Key Considerations: Carbon Capture Transportation and Sequestration

Steven G. Jansto

Ph.D. Materials Science & Engineering (MSE)
Master Business Administration (MBA)

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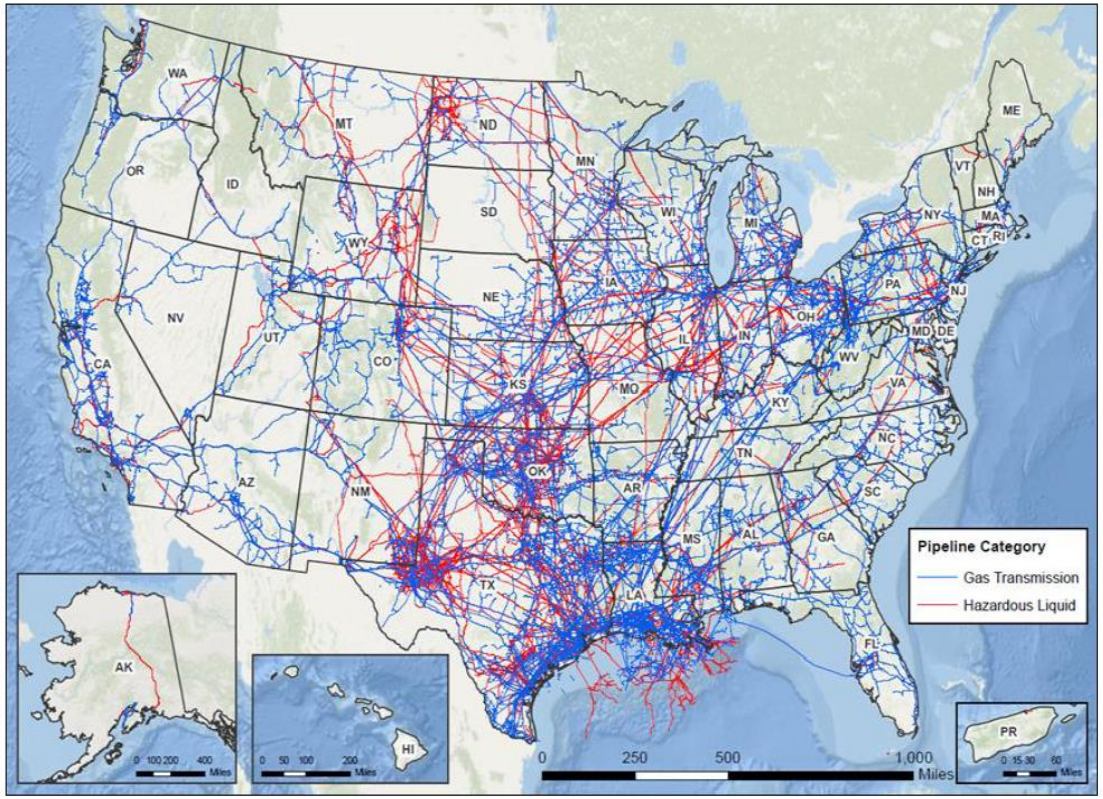
Key Considerations to Address Corrosion Risk with Carbon Capture Transportation & Sequestration

- Background info
- Risks
- Environmental, technical, economic implications
- Conclusions

US Hazardous Liquid Network

- 3.3 million miles of onshore pipelines transporting hazardous liquids
- CO_2 transmission pipelines now approximately 5,150 miles mostly for enhanced oil recovery (pure CO2)
- Proposals to now transport impure waste gas over many miles. **Repurposing: Tallgrass Trailblazer to take waste CO2 from ethanol plant in Nebraska to Wyoming by converting natural gas pipelines**
- PHMSA rules promulgated – now embargoed

Figure 1. U.S. Natural Gas Transmission and Hazardous Liquid Pipelines



Source: National Pipeline Mapping System, October 5, 2021, https://www.npms.phmsa.dot.gov/Documents/NPMS_Pipelines_Map.pdf

Notes: Map does not show gas distribution or gas gathering pipelines. Hazardous liquids primarily include crude oil, gasoline, jet fuel, diesel fuel, home heating oil, propane, and butane. Other hazardous liquids transported by pipeline include anhydrous ammonia, carbon dioxide, kerosene, liquefied ethylene, and petrochemical feedstock.

What we know so far

1) Corrosion hazards especially in vintage, but also in recently constructed pipelines (including hydrogen embrittlement & stress corrosion cracking)

2) Corrosion pipeline costs estimated at $7 billion annually.

3) CO2 pipe and infrastructure require upgrades in materials, welding procedures and construction practices.

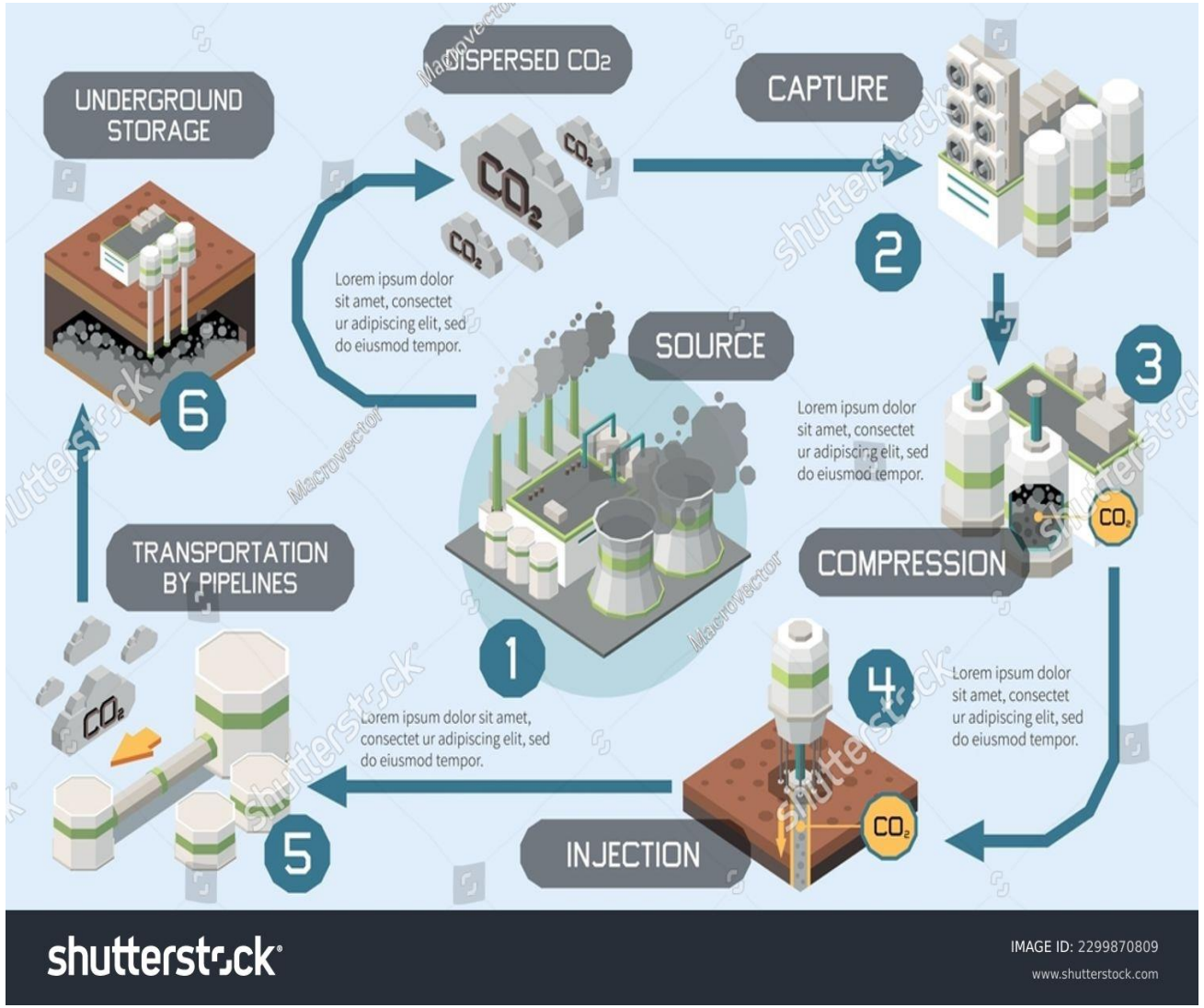
Corrosion Risks

- Internal
- External – site specific
- Pipe, pump station and CCS plant equipment and culvert materials
- Carbonic acid, nitric acid, sulfuric acid & hydrogen sulfide
- Weld/heat-affected zone

Special Considerations

- Variability of the CO2 gas composition including H_2S, NOx and SOx impurities
- High risk of carbonic acid (H_2CO_3) due to moisture

  H20 +CO2 = H2CO3
- Variations in moisture, temperature and pressure creates a high potential for the corrosive attack of carbon steel
- No known complete characterization of contents of waste gas – Archer Daniels FOIA redacted (“proprietary”)
- What is the total water and carbon footprint?



Special Consideration - WATER

- Define water consumption & possible water contamination in the CCS “cradle-to-grave” analysis (CCS location study: regional drought areas, etc., stream crossings, aquifer proximity, etc.)
- Carbon dioxide (CO_2) is released into water dissolves creating carbonic acid lowering pH level, causing increased acidity
  - **Chemical reaction:**

    $CO_2 + H_2O \rightarrow H_2CO_3$ (carbonic acid)
- Subsurface pressurization potential to force brine into aquifers
- Other

Environmental concern: Water Quantity Usage & Quality Impacts

Case Study #1 – Petra Nova

- Mid 2020: Petra Nova facility in Texas closed down.
- Economics: CCUS for Enhanced Oil Recovery (EOR) is more energy intensive than conventional oil extraction at $75 per barrel to breakeven.
- Through December of 2019 with 3-years of operation, there was a 16% shortfall in the total amount of CO_2 captured.
- Operational issues with leaking heat exchangers, calcium deposits in system at seals and unscheduled downtimes (69% functionality).

Case Study #2 – Denbury, Sartaria, MS

- February 2020: Delta pipeline rupture released carbon dioxide (CO2) and traces of H2S (45 people hospitalized – some still symptomatic)
- Emergency responders and hospitals unprepared
- Analysis: API 5L X80 grade, an electric resistance welded (ERW) longitudinal weld seam, a 0.469-inch wall thickness on the mainline pipe, 0.540-inch wall thickness on the bored pipe section under roads, which was 240 feet in length and more than 30 feet below HWY 433.

Case Study #2 – Denbury, Sartartia, MS

- Analysis concluded heavy rains caused soil movement that could induce axial stresses sufficient to cause an overload condition.
- Did not adequately address corrosion in failure analysis
- Assessed over $2 Million Civil Penalty for obstructing PHMSA

- **DOWNPLAY CORROSION RISKS =**

PAY CONSEQUENCES LATER

Case Study #3 – Archer Daniels, Decatur, IL

2024 Incident(s) in Decatur, Illinois at the ArcherDaniels CO2 capture facility

- A leak at the country's first commercial carbon dioxide sequestration project was likely caused by corrosion of the steel used in the well, a finding by **federal regulators** that **"poses a significant risk to dozens other projects around the country planning to use the same type of metal."**

- Risk to Mahomet aquifer – sole source

- EPA concluded that dozens of other planned CO2 projects have dangerous design flaws and risks

- The upgraded steel material (13 Chrome) is still vulnerable to corrosion when exposed to the liquids

Carbon storage projects hit a hurdle: Corroding steel

EPA has concluded that dozens of planned projects contain dangerous design flaws — a discovery that may slow the rollout of a technology central to the Biden administration's plans to conf

By Annie Snider and Ben Lefevbre 10/08/2024 02:52 PM EDT | UPDATED 10/09/2024 03:28 PM EDT
https://subscriber.politicopro.com/article/2024/10/carbon-storage-projects-hit-a-hurdle-corroding-steel-00182889

Upgraded Material?

- EPA: Carbon injection well permits that specify 13 Chrome and a type of cement commonly used by the industry to secure those pipes “are NOT suitable for construction of these wells in most instances, particularly under potentially corrosive conditions when both water and CO2 are present.”
- Only one steel mill in the United States makes 25 Chrome, so the vast majority of the material is imported from Asia
- Two other facilities operate carbon injection wells containing 13 Chrome operate in Nebraska.

Case Study #4: Exxon/Denbury

- April 3, 2024, recently ExxonMobil-owned Lake Charles Pump Station for Denbury's 24-inch Green Pipeline in Sulphur, LA leaked.
- 2548 barrels of CO2 lost at a "smart pig" launcher site at compressor station.
- Possible O-ring or seal failure
- Denbury's "**Green**" Pipeline is "a 314-mile carbon dioxide (CO2) pipeline from the Mosaic Phosphates Company's Faustina Plant in Donaldsonville, LA to the Hasting Oil and Gas Field in Alvin, TX for EOR

What have we learned?

Additional research needed!

- CO2 corrosion data – much more info needed (waste gas composition, etc.)
- Effects of variable impurities
- Cost/Benefit analysis of subsidies (45Q)
- Scope 1, 2 and 3 analysis of cumulative CO2 emissions to build CCS
- Water Protections Required - not enough to just monitor (Canary)
- How much water will be destroyed for carbon capture & sequestration?

Water Usage

Petra Nova usage (https://www.osti.gov/servlets/purl/1608572)

CCS/COGEN WATER USE

(1 Acre-Feet = 325,851 liquid gallons = 496,596,924 gallons average/year)

ITEM	2017	2018	2019	3-Year Avg
Raw Water (primarily used for cooling)	1,303	1,312	1,681	1,432
Well Water (used to make demin water)	85	94	98	92

CCS systems are energy- and water-intensive technologies that, if adopted, will commit humanity to additional water use, further compelling attention to water scarcity [26]. CCS technologies use water during the cooling process at the power-plant level [27] and require additional water as an integral part to the carbon capture processes [28]. For example, it has been estimated that retrofitting a coal-fired power plant with post-combustion CCS would increase the power-plant water intensity by 55%, while decreasing the net plant efficiency by 45% [29] (https://www.sciencedirect.com/science/article/abs/pii/S1364032120307978)

What have we learned?

(The corrosion of carbon steel plate in aqueous CO_2 has been studied for 50 years without consistent, cost-effective solutions - even 13% Chromium)

- Choosing materials also requires a site-specific calculation based on:

- Chemistry and temperature variations in surrounding area
- Risks of subsidence, erosion, etc.

Possible upgrades = more cost

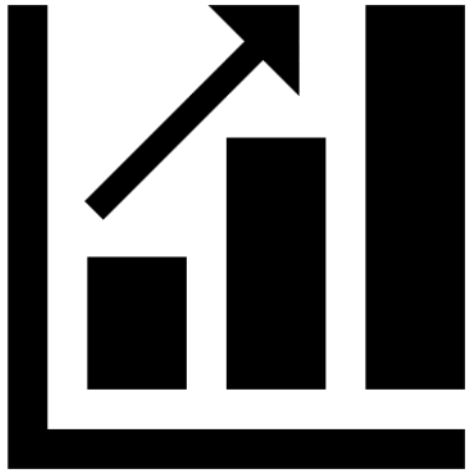
- Cladded pipe (pipe having a metallurgically bonded corrosion-resistant layer on its internal or external surface)
- Cathodic protection
- Air Liquide - purify waste stream

Materials Cost Comparison

Materials	Cost Multiplier	
Carbon steel (X70 approximately $1500-$2000 per ton of pipe)	1X	
13Cr&25Cr	1.5-2.5	
Current pipeline materials → Stainless steel 304L	3 to 5	**(CRA Clad CS pipe cost 4 to 7 times)**
Stainless steel 316L	4 to 6	
Possible alloy materials → Nickel 200	19 to 38	
Monel-Inconel-Incoloy	12 to 20	
Hastelloy	25 to 38	
AL alloys	4	
Copper	3	
Lead	1	

1) As the alloy content increases, the corrosion resistance improves, but so does the materials cost for a given project.
2) Cladded pipe is increasing especially in offshore sour gas areas, saltwater regions to name a few.
3) The Materials Engineering for the safe transport of CO_2 media is complicated, depending upon the chemistry of the waste gas and the processing conditions during transport (temperature and pressure in the pipe).

Additional Costs include:



- Monitoring for leaks
- Purification of waste gas
- Repair and replacement
- Parasitic effect: "If and when it becomes operational, Kemper will need to deal with a "parasitic effect" where about a quarter of the overall electricity generated by the power plant is needed just to run the equipment that will capture the carbon emissions."
https://www.politico.com/agenda/story/2015/05/billion-dollar-kemper-clean-coal-energy-project-000015/

Lack of Regulation

- Current pipeline regulations: only CO2 pipelines greater than 90% CO2 concentration compressed to a supercritical state (no mention as of non-CO2 impurities)
- Treatment for the removal of water and water quality enforcement control limitations critical for CCS pipelines not addressed
- PHMSA should investigate the risks of pipeline conversions and issue regulations appropriate to the serious risks that could result

(https://pstrust.org/wp-content/uploads/2022/03/3-23-22-Final-Accufacts-CO2-Pipeline-Report2.pdf)

Total Cost of 45Q Tax Credit?

- https://news.oilandgaswatch.org/template/brief/environmental-advocates-call-for-repeal-of-carbon-capture-subsidies

"… the technology has not been proven economically viable on a large scale, especially without the 45Q subsidies, which have mostly gone to fossil fuel companies.

Can also be used for EOR

2020 Treasury Inspector General for Tax Administration report: "widespread fraud and abuse in the 45Q program – with nearly $1 billion claimed for unverified or non-existent carbon sequestration."

Conclusions

- **High risk of steel corrosion failures**
- **No steel grade is fully characterized to safely carry waste gas CO2 OVER TIME**
- **Water usage and water contamination risks inadequately considered**

- Cost/benefit & carbon footprint analysis through entire process

- Opportunity costs (zero emissions, clean energy investment, etc.)

Feasibility & Practicality

- **To have any effect on climate change "would entail CO2 pipeline capacity larger than the existing petroleum pipeline system," which totals 2.6 million miles, according to a 2020 study in Biophysical Economics and Sustainability.** (https://www.huffpost.com/entry/gassing-satartia-mississippi-co2-pipeline_n_60ddea9fe4b0ddef8b0ddc8f)

CCS and CCUS are not only unnecessary, ineffective, uneconomic and unsafe – the technologies are also exceptionally risky, prop up the fossil fuel industry and carbon-intensive industrial activities, and distract from the urgent task of transitioning away from fossil fuels at a time when the U.S. and the world must dramatically accelerate that transition. (https://www.ewg.org/news-insights/news/confronting-myth-carbon-free-fossil-fuels-why-carbon-capture-not-climate)

QUESTIONS?

Steven G. Jansto

Jansto@Res-Dev-Res.com

Research and Development Resources

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