LONG-TERM METHANE EMISSIONS RATE QUANTIFICATION AND ALERT SYSTEM FOR NATURAL GAS STORAGE WELLS AND FIELDS

DOE NETL: Methane Emissions Quantification Project Award: DE-FE0029085

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**RESULTS — PROJECT COMPLETED JULY 2018**

**KEY OBSERVATIONS**

- Component counts vary based on classification/count methodology
- Component sub-classifications in Subpart W are appropriate
- Total emission rates and type of equipment emitting varied between field campaigns
- Sampling duration does not affect variability *(except pneumatics)*
- Measured emissions >leaker and <population emission calculated under EPA Subpart W

**2016 DOE-NETL Project Award**

- POP: 22 Months
- $849K federal; $213K cost share

**4 Stations, Gulf Coast Basin, TX**

- 16 Compressors

- 52,000 components screened; ~300 emit (<1%)

**4 Repeat field campaigns**
KEY OBJECTIVES

1. Methane measurement and emission factor development
   • Disaggregated above ground components
   • Ground-level seepage

2. High resolution monitoring of below-ground seepage
   • In-ground thermal sensors
   • Longitudinal methane emissions quantification

2016 DOE-NETL Project Award
POP: 32 Months
$1.3MM federal; $330K cost share

Clay Basin, Utah
43 Depleted Reservoir Wells

U.S. Gulf Coast
9 Salt Cavern Wells

DE-FE0029085: Gas Storage Well Project
CURRENT PROJECT OVERVIEW

Type of Storage
- Depleted Fields
- Salt Formations
- Depleted Aquifers

Total Field Capacity (Billion Cubic Feet)
- Less than 14.5
- 14.5 to 37.8
- 37.8 to 73
- 73 to 122
- Greater than 122

Map source: API, 2016
**DE-FE0029085**

**MEASUREMENT METHODOLOGY**

### Above-Ground Equipment Leaks

1. Detect leaks using optical imaging and gas sensing devices, as needed.

2. Isolate and directly measure leaks with high flow sampling.

### Seepage thru Ground Surface

3. Continuously monitor potential methane emissions from underground leaks with shallow in-ground sensors.

4. Directly measure seepage with isolation flux chamber testing.

### Deep Underground Casing Leaks

5. Continuously monitor pressure differentials between adjacent casing strings.

### Total Emissions

6. Measure and compare upwind vs. downwind methane and tracer concentrations over multiple time intervals.
# EMISSIONS SCREENING & MEASUREMENTS

## Storage Wellheads

<table>
<thead>
<tr>
<th>Field Event</th>
<th>Leak Detection/Screening</th>
<th>Emissions Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depleted Reservoir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar. 2017</td>
<td>43</td>
<td>24</td>
</tr>
<tr>
<td>Oct. 2017</td>
<td>43</td>
<td>20</td>
</tr>
<tr>
<td>Salt Caverns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar. 2017</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Oct/Nov 2017</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>104</strong></td>
<td><strong>62</strong></td>
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</table>
### EMISSIONS SCREENING & MEASUREMENTS

#### Wellhead Components

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Depleted Reservoir (24+20 Wellheads)</th>
<th>Salt Caverns (9x2 Wellheads)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Screened Population</td>
<td>Measurement Count</td>
</tr>
<tr>
<td>Valve, Small (&gt;2” lines)</td>
<td>1,833</td>
<td>69</td>
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<tr>
<td>Valve, Large (&gt;2” lines)</td>
<td>433</td>
<td>46</td>
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<tr>
<td>Connector, Flange</td>
<td>1,376</td>
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<td>Connector, Other</td>
<td>8,128</td>
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<td>Pressure Relief Valve</td>
<td>0</td>
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<tr>
<td>Open-Ended Line</td>
<td>369</td>
<td>12</td>
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<tr>
<td>Regulator</td>
<td>242</td>
<td>3</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12,732</strong></td>
<td><strong>191</strong></td>
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</table>
EMISSION FACTOR CONSIDERATIONS

- False positive leak ID rates; *(FLIR and sniffer screening)*
- Leak rate detection limits *(scf/hr)*
- Sampled vs. total component population counts
## EMISSION FACTORS FOR DISAGGREGATED WELLHEAD COMPONENTS

<table>
<thead>
<tr>
<th>Component Type</th>
<th>PF&lt;sup&gt;1&lt;/sup&gt;</th>
<th>LF&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Subcategory A</th>
<th>PF&lt;sup&gt;1&lt;/sup&gt;</th>
<th>LF&lt;sup&gt;2&lt;/sup&gt;</th>
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<tr>
<td>Connector</td>
<td>0.01 0.0047</td>
<td>6,488 - 0.88 15</td>
<td>Other</td>
<td>- 0.0058 5373</td>
<td>1.1 1.2 9</td>
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<td></td>
<td></td>
<td></td>
<td>Flanged</td>
<td>- 0.0026 1,115</td>
<td>3.4 0.49 6</td>
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<tr>
<td>Valve</td>
<td>0.1 0.20</td>
<td>1,540 4.1 3.6 59</td>
<td>Small&lt;sup&gt;3&lt;/sup&gt;</td>
<td>- 0.032 1,253</td>
<td>- 0.96 26</td>
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<td></td>
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<td></td>
<td>Large</td>
<td>- 0.92 288</td>
<td>- 5.7 33</td>
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<td>PRV</td>
<td>0.17 -</td>
<td>10 3.7 - 1</td>
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<tr>
<td>OEL</td>
<td>0.03 0.011</td>
<td>186 2.3 0.27 4</td>
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<tr>
<td>Regulator</td>
<td>- 0.018</td>
<td>139 - 0.11 4</td>
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</tbody>
</table>

1 PF = Population Factor  
2 LF = Leaker Factor  
3 Small valve can be easily turned with 1 hand

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New emission factors are *similar to or lower than* current EPA values.
POPULATION EMISSION FACTORS FOR GAS STORAGE WELLHEADS

- **Depleted Reservoir Wells**: Different subsets of 24 and 20 wells
  - March 2017: 3.9 scf/hr/well
  - October 2017: 4.3 scf/hr/well

- **Salt Cavern Wells**: Same 9 wells
  - March 2017: 5.3 scf/hr/well
  - October 2017: 4.3 scf/hr/well

- **Study Average**
  - March 2017: 4.3 scf/hr/well
  - October 2017: 4.3 scf/hr/well
EMISSION FACTORS  Next Steps

- Publish EF results in peer-reviewed journal
- Present at conference(s)

- GHGRP (Subpart W) – *New component-level EFs represent actual gas storage wells* (not production wells)
- GHGI – *New well-level EFs supplement existing storage station-level EFs*

*KEY POINT:* Results offer EPA and industry defensible *gas storage well-specific* emission factors previously lacking in the GHGRP and GHGI.

GHGRP = Greenhouse Gas Reporting Program;  GHGI = Greenhouse Gas Inventory
BELOW GROUND EMISSIONS QUANTIFICATION
GROUND-LEVEL METHANE SEEPAGE AROUND WELL HEADS

Estimated Total Ground-Level Methane Emissions
(4 - 8 ft. Radius around Wellhead)

Salt Cavern Wells Depleted Reservoir Wells

In-ground sensors installed at 3 wells

Salt Caverns - March 2017
Salt Caverns - Oct/Nov 2017
Depleted Reservoir - March 2017
Depleted Reservoir - October 2017
IN-GROUND SENSOR INSTALLATION
(Nov 2017, Mar 2018)
HIGH RESOLUTION SOIL HEAT MONITORING

Data Collection and Analysis

Continuous Meteorological, Soil Heat/Moisture Monitoring

Database

5-min Avg.

Soil Heat Signatures

Live Webcams
Clay Basin - Well 52 - Sensor Temperature Time Periods Above Well Temperature Compared With Background Temperatures
Facility Operations

Gas Injection vs. Extraction

![Graph showing gas injection and extraction over time]

- Winter
- Late Spring/Summer

Transition Period
WELL HEAT INTERFERENCE

Key Observations

- Valuable data collected in the past >8 months by the installed instrumentation.

- Subsurface near-well temperature signals largely overshadow methane-generated temperature signals
  - Except during “quiet” injection/extraction transition periods; ~2 months/yr

- More desired temperature change observations (due to methane seepage) can potentially be detected by advanced data analysis
  - Transfer-function-noise (TFN)
  - Artificial neural network (ANN)

- Controlled methane releases can provide valuable data to verify signal processing approach
  - Constant vs. pulsed releases at select sensor locations using existing installed equipment
BELOW-GROUND SEEPAGE  *Next Steps*

**DATA ANALYSIS**

- Signal processing → Heat of biodegradation from subsurface methane seepage

**LONGITUDINAL FLUX TESTING**

- Focused testing on well(s) with strongest usable heat signal
- Controlled below-ground methane release

**TECH TRANSFER**

- TASC Meetings
- Conferences / Publications
TECHNOLOGY TRANSFER ACTIVITIES

- Technical Advisory Steering Committees (TASCs)
  - >50 participants from industry/regulatory/academia/government/NGO on 3 TASC calls in May 2018
- DOE participants on 2 calls in March 2018
- All provided critical feedback to assess EF development and in-ground sensor program

**Gas Composition - Industry**

Q: Could GSI separate data by site visit, e.g., what is the % leaking for FC1 compared to FC2?
A: Yes, done. Comparable results indicate no need for seasonally variable EFs.

**Storage Wells Comment – EPA**

"Storage wells are a small source of methane emissions, but EPA does, and will continue to, track"

**Gas Fingerprinting - Industry**

Q: Can you speak to separating out biogenic vs. thermogenic sources for subsurface CH4?
A: Performed analysis of methane, ethane, propane, etc. ratios to fingerprint gas type.
## PROJECT PROGRESS / TIMELINE

<table>
<thead>
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<th>Task / Description</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
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<td><strong>Phase 1</strong></td>
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<tr>
<td>1 Project Management and Planning</td>
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<td>11 Technology Transfer</td>
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**Milestone**

- Work completed
- Budget Period 1
- Budget Period 3
- Work pending
- Budget Period 2
THANK YOU!

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