Incorporating New Technology Into Emissions Mitigation Policy

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GTI Methane Connections Meeting
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Introduction – Methane Emissions

• Methane emissions from oil and gas activity is a significant source of GHG emissions in US and Canada

• Reducing methane has multiple co-benefits, in addition to climate impact
  • Improve air quality (precursor to low-level ozone)
  • Reduce product waste
  • Social license to operate near population centers

• Recent studies show significant higher emissions compared to EPA GHG Inventory
  • 2.3% (Brandt et al. 2018) vs. 1.7% (GHG Inventory)
  • Significant upward revision in upstream production – 7.6 vs. 3.5 Tg/y
  • Aggregation of facility-level estimates
Policy Approaches to Emissions Mitigation

- Most active jurisdictions (CO, Canada) have prescriptive policies
  - **Venting and Flaring**: Annual limits verified through activity data and production figures
  - **Fugitive Emissions**: Periodic leak detection and repair (LDAR) surveys

- Managing fugitive emissions or leaks
  - LDAR survey typically conducted with infrared camera technology
  - Survey frequency varies from 1/year to 12/year

- Drawbacks of camera-based surveys
  - Component-level measurements are time consuming
  - Highly susceptible to weather conditions
New Technologies and Platforms

• Truck-, drone-, and plane-based detection systems have been developed
  • Truck- and plane-based pilot studies reported in literature

• Strong business and investor interest in testing new technologies

• Potential to provide more cost-effective mitigation
  • Colorado and Alberta actively studying ways to incorporate new tech
Design Space for New Technology

- Continuous monitoring
  - Stationary sensors (e.g., LIDAR)
  - Handheld monitors (e.g., cameras)
  - Mobile Ground Labs (Trucks)
  - UAVs
  - Piloted aircraft
  - Satellites

Temporal Scale (s):
- Component
- Facility
- Field
- Basin
- Continent
- Global

Spatial Scale (m):
- Mitigation Programs

Revisit time ~ 1 week
- Century
- Decade
- Year
- Month
- Day
- Hour
- Minute
- Second

~45 min flying time

Fox et al. In review (2018)
Key Problem – Demonstrating Equivalence

• Need to demonstrate mitigation achieved using new technologies will be equivalent to existing approaches
  • Depends on how effective existing camera-based surveys are

• Recent work – controlled release experiments with cameras at METEC
  • OGI leak detection limits 10x higher than prior lab estimates

• More recent field-work with truck-based measurements in US & Canada
  • Provided facility-level instead of component-level data, but
  • Limited ‘ground truth’ measurements → direct comparisons difficult

Ravikumar et al. EST (2018)
Different Types of Equivalence

• **Detection Equivalence**: Technology-specific
  - Minimum detection threshold, speed, false positive rate, etc.
  - Can be identified by blind-tests (MONITOR program, Stanford/EDF Mobile Monitoring Challenge)

• **Mitigation Equivalence**: Technology + policy
  - Compare effective mitigation under specific survey protocols
  - But cannot be easily experimentally verified

Equivalence = Technology Validation + Modeling Framework

- MONITOR testing,
- Stanford/EDF MMC,
- limited field tests, etc.

- FEAST-like modeling to determine long-term mitigation potential
Stanford/EDF Mobile Monitoring Challenge

- Test mobile approaches to leak detection
- Platforms – drones, trucks, and planes
- 28 applications received for the MMC call
  - 5 countries – US, Canada, Netherlands, UK, and Mexico
  - 12 technologies; 10 ultimately participated

Visit: methane.stanford.edu
Test Locations

• 2 test sites – METEC (Fort Collins, CO), Northern CA gas yard (Knights Landing, CA)
• Technologies split-up by detection sensitivities (based on detailed individual discussions with each participant)

Most Sensitive (0 – 2 scfh)
- Heath (T)
- Picarro (D)

Medium Sensitive (5 – 10 scfh)
- Aeris (T)
- Advisian (D)
- Seek Ops (D)
- ABB/ULC (D)
- BHGE

Least Sensitive (100 - 1000 scfh)
- Ball Aerospace (P)
- U Calgary (T)
- U Calgary (D)

9 – 13 April 2018
METEC (Fort Collins, CO)
7 – 11 May 2018
Gas Yard (Knights Landing, CA)
21 – 25 May 2018
### Test Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location identification</td>
<td>(a) Equipment level (both type and number), (b) Component level</td>
</tr>
<tr>
<td>Binary Yes/No detection</td>
<td>(a) True / False positive percentage, (b) True / False negative percentage</td>
</tr>
<tr>
<td>Quantification accuracy</td>
<td>Parity chart of controlled leak tests</td>
</tr>
<tr>
<td>Ability to resolve leaks</td>
<td>(a) Small vs. large leaks close-by, (b) Multiple similar leaks close-by, (c) Multiple leaks on same pad</td>
</tr>
</tbody>
</table>
METEC Site-Layout and Field Testing

• One technology per pad (rotated periodically)
• Controlled releases were decided ‘on-the-fly’ based on wind speed and direction to avoid interference
Example Technology Testing
General Insights

• Don’t believe everything a brochure says (*not their fault*)

• Most sensors efficient at detecting methane (point measurements), but...
  • Wide variety in algorithms that convert raw data to actionable info

• Quantification is a very difficult problem
  • 2 – 5x of actual leak rate is *very good* performance
  • Expectations should be at ‘order-of-magnitude’ level estimates

• No ‘unicorn’ solutions
  • Most new sensors will serve niche applications / industry segment

• Clearly distinguish ‘screening’ tech and ‘OGI-replacement’ tech
Results – Technology A

- Best-in-class performance (detection & quantification)
- Real time data including quantification (initial estimate)
- “Raw data” – no processing for winds or potential interference
- Cross-terms affected by external weather conditions

Leak identification (overall)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total number of leaks</strong></td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of zeros</strong></td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leak</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>True +</td>
<td>59</td>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>False -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No Leak</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
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Locational Accuracy

<table>
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<tr>
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<tbody>
<tr>
<td><strong>Total number of leaks</strong></td>
<td>63</td>
<td></td>
</tr>
<tr>
<td><strong>Number detected</strong></td>
<td>59</td>
<td></td>
</tr>
<tr>
<td><strong>Number location identified</strong></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td><strong>% location identified correctly</strong></td>
<td><strong>0.85</strong></td>
<td></td>
</tr>
</tbody>
</table>
Technology A - Quantification

- Most leak estimates within 2x of actual leak rates
- (Quantification, in general, is very difficult. Within 2x is exceptional performance for sensors that don’t directly measure flow rates)
Technology B – Detection

- Real time data on detection but not quantification
- Understand the importance of detection probabilities and limits

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<tr>
<td>Leak</td>
<td>39</td>
<td>18</td>
<td>57</td>
</tr>
<tr>
<td>No Leak</td>
<td>32</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>Total number of leaks</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of zeros</td>
<td>45</td>
<td></td>
<td></td>
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<tbody>
<tr>
<td>Leak</td>
<td>0.68</td>
<td>0.32</td>
</tr>
<tr>
<td>No Leak</td>
<td>0.71</td>
<td>0.29</td>
</tr>
</tbody>
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### Locational Accuracy

<p>| | | |</p>
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<td>19</td>
<td></td>
</tr>
<tr>
<td>% location identified correctly</td>
<td>0.49</td>
<td></td>
</tr>
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Technology B – Leak Detection Probability

• Leak detection probability proxy by histogram of leaks detected within a given range
• Median threshold ~ 2 scfh with high false positive rate (Note: company specified ‘definite detection’ is 6 scfh)
Technology B – Weather Considerations

- Need to consider interference between pads (can increase false positive rate) and effect of wind speed on detection capability
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<table>
<thead>
<tr>
<th></th>
<th>Pad 1</th>
<th>Pad 2</th>
<th>Pad 3</th>
<th>Pad 4</th>
<th>Pad 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind = 4 m/s</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

What happens on current pad? Interference on current pad?

<table>
<thead>
<tr>
<th></th>
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<th>Pad 3</th>
<th>Pad 4</th>
<th>Pad 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>L x y</td>
<td>1</td>
<td>0</td>
<td>L10</td>
<td>L00</td>
<td>L10</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>L11</td>
<td>L01</td>
<td></td>
</tr>
</tbody>
</table>
Technology B – After Eliminating Weather Uncertainty

- ‘Cone of interference’ (40 deg) to determine influence of multiple leaks

- Mild vs. Strong interference based on wind speed parameters
  - Mild $\rightarrow$ < 2 m/s $\rightarrow$ no interference
  - Strong $\rightarrow$ > 2 m/s $\rightarrow$ cone of interference

### All leaks

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### Mild interference

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### Strong interference

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Field Campaign to Assess Policy Effectiveness (FEMP-EA)

- 50 x 50 km area NW of Calgary
- ~ 200 sites selected for leak detection and repair surveys
- 3 survey schedules (1, 2 or 3 times/year) and 1 control group
- Goals: Determine time evolution of emissions mitigation – ‘sunset policy’
Field Trials of New Technology (Alt-FEMP)

- Simultaneous testing of new platforms (trucks, planes) along with OGI-based ground LDAR team

- ~1000 sites (Nov ‘18 – Sep ‘19)

- Study objectives
  - determine technology equivalence through direct field measurements
  - Study effectiveness of screening + confirmation approaches
  - Simulations to confirm mitigation equivalence
Future Work and Conclusions

• New technologies are promising alternatives for cost-effective methane emissions detection, but...

  • Technologies should be parametrized through well-designed control studies and pilot demonstrations
  • Couple data with models to estimate ‘equivalent’ emissions reductions and analyze long-term impact

• Policy design should allow for flexibility in mitigation practices
  • Allow for the use of ‘screening’ technologies
  • Re-think survey frequency rules as applicable to new technology
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