years late and 200% over budget, this project has been beset by delays.	\$270m grant and \$133m in investment tax credits	Yes	3.0 Mt/year

Many states in USA provide financial incentives for CCS including grants, loans, tax incentives, off-take agreements, utility cost recovery mechanisms, and others. The Centre for Climate and Energy Solutions has an online map of financial incentives for CCS in the US.<sup>20</sup>

CO<sub>2</sub>-enhanced oil recovery accounts for a large majority of total CCS projects in the US; with a total CO<sub>2</sub> pipeline network of 3,600km serves over 140 operational EOR oil fields, which

<sup>14</sup> DOE; Clean Coal Power Initiative <http://energy.gov/fe/science-innovation/clean-coal-research/major-demonstrations/clean-coal-power-initiative> (accessed on 22 March 2016)

<sup>15</sup> NETL, Press Release, 2015 <http://www.netl.doe.gov/newsroom/news-releases/news-details?id=b3b81c98-25e0-4698-892d-c7e74b71cad5> (accessed on 22 March 2016)

<sup>16</sup> DOE, Texas Clean Energy Project, <http://energy.gov/fe/texas-clean-energy-project> (accessed on 22 March 2016)

<sup>17</sup> GCCSI, Petra Nova Carbon Capture Project, <https://www.globalccsinstitute.com/projects/petra-nova-carbon-capture-project> (accessed 22 March 2016)

<sup>18</sup> GCCSI, Illinois Industrial CCS Project, <https://www.globalccsinstitute.com/projects/illinois-industrial-carbon-capture-and-storage-project> (accessed on 22 March 2016)

<sup>19</sup> MIT CC&ST Program, Kemper County IGCC Fact Sheet, <https://sequestration.mit.edu/tools/projects/kemper.html> (accessed 22 March 2015)

<sup>20</sup> Centre for Climate and Energy Solutions, *Financial Incentives for CCS*, <http://www.c2es.org/us-states-regions/policy-maps/ccs-financial-incentives> (Accessed on 30 March 2016)

have injected more than 3.5Mt CO<sub>2</sub> to date (there is a total of over 6,000km of CO<sub>2</sub> pipeline in the US)<sup>21</sup>.

Under the DOE CCS Regional Partnerships programmes, USA has taken considerable steps toward “storage readiness”, with the market and infrastructure for CO<sub>2</sub> sequestration largely developed and assessed.<sup>22</sup> Detailed storage resource surveys commissioned by the DOE estimate national onshore capacity for at least 1,800, and possibly as high as 20,000 Gigatonnes of CO<sub>2</sub>, equivalent to at least 600 years of total current emissions output.<sup>23</sup> These surveys can be helpful to project developers, as and when CCS becomes a more established technology in the U.S.

### 2.1.3.2 CCS regulation

The USA Clean Air Act lays out the approaches for new and existing energy generators under Section 111. Recently, EPA finalised two rules under Section 111 of the Clean Air Act to reduce CO<sub>2</sub> emissions of power plants:<sup>24</sup>

- **EPA’s Clean Power Plan for Existing Power Plants:** On August 3, 2015, President Obama and EPA announced the Clean Power Plan to reduce carbon pollution from power plants in the US. Briefly, the Clean Power Plan sets interim and 2030 targets for emission rates for each state, and provides incentives and tools to assist them in meeting these targets.<sup>25</sup> States have the flexibility to choose how to meet their targets. On February 9, 2016, the Supreme Court decided to halt the Clean Power Plan; however, EPA will continue to work with the states. CCS is included in the plan as a compliance measure: “*After consideration of the variety of comments we received on this issue, we are confirming our proposal that CCS is not an element of the BSER, but it is an available compliance measure for a state plan.*”<sup>24</sup>
- **Final Carbon Pollution Standards for New, Modified and Reconstructed Power Plants:** EPA set standards to limit CO<sub>2</sub> emissions from new, modified and reconstructed power plants. These standards are examined in the next section.

Federal regulation of CCS reservoirs comprises two main pieces of legislation; the Underground Injection Control (UIC) Class VI rule<sup>26</sup> which regulates the siting, construction, testing, monitoring, and closure of sequestration wells; and the Greenhouse Gas Reporting Program<sup>27</sup>, which includes requirements on the monitoring of CCS reservoirs.

Additional environmental protections are planned under the *Resource Conservation and Recovery Act*. In addition to the regulation of CCS reservoirs, Class II rules apply specifically to enhanced oil recovery (EOR).<sup>28 29</sup>

<sup>21</sup> Advanced Resources International, 2014, OGI EOR/Heavy Oil Survey

<sup>22</sup> DOE Carbon Storage Monitoring, Verification And Accounting Research, <http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/carbon-storage-monitoring-verification-and> (accessed 22 March 2016)

<sup>23</sup> Environmental Protection Agency, Carbon Dioxide Capture and Sequestration, <https://www3.epa.gov/climatechange/ccs/> (accessed 22 March 2015)

<sup>24</sup> Clean Power Plan for Existing Power Plants, <https://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants> (accessed on 31 March 2016)

<sup>25</sup> EPA, Q&A: EPA Regulation of Greenhouse Gas Emissions from Existing Power Plants: <http://www.c2es.org/federal/executive/epa/q-a-regulation-greenhouse-gases-existing-power> (accessed on 31 March 2016)

<sup>26</sup> EPA, Class VI - Wells used for Geologic Sequestration of CO<sub>2</sub> <https://www.epa.gov/uic/class-vi-wells-used-geologic-sequestration-co2> (accessed 22 March 2015)

<sup>27</sup> EPA, Greenhouse Gas Reporting Program, <https://www.epa.gov/ghgreporting>, (accessed on 25 March 2016)

<sup>28</sup> EPA, Class II Oil and Gas Related Injection Wells <https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells> (accessed on 22 April 2016)

<sup>29</sup> At state level, CCS was identified as an option to reduce emissions from power and industrial emitters in California under both the Low Carbon Fuel Standard (LCFS) and the Cap-and-Trade Program in the First Update to the Assembly Bill (AB) 32 Scoping Plan to achieve the near-term 2020 emissions limit. Source: California Environmental Protection Agency Air Resources Board, 2014, First Update to the Climate Change Scoping Plan (Building on the Framework Pursuant to AB 32)

### 2.1.3.3 Legislation for CCS readiness

Although there is no legislation on CCS readiness in the US, learnings can be withdrawn from the recent Carbon Pollution Standards for New, Modified and Reconstructed Power Plants.

In addition to the newly constructed power plants, the Carbon Pollution Standards apply to some of the existing units, which are modified or reconstructed, as defined by EPA:<sup>30</sup>

- **A new source** is any newly constructed fossil fuel-fired power plant that commenced construction after January 8, 2014.
- **A modification** is any physical or operational change to an existing source that increases the source's maximum achievable hourly rate of air pollutant emissions. This standard would apply to units that modify after June 18, 2014.
- **A reconstructed source** is a unit that replaces components to such an extent that the capital cost of the new components exceeds 50 percent of the capital cost of an entirely new comparable facility. This standard would apply to units that reconstruct after June 18, 2014.

The EPA also introduced different standards for two types of fossil-fuel fired sources (i.e. stationary combustion turbines, generally firing natural gas; and electric utility steam generating units, generally firing coal). Similarly, CCS readiness requirements could be differentiated for coal and gas power plants in the EU.

A summary of the emission standards is shown below:

**Table 2.4: Summary of Carbon Pollution Standards in USA<sup>31</sup>**

Affected Electric Generating Unit	Best System of Emission Reduction (BSER)	Final Standards
Newly Constructed Fossil Fuel-Fired Steam Generating Units	Efficient new supercritical pulverized coal (SCPC) utility boiler implementing partial CCS	1,400 lb CO <sub>2</sub> /MWh-g
Modified Fossil Fuel-Fired Steam Generating Units	Most efficient generation at the affected EGU achievable through a combination of best operating practices and equipment upgrades	1,800 or 2,000 lb CO <sub>2</sub> /MWh-g depending on the heat input
Reconstructed Fossil Fuel-Fired Steam Generating Units	Most efficient generating technology at the affected source (supercritical steam conditions for the larger; and subcritical conditions for the smaller)	1,800 or 2,000 lb CO <sub>2</sub> /MWh-g depending on the heat input
Newly Constructed and Reconstructed Fossil Fuel-Fired Stationary Combustion Turbines	Efficient NGCC technology for base load natural gas-fired units and clean fuels for non-base load and multifuel-fired units	1,000 or 1,030 lb CO <sub>2</sub> /MWh-g for base load natural gas-fired units

Earlier versions of the rule required a more stringent 1,100 lb CO<sub>2</sub>/MWh target, or an average of 1,050 lb CO<sub>2</sub>/MWh averaged over the first 7 years of operation; these have now been relaxed. Also, the standard for natural gas generators (1,000 lb CO<sub>2</sub>/MWh) of which far more are expected to be built by 2020, is insufficiently stringent to require CCS.

<sup>30</sup> EPA, Fact Sheet: Carbon Pollution Standards: <https://www.epa.gov/sites/production/files/2015-11/documents/fs-cps-overview.pdf> (accessed on 31 March 2016)

<sup>31</sup> USA Government, Federal Register Vol. 80 No. 205 Part II: <https://www.gpo.gov/fdsys/pkg/FR-2015-10-23/pdf/2015-22837.pdf> (accessed on 31 March 2016)



#### 2.1.3.4 *Key learnings and best practices*

- Deployment of CCS in USA is primarily motivated by enhanced oil recovery opportunities and government incentives at both federal and state level. These drivers could be included in the economic assessments carried out to demonstrate CCS readiness in the EU. However, an assessment of risks of changes in commodity and CO<sub>2</sub> supply prices should also be considered (particularly given that the economics of EOR is based on relatively strong oil prices)
- USA has taken considerable steps toward “storage readiness”, with the market and infrastructure for CO<sub>2</sub> sequestration largely developed and assessed.
- In addition to the newly constructed power plants, the Carbon Pollution Standards apply to some of the existing units, which are modified or reconstructed. CCS readiness requirements at the Member State level in the EU could also apply to existing power plants that are in the process of being significantly modified or reconstructed considering potential negative impacts of such requirements – e.g. some sensible upgrades might not be done in order to avoid meeting this requirement.<sup>32</sup>
- EPA introduced different emissions standards for natural gas and coal power plants. Similarly, CCS readiness requirements could be differentiated for coal, gas and biomass power plants in the EU Considering potential consequences of differentiation – e.g. less stringent regulations for a fuel type or technology would discourage investment in other fuel types and technologies.

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<sup>32</sup> Requiring readiness at the EU level might require an amendment of Article 33 of the CCSD.

## 2.1.4 Australia

### 2.1.4.1 Background

Given its large coal reserves and high per capita emissions, Australia remains committed to CCS, and has developed a robust legislative framework for the steps and lifecycle of CCS projects.

According to the GCCSI<sup>33</sup>, Australia has a comprehensive legal and regulatory CCS framework. In particular, the Australian framework is well developed in terms of its ease of use, coherence of project licensing and regulatory approval, and the extent to which the legal and regulatory framework provides for the appropriate siting and environmental impact assessment of projects. Despite this, there are some regulatory differences by state, particularly around the difficult issue of long term liability and indemnification.

Currently, three large-scale CCS projects are in development in Australia including the Gorgon Carbon Dioxide Injection Project, which is a gas washing project that will be the largest CCS scheme in the world when operational.

Australia is also cooperating with China in the China-Australia Geological Survey (CAGS) which aims to identify available storage reservoirs in both countries and share knowledge.<sup>34</sup>

### 2.1.4.2 CCS regulation

The *Offshore Petroleum and Greenhouse Gas Storage Act 2006*<sup>35</sup> and supporting legislation are dedicated to the regulation of pipeline transportation, injection and storage of CO<sub>2</sub> in geological formations in offshore areas, and allow for the establishment of a regulatory framework for environment and safety requirements and the award of licenses for the exploration of potential geological storage formations.

The power to assess and accept environment plans has been delegated to the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) under the *Offshore Petroleum and Greenhouse Gas Storage (Environment) Regulations*<sup>36</sup> and the monitoring of these reservoirs is governed by the *Offshore Petroleum and Greenhouse Gas Storage (Greenhouse Gas Injection and Storage) Regulations*<sup>37</sup>.

Australian CCS policy is defined in these three acts and the associated legislation and best practice documents. However, long term risk sharing and insurance of reservoirs are not explicitly addressed in any of the current Australian policy instruments.

### 2.1.4.3 Legislation for CCS readiness

The Australian Labor government of 2010 sought to introduce a CCS readiness standard<sup>38,39</sup>, under which it was proposed that:

- “approval will only be granted to new coal-fired generators which are capable of retrofitting CCS technologies;
- all new coal-fired generators will be required to retrofit CCS technologies within an appropriate time after they become commercially available; and

<sup>33</sup> GCCSI, 2015, [Institute Legal Regulatory Indicator](#)

<sup>34</sup> Australian Government, International Carbon Capture and Storage Project, <http://www.ga.gov.au/about/what-we-do/projects/energy/international-ghg> (accessed 25 March 2015)

<sup>35</sup> Australian Government, 2006, [Offshore Petroleum and Greenhouse Gas Storage Act](#)

<sup>36</sup> Australian Government, 2009, [Offshore Petroleum and Greenhouse Gas Storage \(Environment\) Regulations](#)

<sup>37</sup> Australian Government, 2011, [Offshore Petroleum and Greenhouse Gas Storage \(Greenhouse Gas Injection and Storage\) Regulations](#)

<sup>38</sup> Australian Government, 2010, A Cleaner Future For Power Stations, <http://industry.gov.au/Energy/Documents/sustainability-and-climate-change/DiscussionPaperCleanerFuturePowerStation.pdf>

<sup>39</sup> GCCSI, 2012, CCS ready policy and regulations – The state of play

- the standard for CCS ready, tailored for Australian conditions, will be determined by the Government in consultation with stakeholders.”

The key aspects of the proposed CCS readiness legislation are summarised in the box below. The proposed legislation was put out for stakeholder consultation, with industry contending that the parallel introduction of a carbon tax made the CCSR policy unnecessary. Following the introduction of a carbon tax in the 2011 *Clean Energy Bill*, it was therefore announced in the *Draft Energy White Paper* on 13 December 2011 that the Government would not proceed with the CCS readiness requirements for new coal-fired power plants.<sup>40</sup>

As the carbon tax of around \$23/tonne CO<sub>2</sub><sup>41</sup> was only in operation for 2 years,<sup>42</sup> it is difficult to judge the accuracy of this assessment. To date, no similar CCS requirements have been introduced at the national level.

At the state level, Queensland has had an extant CCSR Policy since August 2009<sup>43</sup>. No new coal-fired power station will be approved in Queensland unless:

- “it uses world’s best practice low emission technology in order to achieve the lowest possible levels of emissions; and
- it is carbon capture and storage (CCS) ready and will retrofit that technology within five years of CCS being proven on a commercial scale.
- Note: in Queensland “CCS ready” means that the proponent must demonstrate plans and milestones for incorporation of CCS.”

The Bluewaters Power Plant in Western Australia (WA) was also made subject to a CCSR requirement<sup>44</sup> in 2009; the relevant conditions are:

- “Condition 7-1 which requires a plant layout figure to be submitted to the EPA which clearly delineates the area of land to be set aside to accommodate carbon capture related plant, and to quarantine it to prevent the construction of non-carbon capture related plant and equipment within it;
- Condition 7-2 which requires progress made towards the implementation of CCS be reported to the EPA; and
- Condition 7-3 which requires retrofitting of carbon capture and storage within five years of the technology becoming economically and technically proven.”

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<sup>41</sup> GCCSI, 2012, CCS ready policy and regulations – The state of play

<sup>42</sup> Australian Government, 2015, *About the Mechanism* <http://www.cleanenergyregulator.gov.au/Infohub/CPM/About-the-mechanism>

<sup>43</sup> Queensland Government, 2009, [ClimateQ: toward a greener Queensland](#)

<sup>44</sup> Western Australia, 2010, Report and Recommendations of the Environmental Protection Agency [http://www.epa.wa.gov.au/epadoclib/1349/rep1349blue3\\_4per8310.pdf](http://www.epa.wa.gov.au/epadoclib/1349/rep1349blue3_4per8310.pdf)

### Key aspects of the proposed CCS readiness legislation in Australia

The suggested Carbon Capture and Storage Readiness (CCSR) criteria comprised six requirements:

1. *“Demonstrate sufficient space and access on site and within the facility to accommodate carbon capture and compression facilities for the majority of the plant’s CO<sub>2</sub> emissions;*
2. *Identify potential areas for long term geological storage of captured CO<sub>2</sub> (meeting the plant’s capture needs)*
3. *Undertake a site specific assessment into the technical and economic feasibility of the CO<sub>2</sub> capture retrofit using one or more technology choices;*
4. *Identify a realistic transport method to identified storage sites;*
5. *Demonstrate measures and approvals that deal with the collection and treatment of pollutants resulting from the capture process and provisions for increased water requirements; and*
6. *Estimate the likely costs of retrofitting capture, transport and storage.*

*Although all of the requirements must be applied, item 6 is classed as the key requirement.”*

Project developers were to be required to provide annual reports to the relevant ministry on the power plant’s compliance with these CCS readiness standards and to update feasibility assessments based on the global CCS situation. The Government proposed to conduct a review every two years to test the commercial availability of CCS, which would consider:

- *“the technical viability of CCS, and whether retrofitting a plant is both operable from an engineering perspective and of a comparable scale;*
- *the operational viability of each element of the technology in conjunction with other elements (i.e. carbon capture along with CO<sub>2</sub> transport and storage); and*
- *Australia-specific factors affecting the commercial availability of equipment.”*

Commercial availability of CCS was defined as:

- *“integration of the entire CCS chain has been proven at a comparable scale and technology in several demonstration plants worldwide;*
- *the systems comprising CCS are readily attainable; and safety and environmental risks (CO<sub>2</sub> leakage) have been minimised. (e.g. the potential for carbon leakage from storage sites)”*

The Government stated that if the report confirmed that CCS was commercially available, it would be mandatory for the power plants to implement the CCS retrofit within four years and complete the construction within seven years.

#### 2.1.4.4 *Key learnings and best practices*

- The proposed CCS Readiness standards in Australia (which never went into force) had similar guidelines as in Article 33. It provided a list of six specific requirements and noted that the primary one was the assessment of likely costs of CCS being eventually deployed on the CCS ready plant, when CCS was deemed commercially ready. Similarly, it might be helpful to have a priority-driven list of requirements in the EU.
- The Australian Government proposed that it would be mandatory for the power plants to implement the CCS retrofit within four years and complete the construction within seven years of the commercial availability of CCS being declared by the Government. The EU may also consider explicitly defining when CCS is “commercially available” and therefore there is an obligation for CCS ready power plants to start deploying CCS.
- The Australian Government proposed to conduct a review every two years to test the commercial viability<sup>45</sup> of CCS, based on the technical, operational and commercial considerations. A similar review could be conducted by the European Commission or Member States in the EU.
- The proposed standards required project developers to provide an annual report to the administering authority on their power plant’s compliance with the CCS Readiness standards. Similarly, project developers in the EU could be required to submit regular progress reports on the CCS readiness status of their plants in addition to the initial application document submitted to comply with Article 33.

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<sup>45</sup> CCS Directive has a similar clause in Article 38.3 but for EPS: “Where permanent containment of CO<sub>2</sub> in such way as to prevent and, where this is not possible, eliminate as far as possible negative effects and any risk to the environment and human health, and the environmental and human safety of CCS have been sufficiently demonstrated, as well as its economic feasibility, the review shall examine whether it is needed and practicable to establish a mandatory requirement for emission performance standards for new electricity-generating large combustion installations pursuant to Article 9a of Directive 2001/80/EC.”

## 2.1.5 China

### 2.1.5.1 Background

China has pledged to reach peak CO<sub>2</sub> emissions by 2030<sup>46</sup>. Around three billion tonnes of CO<sub>2</sub> are emitted each year from China's power plants, with up to 1bn tonnes CO<sub>2</sub> emitted per year through the growing coal-chemical industry<sup>47</sup>. The latter constitutes an opportunity for the early development of CCS, due to their large scale and the low cost of CO<sub>2</sub> separation given the processes involved and potential local EOR opportunities.

Onshore storage is feasible in the north and centre of China, where the main coal-chemical industries are located, but more difficult in the south east, where offshore storage may be the only option.<sup>47</sup>

China has not introduced a carbon tax, but seven pilot cap and trade schemes run at the province level, with a national scheme planned for roll out by 2017<sup>48</sup>. However, due to the scale and concerns around program design, information provision and political acceptability it is likely to be some time before this creates a carbon price of the required order to incentivise CCS.

There are nine large-scale CCS projects, which are being developed in China as identified by GCCSI.<sup>49</sup> China also cooperates with USA and Australia on CCS storage identification and assessment.

### 2.1.5.2 CCS regulation

A number of reports, such as those produced by the Asian Development Bank (ADB), highlight the need for the CCS retrofit of coal power plants currently in or near construction during the 2030's in order to meet China's emissions reductions target. Despite this, no government policy demands the CCS retrofitability of new power generating or industrial facilities.

Although 11 pilot projects are currently in development and more than CNY 3bn (\$0.5bn) have been spent on CCS RD&D, central government remains the only source of support for CCS projects, and there are no operational industrially sized projects.

There is also no developed framework for storage resource assessment and licensing, no large scale market for captured CO<sub>2</sub> for EOR, no legislation around insurance and risk sharing, and no policy around storage assessment and accreditation.

### 2.1.5.3 Legislation for CCS readiness

The ADB report<sup>47</sup> recommends a four phase approach to CCS roll out in China, with definition of a readiness standard and the development of a compensation or incentivisation mechanism the key first steps. In particular, it recommends that the 1,000 GW of coal power plants that will be built in China by 2030 are made CCS retrofitable and are sited within a reasonable distance (less than 200km) of a storage site, in order to mitigate the risk of these assets becoming stranded due to carbon intensity policy; specific examples of suitable plants in planning are given in the report.

The report also points out the key policy and regulatory challenges to the creation of a national CCSR policy, and makes a set of policy recommendations as summarised below.

<sup>46</sup> UNFCCC, 2015, INDCs, <http://www4.unfccc.int/submissions/INDC/Submission%20Pages/submissions.aspx>

<sup>47</sup> ADB, November 2015, Roadmap For Carbon Capture And Storage Demonstration And Deployment In The People's Republic Of China, <http://www.adb.org/publications/roadmap-carbon-capture-and-storage-demonstration-and-deployment-prc>

<sup>48</sup> Carbon Tax Centre, 2016, What About China <http://www.carbontax.org/what-about-china/> (accessed 25 March 2016)

<sup>49</sup> Large-scale CCS projects: <http://www.globalccsinstitute.com/projects/large-scale-ccs-projects> (accessed on 9 March, 2016)

**Table 2.5: Key challenges of CCS Ready in China and recommendations<sup>47</sup>**

Factor	Key challenges	Recommended steps
<b>Commercial</b>	<ul style="list-style-type: none"> <li>• CCS Readiness requires up-front investments in plant design (of the order of less than 0.3% of the total capital cost)</li> <li>• Lack of economic incentives for CCS</li> </ul>	<ul style="list-style-type: none"> <li>• Power plant developers could recover costs through a tariff paid on electricity generated by CCS Ready power plants.</li> <li>• Developers of plants could be asked to maintain CCS Ready planning documents and to report periodically on their CCS Readiness.</li> </ul>
<b>Policy and Regulatory</b>	<ul style="list-style-type: none"> <li>• Absence of a regulatory framework for CCS Ready; unified CCS Ready regulations; and CCS Ready related environmental, safety and other government-defined standards.</li> </ul>	<ul style="list-style-type: none"> <li>• The Government should “clarify the roles and responsibilities of relevant regulatory authorities and establish permitting requirements as well as environmental regulations for CCS”, with CCS Ready regulations integrated with existing approval processes.</li> <li>• A selective CCS Ready approach should be adopted in the power sector. It is recommended that a series of mega-coal power bases in China with a certain capacity (2 GW or higher) “should be sited within 200 kilometres of a major oil field or an assessed storage site”.</li> <li>• Government should ensure compliance is an important part of policy implementation.</li> </ul>
<b>Technical</b>	<ul style="list-style-type: none"> <li>• Developers in China lack definition of CCS Ready criteria; and critical information, such as details of locations and characteristics of suitable CO<sub>2</sub> storage sites and pipelines in China.</li> </ul>	<ul style="list-style-type: none"> <li>• Clear CCS Ready criteria should be set including requirements for capture, transport and storage. These requirements are summarised below.</li> </ul>

The report suggests the following framework for CCS Readiness in China:

“(i) CO<sub>2</sub> capture–ready guidelines are recommended to:

- a. give developers the freedom to choose their preferred CO<sub>2</sub> capture technology;
- b. identify key equipment for the CO<sub>2</sub> capture and compression plant in and integrate it into the design of the power plant;
- c. define a minimum percentage of CO<sub>2</sub> to be captured from the flue gas, which will determine the additional land footprint that must be secured to allow for the retrofit;
- d. require a plant design that will provide sufficient space to integrate the capture and compression plant as well as additional piping and access roads to these plant components;
- e. require developers to (1) review whether municipal regulations necessitate adjustments in the plant design to comply with a maximum height limit for the equipment; (2) assess additional water needs and ways of recycling the cleaned water; and (3) work with concerned authorities to ensure the allocation of additional water to the plant at the same time it is retrofitted with CCS—if additional water is not available through traditional means, techniques like coal drying and water production from underground sources should be evaluated;

- f. *provide guidelines on the treatment of additional wastewater from the CO<sub>2</sub> capture plant; and*
  - g. *ensure that additional risks from capturing CO<sub>2</sub> can be assessed.*
- (ii) *CO<sub>2</sub> transport–ready guidelines are recommended to:*
- a. *require the project developer to (1) choose the technology that guarantees safe transport of liquefied CO<sub>2</sub> from the power plant to minimize social health and environment risks; (2) identify a feasible transport route for the CO<sub>2</sub> to the envisaged utilization or storage site to avoid conflicts over rights-of-way on surface and subsurface land; and (3) establish key design parameters for the transport system, such as transport capacity, pipeline length, pressure, and operating temperature, taking into account the need to meet CO<sub>2</sub> quality specifications;*
  - b. *encourage the developer to explore the option of a pipeline network that links various large CO<sub>2</sub> point sources to reduce unit costs;*
  - c. *ensure that risks from potential low-probability, high-consequence pipeline failure events can be addressed; and*
  - d. *complement the technical feasibility analysis for the power plant with a preliminary economic analysis for transport facilities.*
- (iii) *CO<sub>2</sub> storage–ready guidelines are recommended to:*
- a. *require the developer to identify geological locations that are commercially accessible and technically able to store the full volume of captured CO<sub>2</sub>;*
  - b. *provide guidelines on the selection of suitable formations for CO<sub>2</sub> injection and storage, including (1) adequate depth, (2) adequate confining layers, (3) adequate CO<sub>2</sub> storage capacity of formations, and (4) adequate location, avoiding close proximity to urban agglomerations or protected sites of historic or natural value;*
  - c. *require any conflicting surface and subsurface land uses at the storage site to be identified and addressed;*
  - d. *complement the technical feasibility analysis for the power plant with a preliminary economic analysis for storage, taking into account third-party liability insurance and CO<sub>2</sub> monitoring and verification costs; and*
  - e. *facilitate the preparation and publication of a comprehensive CO<sub>2</sub> storage atlas for the PRC.”*

#### **2.1.5.4 Key learnings and best practices**

- The ADB report provides explicit and separate guidelines for each element of CCS: capture, transport and storage. These guidelines provide specific requirements for project developers to follow.
- The ADB report suggests that all coal power plants of above a threshold size (2 GW or higher) should be sited within 200 kilometres of a major EOR field or geological storage formation. This might not be feasible in the EU as some of the Member States plan to use offshore storage sites – mainly in the North Sea. However, it is possible to identify potential onshore CO<sub>2</sub> capture clusters and potential shoreline hubs that will be connected to the offshore storage sites.
- The ADB report suggests that developers should be encouraged to explore the option of a pipeline network that links various large CO<sub>2</sub> point sources to reduce unit costs. As explained above, CO<sub>2</sub> pipeline networks in the EU are expected to connect onshore CO<sub>2</sub> capture clusters with onshore/offshore storage sites.



- The ADB report recommends that a mechanism allowing power plant developers to recover CCSR costs by introducing a tariff for electricity from a CCS Ready power plant be introduced.
- It is suggested that plant developers be required to maintain CCS Ready planning documents for defined time periods and to report periodically on the CCS Ready status of plants.
- The ADB report suggests that the government could consider including CCS Ready requirements in the approval process of industrial sectors like iron, steel, and cement in addition to power plants. CCS readiness requirements for industrial sites could be developed in the EU.

## 2.1.6 Norway

### 2.1.6.1 Background

Norway operates the world's oldest CO<sub>2</sub> storage facility, a 0.9Mt/yr facility at Sleipner as well as the nearby field at Gudrun and a 0.7Mt/yr storage operation at Snohvit. All of these North Sea gas field operations separate the 10% or so of carbon dioxide from the extracted gas and return it to 3km below the coastal shelf<sup>505152</sup>.

In July 2005, the Norwegian state set up Gassnova, a state enterprise company to stimulate RD&D and commercialisation of industrial scale CCS. Gassnova run a test facility at Mongstad, and are currently developing a pilot scheme at an the cement plant at Norcem Brevik, and may pursue 2 further feasibility projects at Yara Porshrunn (Fertiliser) and Klemetsrud Oslo (Energy from Waste)<sup>53</sup>.

The Norwegian Government plans to deliver at least one large-scale CCS demo project by 2020.<sup>52</sup> Shipping is an attractive transport option for Norway.

### 2.1.6.2 CCS regulation

The Norwegian Government's CCS Strategy focuses on technological development and cost reduction.<sup>52</sup>

The CCS related legal framework in Norway consists of<sup>54</sup>:

- "the Act of 13 March 1981 No. 6 Concerning Protection Against Pollution and Concerning Waste ("Pollution and Waste Act");
- the Act 29 November 1996 No. 72 relating to Petroleum Activities ("Petroleum Act");
- the Act of 21 June 1963 No. 12 relating to Scientific Research and Exploration for and Exploitation of Subsea Natural Resources Other than Petroleum Resources ("the Continental Shelf Act")."

Additionally, CO<sub>2</sub> emissions from petroleum activities are subject to a CO<sub>2</sub> tax in Norway.

Norway has developed legislation on the following subjects<sup>54</sup>:

- Permitting requirements for exploration and CO<sub>2</sub> storage
- Access by third parties to petroleum facilities
- Transport of CO<sub>2</sub>
- Liability under the Pollution, Waste and Petroleum Acts
- Transfer of liability
- Public participation and access to information
- Environmental Impact Assessment

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<sup>50</sup>BGS, CO<sub>2</sub> storage - Sleipner field beneath the North Sea, <http://www.bgs.ac.uk/science/CO2/home.html>

<sup>51</sup> GCCSI, Snohvit, CO<sub>2</sub> storage Project, <https://www.globalccsinstitute.com/projects/sn%C3%B8hvit-co2-storage-project>

<sup>52</sup>Norwegian Government, 14.12.2014, *The Government's carbon capture and storage strategy*, <https://www.regjeringen.no/en/topics/energy/carbon-capture-and-storage/the-governments-carbon-capture-and-storage-strategy/id2353948/>

<sup>53</sup> Mott Macdonald, 2013, *NCCS Status Report Final for Gassnova*, [http://www.gassnova.no/en/Documents/NCCS%20Status%20Report%20Final%20for%20Gassnova%20\(Issued%2030%20Jan%202013\).pdf](http://www.gassnova.no/en/Documents/NCCS%20Status%20Report%20Final%20for%20Gassnova%20(Issued%2030%20Jan%202013).pdf)

<sup>54</sup> GCCSI, *Norwegian CCS legislation*,: <https://hub.globalccsinstitute.com/publications/dedicated-ccs-legislation-current-and-proposed/norwegian-ccs-legislation> (accessed on 1 April 2016)

### 2.1.6.3 *Legislation for CCS readiness*

The CCS legislation in Norway does not explicitly address Article 33 of Directive 2009/31/EC; however, CO<sub>2</sub> emissions from petroleum activities are subject to a CO<sub>2</sub> tax and Norway has already established policy that all new coal-fired generation incorporate CCS from the time of commissioning and operation.<sup>55</sup>

Although there is no explicit CCSR legislation, Norway has been identified by GCCSI as the only country that is prepared for wide-scale storage without CO<sub>2</sub>-EOR.<sup>56</sup>

In order to increase “national storage readiness”, the Norwegian Petroleum Directorate has published a complete version of CO<sub>2</sub> atlas identifying possible CO<sub>2</sub> storage sites on the Norwegian Continental Shelf. The atlas is based on the following information:<sup>57</sup>

- Information from more than four decades of petroleum activity in Norway – hydrocarbon project developers have to make a lot of geological information publically available;
- the ongoing CO<sub>2</sub> storage projects – i.e. Sleipner and Snøhvit;
- Norwegian R&D;
- Climit; UNIS CO<sub>2</sub> Lab; and other EU projects on storage and monitoring.

### 2.1.6.4 *Key learnings and best practices*

- Norway has increased “national storage readiness” by establishing CCS legislation, developing a detailed CO<sub>2</sub> Atlas and gaining experience from operational CO<sub>2</sub> storage projects. Article 33 requires power plants with a rated electrical output of 300 megawatts or more to identify suitable storage sites are available. As project developers in the EU rely on the data developed by the Member States, it is important that detailed/all data on bankable/practical storage capacity is available for potential project developers.
- Strong CCS policies or regulations (e.g. requiring all new fossil fuel-fired power plants to install CCS) may make CCS readiness requirements redundant. Similarly, in the EU, if CCS becomes mandatory, then Article 33 implementation is not necessary for power plants.
- For instance, if new power plants are required to consider storage site access (or proximity to potential onshore CO<sub>2</sub> capture clusters and shoreline hubs) as one of the key criteria for siting, then these power plants can be connected to storage sites through large-scale shared CO<sub>2</sub> pipelines or shipping, project developers may not be required to identify suitable storage sites solely for their projects.

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<sup>55</sup> GCCSI, 2012, CCS ready policy and regulations – The state of play

<sup>56</sup> Global CCS Institute, 2015, Global Storage Readiness Assessment

<sup>57</sup> Norwegian Petroleum Directorate, 2014, CO<sub>2</sub> Storage Atlas – Norwegian Continental Shelf

## 2.2 Other case studies and reports on CCS readiness

This section gives a generic definition of CCS readiness and summarises other relevant case studies and reports on CCS readiness.

### 2.2.1 Generic definition of CCS readiness

#### 2.2.1.1 *International Definition of CCS Ready*<sup>58</sup>

ICF International and its partners developed an internationally recognised definition of “CCS Ready” for the Global CCS Institute in 2010. The proposed international definition of “CCS Ready” includes the following components:

- **Components of capture readiness:** Plant site selection; technology selection; design for capture facilities; space allowance; and equipment pre-investment
- **Components of transport readiness:** Transport method; CO<sub>2</sub> transport corridor selection; and design of transport facilities
- **Components of storage readiness:** Storage site selection; verifying injectivity, capacity, and integrity of storage site; and design of storage facility
- **Common components of CCS readiness:** Conflicting uses and rights; cost estimates for CCS facilities; environmental, safety and other approvals; public awareness and engagement; sources for equipment, material and services; and ongoing obligations (i.e. file periodic reports with regulators on status of CCS readiness)

The detailed requirements for each component shown above are presented in 0. The detailed requirements are presented at three different levels of stringency. The study explains the three levels as follows:

- **Level 1** has the lowest cost and time expenditures for compliance by project developers and allows for the greatest amount of flexibility;
- **Level 2** increases requirements through a greater level of design development for the capture facility; selection of transport corridors; and enhanced modelling of storage location, including desktop study of injectivity, capacity, and integrity; and
- **Level 3** identifies the specific capture technologies to be retrofitted, requires acquisition of transport rights of way, establishes planning requirements, and requires geological exploration.

#### *Key learnings*

- CCS readiness is defined by each of element of CCS (capture, transport, and storage)
- Three different levels of CCS readiness are described in the report, allowing for different levels of stringency to be applied to project developers.
- The proposed definition of “CCS Ready” requires power plant developers to file periodic reports (e.g. annually or biennially) after the initial assessment to confirm the CCS readiness of the plant.

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<sup>58</sup> ICFI for GCCSI, 2010, *Defining CCS Ready: An Approach to an International Definition*

### 2.2.1.2 Definition of storage readiness

The Global CCS Institute has recently assessed 61 countries' readiness for large-scale CO<sub>2</sub> geological storage projects and concluded that United States, Canada, Norway and Brazil are prepared for large-scale storage.<sup>59</sup>

For the countries identified as having conventional storage potential, the assessment methodology includes the following criteria:

- **Regional potential:** whether the country has any suitable storage potential
- **Regional assessment:** based on the level of detail the country has completed in their assessments of national storage potential
- **Dataset:** whether the country has any data/datasets on deep sedimentary basins (e.g. exploration data or appraisal data)
- **Assessment maturity:** based on the country's understanding of their storage potential (e.g. regional to country-wide or theoretical to practical capacity assessment)
- **Pilot and/or commercial project:** whether the country has enabled deployment of CCS projects
- **Knowledge dissemination:** whether the country has engaged in any dissemination activities.

All of the important criteria shown above are clearly outside the control of the individual project developers, which suggests that a new power plant's level of "CCS readiness" depends on the storage readiness of the country/region in which the plant is located. It is therefore important that detailed data on bankable/practical storage capacity is available to potential project developers.

The report also recommends regional collaboration on storage assessments as this enables countries with low storage potential to use storage in other countries; allow more advanced countries to assist other countries with fewer resources; and encourages the transfer of methodologies and knowledge.

#### Key learnings

- It is challenging for a project developer to be CCS ready unless the country in which the power plant or industrial site is located is CO<sub>2</sub> storage-ready at the national level.
- Regional collaboration on carrying out multi-country storage assessments is recommended to increase the level of storage readiness at the regional level.

### 2.2.1.3 CO<sub>2</sub> capture ready plants<sup>60</sup>

This 2007 IEA report studies capture readiness in the power sector, with a particular focus on coal power plants. It reviews the literature and gives a summary of the components of CCSR, as well as a precis of the CCS technology options, and the costs and revenues from CCSR based on technology and retrofit date.

It offers the following definition of CCSR, which aims to reduce the risk of stranded assets and 'carbon lock-in':

*"A CO<sub>2</sub> capture ready power plant is a plant which can include CO<sub>2</sub> capture when the necessary regulatory or economic drivers are in place."*

The major findings of the report are that the CCSR pre-investment, while small compared to the overall plant costs, are unlikely to represent an attractive economic proposition if the date

<sup>59</sup> GCCSI, 2015, Global storage readiness assessment: an approach to assessing national readiness for wide-scale deployment of CO<sub>2</sub> geological storage projects

<sup>60</sup> IEA GHG R&D, 2007, CO<sub>2</sub> capture ready plants

of CCS retrofit is a significant period of time after the plant commissioning date, due to the discounting of the future revenues associated with carbon capture.

The report includes an important caveat that is still valid today:

*“None of the technologies is yet in operation at a full commercial scale and therefore there are a number of risks involved in the application of the technologies. These include [that] there is no commercial reference to establish the base cost of each of the technologies and therefore cost estimates are, at best, very approximate.”*

It also reviews the CCS technology options for combined cycle gas turbines (CCGT), but finds that these are a more expensive abatement opportunity than for coal power plants; it does not therefore include any CCSR recommendations for natural gas plants.

#### **2.2.1.4 Carbon Capture and Storage Progress and Next Steps<sup>61</sup>**

This IEA report was prepared with the cooperation of the GCCSI, to coincide with the 2010 Muskoka G8 Summit. It reviews the progress made on CCS across G8 member states and beyond in the context of the pledges made at the 2008 summit. As such the focus is mainly on the global project pipeline, and the national incentivisation of and progress toward commercial scale CCS.

#### **2.2.1.5 Definition of carbon capture and storage ready (CCSR)<sup>62</sup>**

The following definition of a CCSR facility is offered by this 2010 document, which was written by the CSLF:

*“A CCSR facility is a large-scale industrial or power source of CO<sub>2</sub> 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<sub>2</sub> mitigation option, but a way to facilitate CO<sub>2</sub> 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.”*

On CCSR and retrofit, the report outlines a preliminary set of minimum qualifying criteria for a CCSR plant in a bespoke annex; these are technical, operational and economic studies that should be commissioned by the project operator and signed off by the regulator, specifically:

- *“Carry out a site-specific study in sufficient engineering detail to ensure the facility is technically capable of being fully retrofitted for CO<sub>2</sub> 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<sub>2</sub>.*
- *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<sub>2</sub>.*

<sup>61</sup> IEA/CSLF, 2010, Carbon Capture and Storage Progress and Next Steps

<sup>62</sup> IEA/GCSI/CSLF, 2010, Definition of carbon capture and storage ready (CCSR)

- *Identify other known factors, including any additional water requirements that could prevent installation and operation of CO<sub>2</sub> 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.”*

Though the report considers that more or less stringent implementations of these rules may be appropriate in individual countries or regions.

A caveat associated with the aforementioned criteria is also stated:

*“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.”*

#### **2.2.1.6 Assessment of clean-coal strategies: The Questionable Merits of Carbon Capture Readiness<sup>63</sup>**

This 2015 paper examines the value of the CCS readiness of new coal plants through a bespoke Capital Asset Pricing Model (CAPM)<sup>64</sup> model, and compares this value to alternative plant operator emissions reduction options, such as premature decommissioning, across a variety of probability weighted coal, electricity and carbon price scenarios out to 2050. It then quantifies under which of these scenarios CCS retrofit for CCSR and non-CCSR plants is value positive.

The study argues that although CCS readiness dramatically increases the likelihood of CCS retrofit for a new coal power plant, the preferred compliance option for a plant operator may be to decommission that plant and construct a new CCS facility when CCS becomes commercially available, even where this is a short period into the plant lifespan.

*“... we find that the option of replacing older power plants including a premature shut-down with a new CCS power plant is, in the majority of investigated scenarios, found to be the preferred choice. In addition, we show that the option of replacing a new conventional coal-fired power plant (built in 2015) with a new CCS power plant is also much more likely than retrofitting a non-capture-ready or even a capture-ready power plant.*

*For the value of capture-readiness, we conclude that, although capture-readiness increases the chance of a retrofit strongly in comparison to a non-capture-ready power plant, the chances of conducting a retrofit are still low due to the additional option of a premature shut-down in combination with a new-build CCS power plant.*

*Expenditures for capture-readiness should therefore be well-deliberated.”*

<sup>63</sup> Wilko Rohlf, Reinhard Madlener, 2013, Assessment of clean-coal strategies: The Questionable Merits of Carbon Capture Readiness

<sup>64</sup> CAPM models value investment opportunities based on their volatility relative to the market, and their returns relative to those of a risk free instrument, typically 10 year government bonds, and to index funds which track market performance.

### 2.2.1.7 *Planning and Cost Assessment Guidelines for Making New Coal-Fired Power Generation Plants in Developing APEC Economies CO<sub>2</sub> Capture-ready*<sup>65</sup>

This 2010 report describes work done by the Australian engineering firm Aurecon in developing CCS readiness guidelines for APEC member states. The scope of this work relates primarily to plant readiness, using the 2007 IEA definition, but it makes incidental reference to wider infrastructure issues.

Given the report date, much of the analysis concerns uncertainty around legal, financial, incentives and technological barriers to CCS readiness. It explains in some detail the breakdown of the technical requirements and economic costs for plant CCS readiness, going into particular detail on a case study for the very common 600MW plant. The report also includes a review of CCSR capacity of nations in the Asia Pacific region. On the technical plant CCSR definition, it makes reference to the fact that some plants will already have implemented CCSR steps, such as flue gas desulphurization and de-NO<sub>x</sub> equipment installation.

The report caveats the fact that considerable further analysis is required of APEC storage readiness, energy plans of some of the member states, global review of mechanisms for CCSR incentives, and the relative merits of the various technology options and associated industry experience, before national or regional CCSR designations can be sensibly implemented.

**Table 2.6: Range of pre-investment required for capture-readiness**<sup>65</sup>

Level of Pre-investment	Required plant modifications
<b>Low</b>	<ul style="list-style-type: none"> <li>• Identification of CO<sub>2</sub> storage options</li> <li>• Allocation of plant space for additional equipment: CO<sub>2</sub> scrubber, solvent regenerator, CO<sub>2</sub> compressor, auxiliary boiler, ducting and possible booster induced draft fan.</li> </ul>
<b>Medium</b>	<ul style="list-style-type: none"> <li>• Identification of storage options</li> <li>• Turbine steam piping modifications for future take-off</li> <li>• Allocation of plant space for additional equipment: CO<sub>2</sub> scrubber, solvent regenerator, CO<sub>2</sub> compressor, ducting and possible booster induced draft fan.</li> </ul>
<b>High</b>	<ul style="list-style-type: none"> <li>• Identification of storage options</li> <li>• Over-sized boiler for future steam take-off</li> <li>• Allocation of plant space for additional equipment: CO<sub>2</sub> scrubber, solvent regenerator, CO<sub>2</sub> compressor ducting and possible booster induced draft fan.</li> </ul>

<sup>65</sup> Aurecon, 2010, Planning and Cost Assessment Guidelines for Making New Coal-Fired Power Generation Plants in Developing APEC Economies CO<sub>2</sub> Capture-ready



## 2.2.2 Country-specific case studies

### 2.2.2.1 Eskom Generation Project in South Africa

In 2008 the South African state energy company Eskom was commissioned to build 2 coal power plants at Kusile and Medupi, which at around 4,800 MW would be the third and fourth largest coal power plants in the world<sup>66</sup>. Kusile was to be constructed as a CCS ready plant<sup>67</sup>; under a standard based on the IEA 2007 definition, though the Environmental Impact Assessment is not publicly available<sup>68</sup>.

*“a CO<sub>2</sub> capture-ready power plant is a plant which can include CO<sub>2</sub> capture when the necessary regulatory or economic drivers are in place”*

In 2015, ESKOM reported that while the plant has been built as CCS ready, the national policy framework does not support CCS and that in particular:

*“Stipulating carbon capture readiness in the Record of Decision (RoD) is not considered to be a sufficient regulatory framework for the actual deployment of CCS – transport and storage are still lacking.”<sup>68</sup>*

The above point is key in that ESKOM has argued that stipulating capture readiness without any regulatory framework for CCS deployment does not make sense.

However, the South African Centre for Carbon Capture and Storage (SACCS) have made some progress in developing national capture readiness, including the creation of an atlas of potential storage locations<sup>69</sup>, as part of their roadmap to 2025 commercial delivery of CCS.

ESKOM also pointed out that European and North American CCS operation and therefore capture and storage ready requirements are not directly transferable to South Africa, given the lack of available geological formations, lower grade coal stock and higher ambient temperatures.

### 2.2.2.2 CCS for Coal-fired Power Plants in Indonesia

The 2015 World Bank report *CCS for Coal-fired Power Plants in Indonesia*<sup>70</sup> defines and evaluates the conditions under which fossil fuel power plants could be deemed as CCS Ready (CCSR), based on analyses of two archetypal candidate power plant designs: a 2 x 1000 MW lignite-fired power plant and a 1 x 600 MW coal power plant, modelled as commissioned in 2020 and 2022, respectively. It concludes that both candidate plants can be made CCSR at minimal capital cost increases and only minor modifications to the central generating plant, though there is an energy penalty of around 30% at a 90% capture rate based on the modelled amine capture technology.

On CCSR in Indonesia, it finds the lack of policy and institutional support is a key barrier for CCS implementation in Indonesia, and that institutional, legal and regulatory frameworks around operation and monitoring need to be established, as well as support mechanisms that capture the environmental value of CCS. It recommends the creation of a national climate policy that supports CCS and the creation of a Road Map to Commercial Scale CCS rollout. It also encourages concerted government action along the CCS value chain, particularly for EOR.

<sup>66</sup> ESKOM, 2011, *COP17 Factsheet* [http://www.eskom.co.za/OurCompany/SustainableDevelopment/ClimateChangeCOP17/Documents/Kusile\\_and\\_Medupi\\_coal-fired\\_power\\_stations\\_under\\_construction.pdf](http://www.eskom.co.za/OurCompany/SustainableDevelopment/ClimateChangeCOP17/Documents/Kusile_and_Medupi_coal-fired_power_stations_under_construction.pdf)

<sup>67</sup> DEAT, 2007, *Kusile Power Station Record of Decision*, [http://web.eskom.co.za/tenderbulletin/File\\_Show.asp?ID=119574](http://web.eskom.co.za/tenderbulletin/File_Show.asp?ID=119574)

<sup>68</sup> ESKOM, 2015, *CO<sub>2</sub> Capture - Technicalities of Attaching a Capture Plant To Eskom's Power Stations*, <http://www.sacccs.org.za/wp-content/uploads/2015/CCS%20Conference/2015%20CCS%20Conference%20-%20Retrofit%20CC%20-%20MacColl%20Eskom.pdf>

<sup>69</sup> SACCS, 2010, *Atlas on geological storage of carbon dioxide in South Africa* <http://www.sacccs.org.za/wp-content/uploads/2010/11/Atlas.pdf>

<sup>70</sup> World Bank, 2015, *CCS for Coal-fired Power Plants in Indonesia*

To close the technical and financial gap, it recommends that:

- CCS Readiness provisions be mandated for new power plants, perhaps through their inclusion in Power Purchase Agreements (PPAs)
- The government provides policy incentives for future CCS implementation, and initiates CCS pilot and demonstration activities.

It also advocates the establishing of an Indonesian Centre of Excellence in CCS technology, similar to the Norwegian Gassnova that builds technical and economic capability, develops an understanding of CCS in Indonesian conditions and promulgates the opportunities and limitations of CCS.

### **2.2.2.3 *CO<sub>2</sub> capture-ready Ultra Mega Power Projects in India***

The 2008 Mott MacDonald, *CO<sub>2</sub> capture- ready UMPPs in India* report<sup>71</sup> examines the opportunities for CCS at the nine 4,000MW Ultra Mega Power Projects (UMPPs) in development in India. It estimates the cost of plant capture readiness at less than 1% of total plant capex (at up to £50m) and an effective 2020 abatement cost of \$33/tonne CO<sub>2</sub> at an 85% capture rate.

Given the 2008 publication date and the technical focus of the report, there are few CCSR findings in the document. It posits that a cost benefit analysis is sufficient to ensure CCS readiness, even though the policy, regulatory and incentive frameworks for CCS are not well developed. It notes the need for government action to define plant CCS readiness, incorporating technical, transport and storage assessments, and to assist in the investment to produce capture ready UMPP design, the process of which would include:

- A technical and financial assistance package to the UMPP developer;
- As part of the above assistance package, an offer for secondment of international experts to the selected UMPP developer to assist with capture-ready design;
- Detailed exploration of routes to storage, including permitting and regulatory barriers to pipeline construction and exploration of export by ship where possible for the relevant site;
- Geological surveying of potential CO<sub>2</sub> storage locations relevant to the specific plant, and of CO<sub>2</sub> storage capacity for all of India;
- Development of detailed thermal performance and economic appraisal tools, focussed on specific UMPP sites; and
- A general review of regulatory barriers to CCS in India, identifying changes required to legislation and planning law before CCS retrofit to capture-ready plants, and the associated investor risks.

### **2.2.2.4 *Large-scale storage of CO<sub>2</sub> on the Norwegian shelf: Enabling CCS readiness in Europe***<sup>72</sup>

This 2013 report reviews Norwegian progress on the path to storage readiness for geological formations in the Norwegian North Sea. It concludes that while there are no insuperable barriers, greater technical knowledge will need to be developed, especially in geological modelling of long term CO<sub>2</sub> migration, trapping mechanisms, reservoir pressure estimation and seal integrity. It makes the point that good quality data in these areas is expensive to obtain, and given the lack of obvious investment customers for the service, and the scarce financial incentives, this means that very little of it exists.

It finds that in particular:

<sup>71</sup> Mott MacDonald, 2008, *CO<sub>2</sub> capture- ready UMPPs in India*

<sup>72</sup> Grethe Tangen and Erik G. B. Lindeberg, Arvid Nøttvedt, Svein Eggen, 2013, *Large-scale storage of CO<sub>2</sub> on the Norwegian shelf: Enabling CCS readiness in Europe*

*“To enable CO<sub>2</sub> storage readiness by 2018, full reservoir simulations of CO<sub>2</sub> injection in selected targets should be conducted to demonstrate applicability of existing models and simulation tools, and to pinpoint critical limitations that must be addressed.”*

In order to achieve large-scale development solutions and infrastructure for CO<sub>2</sub> storage in Norway, the study identified the following technical and non-technical gaps including development of design specifications for offshore CO<sub>2</sub> injection into saline aquifers; implications of using CO<sub>2</sub> as a primary method for oil production; business model for large-scale CO<sub>2</sub> infrastructure; and CO<sub>2</sub> transportation across international borders.

#### **2.2.2.5 The GDCCSR project promoting regional CCS Readiness in the Guangdong province, South China<sup>73</sup>**

This report gives an interim summary of the 3 year *Guangdong, China's First CCS Ready Province*, (GDCCSR) a regional CCSR project. Guangdong is a coastal province; and the GDCCSR concludes that all viable storage reservoirs are offshore. The capacity of the offshore formations is assessed in the referenced 2009 *CO<sub>2</sub> Point Emission and Geological Storage Capacity in China*, though this is a very preliminary report in the process toward storage readiness. The depleted undersea oil and gas field at the Pearl River mouth basin is identified as particularly well suited to use as a CO<sub>2</sub> reservoir, with potential for EOR, and the report suggests that it should be CCSR assessed, though no subsequent, more detailed work appears to have been in this area.

Although the Provincial Government stated in March 2010 that no further unmitigated coal plants would be permitted in Guangdong, GDCCSR modelling suggests that they key driver of CCS rollout will be the price of carbon relative to the price of storage. The value of CCS readiness was modelled by the project for a plant of the 1GW scale (over 30 GW were in construction or in planning at the time of writing), which finds that plant CCSR increases the likelihood of retrofit by 5-8% and brings the optimal CCS retrofit year forward. It also finds CCS retrofit has a large NPV, but the carbon price assumptions are not visible in the report.

Finally, it assesses the value of creating a CCS Ready Hub at the province level, and finds that this reduces emission abatement costs by around 20%; however, no further details are provided in the report.

*“In contrast with making an individual project carbon capture ready, ‘CCS Ready Hub’ is a concept which requires implementation CCR at a regional level. Building a CCS Readiness Hub would not only require the CCR design in new plants, but also assess the economics of retrofitting existing power plants. Modelling results show that if ‘CCS Ready Hub’ concept is applied for the Shenzhen city, which is the city adjacent to Hong Kong, the average CO<sub>2</sub> abatement cost of CCS retrofit in 2020 will be reduced by ~20%.”*

#### **2.2.2.6 The potential for equipping China's existing coal fleet with carbon capture and storage<sup>74</sup>**

This report assesses the potential for retrofitting 310 GW (55%) of China's existing coal-fired power capacity with carbon capture and storage capabilities. A major contributor to global energy-related CO<sub>2</sub> emissions, China released 8.6 billion tonnes of CO<sub>2</sub> in 2014, with coal-fired power stations representing about 50% of these emissions. Ultimately, the report concludes that emissions rates can be reduced by 85% through the application of CCS to existing power stations.

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<sup>73</sup> Di Zhou, Daiqing Zhao, Qiang Liu, Xiao-Chun Li, Jia Li, Jon Gibbins, Xi Liang, 2013, The GDCCSR project promoting regional CCS readiness in the Guangdong province, South China<sup>73</sup>

<sup>74</sup> OECD/IEA, 2016, The potential for equipping China's existing coal fleet with carbon capture and storage

A key driver in the feasibility of CCS implementation for a given coal-fired power station is the distance between it and a suitable storage location. The study suggests that 385GW of China's installed capacity from coal-fired plants is within a 250km radius of such a location.

In terms of retrofitting existing plants, the report finds that although 55% of installed CEC (China Electricity Council) capacity could utilise CCS, it is conceivable that a much greater proportion of plants constructed post-2015 could be retrofitted at a reduced cost.

Overall, for an adequate assessment of CCS readiness, the following factors must be considered:

- *"The likely longevity of the proposed coal-fired plant under anticipated Chinese policies relating to local pollution, climate change and natural resources.*
- *Design of the power plant unit to ensure that heat can be provided with minimal impact on power generation efficiency, either from the steam turbine or an external heat source.*
- *Impact of the retrofit on local water availability.*
- *Distance to a good quality CO<sub>2</sub> storage site with adequate capacity for the expected lifetime of the retrofitted plant, and without likely competition from other CO<sub>2</sub> capture plants in the "carbonshed"<sup>75</sup> that might prevent the future retrofit.*
- *Reservation of sufficient available space on site for the CO<sub>2</sub> capture equipment.*
- *The possible pipeline routes if the plant is to use onshore CO<sub>2</sub> storage, and whether they are likely to pose any significant geographic, political or social challenges, either now or in the future.*
- *The total expected economic costs and benefits of the future retrofit in comparison with other possible new build plant locations and designs, taking into account such factors as the respective future values of imported and domestically produced coal, the needs of the local and national power grids and the policy options for rewarding low carbon electricity generation.*
- *How the conditions for supporting the future retrofit will be maintained and developed during the operation of the unit before the time of retrofit."*

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<sup>75</sup> "Carbonsheds" are regions analogous to watersheds in which the estimated cost of transporting CO<sub>2</sub> from any location in the region to the storage site it encompasses is cheaper than piping the CO<sub>2</sub> to a storage site outside the region. Building on the discussion in this study, this definition can be extended to include the combined costs of CO<sub>2</sub> transport and storage, and not the transport costs alone.

### 3 Conclusions

A review of CCS Readiness legislation, studies and experience globally has provided important learnings that could be useful to developing Article 33 guidance. The review has considered relevant legislation in Canada, the US, Australia, China and Norway, and other case studies and reports on CCS readiness.

From these key learnings, which are summarised in the table below, conclusions have been developed.

**Table 3.1: Key learnings and recommendations for the EU Member States**

Global best practices and key learnings	Conclusions in the context of Article 33	Storage readiness	Transport readiness	Capture readiness	Economic feasibility
1. USA has taken considerable steps toward “storage readiness”, with the market and infrastructure for CO <sub>2</sub> sequestration largely developed and assessed.	1. <b>Increasing storage readiness in the EU:</b> EU Member States could increase their storage readiness by carrying out collaborative multi-country storage assessments, developing CO <sub>2</sub> storage datasets, appraising storage units and supporting CO <sub>2</sub> storage projects. These requirements are already called for in Article 4(2) of the CCS Directive. To comply with Article 33, all combustion plants with a rated electrical output of 300 megawatts or more are required to ensure that suitable storage sites are available. As project developers in the EU rely on the available data on storage availability developed by the Member States, it is important that detailed data on bankable/practical storage capacity is available to potential project developers.	✓			
2. It is challenging for a project developer to achieve CCS readiness unless the country in which the power plant or industrial site is located is CO <sub>2</sub> storage-ready.					
3. Regional collaboration for carrying out multi-country storage assessments is recommended to increase the level of storage readiness.					
4. Norway has achieved storage readiness by establishing CCS legislation, developing a detailed CO <sub>2</sub> Atlas and gaining experience from two CO <sub>2</sub> storage projects.					
5. The Canadian regulations on temporary exemption from	2. <b>Periodic progress reports:</b> Power plant developers in the EU	.	.	.	.

<p>meeting an EPS requires power plant developers to submit regular progress reports, in addition to the initial information that must be submitted, to demonstrate the plant will be able to be retrofitted with CCS.</p>	<p>could be required to submit periodic progress reports to report on the CCS Ready status of the plant considering the CCS development (e.g. new capture technologies, better data on storage potential, etc.) and market conditions (e.g. fuel prices, Government incentives, carbon price, etc.). Power plant developers may be required to review:</p> <ul style="list-style-type: none"> <li>a. storage suitability considering the most up-to-date data on sites;</li> <li>b. technical and economic feasibility of transport, considering the availability of nearby over-sized transport and storage infrastructure; and</li> <li>c. technical and economic feasibility of CO<sub>2</sub> capture, considering cost reductions achieved and fuel prices.</li> </ul>				
<p>6. The proposed definition of “CCS Ready” by GCCSI requires power plant developers to file periodic reports (e.g. annual or biennially) after the initial assessment to confirm the CCS readiness of the plant.</p>					
<p>7. The proposed CCS Readiness standards in Australia (which never went into force), required project developers to provide an annual report to the administering Authority on the power plant’s compliance with the CCS Readiness standards.</p>					
<p>8. It is suggested that plant developers should be required to maintain CCS Ready planning documents for defined time periods and to report periodically on the CCS Ready status of plants in China.</p>					
<p>9. The ADB report suggests that all coal power plants of above a threshold size (2 GW or higher) should be sited within 200 kilometres of a major EOR field or geological storage formation in China.</p>	<p>3. <b>Identification of locations of potential CO<sub>2</sub> capture and storage clusters and feasible CO<sub>2</sub> pipeline routes within the EU:</b> As CCS clusters are expected to be developed in the EU to minimise transport and storage costs, locations of potential clusters could be considered in the CCS readiness assessments. To achieve CCS Readiness, power plants in the EU could be required to be located close to potential onshore CO<sub>2</sub> capture clusters and shoreline hubs. These could be identified by the EC and/or Member States by considering potential CO<sub>2</sub> transport routes from onshore CO<sub>2</sub> clusters to shoreline hubs / ports. If power plant developers can demonstrate that it is feasible to capture and transport CO<sub>2</sub> to a nearby potential cluster, which will likely be connected to storage sites through large-scale shared CO<sub>2</sub> pipelines or ships, project developers may not be required to identify suitable storage sites specifically for their projects.</p>	✓	✓		
<p>10. Alberta’s Regulatory Framework Assessment promotes efficient and fair development of CCS by encouraging CCS project proponents to work together and allowing power plants to apply for access to another operator’s pipelines or storage sites.</p>					
<p>11. The ADB report suggests that developers should be encouraged to explore the option of a pipeline network that links various large CO<sub>2</sub> point sources to reduce unit costs.</p>					

12. Three different levels of CCS readiness are described by GCCSI with different levels of stringency.	<p><b>4. Increasing the level of required CCS readiness over time:</b> The Member States could require different levels of CCS readiness as the CCS market develops (e.g. Level 1 before 2020, Level 2 between 2020 to 2025 and Level 3 after 2025) – an even more stringent regulation could require all new fossil fuel-fired power plants to install CCS from the time of commissioning. Compliance with increasing CCS readiness requirements could be demonstrated by submitting periodic progress reports as recommended above.</p>				
13. The proposed CCS Readiness standards in Australia (which never went into force) provided a list of six specific requirements and noted that the primary one was the assessment of likely costs of CCS being eventually deployed on the CCS ready plant, when CCS was deemed commercially ready. Similarly, it might be helpful to have a priority-driven list of requirements in the EU.		✓	✓	✓	✓
14. Strong CCS policies or regulations (e.g. requiring all new fossil fuel-fired power plants to install CCS) may make CCS readiness requirements redundant.					
15. The ADB report suggests that the government could consider including CCS Ready requirements in the approval process of industrial sectors like iron, steel, and cement in addition to power plants.	<p><b>5. Industrial CCS readiness:</b> CCS Readiness requirements for the energy-intensive industrial sectors including cement, chemicals, refining, and iron and steel may be developed by the EC. Existing and/or new energy-intensive industrial sites may then be required to be CCS ready.</p>			✓	
16. Learnings from the Boundary Dam project suggest that in addition to technical and economic feasibility of the power plant, some important financial and market considerations must be taken into account including government incentives, and the potential market for any by-products including CO <sub>2</sub> -enhanced oil recovery.	<p><b>6. CO<sub>2</sub> utilisation opportunities and Government incentives:</b> Economic feasibility assessment carried out by the project developers in the EU to demonstrate CCS Readiness could consider any available government incentives and potential market for any by-products including CO<sub>2</sub>-EOR. Although the carbon price in the EU is still low, potential government incentives and/or potential market for any by-products including CO<sub>2</sub>-EOR may improve commercial feasibility of CCS retrofit in the EU.</p>				
17. Deployment of CCS in USA has been driven by enhanced oil recovery opportunities and Government incentives at both federal and state level.					✓
18. The OECD/IEA report on CCS retrofit in China suggests that likely longevity of the proposed coal-fired plant under anticipated Chinese policies relating to local pollution, climate change and natural resources should be considered for an adequate assessment of CCS readiness					

<p>19. In addition to the newly constructed power plants, the Carbon Pollution Standards in USA apply to those existing units which are modified or reconstructed. CCS readiness requirements in the EU could also apply to existing power plants where they are modified or reconstructed.</p>	<p>The following recommendations could be considered in the longer term although they may not be required in the EU in the near term:</p> <ul style="list-style-type: none"> <li>• CCS readiness requirements in the EU could also apply to existing power plants where they are modified or reconstructed.</li> <li>• CCS readiness requirements could be differentiated for different types of fuel types (e.g. coal, gas, biomass, etc.) and for different technologies (e.g. open cycle gas turbine, combined cycle gas turbine, integrated gasification combined cycle, combined heat and power, etc.) for the power plants in the EU.</li> <li>• If more stringent requirements for CCS readiness are introduced in the EU, an incentive mechanism allowing power plant developers to recover stringent CCSR costs through could be introduced in the EU.</li> <li>• European Commission and/or Member States may consider periodically reviewing CCS market conditions to confirm commercial availability of CCS in the EU. Capture-ready power plants in the EU might be required to be retrofitted with CCS within a reasonable time, once CCS is judged to be commercially available. This would reduce the risk of 'carbon lock-in' in the EU.</li> </ul>
<p>20. US Environmental Protection Agency has introduced different standards for natural gas and coal power plants. Similarly, CCS readiness requirements could be differentiated for coal and gas power plants in the EU.</p>	
<p>21. The Australian Government proposed to conduct a review every two years to test the commercial availability of CCS considering the technical, operational and commercial viability of CCS.</p>	
<p>22. The Australian Government proposed that it would be mandatory for the power plants to implement the CCS retrofit within four years and complete the construction within seven years of the commercial availability of CCS being declared by the Government.</p>	
<p>23. The ADB report recommends that a mechanism allowing power plant developers to recover CCSR costs through a tariff for electricity from a CCS-Ready power plant should be introduced in China.</p>	



## Annex - Information from reviewed material

### Checklist for the next coal power plant retrofit by SaskPower<sup>76</sup>

1. *Capital costs make or break any project for a small power utility like SaskPower. With the intent of reducing capital costs, conduct an equivalent availability study to ascertain how much "up time" would be required on the capture plant to meet regulations.*
2. *Would it be necessary to capture 90% of the CO<sub>2</sub> in the flue gas or would 80% be acceptable?*
3. *What on-line timing and on-off delays would be required to operate both of the plants (power and capture)?*
4. *What efficiency improvements could be made in the power plant to generate the steam required for capture?*
5. *What would be the impact of coal quality and availability on the operation of both plants?*
6. *Simplify the power and capture plants.*
7. *What equipment was added to BD3 after construction in order to improve operation on the basis of safety, ease of use, maintainability, reliability, and efficiency of overall power generation?*
8. *What would be the critical pieces of equipment, and what would be their reliability in terms of maintenance and repair? Consequently, how many replacement units must be on site in the event of equipment breakdown?*
9. *Has there been a change in regulations or interpretation of regulations that might impact the level of required CO<sub>2</sub> capture or even the need for CO<sub>2</sub> capture (e.g. Equivalency Agreement)? Future regulations could be imposed upon emissions from alternative power generating facilities that could change the economics of comparisons.*
10. *Would it be better to over-achieve the regulated capture target or just meet the target? A smaller capture unit would require a lower parasitic load on the power plant, and somewhat lower capital costs. A larger capture unit would have the economic benefit of scale and could have an emission profile that would be significantly cleaner than NGCC.*
11. *Would the 300 MW units at Poplar River and Shand Power Stations, which already operate with more efficient turbines and are almost identical in design, be better, more cost effective targets for future retrofitting than the power units at Boundary Dam Power Station?*
12. *Modularize the plant so that large sections of it could be constructed elsewhere by more highly skilled tradespeople than could be enticed to work at the construction site. This could likely be achieved at a much lower construction cost. Site installation would also become simpler and would likely entail a much lower risk for cost overrun(s).*
13. *Continue the good work on operational standards and safety procedures that began with BD3 (e.g. new confined space procedure, new PPEs, new chemical handling SOP, etc.).*
14. *Perform a labour market assessment for skilled trades and map out a construction schedule that would eliminate the impact of any possible shortage of skilled labour.*
15. *Fully develop design and engineering and let fixed-price contracts to eliminate cost overruns.*
16. *Reduce construction costs. This could entail packaging engineering and construction activities differently than BD3 and potentially modularization.*
17. *Ensure the next PCC unit would be similar enough to reduce technical, construction and operating risks based on the learnings from BD3.*

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<sup>76</sup> IEAGHG, 2015, Integrated Carbon Capture and Storage Project at Saskpower's Boundary Dam Power Station

18. *Continue to have the flexibility to generate power without capture and still meet regulatory requirements. This would likely necessitate PCC technology in the near term and most likely focus technology choices on amine-based capture as they would be the most mature and less technically and operationally risky.*
19. *Utilize a solid staff retention plan to avoid critical shortages in SaskPower staff that have gained invaluable experience from the BD3 ICCS project. This would include developing a SaskPower culture that would reward the behaviours and the stamina that would create a successful project outcome.*
20. *Ensure meaningful public engagement about the costs and benefits of clean coal broadly throughout the Province. Expect that public engagement would be more critical in a region where there would be no oil industry presence to support infrastructure to capture CO<sub>2</sub> that could be used for EOR. Develop a communications and engagement plan accordingly. Public acceptance would doubtless necessitate a third party business investment and technology review for each proposed clean coal project.*
21. *Invest in the establishment of a CO<sub>2</sub> end-use market amongst oil producers. This could require building a CO<sub>2</sub> trucking infrastructure at the BD3 capture plant to support CO<sub>2</sub>-EOR pilots in SE Saskatchewan and to provide CO<sub>2</sub> at a reasonable cost to oil producers that wish to pilot CO<sub>2</sub>-EOR at their operations.*
22. *Consider a change of “ownership” of the retrofitting projects. SaskPower is a power generation utility whose main job is to maintain facilities to ensure the “lights stay on”. It is not an EPC company that designs and builds major facilities on a regular basis.*
23. *Deploy a larger SaskPower group to work on the planning phase of the project if it would be reasonably certain the project would be approved. This would shorten the time from inception to operation and would minimize the burnout experienced during the BD3 ICCS retrofit project.*

## Reduction of CO<sub>2</sub> Emissions from Coal-fired Generation of Electricity Regulations in Canada<sup>77</sup>

### Carbon Capture and Storage

#### Temporary Exemption — System to be Constructed

##### Application

**9 (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 subsection 3(1) 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.

##### Granting and content of application

**(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 — based on information referred to in Schedule 2 related to the capture, transportation and storage elements of the carbon capture and storage system — that there are no insurmountable technical barriers to carrying out the following activities:
  - **(i)** capturing a sufficient volume of CO<sub>2</sub> emissions from the combustion of fossil fuels in the unit to enable the responsible person to comply with subsection 3(1),
  - **(ii)** transporting the captured CO<sub>2</sub> emissions to suitable geological sites for storage, and
  - **(iii)** storing the captured CO<sub>2</sub> emissions in those suitable geological sites;
- **(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 set out in section 10, and
  - **(ii)** compliance of the responsible person with subsection 3(1) by January 1, 2025 when the unit is operating with an integrated carbon capture and storage system that captures CO<sub>2</sub> emissions from the combustion of fossil fuels in the unit in accordance

<sup>77</sup> Government of Canada, Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations (SOR/2012-167) - Regulations are current to 2016-02-03 and last amended on 2015-07-01

*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.*

### **Granting of temporary exemption**

**(3)** *The Minister must, within 120 days after receiving the application, grant the temporary exemption if*

- **(a)** *the application includes the documents referred to in subsection (2); and*
- **(b)** *the information contained in those documents can reasonably be regarded as establishing that*
  - **(i)** *the unit, when operating with an integrated carbon capture and storage system, will be economically viable,*
  - **(ii)** *the capture, transportation and storage elements of the carbon capture and storage system will be technically feasible,*
  - **(iii)** *if applicable, a requirement set out in section 10 has been satisfied by work done before the application was made, and*
  - **(iv)** *the responsible person will satisfy the requirements set out in section 10 and, as a result, will be in compliance with subsection 3(1) by January 1, 2025 when the unit is operating with an integrated carbon capture and storage system.*

### **Duration**

**(4)** *A temporary exemption, unless revoked under section 13, remains in effect until December 31, 2024.*

### **Requirements**

**10** *A responsible person who has been granted a temporary exemption in respect of a unit under subsection 9(3) must satisfy the following requirements:*

- **(a)** *carry out a front end engineering design study is to be carried out by January 1, 2020;*
- **(b)** *purchase any major equipment that is necessary for the capture element is to be purchased by January 1, 2021;*
- **(c)** *enter into any contract required for the transportation and storage of CO<sub>2</sub> emissions from the unit is to be entered into by January 1, 2022;*
- **(d)** *take all necessary steps to obtain all permits or approvals required in relation to the construction of the capture element are to be taken by January 1, 2022; and*
- **(e)** *ensure that the unit, when operating with an integrated carbon capture and storage system, captures CO<sub>2</sub> 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 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, by January 1, 2024.*

### **Implementation report**

**11 (1)** *A responsible person who has been granted a temporary exemption in respect of a unit must, for each calendar year following the granting of the temporary exemption, provide the Minister with an implementation report that indicates the unit's registration number and includes supporting documents that contain the following information:*

- **(a)** *the steps taken during that year to construct the capture, transportation and storage elements of the carbon capture and storage system and to integrate those elements with the unit;*

- **(b)** any requirement set out in section 10 that was satisfied during that year, along with the information and documents referred to in Schedule 3;
- **(c)** a description of the manner in which those steps were carried out or those requirements were satisfied;
- **(d)** any changes, with respect to the information most recently provided to the Minister, to the proposed engineering design for the capture element, to the preferred transportation methods or routes or to the preferred storage sites, for the carbon capture and storage system; and
- **(e)** a description of any steps necessary, with a schedule for those steps, to achieve the following objectives:
  - **(i)** the satisfaction of any requirements set out in section 10 that remain to be satisfied, and
  - **(ii)** the compliance of the responsible person with subsection 3(1) by January 1, 2025 when the unit is operating with an integrated carbon capture and storage system that captures CO<sub>2</sub> emissions from the combustion of fossil fuels in the unit in accordance with laws of Canada or a province that regulate that capture and transports and stores those emissions in accordance with laws of Canada or a province, or of the United States or one of its states, that regulate, as the case may be, that transportation or storage.

#### **Due date**

**(2)** The implementation report must be provided by March 31 of the calendar year that follows the calendar year in question.

#### **Updated information**

**12** If any event occurs or any circumstance arises that may prejudice the ability of the responsible person to achieve an objective referred to in paragraph 11(1)(e), the responsible person must send to the Minister, without delay, a notice that indicates the unit's registration number and contains the following information:

- **(a)** a description of the event or circumstance and the nature of the prejudice;
- **(b)** an explanation of how the prejudice is to be overcome in order to ensure that the objective will be achieved; and
- **(c)** in relation to that explanation, an update to any information previously provided to the Minister under paragraphs 11(1)(c) to (e), together with any necessary supporting documents.

#### **Revocation — non-satisfaction or misleading information**

**13 (1)** The Minister must revoke a temporary exemption granted under subsection 9(3) if

- **(a)** the responsible person does not satisfy a requirement set out in section 10; or
- **(b)** any information indicated or contained in the application for the temporary exemption, in an implementation report referred to in section 11 or in a notice referred to in section 12 is false or misleading.

#### **Revocation — implementation report or reasonable grounds**

**(2)** The Minister may revoke the temporary exemption if

- **(a)** the responsible person has not provided an implementation report in accordance with section 11;
- **(b)** there are reasonable grounds for the Minister to believe that the carbon capture and storage system will not operate so as to capture, transport and store CO<sub>2</sub> emissions as described in paragraph 10(e) by the date referred to in that paragraph; or

- *(c) there are reasonable grounds for the Minister to believe that the responsible person will not emit CO<sub>2</sub> from the combustion of fossil fuels in the unit in accordance with subsection 3(1) by January 1, 2025.*

***Reasons and representations***

**(3)** *The Minister must not revoke the temporary exemption under subsection (1) or (2) unless the Minister has provided the responsible person with*

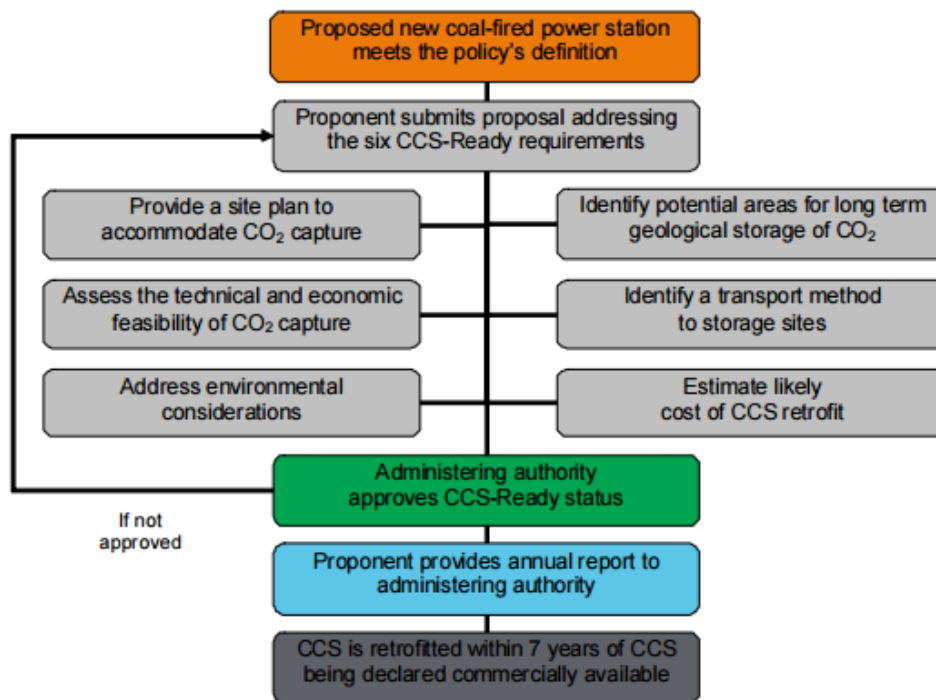
- *(a) written reasons for the proposed revocation; and*
- *(b) an opportunity to be heard, by written representation, in respect of the proposed revocation.*

## Proposed CCS readiness requirements in Australia<sup>78</sup>

### **Mandatory requirements**

- *Demonstrate sufficient space and access on site and within the facility to accommodate carbon capture and compression facilities for the majority of the plant's CO<sub>2</sub> emissions;*
    - *Proponents will submit a site plan that satisfactorily details the footprint of the CCS equipment needed (i.e. CO<sub>2</sub> compression and capture equipment, chemical storage facilities) to capture the majority of the plant's CO<sub>2</sub> emissions. The site plan must allow sufficient space, as determined by design studies, for needed equipment, construction zone and the effective handling of environmental and safety issues.*
  - *Identify potential areas for long term geological storage of captured CO<sub>2</sub> (meeting the plant's capture needs);*
    - *Proponents will estimate the total CO<sub>2</sub> to be captured for the plant's life and identify geological formations that could realistically store this amount. A storage assessment will evaluate the formations based on pre-competitive data, such as work completed by state governments, the Australian Government and the Carbon Storage Taskforce. Proponents are not required to obtain a permit for these areas until CCS must be retrofitted. A risk assessment must be included, including key environmental considerations, such as post-injection CO<sub>2</sub> leakage and land use conflicts in the proposed basins, based on the information utilised in the storage evaluation.*
    - *Where a project developer proposes to use an option other than geological storage of CO<sub>2</sub> to dispose of part of the captured CO<sub>2</sub>, the proponents must identify the proportion of CO<sub>2</sub> expected to be disposed of by an alternative method and the site requirements and timeline for the conversion process plant. The Government may consider developments in emerging technologies in the future, and reassess the proportion of captured CO<sub>2</sub> that may be disposed of by alternative methods.*
  - *Undertake a site specific assessment into the technical and economic feasibility of the CO<sub>2</sub> capture retrofit using one or more technology choices;*
    - *Proponents will identify an appropriate capture technology and prepare a feasibility study on retrofitting this technology into the plant's design. This must include an economic analysis of capture implementation and identify environmental and safety approvals required. Proponents are not required to obtain these approvals until CCS must be retrofitted.*
  - *Identify a realistic transport method to identified storage sites;*
    - *Proponents will identify a transport method technically capable of transporting the total CO<sub>2</sub> to be captured for the plant's life. Proponents must include an assessment addressing land use conflicts and environmental and safety approvals. However these approvals are not required to be obtained until CCS must be retrofitted.*
  - *Demonstrate measures and approvals that deal with the collection and treatment of pollutants resulting from the capture process and provisions for increased water requirements; and*
    - *Proponents will address further environmental considerations by providing an environmental impact statement. This must outline measures that will be taken to manage chemical wastes and increased water use including any environmental or safety approvals required. Proponents are not required to obtain these approvals until CCS must be retrofitted.*
  - *Estimate the likely costs of retrofitting capture, transport and storage.*
    - *Proponents will provide a detailed economic feasibility study of retrofitting CCS.*
- Although all of the requirements must be applied, item 6 is classed as the key requirement.*

<sup>78</sup> Australian Government, 2010, A Cleaner Future For Power Stations, <http://industry.gov.au/Energy/Documents/sustainability-and-climate-change/DiscussionPaperCleanerFuturePowerStation.pdf>



## Reporting

Proponents will provide an annual report to the administering Authority on the plant's compliance with the standards, ensuring that the Authority is aware of any change in circumstance that affects the CCS Readiness of the plant. Proponents must respond to developments in CCS and update feasibility assessments accordingly.

## How will CCS be assessed as commercially available?

Several demonstration projects are planned in Australia as there are currently no plants operating at a level sufficient to demonstrate that the integrated technology is effective at scale. CCS is in a similar situation worldwide.

New coal-fired generators covered by the CCS Ready standard will be required to retrofit CCS technologies within an appropriate timeframe after they become commercially available. A commitment of this nature requires a trigger point to define when CCS is considered commercially available and a defined appropriate time for retrofit.

To determine whether CCS is considered commercially available the Australian Government, in consultation with bodies such as the Global CCS Institute and IEA, would undertake a review process every two years. The review would consider:

- the technical viability of CCS, and whether retrofitting a plant is both operable from an engineering perspective and of a comparable scale (an indicative scale-up will be advised at a future date);
- the operational viability of each element of the technology in conjunction with other elements (i.e. carbon capture along with CO<sub>2</sub> transport and storage); and
- Australia-specific factors affecting the commercial availability of CCS.

Further, the Australian Government would define commercial availability as:

- integration of carbon capture, transport and storage has been proven at a comparable scale and technology in several demonstration plants worldwide;
- the systems comprising CCS are readily attainable; and



- *safety and environmental risks of CCS have been minimised (e.g. the potential for carbon leakage from storage sites).*

*If the report positively assesses that CCS is commercially available, the Minister for Resources and Energy may make a declaration that a retrofit must occur. Due to the costs and planning involved with CCS being retrofitted to power generators, it is proposed that it will be mandatory to implement the planned CCS retrofit within four years and complete the retrofit within seven years of it being declared. This may allow the CCS retrofit to be implemented in a graduated manner.*

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