REX2025
PRCI Research Exchange

Seeing and Hearing Methane Emissions from Buried Pipelines in the Midstream Sector

The Lamar CMMS Methane-Leak Detection Team

*Dr. Alek Hutson (Postdoctoral Researcher, College of Engineering & **Deputy Lead**)*
Dr. Daniel Chen (Prof., Chemical Engineering)
Dr. Jim Jordan (Prof. Emeritus, Earth and Space Sciences)
Prof. Darrell Grissom (Dept. of Technology, LIT & Petroleum Landman)
Mr. Najmul Sajal (Master's Student, Chemical Engineering)
Ms. Nimra Usman (Master's Student, Chemical Engineering)
Mr. Reese Bonin (Master's Student, Mathematics)
Mr. Gabriel Bonin (Undergraduate Researcher, Physics)
Mr. Chase Marshburn (Undergraduate Researcher, Physics/Math)
Ms. Alysa Patteson (Undergraduate Researcher, Physics)
Mr. David Halnon (MultiSensor AI – Infrared Cameras Inc. Division – Lamar Grad in Physics)

Philip Cole, PhD

Executive Director, CMMS

Center for Midstream Management & Science
LAMAR UNIVERSITY

March 4, 2025

Objectives for the Lamar University CMMS

- **The Lamar University CMMS is establishing a facility for midstream research based in the Beaumont area. The focus will be on coordinating cohesive research projects.**
- **This research will be founded upon data-driven experiments conducted in realistic and industrial environments.**
- **It is the goal of CMMS to bring insight into solving key issues facing the midstream sector.**
- **Towards these ends, we are taking a highly-focused approach for addressing the problem of methane leaks from pipelines.**
  1. Where do leaks originate?
  2. How does methane move through soils?
  3. How can we detect these leaks in the atmosphere?
  4. How do we mitigate environmental impact through soil remediation?
- **We are actively searching for strategic partnerships to achieve these goals, with the belief that innovation through collaboration is a proven path for successful and impactful research for optimizing methane flow in the midstream sector.**

Collaborations within the Texas State University System

- **Collaborate on LIT programs on the construction and maintenance of the experiment.**
  - Advance Engine Technology – diesel and natural gas engine training (natural gas compressors are often driven by a stationary engine)
  - Computer-Aided Drafting Technology – AutoCAD training specific to piping and electrical
  - Heating-Air Conditioning-Refrigeration Technology – compressor, heat exchanger & refrigeration training
  - Industrial Mechanics Technology – millwright and pipefitting training (repair & replace valves, bolt up flanges, and layout & fit piping.
  - Instrumentation Technology – Petro-chemical controls and instrumentation training, including analyzers
  - Process Operating Technology – Petro-chemical systems operator training
  - Welding Technology – Pipe welding training

- **Such a collaboration between Lamar and LIT has already been established**
  - Emerson ATC partnership with Lamar Institute of Technology (LIT) with the instrumentation & process technology programs on LIT's distillation plant.
  - Engineering majors can run models and analyze data. Lamar labs are networked to LIT's process operating control room.

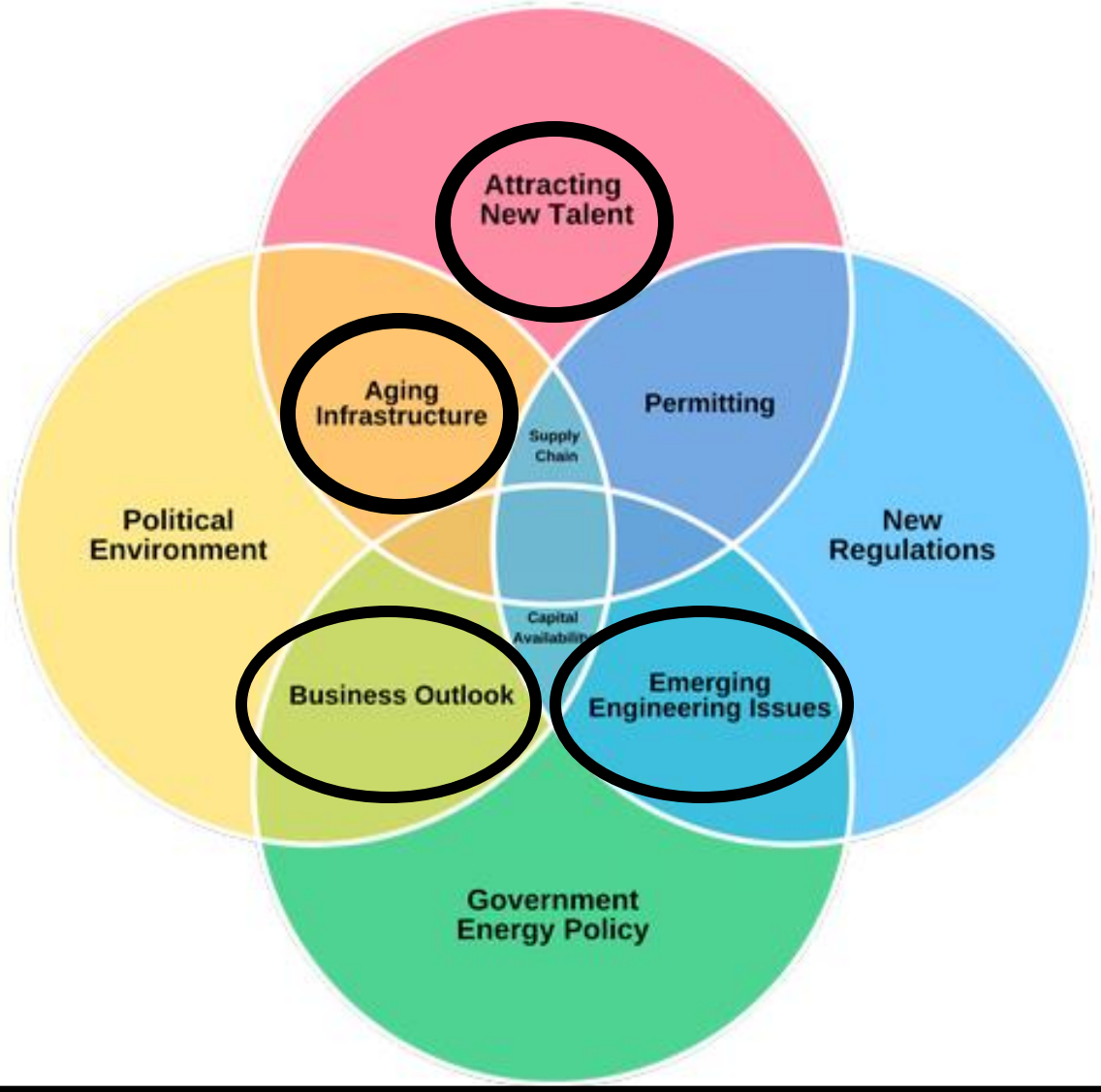
LAMAR INSTITUTE OF TECHNOLOGY
MEMBER THE TEXAS STATE UNIVERSITY SYSTEM™

Top Ten Issues Facing Midstream Industry in 2024

"The Center for Midstream Management and Science was established and funded by the Texas Legislature in late 2019 to serve as a bridge between Lamar University and the midstream industry…"

1. Emerging Engineering Issues
2. Aging Infrastructure
3. Attracting New Talent
4. Business Outlook

(Not necessarily in that exact order)



PRCI Announces New Strategic Plan for 2022-2024

Wed, February 09, 2022

Research Objective (3/2018): 7. Reduce all product leaks and equipment emissions from all parts of the hydrocarbon transport and storage infrastructure by developing, demonstrating and validating processes and technologies to detect, quantify and mitigate such releases.

3. Build upon PRCI's legacy of environmental commitment to assist members and the industry in achieving a low carbon future and zero emissions. As a leader in pipeline research, PRCI is positioned to be the primary research body for eliminating emissions and enabling emerging fuels transportation & storage via the global pipeline network.

INGAA Members Announce Enhanced Pipeline Safety Commitments

FOR IMMEDIATE RELEASE Washington, District of Columbia, United States, January 25, 2022

The Interstate Natural Gas Association of America (INGAA) and its member companies announce the update of their Integrity Management – Continuous Improvement (IMCI) program. The IMCI program has guided INGAA's safety efforts for over a decade. Today's IMCI 2.0 update builds upon years of safety leadership and technological progress by the natural gas transmission pipeline industry, as well as informed recommendations from third-party stakeholders, and ensures that our safety efforts are complementing our work towards net-zero greenhouse gas emissions. Through the IMCI program, INGAA members reaffirm their commitment to pipeline safety, incorporating the latest advanced technologies and processes to ensure the safe, reliable, and clean transport and delivery of natural gas to families and businesses across the country .

The updated IMCI commitments provide a foundation to advance INGAA members' ongoing pipeline safety efforts while also progressing towards our climate goals. The program is comprised of a series of initiatives to bolster the industry's work towards zero pipeline incidents and net-zero greenhouse gas emissions from natural gas transmission and storage operations. Key program elements include:

- Regular Stakeholder Engagement
- Transportation and Storage of Renewable Natural Gas
- Transportation and Storage of Hydrogen
- Rupture Detection and Response
- Managing Emissions from Integrity and Maintenance Work
- Development of an American National Standards Institute Standard for Managing Geohazards
- Integration of Electro-Magnetic Acoustic Transducer In-Line Inspection into Standards
- Regulatory Acceptance of Non-Traditional Pipe

Optical Gas Imaging (OGI) via Infrared (IR) Technology

Take Home Message

Remote OGI IR Technology key for Rupture Detection and Response?

More information about INGAA's IMCI program can be found at ingaa.org.

INGAA represents the U.S. natural gas pipeline industry. INGAA's members deliver clean, abundant, affordable natural gas throughout North America and operate approximately 200,000 miles of pipelines that serve as an indispensable link between natural gas producers and consumers.

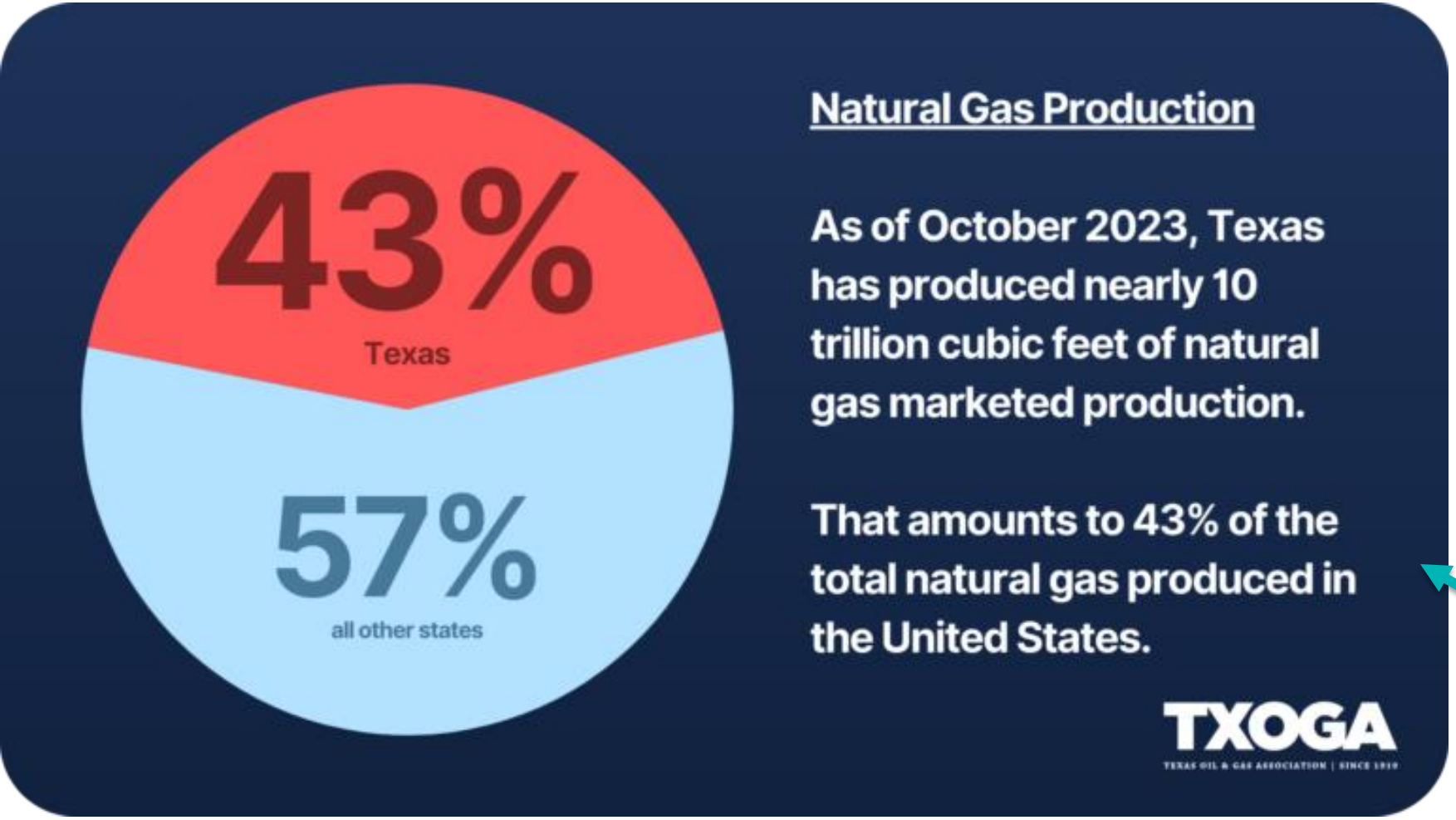
Objectives

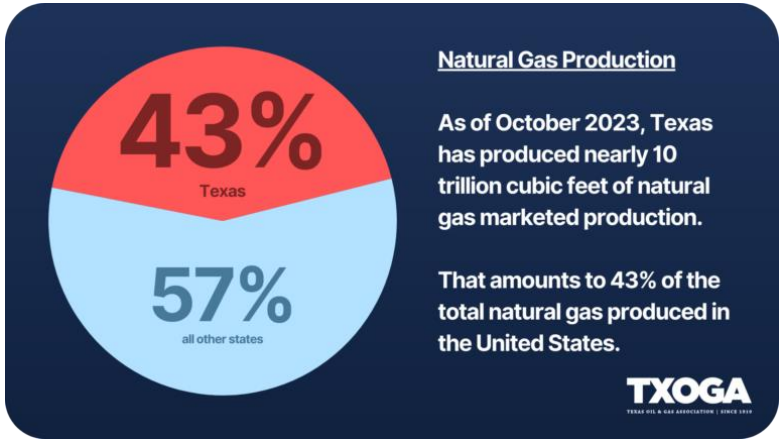
Identify methane and quantify leaks

Empirically understand the fluid dynamics of methane leakage and its propagation through various soils, which then may exit into the atmosphere.

The United States is the largest exporter of natural gas in the world

As of 2023 natural gas accounts for 36% of U.S. energy consumption

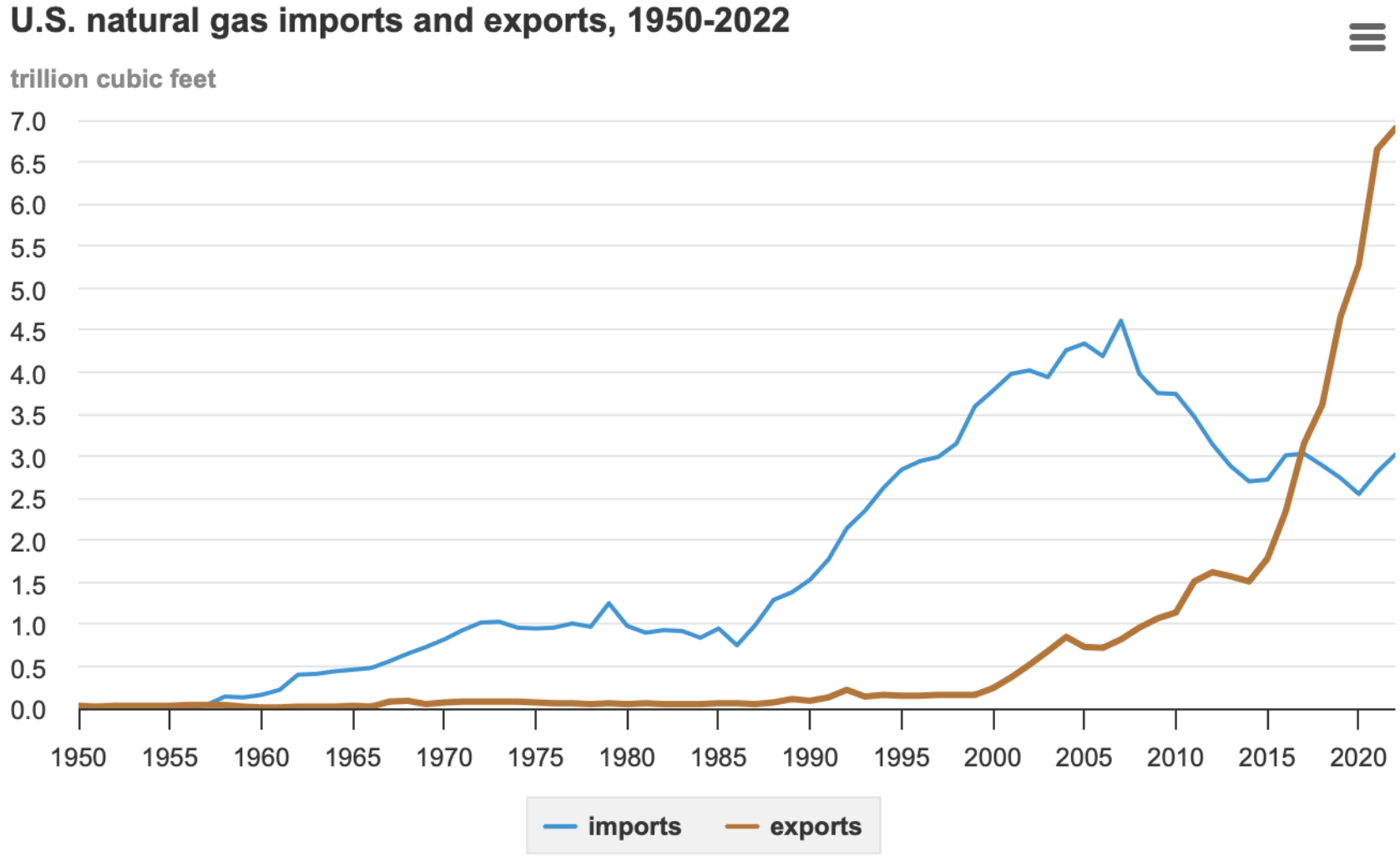




Texas is the Nation's #1 Producer of Natural Gas, and the World's #3 Producer

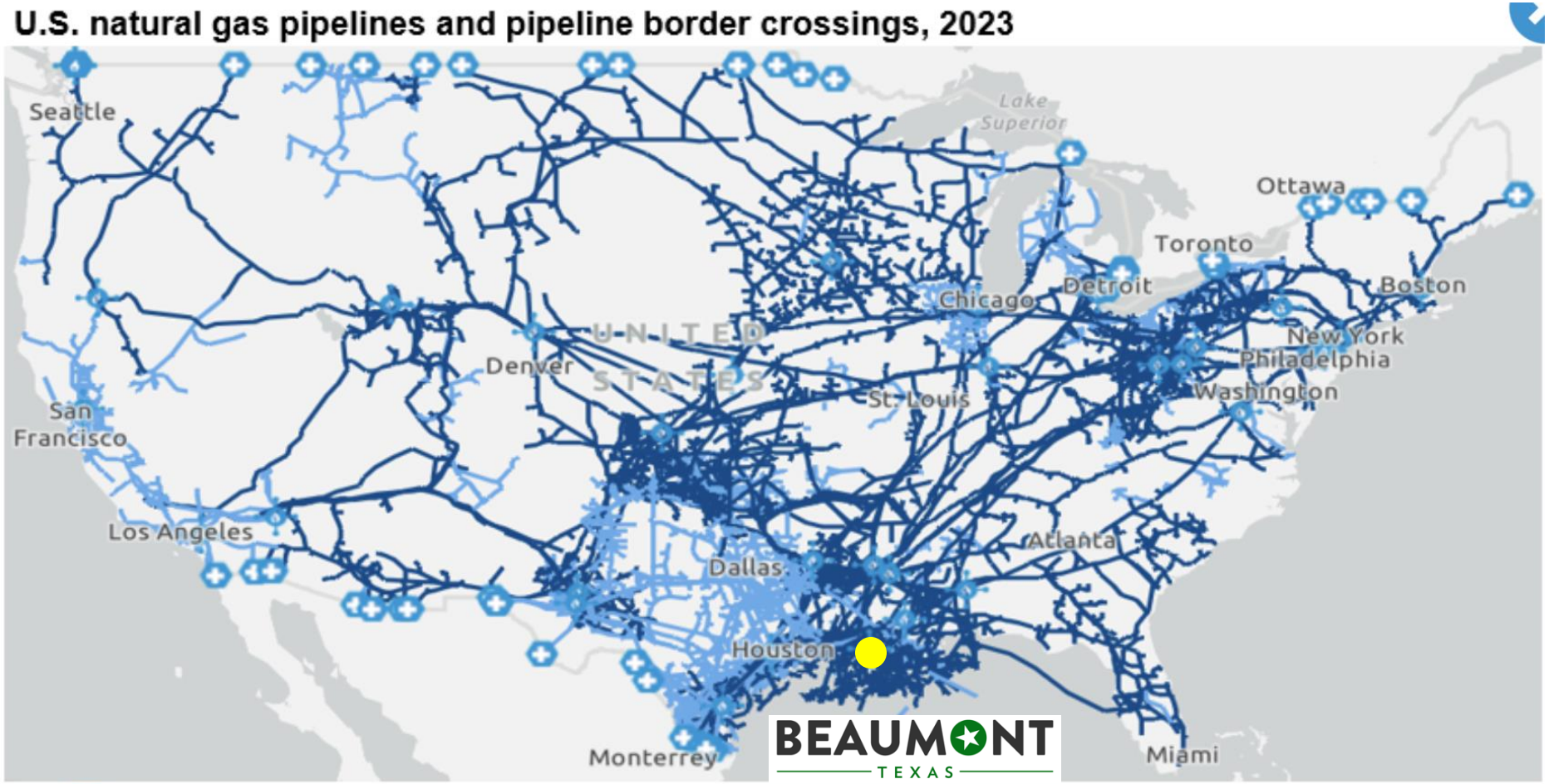
Data source: U.S. Energy Information Administration, *Monthly Energy Review*

The United States is the largest exporter of natural gas in the world



eia Data source: U.S. Energy Information Administration, *Natural Gas Monthly*, April 2023; data for 2022 are preliminary

3 million miles of NG pipeline in the U.S.



Source: U.S. Energy Information Administration, U.S. Energy Atlas, January 29, 2024
Note: Light-blue lines are intrastate pipelines, dark-blue lines are intrastate pipelines, and + are border crossings.

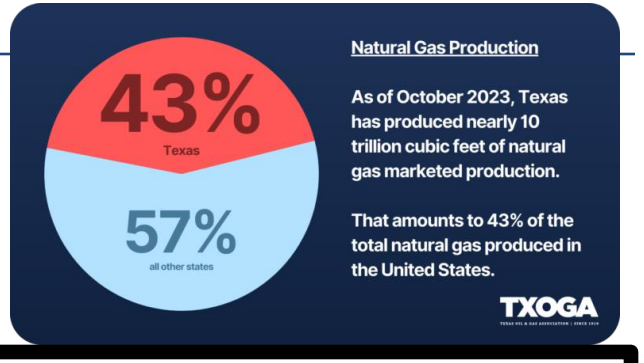
Texas is the Nation's #1 Producer of Natural Gas, and the World's #3 Producer

Why Natural Gas?

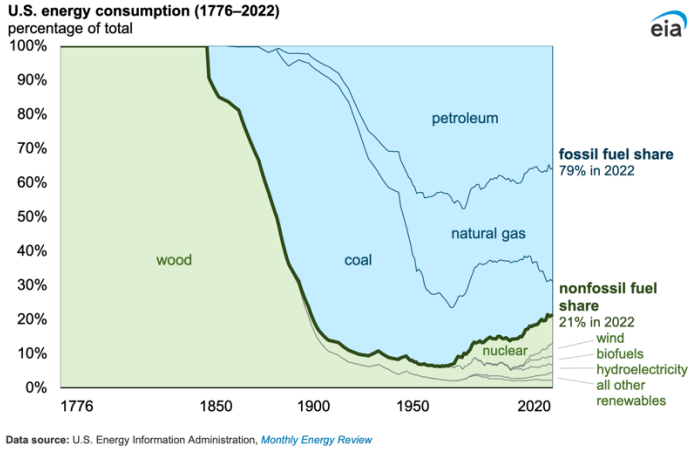
Why pipelines?

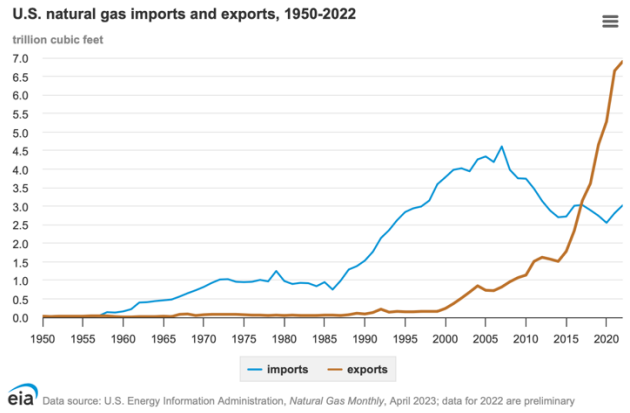
The five largest natural gas-consuming states and their percentage shares of total U.S. natural gas consumption in 2021 were:[4]

15.2%	6.8%	5.9%	5.7%	5.0%
Texas	California	Louisiana	Pennsylvania	Florida

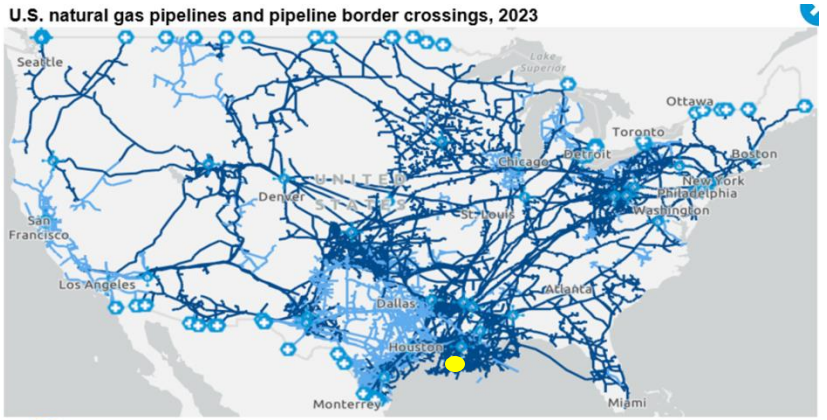


As of 2023 natural gas accounts for 36% of U.S. energy consumption





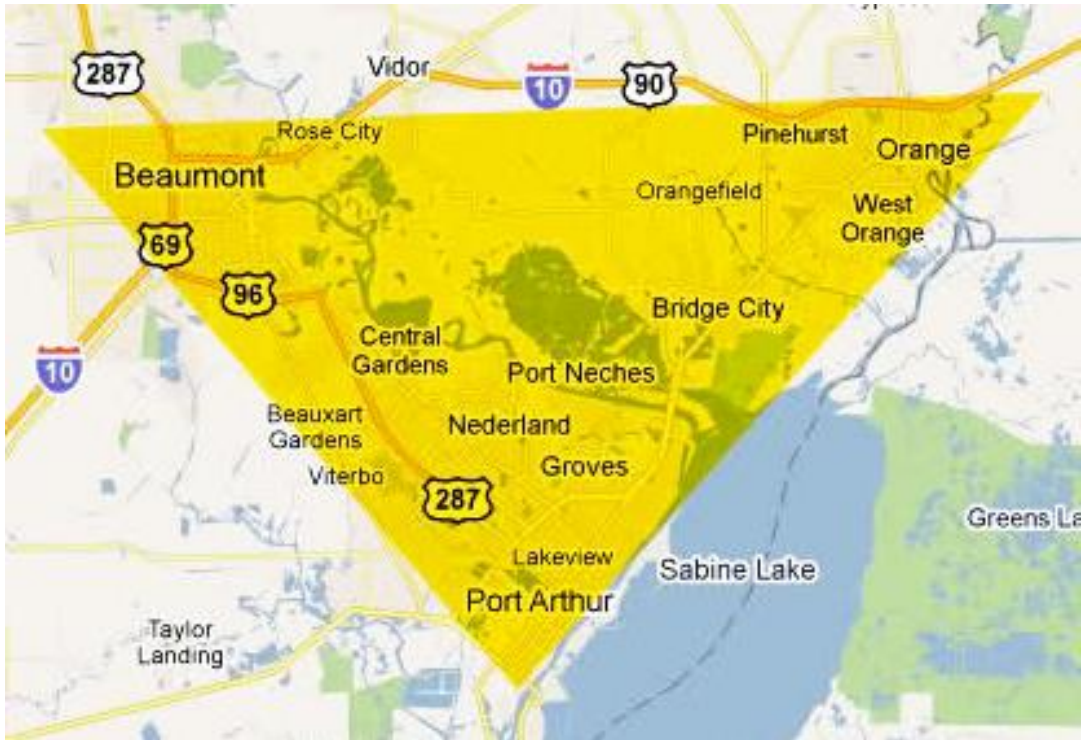
The United States is the largest exporter of natural gas in the world



3 million miles of NG pipeline in the U.S.

"Entergy Texas has announced that they filed an application with the Public Utility Commission of Texas for approval of two new state-of-the-art natural gas power plants, one in Port Arthur and the other near Cleveland."

Golden Triangle Area



- **The Golden Triangle** hosts the second and third largest refineries in the U.S. (i.e. Motiva Port Arthur, and Exxon Beaumont).
- **The Port of Beaumont** consistently ranks in the top 10 largest ports in the country by tonnage (Bureau of Transportation Statistics)

Lamar University is the only full-scale research institution of its kind in the golden triangle region, producing highly skilled graduates and forging innovative research partnerships that power the Golden Triangle's midstream and refining sectors.

"Entergy Texas has announced that they filed an application with the Public Utility Commission of Texas for approval of two new state-of-the-art natural gas power plants, one in Port Arthur and the other near Cleveland."

The Plan

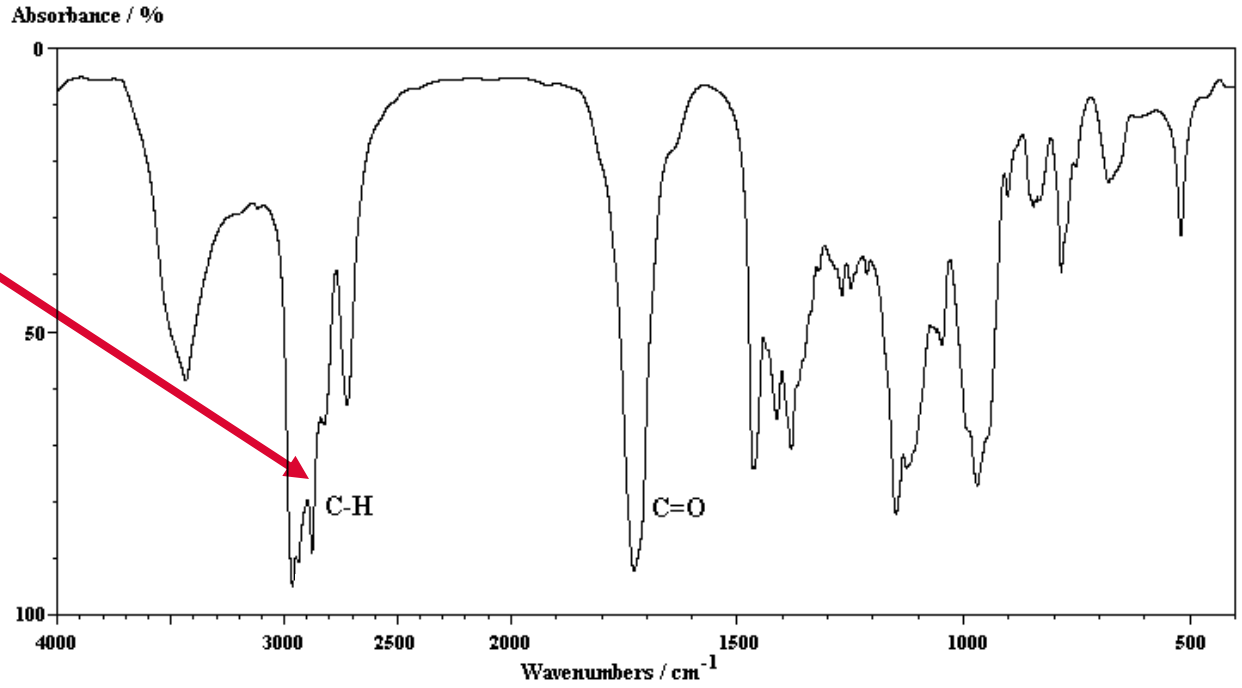
1. Identification of hydrocarbon spills via optical gas imaging equipment;
2. Identification of pipeline ruptures via acoustical signals;
3. Acquiring the samples through geology coring techniques; and
4. Analyzing the samples for the presence of specific volatile organic through chemical spectroscopy via mass spectroscopy (up to 50 amu).

Identify and characterize how methane flows in different SETX soils from leaks in gas pipelines

Typical Absorption Spectra (IR) of Methane (CH_4)

- All hydrocarbons absorb infrared radiation at ~3000 cm^{-1} through the stretching or bending of the C-H bond.
- The fingerprint region (1500 cm^{-1} > wavenumber > 500 cm^{-1}) is unique to each hydrocarbon molecule.

3000 cm^{-1} = 3.3 µm



Find The Egress Points

- **TVA2020 Toxic Vapor Analyzer (Methane Sniffer):** This Flame Ionization Detector & Photo Ionization Detector Analyzer is designed to perform the requisite EPA Method 21 inspections of hydrocarbons. www.thermofisher.com (DETECT Services Corp; Pasadena, TX)

- **Tunable Diode Laser Absorption Spectrometer:** In 2003 the Texas Commission on Environmental Quality ordered studies to determine whether Optical Gas Imaging technology, via infrared cameras, could be used to better monitor fugitive emissions, or addressing the inadequacies of the EPA's Method 21.

TVA2020 Toxic Vapor Analyzer

Tunable Diode Laser Absorption Spectrometer

Measuring surface emission of methane (seeing)

Employing technologies such as infrared cameras and acoustic sensors one can detect and characterize methane leaks in the atmosphere.

Measuring surface emission of methane (hearing)

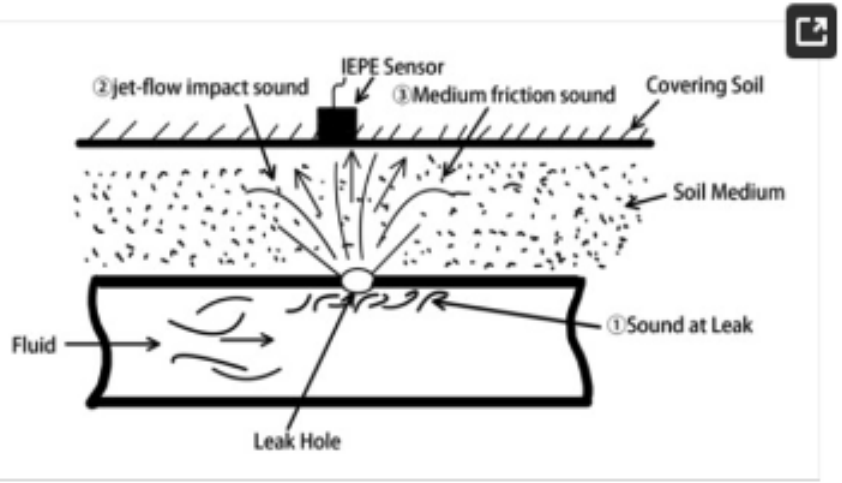


Fig. 1 Geophone on the ground for gas leaks detection

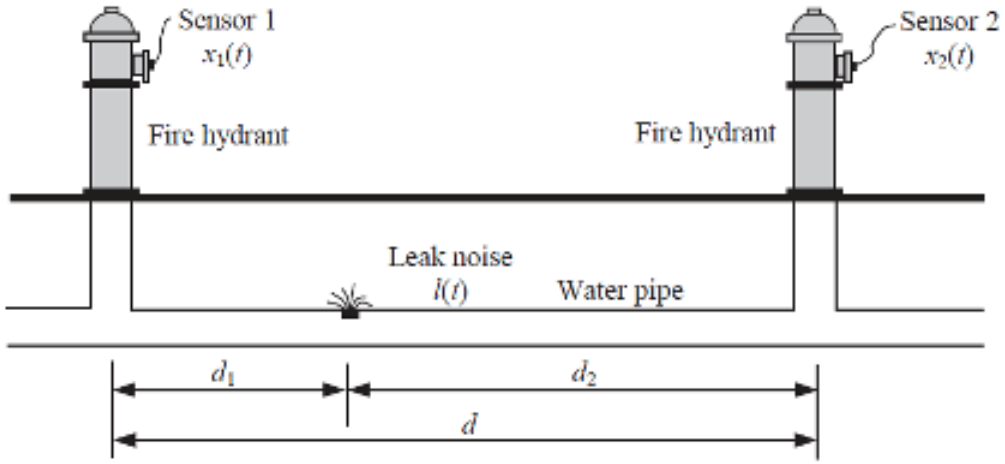
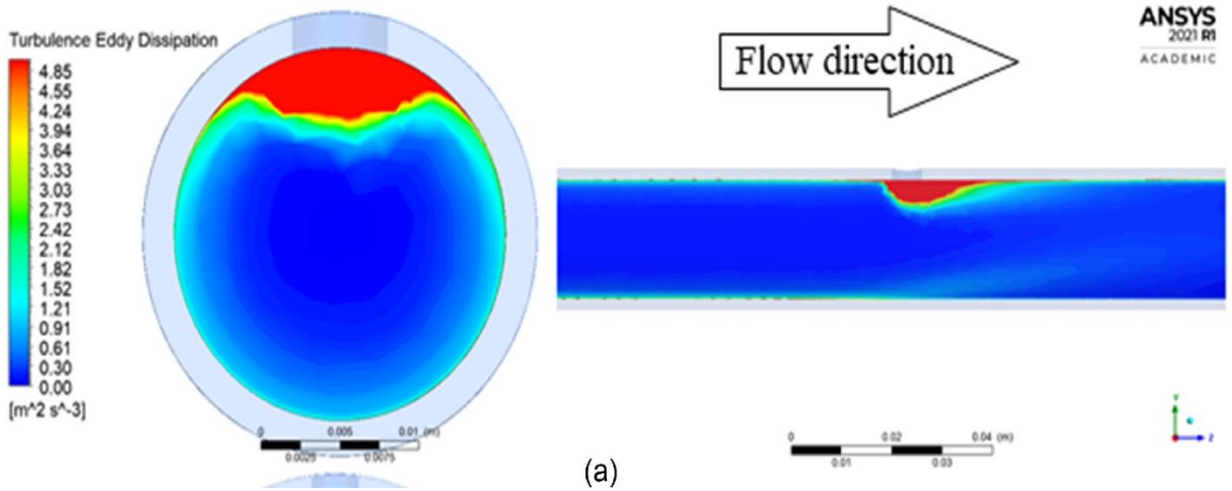


Fig. 2 Ultrasound AE sensor for locating methane leaks

- **Fig.1. Geophone (Geospace Tech., on the ground, 4-500 Hz, 2 each; plus data logger)**
- **Fig 2. Ultrasound acoustic emission (AE) sensor with cable (piezoelectric, Mistras, on the pipe, 20-40 kHz, 2 each; plus high-speed sampling/pre-amplification system.**

Testbed for prototyping methane migration in soils

- **Acoustic Leak Detection:** Utilizes acoustic signals within the pipeline to identify anomalies that may indicate a leak.
- **Turbulent Flow Detection:** Monitors for turbulence in the gas flow, a potential sign of a leak, by analyzing deviations in acoustic patterns.
- **Real-Time Monitoring Potential:** Enables continuous monitoring of pipeline integrity, providing immediate insights into potential leaks and gas flow disruptions.



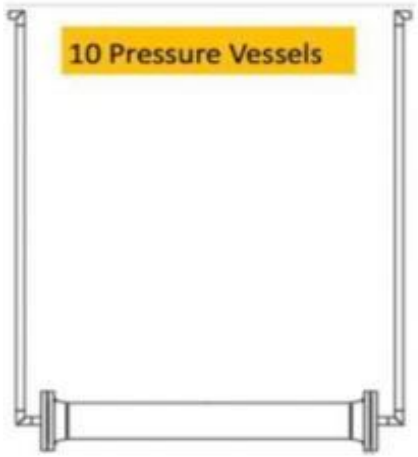
Gescilam, J. S. M. U., Yu, T., Yu, S., & Lima Neto, I. E. (2023). *Computational Simulation of the Flow Induced by Water Leaks in Pipes*. Journal of Irrigation and Drainage Engineering, 149(6). https://doi.org/10.1061/JIDEDH.IRENG-10089

Setup

Pressure Vessels

Two views of an assembled pressure vessel sans the gas tank and regulator (not all bolts are in)

Testbed for prototyping methane migration in soils



At the MultiSensor AI site (formerly known as Infrared Cameras Inc.).

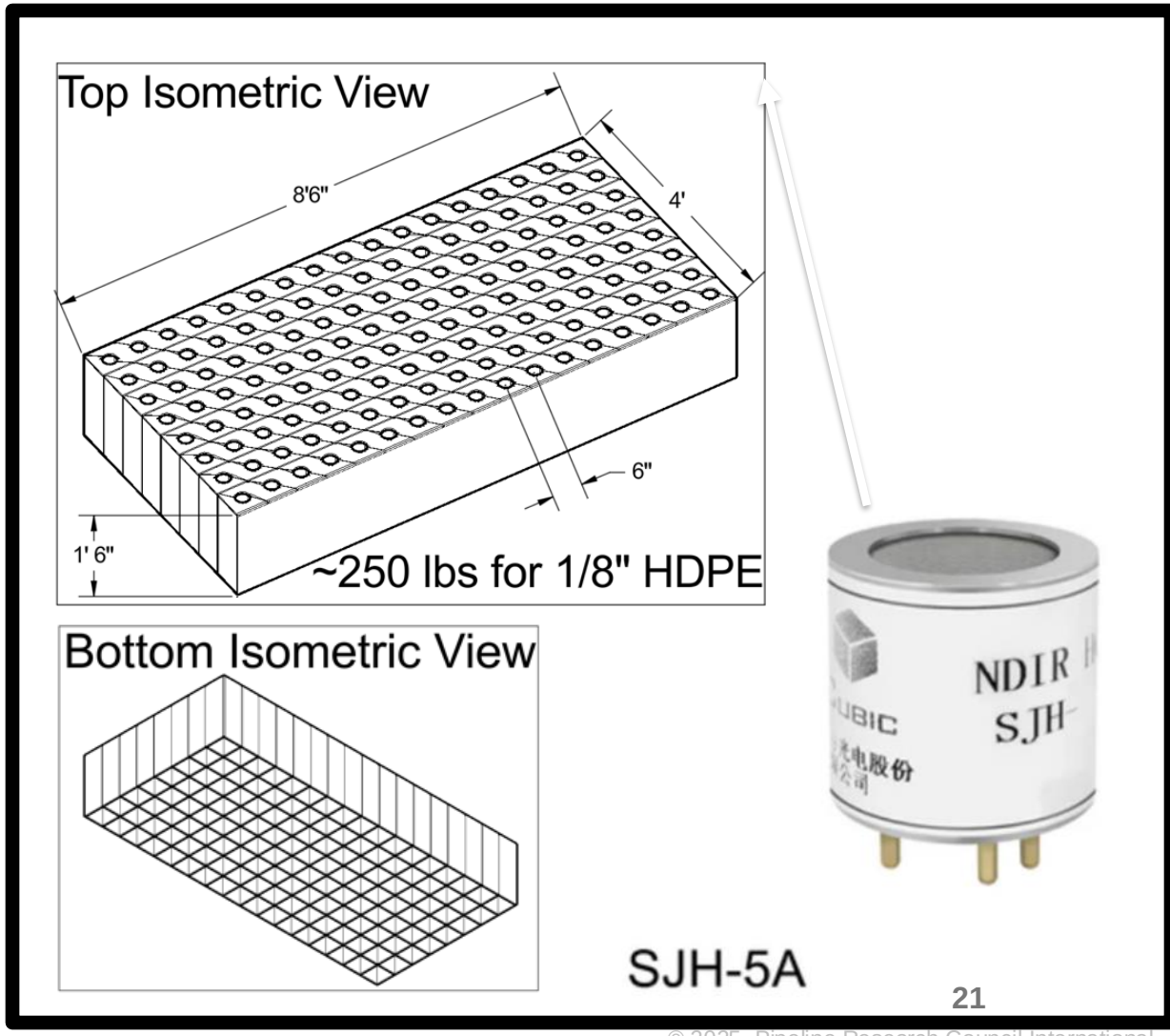
(a) Three pressure vessels per trench for a given soil type; we have one spare. The pressure vessels are positioned so that the 1/8” holes are at 12 o’clock, 3 o’clock, and 6 o’clock.

(b) In the process of burying the pressure

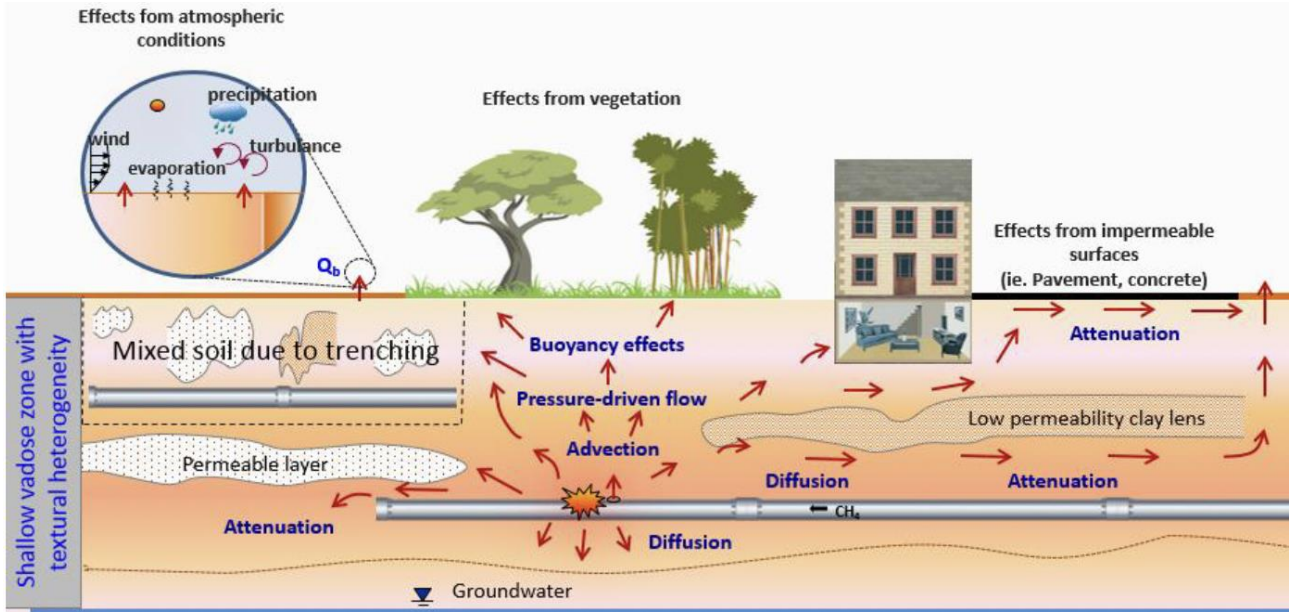
(c) The soil is fully packed down, with the 1” intake and outtake piping emerging from the soil in of the three trenches on ICI property as depicted in the photograph.

Surface Emission Study

- **Methane Capture Grid:** A high-density plastic system divided into 136 chambers to measure surface methane emissions from below-ground sources.
- **Real-Time Monitoring:** Upgraded with SJH-5A infrared methane sensors in each chamber for precise, real-time concentration measurements.
- **Enhanced Data Acquisition:** DAQ system enables high-resolution temporal and spatial data, capturing methane emission dynamics across varying soil types and conditions.
- **Predictive Modeling Potential:** Supports the development of predictive models by accounting for environmental factors like soil moisture, composition, and temperature.
- **Advancing Leak Detection**: Provides detailed insights into methane migration and emission patterns, aiding in environmental impact assessments and leak detection.



Understanding subsurface migration (Qualitative & Quantatative)



Using data from environmental sensors and the mass spectrometer along with analytical tools such as ANSYS we will build data-driven models of subsurface migration of methane.

Mitton, M. (2022). *Subsurface methane migration from natural gas distribution pipelines as affected by soil heterogeneity: Field scale experimental and numerical study* (Master's thesis, Colorado School of Mines).

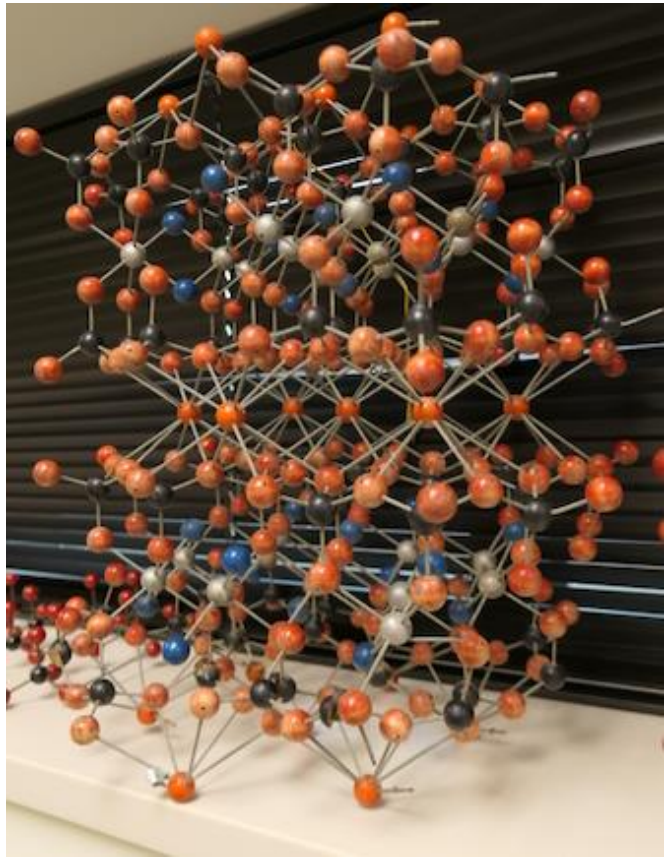
Environmental factors (such as moisture) play a significant role in the subsurface migration of methane. Temperature/moisture (TM) sensors will be installed at varying depths throughout the trench to create a profile of the moisture and temperature as a function of depth in the soil.

Measurements of Methane from Beaumont Soils

Clay

- The main constituent of the Beaumont clay minerals is smectites – a suite of clay minerals including Montmorillionite, a clay mineral known for its high expansion with infusion of water to its structure.
- Clay minerals are layered silicates formed of three layers
- Chemical groups and ions attaching to the middle layer are chemically and structurally controlled.
- Ions attracted to the edge and top and bottom of the minerals are mainly structurally controlled but are less tightly bound.

Top
Middle
Bottom



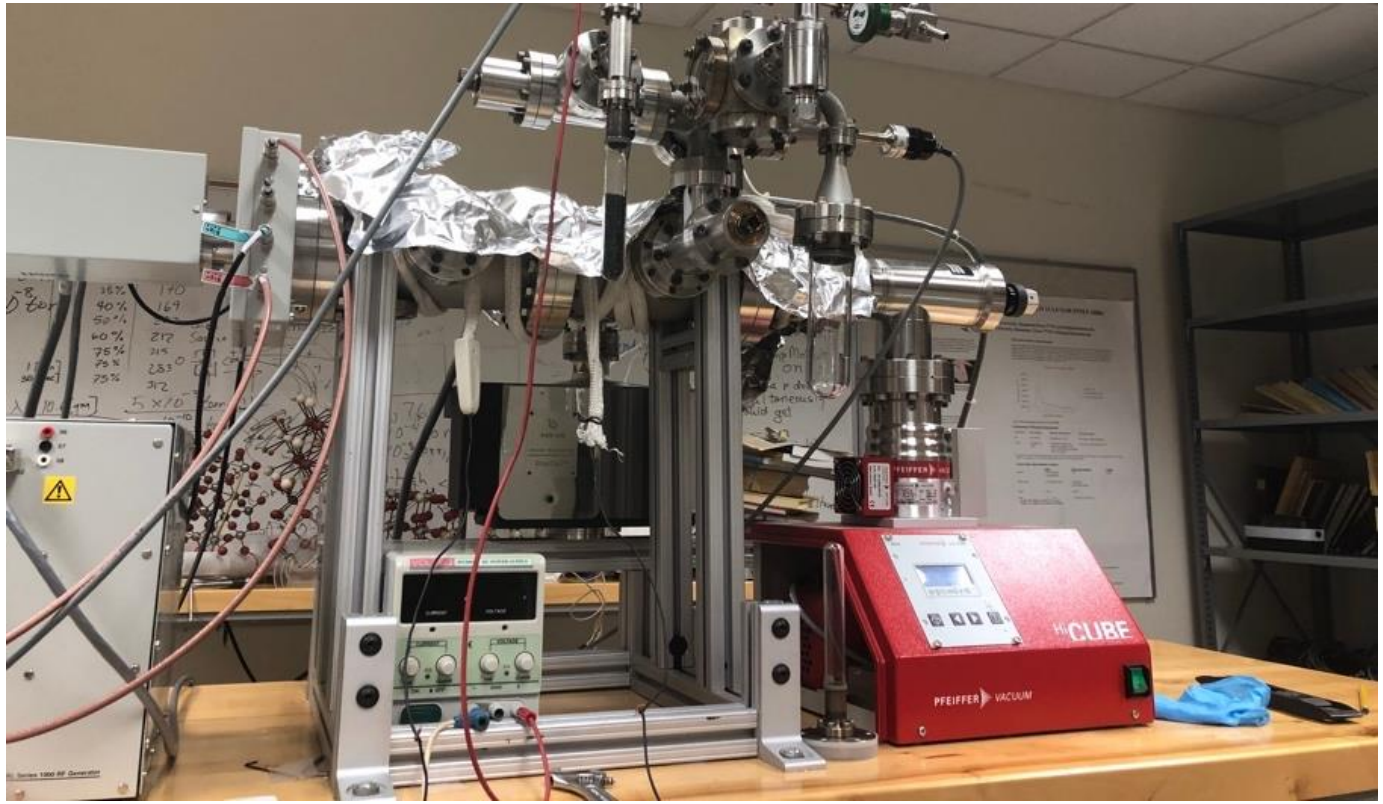
Measurements of Methane from Beaumont Soils

Methane (CH_4)

- Studies of methane in smectites indicate that CH_4 is mainly attracted to the edges + the top and bottom surfaces. (Pawel P. Ziemianski *et al.* 2020)*
- The operating background pressure of the Hiden HAL-7 is between 10^{-10} and 10^{-9} torr (1 torr=1mmHg; 760 mmHg = 1 atmosphere = 760 torr).
- Sample signals were of the order of 10^{-5} torr, well above the background. Excellent Signal to Noise Ratio.

* The structural versus textural control on the methane sorption capacity of clay minerals, International Journal of Coal Geology, Vol. 24, 2020.

Measurements of Methane from Beaumont Soils



- The Dept. of Earth and Space Sciences has a quadrupole mass spectrometer (Hiden HAL-7).
- Located in the Space Vacuum Physics Lab in the Geology building. Another NEW is one on order for the new CMMS laboratory with a 12' x 12' x 7' cleanroom ISO-7 (Class 10,000).
- The Hiden HAL-7 can measure methane with high accuracy.

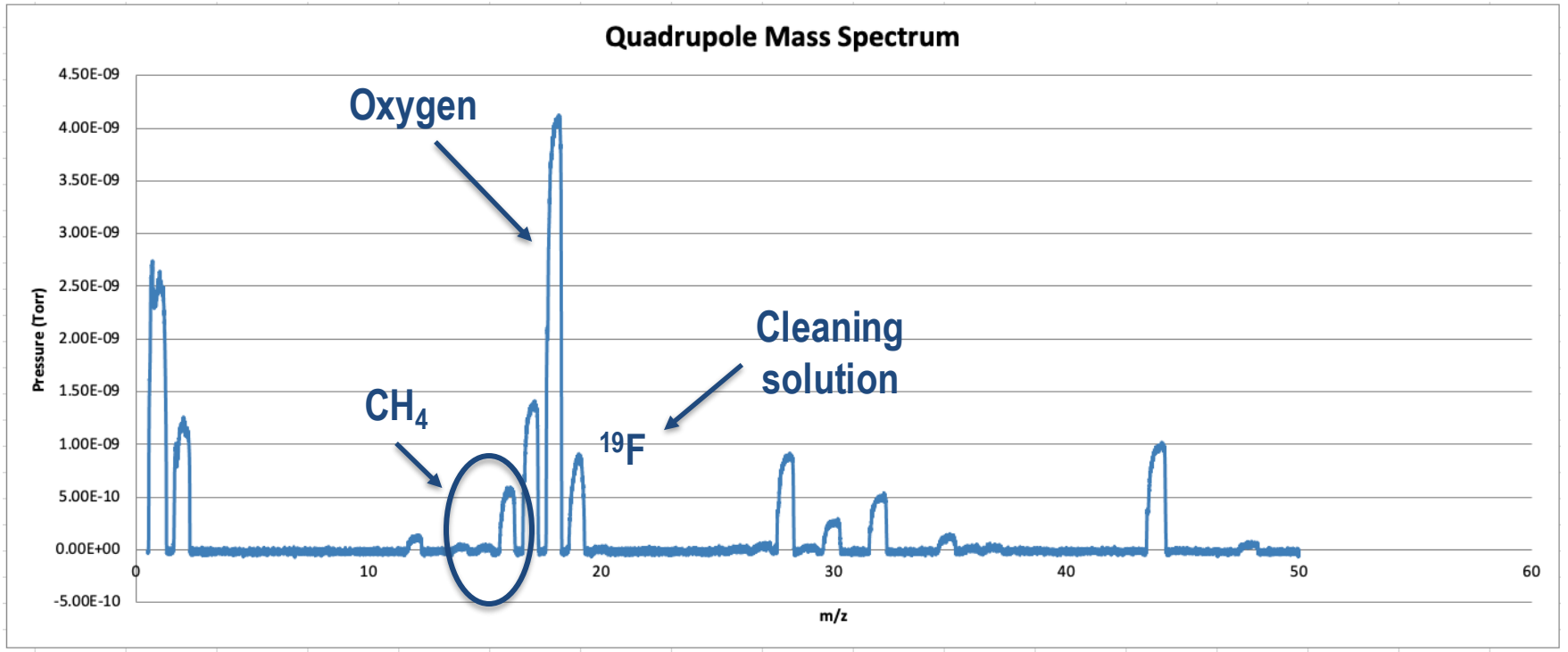
LAMAR UNIVERSITY

Measurements of Methane from Beaumont Soils

Methane (CH_4)

- Methane should have a mass peak at 16 for CH_4, but it also has residual peaks of 15 and 14 due to the breakup of the molecule at the source under 2-keV acceleration energy.

- The breakup pattern is well known for 2 keV; however, we confirmed it with introducing UHP methane to the system.

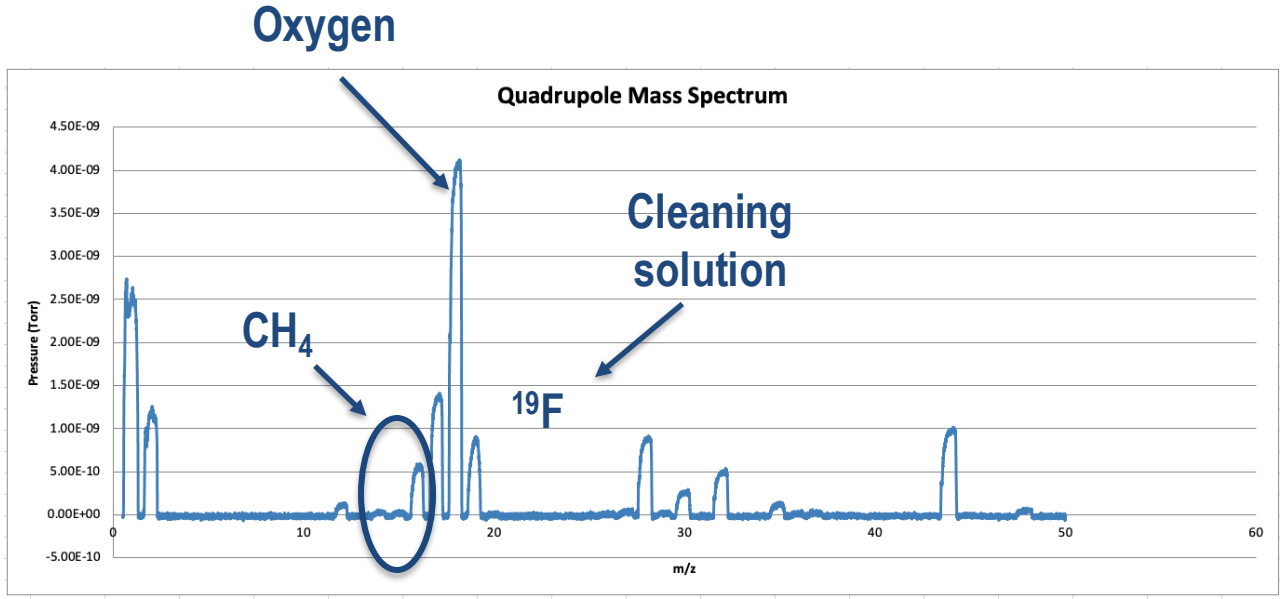


It should be emphasized that the results are preliminary.

Measurements of Methane from Beaumont Soils

Methane (CH_4)

- Of interest are the peaks 18, 17, and 16. The water molecule breaks up at the ion source into fragments.
- It is noteworthy that this source of mass 16 makes a very small contribution to the peak That is established with the ratio of the fragments which are constant for constant source parameters.
- Thus, most of the mass 16 in this measurement is methane. This is further confirmed by the appearance of small peaks at 15 and 14 from the breakup of methane.
- Other higher mass peaks: N_2 (28), CO (28), and carbon dioxide, CO_2 (44)



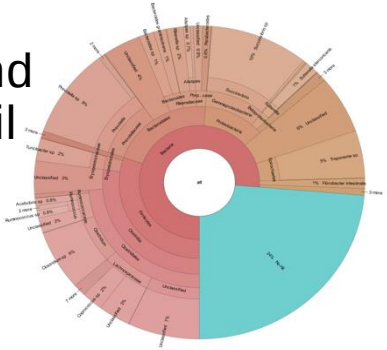
It should be emphasized that the results are preliminary.

Soil Remediation Using Methanotroph Bacteria

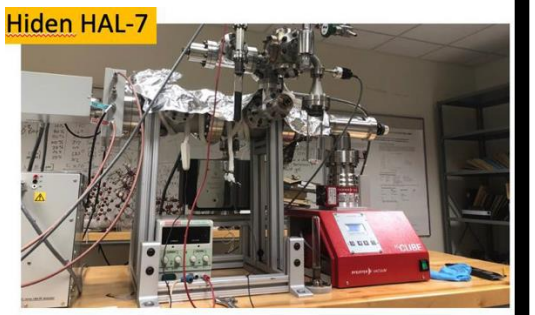
- **Study Objective:** To test the effectiveness of soil amendments in enhancing methane consumption by methanotrophs for soil remediation.
- **Methane Reduction Goal:** Identify optimal combinations of treatments to maximize methane oxidation in contaminated soils.

- **Treatment Combinations:** experimental rings with contaminated soil. Each ring receives a unique combination of amendments to enhance methanotroph activity (e.g. compost)
- **Data Collection:** Regular monitoring of gas levels and microbial activity through mass spectrometry and DNA analysis.

- **Microbial Analysis:** PCR will identify and quantify methanotroph populations in soil samples.
- **Treatment Efficacy:** Assesses changes in methanotroph abundance to evaluate the impact of soil amendments.

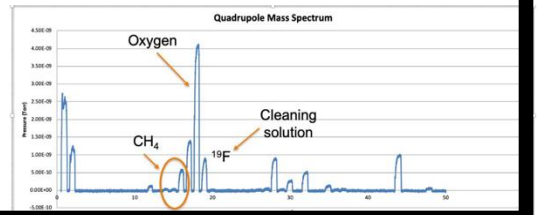


- **Gas Level Monitoring:** Tracks methane reduction in soil to assess methanotroph effectiveness.



Measurement of Methane from Beaumont soils

- **Data Correlation:** Links gas levels with treatment impacts for optimized remediation strategies.



Measurements of Methane from Beaumont Soils

- **Why Natural Gas and Pipelines?**
  - **U.S. leads in natural gas production and export, accounting for 36% of energy consumption.**
  - **Maximizing throughput of methane and minimizing greenhouse gas emissions (ruptures and leaks).**

- **Ongoing Research**
  - **Methane emission studies using real-time monitoring with infrared sensors.**
  - **Advanced acoustic leak detection technologies.**
  - **Soil remediation using methanotrophic bacteria and optimized soil amendments.**
  - **Development of predictive models for methane migration in various soil types**

- **Proposed Research Facility (New Facility)**
  - **A new Lamar-based facility dedicated to methane transport and emissions studies.**
  - **Features realistic industrial setups and soil conditions for enhanced research capabilities.**
  - **Aims to position Lamar as a leader in methane-leak detection.**
- **Flagship Experiment (New Facility)**
  - **A large-scale closed-loop pipeline system to study methane leak emissions.**
  - **Will integrate soil sensors and test various pipeline geometries.**
  - **Collaboration opportunities for equipment testing and data collection with local industries.**

CENTER FOR MIDSTREAM MANAGEMENT & SCIENCE
LAMAR UNIVERSITY

thank you

REX2025
PRCI Research Exchange

CENTER FOR MIDSTREAM MANAGEMENT & SCIENCE
LAMAR UNIVERSITY

Dr. Philip L. Cole
Executive Director

409-880-7921
pcole@lamar.edu
www.lamar.edu/midstream
P.O. Box 10008
Cherry Signature Centers 103B

SEE FOR YOURSELF

Like and Follow Us!

Seeing the Methane Leak

Tunable Diode Laser Spectroscopy | TDLAS

(TDLAS)

- ICI's Tunable Diode Laser Absorption Spectrometer (TDLAS) is an innovative long-range detector which allows methane gas (CH4) to be detected at distances of up to 50 m in as little volume as 1 pmm.m.
- Detects methane by emitting infrared light and examining reflected light density.
- It can be fixed mounted or attached to an aerial vehicle.
- Combine the tunable laser with ICI's line of thermal devices to gather infrared data for temperature analysis.
- Ideal for use in industrial, commercial, and research environments.

Methane Sniffer – EPA Method 21

FLAME IONIZATION DETECTOR PHX42