Practical Considerations for Carbonated Brine Injection

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Disclaimer

The information I am presenting today identifies practical considerations relating to the regulation of geologic sequestration of carbon dioxide through injection of carbonated brine streams. I acknowledge that this work is supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) and conducted in coordination with the University of North Dakota Energy & Environmental Research Center (EERC). The views I am presenting, however, are my personal views and are not presented on behalf of NETL, EERC, or any other organization with which I have a relationship.

Carbonated Brine Projects

Carbon dioxide geologic storage study projects have:

- Examined the potential for enhancing storage capability and capacity using brine extraction as part of active reservoir management (ARM) programs
- Changed withdrawal and injection of brine to ameliorate the pressure effects of carbon dioxide free phase injection
- Shown it is possible to store carbon entirely dissolved in injected brine through a process known as carbonated brine injection (CBI)

CBI Background

- Related activities include carbon dioxide (CO_2) enhanced oil recovery (EOR)
- Rather than carbonated brine, CO_2-EOR more typically involves alternated injection of brine and CO_2 – a process known as water alternating gas (WAG)
- Injecting water near saturation with carbon dioxide has many unique advantages for carbon storage
- To date, studies have examined technical feasibility and storage performance
- But have not explored how application of CBI for geologic storage of CO_2 might fit within relevant regulatory frameworks of jurisdictions where projects might be implemented, a critical consideration for commercial deployment.

Potential CBI Storage Advantages

- CBI has no free phase CO_2 plume because dissolution trapping is intrinsic to the injection process
- Mitigating risks associated with potential migration of buoyant CO_2
- CBI removes differences in fluid compressibility between the brine phase and a supercritical CO_2 phase
- Pressure equilibration post injection is not inhibited by two-phase flow, as the CO_2 is a component of the brine and thus stored in the aqueous phase
- Reduces CO_2 risks associated with vertical and lateral mobility of injected CO2 and geomechancial stresses on the confining zones

CBI Process

- Injected fluids would consist of a combination of brine and captured anthropogenic carbon dioxide
- Both the brine and CO2 are in the aqueous phase
- CO_2 mass fraction likely to be between 1%-5% depending on the salinity and pressure and temperature conditions at depth
- Volume of CO_2 that can be dissolved into disposal brine is dependent on the brine's salinity as well as the temperature and pressure of the reservoir
- Considering a 2% mass fraction, it is estimated that as much as 50 million tons of CO_2 could be geologically stored using a CBI process each year

Potential CBI Scenarios

1. Capture and secure storage of CO2 with disposal of produced water associated with hydrocarbon production (e.g., gas plant separation)
2. Storage of incremental CO2 using CBI in conjunction Enhanced Hydrocarbon Recovery operations
3. Storage of incremental CO2 using CBI in conjunction with water produced and reinjected for ARM at CO_2 storage sites
4. Anthropogenic CO2 combined with produced water for disposal onshore
5. Anthropogenic CO2 combined with produced water for disposal offshore
6. Anthropogenic CO2 combined with industrial waste for disposal onshore
7. Anthropogenic CO2 combined with drinking water treatment residuals for disposal onshore
8. Storage of CO2 from direct air capture as carbonated brine

Underground Injection Control (UIC) Program Wells

- Class I wells are used to inject hazardous and non-hazardous wastes into deep, isolated rock formations. Most Class I wells dispose of industrial wastes or municipal wastewater treatment wastes.
- Class II wells are used exclusively to inject fluids associated with oil and natural gas production.
  - Class II disposal wells inject waste fluids produced used in wells (e.g., drilling).
  - Class II enhanced recovery wells inject fluids consisting of brine, freshwater, steam, polymers, or carbon dioxide into oil-bearing formations to recover residual oil or natural gas.
- Class V wells inject other non-hazardous fluids.
- Class VI wells inject carbon dioxide (CO2) streams for long-term storage, or geologic sequestration.
  - CO2 stream means "carbon dioxide that has been captured from an emission source (e.g., a power plant), plus incidental associated substances derived from the source materials and the capture process, and any substances added to the stream to enable or improve the injection process."

Bases for Class VI Development

- EPA determined a need to tailored existing UIC regulatory framework and create new Class VI due to:
- Anticipated large CO_2 injection volumes at GS projects,
- Relative buoyancy of CO_2,
- Its mobility within subsurface geologic formations,
- Its corrosivity in the presence of water, and
- Potential presence of impurities in the captured CO_2 streams

Disposal of CO_2 with produced water

- CO_2 separated from a hydrocarbon production stream when mixed with produced water should be eligible for injection in a Class II disposal well as fluids associated with oil and natural gas production
- Similarly, CO_2 and H_2S from oil and gas production are injected into Class II acid gas disposal wells
- Should be acceptable even if the CO_2 is separated during production within a gas stream and then separated from the gas stream in a gas plant before being recombined with produced water
- Should be eligible for 45Q tax credit as disposal in secure geological storage

CBI for EOR

- CBI for enhanced hydrocarbon production (EOR), such as water flooding should be eligible for Class II EOR injection, regardless of the source of the CO_2
- If the injected fluid is being used for EOR, the injection should qualify for Class II injection
- Qualification for 45Q tax credits would require meeting reporting either under 40 CFR part 98 subpart RR or ISO 27916 in accordance with IRS rule
- Quantification under either approach would require mass balance accounting for any CO_2 emitted

Onshore produced water CBI

- Combining anthropogenic CO_2 with produced water for CBI onshore would raise a UIC question regarding whether the injected fluid is a CO_2 stream within the meaning of Class VI
- Focus may be whether the brine is "added to the stream to enable or improve the injection process"
  - Factors that improve storage by reducing mobility (e.g., buoyancy and two-phase flow) and ameliorating pressure could support this view
  - Great difference in ratio of CO_2 to brine could undercut
- Alternative consideration could focus on buoyancy and potential for migration as major underpinning for Class VI justification, which would be absent for CBI storage 75 Fed. Reg. 77230, 77233 (Dec. 10, 2010)

Storing CO2 in ARM Brine

- Storage of incremental CO2 using CBI in conjunction with water produced and reinjected for ARM at CO_2 storage sites should be subject to the same provisions as onshore CBI
- Produced ARM brine could be reinjected with or without the addition of more CO2 as dictated by the salinity – pressure – temperature conditions at depth
- Considerations are the same as on the previous slide

Offshore produced water CBI

- For offshore CBI storage, considerations differ
- Section 40307 of the Infrastructure Investment and Jobs Act (2021) provides a different definition of CO_2 stream
  - "carbon dioxide that has been captured"
  - "consists overwhelmingly of carbon dioxide"
  - "incidental associated substances derived from the source material or capture process"
  - "substances added to the stream for the purpose of enabling or improving the injection process"
  - "does not include additional waste or other matter added to the carbon dioxide stream for the purpose of disposal"
- Inclusion of "overwhelmingly" argues against CBI being CO_2 stream because the CO_2 would be ≤2%
- Moreover, brine could be viewed as added for disposal
- However, current OCS rules limit injection to hydrocarbon storage

Industrial Waste CBI

- Class I industrial waste disposal wells are currently used at petroleum refineries, petrochemical plants, electricity generating plants, steel mills and other types of facilities, all of which have been identified as having potential to capture CO_2
- Combining CO_2 captured onsite, which can be viewed as an industrial waste, with other waste fluids could qualify for injection into either Class I hazardous or nonhazardous wells, especially if CBI not CO_2 stream
- Such CBI plumes could behave more similarly to Class I injectate than Class VI plumes

CBI with DWTR Disposal

- Residuals from drinking water treatment plants (e.g., desalination plants) are sometimes injected through Class V wells – deemed not covered in other classes
- Such wastes have also been injected into wells dual permitted as Class V and Class II brine disposal
- If CBI streams are not deemed Class VI CO2 streams, Class V permitting should be another option, whether or not the CBI stream is combined with other streams
- Likewise, captured CO2 could be combined into such previously injected streams to form CB for injection

CBI from DAC

- Storage of CO_2 from direct air capture as carbonated brine could be injected into wells as previously noted depending on whether the carbonated brine is a CO_2 stream within the meaning of Class VI
- If DAC CBI is not a CO_2 stream
  - Class II disposal wells could be co-permitted as Class V wells for CBI of captured CO_2 with produced water
  - DAC CO_2 could be commingled with Class V DWTR
  - Class I commercial wells could inject DAC CO_2
  - Class I industrial wells could be used at collocated DAC

Discussion

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