Carbon Management Collegiate Competition Summary

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AMERICAN MADE
U.S. DEPARTMENT OF ENERGY

Carbon Management Collegiate Competition

The Carbon Management Collegiate Competition invited students across the country to help shape the future of carbon management.

Competitors proposed a regional network business model to transport at least 1 million metric tons of CO_2 per year, optimized across five parameters:

- Economics and business model
- Operational safety considerations
- Life Cycle Analysis
- Climate change projected impacts
- Environmental justice, social impacts, and engagement

Rules and eligibility guidelines at: www.herox.com/carboncomp

Competition & Selection Overview

COMPETITION:

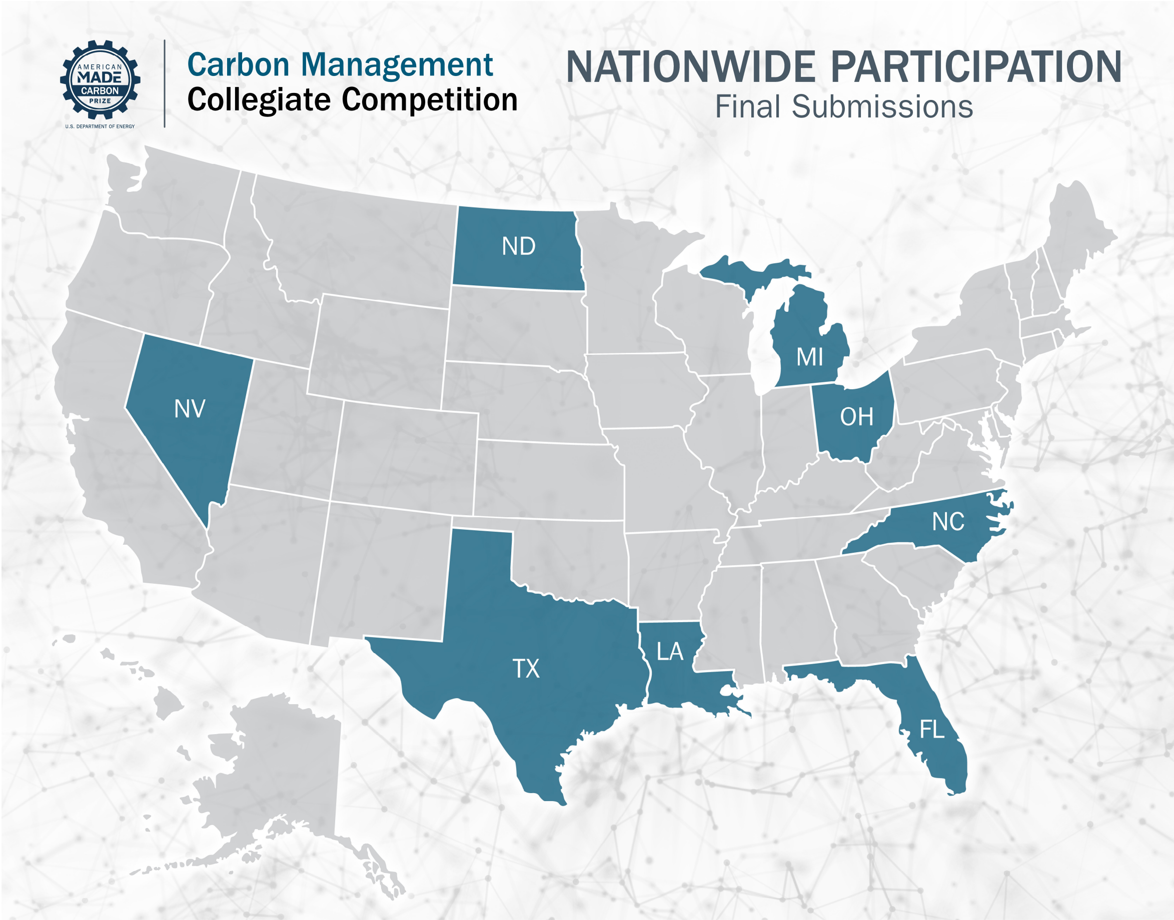
- The Carbon Management Collegiate Competition was announced on Tuesday, July 19, 2022.
- The competition ran from January 2nd to April 14th, 2023.
- Three teams were selected as top winners of the competition and were awarded various prizes.

SELECTION:

- Each submission was reviewed by three individual subject matter experts from either government, industry, or academia backgrounds.
- Reviewers were asked to rate submissions based on how well the submission addressed the five competition parameters.

Participation & Winning Teams

- 12 collegiate universities represented across 8 states
- Winning Teams include:
  - Green Houston from University of Houston
  - Biggest Little Lithium from University of Nevada, Reno
  - Sequestration Squad from Rice University



Our Team: Sequestration Squad

Tess Antrim-Cashin
MBA

Greg Allinson
MBA/MS

Stephen Brown
MBA

Caroline Chisolm
MBA

Our Problem Statement

- CO_2-producing facilities exist across the country, but the high capital costs and capacity limitations of pipeline limit the feasibility of nationally networked pipeline design
- Pipeline politics are influenced by risk perception from other industries and dictate stringent safety standards for long-term success
- A green energy transition is not inherently a just transition

Our Solution

A hyperlocal blueprint for safe CO_2 sequestration and integrative city planning.

Economics and Business Case

1. A localized, replicable pipeline system designed for major metropolitans.

2. $10.73/$CO_2$-tonne pipeline costs in initial region (Houston, TX)

3. Support circular economy with local concrete reuse and EV transport

Operational Safety

1. Short network allows full geotechnical analysis
2. More frequent valve/sensor placement
3. Automatic valves
4. Strategically positioned emergency equipment

Public trust is critical to repeatability

Life Cycle Analysis

1. 1.22kg CO_2 emitted per mile-ton of CO_2 captured

2. 98% of emissions from energy intensity, 1% construction/decom, 1% leakage

3. 44% reduction in annual emissions over project lifetime from change in grid mix.

Climate Change Impacts

1. Extreme weather events risk power outages and emergency response delays

2. Flooding and water extraction risk pipeline shifting, damage and leakage

3. Mitigate by avoiding high-risk areas and localized emergency response plans

EJ, Social Impacts, and Engagement

1. Maintain area tax base in energy transition

2. Diverse recruitment from local institutions

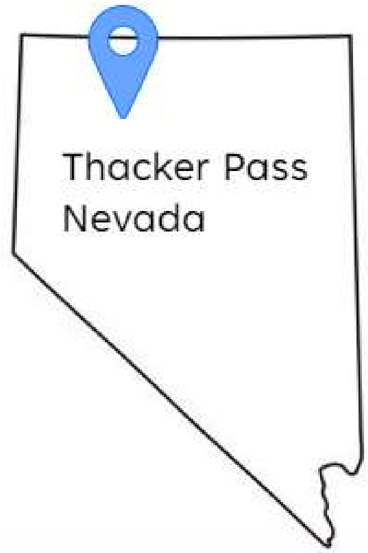
3. PM, NOx and SOx scrubbing improves air quality

4. Houston Wilderness partnership to plant native species

Biggest Little Lithium

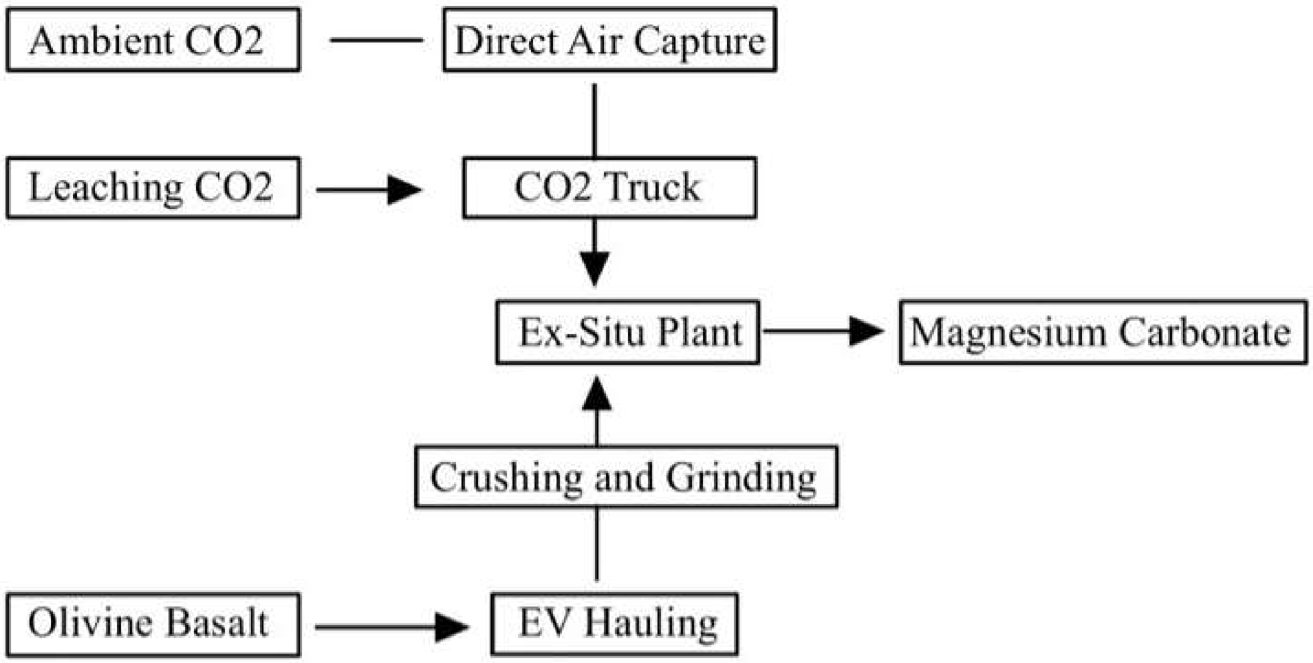
Solutions for greener transport in Nevada's mining:

reducing the footprint of Thacker Pass Lithium Mine



Combining direct air capture and electric vehicle transport to turn CO2 into profitable magnesium carbonate

Flow Diagram



Map of Proposed Operations

Proposed Infrastructure:

- Ex-Situ Carbonation Plant
- Direct Air Capture Facility
- Future basalt drilling sites

Key Takeaways

Thacker Pass History

- Site of 1865 massacre
- Partnering with local interest groups
- Balancing sustainability and social justice

Future Applications

- More personalized approach to regional transport
- Ex-situ indicates profitability
- Changes with growing

Thank You!

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UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING

Green Houston Team

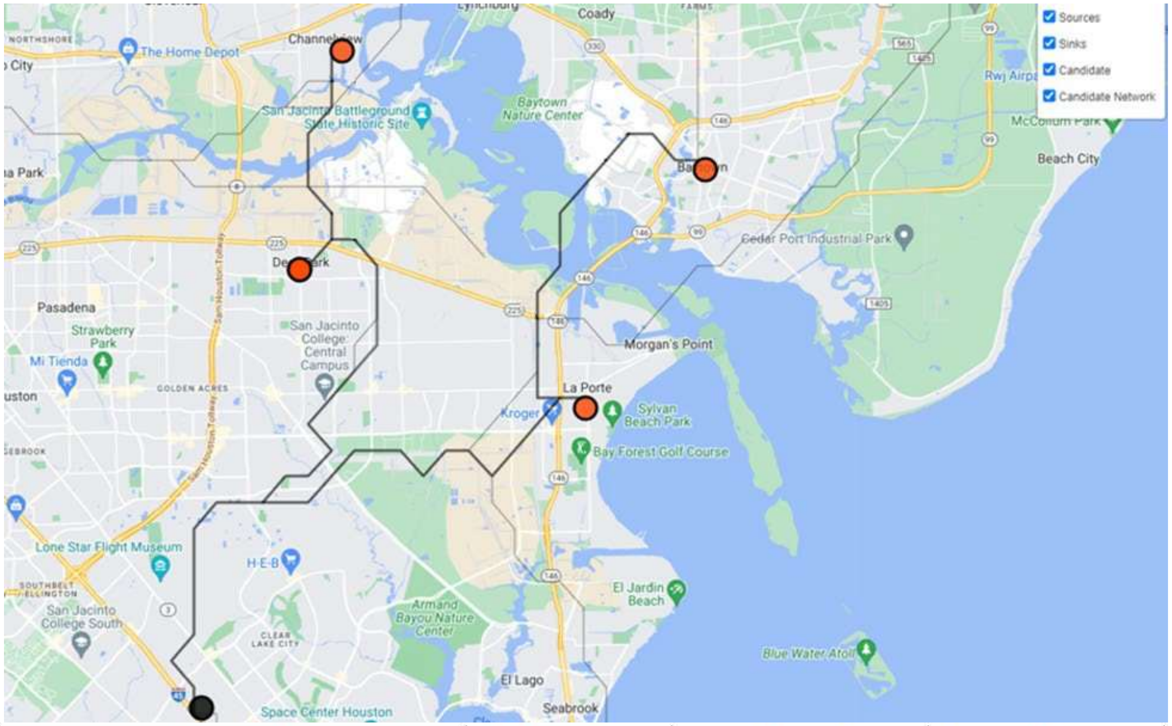
A Case Study of Optimally Transporting CO_2 in the Greater Houston Area

FECM/NETL

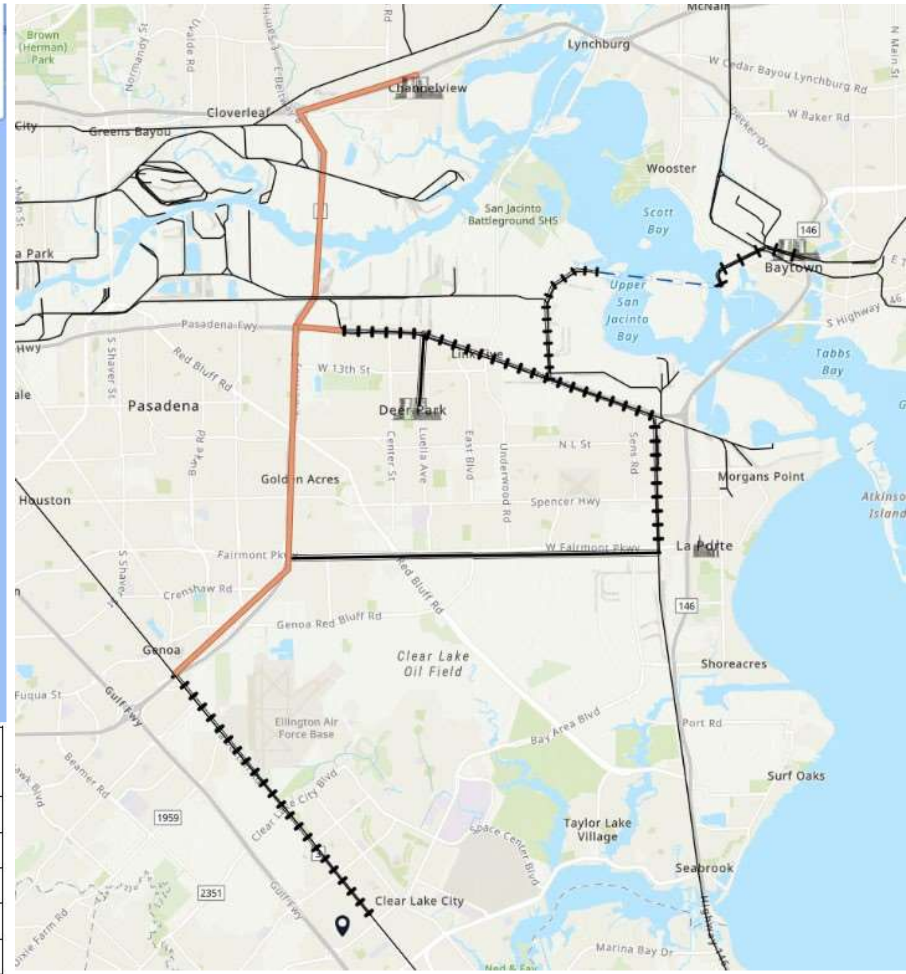
Pittsburgh

August 2023

Economics and Business Model



Summary of Financial Inputs	Real *- Base Year 2011	Real* -First Year of Project -2023	Nominal or Escalated Year
Capitalization	45 %		
Cost of Equity	13 [%/yr]		
Cost of Debt	6 [%/yr]		
Tax Rate	25.7 [%/yr]		
Escalation	2.2[%/yr]	2.3 [%/yr]	2.3 [%/yr]
Tax affected cost of debt	4.5 [%/yr]		
Weighted average cost of capital	8.30 [%/yr]		



The optimized transport network using Pipeline, rail, truck, and barge in Houston Gulf coast area.

Operational Safety Considerations

Safety Protocol	Description
Assessment of environmental condition	Assessment of nearby environmental conditions and accounting for global climate change during the pipeline system design. The proposed pipeline system will avoid areas with a higher likelihood of flooding.
Pipeline Maintenance and Protection	Regular maintenance and inspection of the pipeline to minimize the risk of rupture. The status of the pipeline can be monitored using Supervisory Control and Data Acquisition (SCADA). In case of rupture, an emergency shut-off valve or backup pipeline may be utilized. Pipeline leak detection system mostly - Fiber optic-based leak detection system that can detect disturbance of the pipeline that may cause rupture and monitor temperature changes caused by even small leakage. Pipelines need to have corrosion protection systems such as Cathodic Protection for onshore and the use of thermal sprayed metallic coatings for offshore pipelines.
Emergency Response	Develop and implement an emergency response program. Dispersion area modeling during the pipeline system design phase, along with the incorporation of an alarm system to signal evacuation in the affected area. Emergency responders should be notified immediately in case of an incident.
Alarm System	Incorporation of an alarm system to signal evacuation in the affected area.
Public Awareness	Notification of nearby residents about the existence of the pipeline and conducting safety lessons. Adequate safety measures should also be taken to evacuate or shelter residents in the potentially affected area.

Table 5: The proposed timeline for the development of the pipeline project.

Stage	**Timeline**
Preliminary Study and Feasibility Assessment	6-12 months
Route Selection and Environmental Impact Assessment	6-12 months
Permitting and Regulatory Approval	12-18 months
Detailed Engineering and Design	12-18 months
Procurement and Construction	24-36 months
Testing and Commissioning	6-12 months
Operations and Maintenance	Ongoing

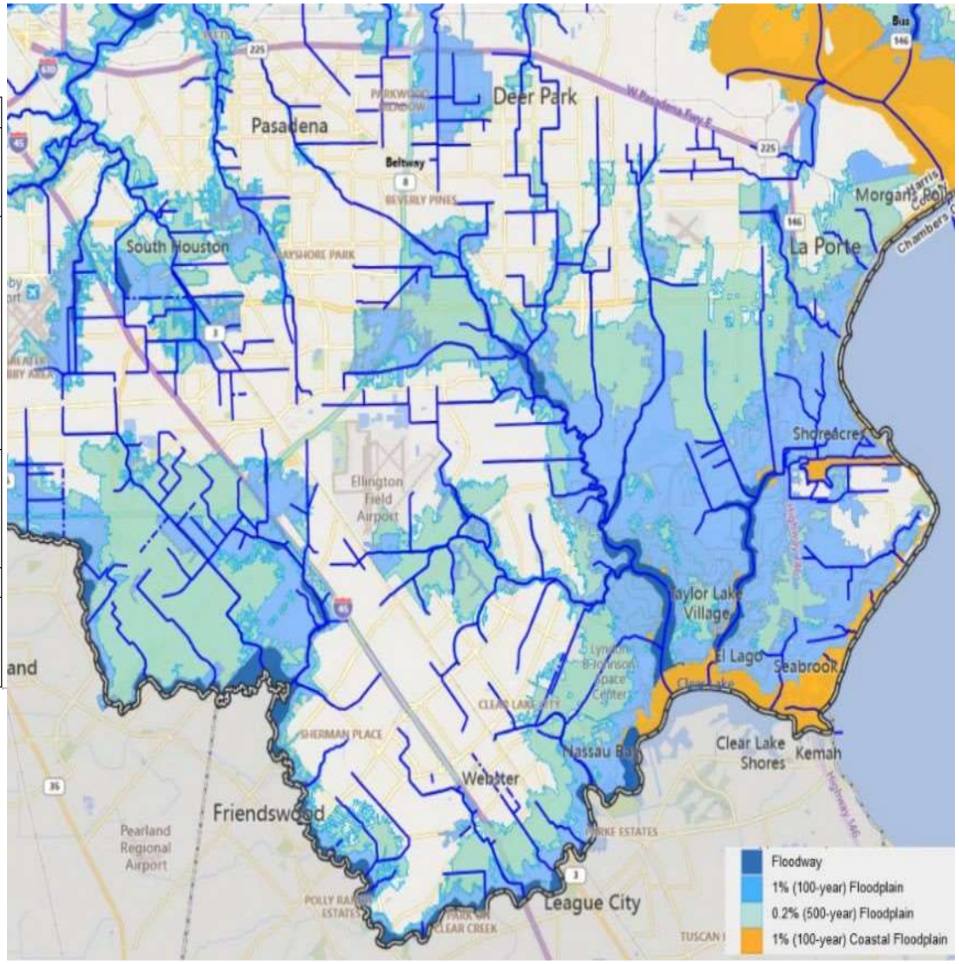
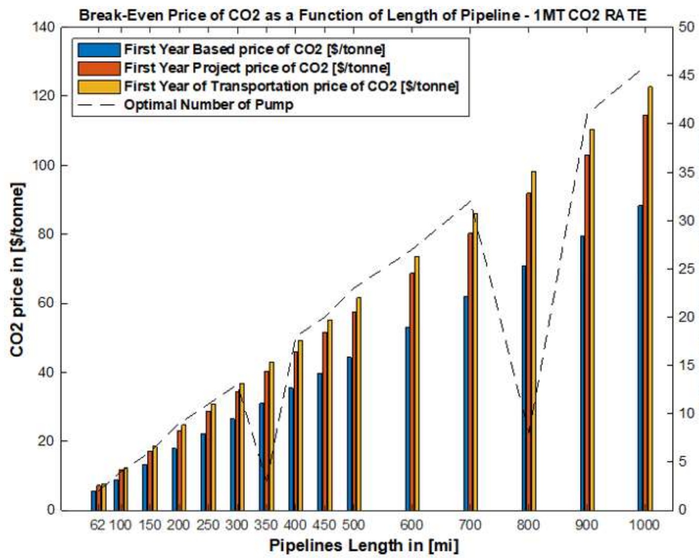
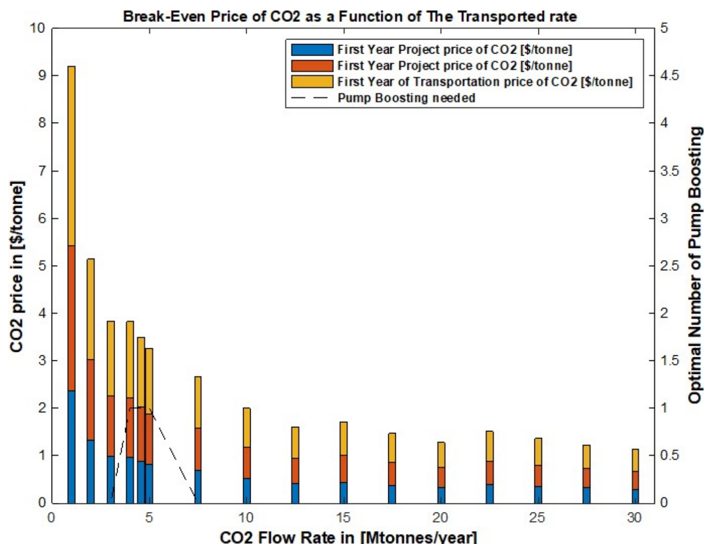


Fig. 3. Flood plain map of the proposed pipeline system.





Life Cycle Analysis

Table 3: The price of CO_2 as a function of both the CO_2 rate and length and the optimal desired number of pumps.

Annual Average CO2 Mass Flow Rate	Pipeline Length	First Year Price base year	First Year Price 2023	First Year Price 2026	Optimal Number of Pumps
Mtonnes/yr	mi	$/ton	$/ton	$/ton	Pumps
1.00	60.0	5.38	6.99	7.48	2
1.00	100.0	8.94	11.61	12.43	4
1.00	150.0	13.26	17.22	18.44	6
1.00	200.0	17.84	23.16	24.80	9
1.00	250.0	22.16	28.77	30.80	11
1.00	300.0	26.48	34.38	36.81	13
50.00	60.0	0.53	0.69	0.74	0
50.00	100.0	1.10	1.43	1.53	0
50.00	150.0	1.65	2.14	2.29	0
50.00	200.0	2.24	2.91	3.12	2
50.00	250.0	2.93	3.80	4.07	3
50.00	300.0	3.53	4.58	4.90	1
100.00	60.0	0.41	0.53	0.57	0
100.00	100.0	0.93	1.21	1.30	1
100.00	150.0	1.27	1.65	1.77	1
100.00	200.0	1.86	2.42	2.59	2
100.00	250.0	2.45	3.18	3.40	3
100.00	300.0	2.79	3.62	3.88	3
150.00	60.0	0.53	0.69	0.74	1
150.00	100.0	0.96	1.25	1.34	2
150.00	150.0	1.69	2.19	2.34	4
150.00	200.0	2.17	2.82	3.02	5
150.00	250.0	2.65	3.44	3.68	6
150.00	300.0	3.38	4.39	4.70	8
200.00	60.0	0.71	0.92	0.98	2
200.00	100.0	1.36	1.77	1.89	4
200.00	150.0	2.28	2.96	3.17	7
200.00	200.0	2.96	3.84	4.11	9
200.00	250.0	3.89	5.05	5.41	12
200.00	300.0	4.56	5.92	6.34	14

Climate Change Projected Impacts

Table 15: Summary of Climate-related hazards from the CMRA tool.

Asset	Hazard	Annualized Frequency	Hazard Potential	Min-Max	Indicator
Pipeline	Extreme Heat	0.16	-	47 – 106 ^{0} F	Annual days > 95^0 F
	Drought	18.28	-	15 - 26	Max consecutive dry days
	Wildfire	0.00	37.40	15 - 26	Max consecutive dry days
	Flooding	5.25	-	10 - 14	Max consecutive wet days
	Coastal Inundation	3.93	-	-	-

Table 16: Climate-related hazard impact on pipeline network.

Environmental Condition	Impact on CO2 Pipelines
Extreme Heat	Susceptible to stress corrosion and significant degradation of the pipeline.
Floods	Changes in soil weight and density can cause the pipe to bend and shift, eventually thinning the metal and causing a rupture. Floods can also unearth pipelines, exposing them to damage caused by floodwaters and debris.
Wildfires	Can cause breakage and significant degradation of the pipeline. Wildfires can also expose parts of the pipeline due to the consumption of vegetation.
Landslides and Hurricanes	Landslides present significant hazards to buried pipelines, inducing pipe longitudinal stresses above normal code-allowable stresses and strains. Heavy rain or hurricanes can cause landslides affecting CO2 pipelines.

Table 12: Global Warming and Temperature Potential.

	Pipeline (Tons/year)	Truck (Tons/year)	Railroad (Tons/year)
Total CO_2 footprint	110746	11854	8621

Table 13: Global Warming and Temperature Potential.

	Pipeline [kg/kg]	Truck [kg/kg]	Railroad [kg/kg]
Global Warming Potential – 50 years	110746000	11854000	8621000
Global Temperature Potential – 50 years	110746000	11854000	8621000

Potential Environmental Justice, Social Impacts, and Engagement

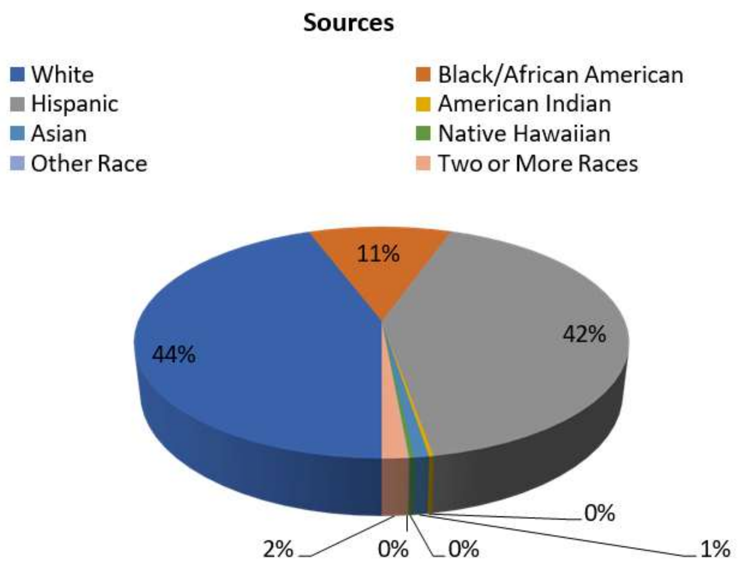


Table 19 Potential Environmental Justice, Social Impacts, and Engagement

	Zip Codes	TX Location	Disadvantage	Income	Flood %	High School education %	Air Toxicity Respiratory hazards HI*/ National/state %
Sink	77598	Webster	Yes	Low	98/90	14/10	77/81
Source	77536	La Porte	Yes	Low	97/90	24/10	80/84
Source	77571	Baytown	Yes	Low	94/90	42/10	80/84
Source	77530	Channelview	Yes	Low	94/90	34/10	80/84
Source	77520	Deer Park	No	No	NA	8/10	84/92

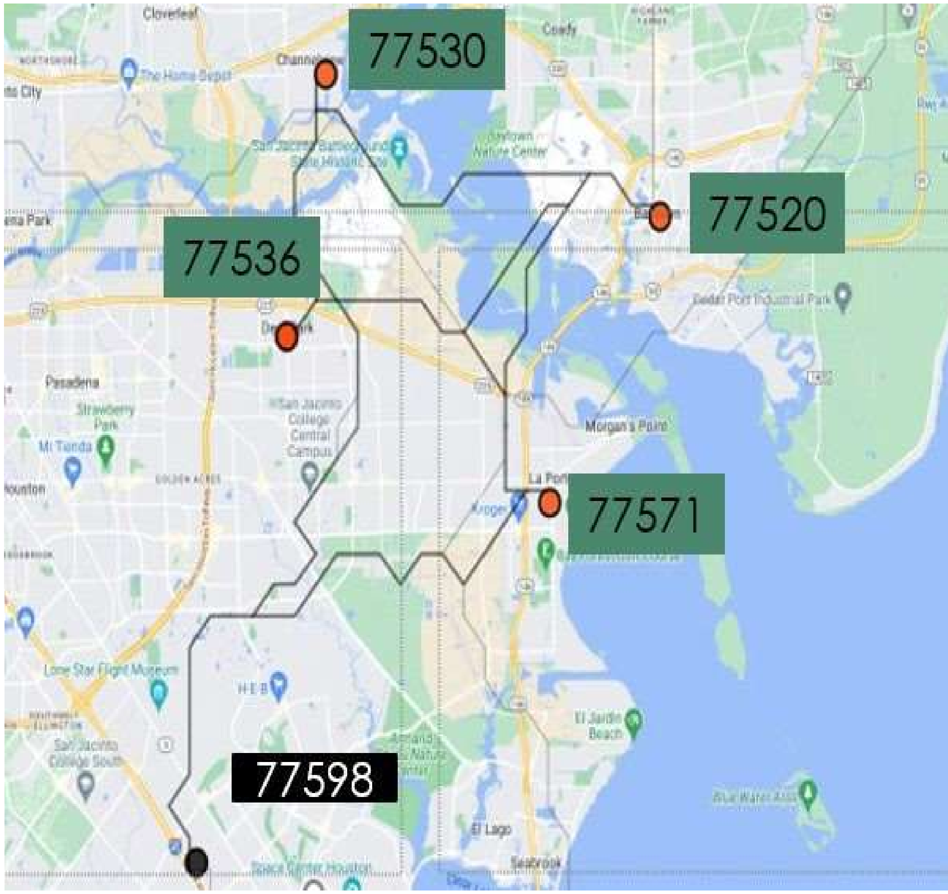


Fig. 9. Community postal codes.

Thank You!

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