An estimate of the amount of geological CO_2 storage over the period 1996-2020

Yuting Zhang[1], Christopher Jackson[2], Samuel Krevor[1]

[1] Department of Earth Science and Engineering, Imperial College London, UK

[2] Department of Earth and Environmental Sciences, University of Manchester, UK

***Correspondence:**
Yuting Zhang
+44 7446137581
yuting.zhang16@imperial.ac.uk

Peer review statement
The paper is a non-peer reviewed preprint submitted to EarthArXiv.
This preprint has been submitted to Environmental Science and Technology Letters.

ABSTRACT

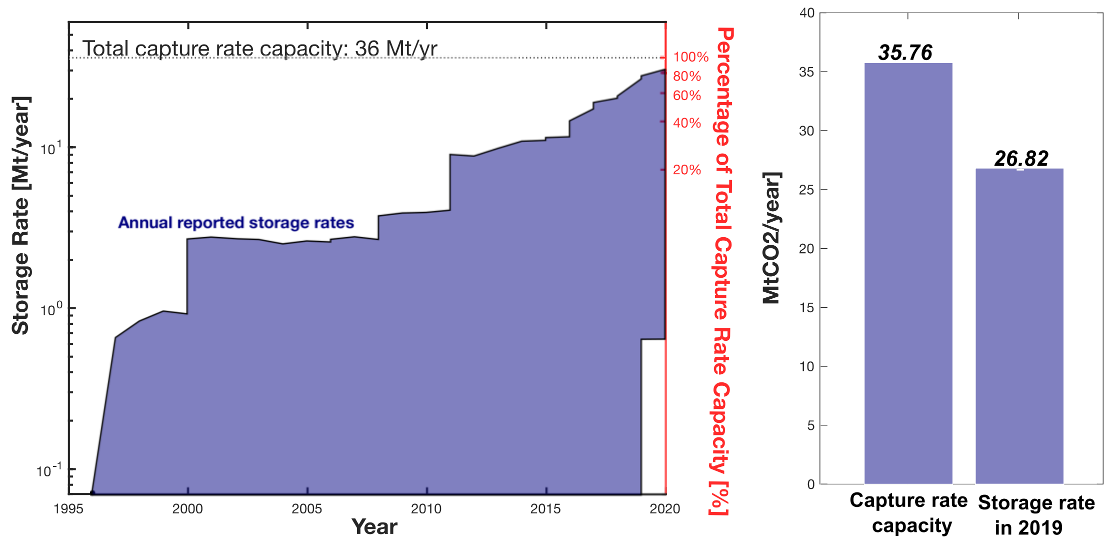
Existing centralised databases of industrial-scale CCS report various characteristics including capture capacities but do not specify the amount of CO_2 stored from commercial CCS facilities. We review a variety of publicly available sources to estimate the amount of CO_2 that has been captured and stored by operational CCS facilities since 1996. We organise these sources into three categories broadly corresponding to the associated degree of legal liability or auditing. Data were found for twenty commercial-scale facilities, indicating a combined capture capacity of 36 $MtCO_2$ per year. Combining data from all three categories suggests that approximately 27 $MtCO_2$ of this was stored in the subsurface in 2019. However, considering only categories 2 and 1 of reporting, storage estimates for 2019 reduce to 25 $MtCO_2$ and 11 $MtCO_2$, respectively. Nearly half of the projects investigated here are reporting injection rates close to their originally proposed capture rate capacity. Our data also show that between 1996 and 2020, 196 Mt of CO_2 has been cumulatively stored, combining data for all three categories. The database presented here provides further insight into the factors influencing performances of CCS operations and the data can be used to parameterise energy system models for analysing plausible scaleup trajectories of CCS.

Keywords: CCS; carbon storage; energy; climate change mitigation; CCS statistics; $MtCO_2$

Synopsis: current reporting for CO_2 storage efficiency reflects capture rate capacity; we find actual stored CO_2 could potentially be overestimated by 33%.

Table of Contents/Graphical Abstract

Comparison between reported capture rate capacity and estimated storage rates of carbon dioxide



INTRODUCTION

Integrated assessment models such as those analysed by the International Panel on Climate Change (IPCC) suggests scaleup of carbon capture and storage (CCS) takes place quickly, with global injection of 5-10 $GtCO_2$ per year needed by 2050 to limit global warming to less than 1.5 °C or 2 °C [1]. With increasing numbers of industry-scale storage projects operating around the world, data is becoming available through which project performance, and scaleup potential, may be evaluated.

The most centralised and updated information on which to assess project performance and scaleup potential comes from the annual reports of the Global CCS Institute (GCCSI). Similar datasets were produced by the MIT Carbon Capture and Sequestration Technologies Program and the National Energy Technology Laboratories (NETL), which ceased updating in 2016 and 2019, respectively. There are several websites compiling lists of CCS projects. In many cases, GCSSI is often used as a primary source, with significant overlap in, for example, capture capacity data, between databases. Capture capacity provides a reference for the maximum potential of operation of a CCS project and is often reported in Mtpa; based largely on these data, global annual growth in the capture capacity of CCS projects is estimated to be an average of 8.6% over the past 20 years[2]. The global capture capacity in 2020 is reported to be 40 $MtCO_2\ yr^{-1}$, with more than half of this being in the United States (US)[3].

More challenging than compiling capture capacity data is to identify how much CO_2 has been stored for current projects or those that have been operating in the past. This information is necessary to evaluate the climate change mitigation impact of existing operations and should form the basis for modelled projections of CCS deployment trajectories. Comparing the amount of CO_2 stored and CO_2 captured to facility capture capacity can help us to identify factors arising between the capture, transport, and storage phases of CO_2 during CCS, which may ultimately lead to variations in storage amounts relative to capture capacity. Variations in the performance of industry-scale CCS may also help us to understand and potentially mitigate the range of issues affecting the performance of projects of a given type (e.g., natural gas production with CCS), or they may allow us to distinguish between issues arising for particular configurations of the integrated CCS chains relative to each other.

In this study, we make use of publicly accessible documents to compile information about how much CO_2 is stored. We first classify the data sources and review how current statistics are reported. From this, we compile a global CO_2 storage database and estimate the amount of CO_2 that has been captured and geologically stored, comparing this with the more widely reported capture capacities. We analyse trends in storage rates of projects in addition to summary statistics. Finally, we provide recommendations for future reporting of CO_2 storage rates.

2 MATERIALS & METHODS

2.1 Project Selection

We use the database of the GCCSI, given it provides the most up-to-date information on existing CCS projects[3]. The most recent database lists 26 operational, industry-scale carbon capture facilities, two operational-suspended industry-scale facilities, and 37 planned projects starting between 2020 - 2030. For each project, project phase (e.g., operational, suspended, completed, early or advancement development), country, operation date, industry type, maximum capture capacity in Mtpa, and capture and storage types are provided. Although, as mentioned, reporting of amounts of the amount of CO_2 stored is currently absent.

In our database, we estimate captured and stored amounts for 20 of these projects that are currently operational, representing 93% of the existing global capture capacity. The GCCSI database only provides the name of the capture facility, so we first identify the source to sink matches for each capture project, i.e., finding the associated storage operator/storage site. This is necessary as some capture facilities are associated with more than one storage site, each with a different project name, and may be operated by different corporations. For the remaining six projects, we did not find sufficient data reported across the literature, press releases, or company documents. Terrell, Enid, Bonanza, and PCS Nitrogen are all relatively small enhanced oil recovery (EOR) projects and their storage site operator was difficult to identify. The Uthmaniyah and Abu Dhabi CCS projects did not release any detailed storage information and were also excluded from our analysis.

2.2 Data characterisation

For the 20 investigated CCS projects, we record the capture capacity provided by the GCCSI's report for the period 2019-2020, and we refer to them in our database as the "capture rate capacity". This is typically announced at the launch of new projects or updated throughout the lifetime of the project, and it provides a sense of scale or benchmark for a particular capture operation. Capture rate capacity can be referring to the maximum quantity of CO_2 that has been captured in a year but not consistently achieved before or thereafter (i.e., at Sleipner) or the maximum amount of CO_2 one intends to capture in a year based on the facility design but have not yet done so (i.e., for Illinois Industrial CCS project). We use this figure as a reference for comparison with the actual capture and storage rate that we subsequently identify using publicly available resources including press releases, company reports and presentations, and governmental reports.

The "capture rate" refers to the annual amount of CO_2 that has been captured after the project commenced. Where this information is not reported, the reported storage rate is used as the capture rate for the project. Of this captured amount, some proportion may be recycled or re-used for producing synthetic chemicals, therefore, it is necessary to additionally distinguish the amount of CO_2 that is geologically sequestered into the subsurface for long-term storage.

We report the “cumulative storage”, the quantity of CO_2 that has been cumulatively stored over a period of time and an “average storage rate” which is the average amount of CO_2 stored per year over a specified period. This allows us to uniformly compare between projects that report the storage amount in various ways; for example, some sources provide the storage rate for 2019 only, some provide the annual storage rate on a year-on-year basis, whereas some provide the cumulative storage over several years. Finally, we estimate the “storage rate in 2019” for some projects to compare with the capture capacity that is provided for the year 2019-2020[3].

2.3 Source categorisation

We compile publicly available information about storage for 20 of the projects from multiple data sources, including multiple reports for single projects. We placed these sources into three categories (Table 1), broadly corresponding to the degree of legal liability or auditing associated with the reporting.

Data in the first category are reported under authoritative legal frameworks, i.e., the National Inventory Report submitted to the United Nations Framework Convention on Climate Change (UNFCCC) and the Greenhouse Gas Reporting Program at the US Environment Protection Agency (EPA) (Category 1). The NIR is generally prepared by an institution of state, such as the national environment agency, according to the requirement of the Convention that includes quality assurance and control procedures for the preparation of the national Greenhouse Gas (GHG) inventory (Norwegian Environmental Agency, 2020). Subsequently, the UNFCCC expert review teams perform an internal technical review of individual annual inventories[4]. Similarly, the US EPA also implements certain reporting guidelines and verifications protocols are carried out for all submitted inventories[5]. As a result, these types of frameworks employ relatively rigorous quality control and assurance of the reported actual CO_2 capture and storage data.

We extract Category 2 data from annual corporate sustainability or Environmental, Social and Governance (ESG) report that provide the quantitative performances of CCS projects. Such reports are typically prepared under the reporting standards of the Global Reporting Initiative (GRI), an independent international standards organisation that facilitates clear communication on impacts such as climate change for businesses and governments[6]. These reports are also accompanied by statements that offer some assurance, provided by an independent assurance service, e.g., KPMG. Category 2 reports are typically then approved by the Executive Board of the company who hold the ultimate legal liability. In this category we also include the China Annual Report 2019 prepared by the Chinese Academy of Environmental Planning, an organisation founded by the Chinese government.

In the final category – Category 3 – sources include company websites, press releases and presentations that provide information on capture and storage rates, but without an associated statement of legal assurance or quality control of the data.

The categories are summarised in Table 1. For each project, we compile data from multiple sources with varying levels of assurance to show the range of uncertainty that exists in the reporting of the storage information. However, in the final estimate for each rate compared, we use the data from each project that is supported by the highest degree of assurance only.

Table 1: A summary of the three categories of sources of reporting on CO_2 storage with varying degrees of data assurance and quality control associated with each category. Category 1 documents (green) have the highest degree of assurance, followed by category 2 documents (blue), and category 3 (red).

Category 1	Category 2	Category 3
• UNFCCC • Governmental databases i.e., US EPA	• Corporate Sustainability report • Corporate ESG report • Non-governmental organisation prepared reports	• Press releases • Webpages • Company presentations

3 RESULTS & DISCUSSION

3.1 Combined rates and cumulative storage

Here, we show comparisons between the stated capture rate capacity, the reported capture rates, the reported storage rate in 2019 and the reported average storage rates for the 20 CCS projects for which we found information (Figure 1; raw data are provided in Table 1 of Supporting Information). The total capture rate capacity is 36 $MtCO_2$ yr^{-1}. According to widely available independent reports and databases for these projects (references are provided in 'sources' column in Table 1 of SI), 88% of the total capture rate capacity is achieved annually. Combining all categories of reporting we find that 85% of the total captured CO_2 is subsequently being geologically sequestered in 2019. Storage rates have scaled up from under 1 Mt yr^{-1} in 1996 to c. 27 Mt yr^{-1} in 2019. The maximum percentage of capture rate capacity that is translated into actual storage across all analysed regions in 2019 is 75%.

In Figure 1, we show the distribution of projects that are associated with each source category for capture capacity, capture rate, storage rate in 2019, and average storage rate. Notably, we find that a substantial proportion (33-48%) of our estimates are supported by category 1 sources (green shades in Figure 1). Projects with Category 2, but not Category 1 sources make up half of the actual capture rate and actual storage rate in 2019 estimates (blue shades in Figure 1); these projects generally include capture facilities that have associated storage sites for the purpose of EOR, i.e., in China, the US, Qatar, Brazil and Canada, except for the Gorgon project in Australia that is injecting CO_2 into a saline aquifer for dedicated geological storage (GCCSI, 2020). Only operations associated with Arkalon and the Great Plains synfuel plants in the US have data sourced from category 3 documents alone. However, this accounts for <10% of the reported estimates for each rate we compare here (red shades in Figure 1). Overall, >90% of the estimated data fall into Category 1 or 2 sources. Furthermore, there are no systematic trends linking differences in capture rate capacity, capture and storage depending on the category of reporting.

Current operational CCS facilities are reporting geological storage of a significant proportion of their stated capture rate capacities, however, there are observable differences between the two rates. Therefore, we find the use of capture capacity as a proxy for storage rates may overestimate the amount of CO_2 stored by 33%. Overall, the cumulative storage of CO_2 (between 1996 and 2020) is estimated to be 196 Mt, combining all reporting categories. This suggests a significant climate change impact of CCS operations since 1996. The amount stored in 2020 is roughly equivalent to achieving the climate change mitigation of c. 2% impact of Solar Photovoltaics[7,8]. The growth required for CCS to achieve gigatonne scale impacts by 2050 is similar to that achieved by renewable energy since the early 2000s. The large-scale nature of each CCS installation has been identified as a significant barrier to growth[9], but the benefit of large projects is observed here in the outsized climate impact of a technology early in its development with only relatively few operational projects.

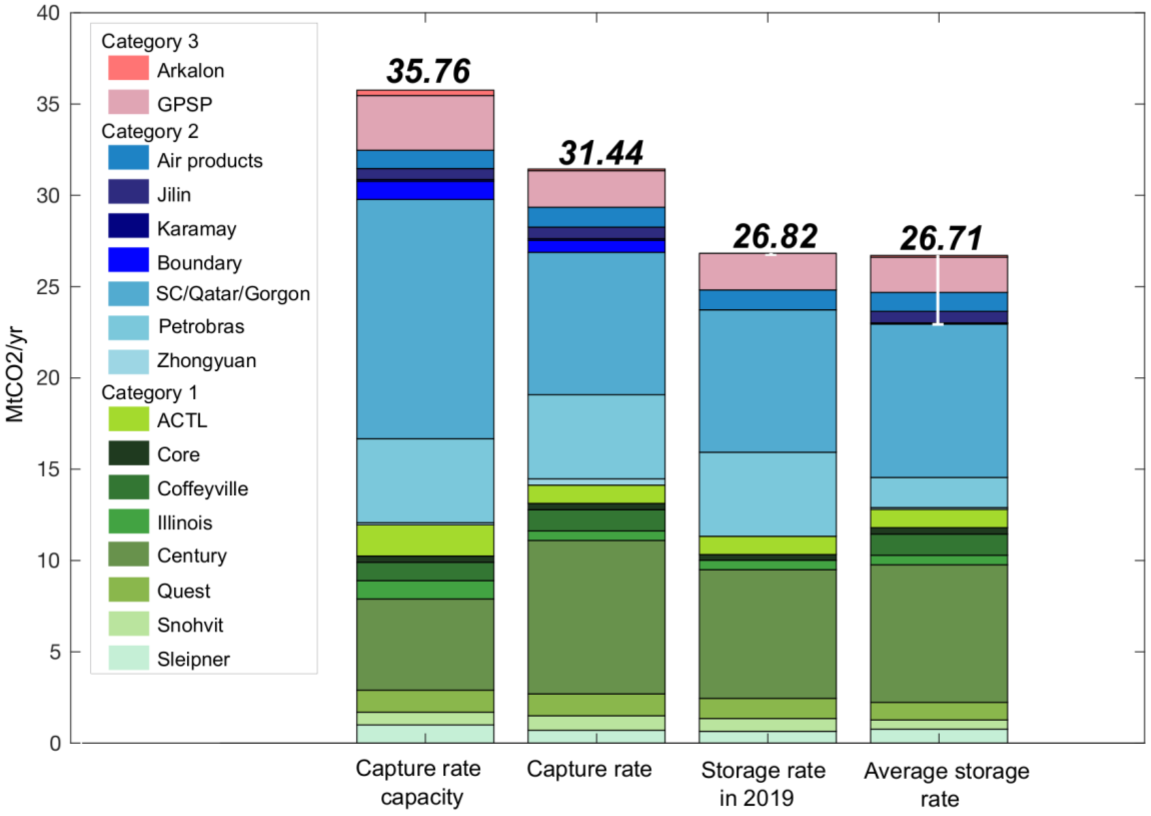


Figure 1: Plot comparing the compiled capture rate capacity, actual capture rate, actual average storage rate and actual storage rate in 2019 for 20 operational CCS projects. The range of colours illustrate the distribution of projects across the three reporting categories that are summarised in Table 1 and it is showing the maximum reporting category identified for each project. Uncertainty bars are shown in white. Definitions of rates compared here and source categorisation is provided in ***Methods***

3.2 Annual reported storage rates 1996 - 2020

We have compiled 17 time series of CO_2 storage data for 20 operational projects for the time period 1996-2020 in Figure 2. For each project or group of projects, the estimated annual storage rate is compared in reference to the capture capacity (coloured lines in Figure 2). The shaded area under each time series indicates the cumulative storage and the three ranges of colours: green, blue, and red are associated with the data categories in Table 1. Several projects have not yet published storage data between 2019 and 2020, including Sleipner, Snohvit, Illinois Industrial CCS, Coffeyville, Zhongyuan and Karamay (white gaps in Figure 2). If each of those storage operations achieved as much as the average annual stored amount between 2018-2019, the total annual storage reported in 2020 would reach a rate of 31 Mt yr^{-1} – the highest since 1996 and 80% of the total capture rate capacity. Eight of the 20 projects comprising 27% of the total capture capacity (36 Mt yr^{-1}) report storage store amounts greater than 90% of their stated capture capacity.

The time-series' reveal a number of factors driving the dynamics of capture and storage rates. Capture operations may undergo a phase of ramp-up within the first year of operation as with the Quest project. Technical difficulties with the CCS system could result in the delay of capture and storage operations reaching maximum potential. For example, the Gorgon project in Western Australia experienced a delay in start-up due to corrosion of injection pipes and it continuously failed to meet the stated capture rate capacity as a result of out-of-action water wells which increases the risk of rapid pressurisation of the reservoir, therefore injection rates were significantly limited by governmental regulators[10,11]. In contrast, the performance of the CCS systems in the Norwegian projects is controlled by the production of natural gas that is the source of the CO_2. Snohvit has been experiencing an average annual growth (between 2010-2019) in storage rate of 10%, surpassing its capture capacity of 0.7 Mt yr^{-1} in 2016, 2018 and 2019 (light green area and line in Figure 2). In contrast, the storage rate at Sleipner has been gradually decreasing from a peak of 1 Mt yr^{-1} in 2001 to 0.649 Mt yr^{-1} in 2019 (average annual decline of 1% since 2000), despite a continuously stated capture capacity of 1 Mt yr^{-1} (tea-green area and line in Figure 2). These are associated with variations in natural gas production at the projects. Data provided by the Norwegian Petroleum Directorate[12] suggest Sleipner's annual production of gas between 2000-2020 has been declining at an annual average rate of 14%, whereas our results indicate that the annual storage rate of CO_2 captured at Sleipner is also in the decline phase but at a much slower rate of 1%. In contrast, both annual production and storage operations of Snohvit are increasing at a similar rate of growth – 8% and 10%, respectively[13].

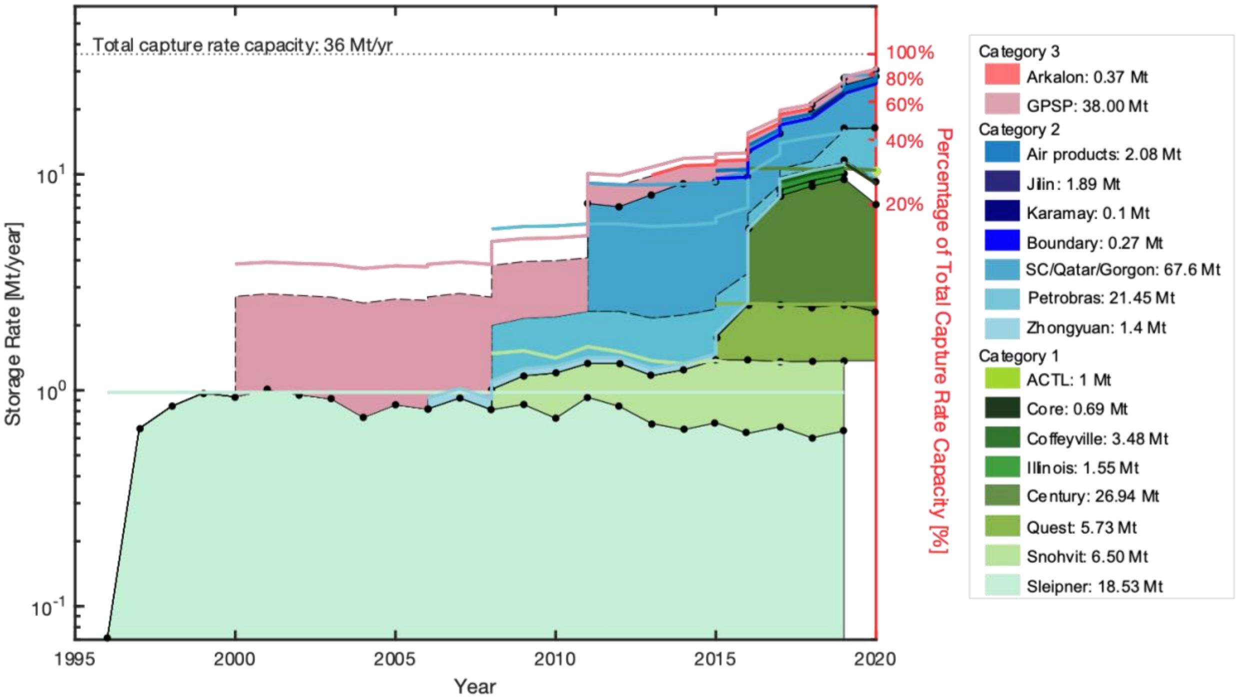


Figure 3: Times series of annual CO_2 storage between 1996 – 2020 comparing the annual storage rate with the relative capture capacity for each project. Note, the vertical axis is only using the logarithmic scale so that all of the projects can be seen in the graph. The bars in Figure 1 provide a better visual of relative project size. Black smooth lines joined by dots indicate time series that have an annual storage rate specified for each year. Black dashed line illustrates time series compiled using the average storage rate. The thick coloured line indicates the capture capacity relative to each project, the colour of each line corresponds to the colour of the associated project indicated in the legends. The area under each time series indicated by a different shade of green, blue, and red represents the cumulative stored and the value is provided in the legend. The three ranges of colours are associated with the maximum source category identified for each project and the definition of each category corresponds to the summary provided in Table 1. The green dot represents the storage rate for the Alberta Carbon Trunk Line projects including Nutrien and Sturgeon which only began operation in 2020.

3.3 Implications

Our database provides further insight into the status of CCS, its climate change impact, and it can be used as a reference in the near term for understanding the total performance of CCS project chains. However, our study shows there is an absence of consistently reported information and thus a need for a framework within which to systematically report and assess the degree of uncertainty for field- and site-level CCS statistics. For example, project names often only relate to the capture facility and there may be a lack of information provided for storage facilities or operators, making it difficult at times to identify the correct match between sources and sinks. Further complicating this are situations where there are multiple storage projects obtaining CO_2 from a single capture facility. As a result, uncertainty arises from the absence of uniformity and consistency in the reporting of data, i.e., annual quantity of CO_2 stored for multiple projects without granularity and differentiation in the case for ExxonMobil, the lack of specification of the quality control of measurements at the field level, and the overall compilation of estimates.

The importance of recording CO_2 storage data can be observed in analogous industries like the hydrocarbon sector[14]. Historical data for oil production has been invaluable in allowing future predictions and trends to be modelled. This has been central to studying demand and the availability of resources, analyses which will also be required should CO_2 storage scale-up to the size envisioned by climate change mitigation scenarios. Additionally, a framework should include data reported for: 1) intended capture rate capacity, 2) maximum capture rate capacity, 3) actual captured CO_2, 4) actual transported CO_2, 5) actual stored CO_2, and 6) quality assurance measures such as auditing and key uncertainties. The framework for reporting itself should also be clear. This would enable the accurate assessment of climate change mitigation benefits explicitly attributed to CCS operations.

We identify that the use of stated capture capacities as a proxy for storage rates may currently result in significant overestimates of the amount of CO_2 stored through CCS. However, individual projects range in storage rates from achieving 50% to 100% of their stated capture rate capacity, or in the case of Snohvit achieving even greater than its capture rate capacity. It is evident that storage very close to designed capture capacities can be achieved and that the current reasons for trends in individual project performance are project specific. Thus, we also warn that the aggregate statistics herein are a snapshot of the technology in its early development and may not be appropriate as the basis for future estimates of a performance factor for CCS operations in modelling or other analyses.

ABBREVIATIONS

CCS – Carbon Capture and Storage
EOR – Enhanced Oil Recovery
EPA – Environmental Protection Agency
ESG – Environmental, Social and Governance
GHG – Greenhouse Gas
GCCSI – Global Carbon Capture and Storage Institute
GRI – Global Reporting Initiative
IPCC – International Panel on Climate Change
Mtpa – Megaton per annum
NPD – Norwegian Petroleum Directorate
UNFCCC – United Nations Framework Convention of Climate Change

ACKNOWLEDGEMENT

Funding for this work was provided by the Engineering and Physical Sciences Research Council.

REFERENCES

1. *IPCC Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (eds Masson-Delmotte, V. *et al.*) (IPCC, 2018).
2. Zahasky, C., & Krevor, S. Global geologic carbon storage requirements of climate change mitigation scenarios. *Energy Environment. Sci.* **13,** 1561-1567 (2020). https://doi.org/10.1039/D0EE00674B
3. *Global Status of CCS: 2020* (Global CCS Institute, 2020).
4. *Guidelines for the technical review of information reported under the Convetion related to greenhouse gas inventories, biennial reports and national communication by parties included in Annex I to the Convetion*, FCCC/CP/2014/10/Add.3 (General. Feb 2, 2015)
5. GHGRP methodology and verification; https://www.epa.gov/ghgreporting/ghgrp-methodology-and-verification
6. GRI mission & history; https://www.globalreporting.org/about-gri/mission-history/
7. Pacala, S., & Socolow, R. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science*. 2004, *305*(5686), 968-972. doi: 10.1126/science.1100103

8. *Snapshot of Global PV Markets 2021;* Report IEA-PVPS T1-39:2021; 2021;https://iea-pvps.org/wp-content/uploads/2021/04/IEA_PVPS_Snapshot_2021-V3.pdf
9. Abdulla , A. *et al.* Explaining sucessful and failed investments in U.S. carbon capture and storage using empirical and expert assessments. *Enviornmental Research Letters.* **2021**, *16(1).* doi: 10.1088/1748-9326/abd19e
10. *Gorgon project carbon dioxide injection project low emission technology demonstration fund annual report 1 July 2016 - 30 June 2017;* Department of Industry, Innovation and Science Western Australia Government: Western Australia, 2017; https://s3.documentcloud.org/documents/20509165/gorgon-project-carbon-dioxide-injection-project-low-emissions-technology-demonstration-fund-annual-report-1-july-2016-30-june-2017.pdf
11. *Gorgon project carbon dioxide injection project low emission technology demonstration fund annual report 1 July 2019 – 30 June 2020;* Department of Industry, Innovation and Science Western Australia Government: Western Australia, 2020; https://s3.documentcloud.org/documents/20440488/foi-2-gorgon-project-2020-letdf-annual-report-rev-1-ar.pdf
12. Sleipner; https://www.norskpetroleum.no/en/facts/field/sleipner-ost/
13. *Snohvit:* https://www.norskpetroleum.no/en/facts/field/snohvit/
14. Aleklett, K. & Campbell, C. (Eds.), Proceedings of the first international workshop on oil depletion, Uppsala, Sweden 23-25 May 2002. ASPO (2002)

DISCLOSURES

The authors declare no competing financial interest

SUPPORTING INFORMATION

Table 1: The compiled global geological CCS statistical database for 20 operational commercial-scale CCS facilities between 1996-2020. The capture rate capacity stated for 2019-2020 is sourced from the GCCSI global status of CCS 2020" report (GCCSI, 2020). The capture rate estimated here is determined based on 1) individual sources (indicated with an asterisk, the source is provided in the "source" column), 2) the storage rate in 2019, and 3) the average storage rate depending on the availability of data. We show source to sink matches by indicating the associated CO_2 storage facility or operator relative to the capture facility/project. Each capture project is separated by thin black lines. Related projects i.e., capture facilities that have multiple storage operators or data reported for a group of projects without specification is highlighted by bold lines. Multiple sources and data for each project are separated by thin dashed lines. The average storage rate is calculated based on the reported cumulative storage over the number of years specified in the Period column. We indicate the categories each source has been allocated to which corresponds to the summary of source categories in Table 1. The colour in the Sources column corresponds to the colour introduced in Table 1 and indicates the maximum category of source collected for each capture project. Where there are multiple sources available for each project, data that are highlighted in red are used to calculate uncertainty but not included in the total estimate for each rate because data associated with a higher level of assurance is used instead.

Country	CO2 Capture Facility	Capture rate Capacity 2019-2020	Capture Rate	Associated CO_2 storage facility/operator	Storage Rate in 2019	Average Storage Rate	Cumulative storage	Period	Source Categorisation	Sources
Brazil	Petrobras	4.6	4.6	Santos Basin Petrobtras	4.6	1.65	21.4	2008-2020	1	https://api.mziq.com/mzfilemanager/v2/d/25fdf098-34f5-4608-b7fa-17d60b2de47d/2a0029b5-75e7-ad89-7c3e-30793604118e?origin=1
									2	https://sustentabilidade.petrobras.com.br/en/src/assets/pdf/Sustainability-Report.pdf
									1	https://petrobras.com.br/en/news/our-2020-sustainability-report-with-advances-in-esg.htm
									2	https://sustentabilidade.petrobras.com.br/en/
Canada	Boundary Dam	1	0.65*	Project Aquistore		0.045	0.27	2015-2020	2	https://ptrc.ca/pub/docs/annual-reports/Annual%20Report_Shortened.pdf
									1	https://www.saskpower.com/about-us/our-company/blog/2021/bd3-status-update-may-2021
US/Canada	Great Plains Synfuel Plant	3	2	Weyburn-Midale Whitecap Resources	2	1.93	5.8	2018-2020	1	https://www.wcap.ca/application/files/3316/2403/8674/WCP_2021_06_18.pdf
						1.89	32.2	2008-2018	1	https://www.wcap.ca/operations/core-areas/southeast-saskatchewan
									1	https://www.wcap.ca/operations/core-areas/southeast-saskatchewan
									1	https://www.wcap.ca/sustainability/co2-sequestration
									1	https://dakotagas.com/News-Center/news-releases/carbon-capture-milestone-reached-at-dakota-gas
Canada	Quest	1.2	1.2	Quest Shell	1.13	0.96	5.39	2015-2019	1	https://www.shell.ca/en_ca/media/news-and-media-releases/news-releases-2020/quest-ccs-facility-captures-and-stores-five-million-tonnes.html
					1.128	0.96	4.8	2016-2020	2	https://reports.shell.com/sustainability-report/2020/servicepages/downloads/files/shell-sustainability-report-2020.pdf
									3	https://open.alberta.ca/dataset/f74375f3-3c73-4b9c-af2b-ef44e59b7890/resource/ff260985-e616-4d2e-92e0-9b91f5590136/download/energy-quest-annual-summary-alberta-department-of-energy-2019.pdf

Canada	ACTL-Nutrien	0.3	1	ACTL Enhance energy	1	1	1	2020-2021	1	https://actl.ca/wp-content/uploads/2021/03/Enhance_Energy_Megatonne_Announcement_2021_03_09.pdf
Canada	ACTL-Sturgeon	1.4		ACTL Enhance energy					3	https://vimeo.com/527500313
China	Sinopec Zhongyuan	0.12	0.35	Zhongyuan Sinopec		0.1			2	http://www.cityghg.com/uploads/soft/200119/1-200119204941.pdf
China	CNPC Jilin	0.6	0.63	Jilin CNPC		0.3			2	http://www.cityghg.com/uploads/soft/200119/1-200119204941.pdf
						0.63	1.9	2018-2020	2	https://www.cnpc.com.cn/en/csr2020enhmshn/202105/64f93c5684754f859b9b81602fba1979/files/e52454722e1c4c269071c16987f70255.pdf
China	Karamay Dunhua	0.1	0.1	Karamay Dunhua		0.02			2	http://www.cityghg.com/uploads/soft/200119/1-200119204941.pdf
Norway	Sleipner	1	0.7*	Sleipner Equinor	0.65	0.77	18.5	1996-2019	3	https://unfccc.int/documents/273425
Norway	Snohvit	0.7	0.8*	Snohvit Equinor	0.7	0.5	6.5	2007-2019	3	https://unfccc.int/documents/273425
				Norway Equinor	1.37	1.1	26.2	1996-2020	2	https://www.equinor.com/en/investors/annual-reports.html#downloads
US	Illinois Industrial CCS	1	0.52	Illinois ADM	0.52	0.52	1.55	2017-2020	3	https://ghgdata.epa.gov/ghgp/service/facilityDetail/2019?id=1005661&ds=E&et=&popup=true
					0.522	0.52	1.042	2019-2020	2	https://assets.adm.com/Sustainability/3860041_20_Archer-Daniels-Midland_ESG-Report_WR.pdf
US	Arkalon	0.29	0.092	Farnsworth Unit		0.092	0.46	2013-2017	2	https://www.netl.doe.gov/sites/default/files/2018-11/Farnsworth-Unit-Project.pdf
US	Coffeyville	1	1.16	North Burbank Unit		1.16	3.49	2017-2019	3	https://www.epa.gov/sites/production/files/2020-12/documents/nbu_decision.pdf
Qatar	Qatar LGN	2.1	6.8	Exxon Mobile	6.8	6.4	63.6	2010-2020	2	https://corporate.exxonmobil.com/-/media/Global/Files/energy-and-carbon-summary/Energy-and-Carbon-Summary.pdf
Australia	Gorgon	4	1	Chevron	1	2	4	2019-2020	2	https://www.chevron.com/-/media/chevron/sustainability/documents/climate-change-resilience-report.pdf
US	Shute Creek	7							1	https://www.chevron.com/-/media/chevron/sustainability/documents/climate-change-resilience-report.pdf
US	Air products	1	1.09	Gulf Coast Denbury	1.09	1.04	2.08	2018-2020	2	https://s27.q4cdn.com/166477028/files/doc_downloads/Denbury-2021-Corporate-Responsibility-Report.pdf
									1	https://s1.q4cdn.com/594864049/files/doc_downloads/2021/03/03-2021-Credit-Suisse-Presentation.pdf
US	Century	5	8.4*	Occidental Petroleum	7.1	4.27	25.66	2015-2020	2	https://www.oxy.com/Sustainability/overview/SiteAssets/Pages/Social-Responsibility-at-Oxy/Assets/Annual%20Performance%20Summary%20Table.pdf
				Denver Unit	3.39	3.232	16.16	2016-2019	3	https://ghgdata.epa.gov/ghgp/service/facilityDetail/2019?id=1011767&ds=A&et=&popup=true
				Hobbs Unit	3.66	4.312	10.78	2017-2019	3	https://ghgdata.epa.gov/ghgp/service/facilityDetail/2019?id=1012121&ds=A&et=&popup=true
US	Core Energy	0.35	0.35	Core Energy	0.31	0.35	0.69	2018-2020	3	https://ghgdata.epa.gov/ghgp/service/facilityDetail/2018?id=1010117&ds=A&et=&popup=true
TOTAL		**35.76**	**31.42**		**26.82**	**26.95**	**196.12**			