U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

DOE Fossil Energy Carbon Management Undocumented Orphaned Wells R&D (CATALOG) Program

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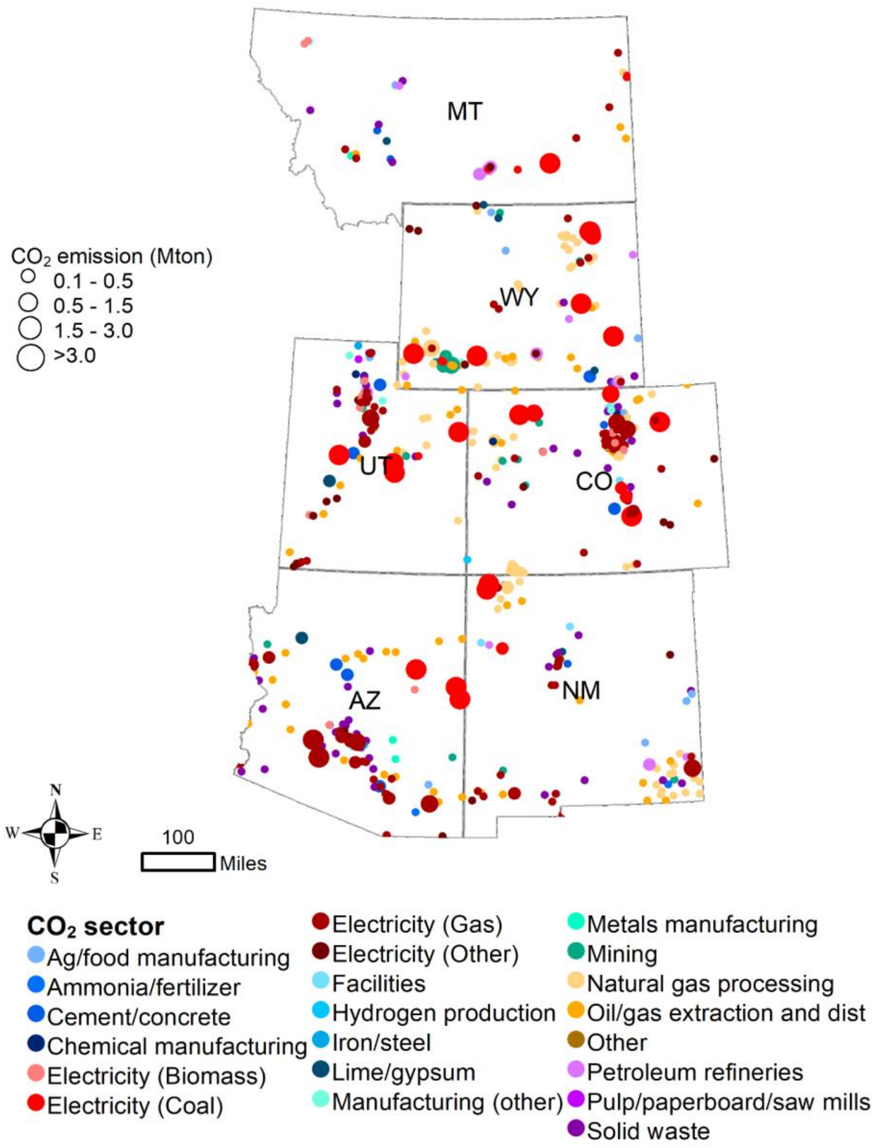
Pictures Source: PADEP

I-WEST supports regional projects

- Techno-economic and lifecycle analyses
- Storage, utilization, conversion analysis
- Connecting communities, industry, end-users, research institutes, and initiatives
- Test bed for energy transition that is taking place worldwide
- Reducing emissions of CO2 and methane critical for reaching net zero.



Methane Mitigation Technologies Division Overview

Methane Emissions Mitigation

Advanced materials, data management tools, inspection and repair technologies, and dynamic compressor R&D for eliminating fugitive methane emissions across the natural gas value chain

Methane Emissions Quantification

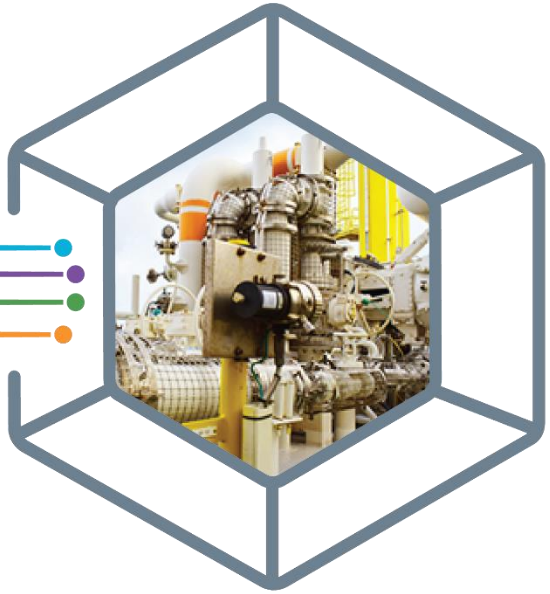
Direct and remote measurement sensor technologies and collection of data, research, and analytics that quantify methane emissions from point sources along the upstream and midstream portion of the natural gas value chain

Decarbonization of Natural Gas Resources

Technologies for carbon-neutral hydrogen production, safe and efficient transportation, and geologic storage technologies supported by analytical tools and models

Undocumented Orphaned Wells Research

Developing tools, technologies, and processes to efficiently identify and characterize undocumented orphaned wells in order to prioritize them for plugging and abandonment.



METHANE MITIGATION TECHNOLOGIES

Administration Goals:

50% emissions reduction by **2030**
100% clean electricity by **2035**
Net-zero carbon emissions by **2050**

Bi-Partisan Infrastructure Legislation

Relevant Appropriations Language

Section H2 (a, b)
Conduct research and development activities in cooperation with the Interstate Oil and Gas Compact Commission to assist the Federal land management agencies, States, and Indian Tribes in--

(A) identifying and characterizing undocumented orphaned wells; and

(B) mitigating the environmental risks of undocumented orphaned wells;

Program Budget

DOE's Undocumented Orphaned Well Program will be executed over **5 years with $30M** in appropriated budget.

FY2023 Appropriations

Up to $10 million to be spend on identification and characterization of undocumented orphaned wells.

IOGCC 2021 estimate of undocumented orphaned wells is between **310,000** and **800,000**.

Key Partnerships and Stakeholders

National Laboratories

- Data Analytics/Machine Learning (critical to disparate datasets)
- Well characterization (subsurface and surface)
- Experience with detecting and characterizing undocumented wells
- ***NLs*** will be critical in identifying existing and new technology pathways

IOGCC (States)

- The ***IOGCC*** will collaborate with individual State Environmental Agencies to gain critical insight into best practices and technology development needs.
- The ***IOGCC*** will develop and maintain a list of critical points of contact within the ***States*** and assist in maintaining effective communications.

DOI, BLM

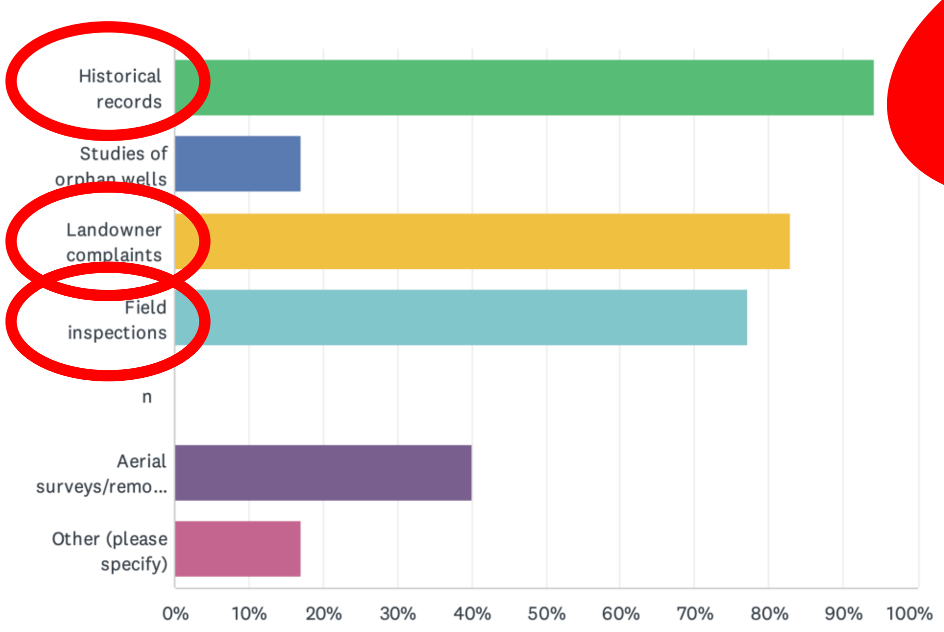
- Understanding the technology needs and estimation of undocumented orphaned wells.
- Collaborate to ensure effective communications and project engagement.
- Conduct critical identification and characterization of undocumented orphaned wells.

2022 IOGCC Survey Responses

- 37 respondents representing 30 states
- 70% indicated "moderate" or "low" priority -> constrained resources

Q5 What approach/methods has your state been using or contemplated using to identify undocumented orphan wells?

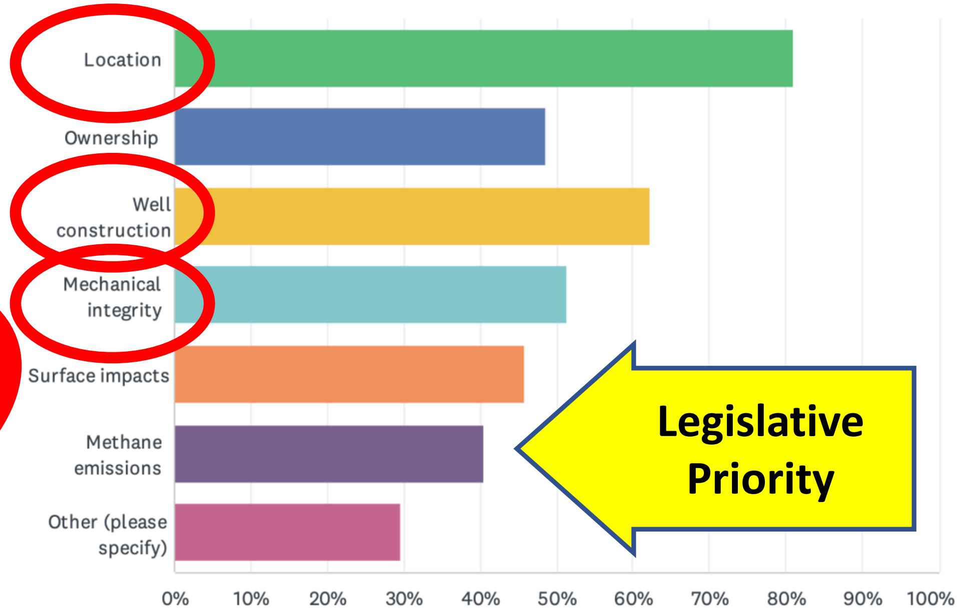
Answered: 35 Skipped: 2



Top Three Responses

Q4 What are your state's biggest data needs/gaps relative to undocumented orphan wells?

Answered: 37 Skipped: 0



Legislative Priority

State of Practice

- Labor intensive, largely non-technical
- Where is it? What's the state of health?
- Varying local constraints on inspection

Survey Responses set CATALOG Research Priorities

DOE Undocumented Orphaned Wells Program Priorities

1. Methane Detection and Quantification
2. Well Identification
3. Sensor Fusion and Data Integration with Machine Learning
4. Well Characterization
5. Integration and Best Practices
6. Data Management
7. Records Data Extraction
8. Wells Database
9. Field Teams

CATALOG
Locate
Characterize
Inform

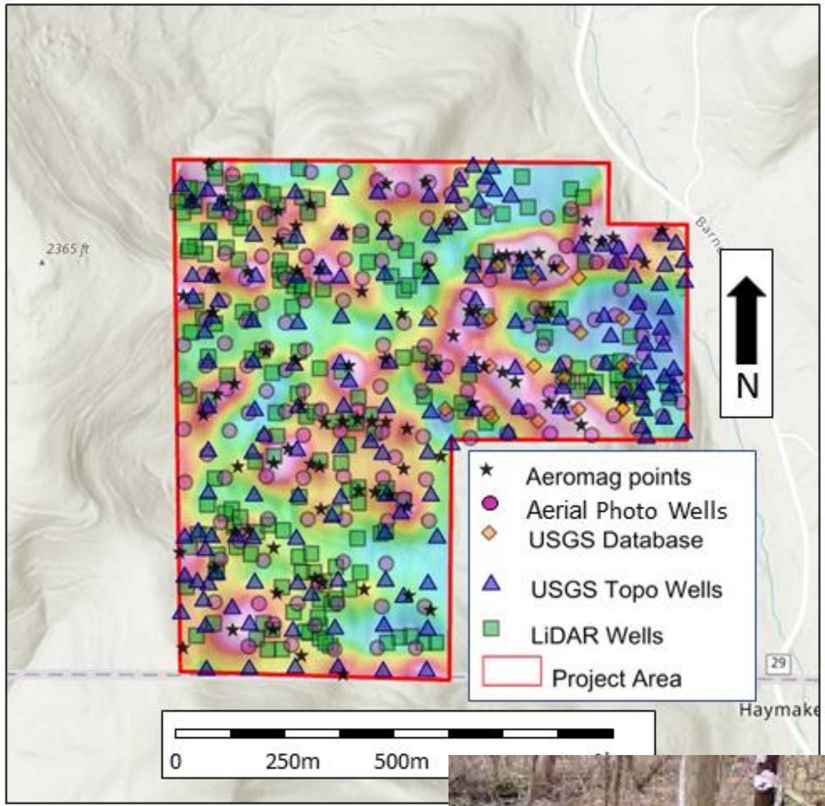
Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

catalog.energy.gov

BERKELEY LAB
Los Alamos NATIONAL LABORATORY EST.1943
Lawrence Livermore National Laboratory
NETL NATIONAL ENERGY TECHNOLOGY LABORATORY
Sandia National Laboratories

There's no silver bullet for finding these wells

- Various methods could be used to locate wells
  - magnetic survey, aerial or satellite photography, LiDAR, methane measurements, historical records
- No method works in all cases
  - Magnetics fail when the well casing is removed (~15,000 wells had casings salvaged during WW2 for the metal) and is challenging in steep terrain or tall vegetation
  - Methane measurements fail when the well is not emitting (emissions are highly transient)
  - Aerial/satellite photos could be obstructed by vegetation or construction
  - Four Corners Area is a test bed for undocumented orphan wells and I-WEST



2023 Activity

CATALOG

Locate
Characterize
Inform

Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.

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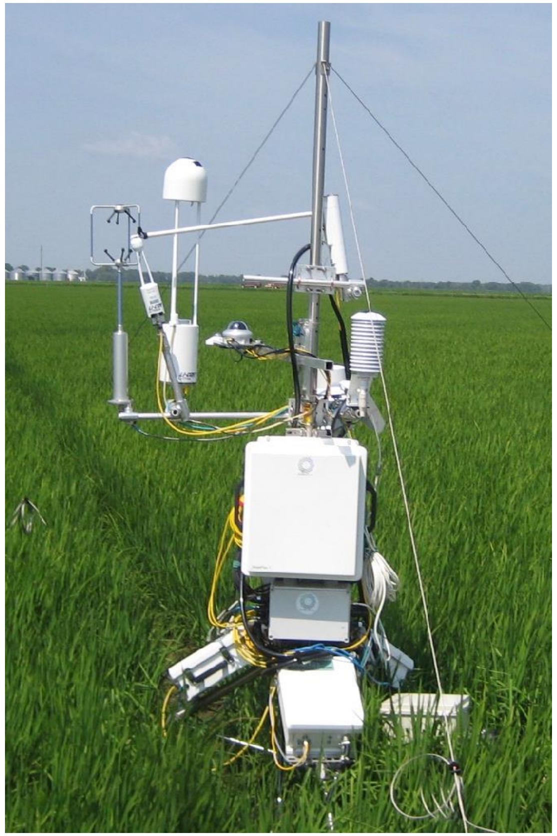
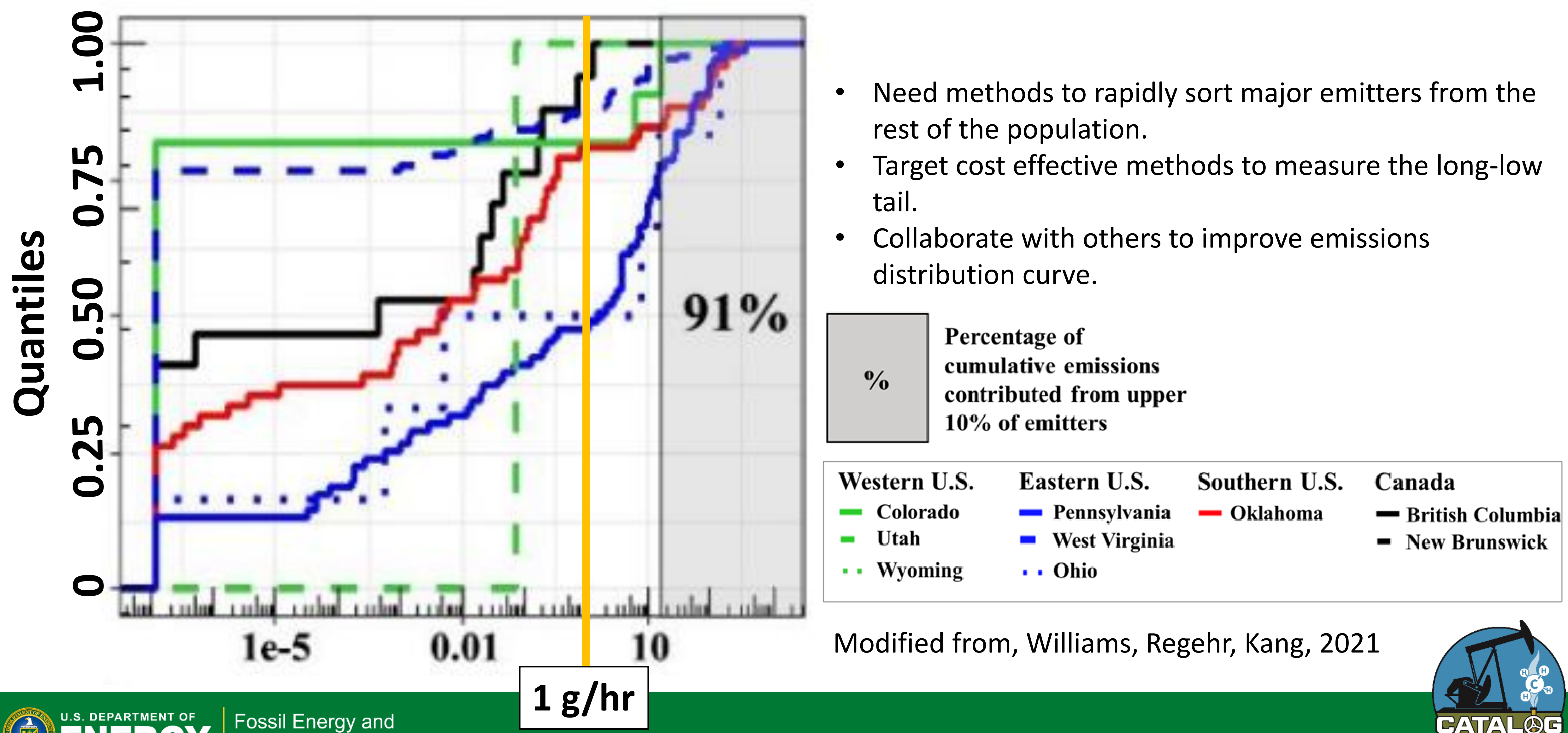
Cost-effective estimation of methane emission rates from undocumented orphan wells

- The state-of-the-art uses a flux tower to estimate the emissions rate and costs about $2500+ per well
  - Measuring methane emission rates before and after plugging and abandonment is a top priority for the White House – "How much methane did we keep out of the atmosphere?"
- We need to drive this cost down dramatically to efficiently use DOI's $4.7B budget
- White house asked CATALOG to develop a screening methodology to estimate flow rate from cheap concentration measurements: **defensible, simple procedure and cost effective**



Flux Tower

Few wells produce most of the emissions



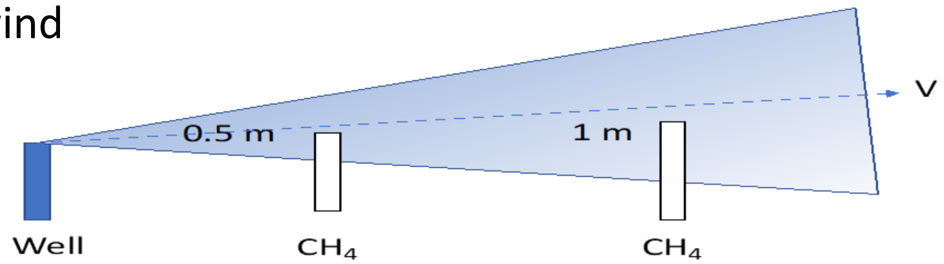
- Need methods to rapidly sort major emitters from the rest of the population.
- Target cost effective methods to measure the long-low tail.
- Collaborate with others to improve emissions distribution curve.

Modified from, Williams, Regehr, Kang, 2021

Plume Model Data Collection

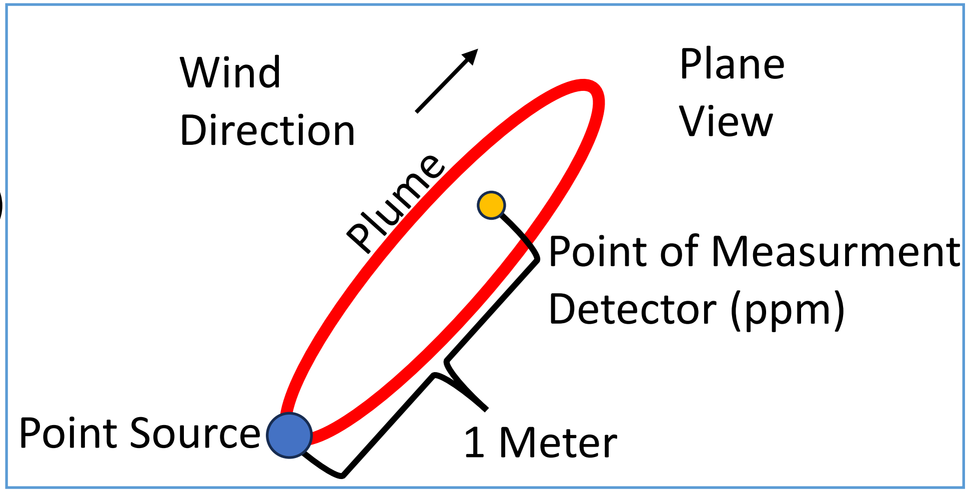
Equipment

- Ppm sensitivity, calibrated, and compact CH4 sensor (MOS or spectroscopic)
- Handheld anemometer (vane, thermal, sonic and/or wind-sock) to measure wind speed and direction
- Tape to measure distance



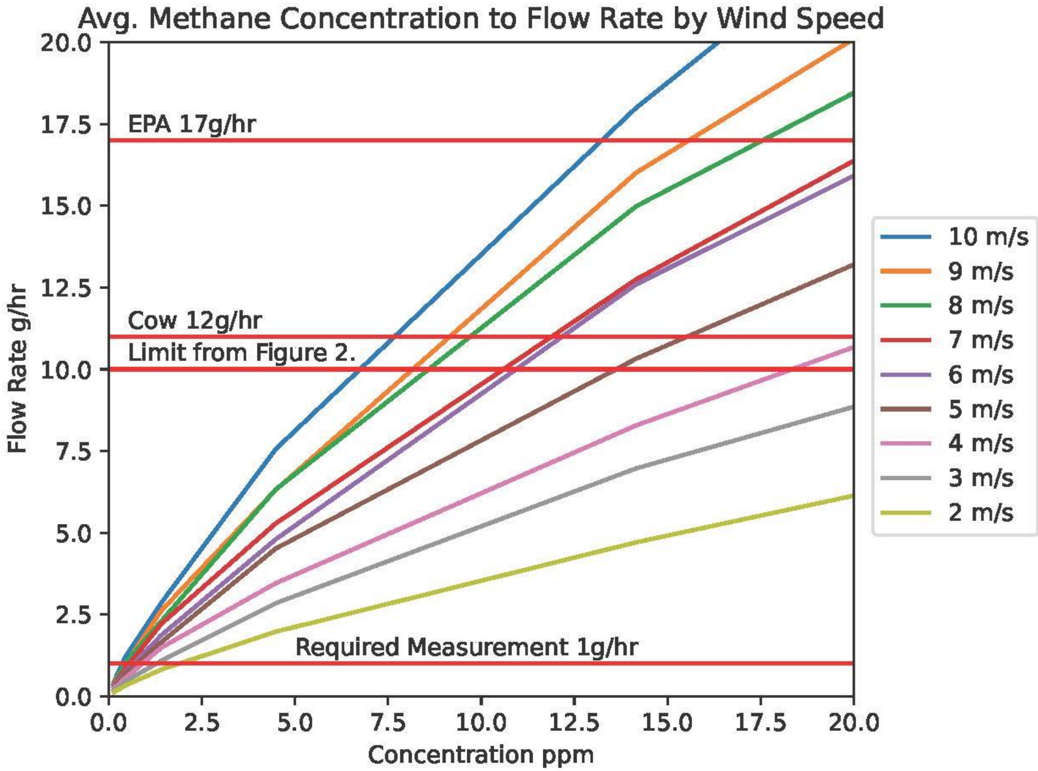
Procedure

- Locate orphan well source and determine wind direction
- Ensure winds are stable or create them by use a fan upwind of the well
- Measure CH4 downwind at multiple points downwind near the source (0-1m)
- Can sample over minutes with a single sensor during stable winds
- Record wind speed, distance downwind, and CH4 concentrations
- Use a calibrated CH4 increase to flux conversion being developed by DOE



Cost-effective estimation of methane emission rates from undocumented orphan wells

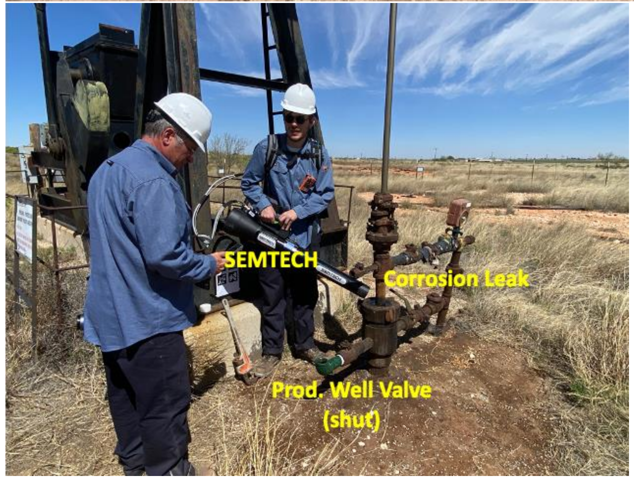
- Innovations: Combine Gaussian plume models, inverse analysis and uncertainty quantification to develop a relationship between concentration and flow rate as a function of wind speed
- Provides a cost-effective way to screen wells and filter out low emitters
  - High emitters can still be measured with a flux tower, if desired
- Result: Our approach is currently being validated by CATALOG and DOI



Cost-effective estimation of methane emission rates from undocumented orphan wells

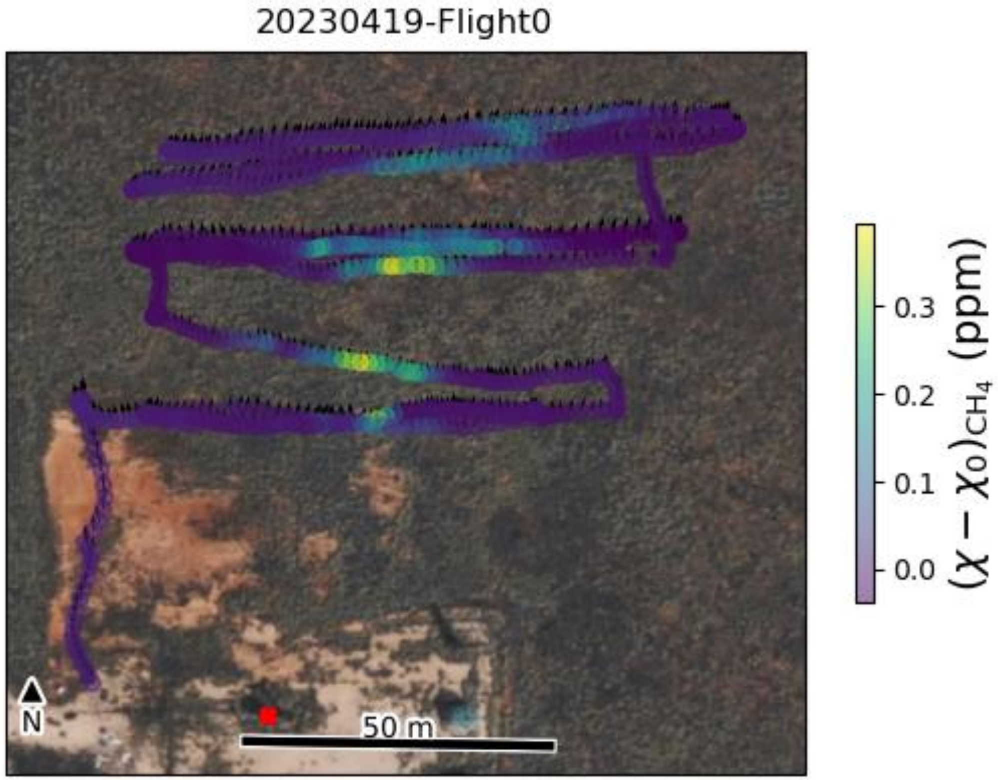
- Gas concentration and composition (ppm) measurements from orphan wells prioritized for plugging in Hillman Park, PA and Hobbs, NM
- Observed WellDone's protocols in NM
- Picarro backpack and RMLD deployed to detect CH4 leaks.
- Deployed FLIR (NETL) used to find leakage point.
- Xplorobot LIDAR and SEMTEC HI-FLOW2 to quantify CH4 leak rate at the well head.
- Leak rates range between 10 and 100 g/hr (relatively small)

Hillman Park, PA



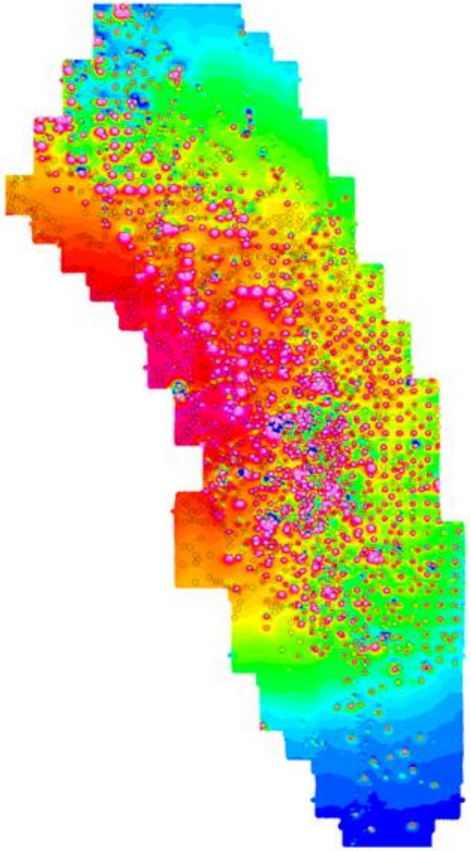
Hobbs, NM

UAV capability to monitor/find leaky orphan well from > 100m

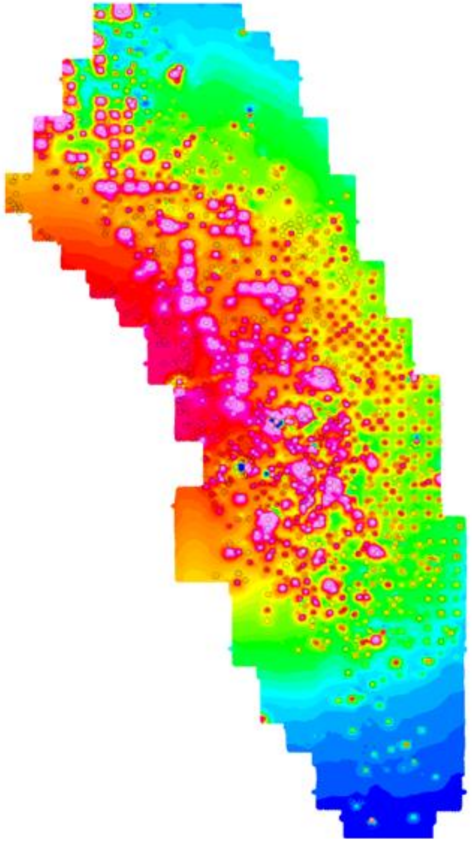


Demonstrated ability to measure leaky wells from 100s m downwind using UAV/Aeris at Hobbs, NM

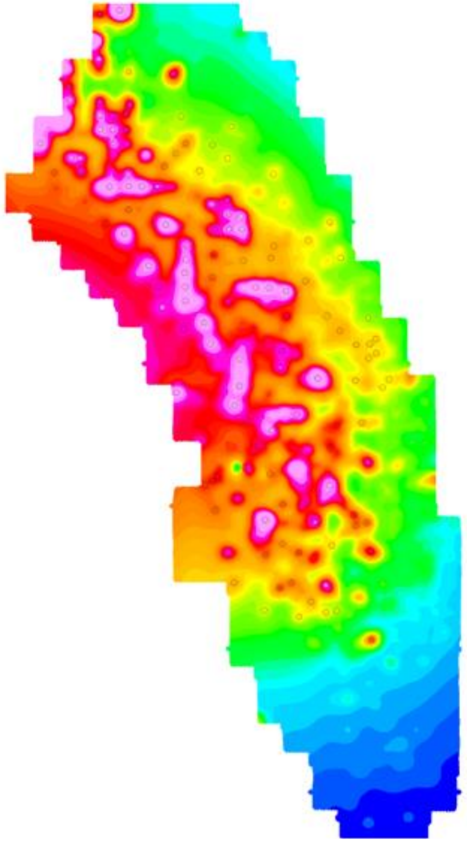
How high can we fly and still detect metal from wells?



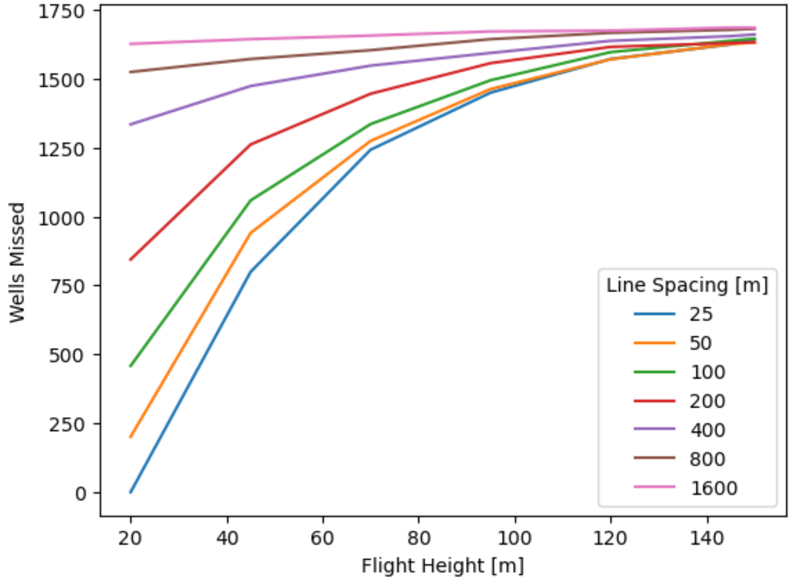
20 m Altitude



45 m Altitude



120 m Altitude



Key Takeaway – Aeromagnetic surveys must be flown at altitudes ≤ 45 m and line spacing ≤ 50 m for acceptable well identification (≥70% detection)

Is Fixed Wing Drone the Sweet Spot for Good Detection and Low Cost?

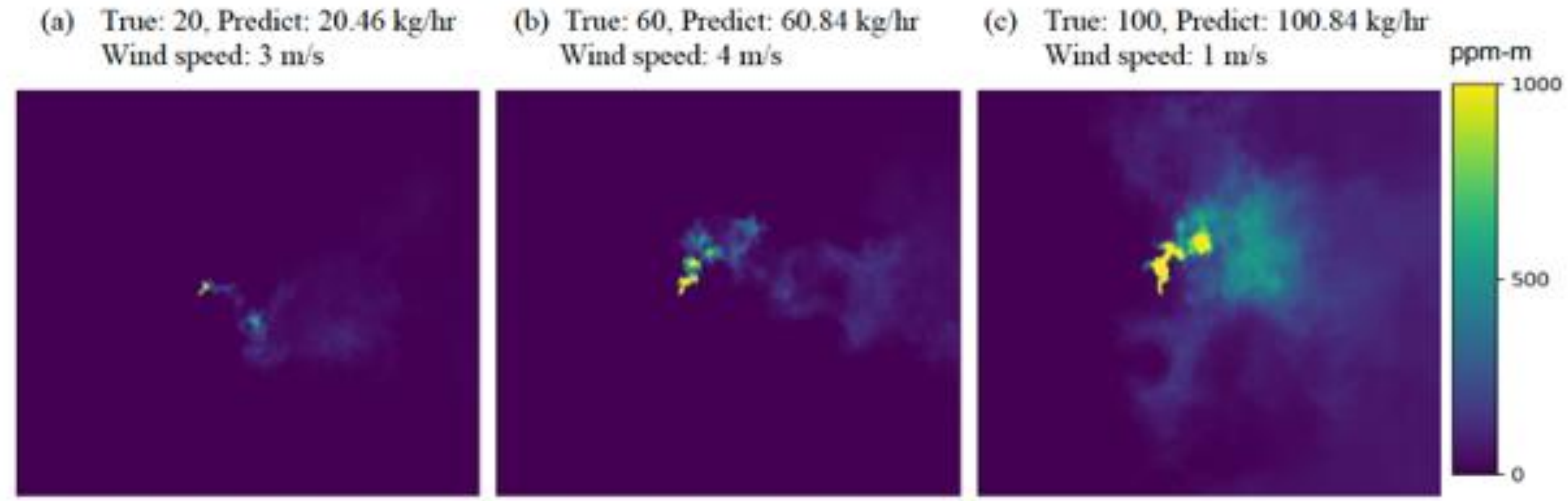
Rotary Drone: Can fly low, inexpensive, covers small area, good for CH4 and characterization with EM and GPR

XV-H Fixed-Wing Drone: Covers large area inexpensively, could find large number of wells over big areas with magnetometer, lidar and high resolution photography, too fast and high for CH4 -> We will be testing this in the fall

Helicopter: Covers large area but expensive, can find large number of wells over big areas, too fast and high for CH4

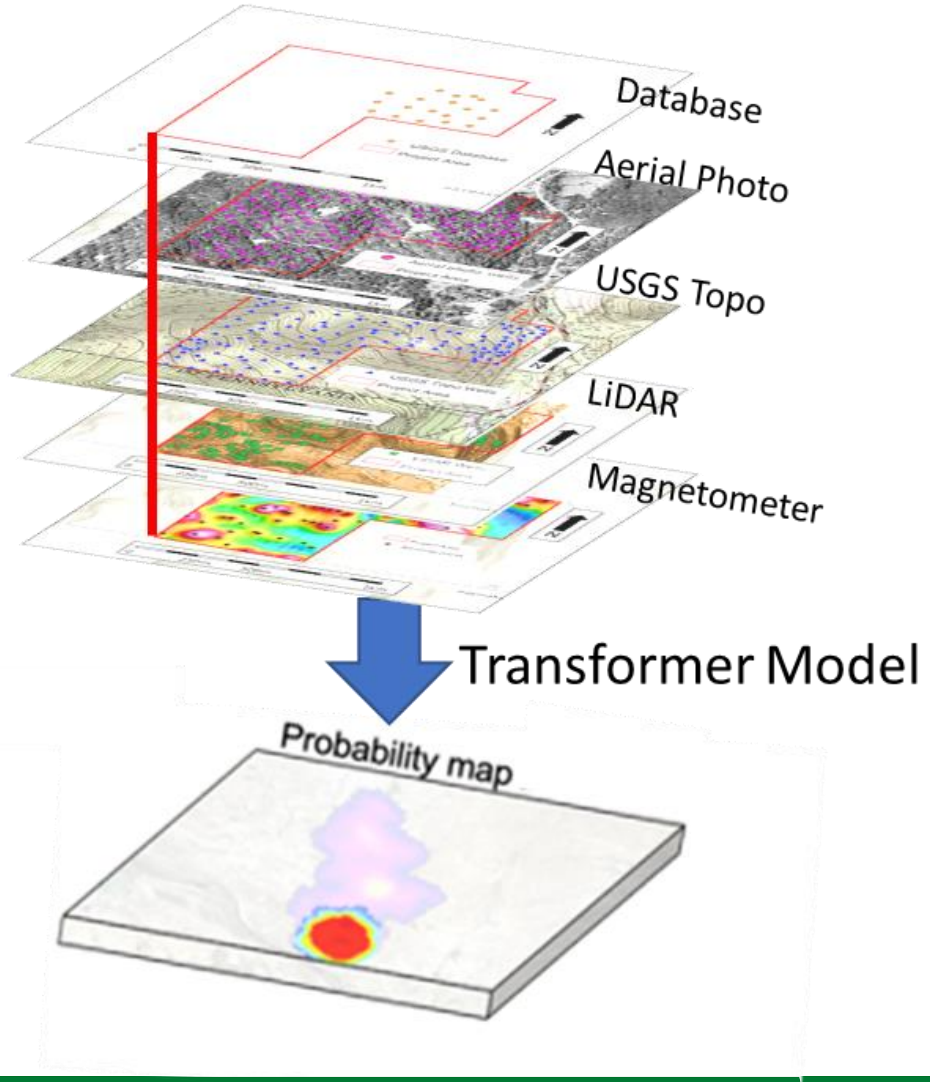
Can we estimate methane leak over a region with UAVs

Current method can only estimate large methane leaks (10 kg/hr)

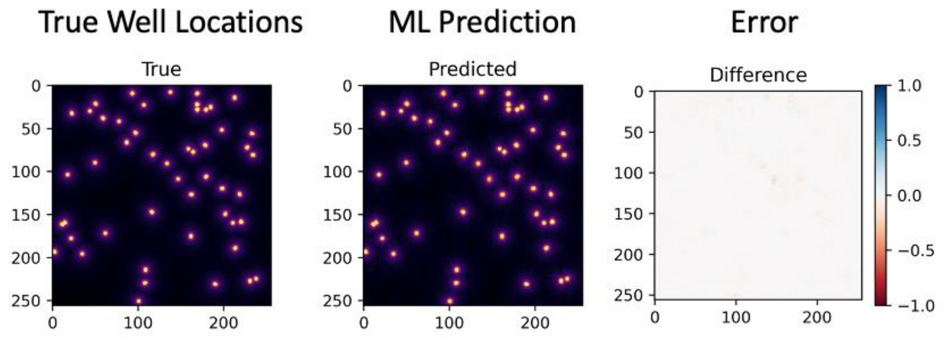


Initial ML model shows accurate estimation of methane emission, which can be used identifying emission rates more accurately over large area and prioritizing undocumented well for sealing.

Can we use multiple noisy signals to find wells?



- Machine Learning models have shown impressive results in fusing data from different sources (e.g., text and images).
- Our approach suggests that having two data sources (compared to just a methane sensor) increases the accuracy of the model by a wide margin. *Next steps:* Advancing towards NETL data from Hillman State Park.
- Initial ML model shows accurate prediction of well location based on environmental data, which can be used for undocumented well locating and identification



Well Database

Updatable, Relational Database

Purpose

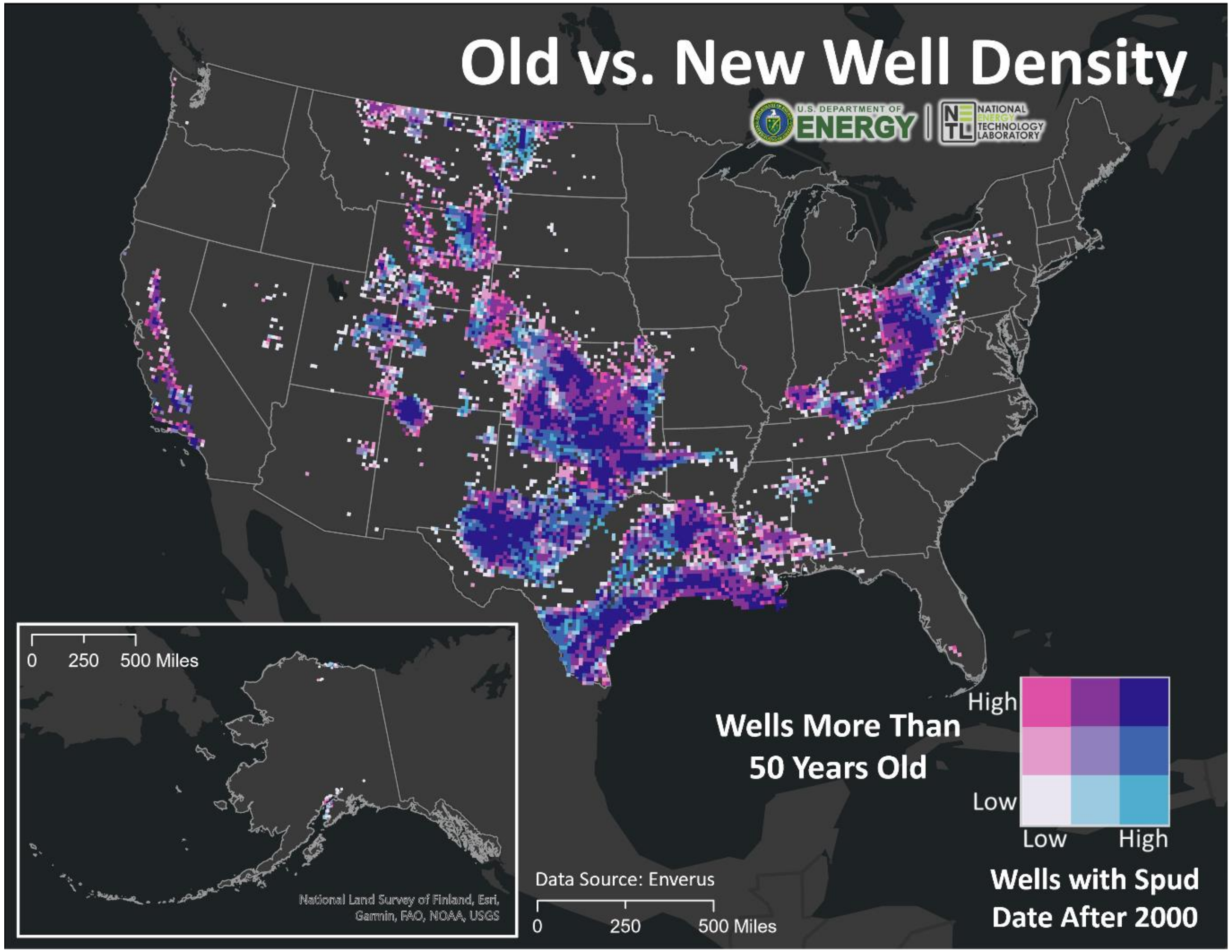
- Limit identifying known wells
- Framework for ML

Sources

- States, Tribes, Private, DOI, GWPC, NGOs

Attributes

- Comparison and ranking via sources etc.
- Evergreen
- Tag back to managing agency.
- Framework for additional well data



Historical Records from the 1850-1950 are in bad shape

Large language model (LLM):

- **DocQuery**[1], developed/fine-tuned by Impira
- Based on Microsoft's LayoutLM model
- Used two dataset, i.e., SQuAD2.0 and DocVQA
- Document Query Engine Powered LLMs
- Able to analyze semi-structured and unstructured documents (PDFs, scanned images, etc.)
- Zero-shot learning (no-training is used for this task at the current stage)

Historical documents

- 150 Drilling Completion Reports from Colorado
- Text-based PDFs
- Information of well location, depth, etc.

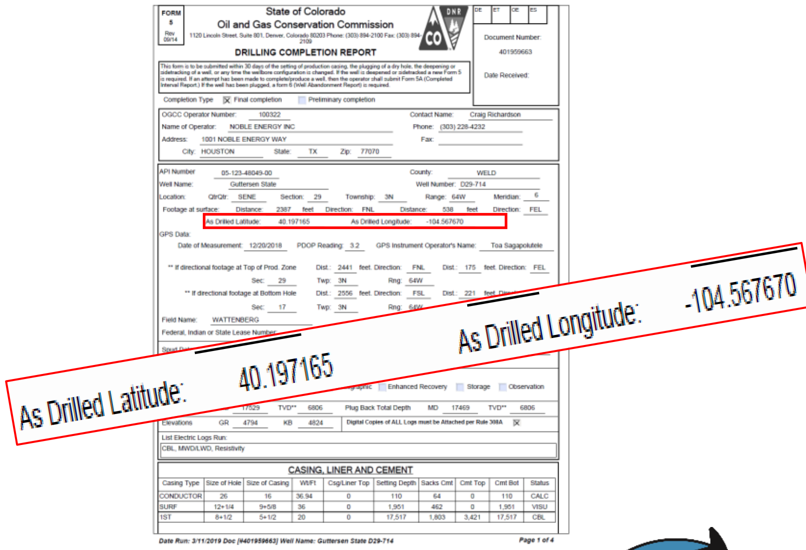
Model performance:

- Extraction time: within two seconds per document
- Accuracy: **100%** on a simple dataset
- Struggles with a more complex dataset

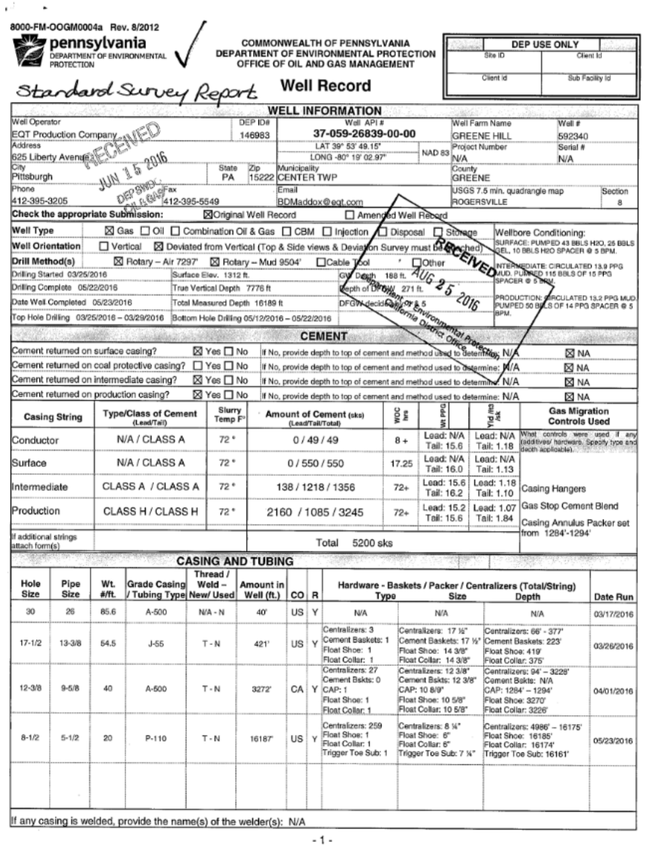
Future direction:

- Generate our own dataset for with questions and answers based on historical documents
- Fine-tuning LLM models
- Use more powerful LLMs, which show more promising preliminary results on the complex dataset

By using Large Language Models, we can obtain correct well location information from historical documents



Extracting data from historical records with large language models



1. Document image

2. Semi-structured text

```
8000-FM-OOGM0004a Rev. 8/2012
pennsylvania
DEPARTMENT OF ENVIRONMENTAL PI
COMMONWEALTH OF PENNSYLVANIA I
Standard Survey Report
Well Operator
EQT Production Company
Address
RECEI
625 Liberty Avenue.
City
Pittsburgh
Phone
412-395-3205
JUN 15 2016
DEP ID#
146983
Well Record
WELL INFORMATION
Well API # 37-059-26839-00-00
Site ID
Client Id
DEP USE ONLY
Client Id
Sub Facility Id
Well Farm Name
Well #
LAT 39° 53' 49.15"
LONG -80° 19' 02.97"
GREENE HILL Project Number
```

OCR

LLM

3. Structured Well Information

```
{ "latitude": 39.896986
  "longitude": -80.3174
  "depth": 7776}
```

We have had early success extracting well characterization information from image-based documents using optical character recognition (OCR) and large language models (LLMs) like ChatGPT

Field Teams

Stonewall Jackson State Park, West Virginia

- Two potential survey locations
    - 11 km2
    - 15 km2
- Drone based magnetic survey
- Ground truthing and methane leak measurements
- Forested with steep terrain
- Working with BLM to finalize areas of interest

Chuza oil field near Farmington, NM

- 29 Wells designated as “reclamation fund approved” by NMOCD
    - 8 wells on BLM land
    - 21 wells on Navajo Nation
- ~ 5.8 km2
- Methane and magnetometer drone based survey
- Scarce vegetation with moderate topography
- Gas leaks have been detected w/ FLIR cameras
- Farmington BLM access approved. Working on access with the Navajo Nation
- Will test rotary and fixed wing drone based techniques

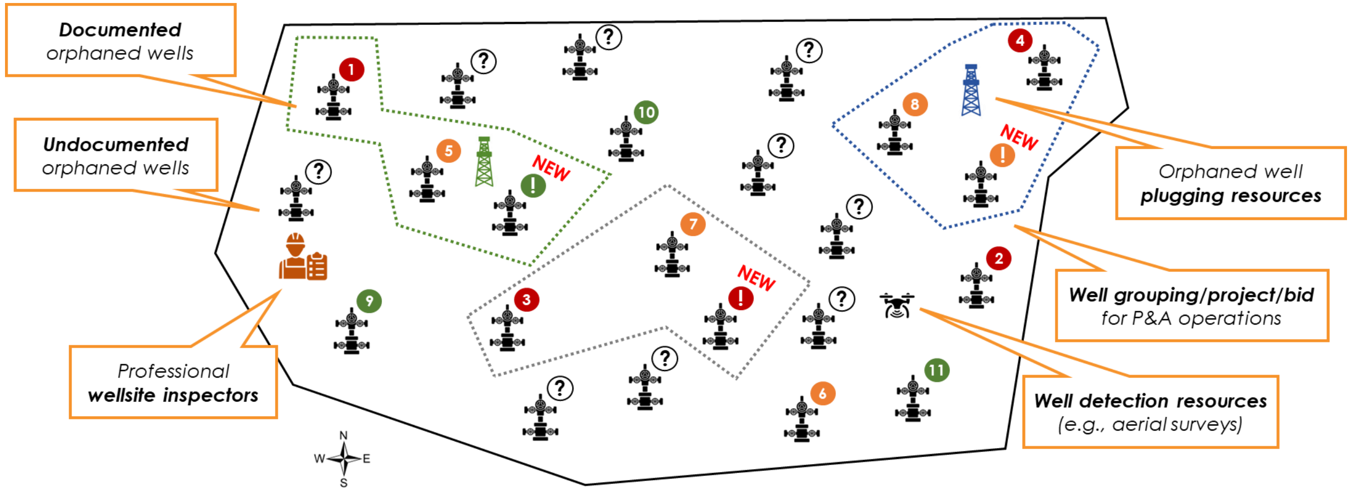
Future Ideas: A Well Plugging Optimization Initiative

Premise: Develop a free, open-source, and optimization-based well plugging decision-support program to aid state regulators and others in planning and managing efficient and impactful P&A campaigns.

The program will help with:

1) **selecting** and grouping wells for plugging
   a) which wells to assign to a bid
   b) how many wells to include in any bid
2) **deploying** and scheduling P&A resources
3) **identifying** detection "regions of interest"
4) **allocating** budget between plugging/detecting

- Views well plugging from "macro" perspective
- Aims to serve as a resource to all stakeholders



Vision: a multi-year, multi-organizational effort involving DOI, DOE and relevant stakeholders (e.g., IOGCC, GWPC)

The proposed well plugging optimization framework is meant to become a trusted decision-support tool for the broader P&A community (i.e., regulators, non-profits, P&As, …)