14 July 2022

Carbon Capture and Storage and climate mitigation, what next? - A conversation with Ruth Herbert, CEO of Carbon Capture and Storage Association (CCSA)
30 June 2022

Website: https://cil.nus.edu.sg/event/cil-climate-conversation-series-with-ruth-herbert-ceo-carbon-capture-storage-association-ccsa/
YouTube: https://youtu.be/09w-8a68XWM

(CIL Climate Conversation Series, moderated by Danielle Yeow, Adjunct Senior Research Fellow, Lead Climate Change Law and Policy)

What is Carbon Capture and Storage (CCS)?

CCS refers to a technology that reduces carbon emissions in a three-step process. First, the carbon dioxide (CO2) produced from industrial processes is separated from other gases and captured. Second, the CO2 is compressed to a liquid-like state and transported to storage sites using pipelines, ships, trucks and/or trains. Third, the CO2 is injected deep underground for permanent storage, in storage sites such as saline aquifers or depleted oil and gas fields.[1] This storage process is described as akin to the processes that have naturally trapped hydrocarbons in the Earth's subsurface for millions of years.[2] Other than being stored, the CO2 can also be converted to other products through chemical synthesis, or used in enhanced oil recovery (EOR), where the CO2 is used to increase oil production.[3] Such utilisation of the captured CO2 is known as carbon capture, utilisation and storage (CCUS).

Other forms of CCS include Direct Air Carbon Capture and Storage (DACCS) and Bio-Energy with Carbon Capture and Storage (BECCS). DACCS captures existing CO2 from the atmosphere while BECCS captures and stores CO2 released from biomass-based processes.[4]

According to the 2021 Global Status of CCS Report by the Global CCS Institute, as of 2021, there are currently 27 operational CCS facilities, four in construction, and 102 in various stages of development worldwide.[5] Out of the 27 commercially operational CCS projects, 21 utilise the CO2 for EOR. The remaining six projects use geological storage which are mostly offshore.[6] It was observed by Ruth Herbert, CEO of CCSA, during the CIL Climate Conversations dialogue on 30 June 2022, that CCS projects are increasing in scale and expanding to more industries beyond the oil and gas sectors. However, there are currently only a small number of CCS facilities in the Asia-Pacific, highlighting the potential for CCS in the region.

2022 IPCC WG III Report: CCS as a climate change mitigation option

The 2022 IPCC Working Group III Report: Mitigation of Climate Change, indicates that among the 97 assessed pathways that keep warming below 1.5°C, there is a median of 665 gigatonnes of CO2 cumulatively captured and stored between the present and 2100.[7] The IPCC Report also identifies seven "Illustrative Mitigation Pathways" (IMPs) that summarise different decarbonisation strategies. Only

---

[1] "What Is Carbon Capture and Storage?" *National Grid*, https://www.nationalgrid.com/stories/energy-explained/what-is-ccs-how-does-it-work. Accessed 6 July 2022.
[2] Global CCS Institute. "Key Messages." April 2021, https://www.globalccsinstitute.com/wp-content/uploads/2021/04/GCCSI_KeyMessages_04.2021.pdf. Accessed 6 July 2022.
[3] Frasen, Bas. "Carbon Capture and Utilization (CCU)." 13 February 2020, https://www.ecomatcher.com/carbon-capture-and-utilization-ccu/. Accessed 6 July 2022.
[4] Bright, Matt, and Lockwood, Toby. "What does the latest IPCC report say about carbon capture?" *Clean Air Task Force*, 20 April 2022, https://www.catf.us/2022/04/what-does-latest-ipcc-report-say-about-carbon-capture/#:~:text=The%20report%20is%20clear%20that,improving%20carbon%20capture%20deployment%20rates. Accessed 6 July 2022.
[5] Global CCS Institute. "Global Status of CCS 2021." 2021, https://www.globalccsinstitute.com/wp-content/uploads/2021/10/2021-Global-Status-of-CCS-Report_Global_CCS_Institute.pdf. Accessed 6 July 2022.
[6] Harrison-Broninski, Bertie. "What is happening with Carbon Capture and Storage?" *Economy, Land & Climate Insight*, https://elc-insight.org/what-is-happening-with-carbon-capture-and-storage/. Accessed 6 July 2022.
[7] Bright, Matt, and Lockwood, Toby. "What does the latest IPCC report say about carbon capture?" *Clean Air Task Force*, 20 April 2022, https://www.catf.us/2022/04/what-does-latest-ipcc-report-say-about-carbon-capture/#:~:text=The%20report%20is%20clear%20that,improving%20carbon%20capture%20deployment%20rates. Accessed 6 July 2022.

one IMP does not include CCS, and has been termed "socio-politically unrealistic" as it requires global energy demand to nearly halve in the next 30 years.[8] As indicated in the IPCC Report (Summary for Policymakers), "[n]et-zero CO2 energy systems entail: a substantial reduction in overall fossil fuel use, minimal use of unabated fossil fuels, and use of CCS in the remaining fossil system".[9]

This indicates the importance of CCS in climate change mitigation, especially in "hard-to-abate" sectors such as cement and steel. These sectors have few alternatives to the direct use of fossil fuels as they require high temperatures and chemical reactions which release CO2.[10] Ms Herbert explained that these are sectors that cannot be decarbonised to achieve net-zero without CCS deployment, even with the shift to renewable energy and hydrogen-generated power.

However, according to the IPCC Report (Summary for Policymakers), current rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C.[11] Ms Herbert explained that CCS facilities are strategic infrastructure projects which require a significant amount of planning time. This presents a challenge given the pace at which CCS facilities have to be deployed. The long lead time comes from the need to appraise storage sites and build and test the infrastructure involved. Countries should thus start appraising storage sites as soon as possible.

Ms Herbert observed that "the overwhelming impression [from the IPCC Report] is one of urgency and pace" and that early action is necessary. While CCS is important, it is only one of many mitigation measures required to limit warming to 1.5 degrees. She stressed the need for governments to incentivise CCS investment through creating conditions for investment, direct financial support, and clarifying key regulatory and policy issues.[12] Other enabling conditions for CCS deployment include greater public support and technological innovation.[13]

CCS and regulatory frameworks

An adequate regulatory framework nationally, regionally and internationally is required for large-scale CCS deployment. Many regulatory issues have an international dimension e.g. agreements regarding emissions reductions and carbon markets might be international in scope, potential storage sites can cross international borders, and the transport of CO2 may cross international borders. Ms Herbert commented that while there are currently few cross-border facilities in Europe, there are developing projects considering that option. She also observed that storage resilience can potentially be achieved by a network of transboundary stores, with an inherent international dimension.

International conventions relevant for offshore and/or cross-border CCS projects include the United Nations Convention on the Law of the Sea (UNCLOS), the London Protocol and the Basel Convention.

[8] Ibid.
[9] IPCC. "Climate Change 2022: Mitigation of Climate Change: Summary for Policymakers". 2022, C.4.1.
[10] Global CCS Institute. "Key Messages." April 2021, https://www.globalccsinstitute.com/wp-content/uploads/2021/04/GCCSI_KeyMessages_04.2021.pdf. Accessed 6 July 2022.
[11] IPCC. "Climate Change 2022: Mitigation of Climate Change: Summary for Policymakers". 2022, C.4.6.
[12] See also Global CCS Institute. "Key Messages." April 2021, https://www.globalccsinstitute.com/wp-content/uploads/2021/04/GCCSI_KeyMessages_04.2021.pdf. Accessed 6 July 2022.
[13] IPCC. "Climate Change 2022: Mitigation of Climate Change: Summary for Policymakers". 2022, C.4.6.

United Nations Convention on the Law of the Sea (1982) (UNCLOS)

In general, offshore CCS activities fall under the authority of the relevant coastal states, whether they occur in internal waters, the territorial sea, the exclusive economic zone (EEZ), the continental shelf or any archipelagic waters.[14]

While UNCLOS does not expressly regulate CCS activities, its provisions may have an impact if CCS activities are deemed to constitute pollution as defined in Article 1(4). Under Article 210 of UNCLOS, dumping is a form of pollution. Currently, there is no conclusive opinion on whether the transport of CO2 to an injection platform, or the injection of CO2 into subsea geological formations, constitutes dumping and/or pollution under UNCLOS.[15]

Furthermore, to protect the marine environment from pollution, Article 195 of UNCLOS requires states "not to transfer, directly or indirectly, damage or hazards from one area to another". There is no conclusive opinion as to whether CO2 constitutes a hazardous substance under UNCLOS, and hence whether CO2 is prevented from being transported from a capture site to an offshore storage site.[16] These definitional issues will have to be clarified for cross-border transfer of CO2 and the injection of CO2 offshore.

London Protocol (1996)

The London Protocol aims to create a more modern and comprehensive waste management system for the seas than the 1972 London Convention, with an increased emphasis on the protection of the environment. Under Article 4, all parties are required to "prohibit the dumping of any wastes or other matter with the exception of those listed in Annex 1". CO2 was not initially listed in Annex I and would have prohibited the disposal of CO2 in sub-sea formations. Annex I was subsequently amended in 2006 to expressly list "[c]arbon dioxide streams from carbon dioxide capture processes for sequestration". The amendment entered into force on 10 February 2007, paving the way for offshore storage of CO2, provided that three conditions are met. First, the disposal must be into a sub-seabed geological formation. Second, the waste stream must consist "overwhelmingly of carbon dioxide" but "may contain incidental associated substances". Third, no wastes or other matter can be added "for the purpose of disposing of those wastes or other matter".[17]

However, Article 6 of the London Protocol provides that "[c]ontracting Parties shall not allow the export of wastes or other matter to other countries for dumping or incineration at sea", hence prohibiting an export of CO2 to another country for injection into the sub-seabed. In October 2009, the Contracting Parties adopted a Resolution to amend Article 6 such that an export of CO2 for disposal may occur if the countries concerned entered into an agreement. While this amendment has not entered into force as

[14] Bankes, Nigel. "Carbon Capture and Storage and the Law of the Sea." *The Law of the Sea and Climate Change: Solutions and Constraints*, edited by Elise Johansen et al., Cambridge University Press, Cambridge, 2020, 160–183.
[15] "Offshore CO2 Storage." *UCL Carbon Capture Legal Programme*, https://www.ucl.ac.uk/cclp/ccsunclos.php. Accessed 6 July 2022.
[16] "International Marine Legislation." *UCL Carbon Capture Legal Programme*, https://www.ucl.ac.uk/cclp/ccstransport-int-marine-unclos.php. Accessed 6 July 2022.
[17] Bankes, Nigel. "Carbon Capture and Storage and the Law of the Sea." *The Law of the Sea and Climate Change: Solutions and Constraints*, edited by Elise Johansen et al., Cambridge University Press, Cambridge, 2020, 160–183.

an insufficient number of parties have ratified it, parties have adopted a resolution on the provisional application of the amendment.[18] Ms Herbert referred to this development as helpful in allowing parties to transfer CO2 across borders.

Basel Convention (1989)

The Basel Convention aims to protect human health and the environment from the risks caused by international trade in hazardous waste. The Convention provides that international trade in hazardous waste is subject to the prior consent of the receiving country, which is also entitled to prohibit this transport to, or across, its territory. The main unresolved issue is whether CO2 constitutes a hazardous waste within the scope of the Convention which would potentially impact the development of CCS by imposing stricter conditions for its transport across international borders.[19]

Other regulatory issues

Other regulatory issues relevant to CCS deployment include that of legal liability i.e. apportionment of legal responsibility in the case of an accident and/or leakage, even after the closure of a storage site. This question also relates to other issues such as licensing and monitoring of storage facilities. A well-defined liability regime is important as it clarifies operators' potential liabilities, promotes high standards, encourages investment, raises public confidence, and provides clear parameters for regulators as to their responsibilities and power of recourse.[20]

Ms Herbert agreed that legal liability remains a key issue to be solved, citing the EU Directive on the geological storage of carbon dioxide (2009/31/EC), a legal framework governing CCS in the European Union.[21] Under the Directive, the government assumes responsibility for the storage site twenty years after injection of CO2 into the site has stopped. In her view, this is a viable option for attributing legal responsibility, as responsibility for the storage site will have to be eventually transferred to the government. This encourages investment as it provides clarity to companies as to the limits of their liabilities.

Ms Herbert also pointed to the need for a transparent and global standard for monitoring and reporting on CO2 storage. This can potentially be attained through an intergovernmental agreement regulating CCS, together with an independent regulator approving, monitoring and reporting on the CO2 storage sites. Global standards are especially important if a carbon market is involved, as it ensures that a country passing over their emissions can claim credit for the emissions reduction. Such an intergovernmental agreement could also clarify issues of legal liability in the unlikely scenario that the CO2 leaks from the storage site. Ruth observed that the EU Directive is crucial in setting such a standard across Europe and is an important piece of legislation with learning points that are potentially transferable to other regions.

---

[18] Ibid.
[19] "CO2 transport for storage: Regulatory regimes." *UCL Carbon Capture Legal Programme*, https://www.ucl.ac.uk/cclp/ccstransport-int-waste-basel.php. Accessed 6 July 2022.
[20] Havercroft, Ian, and Macrory, Richard. "Legal Liability and Carbon Capture and Storage". *Global CCS Institute*, October 2014, 5, https://www.globalccsinstitute.com/archive/hub/publications/179798/legal-liability-carbon-capture-storage-comparative-perspective.pdf. Accessed 6 July 2022.
[21] "Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide". *Official Journal of the European Union*, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF. Accessed 13 July 2022.

Potential challenges

There remain concerns over risks posed by climate geoengineering such as incomplete knowledge, a false sense of security, and a lack of inclusiveness.[22] Responding to these concerns, Ms Herbert explained that the technologies involved are fully understood and have been operating for many decades in some sectors of the economy, such as the chemicals industry. Furthermore, knowledge about transporting CO2 by pipeline or ships is well-known as such systems are used for EOR. In relation to carbon storage, she pointed to the over 20 years of data from Norway on the behaviour of CO2 in a saline aquifer, while EOR has contributed to understanding how CO2 behaves in depleted oil and gas fields. She emphasized that generally, once the CO2 has entered these storage formations, it is difficult to get it out, describing it as being akin to the natural process of storing CO2.

In her opinion, the barriers to CCS deployment are mainly economic and political in nature. One of the key challenges is the cost of operating a CCS facility. At present, while carbon markets can provide some incentive for CCS projects, given the cost of the technology, CCS facilities are not investable based on the carbon price alone. Sectors that wish to decarbonise through CCS will require economic support from the government. The UK Government, for instance, has developed business models to cover the difference between the carbon price and the cost of capturing CO2. These governmental support measures are likely to be necessary in the initial phases of CCS deployment until economies of scale can be achieved.

In her view, a country's Nationally Determined Contribution (NDC) under the Paris Agreement plays an important role in driving the deployment of CCS facilities. Once a country has set a net-zero target, CCS is likely to feature in their strategy to achieve that goal. In addition, another possible driver for CCS technologies is the demand for cleaner products by consumers, as decarbonisation can allow companies to differentiate themselves on the market. While there is demand for "clean" products, standards are required to ensure that such products are genuinely "clean", especially through analysing the entire life-cycle of the product.

Addressing criticisms that CCS might prolong the use of fossil fuels, Ms Herbert referred to the IPCC report that flagged the role of CCS in achieving net-zero emissions, adding that some industries simply cannot decarbonise without resorting to CCS. This is to be distinguished from the utilisation of captured CO2 in EOR to increase oil production which does not result in climate mitigation. The CO2 captured must be permanently stored in storage sites, rather than being used to attain more fossil fuels, if CCS is used for mitigation purposes. Recalling the importance of transparent standards, she suggested that clear data of CO2 remaining in the storage site would address such concerns.

Commentary

CCS developments in Singapore

[22] 2013 report from a group of representatives from the Small Island Developing States (SIDS) in the Pacific: Penehuro Fatu Lefale and Cheryl Lea Anderson, *Climate Engineering and Small Island States: Panacea or Catastrophe?,* in Geoengineering our Climate? Ethics, Politics, and Governance 159, (Jason Blackstock and Sean Low ed., 2019).

Singapore's Long-Term Low-Emissions Development Strategy (LEDS) submitted in March 2020 sets out the aspiration to halve emissions from its peak by 2050 and to achieve net-zero emissions in the second half of the century.[23] Singapore recently announced her raised ambition of achieving net-zero emissions by or around 2050, earlier than previously committed.[24] The strategy to achieve net-zero emissions will have three thrusts, one of which includes the adoption of low-carbon technologies such as CCUS and low-carbon hydrogen.[25]

This was reiterated in a joint press release by the National Climate Change Secretariat (NCCS), Economic Development Board (EDB), Energy Market Authority (EMA), Maritime and Port Authority of Singapore (MPA) and Civil Aviation Authority of Singapore (CAAS), which stated that, Singapore, as an alternative-energy disadvantaged country, "expects [low-carbon hydrogen and CCUS] technologies to play important roles in the transition to a low-carbon future". [26]

According to a 2021 study jointly commissioned by NCCS and EDB, there are barriers to CCS deployment in Singapore, namely: (a) the high cost of CCS as most of the CO2 emitted is from low concentration flue gas, and (b) the lack of incentives for industries to address their emissions as the carbon tax is presently much lower than the cost of CCS.[27] Thus, the economics of CCS needs to improve through cost reductions, technology development and other supporting mechanisms.[28] While Singapore does not have any known suitable reservoirs for the permanent storage of CO2, there is storage potential in the region.[29] Despite the challenges, CCS presents promising opportunities: (a) CCS can be used as a feedstock to produce chemicals, enabling the chemical sector to decarbonise, (b) emission-intensive companies will likely demand for solutions like CCS to keep up with increasingly stringent regulation, (c) costs for CO2 capture are decreasing, and (d) CCS research can spur innovation in Singapore. [30]

The findings from the study will be used to inform existing research and development efforts, such as the S$49 million Low Carbon Energy Research (LCER) Funding Initiative which aims to accelerate the technical and economic viability of low-carbon energy technologies in hydrogen and CCUS.[31] Research projects can include technologies that enable the effective capture of CO2 from low-concentration

[23] "Charting Singapore's Low-Carbon and Climate Resilient Future." (Singapore's LEDS). National Climate Change Secretariat. 2020, https://www.nccs.gov.sg/files/docs/default-source/publications/nccsleds.pdf. Accessed 13 July 2022.
[24] See the Budget Speech by Finance Minister Lawrence Wong delivered on 18 February 2022. "Advance Our Green Transition." Ministry of Finance, 2022, https://www.mof.gov.sg/singaporebudget/budget-2022/budget-statement/d-advance-our-green-transition. Accessed 14 July 2022.
[25] "Singapore Looks to Develop and Deploy Low-Carbon Technological Solutions." *National Climate Change Secretariat,* 23 June 2021, 10, https://file.go.gov.sg/hydrogen-ccus-press-release-23june2021.pdf. Press release. Accessed 6 July 2022.
[26] Ibid, 1.
[27] Srivastav, Preeti et al. "Carbon Capture, Utilisation and Storage, (CCUS): Decarbonisation Pathways for Singapore's Energy and Chemicals Sectors." *Navigant*, June 2021, 28, https://file.go.gov.sg/carbon-capture-utilisation-and-storage-decarbonisation-pathway-for-singapore-energy-and-chemical-sectors-pdf.pdf. Accessed 6 July 2022.
[28] Ibid, 3.
[29] Ibid, 33.
[30] Ibid, 29.
[31] "Singapore Looks to Develop and Deploy Low-Carbon Technological Solutions." *National Climate Change Secretariat,* 23 June 2021, 2, https://file.go.gov.sg/hydrogen-ccus-press-release-23june2021.pdf. Press release. Accessed 6 July 2022.

emission sources, and technologies to convert the CO2 into building materials, reclamation sand and synthetic fuels.[32]

Looking ahead

COP27 will be held in Sharm el-Sheikh, Egypt, in November 2022. According to Egypt's Foreign Minister Sameh Soukry, an evaluation of how countries are collectively implementing the Paris Agreement (the global stocktake) will be high on the agenda.[33] In addition, technical discussion on CCS will be timely and relevant in light of the IPCC Report.[34]

In addition to advances in CCS technology, and conducive economic and political conditions, an increased rate of CCS deployment would also require:

(a) transparent and possibly harmonised technical standards;
(b) clarity in CCS regulation e.g. on questions of apportionment of legal liability;
(c) clarity in international agreements in addressing the cross-boundary dimensions, and the permissibility and consistency of CCS activities with international law.

There is a need for countries to engage both domestically and internationally, including with private sector stakeholders as appropriate, to discuss and address these gaps and uncertainties on an urgent basis, in tandem with any increased rate of CCS deployment to meet the goals of the Paris Agreement. While COP27 offers an opportunity to continue and deepen such dialogue, the visibility accorded to CCS deployment in the IPCC WG III Report: Mitigation of Climate Change has added urgency to addressing these questions.

Contributors:
Danielle Yeow
Whang Chia Ning

[32] "Low-carbon Technologies." *National Climate Change Secretariat*, https://www.nccs.gov.sg/singapores-climate-action/low-carbon-tech/#:~:text=Carbon%20Capture%2C%20Utilisation%20and%20Storage,-CCUS%20has%20the&text=Singapore%20is%20currently%20studying%20potential,are%20high%20at%20the%20moment. Accessed 6 July 2022.
[33] Lin, Max Tingyao. "COP27, COP28 to see climate stocktaking, more focus on developing world, renewed fossil fuel debates." *IHS Markit*, 19 January 2022, https://cleanenergynews.ihsmarkit.com/research-analysis/cop27-cop28-to-see-climate-stocktaking-more-focus-on-developin.html. Accessed 6 July 2022.
[34] Amer, Noora Al. "Boon Climate Conference Outcomes." *Global CCS Institute*. July 2022, 8, https://www.globalccsinstitute.com/wp-content/uploads/2022/07/Bonn-Climate-Conference-Outcomes-2022-Global-CCS-Institute-1.pdf. Accessed 13 July 2022.