Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 114 (2017) 7348 – 7355

Energy Procedia

13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland

Carbon capture and storage readiness index: comparative review of global progress towards wide-scale deployment

Christopher P. Consoli*, Ian Havercroft, Lawrence Irlam

Global CCS Institute, Level 6, 707 Collins Street, Docklands VIC, Australia.

Abstract

Carbon capture and storage (CCS) is critical for meeting international climate change targets and deployment must therefore be both rapid and global. To date, deployment has been limited to only a few countries with several factors slowing progress. These factors can be quantified to track a country's development and to identify enabling opportunities for wide-scale commercial deployment of CCS. This paper outlines the results of the Global CCS Institute's CCS Readiness Index. The CCS Index quantifies these factors through a set of criteria across four indicators — inherent interest, policy, legal and regulatory, and storage — which are major barriers or accelerators to the deployment of CCS and compares results for over 30 countries. The methodology behind all three indicators is similar, with each indicator employing its own set of criteria to assess conditions within a country at a particular point in time. Countries are then scored against the criteria with the premise being that the highest scoring jurisdictions have the best opportunity for the deployment of a CCS project. The CCS Index demonstrates that countries with clear, long-term policy commitments to use CCS technologies as an emissions reduction method rank highly. Despite strong development trends in some regions of the world, the majority of countries cluster around the midpoint of the analysis, suggesting some progress towards enabling CCS development, but not yet enough to encourage wide-scale deployment.

Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: Carbon capture and storage; policy; law and regulation; geological storage.

*Corresponding author. Tel.: +61-3-8620-7308.
E-mail address: Chris.Consoli@globalccsinstitute.com

Peer-review under responsibility of the organizing committee of GHGT-13.
doi:10.1016/j.egypro.2017.03.1585

1. Introduction

The deployment of carbon capture and storage (CCS) as a critical technology for reducing greenhouse gas emissions is becoming increasingly urgent. CCS is prominent amongst a suite of technologies that can be deployed immediately and widely in the power sector and other industries, to reduce atmospheric carbon dioxide (CO_2) emissions – the primary cause of climate change [1]. Subsequently, the deployment of CCS needs to be rapid and widespread across many nations around the world [2]. Despite the CCS component technologies being mature and the capture, transport and geologically storage of CO_2 being achieved for over three decades [3], not all countries are ready for the wide-scale deployment of commercial CCS projects. Furthermore, the deployment of CCS has not been uniform around the world. Four key pillars, may be seen as either major barriers or accelerators to drive investment in CCS as a low-carbon technology:

1. A predictable and enduring policy environment
2. Effective and comprehensive CCS law and regulation
3. Early storage site identification and site characterisation
4. Research and development into cost reduction of CCS technologies.

The Global CCS Institute ('The Institute') continues to track the progress of CCS technologies and projects, to build a large knowledge base that has enabled a critical review of the deployment of CCS including enabling factors as well as barriers to the technology's success. A series of CCS-specific 'indicators' have been developed which examine national approaches to: CCS inherent interest (interest), law and regulation (legal), policy, and storage. The CCS Readiness Index (CCS Index) combines these four indicators to provide a unified, quantified assessment and enables the tracking of a country's CCS development and deployment. This paper represents the first results of the CCS Index of 30 countries.

2. Methodology

A country's position within the CCS Index is based on final scores across the four indicators: interest, legal, policy, and storage. The four indicators each comprise a set of criteria which are used to individually score each nation. For the detailed methodology, including the criteria used in each indicator, the reader is referred to the Global CCS Institute [4, 5, 6]. A summary of each of the indicators is outlined below:

- Storage: Utilises criteria that take into account all geological and technical aspects that could impact an injection and storage project within the borders of a country, including the geology, the maturity of storage assessments, site characterisation development and technical ability to store CO_2.
- Legal: Criteria used offer a detailed examination and assessment of a country's national legal and regulatory frameworks, which are critical to the regulation of CCS. These may include environmental assessments, public consultation and long-term-liability.
- Policy: Criteria are based on an extensive range of policy measures that governments at all levels can use and are critical to CCS. This includes direct support for CCS as well as broader implicit support through measures such as carbon pricing and research funding for example.
- Interest: Set of criteria based on global shares of fossil fuel production and consumption.

The final country scores awarded in each of the four individual indicators were normalized (to 100), to enable an effective comparison within the CCS Index. It must also be noted that this report is an amalgamation of four indicators published in 2015 and as such, represents a snapshot of that year alone.

Notwithstanding these results, it should be acknowledged that a country's score within the indicators may change dramatically, particularly in the policy and regulatory space. The comparative assessment is therefore designed to be

updated regularly in order to track the progress of each of these 30 countries as CCS deployment progresses. This paper does not present an exhaustive examination of each country's results, but instead aims to provide a broad overview of the trends identified.

3. Results

The CCS Index reflects the current state of the CCS industry after approximately two decades of progress developing CCS as a low emissions technology. The storage indicator has an overall higher score when compared to the legal and policy indicators; the latter cumulatively scores the lowest. Within the interest indicator results, the correlation between a need to deploy CCS does not always result in higher scores across the other indicators.

3.1. Storage Indicator

The storage component of the CCS Index has a higher score on average than the other indicators (Fig. 1). High scoring countries generally have favorable geology for storage, such as the Northwest Shelf of Australia [7], North Sea for Norway [8] or the Cambrian Sands of Canada [9]. These countries also have an advanced, mature petroleum industry or CO_2-EOR operations, including Brazil, the Netherlands, UAE, UK, and US. All high scoring nations, apart from UAE have publically published national assessments for their storage potential, with most subsequently advancing to storage site assessments. Importantly, all but the UK have completed an injection project.

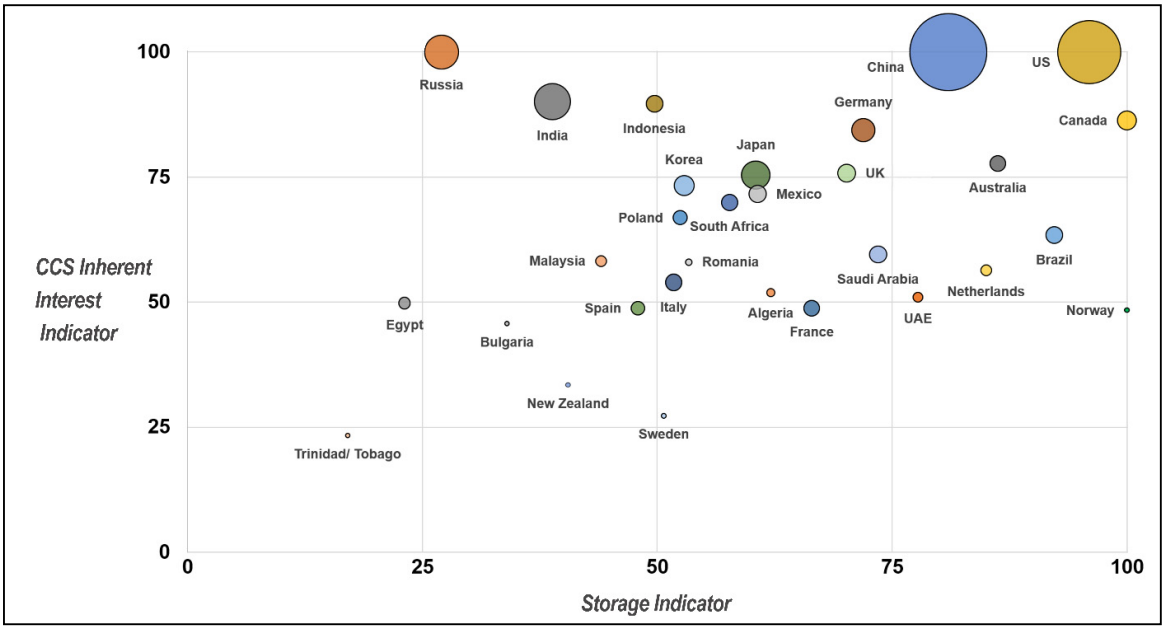

Fig. 1. Comparison between the storage and interest indicators. Bubble size reflects the total emissions according to the World Resources Institute 2010 data [11].

Most of the countries with moderate scores have not implemented a large-scale (>1 million tonnes) or commercial storage project. The absence of a project, together with a mix of immature or sporadic hydrocarbon field development (inherently linked to presence of subsurface data) and less favorable geological storage potential, has resulted in moderate scores. For nations with lower scores, there is not an individual criterion which has not been

addressed, but a combination of factors which have impacted storage. Most prominently, these lower-scoring countries have not completed detailed geological storage assessments and typically have no experience in completing an injection project at any-scale. Fig. 1 shows the comparison between the storage and interest indicators. Importantly the majority of the countries with high scores also score highly in their interest indicator, with a few critical exceptions in India, Indonesia, Malaysia and Russia.

3.2. Legal Indicator

The majority of countries received moderate scores under the legal and regulatory indicator, which reflects the present level of progress in the development of CCS laws and regulations globally (Fig. 2). Only four countries score particularly highly. These countries, Australia, Canada, UK and US have been historically recognized as champions of the development of effective and comprehensive legal frameworks for CCS [10]. These nations have developed detailed CCS-specific laws or have existing laws that are applicable across most parts of the CCS project cycle.

Despite this progress, there are no countries that have a regime that comprehensively addresses all of the core elements of a legal and regulatory model for the technology. Accordingly, there are no countries with an exceptionally high score (90+) as seen in the storage assessment. The four countries listed previously, as well as some of those with more moderate scores, have relatively comprehensive frameworks that can address legal and regulatory aspects across most of the CCS technology chain. Some countries have made amendments to existing resource legislation to regulate CCS activities, which indicates that mature industrialized countries, with an established oil and gas industry, may have a distinct advantage in CCS development.

Countries with low to moderate scores have far fewer CCS-specific laws and, in some instances, have prohibited CO_2 storage activities in their territory. When comparing the legal indicator results to the inherent interest and emissions profile of nations, there is a clear trend that the majority of countries do not yet have adequate legal and regulatory frameworks across the entire CCS technology chain to support CCS development in their nations (Fig. 2).

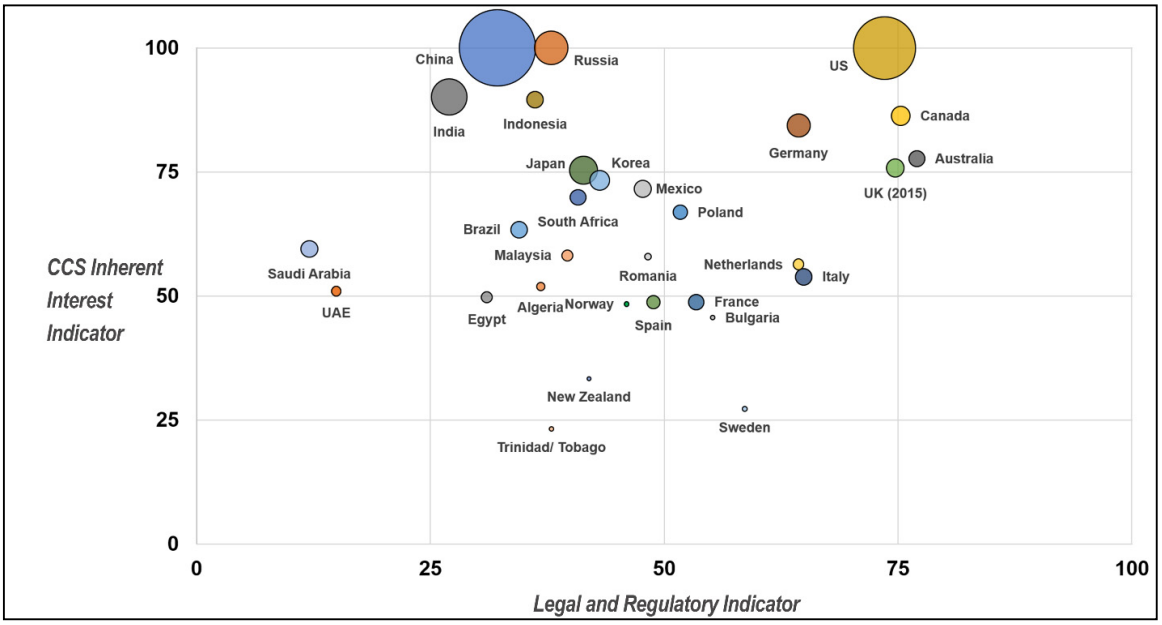

Fig. 2. Comparison between the legal and interest indicators. Bubble size reflects the total emissions according to the World Resources Institute 2010 data [11].

3.3. Policy Indicator

The majority of countries in the policy indicator have low scores (Fig. 3). This finding is unsurprising as CCS does not receive equal policy support when compared to greenhouse gas mitigation technologies such as renewable electricity generation; supporting policy is the key enabler for the development of CCS. Countries with higher scores (Canada, Netherlands, Norway, UK and US) have long-term, clear and targeted support for CCS as a specific greenhouse gas mitigation technology. As can be seen from Fig. 3, the UK dropped in ranking between 2015 and 2016 as a result of the cancellation of its CCS Commercialisation Programme. Notwithstanding this, it still has various policies that can act to encourage CCS, in the form of emission performance standards and a carbon price floor, as well as supportive institutions. Hence, the policies of the UK still enable a high score relative to most nations. The UK Government's stance on CCS in the absence of large-scale funding is expected to become clearer by early 2017.

Countries that rank highly within the policy indicator have employed a broad range of measures to pursue climate change targets. Governments in these countries have also made consistent statements that identify the important role of CCS alongside other low and zero emission technologies. Investment in CCS projects and research is supported via a combination of legislated requirements, market based incentives and supportive institutional arrangements. Countries with higher rankings have direct regulation of emissions from power plants, thus encouraging the deployment of CCS in this sector. Subsequently, aside from the UK, most of the nations that rank highly against the policy indicator have an operational large scale CCS project.

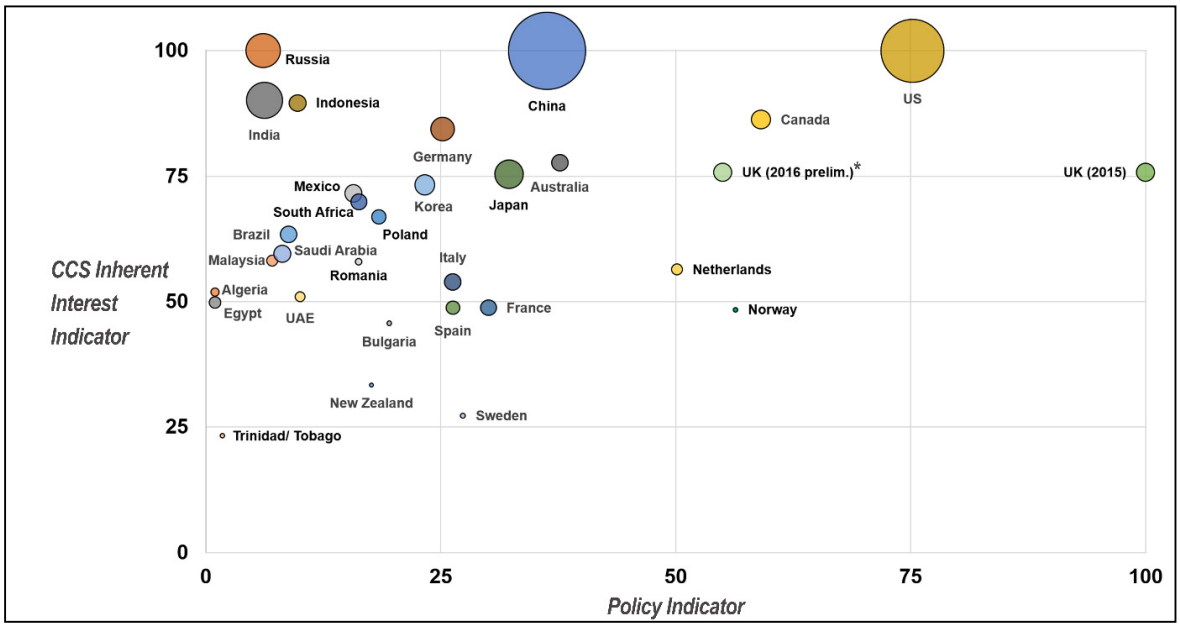

Fig. 3. Comparison between the policy and interest indicators. Bubble size reflects the total emissions according to the World Resources Institute 2010 data [11].*Note: UK dropped in ranking between 2015 and 2016 as a result of the cancellation of its CCS Commercialisation Programme.

Countries that score moderately have fewer direct policies with regard to the role of CCS in overall climate change policy. Some of these countries have CCS projects in the operational stage, but without significant direct subsidies, rely upon enhanced oil recovery using CO_2 (CO_2-EOR) to make the projects commercially viable. Countries with lower scores have not developed clear policies on the role of CCS as a specific greenhouse gas mitigation technology. Despite a significant proportion of countries scoring moderately, in the overall comparative assessment, nations such as Australia, China and Japan are making significant progress.

Compared to the legal and storage indicators, the majority of nations in the policy assessment receive lower scores. Countries in this category have relatively less stringent climate change targets than higher scoring nations or are at earlier stages of economic development. Accordingly, CCS may be considered to be less of a priority in the short term. Brazil, Indonesia, Mexico and Poland, Saudi Arabia, UAE have demonstrated an interest in pursuing CCS in achieving climate change objectives, but generally also observe CCS primarily for EOR. Some of these nations do have CCS demonstration and pilot projects, which suggest that a CCS project can still be developed.

4. Discussion

4.1. Key Findings

The results of the CCS Index show that nations with a long-term (decadal), strategic approach to CCS as a low-emission technology for its climate change emission reduction goals, score high across the policy, legal and storage indicators. These nations include Australia, Canada, the Netherlands, Norway, UK and the US. When compared to the interest indicator, all but the Netherlands and Norway all score highly. This demonstrates that nations that are high consumers and/producers of fossil fuels have long acknowledged the role CCS will play in emissions reduction for climate change objectives. The same group of high-scoring nations, again with the exception of the Netherlands and Norway, are also major emitters [11]. In contrast, there are nations that are both high scoring in terms of CCS interest and emissions, but do not score highly across all indicators. These countries include China, Germany, Japan, India, Korea and Russia.

High scoring nations have largely developed a long-term strategic approach to the technology and have a cohesive and holistic framework around CCS. Lower-scoring nations, conversely, have adopted an ad-hoc or sporadic approach to the inclusion of CCS in their domestic emission reduction targets. Among some of the lower scoring countries, certain nations score highly in storage (for example China and Germany), but those same nations do not have, publically at least, clear and targeted support for CCS as a specific greenhouse gas mitigation technology. Nations such as Canada and Australia have clearly identified a need for CCS and have policies supportive of CCS across many key government platforms (direct regulation, CCS funding agreements etc.), whilst collectively developing their CO_2 storage potential and legal and regulatory frameworks to enable a CCS project. Subsequently, Canada and Australia have CCS projects operating (Quest CCS Project, Canada [12]) or under construction (Gorgon CO_2 Injection Project, Australia [12]) that will capture and store CO_2 from industrial processes specifically for emission reduction.

A further important observation from the CCS Index is the fact that that no country possesses a perfect score. Storage results, when contrasted with those from the policy and legal indicators, sees countries score higher overall despite several areas of potential improvement. The large majority of countries score moderate to low in the legal indicator and low in the policy indicator, which is perhaps indicative of the previous assumption that technological development always leads policy and regulatory development. This assumption reflects the desire of policy makers to examine the technical feasibility of a technology, in this case the capture, transport, storage of CO_2 prior to implementing policies and legislation to support fuller deployment of CCS. The lower scores of the policy and legal indicators actually present significant opportunities. Specifically, countries could readily create an enabling environment with particular policy or legal developments by addressing particular low scoring criteria within the

indicators. Japan, for example, received a low regulatory assessment score for its current regulatory frameworks for offshore storage, however the government is actively addressing many of the remaining barriers and according to Gibbs [13] is developing its regulatory framework for CCS.

The Global CCS Institute [12], highlights that worldwide there are presently 22 large-scale projects, 16 of which are associated with CO_2-EOR. The capture of anthropogenic CO_2 from industrial sources and power stations with storage has mainly been commercially viable because of the revenue from the increase in production of oil. However, the six remaining large-scale projects — which are operational or under-construction — are not CO_2-EOR projects and are directly related to emissions reduction. The commercial driver for all of these projects was regulation, either through direct emissions reduction requirements or regulation such as a price on carbon dioxide. Unsurprisingly, of the six high scoring nations of the CCS Index (Australia, Canada, the Netherlands, Norway, UK and the US), five have CCS projects without CO_2-EOR. This shows that creating an enabling environment through regulation and policy development, in concert with the appraisal and development of storage sites does result in investment of CCS as an emission reduction technology.

4.2. Key Implications

The CCS Index provides a detailed perspective of the current status of CCS in 2015. The findings reveal four main implications based on the countries' results within the four indicators:

1. Long-term, cohesive and clear policies, in concert with the development of storage sites and regulatory frameworks across the entire CCS technology chain, creates an enabling environment for investment of CCS in a country.
2. High-scoring nations have developed their CCS industry over at least two decades. This has included the development of policy commitments, legislative development, and storage characterisation and testing across government at all levels, as well as industry engagement and applied research.
3. The legal, policy and storage indicators provide a point-in-time assessment of a country's strengths and weaknesses in seeking investment for CCS deployment and can highlight individual barriers and opportunities through the criteria-based approach.
4. If the emission reduction goals and climate change objectives of the majority of the 30 nations reviewed in the CCS Index are to be achieved, addressing of individual criteria to create an enabling environment for CCS investment needs to be expedited globally.

5. Summary

The overall premise of the CCS Index is that a high score across the storage, legal and policy indicators, especially for those nations with a high CCS interest will create an enabling environment for investment in the wide-scale, commercial deployment of CCS. These indicators are based on criteria that are barriers or accelerators for CCS. The obvious lack of high scoring countries is reflective of the overall CCS policy environment in 2015, but there are a few leading nations, which show that a long term strategic approach in addressing those criteria can lead to the deployment of CCS for emission reduction targets.

Acknowledgements

We would like to acknowledge the early contributions by Rick Causebrook and Mark Bonner. This paper benefited greatly from the input of Alex Zapantis.

Reference

[1] Metz B, Davidson O, de Coninck H, Loos M. IPCC Special Report on Carbon Dioxide Capture and Storage. Prepared by working Group III of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press; 2005.
[2] International Energy Agency. Energy Technology Perspectives 2016. Paris: OECD/IEA; 2016.
[3] Reiner D. Learning through a portfolio of carbon capture and storage d.emonstration projects. Nature Energy 2015; 1:doi:10.1038/nenergy.2015.11.
[4] Global CCS Institute. Carbon Capture and Storage Policy Indicator (CCS-PI). Melbourne: Global CCS Institute; 2015.
[5] Global CCS Institute. CCS Legal and Regulatory Indicator. Melbourne: Global CCS Institute; 2015.
[6] Global CCS Institute. Global Storage Readiness Assessment. Melbourne: Global CCS Institute; 2015.
[7] Carbon Storage Taskforce. National Carbon Mapping and Infrastructure Plan – Australia: Full Report. Canberra: Department of Resources, Energy and Tourism; 2009.
[8] Halland E, Mujezinovic J, Riis F, (eds). CO_2 storage atlas, Norwegian Continental Shelf. Stavanger: The Norwegian Petroleum Directorate; 2014.
[9] US Department of Energy. Carbon Storage Atlas - Fifth Edition (Atlas V). Pittsburgh: US Department of Energy; 2015.
[10] Dixon T, McCoy ST, Havercroft I. Legal and Regulatory Development on CCS. Int. J. Greenh. Gas Control 2015; 40:431-448.
[11] World Resources Institute. Climate Analysis Indicators Tool Country GHG Emissions 2010 dataset [Online]; Accessed 2016.
[12] Global CCS Institute. Global Status of CCS: 2015. Melbourne: Global CCS Institute; 2015.
[13] Gibbs M. Japan's legal and regulatory framework for CCS. Melbourne: Global CCS Institute; 2016.