STEPPING UP DECARBONIZATION WITH CARBON CAPTURE AND SEQUESTRATION

A look at how emissions-reduction technology plus the storage of carbon dioxide and hydrogen can accelerate the transition to net zero

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Contributors

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Technical and advisory teams in the United Kingdom and Canada have experience in the provision of engineering design, technical support and specialist consultancy services to the upstream and midstream hydrocarbons and energy sectors. Their technical expertise covers carbon capture and storage, hydrogen, liquefied natural gas and industrial decarbonization.

- Kaycee Garrett – Vice President, Geologist, Director of Regulatory Engineering and Geological Services, United States
- Ray Steppe – Assistant Vice President, Petroleum Engineer, United States

Members of the Regulatory Engineering and Geological Services (REGS) team in WSP's Texas Energy, Underground Storage Group have backgrounds in the environmental, regulatory and oil and gas industries; the team has as a 30-year history of permitting and drilling injection wells under the Underground Injection Control (UIC) regulatory framework.

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Rapid decarbonization is essential as the world seeks to achieve net-zero emissions by 2050[1] —less than 30 years away. Carbon capture[2] together with geological carbon sequestration can accelerate global decarbonization outcomes; the production and storage of low-carbon hydrogen[3] represents a way to advance clean energy use.

In the following article, members of WSP's technical and advisory teams who have worked on carbon capture and sequestration (CCS) and hydrogen storage projects discuss the significant role[4] of these technologies in tackling the pressing global issue of decarbonization; they also consider the challenges that must be addressed to support carbon sequestration/storage and hydrogen storage.

Can you provide an overview of carbon capture and sequestration?

Kaycee Garrett: CCS prevents CO_2 from entering the atmosphere, or removes it from the atmosphere, then permanently stores it in geological formations. There are three main parts to the CCS process: carbon capture, which captures most of the CO_2 emissions from industrial processes or removes CO_2 directly from the atmosphere; the transportation of CO_2 (by land or sea) to the storage site; and carbon sequestration, which permanently stores the CO_2 in onshore or offshore underground geologic formations.

1 United Nations, Climate Action: The science shows clearly that in order to avert the worst impacts of climate change and preserve a livable planet, global temperature increase needs to be limited to 1.5°C above pre-industrial levels. Currently, the Earth is already about 1.1°C warmer than it was in the late 1800s, and emissions continue to rise. To keep global warming to no more than 1.5°C—as called for in the Paris Agreement—emissions need to be reduced by 45% by 2030 and reach net zero by 2050.

2 The word "carbon" (as represent by "C" in "CCS") is common parlance for carbon dioxide.

3 Low-carbon hydrogen considers "well to wheel" or full lifecycle CO_2 emissions.

4 "6 Takeaways from the 2022 IPCC Climate Change Mitigation Report," World Resources Institute, April 4, 2022.

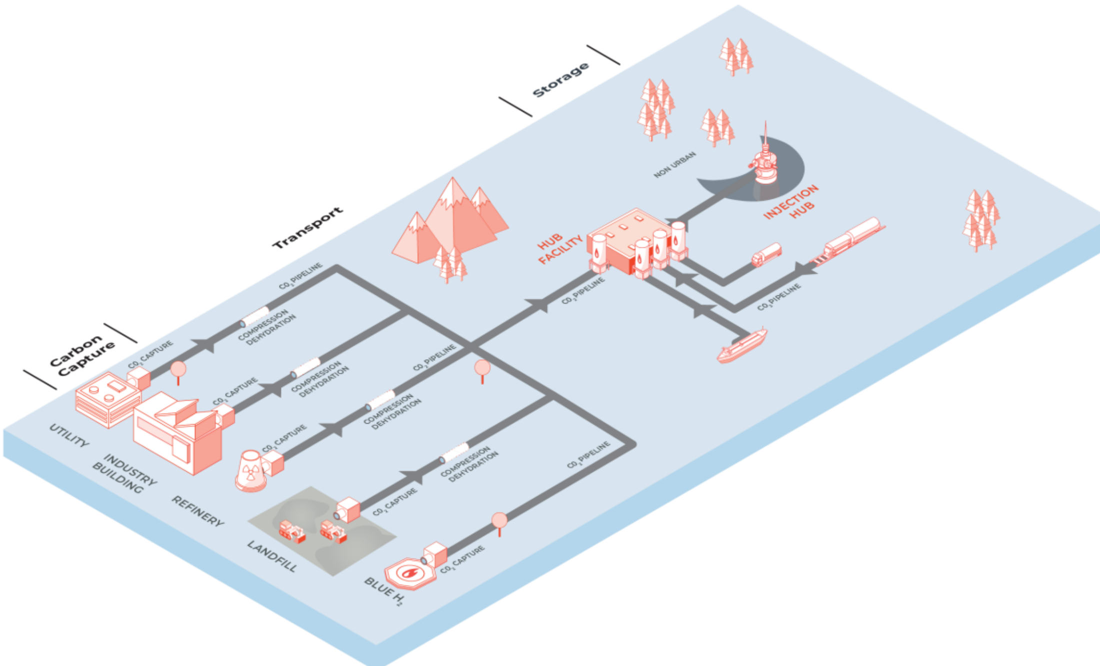

Figure 1 – The main parts of CCS as applied to industrial processes and hydrogen production.

Why is CCS an important aspect of decarbonization efforts?

Tony Alderson: Carbon capture allows society to progress with decarbonization while transitioning away from fossil fuels and traditional industrial technologies. Applying carbon capture to fossil fuel-fired power generation allows the production of low-carbon power on demand to complement the supply of intermittent renewable power[5]. Energy intensive industries, and those that produce CO_2 as part of the intrinsic industrial process such as cement production, can also be decarbonized without needing to wait until new production technologies or alternative products have been developed, which may still be several decades away—thereby achieving decarbonization benefits in a much shorter timescale.

Kaycee Garrett: The International Energy Agency has acknowledged the importance of carbon storage under its Clean Technology Scenario, which assumes wide availability of CO_2 storage to meet global climate goals.[6] Together, carbon capture and sequestration can achieve significant CO_2 reductions.

[5] Intermittent energy sources are those that are not constantly available or predictable.

[6] Clean Technology Innovation, Energy System Overview, IEA.

Tony Alderson: A further area in which carbon capture can be beneficially applied is in the production of low-carbon “blue” hydrogen. Utilizing this hydrogen as a carbon-free alternative to fossil fuels facilitates the decarbonization of sectors such as transportation and domestic heating. While ultimately we can expect most hydrogen produced to be “green” hydrogen—created via electrolysis of water using renewable electricity— the application of carbon capture to traditional hydrogen production technologies from natural gas feedstock supports the acceleration of the transition to clean-energy alternatives worldwide.

What is the state of the CCS industry today?

Ray Steppe: The technology to capture carbon is rapidly advancing and has been applied in several large-scale plants in North America but has not yet been applied at the scale necessary around the world to advance the reduction initiative. However, the technology and practice of emplacing CO_2 underground has been practiced for nearly 40 years using injection wells for enhanced oil recovery (EOR) in Texas.

Blaise Moore: WSP has been designing CO_2 (and acid gas) capture and sequestration projects for over 40 years (far before the term CCS was coined). The capture has been mainly from the produced gas to make pipeline specification gas and/or to enrich the acid gas prior to sulphur recovery. Capturing CO_2 from flue gas has been cost prohibitive in the past; monetizing the CO_2 such as through tax credits and subsidies and the goal of making 2030 then 2050 targets will allow these projects to gain momentum.

What technologies are being used for carbon capture?

Tony Alderson: The technologies currently used commercially for carbon capture of industrial emissions utilise amine-based solvents to absorb the CO_2 from the exhaust gas streams from power generation plants and other industrial facilities. Applying this process can eliminate 90-95 percent or more of the CO_2 emissions that would otherwise enter the atmosphere. The solvent, now loaded with CO_2, is then heated in a regenerator column to desorb the CO_2, resulting in a high-purity CO_2 stream that requires compression and dehydration so that it can be sent for permanent sequestration.

Amine-based capture technologies are available from a range of highly-regarded technology providers with proven track records. These technology providers are constantly striving to improve the performance and drive down the costs of their processes.

In addition, there are alternative carbon capture technologies under development by industry and academia. These include alternative solvent systems that do not use amines, processes that use solid sorbents to capture the CO_2, and more novel processes, such as freezing out the CO_2 to separate it from the exhaust gas stream. As these technologies reach commercial maturity, they will offer the potential to further improve the performance and reduce the costs (capital and/or operating) associated with carbon capture, widening its applicability and increasing the potential for CO_2 emissions reduction.

While these technologies are primarily focused on carbon capture from industrial emissions, they can, with some modification, also be applied to direct carbon capture from the atmosphere. However, the technical challenges with direct air capture are greater, principally due to the CO_2 concentration in the atmosphere being around one hundred times less than in the exhaust gas streams from industry.

WSP has worked with several carbon capture technology developers as they seek to commercialize their processes, and we have assisted project developers in assessing and selecting preferred capture technologies for their specific applications.

Can you discuss the role of siting and permitting injection wells in the sequestration process?

Ray Steppe: The primary objectives in siting and permitting injection wells are to ensure that CO_2 injection will remain permanently confined to geologic formations and to design an injection well program that prevents vertical migration of injected fluid to underground sources of drinking water. We transfer our knowledge and experience in permitting, drilling, and operating various types of injection wells to CO_2 projects, applying proven methods of demonstrating regulatory and operational compliance.

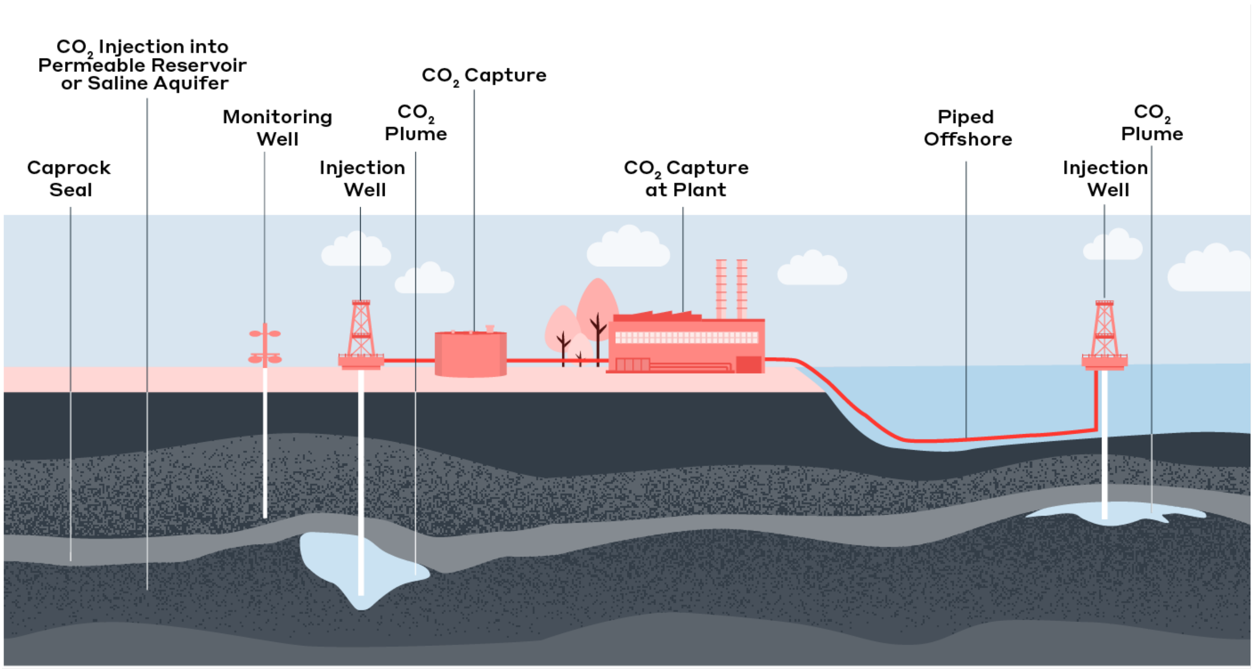

Figure 2 – Onshore and offshore storage of carbon dioxide

How does storage support hydrogen as a viable decarbonization pathway?

Kaycee Garrett: The application of technology and geology enables a complete process whereby the hydrogen that is produced can be temporarily stored for later use as a clean energy source.

There are various methods for producing hydrogen; some meet zero-carbon standards, while others are carbon neutral. As Tony explained earlier, green hydrogen, which is the cleanest of the hydrogen options, is produced through electrolysis using renewable energy sources, such as solar or wind, to electrolyze water, while blue hydrogen is produced from natural gas with a CO_2 by-product that is captured before emission. No matter how the hydrogen is produced, carbon emissions are not produced when burning hydrogen or converting it into electricity.

Hydrogen can help create an energy system that promotes power generation, hydrogen vehicles, synthetic fuels, fertilizers, heating and cooling, and material refining. An integral component of the hydrogen supply chain is identifying suitable underground storage structures for large quantities, which can then be used for power generation and heating during periods of high demand. WSP has considerable experience drilling, solution mining, and creating caverns in salt formations for energy storage. Our teams have completed the design of a 1.3 million m^3 hydrogen storage cavern in a salt dome in southeast Texas for a large midstream oil and gas company and have also drilled and commissioned two hydrogen cavern wells in bedded salt as part of the world's largest green hydrogen storage project located in Utah for Advance Clean Energy Storage (ACES).

Tony Alderson: Hydrogen storage in salt caverns has also been deployed in the UK for several decades, with further projects under development. Large-scale electrolytic hydrogen projects are under development throughout the world, including in Europe, Asia and Australasia as well as North America. The development of hydrogen storage will be a key element of this evolving industry.

What factors challenge efforts to increase carbon sequestration and hydrogen storage?

Blaise Moore: The main challenge in North America is commercial. Often the source of the CO_2 is not near a sequestration point, making transportation expensive and approvals difficult. The commercial justification for CCS is a challenge, often needing multiple sources of CO_2 to make the overall project viable. The various industries involved in CO_2 production are not currently talking details with each other. Individual CO_2 producers working together, combining their CO_2 sources through hubs to a common sequestration point and sharing common costs, will aid the industries to scale CO_2 injection volumes necessary to get to 2030 then 2050 targets.

Tony Alderson: In the UK, commercial challenges are also the main barrier to the implementation of CCS. However, the UK Government is seeking to address this through a range of financial support mechanisms that will be applied to both the capture plant operators and the transport & storage (T&S) operators that are developing the first two CCS clusters in the UK. Additional clusters, and the addition of further capture plants to the initial clusters are planned, with an overall Government commitment of

£20 billion over the coming decades to support the development of the CCS sector.[7] The development of CCS clusters facilitates the sharing of T&S infrastructure between capture plants, further helping to address the cost challenges of CCS implementation as noted by Blaise.

Kaycee Garrett: A major factor in the US relates to pore space;[8] there is no consensus from state to state as to who owns the pore space rights and no determination as to how pore space access is established across property lines. Pore space rights and access has been intrinsically linked to carbon sequestration initiatives in a way that has not been previously established for other injection well operations, specifically industrial waste disposal. There are concerns that the debate over pore space rights and access will impede progress on the climate change initiatives and indirectly impact historical use of other types of injection wells.

One of the challenges facing hydrogen storage is collocating resources. If underground hydrogen storage is limited to salt features, then there are limited geographic locations across North America where the geology is viable. Several other factors further complicate their siting: the accessibility of existing or new hydrogen, CO_2 or natural gas pipelines; available renewable power sources; subsurface space for carbon sequestration, brine disposal, or wastewater (electrolysis waste stream) disposal; and proper state and federal regulatory framework.

Most importantly, there are serious misconceptions held by significant stakeholders integral to these projects. We have seen local councils block or ban injection well permits within their jurisdiction based on misconception and politics, leading to delays on projects while these issues are adjudicated.

[7] "The UK Government Unveils Significant CCS Funding in 2023 Spring Budget," Global CCS Institute, March 16, 2023.

[8] Pore space is the empty space within and between rocks or between particles of sand and sediment. When CO_2 is injected into the ground during sequestration, it fills in these spaces.

To further both CCS and Hydrogen storage initiatives, improvement in the following areas are needed:

- Additional research and technology development to advance the safe and sustainable application of CO_2 sequestration
- The expedited development of new and improved carbon capture technologies that improve performance and reduce cost
- Government support to address the commercial challenges associated with implementing CCS
- National and international consensus on regulatory and legal issues so that operators and consultants can execute CCS projects more efficiently
- Investment in stakeholder engagement by operators and local leaders to inform and educate the public on the necessity and safe practice of CCS and hydrogen storage
- Research into the viability of utilizing depleted hydrocarbon fields for hydrogen storage – Conventional and unconventional geologic sites are being researched and considered as underground storge options for hydrogen. Due to the well-documented history of hydrocarbon storage in salt caverns, they are the recommended option for storage at this time.

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