Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 114 (2017) 4623 – 4628

Energy Procedia

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

Current status of global storage resources

Christopher P. Consoli,* Neil Wildgust

Global CCS Institute, Level 6, 707 Collins Street, Melbourne, Australia.

Abstract

The successful deployment of carbon capture and storage as a means to mitigate greenhouse gas emissions requires the availability of significant geological storage capacity. Assessments that identify suitable sedimentary basins and their capacity are the first logical step in defining global carbon capture and storage potential. This paper presents a collation and summary of the current status of storage assessments worldwide known as the Global Storage Portfolio. The analysis found that there are substantial storage resources available in most regions of the world. Almost all nations that have published regional assessments have identified sufficient storage resources to support multiple carbon capture and storage projects. This analysis also found that the methods to determine and classify resources are highly variable across regions despite reliable assessment methodologies being available. Case studies on Europe and Southeast Asia discuss the different approaches being undertaken for their respective regional assessments and their progression towards being ready for the deployment of CCS.

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

Keywords: Carbon capture and storage; geological storage; storage capacity; storage assessments.

1. Introduction

The industrial-scale, geological storage (herein referred to as storage) of anthropogenic carbon dioxide (CO_2) has been successfully and securely demonstrated at a number of sites globally over the last two decades, both in deep saline formations and associated with enhanced oil recovery (CO_2 -EOR) operations [1]. Storage has been undertaken in both onshore and offshore environments and across a wide variety of geological formations. The IEA [2] and IPCC [3] both confirm that carbon capture and storage (CCS) is a critical component in reducing emissions to avoid climate change. The IEA predicts that around 90 gigatonnes (GT; billion tonnes) of storage capacity will be required if CCS

* 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.2017.03.1866

is to contribute up to 12% of emissions reductions; in 2050 that equates to approximately 6 GT per year [2]. The availability of CO_2 storage capacity is the critical precondition to meet this ambitious target, which will have to happen through the wide-scale deployment of CCS projects. This raises the question: is there sufficient storage resource available to support the industrial-scale deployment of CCS required to achieve CO_2 mitigation targets over the coming decades?

The *Global Storage Portfolio* (portfolio) was published by the Global CCS Institute in 2015 to help answer this question. It presented the storage resource results of over 30 countries [4].

2. Methodology

The portfolio focuses on the storage resource of countries that have publically published assessments, where storage resource values are presented. It covered five regions, Asia-Pacific (14 countries), Americas (four countries), Middle East (three countries), EU and surrounds (EU plus three countries) and Africa (four countries). Multi-national or national-level assessments that calculated the storage resource using a single methodology was the main publication type. The goal of the portfolio was to identify the storage potential for the future deployment of CCS. For this reason, only proven storage formations including deep saline formations (DSF), depleted/depleting oil and gas fields (DGOF) and enhanced oil recovery using CO_2 (CO_2-EOR) are considered. The term storage resource is used throughout this document. There is a crucial distinction between storage resource – which may be regarded as technically accessible storage space not allowing for economic, legal and regulatory factors – and storage capacity, which could be regarded as storage space proven with a higher degree of confidence, and allowing for non-technical factors.

There are three key factors surmised in the portfolio:

1. Estimated resource: published value calculated through typical volumetric calculations, the accuracy of which is defined by point's one and two below.
2. Status of assessment: categorises the specific details behind the resource assessment, ranging from a detailed national assessment identifying prospective basins and their storage resource ('full'), through to an international study based on large assumptions and sparse datasets ('limited').
3. Resource level: degree of detail that has gone into that estimated resource using the CSLF classification pyramid [5].

In the portfolio, there was no attempt to combine or standardised results from individual studies, and it is assumed that the values presented in the referenced publications are accurate. For more information, the reader is referred to the Global CCS Institute report [4].

3. Results

A summary of the results of the portfolio are tabled below (Table 1). A review of the results finds that the current published studies show there is vast storage resource potential when compared to the ambitious goals of the IEA [2]. The majority of regional assessments used the CSLF [5] calculation method or a method closely comparable. This method is a simple static volumetric calculation of the total pore space, followed by determining how much of the pore space can be physically accessed by CO_2, using an efficiency factor. Numerous other methods were used but most were still essentially static volumetric calculations. Moreover, some nations completed probabilistic calculations, resulting in a range of values for this storage resource (eg. US), whilst other nations published single values, such as the UK. Probabilistic calculations account for uncertainty in geological properties and subsurface conditions by using multiple ranges of values in the calculation. Deterministic calculations on the other hand uses single values, often the best estimate.

The majority of nations have not undertaken sufficiently detailed analysis, with only nine nations completing 'full' assessments (Fig 1.). This suggests that most estimates presented in the portfolio do not take into account the full potential of the nation, most being limited to only oil and gas fields or specific basins. According the CLSF classification pyramid [5], the portfolio results show that most assessments have estimated their theoretical storage resource, with only eight nations estimating their effective storage resource. The theoretical resource is defined by the CSLF as the maximum storage potential of a storage area [5], whereas the effective resource is a subset of the theoretical, constrained by technical factors.

Table 1. Global Storage Portfolio Assessment Summary. Note: Each resource value was developed independently and should not be compared or collated to represent storage resource globally.

Country	Assessment status	Estimated resource (GT CO_2)	Resource level
ASIA-PACIFIC			
Australia	Full	227-702	Effective
Bangladesh	Limited	20	Theoretical
China	Full	1573	Effective
India	Moderate	47-143	Theoretical
Indonesia	Moderate	1.4-2	Effective
Japan	Full	146	Effective
Korea	Full	100	Theoretical
Malaysia	Moderate	28	Effective
New Zealand	Moderate	16	Theoretical
Pakistan	Limited	32	Theoretical
Philippines	Limited	23	Theoretical
Sri Lanka	Limited	6	Theoretical
Thailand	Limited	10	Theoretical
Vietnam	Limited	12	Theoretical
AMERICAS			
Brazil	Moderate	2,030	Theoretical
Canada	Full	198-671	Effective
Mexico	Moderate	100	Theoretical
USA	Full	2,367-21,200	Effective
MIDDLE EAST			
Jordan	Limited	9	Theoretical
Saudi Arabia	Very Limited	5-30	Theoretical
UAE	Very Limited	5-25	Theoretical
EUROPE AND RUSSIA			
Europe excluding UK	Full	72	Theoretical
Norway	Full	82	Effective
Russia	Very Limited	6.8	Theoretical
UK	Full	78	Theoretical
AFRICA			
Algeria	Very Limited	10	Theoretical
Morocco	Limited	0.6	Theoretical
Mozambique	Moderate	2.7-229	Theoretical
South Africa	Moderate	162	Theoretical

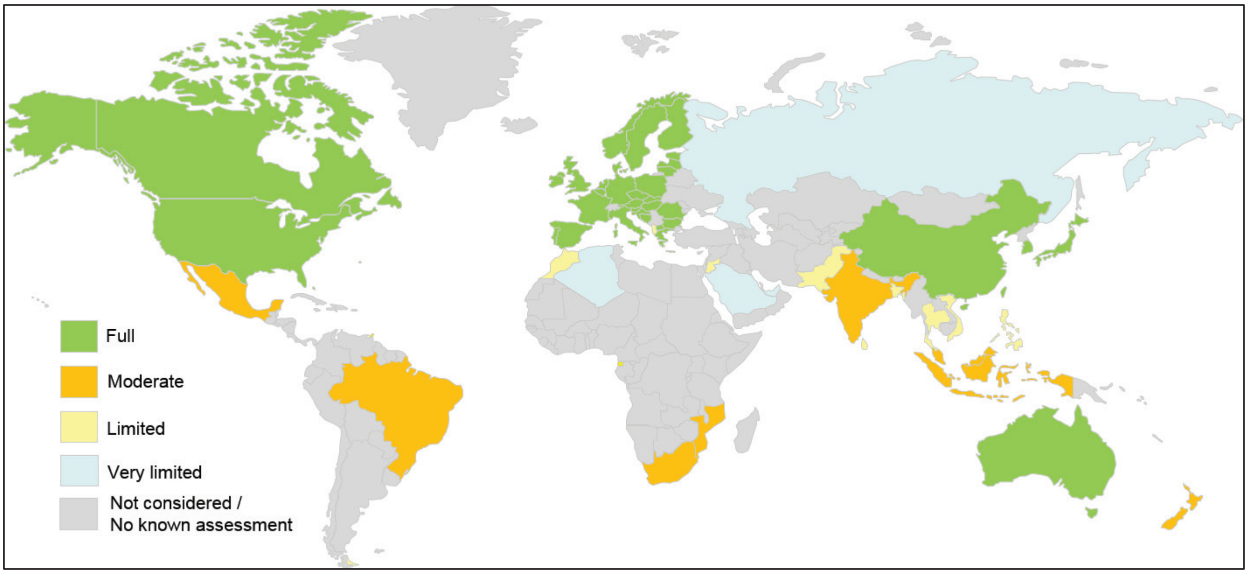

Fig. 1. Geographical coverage of the status of storage resource assessments. After Global CCS Institute [1].

Based on these findings, it is important to state that each resource value should not be compared or collated to represent storage resource globally. This is largely because in each assessment the geological parameters, calculation method, quality of data and level of detail are different. Also that regional storage resource does not equate to proven storage capacity, which can only be obtained through detailed site-scale appraisal and includes engineering, economic, legal and regulatory factors. Each of these factors affect the final amount of CO_2 able to be injected and stored. Also, as research and storage exploration continues over time, the suitability of basins for storage will evolve along with the storage resources.

4. Discussion

Accurate estimates of a region's storage capacity are a challenge, as each geological storage assessment will be inherently different. Regional assessments that estimate storage potential over wide geographical areas, for example multi-national surveys, are the first step to answering this challenge. Regional assessments typically focus on the technical aspects of storage and can provide valuable information to policy makers, regulators and industry on the distribution and scale of the storage potential to support CCS deployment. The main outcomes from regional assessments are an estimation of the storage resource, which is the potential storage space that could be utilised, subject to engineering, economic and regulatory factors. Two case studies represent how two regions have completed their storage assessments differently.

Europe

Europe (herein to include the European Union, the Balkans and Norway) were early movers on CO_2 storage assessments. Europe has undertaken an almost classical systematic, 'bottom-up' approach to storage assessments for at least a decade. This has been led through government directives and through dedicated CCS programs and projects, which work openly in the scientific community having completed several programs focusing on storage capacity. The approach has been methodical. Working on previous studies (eg. CASTOR, GESTCO), GeoCapacity's multi-national approach, was essentially a collation of previous studies. GeoCapacity firstly analysed 23 European countries including most EU nations and surrounding nations such as Norway [6]. The assessment included the majority of onshore and offshore sedimentary basins, including emission sources-sink mapping. The assessment used various methodologies to calculate storage resource in each country. The resource calculation methods were all typically standard volumetric calculations with some efficiency factor to account for the fact that not all the pore space could be utilised. This efficiency factor ranged from measured porosity values through to single percentage factor (eg. 1% of total pore space is accessible to CO_2).

GeoCapacity was followed by the CO2StoP (CO_2 Storage Potential in Europe Project) study which reviewed 27 EU nations. A single resource volumetric calculation using efficiency factors was used [7]. Also a more detailed approach to storage characterisation identified over 400 storage formations, many with resource estimates. However, no cumulative figures were given due to a lack of uniform data in some of the nations [7]. In tandem with CO2StoP, and which can be viewed as the next logical step in site characterisation, a series of national studies in Norway and the UK have been completed, focusing on individual storage formations in their offshore basins [8, 9]. These detailed studies also take into account non-geological aspects of storage including economics, risk assessment, etc., which are factors as vital as the geology to enable a CCS project to proceed.

Europe has adopted a 'bottom-up' approach to site characterisation. Firstly completing studies at a multi-national level, collating existing knowledge that progresses to individual identification of storage formations using a single calculation method. This approach enables all countries covered in the assessment to identify all their storage basins, understand their total storage potential and then select the most prospective basins for further appraisal. The North Sea is consistently identified as the most prospective area for storage [7]. Unsurprisingly, the North Sea also hosts three commercial CCS projects in Sleipner, Snøhvit, and K12-B [1] and is identified as the primary location for future CCS hub development [10]. Using a single methodology to identify storage formations and their storage resources (eg. CO2StoP), provides consistency and enables comparison of potential sites for storage. Strategic, long-term national (and multi-national) CCS infrastructure planning is therefore possible through the 'bottom-up' approach. However, this approach can often be time consuming given the large datasets required and coordination of organisations. Away from oil and gas fields, which often have extensive subsurface seismic and well data, knowledge of the subsurface can be sporadic, or completely absent. This results in either large assumptions of the resource or that basin/storage formation being omitted completely as it does not comply with data requirements. Hence, the level of detail in the bottom-up approach, where specific data for storage evaluation is obtained, becomes more important but even more time and cost intensive.

Southeast Asia

In contrast to Europe, the majority of countries in Southeast Asia (specifically Indonesia, Philippines, Malaysia, Thailand and Vietnam) have a 'top-down' approach, where the most prospective storage formation are being actively characterised first. The Asian Development Bank (ADB) funded a storage assessment study which undertook an assessment of the most prospective basins in several countries of Southeast Asia [11]. Although it was a multinational study, it focused on individual prospective areas including large (>10 million tonnes at injection rate of 100 tonnes per day per well) DGOF and/or areas with the best subsurface datasets. The latter could include DSF. By assessing these prospective storage formations only, the ADB study could use a single methodology (known as estimated ultimate recovery) that resulted in more restrained (but smaller overall) resource estimates. The CCOP is expanding on previous assessments to include the majority of Southeast and East Asian nations including more basins whilst ensuring a single methodology for resource calculation [12]. Prospective basins will also be identified and ranked to enable greater planning and development at the national and international level. The CCOP is therefore more akin to the CO2StoP European assessment.

The 'top-down' approach in Southeast Asia, of identifying the most suitable storage formations, is arguably a more efficient approach to storage development, focusing knowledge and funding resources on the regions with the highest potential. The top-down approach does not allow national planning for CCS infrastructure development when the total storage potential of the entire country is not known. However, focusing on the most prospective basins, which typically host oil and gas fields, and will likely have higher density of subsurface data, and be well characterised and delivers more robust resource estimates.

A review of the assessments in the portfolio found that the 'bottom-up' approach is used most widely with Australia, Brazil, Indian Sub-continent, North America, and South Africa, amongst other nations, all taking the approach of more extensive, but less detailed initial national assessments. In contrast, fewer countries – Japan, Korea, Saudi Arabia, UAE and New Zealand – identified prospective basins / storage for their initial assessments. It is important to note that there are variations on these assumptions. For example, in the US, the US Geological Survey did complete a national assessment focusing on storage formations, called technically accessible storage resource [13].

5. Summary

This study collated and summarised the results from published regional assessments of nations globally. The analysis has found that:

- The published storage resources are vastly greater than those required for CCS to meet future emission reduction targets.
- Substantial storage resources are present in most of the high emitting nations of the world.
- Despite reliable methodologies to determine and classify regional storage resources being available and widely applied, there is no formally recognised international standard.
- The level of resource assessment undertaken and the availability of characterisation data varies greatly between regions.
- Regional resource assessments are not a substitute for the detailed site-scale appraisals of storage capacity required to support financial investment decisions for projects.

Reference

[1] Global CCS Institute. Global Status of CCS: 2015. Melbourne: Global CCS Institute; 2015.
[2] International Energy Agency. Energy Technology Perspectives 2016. Paris: OECD/IEA; 2016.
[3] 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.
[4] Global CCS Institute. Global Storage Portfolio. Melbourne: Global CCS Institute; 2015.
[5] Carbon Sequestration Leadership Forum (CSLF). Estimation of CO_2 storage capacity in geological media. Washington: Carbon Sequestration Leadership Forum; 2007.
[6] Vangkilde-Pedersen T, Vosgerau HJ, Willscher B, Neele F, Van der Meer B, Bossie-Codreanu D, Wojcicki A, Le Nindre Y-M, Kirk K, Anthonsen KL. Capacity standards and site selection criteria: EU GeoCapacity report D. GeoCapacity; 2009.
[7] Poulsen N, Holloway S. Neele F, Smith NA. Kirk K. CO2StoP final report: assessment of CO_2 storage potential in Europe; 2014.
[8] Halland E, Mujezinovic J. Riis F, (eds.). CO_2 storage Atlas, Norwegian Continental Shelf. The Norwegian Petroleum Directorate; 2014.
[9] Bentham M, Mallows T, Lowndes J, Green A. CO_2 STORage Evaluation Database (CO2Stored). The UK's online storage atlas. Energy Proc 2014; 63: 5103-5113.
[10] Pale Blue Dot Energy. Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource. A Summary of Results from the Strategic UK CO_2. Pale Blue Dot Energy; 2016.
[11] Asia Development Bank. Prospects for carbon capture and storage in Southeast Asia. Manila: Asian Development Bank; 2013.
[12] CCOP Secretariat. CCOP guideline on the methodologies for selecting geological carbon dioxide (CO_2) storage and estimation of storage capacities. Bangkok: Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP); 2014.
[13] US Geological Survey. National assessment of geologic carbon dioxide storage resources—Results. US Geological Survey; 2013.