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GROUNDWATER PROTECTION COUNCIL

Flue Gas Injection as an Alternative to CO_2 Capture: Subsurface Risk Considerations and Financial Tradeoffs

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Summary

Results:

- Flue gas injection can be cheaper than carbon capture, depending on the %CO_2 in the waste stream
- Decreased %CO_2 in the waste stream leads to larger pressure buildups
- Pressure-driven risks can be mitigated with increased well spacing

Motivation

Estimates of CO_2 Stationary Source Emissions and Estimates of CO_2 Storage Resources for Geologic Storage Sites											
RCSP or Geographic Region	CO_2 Stationary Sources		CO_2 Storage Resource Estimates (billion metric tons of CO_2)								
	CO_2 Emissions (million metric tons per year)	Number of Sources	Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
			Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232		--		--	--	--	--	--	--
Total	3,071	6,358	2,379	8,328	21,633	86	205	232	54	80	113

Source: U.S. Carbon Storage Atlas –Fifth Edition (Atlas V); data current as of November 2014

* Totals include Canadian sources identified by the RCSP

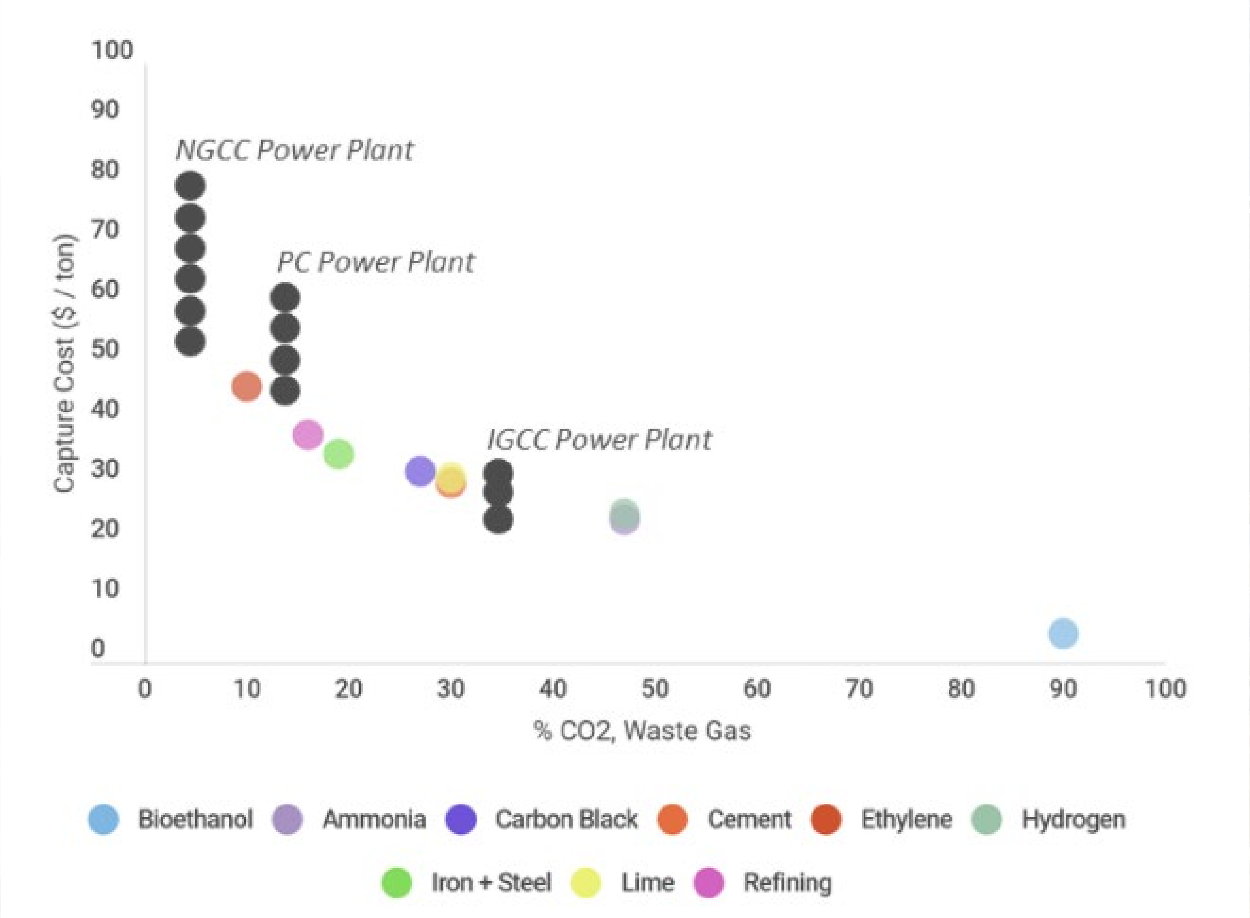
** As of November 2014, "U.S. Non-RCSP" includes Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and Puerto Rico

*** Medium = p50

Source: NETL NATCARB Atlas, 2014

- CCS captures 70%-90% of CO_2, conserving pore volume
- Capture costs have slowed down deployment
- There are 2-22 trillion tons (!) of PV available in US saline aquifers *alone*
    - Compared to 3.1 Gtpa CO_2 emissions from PSEs in the US
- Why not just inject the flue gas?

Carbon Capture vs Transport

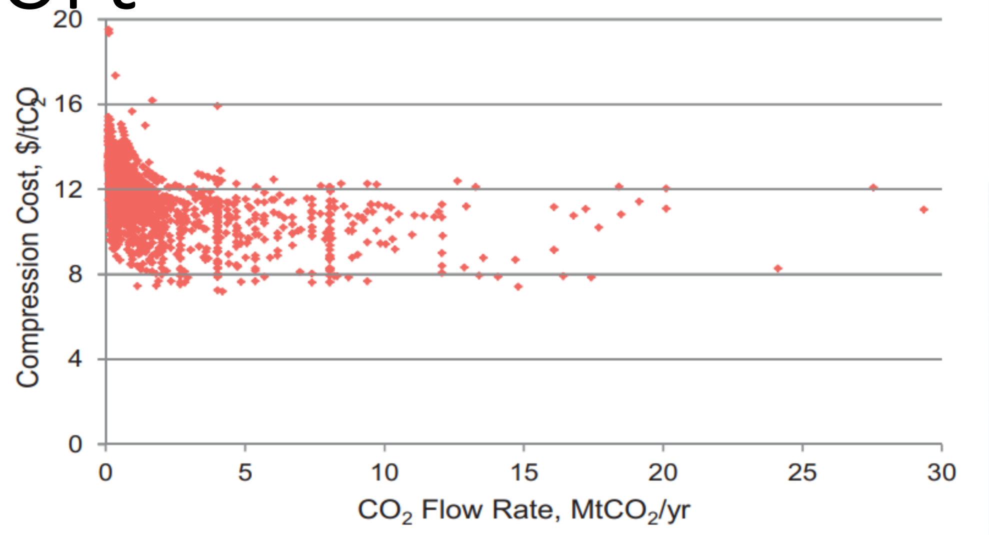


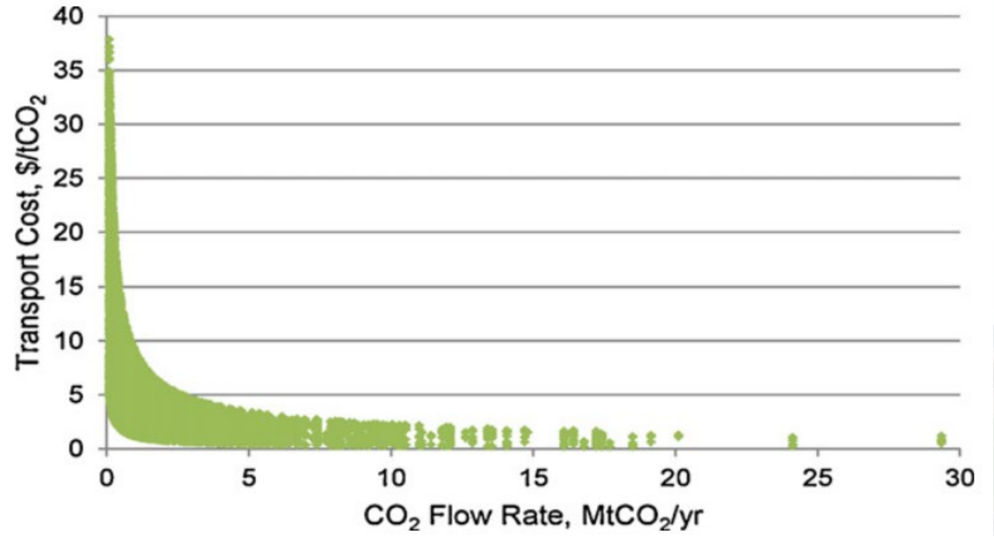
Source: Pilorgé et al., Env. Sci. & Tech., 2020

- Wide range on capture costs for each PSE
- Cost increases as %CO_2 decreases
- Represents a parasitic load on PSEs, up to 30% power production
- Does not include the cost of compression, transport, and storage (CTS)

Carbon Capture vs Transport

- Cost of CTS also variable
- Compression ranges from \$7 to \$20 per ton CO_2
- Transport adds another \$1 to \$10 per ton
- Wholesale discounts, shorter travel distances can make a big difference
- This is added on after the cost of capture

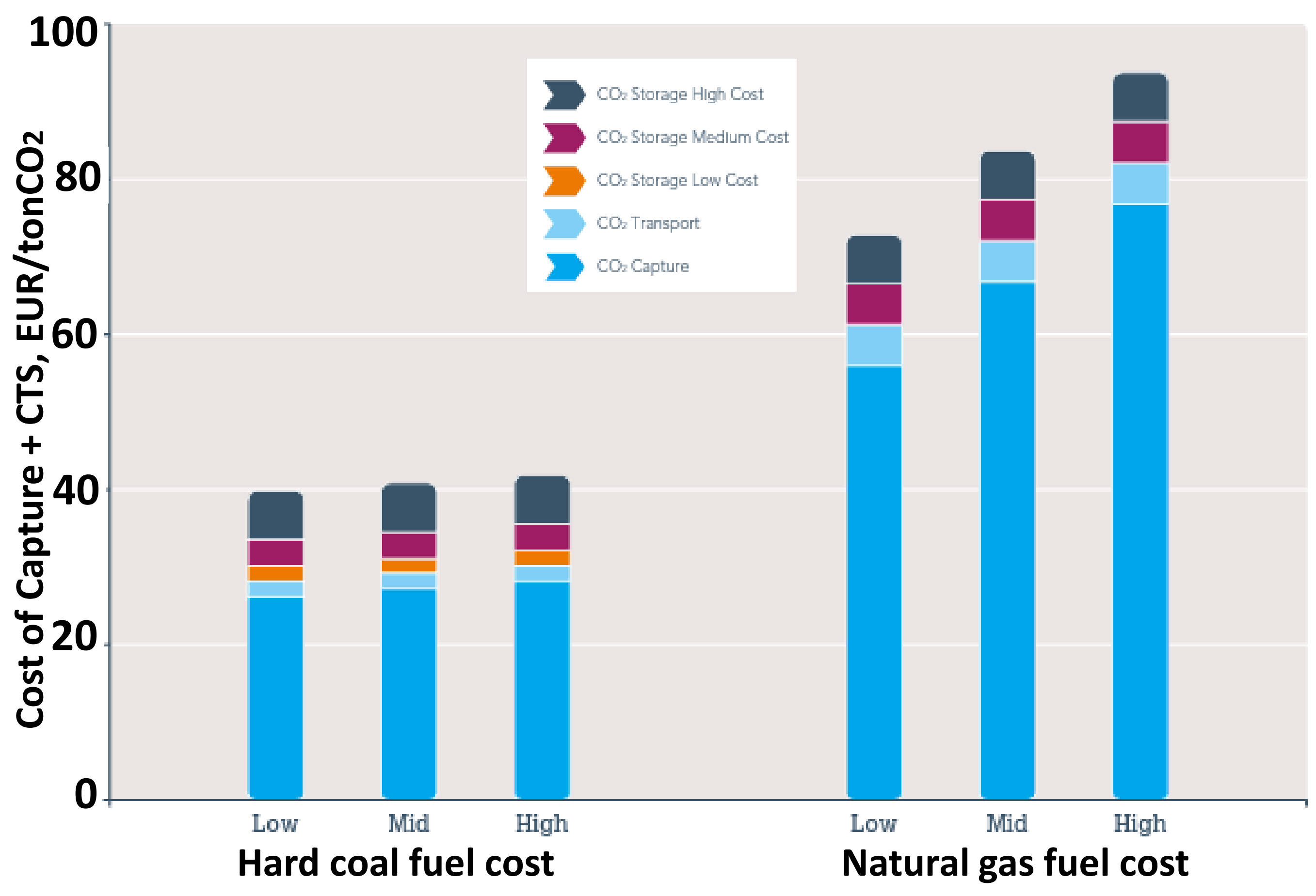




Source: Dahowski et al., IJGGC, 2012

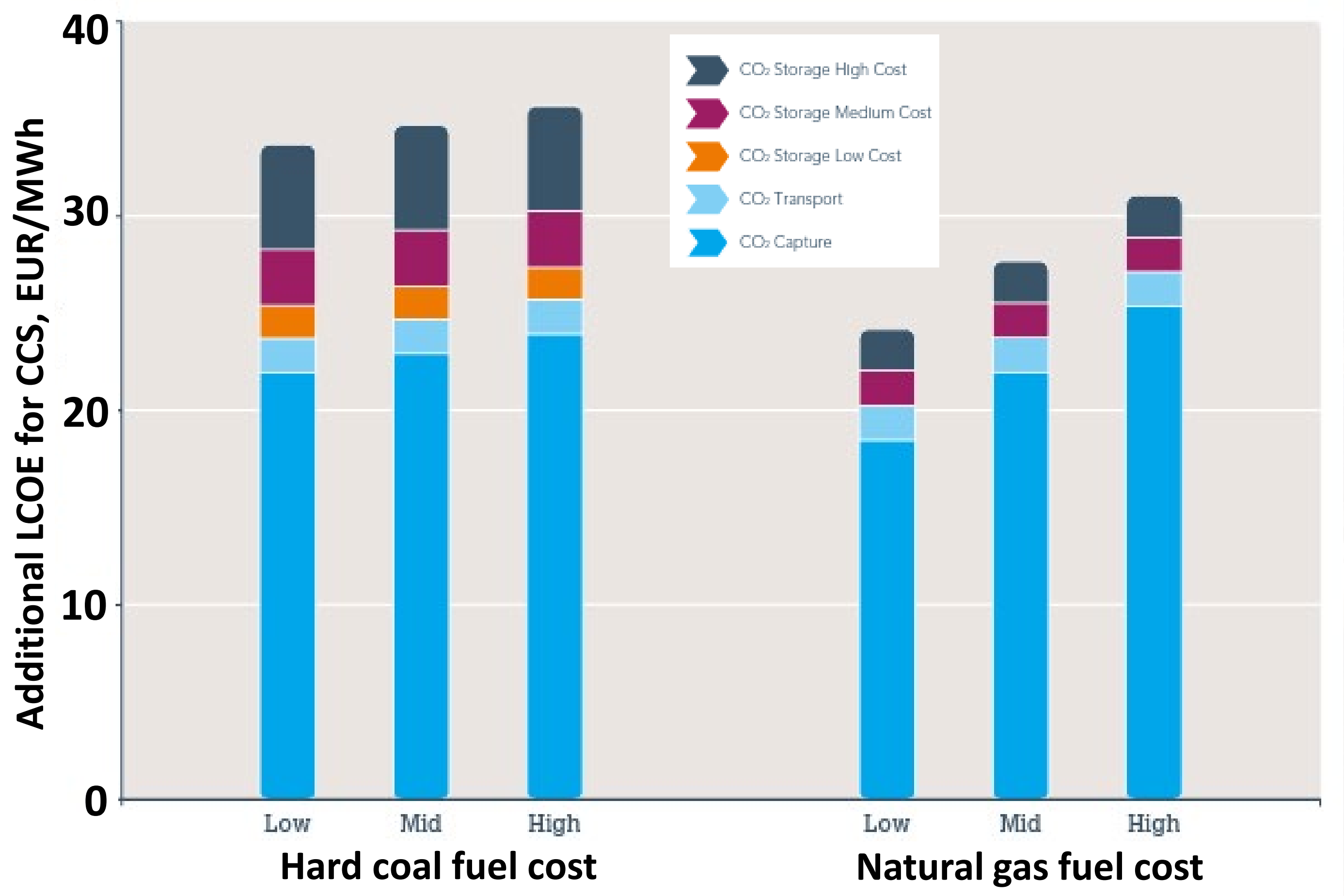
Carbon Capture vs Transport

- Compression, transport, and storage (CTS) make up a small fraction of CCS
- Estimates vary from \$8 - \$20 per ton CO_2
- We use \$10 and \$16 per ton CO_2 in our study



Source: The Costs of CO_2 Capture, Transport and Storage, European Technology Platform for Zero Emission Fossil Fuel Power Plants, 2011

Parasitic Load on PSEs



Source: The Costs of CO_2 Capture, Transport and Storage, European Technology Platform for Zero Emission Fossil Fuel Power Plants, 2011

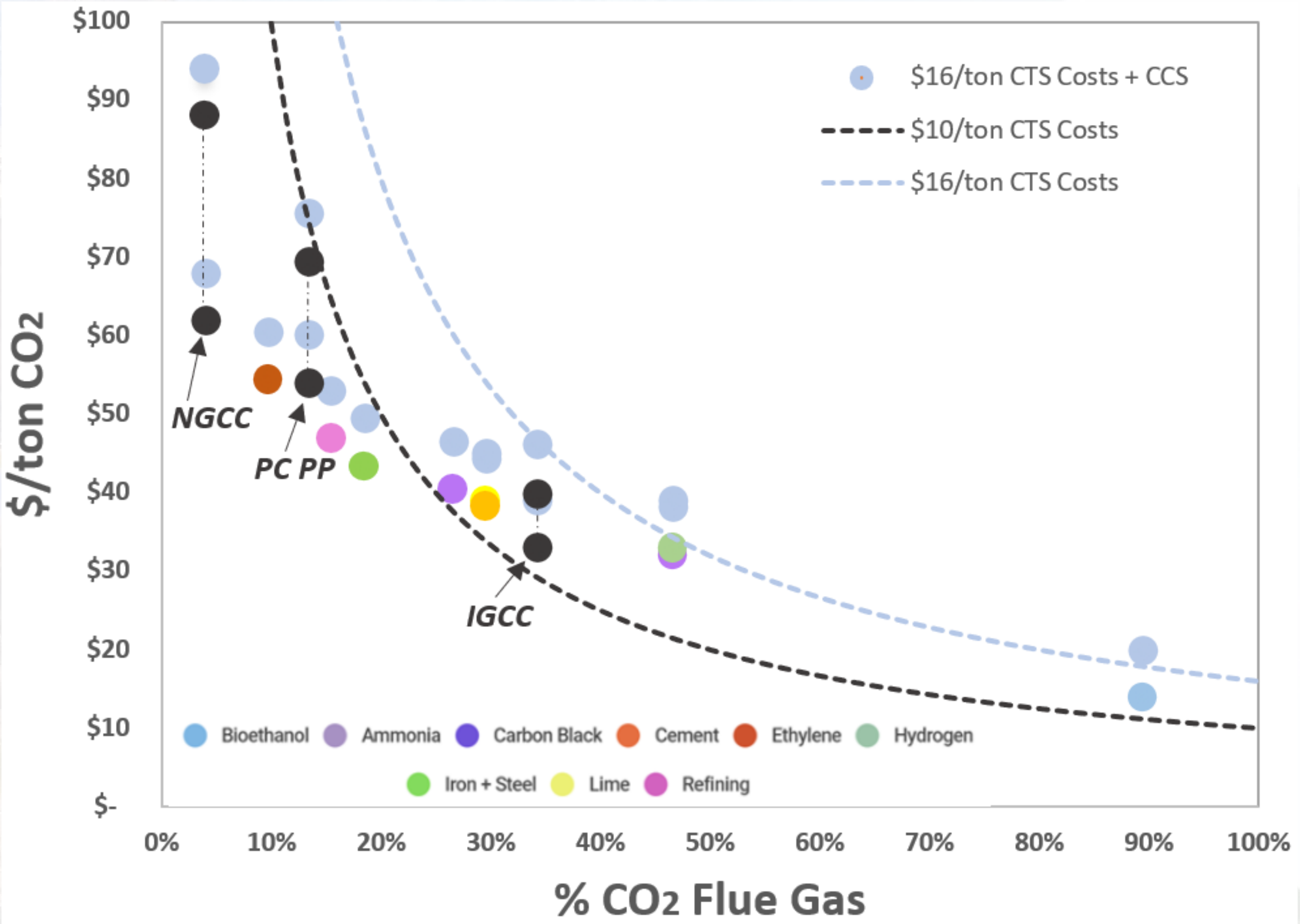
- Capture technology can require 15% to 30% electricity demand from PSE
- CTS requires energy, but not directly from the PSE
- Flue gas injection removes the parasitic load from PSEs

Cost Comparison Model

- Flue gas injection avoids the cost of capture, but requires CTS for more gas volume
  - To inject an equal volume of CO_2 from a waste stream that is 20% CO_2 requires 5 times the volume be compressed, transported, and stored
- We compare the costs of flue gas injection to the cost of capture based on %CO_2 in the waste stream for each PSE
- We add the cost of CTS ($/ton CO_2) back into the cost of capture using $10 and $16 CTS scenarios

Results

- At low CTS costs, flue gas injection is cheaper than CCS when %CO_2 is >20%
- Requires 1.1 to 5x pore volume
- Includes some PC power plants, all IGCC power plants, and many industrial sources of CO_2 emissions
- Results are sensitive to the cost of CTS: at $16/ton, only hydrogen, ammonia, and bioethanol production still attractive for flue gas injection

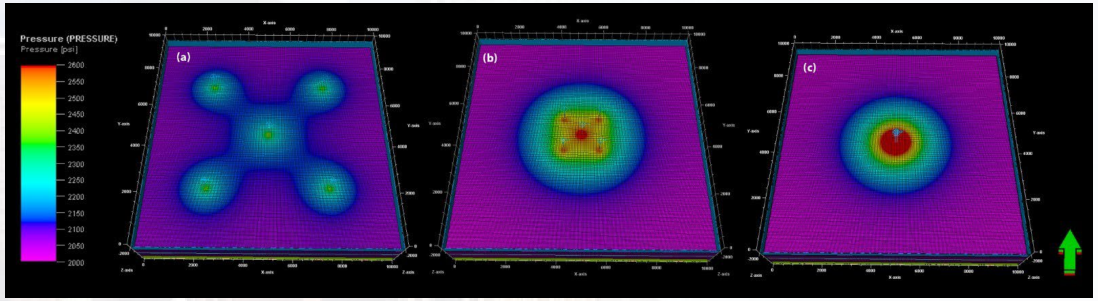


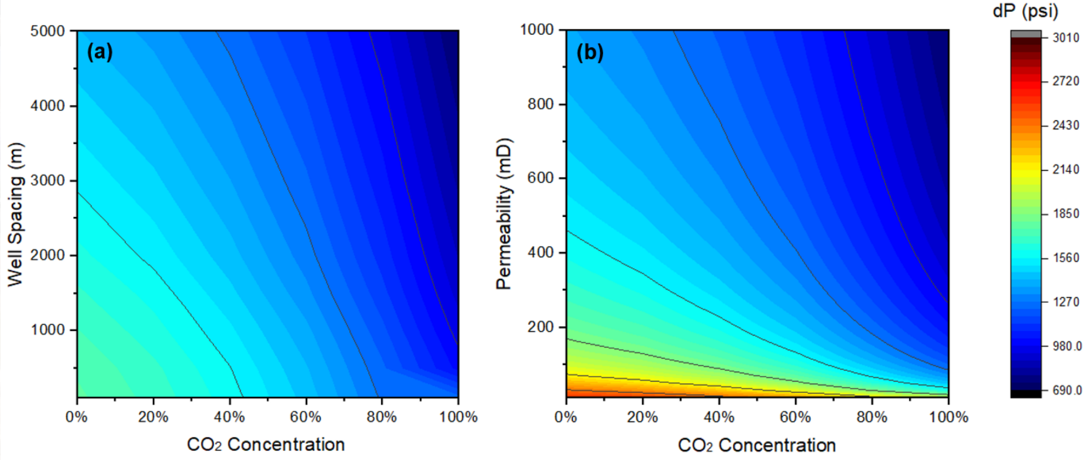
Subsurface Characterization

- Flue gas injection is often cheaper! But what about the subsurface response?
- We model 5 Mtpa flue gas injection to account for 1 Mtpa CO_2 sequestration in a 140 F saline aquifer
- Five injection wells are included in a 2-1-2 pattern with no production wells for pressure relief. We vary spacing.
- Permeability is varied from 10 mD (bad reservoir) and 1,000 mD (great reservoir)
- Flue gas composition is reduced to an N_2-CO_2 binary mixture, which is varied from 0% CO_2 to 100% CO_2

Results

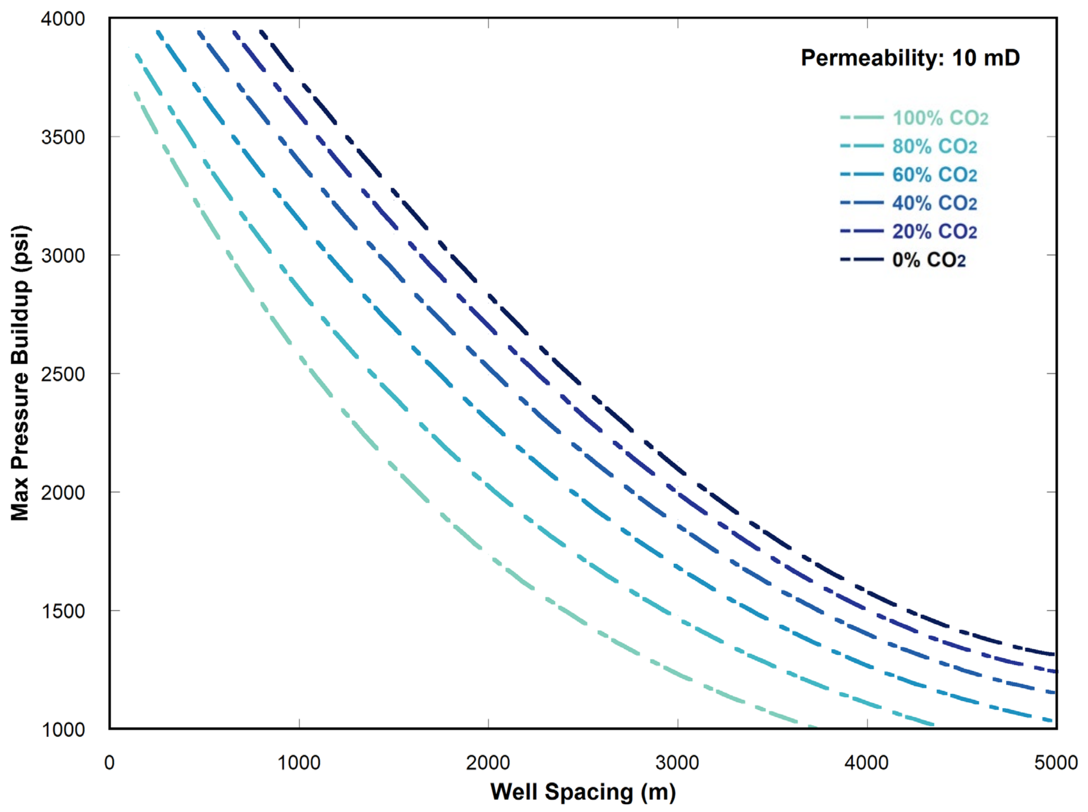
- As CO_2 concentration increases, pressure buildup decreases
- 10 mD permeability experiences high pressure buildup relative to 1,000 mD
- Increased well spacing causes an exponential decrease in pressure buildup



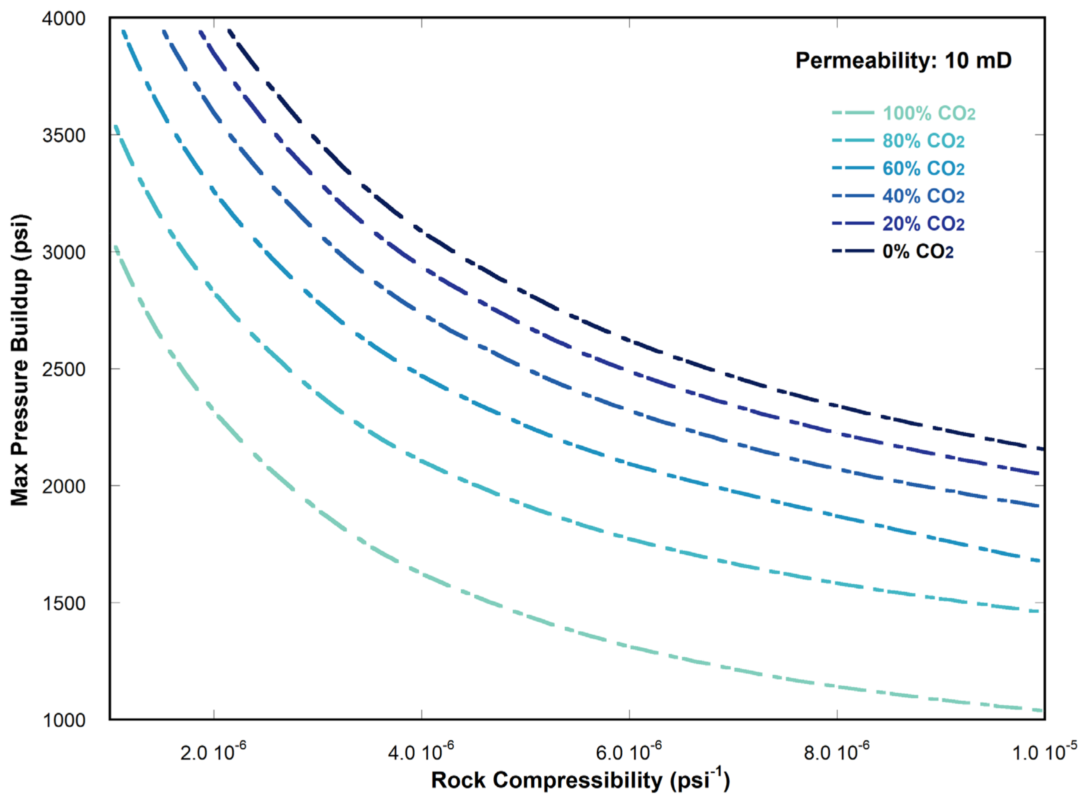


Changing Fluid Compressibility

As the %CO_2 in the flue gas decreases, pressure buildup increases. Increased well spacing decreases pressure buildup

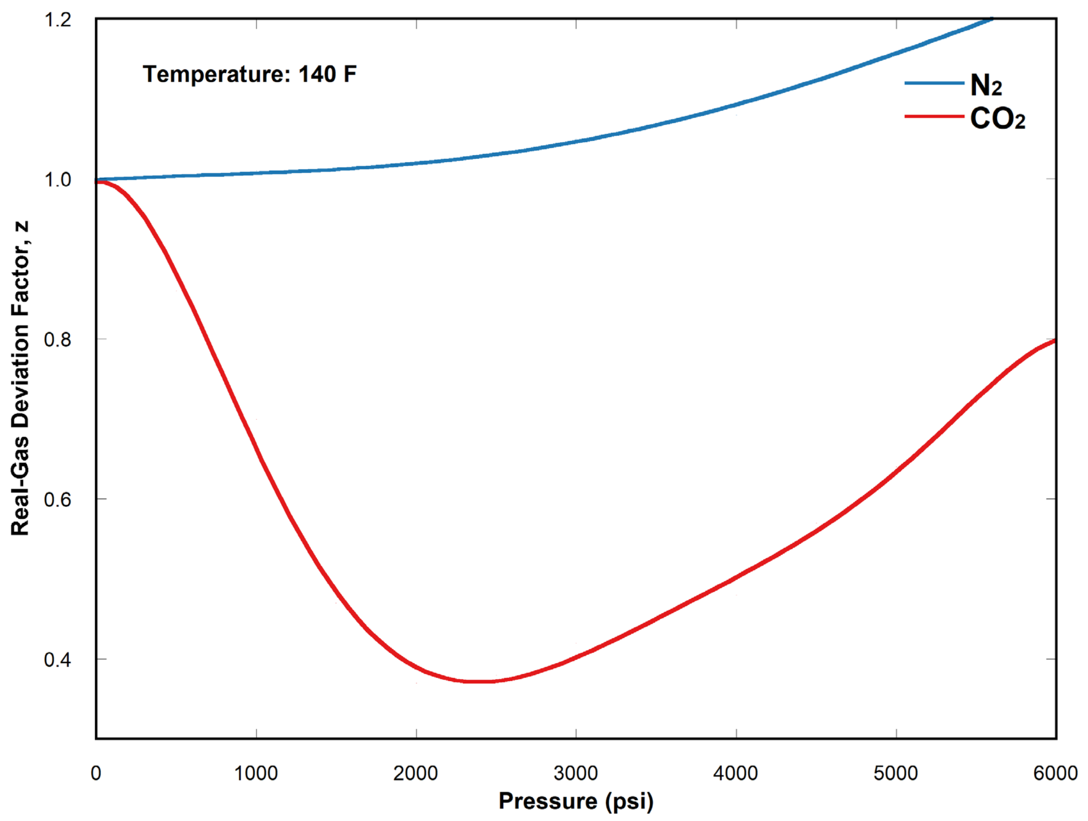


As system compressibility (Ct) increases, pressure buildup decreases. CO_2 is approximately twice as compressible as N_2 at reservoir conditions.

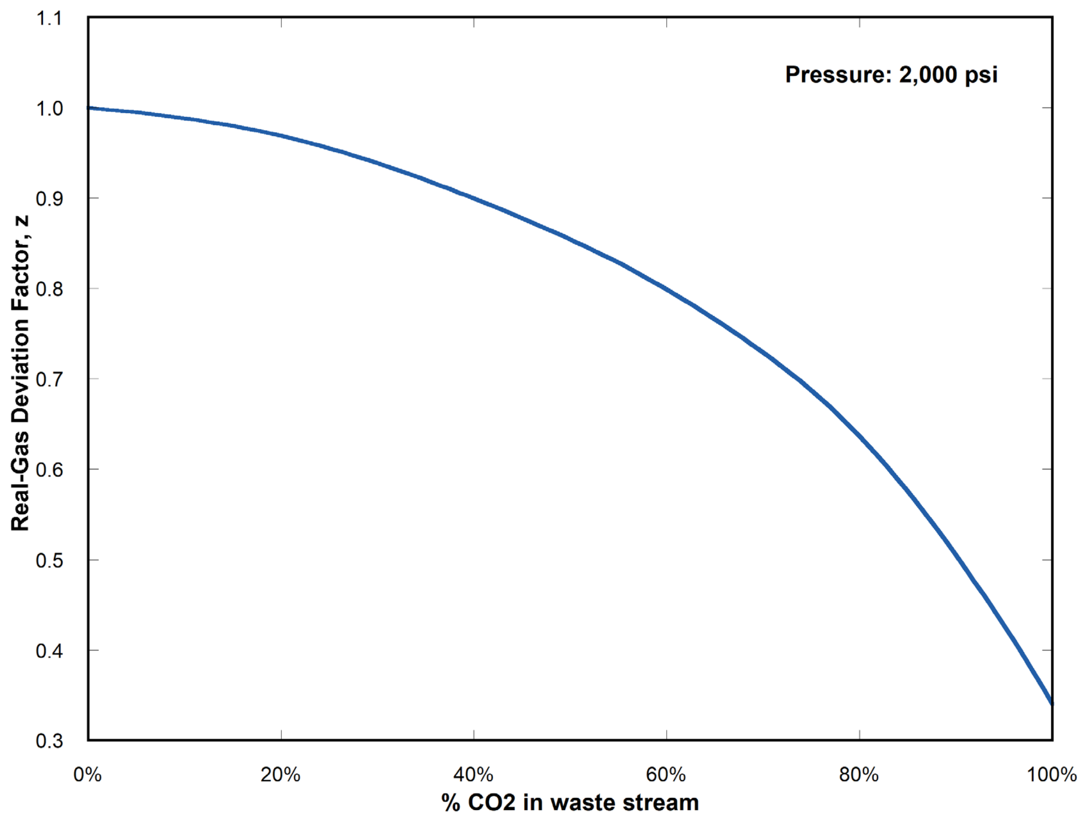


Fluid Compressibility Factor

The Z-factor of CO_2 is very different from N_2 at 140 F and at pressures experienced during flue gas injection.



Binary mixture's Z-factor decreases at initial reservoir pressure as flue gas composition shifts from 100% N_2 to 100% CO_2, also shifting fluid compressibility



Risk Assessment

- Financial risk:
  - Capture facilities are an up-front cost that is typically levelized
  - CTS is largely a cost per unit, flue gas injection reduces financial risk
- Project risk:
  - Capture facilities cannot capture 100% of the CO_2, whereas flue gas injection can
  - CCS represents a large parasitic power load
  - Flue gas injection transfers energy demands away from the PSE, removing the parasitic load
- Subsurface risk:
  - Flue gas injection has a larger pressure buildup, but this can be mitigated with increased well spacing and proper site selection

Conclusions

- There are thousands of years of pore space available at current US emissions from stationary sources
- Flue gas injection "captures" 100% of the CO_2 instead of 70%-90% as in traditional capture technologies at a penalty of 1.1 to 5 times pore volume
- Flue gas injection costs less than carbon capture technologies when the %CO_2 in the waste stream is 20% or greater
  - This includes carbon black, lime, ethylene, hydrogen, ammonia, and bioethanol production. It includes IGCC power plants and can include PC power plants.
  - This is sensitive to the price of compression, transport and storage
- The additional pressure buildup associated with higher N_2 compositions can be mitigated with well spacing

Thank you!

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