Methane Leaks from the U.S. Natural Gas Value Chain

Robert Harriss
Boulder, CO.
rharriss@edf.org
EDF natural gas projects & goals

- Public Disclosure of Chemicals & Emissions
- Well Construction & Completion
- Water & Waste Management
- Air Standards
- Cumulative Impacts
- Strengthen /Leverage State Regulatory Associations
- Advise Industry Leaders
- Supply Chain Methane Study

EDF

Producers
Pipelines
Gas Utilities
State Regulators
Feds
Cities, Counties & Communities
Other NGOS
Academia

Safer, Environmentally Sound Natural Gas Supply

Reduce Risk to Public Health & The Environment
Maximize GHG Value by Reducing Methane Emissions Below 1%
EDF’s CH₄ Emissions Field Studies
What’s in natural gas?

Produced “raw gas” is composed of 70-90% methane

Composition of gas varies from one basin/formation/well to another.

Distribution gas is >90% methane
How much gas is leaking from US natural gas infrastructures?

- 500,000 oil and gas wells,
- 493 processing plants
- over 20,000 miles of gathering pipelines,
- ~300,000 miles transmissions pipelines,
- > 1,400 compressor stations
- ~400 underground storage facilities
- ~2,000,000 miles of local distribution pipelines

*US Statistics: EIA, DOT, OGJ*
Bottom-Up Production Study

Academic lead

Science Advisory Panel
Professor Matthew Fraser
Arizona State University
Professor A. Daniel Hill
Texas A&M University
Professor Brian Lamb
Washington State University
Professor Jennifer Miskimins
Colorado School of Mines
Professor Robert Sawyer
University of California, Berkeley
Professor John Seinfeld
California Institute of Technology

Steering Committee

Technical working group co-chairs
Ramon Alvarez
EDF
Emily Rodgers
Anadarko

Partner companies

Academic lead

Steering Committee

Partner companies
Summary of Results

Direct, on-site measurements of CH4 emissions from gas production operations were made; for some sources (well completions and unloadings) these are the first measurements reported.

67% of well completions sampled during the study had equipment in place that reduces CH4 emissions by 99%. The well completions were 97% lower than calendar year 2011 EPA national emission estimates, released in April 2013.

Emissions from pneumatic devices were 70% higher than current EPA net emissions estimates, and equipment leaks are 50% higher than current EPA net emission estimates; collectively these emissions accounted for more than 40% of methane net emissions from natural gas production.
Summary (cont.)

Total methane emissions from gas production measured in this study were comparable (957 Gg ± 200 Gg) to the most recent EPA estimates (~1200 Gg).

The 957 Gg in emissions for completion flowbacks, pneumatics and equipment leaks, coupled with EPA national inventory estimates for other categories, leads to an estimated 2300 Gg of methane emissions from natural gas production (0.42% of gross gas production).

Comprehensive results at:
http://dept.ceer.utexas.edu/methane/study/index.cfm
http://www.engr.utexas.edu/news/releases/methanestudy
EDF Bottom-Up/Top-Down Field Campaigns in Colorado & Texas
Top-Down Aircraft Mass Balance Method

\[ \dot{n}_{CH_4} = V \cos \theta \int_{-b}^{+b} \Delta X_{CH_4} \left( \int_{z_{gnd}}^{z_{PBL}} n_{air} \, dz \right) \, dx \]

Perpendicular wind speed in PBL

References: White et al., 1976; Ryerson et al., 2001; Mays et al., 2009
Denver-Julesburg Basin

<table>
<thead>
<tr>
<th>Flux estimate</th>
<th>Total CH$_4$ source (tonnes/hr)</th>
<th>Relative 1-s Uncertainty in CH$_4$ source</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 29$^a$</td>
<td>25.8±8.4</td>
<td>33%</td>
</tr>
<tr>
<td>May 31</td>
<td>26.2±10.7</td>
<td>41%</td>
</tr>
<tr>
<td>Average</td>
<td>26.0±6.8</td>
<td>26%</td>
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</tbody>
</table>

Petron et al., submitted
## Denver-Julesburg Basin CH4 Emissions Budget

<table>
<thead>
<tr>
<th>Source</th>
<th>May 29 (tonnes/hr)</th>
<th>May 31 (tonnes/hr)</th>
<th>Uncertainty (1-σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Emissions</td>
<td>25.8</td>
<td>26.2</td>
<td>26%</td>
</tr>
<tr>
<td>Enteric</td>
<td>5.15</td>
<td>5.15</td>
<td>18%</td>
</tr>
<tr>
<td>Livestock</td>
<td>0.97</td>
<td>0.97</td>
<td>100%</td>
</tr>
<tr>
<td>Landfill</td>
<td>1.44</td>
<td>0.66</td>
<td>100%</td>
</tr>
<tr>
<td>Waste treatment</td>
<td>0.47+0.47</td>
<td>0.47+0.47</td>
<td>15%+25%</td>
</tr>
<tr>
<td>Natural Seepage</td>
<td>0.1</td>
<td>0.1</td>
<td>100%</td>
</tr>
<tr>
<td>Remaining Emission</td>
<td>17.3±8.6</td>
<td>18.5±10.8</td>
<td>54%</td>
</tr>
</tbody>
</table>

**Average O&G production = 17.9±9.7 tonnes/hr**

67% of total emissions (assuming highest possible non O&G emissions)

Petron et al., submitted
Barnett Shale

Texas Railroad Commission
The ratio of VOC to CH$_4$ will vary along the oil \(\rightarrow\) dry gas gradient.
Newark, East (Barnett Shale)
Drilling Permits Issued
(1993 through April 2013)

Source: Texas Railroad Commission DrillingPermitQuery (Includes New Drill & ReEnter Permits)
Midstream O&G Facilities

- 83 compressor stations & 21 processing plants in 2011 NEI

- 400 midstream facilities in TCEQ 2009 special EI

- 40 compressor stations & 23 processing plants with 12.5 Gg CH$_4$ emissions in 2011 GHGRP
• 23 landfills with 88.5 Gg CH₄ emissions in 2011 GHGRP
• ~60 smaller landfills
Barnett Methane Experiment

Phase I: March 2013
- University of Colorado
- NOAA/ESRL (GMD, CSD)
- Picarro
- Shell / Sanders Geophysics
- Aerodyne
- Penn State

Phase II: October 2013
- Purdue
- University of Michigan
- University of Cincinnati
- UC Irvine
- University of Houston
- West Virginia University
- Duke
- Princeton & UT Dallas
Barnett II Methane Experiment: Aircraft

Purdue Duchess

Scientific Aviation Mooney
Aircraft Instrumentation

Measurement of additional species (such as ethane and $^{13}\text{CH}_4$) help with attribution of methane to an oil and gas source.

Flasks (50+ species)

C$_2$H$_6$

CH$_4$, CO$_2$, CO, H$_2$O

Bags ($^{13}\text{CH}_4$)

Also: Wind, GPS, Temperature, Relative Humidity
Upwind (Duchess)

Downwind (Mooney)
Fort Worth Air Quality Study

- 388 sites surveyed with infrared camera for leaks
- CH₄ emissions measured from 2,126 components
- 68% of emissions from 10% of components

<table>
<thead>
<tr>
<th></th>
<th>kg/hr CH₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0</td>
</tr>
<tr>
<td>25%</td>
<td>0.004</td>
</tr>
<tr>
<td>Mean</td>
<td>0.67</td>
</tr>
<tr>
<td>Median</td>
<td>0.11</td>
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<tr>
<td>75%</td>
<td>0.52</td>
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<tr>
<td>90%</td>
<td>1.6</td>
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<tr>
<td>99%</td>
<td>9.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>29.5</td>
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</tbody>
</table>

Component Emissions

- kg CH₄/hr

Graph showing component emissions distribution.
Sanders Geophysical & Shell: Low altitude CH₄ mapping
Decarbonization
Evolution of C:H Ratio in Global Fuel Mix

Source: Ausubel 2007, after Ausubel, 1996 and Marchetti, 1985