Advanced Mobile Technologies for the Identification, Attribution, Quantification, and Visualization of Fugitive Methane Emissions from Natural Gas Production

Chris Rella, Ph. D.
Picarro Research Fellow
Picarro, Inc., Santa Clara, CA

rela@picarro.com

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What Is Picarro?

• High-Performance mobile gas and isotope analysis based on Cavity Ringdown Spectroscopy

• Advanced Meteorology & Geospatial Awareness

• Sophisticated Scientific Algorithms

• Cloud-based Computing and Visualization

• 15+ Ph.D. Physicists, Chemists, and Environmental Scientists collaborating with dozens of world-class research institutions

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Green or Not Green? Natural Gas Emits Less CO\textsubscript{2} Than Coal … IF you burn it

\[ 29 \text{ MJ} = \text{1 kg coal} \quad \text{\sim75\% C} \]

\[ 1.5 \text{ kg CO}_2 = 45\% \text{ lower carbon emissions} \]

\[ 0.55 \text{ kg nat. gas} \quad \text{\sim75\% C} \]

But what if you don’t burn all the methane?
Make Sure You Burn All of It!

Over 100 years: 33X Global Warming Potential of CO₂

0.55 kg nat. gas

10% loss

1.8 kg CO₂e

20% WORSE than coal

1.5 kg CO₂

100 year: Methane “breaks even” at 6.9% atmospheric loss
Make Sure You Burn All of It!

Over 20 years: 105X Global Warming Potential of CO₂

20 year: Methane “breaks even” at 2.2% atmospheric loss

0.55 kg nat. gas = 29 MJ + 5.8 kg CO₂e + 1.5 kg CO₂

165% WORSE than coal
Why Are Measurements Vital?

- Methane emissions are “fugitive” emissions – i.e., unintentional emissions
  - Leaks from a pipe or fitting
  - Gas that is released episodically during production, transport, or consumption

- Emissions factors and methane inventories are not accurate at estimating unintentional emissions!

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Methane and the greenhouse-gas footprint of natural gas from shale formations
A letter
Robert W. Howarth · Renee Santoro · Anthony Ingraffea

Table 2 Fugitive methane emissions associated with development of natural gas from conventional wells and from shale formations (expressed as the percentage of methane produced over the lifecycle of a well)

<table>
<thead>
<tr>
<th></th>
<th>Conventional gas</th>
<th>Shale gas</th>
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</thead>
<tbody>
<tr>
<td>Emissions during well completion</td>
<td>0.01%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Routine venting and equipment leaks at well site</td>
<td>0.3 to 1.9%</td>
<td>0.3 to 1.9%</td>
</tr>
<tr>
<td>Emissions during liquid unloading</td>
<td>0 to 0.26%</td>
<td>0 to 0.26%</td>
</tr>
<tr>
<td>Emissions during gas processing</td>
<td>0 to 0.19%</td>
<td>0 to 0.19%</td>
</tr>
<tr>
<td>Emissions during transport, storage, and distribution</td>
<td>1.4 to 3.6%</td>
<td>1.4 to 3.6%</td>
</tr>
<tr>
<td>Total emissions</td>
<td>1.7 to 6.0%</td>
<td>3.6 to 7.9%</td>
</tr>
</tbody>
</table>
“Houston, We Have a Problem”

- 490,000 wells in the U.S.
- 2.5 million miles of (ageing) natural gas pipeline
- 1000’s of potential leaks / well pad

How do you assess 1,000,000,000 potential leaks without spending $1,000,000,000?
Our Solution: Drive, and Let the Atmosphere Carry The Methane to You!

- **TRIAGE**: figure out where the leaks are (and aren’t) at a distance, without stopping the car

- **LOCALIZE**: if you see a leak, use the wind to understand where the source of the gas is

- **ATTRIBUTE**: don’t get confused by the cows!

- **QUANTIFY**: concentration means (almost) nothing – the only thing that matters is emission rate
Concentrations 3-5X above background levels over 100’s of square miles … all from natural gas extraction!

Lots and lots of individual emission sources
Example: Compressor Station in the Denver – Julesburg Basin
45 Second Drive Around Compressor Station Detects Multiple Methane Plumes

Methane plume as measured while driving around perimeter
“Bubbles” indicate signatures of methane emission sources via automated plume height and width algorithms.
Maps Show Many Possible Sources
Leak Source Indicators Indicate Plume Origin

Wind direction (and standard deviation) determines possible wind angles, with car motion removed.
Field of View Indicates Area Measured

Field of view calculated for small leak and narrow plumes – larger leaks can be detected at greater distances
Source Attribution Using Stable Isotope Analysis

Drive-by isotope analysis with Air Core (thanks Pieter Tans & NOAA team)!

- Petrogenic methane (O&G)
- Feedlots (biogenic)
- Landfills (biogenic)
Isotope Ratio Analysis in 10 Minutes

We know where the leak is, and that it is from O&G activities. But, how do we QUANTIFY the emission rate?
Measuring Emissions Rate: A 1 liter / second leak

- 1 meter: 10,000+ ppm
- 10 meter: 500 ppm
- 100 meter: 20 ppm
- 1000 meter: 0.5 ppm

Methane
Three Ways To Measure the Emission Rate

• Direct Measurement of the emissions
  – requires physical access to the leak

• Measurement at a distance + Atmospheric Modeling
  – Use downwind measurements + atmospheric measurements + atmospheric models to back calculate emission rates
  – Requires knowledge of distance to source, height of source, and atmospheric turbulence

• Direct Measurement of plume through a downwind surface
  – Measure downwind concentration map and wind speed only
  – No knowledge of distance, source location, and atmospheric turbulence required
Quantify emissions using direct plume measurements

- Counting molecules passing through an area
  - Measure CH$_4$ concentration on a spatial grid downwind of the source
  - Measure wind through the surface

\[
Q(t) = \int_A k(C(y, z, t) - C_0)\bar{u}(x, y, t) \cdot \hat{n} \, dA
\]

All distances give the same result!
Quantify emission using plume measurements

- Drive through plume while measuring methane concentrations from four elevations (4 pixels) and simultaneously measuring vehicle position and speed, and wind velocity.

Use a virtual net to ‘catch’ the methane molecules
Measuring Emissions Rates in Real Time
Final Reconstruction of 2D Plume Picture
Measurement Time = ~ 5 minutes

CH4 Plume Observed 1 Feb 2013  12:21

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<tbody>
<tr>
<td>Car Speed</td>
<td>10.8 m/s</td>
</tr>
<tr>
<td>Lateral Wind Speed</td>
<td>2.5 m/s</td>
</tr>
<tr>
<td>Flux Estimate</td>
<td>1.5 L/s (± 0.3 L/s)</td>
</tr>
</tbody>
</table>
Compressor Station Findings

Average Leak was 3.5 L/s (± 1.4 L/s):

- 3.5 balloons in 1 second!
- Enough CH₄ to heat 35 homes
- The carbon footprint of ~100 citizens
Thank You!

Uintah Basin, Utah