

Pipeline Research Council International

PRCI CO₂ Task Force

Project ALT-1-6: Pipeline Transportation of CO₂ – SOTA Review, Gap Analysis and Future Project Roadmap

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LEADING PIPELINE RESEARCH

October 2023

Pipeline Research Council International is...

PIPELINE

- Natural gas
- Crude oil & petroleum products
- Biofuels
- Hydrogen/renewable natural gas
- CO₂
- Related facilities

COUNCIL

- Forum for ideas & opportunities
- Peer-based
- Industry-driven
- Source of research inventory

PRCITM



RESEARCH

- Knowledge
- Technology
- Deployment & transfer
- Innovation

INTERNATIONAL

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- Australia
- Europe
- Middle East
- North America

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LEADING PIPELINE RESEARCH

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aramco **ATCO Pipelines** **BHE GT&S** **BOARDWALK PIPELINE PARTNERS** **BUCKEYE PARTNERS, L.P.** **Cadent** Your Gas Network **Chevron**

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Associate Members



CHINA PETROLEUM PIPELINE ENGINEERING CO., LTD.



Technical Program Associate Members

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T.D. Williamson



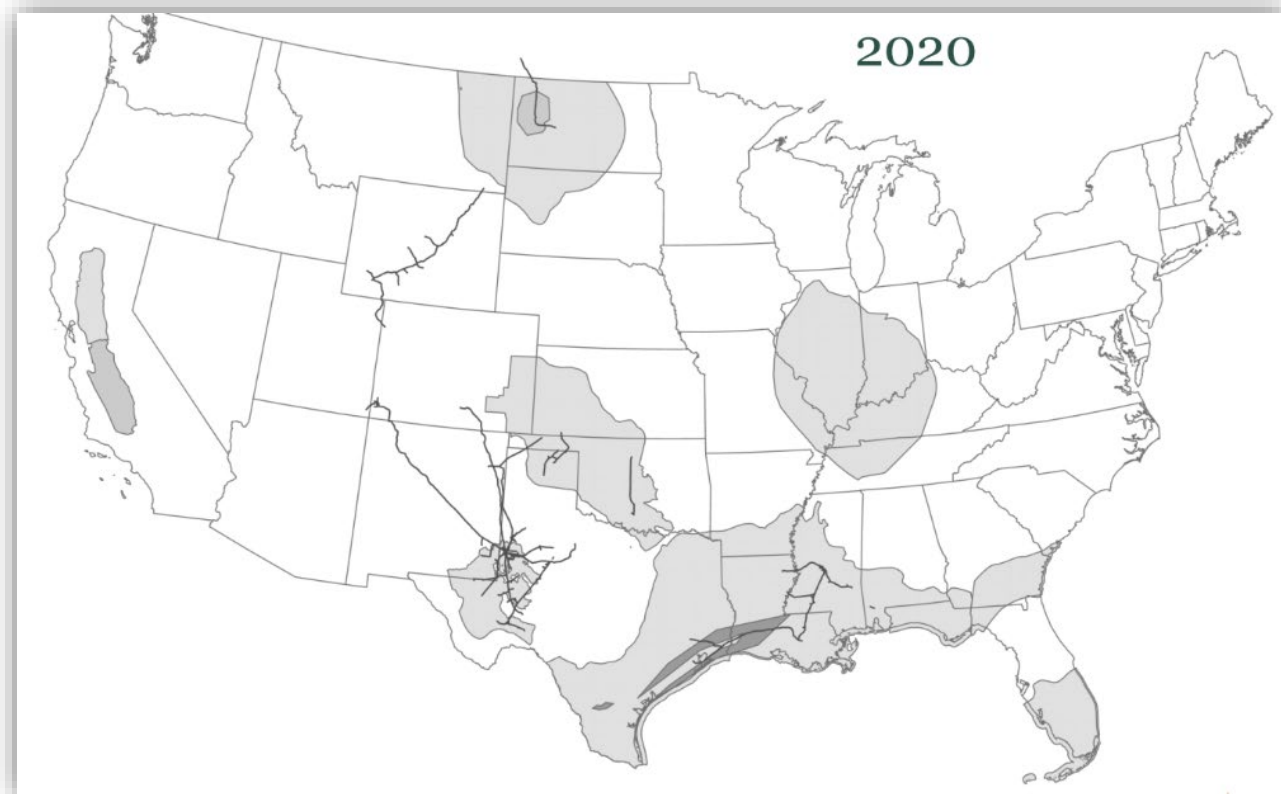
Content

- **The “Why” for ALT-1-6: continuous safety improvements as infrastructure expands**
- **Diversity of involvement in this effort**
- **SoW and Tasks**
- **Roadmap of Priorities**
- **Organization**

The “Why?”: Potential Large Increases in CO₂ Pipelines

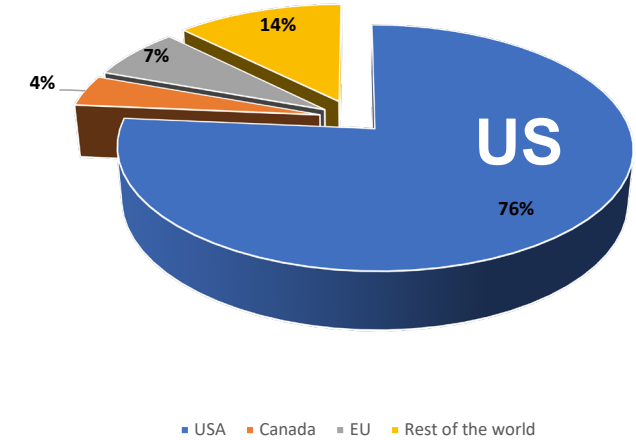
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- Currently ~6,000 miles of CO₂ pipelines globally
- ~5,300 miles of CO₂ pipelines in USA

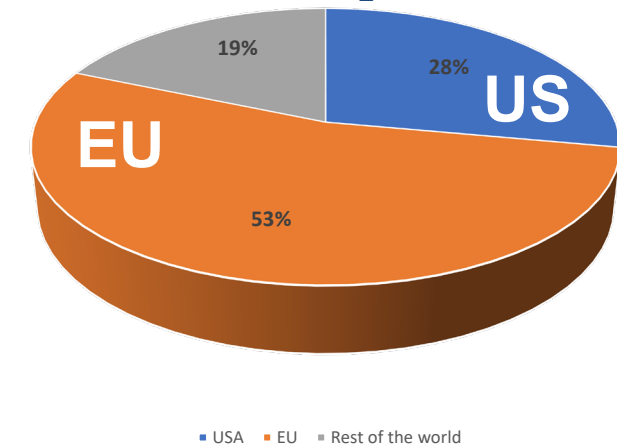


[https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20\(29Oct2021\).pdf](https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20(29Oct2021).pdf)

Estimate of Existing CO₂ P/Ls



Estimate of New CO₂ P/Ls



The “Why?”: Potential Large Increases in CO₂ Pipelines

NOTES:

- E+: high electrification
- ~13,000 miles of trunklines
- ~53,000 miles of spur lines

E+ scenario

929 million tCO₂/y
 106,000 km pipelines
 Capital in service: \$170B

CO₂ point source type

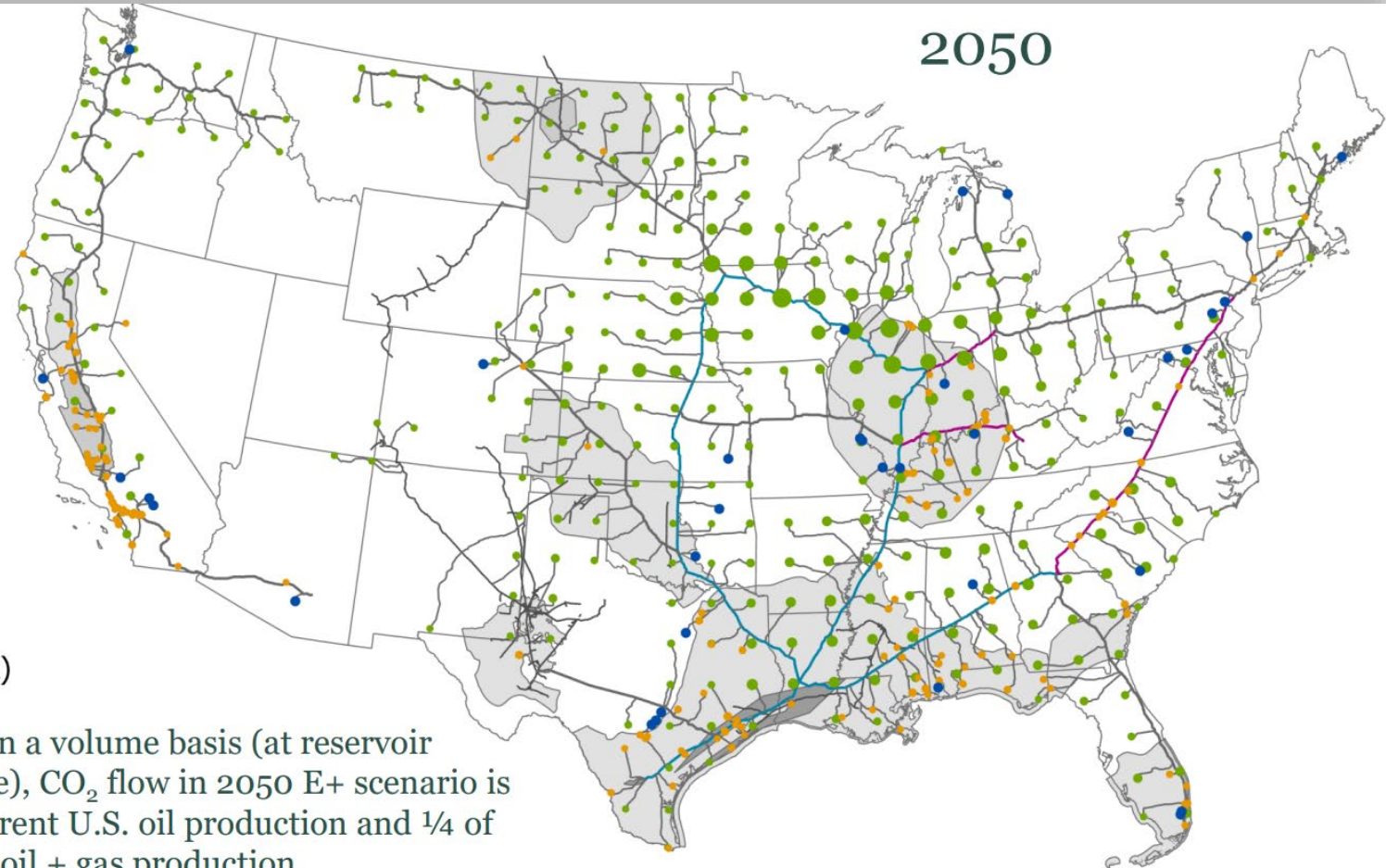
- CO₂ point sources
- BECCS - power and fuels
- Cement w/ ccs
- Natural gas power ccs oxyfuel

CO₂ captured (MMTPA)

- 0.0006449
- 7.9144
- 15.8282
- 23.7419

Trunk lines (capacity in MMTPA)

- < 100
- 100 - 200
- > 200



Note: On a volume basis (at reservoir pressure), CO₂ flow in 2050 E+ scenario is 1.3x current U.S. oil production and 1/4 of current oil + gas production.

[https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20\(29Oct2021\).pdf](https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20(29Oct2021).pdf)

Level of Involvement

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- Over 75 individuals involved representing over 40 organizations.
- Organization types consisted of
 - 19 Operators (4~Global)
 - 4 Government Entities
 - 3 Pipeline Industry Organizations
 - 2 Universities
- Engagement with the following performing research in CO₂
 - DOT
 - DOE
 - UK HSE
 - Texas A&M
 - Colorado School of Mines

SoW and Tasks

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Development of a clear roadmap which, through clearly defined projects and associated objectives, will enhance the knowledge base for safe and reliable transport of anthropogenic CO₂ by pipelines in any fluid state of matter (e.g. gas, liquid, etc.).

The roadmap was performed by performing an exhaustive State of the Art (SOTA) review, technology mapping and gap analysis.

Task 1 – Literature review

- **Task 1.1 – Mapping of current CO₂ pipelines**
- **Task 1.2 – SOTA analysis of existing data**
 - **Corrosion**
 - **Fracture**
 - **Safety/Control Dispersion**
 - **Re-purposing**

Task 2 – Gap analysis

Task 3 – Roadmap proposing future R&D projects to address gaps

Prioritization: CO₂ workshop at EFS June-23 (Orlando)

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Groups were formed to review the individual poll results and present their own priority lists, which were then combined to get the top three topics for each area

Corrosion

- 1 - Effect of impurities on corrosion
- 2 - Stress Corrosion, Fatigue and Cracking
- 3 - CO₂ specifications

Fracture

- 1 - Fracture Propagation
- 2 - Crack Arrestor
- 3 - EOS

Safety/Dispersion

- 1 - Release
- 2 - Leak identification
- 3 - Social acceptance

Repurposing

- 1 - Pipeline status
- 2 - Standards
- 3 - Non-metallic materials

Roadmap of Priorities: Corrosion

Priority on the investigation of trace elements on corrosion

Gap	Idea	Work type	Technical impact	Cost	Time
Corrosion mechanism – Understand which mechanisms are relevant and when	Lab work e.g., electrochemical methods, autoclave testing, to improve understanding of mechanisms.	Lab testing	Medium	High	High
Improve experimental results	Lab work with autoclaves to create database of experimental data (with verified trace element levels) for different trace element scenarios and operational cases.	Lab Testing	High	High	Medium
Enhance corrosion rate prediction capability for different scenarios i.e. during water drop out (normal and upset conditions) or in the presence of condensed acids during pipeline operation	Modelling + experimental work with autoclaves to validate models for corrosion rate due to condensed acids and during water drop out.	Modelling/Lab Testing	High	Medium	High
Develop data on possible preferential internal corrosion of welds exposed to the CO₂ stream	Experimental work with autoclaves to assess corrosion of welds due to water drop out and from condensed acids.	Lab Testing	High	Medium	Medium
Develop guidance on the risk of acid condensation for different trace element combinations in different pipeline operating conditions	Develop a risk assessment tool that identifies the highest risk combinations of impurities leading to corrosion.	Modelling	High	Medium	Medium

Roadmap of Priorities: Fracture

Priority on the investigation of fracture propagation

Gap	Idea	Work type	Technical impact	Cost	Time
Extend the range of applicability of the empirical methods (cf. DNV-RP-F104)	Full-scale tests in larger/smaller diameters and higher/lower grades	Full Scale Testing	Medium	High	High
	Laboratory-scale tests to characterise materials	Lab Scale Testing	Medium	Low	Medium
Improve (or replace) the Two Curve Model; improve numerical (finite element) modelling	Develop alternatives (modified or reformulated) to the Two Curve Model	Desk Study/Modelling	Medium	Medium	High
	Develop alternatives to the Charpy V-notch impact energy	Lab Scale Testing/Desk Study	Medium	Medium	High
	Develop numerical modelling to (partially) replace full-scale tests	Modelling	High	Medium	High
Full-scale test(s) with CO ₂ in the gas phase, to validate the Two Curve Model (or other model)	Full-scale test(s) with CO ₂ in the gas phase	Full Scale Testing	Medium	High	Medium

Roadmap of Priorities: Safety/Control Dispersion

Priority on the investigation of release

Gap	Idea	Work type	Technical impact	Cost	Time
Improve release modelling	State of the art of CO ₂ dispersion models and relevant validation tests	Desk study	Medium	Medium	Medium
	Identification of the most appropriate CO ₂ dispersion models considering phase and terrain specific data	Modelling	Medium	Medium	Medium
	Improvement of the combination of integral dispersion modelling with topography and terrain data	Modelling	Medium	Medium	Medium
	Evaluation of the impact of pipeline operating conditions (Pressure, Temperature, etc.) on the expected CO ₂ hazardous distances and pipeline stress design requirements	Desk study	Medium	Medium	Medium
	Develop better release modelling (3-phase) and testing	Modelling	Medium	Medium	Medium
	Better CO ₂ -fluid interaction modelling (H ₂ O acidification) for offshore and testing	Modelling / Full Scale Testing	Medium	High	High
	Comparative risk analysis between different failure modes of CO ₂ pipeline (single release point vs crack arrestor solution)	Modelling / Full Scale Testing	Medium	Medium	Medium

Roadmap of Priorities: Repurposing Pipelines for CO₂

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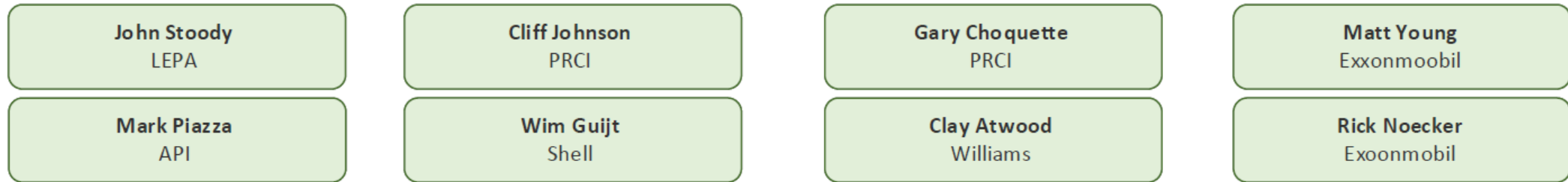
Priority on the investigation of pipeline status

Gap	Idea	Work type	Technical impact	Cost	Time
How to assess existing pipeline for repurposing	Develop criteria and testing for assessing pipeline materials by era of installation	Desk Study/Lab Testing	Medium	High	High
	Create a database in which materials/weldments are grouped and data can be used as a reference	Desk Study/Lab Testing	Medium	High	High

Organization

PRCI - CO2 Task Force Organization Chart

CO2 Task Force Steering Team



Member / Staff Leads



Research Execution Focus Area Leads



Thank you

*and a big thank you to the RINA team and Ninth Planet
(Andrew Cosham) for their commitment to the project*



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