Using drones to measure fugitive methane emissions

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What are fugitive methane emissions?

In the fossil fuel sector, fugitive emissions are broadly defined as any emissions unrelated to the end use of fuel (IPCC, 2006)

- Leaks from processing facilities and pipelines
- Defective valves or seals
- Migration of gas to the surface
- Emissions from abandoned wells

Methane

- Methane (CH$_4$) has a global warming potential (GWP) **28 times greater** than CO$_2$ over a 100-year period

- GWP **84 times greater** than CO$_2$ over a 20-year period

- Methane is the second biggest contributor to Australia’s greenhouse gas emissions
Methane emissions in Australia

Methane emissions in Australia (2019, tonnes CO₂e)

Australian emissions
2019 = 529 Mt
24% from methane (126 Mt)

29% of Australia’s methane emissions are from the energy sector (37 Mt)

1.74% of Australia’s emissions are from methane released from the oil and gas industry (9.2 Mt)

Source: The Australian Natural Gas Industry: Monitoring, reporting, and reducing methane emissions (AGIT)
Methane

- Methane (CH₄) has a global warming potential (GWP) 28 times greater than CO₂ over a 100-year period
- GWP 84 times greater than CO₂ over a 20-year period
- Methane is the second biggest contributor to Australia’s greenhouse gas emissions
- Global commitment to reduce emissions
- Net-zero state government commitments

**Australia signs up to global methane pledge**

The Albanese government has pledged to join other developed countries such as the United States, the United Kingdom and the European Union to cut global methane emissions by 30 per cent on 2020 levels by 2030.

The move will put further pressure on the Coalition and its energy and climate policies after Labor committed to increasing Australia’s emissions reduction target to 43 per cent by the end of the decade.

Source: Australian Financial Review

**A 2050 zero net emissions target for Queensland**

Zero "net" emissions means that carbon pollution may still be produced in one part of the economy (e.g. some industrial processes) and count towards our pollution profile. However, the Queensland Government will be looking to find ways to offset that pollution in another part of the economy, such as increasing carbon storage in the landscape.

Queensland joins Victoria, New South Wales, South Australia, Tasmania and the Australian Capital Territory in setting a zero net emissions by 2050 target.

Source: Queensland Climate Transition Strategy
Fugitive methane emissions

Source: Country Caller Regional News

Source: www.federatedenvironmental.com


Source: Country Caller Regional News
Social implications

Negative impacts on the gas industry’s social license to operate

Source: www.lockthegate.org.au Source: www.lockthegate.org.au
Quantification is key

GHG Accounting and Reporting Principles

**RELEVANCE**
Ensure the GHG inventory appropriately reflects the GHG emissions.

**COMPLETENESS**
Account for and report on all GHG emission sources and activities within the chosen inventory boundary.

**CONSISTENCY**
Use consistent methodologies to allow for meaningful comparisons of emissions over time.

**TRANSPARENCY**
Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used.

**ACCURACY**
Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

Source: https://ghgprotocol.org
Estimation and reporting of GHG emissions

United Nations Framework Convention on Climate Change (UNFCCC)

- Support the “global response to the threat of climate change”
- Bind “member states to act in the interest of human safety even in the face of scientific uncertainty”
- Ultimate objective “to stabilize GHG concentrations in the atmosphere at a level that will prevent human interference with the climate system”
Estimation and reporting of GHG emissions

Annex 1 parties to the United Nations Framework Convention on Climate Change (UNFCCC)
Estimation and reporting of GHG emissions

13 of the world’s top 20 gas producing nations are not included in Annex 1 of the UNFCCC

<table>
<thead>
<tr>
<th>Nation</th>
<th>Date of last UNFCCC emissions submission</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>2014</td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>2014</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>2012</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>2012</td>
</tr>
<tr>
<td>Argentina</td>
<td>2012</td>
</tr>
<tr>
<td>Malaysia</td>
<td>2011</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>2010</td>
</tr>
<tr>
<td>Qatar</td>
<td>2007</td>
</tr>
<tr>
<td>Iran</td>
<td>2000</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2000</td>
</tr>
<tr>
<td>Algeria</td>
<td>2000</td>
</tr>
<tr>
<td>Nigeria</td>
<td>2000</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>1990</td>
</tr>
</tbody>
</table>

Source: The Australian Natural Gas Industry: Monitoring, reporting, and reducing methane emissions (AGIT)
Estimation and reporting of GHG emissions

- Emissions inventory developed for regulatory purposes is typically based on “bottom-up” estimates

- Identifying each emission source and estimating their emissions

- Commonly based on emissions factors and activities from a representative sample of sources

- Small, regional, or global scale

- Remote sensing based observations

- Emissions estimates through inverse modelling
Bottom-up emissions estimation

- To support consistency in reporting under the UNFCCC, the IPCC established requirements for how the inventories are prepared and the format of the reports.

- Defines the global warming potential of GHG.

- Provides methodologies to estimate sources and sinks, and emission factors used to link the emission of a greenhouse gas for a particular source to the amount of activity causing the emission.
Bottom-up emissions estimation

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

**Equation 4.2.17 (New)**

**General equation for estimating fugitive emissions from gas distribution**

\[
E_{\text{distribution}} = A_{\text{gas distribution}} \times EF_{\text{gas distribution}} + A_{\text{surface storage}} \times EF_{\text{surface storage}} + A_{\text{distribution of town gas}} \times EF_{\text{distribution of town gas}}
\]

Where:

- \(E_{\text{distribution}}\) = Total amount of GHG gas emitted due to all relevant natural gas distribution activities
- \(A_{\text{gas distribution}}\) = Volume of natural gas consumed or length of distribution pipeline
- \(EF_{\text{gas distribution}}\) = Emission factor for gas distribution
- \(A_{\text{surface storage}}\) = Volume of natural gas stored (in surface storage) or consumed
- \(EF_{\text{surface storage}}\) = Emission factor for surface storage
- \(A_{\text{distribution of town gas}}\) = Length of town gas distribution pipeline
- \(EF_{\text{distribution of town gas}}\) = Emission factor for town gas distribution

Source: www.minnesotaenergyresources.com
Bottom-up emissions estimation

National Greenhouse and Energy Reporting Act 2007 (NGER)

3.73LB Method 2—onshore natural gas production, other than emissions that

<table>
<thead>
<tr>
<th>Item</th>
<th>Equipment type (k)</th>
<th>Emission factor for gas type (f)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CH$_4$</td>
<td>CO$_2$</td>
</tr>
<tr>
<td>1</td>
<td>Onshore gas gathering and boosting pipelines (cast iron)</td>
<td>$7.72 \times 10^{-3}$</td>
<td>$3.14 \times 10^{-5}$</td>
</tr>
<tr>
<td>2</td>
<td>Onshore gas gathering and boosting pipelines (plastic)</td>
<td>$6.99 \times 10^{-4}$</td>
<td>$2.85 \times 10^{-6}$</td>
</tr>
<tr>
<td>3</td>
<td>Onshore gas gathering and boosting pipelines (protected steel)</td>
<td>$1.31 \times 10^{-4}$</td>
<td>$5.34 \times 10^{-7}$</td>
</tr>
<tr>
<td>4</td>
<td>Onshore gas gathering and boosting pipelines (unprotected steel)</td>
<td>$4.64 \times 10^{-3}$</td>
<td>$1.89 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

$S_{Df}$ is the default share of gas type (f) in the unprocessed gas (i), for methane $S_D$ is 0.788 and for carbon dioxide $S_D$ is 0.02.
Top-down emissions estimation

Source: www.ghgsat.com/en/
Source: https://pergamusa.com/
Top-down emissions estimation

- Global coverage
- Coarse resolution (TROPOMI 5km x 3.5km, GHGSat 25m x 25m)

- Regional scale coverage (< 1000km²)
- Medium resolution (< 10m x 10m)

- Local scale coverage (< 5km²)
- High resolution (< 1m x 1m)

Spatial coverage and resolution

Source: www.ghgsat.com/en/
Source: https://pergamusa.com/
Source: www.terrasanaconsultants.com
Source: The APPEA Journal 57(2) 561-566 https://doi.org/10.1071/AJ16098
Top-down emissions estimation

- TROPOMI: 25000 kg/hr
  - GHGSat-D: 1000-3000 kg/hr
  - GHGSat-CX: 100-200 kg/hr

Detection limit (self reported)

Source: www.ghgsat.com/en/
Source: https://pergamusa.com/
Source: www.terrasanaconsultants.com
Source: The APPEA Journal 57(2) 561-566
https://doi.org/10.1071/AJ16098
Top-down emissions estimation

TROPOMI: 25000 kg/hr

Assumption: CH$_4$ 50 MJ/kg

50 MJ/kg * 25000 kg/hr = 1250000 MJ/hr = 1250 GJ/hr

1250 GJ/hr * 24 hr/d = 30000 GJ/d = 30 TJ/d

30 TJ/d * 365 d/a = 10950 TJ/a = 10.95 PJ/a

Source: The Australian Natural Gas Industry: Monitoring, reporting, and reducing methane emissions (AGIT)
Top-down emissions estimation

Assumption: CH$_4$ 50 MJ/kg

50 MJ/kg * 150 kg/hr = 7500 MJ/hr = 7.5 GJ/hr

7.5 GJ/hr * 24 hr/d = 180 GJ/d = 0.18 TJ/d

0.18 TJ/d * 365 d/a = 65.7 TJ/a = \textbf{0.066 PJ/a}

Assumption*: ~ 9000 producing CSG wells

1400 PJ/a / 9000 wells = \textbf{0.15 PJ/a/well}

Source: The Australian Natural Gas Industry: Monitoring, reporting, and reducing methane emissions (AGIT)

* GASFIELDS COMMISSION QUEENSLAND Shared Landscapes – Industry Snapshot
Top-down emissions estimation

Top-down approaches do not measure the actual emissions (flow rates)

Source: www.ghgsat.com

Source: www.terrasanaconsultants.com
Top-down emissions estimation

Measuring methane concentrations through laser absorption spectroscopy
Quantifying fugitive methane emissions

Concentration

- Snapshot in space and time
- ppm, ppb, g/L

Flux

- Rate of mass flow
- L/min, kg/s, t/yr

Source: www.ghgsat.com

Tarantola (2005): ‘The inverse problem consists of using the actual result of some measurement to infer the value of the parameter that characterize the system’
Quantifying fugitive methane emissions

Concentrations (x, t)

- Wind speed
- Wind direction
- Air temperature
- Air pressure
- Atmospheric stability

Flux?

Q=?
Quantifying fugitive methane emissions

Coal seam gas industry methane emissions in the Surat Basin, Australia: comparing airborne measurements with inventories

Bruno G. Neininger1,†, Bryce F. J. Kelly2,†, Jorg M. Hacker3,†, Xinyi Lu3 and Stefan Schwietzke5,†

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2School of Biological, Earth and Environmental Sciences, UNSW
3CSIRO Oceans and Atmosphere, Aspendale, 3195, Victoria, Australia
4Koala Environmental Pty., Ltd., Milton, 4064, Queensland, Australia
5CSIRO Energy, Kensington, 6152, Western Australia, Australia

“...indicates that CSG sources emit about 0.4% of the produced gas, which is two to three times greater than existing inventories for the region...”

Quantifying methane emissions from Queensland’s coal seam gas producing Surat Basin using inventory data and a regional Bayesian inversion

Ashok K. Lahar1, David M. Etheridge1, Zoe M. Loh1, Julie Noonan1, Darren Spencer1, Lisa Smith2, and Cindy Ong2

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2CSIRO Energy, Kensington, 6152, Western Australia, Australia

“...covering the CSG development areas, the inferred emissions are 33% larger than those from inventory.”
Quantifying fugitive methane emissions

46 plumes resolved, georeferenced by UQ-CNG

Possible sources?

1. ‘mega’ plume (#16, mainly ag. but maybe coalesced)
2. piggeries
3. coal mines
3. towns
1. water body
17. feedlots (most of the active ones)
16. gas “facilities” (small proportion, mainly comp. stns)
3. towns
2. piggeries
Quantifying fugitive methane emissions


- 10 teams, drone-, vehicle-, plane-, helicopter-based
- Mobile Monitoring Challenge:
  - 1 hidden CH₄ source per pad
  - Random pad allocation
  - Teams to measure and estimate, report back
Quantifying fugitive methane emissions

Quantifying fugitive methane emissions

Flux estimation accuracy

No data available!

\[ R^2 \approx 0.8 \text{ (super-emitters)} \]

\[ R^2 < 0.2 \]

Source: www.ghgsat.com/en/

Source: https://pergamusa.com/

Source: www.terrasanaconsultants.com

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Novel statistical estimation of fugitive methane emissions using drones
UQ-CNG AQIRF

Novel statistical estimation of fugitive methane emissions using drones

- Test and improve inversion algorithms
- Perform a UQ-CNG controlled release experiment
  - Validate algorithms
  - Trial and optimize data acquisition strategies (e.g., flight pattern, flight height)
  - Increase data density of external factors (e.g., wind information from drone)

Source: www.terrasanaconsultants.com
Acknowledgments

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Thank you!

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