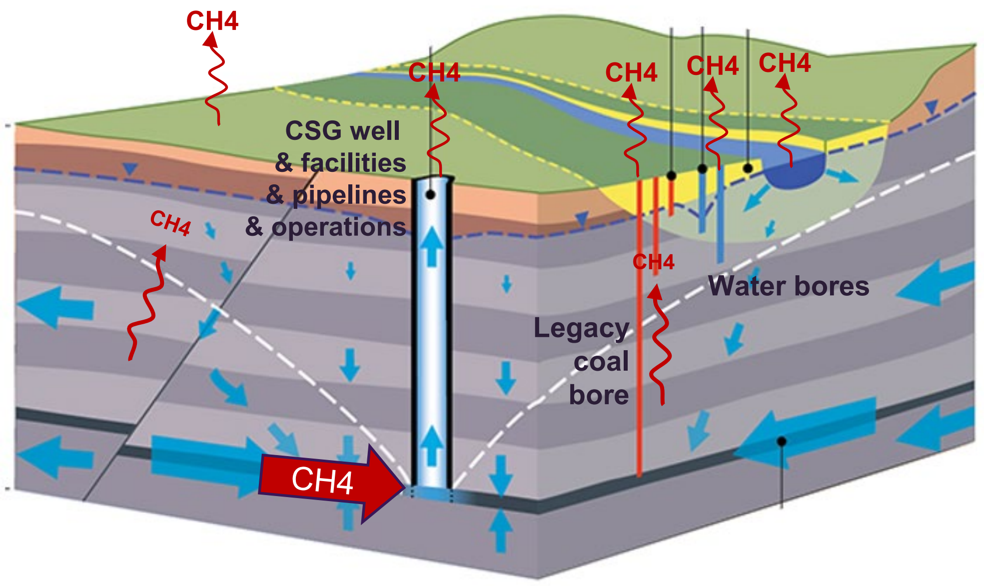
Using drones to measure fugitive methane emissions

Dr.-Ing. Sebastian Hörning – The University of Queensland, Centre for Natural Gas

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)

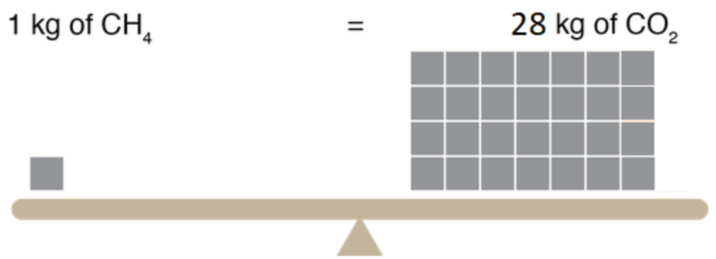
- Leaks from processing facilities and pipelines
- Defective valves or seals
- Migration of gas to the surface
- Emissions from abandoned wells

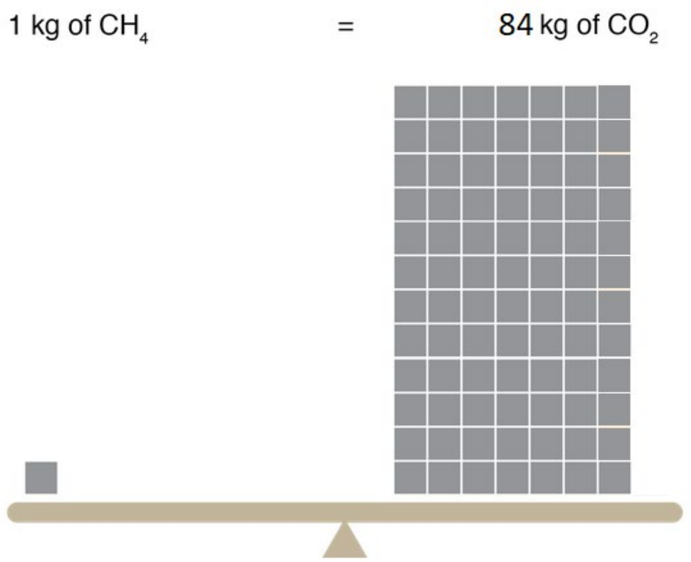


modified from www.industry.nsw.gov.au/water/science/groundwater/

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





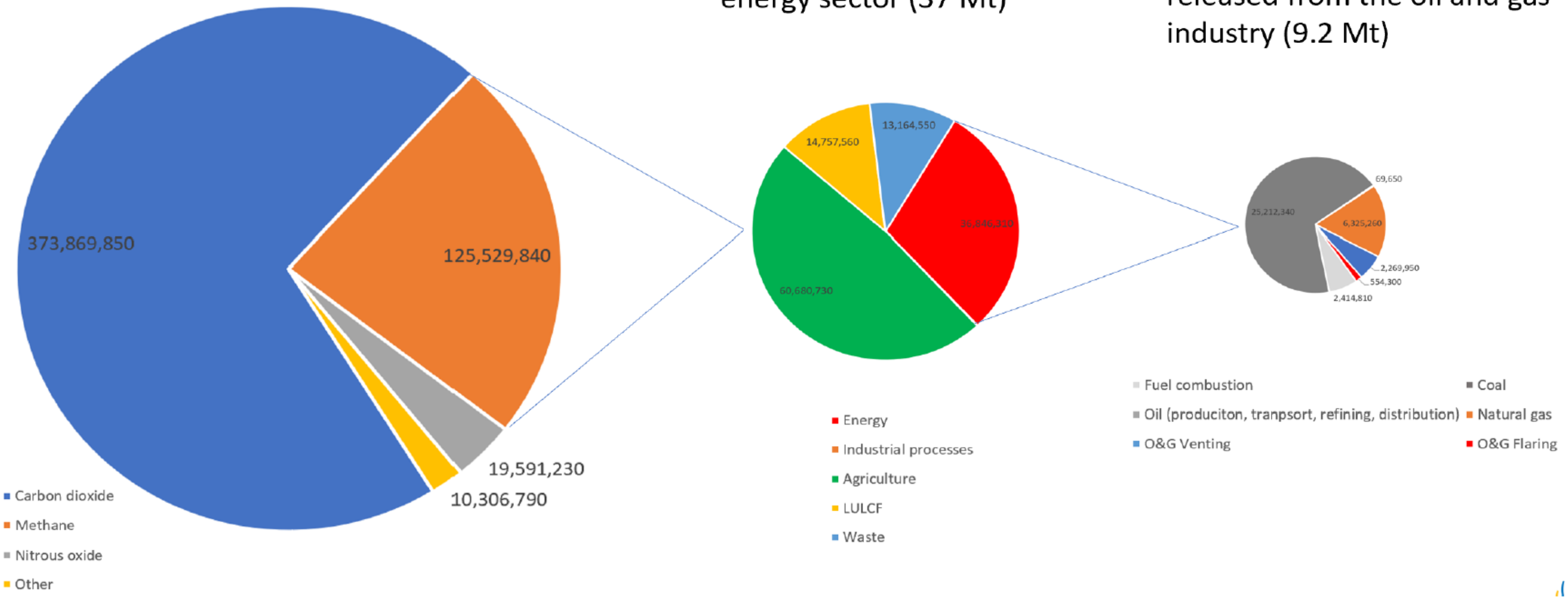
Methane emissions in Australia

Methane emissions in Australia (2019, tonnes CO_2e)

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

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- Global commitment to reduce emissions

- Net-zero state government commitments

Australia signs up to global methane pledge

Mark Ludlow
Queensland bureau chief

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.**

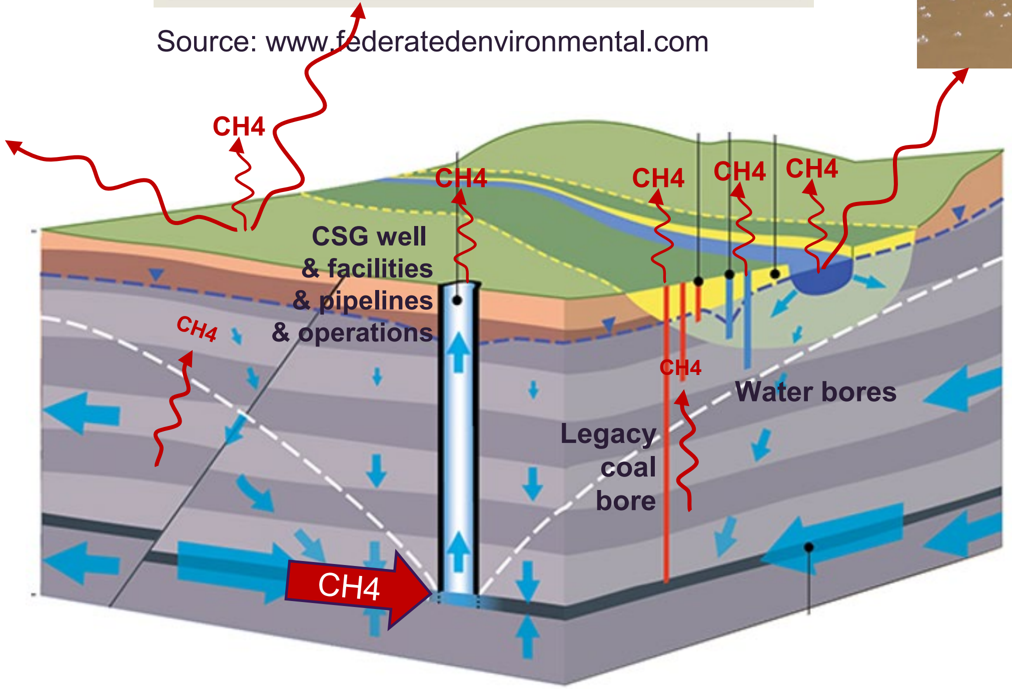
Source: Queensland Climate Transition Strategy

Fugitive methane emissions

Source: Country Caller Regional News

Source: www.federatedenvironmental.com

Source: Country Caller Regional News



modified from www.industry.nsw.gov.au/water/science/groundwater/

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)

Last updated on 25 October 2022

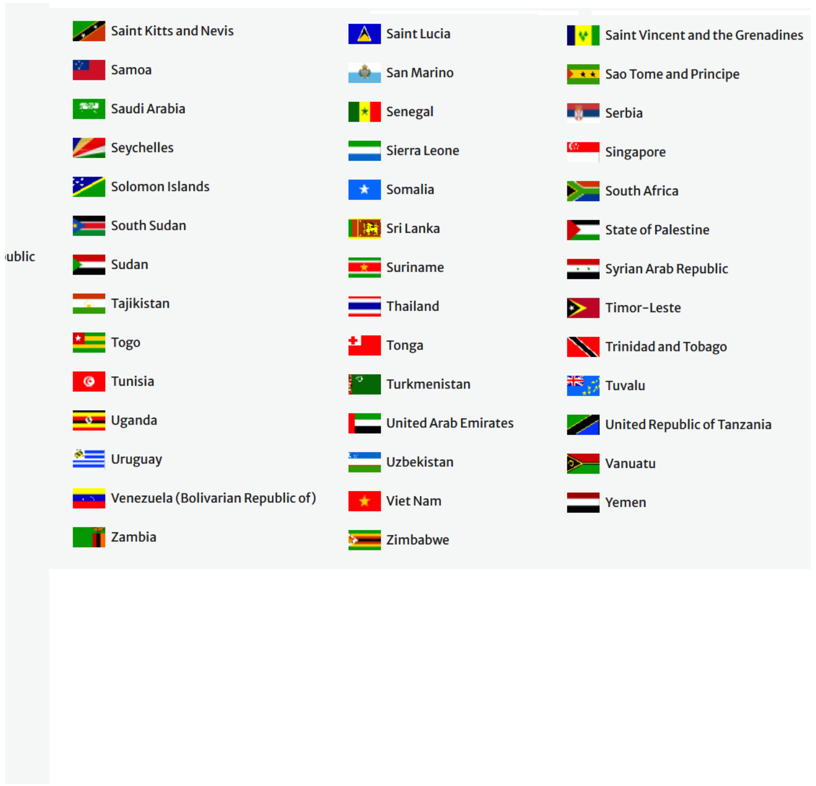
Australia	Austria	Belarus
Belgium	Bulgaria	Canada
Croatia	Cyprus	Czechia
Denmark	Estonia	European Union
Finland	France	Germany
Greece	Hungary	Iceland
Ireland	Italy	Japan
Latvia	Liechtenstein	Lithuania
Luxembourg	Malta	Monaco
Netherlands	New Zealand	Norway
Poland	Portugal	Romania
Russian Federation	Slovakia	Slovenia
Spain	Sweden	Switzerland
Türkiye	Ukraine	United Kingdom of Great Britain and Northern Ireland
United States of America		

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

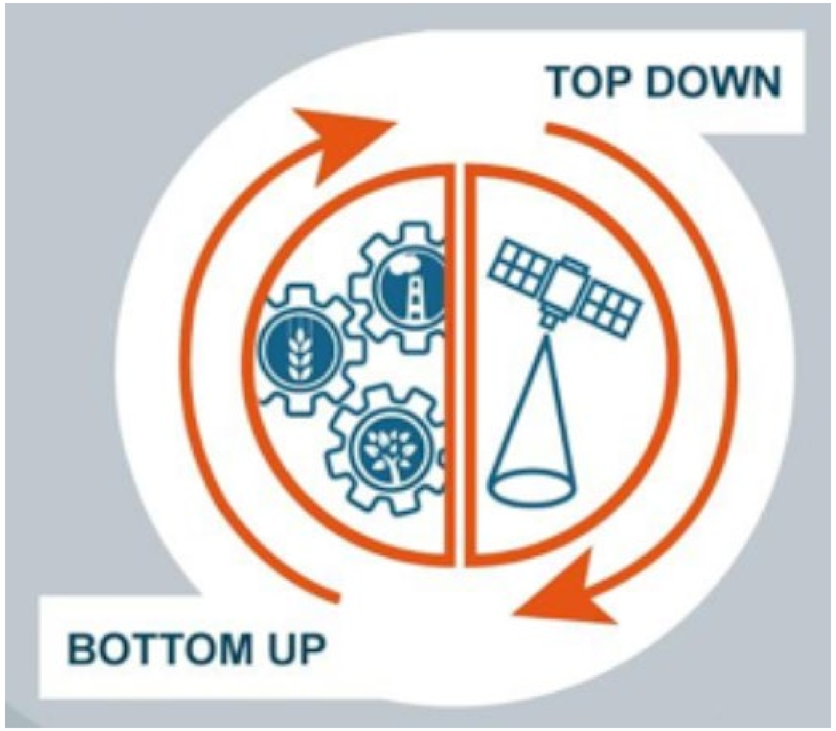
Nation	Date of last UNFCCC emissions submission
China	2014
United Arab Emirates	2014
Saudi Arabia	2012
Uzbekistan	2012
Argentina	2012
Malaysia	2011
Turkmenistan	2010
Qatar	2007
Iran	2000
Indonesia	2000
Algeria	2000
Nigeria	2000
Trinidad and Tobago	1990

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 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

$$E_{distribution} = A_{gas\ distribution} \bullet EF_{gas\ distribution} + A_{surface\ storage} \bullet EF_{surface\ storage} + A_{distribution\ of\ town\ gas} \bullet EF_{distribution\ of\ town\ gas}$$

Where:

$E_{distribution}$ = Total amount of GHG gas emitted due to all relevant natural gas distribution activities

$A_{gas\ distribution}$ = Volume of natural gas consumed or length of distribution pipeline

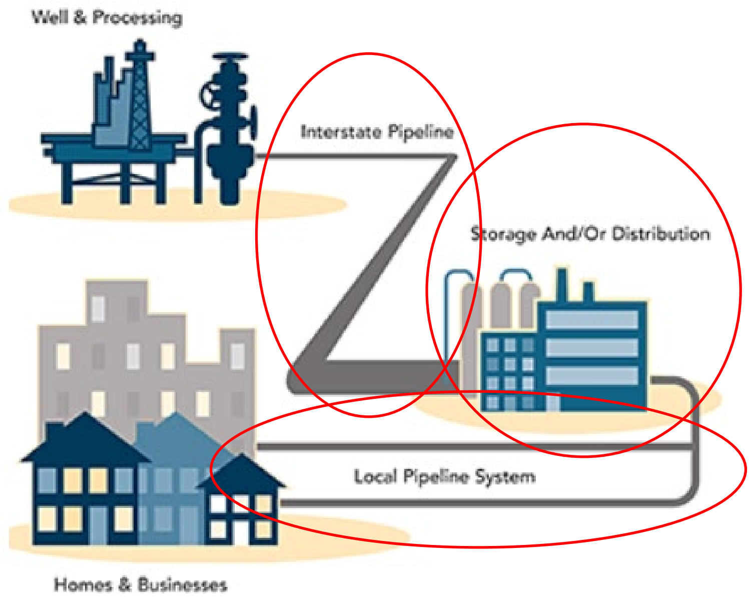
$EF_{gas\ distribution}$ = Emission factor for gas distribution

$A_{surface\ storage}$ = Volume of natural gas stored (in surface storage) or consumed

$EF_{surface\ storage}$ = Emission factor for surface storage

$A_{distribution\ of\ town\ gas}$ = Length of town gas distribution pipeline

$EF_{distribution\ of\ town\ gas}$ = 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

Section 3.73LA

Item	Equipment type (k)	Emission factor for gas type (j)		
		CH_4	CO_2	Units
1	Onshore gas gathering and boosting pipelines (cast iron)	7.72×10^{-3}	3.14×10^{-5}	tonnes CO_2-e /kilometres of pipeline hour
2	Onshore gas gathering and boosting pipelines (plastic)	6.99×10^{-4}	2.85×10^{-6}	tonnes CO_2-e /kilometres of pipeline hour
3	Onshore gas gathering and boosting pipelines (protected steel)	1.31×10^{-4}	5.34×10^{-7}	tonnes CO_2-e /kilometres of pipeline hour
4	Onshore gas gathering and boosting pipelines (unprotected steel)	4.64×10^{-3}	1.89×10^{-5}	tonnes CO_2-e /kilometres of pipeline hour

SD_{ij} is the default share of gas type (*j*) in the unprocessed gas (*i*), for methane SD is 0.788 and for carbon dioxide SD is 0.02.

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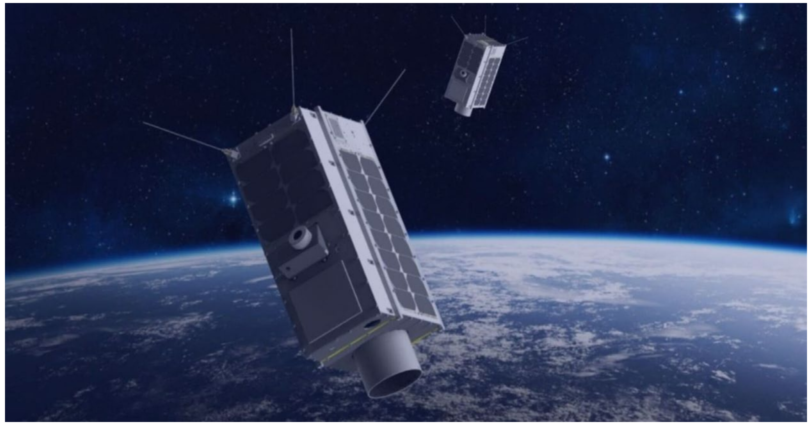
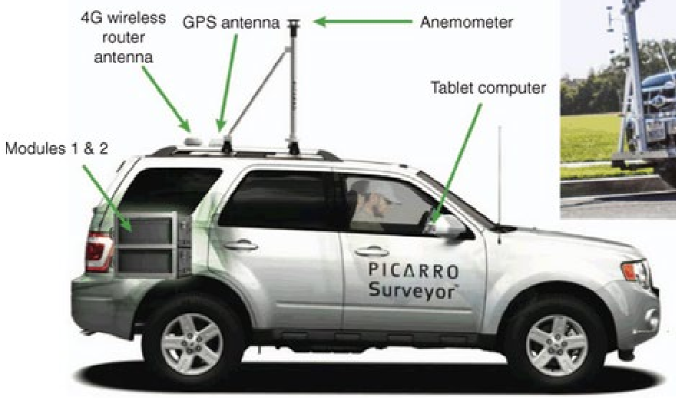
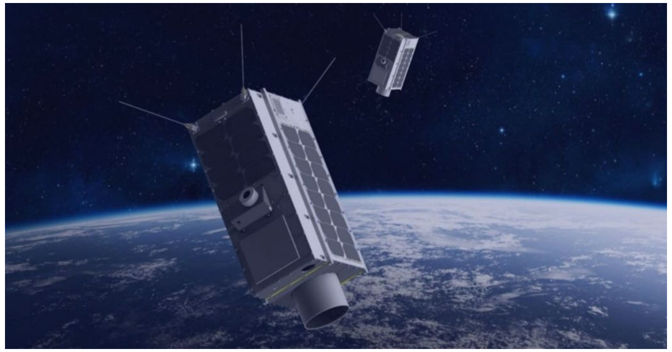
Top-down emissions estimation





Top-down emissions estimation

THE UNIVERSITY OF QUEENSLAND AUSTRALIA



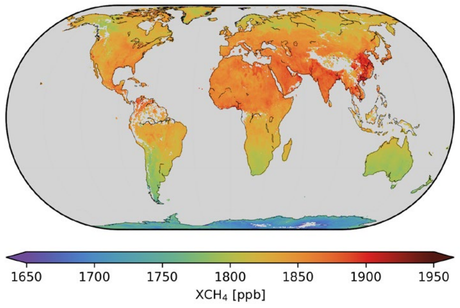
Source: www.ghgsat.com/en/

Source: https://pergamusa.com/

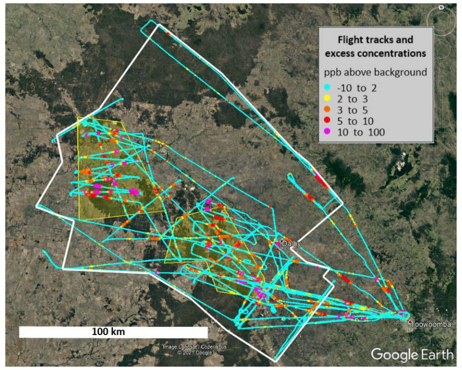
Source: www.terrasanaconsultants.com

Source: *The APPEA Journal* 57(2) 561-566
https://doi.org/10.1071/AJ16098

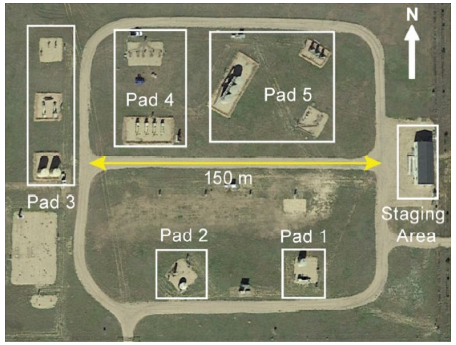
- Global coverage
- Coarse resolution (TROPOMI 5km x 3.5km, GHGSat 25m x 25m)



- Regional scale coverage (< 1000km^2)
- Medium resolution (< 10m x 10m)



- Local scale coverage (< 5km^2)
- High resolution (< 1m x 1m)



Spatial coverage and resolution

Top-down emissions estimation

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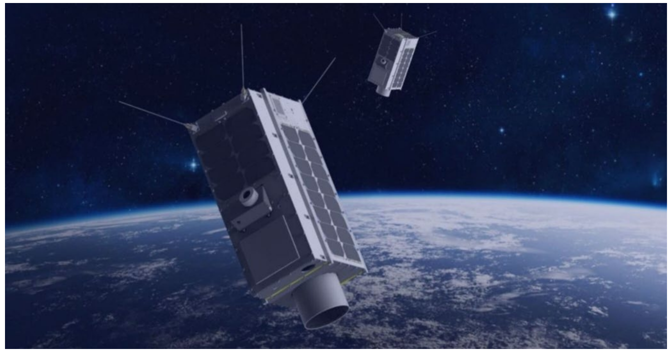

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Source: https://pergamusa.com/

Source: www.terrasanaconsultants.com

Source: *The APPEA Journal* 57(2) 561-566
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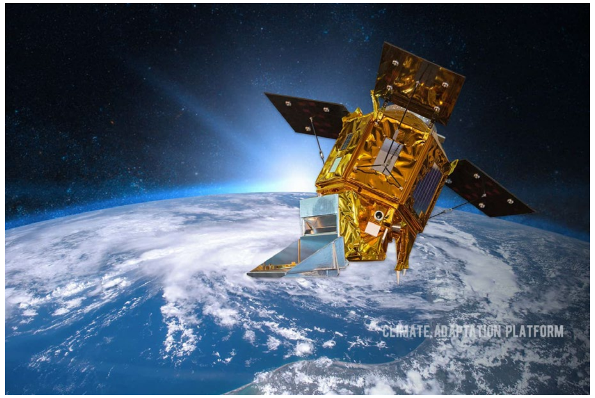
- TROPOMI: 25000 kg/hr
  - GHGSat-D: 1000-3000 kg/hr
    - GHGSat-CX: 100-200 kg/hr

10-20 kg/hr

< 0.1 kg/hr

Detection limit (self reported)

Top-down emissions estimation



Source: https://climateadaptationplatform.com/climate-change-monitoring-using-tropomi/

TROPOMI: 25000 kg/hr

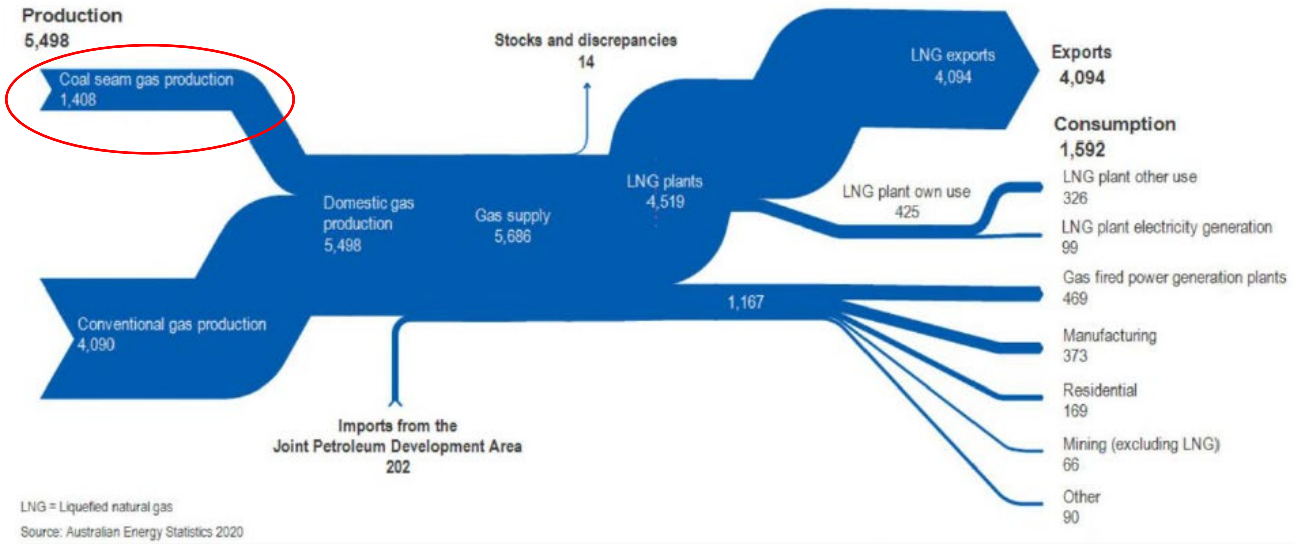
Assumption: CH_4 50 MJ/kg

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

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

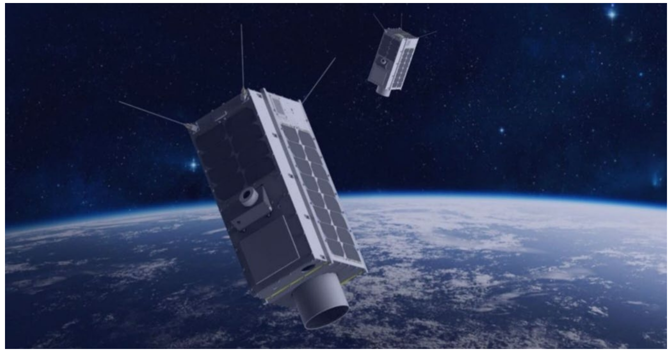
30 TJ/d * 365 d/a = 10950 TJ/a = **10.95 PJ/a**

Australian natural gas flows (PJ) 2018/19



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

Top-down emissions estimation



Source: www.ghgsat.com/en/

GHGSat-CX: 100-200 kg/hr

Assumption: CH_4 50 MJ/kg

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

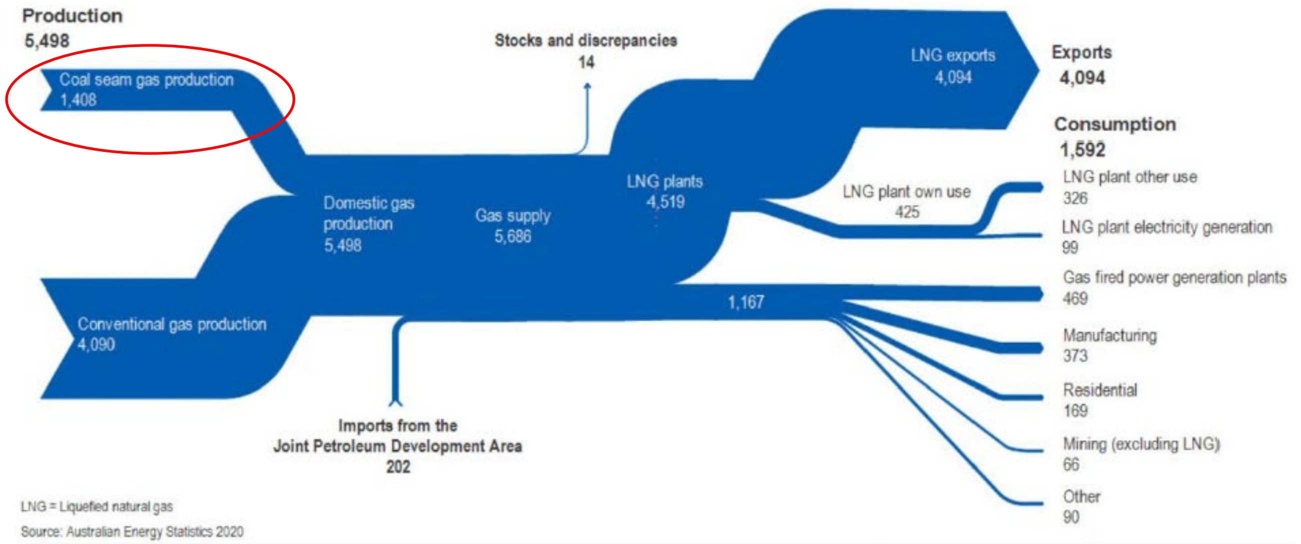
7.5 GJ/hr * 24 hr/d = 180 GJ/d = 0.18 TJ/d

0.18 TJ/d * 365 d/a = 65.7 TJ/a = **0.066 PJ/a**

Assumption*: ~ 9000 producing CSG wells

1400 PJ/a / 9000 wells = **0.15 PJ/a/well**

Australian natural gas flows (PJ) 2018/19

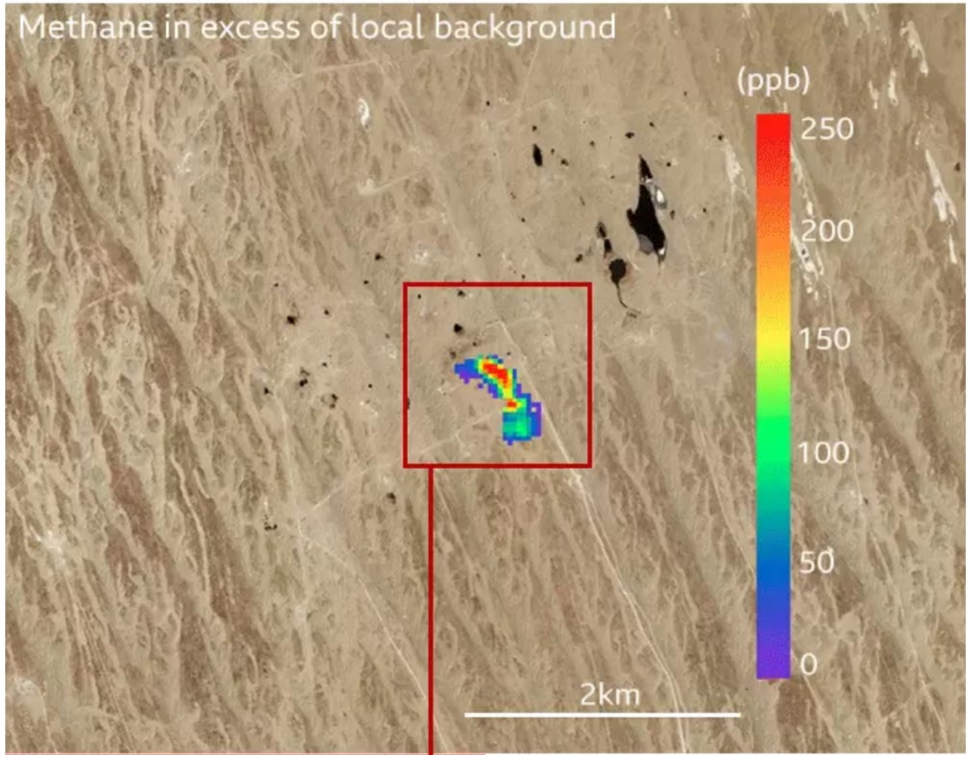


Source: The Australian Natural Gas Industry: Monitoring, reporting, and reducing methane emissions (AGIT)

* GASFIELDS COMMISSION QUEENSLAND Shared Landscapes – Industry Snapshot

Top-down emissions estimation

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



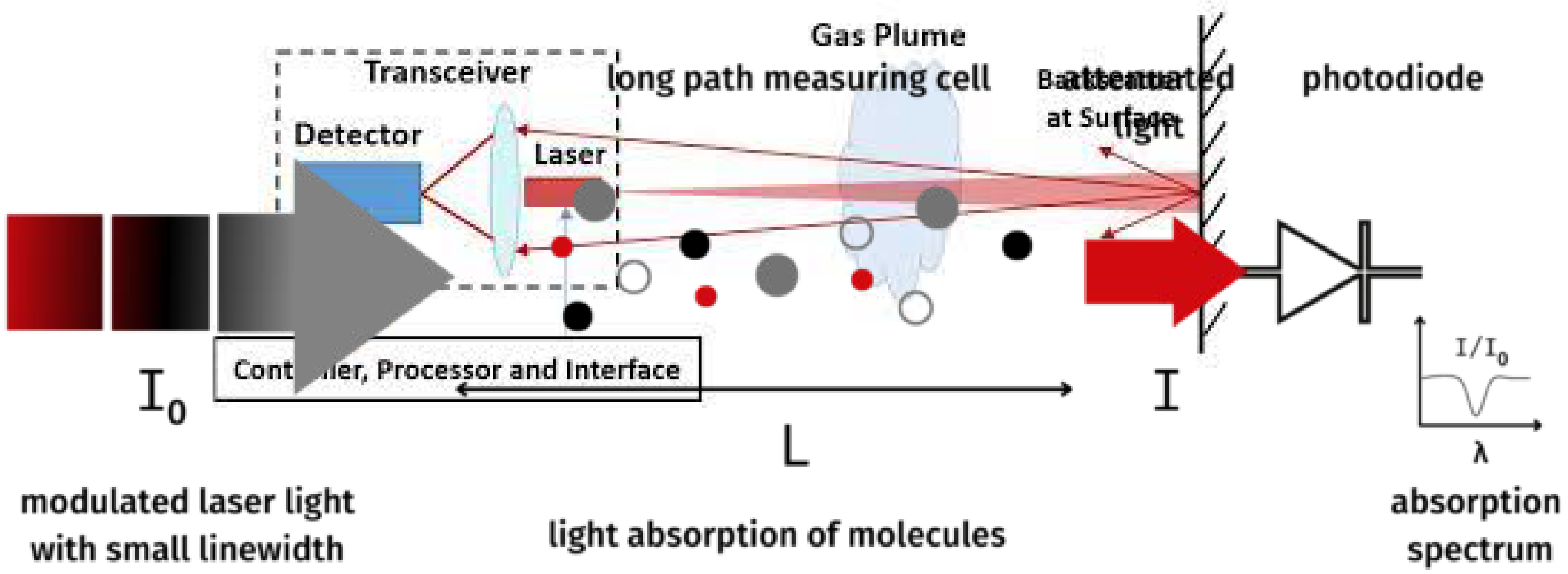
Source: www.ghgsat.com

CH_4 concentrations in ppm

Source: www.terrasanaconsultants.com

Top-down emissions estimation

Measuring methane concentrations through laser absorption spectroscopy



Quantifying fugitive methane emissions

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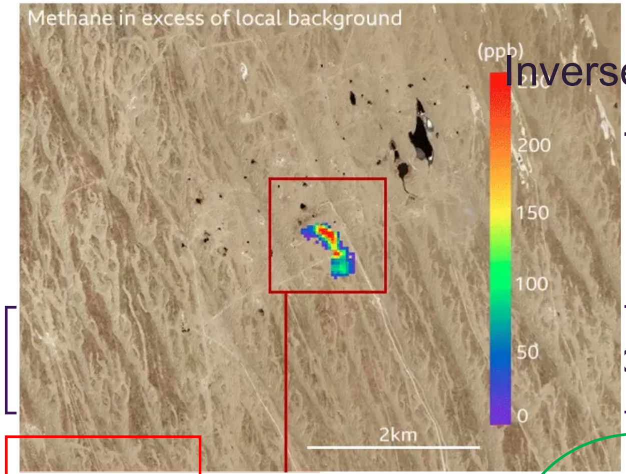
Concentration ≠ **Flux**

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

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



Source: www.ghgsat.com

?

odel

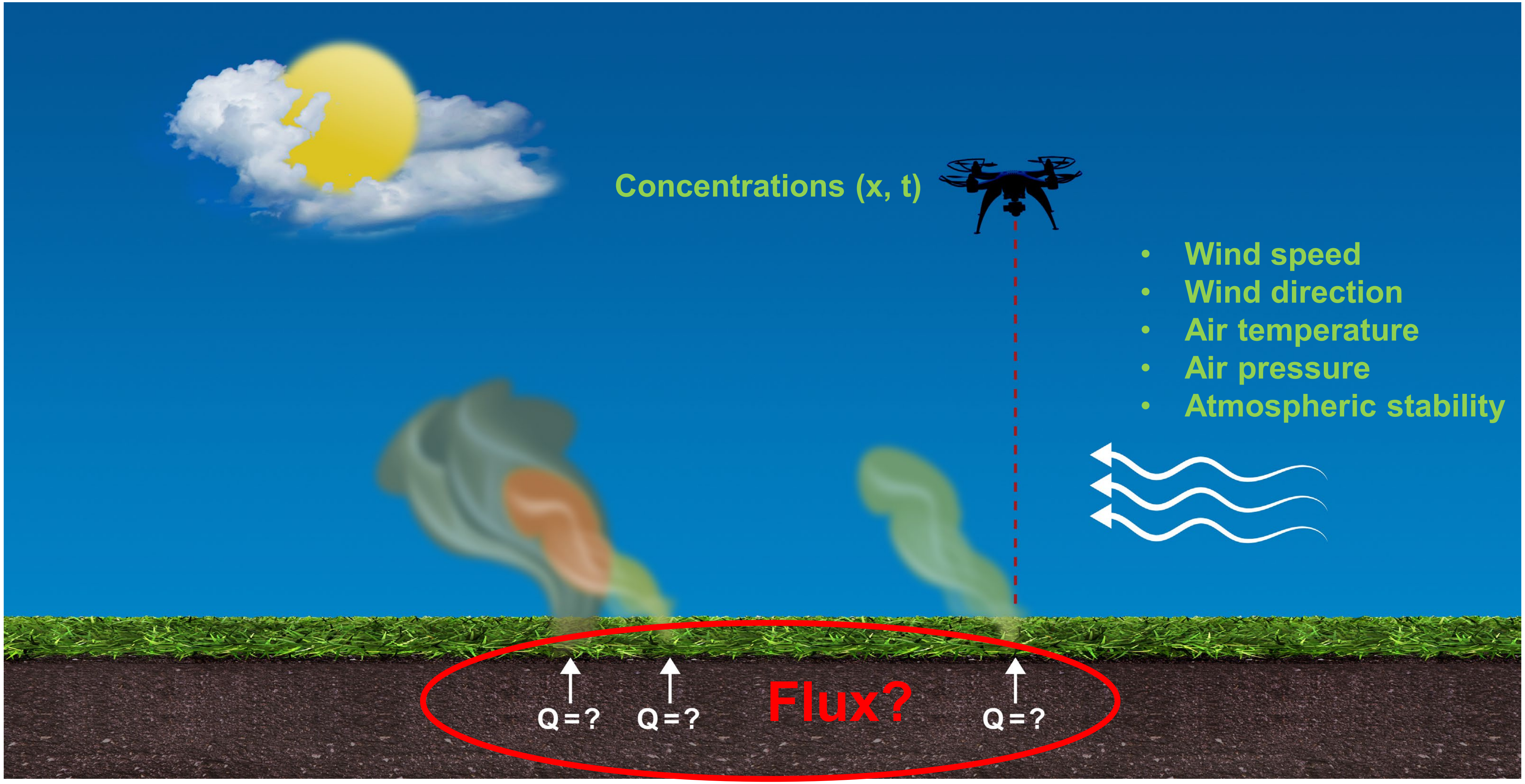
Inverse problem

partly known

partly known

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



Quantifying fugitive methane emissions

PHILOSOPHICAL TRANSACTIONS A

royalsocietypublishing.org/journal/rsta

Research

Check for updates

Cite this article: Neininger BG, Kelly BFJ, Hacker JM, LU X, Schwietzke S. 2021 Coal seam gas industry methane emissions in the Surat Basin, Australia: comparing airborne measurements with inventories. *Phil. Trans. R. Soc. A* **379**: 20200458. https://doi.org/10.1098/rsta.2020.0458

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

Bruno G. Neininger[1,†], Bryce F. J. Kelly[2,†], Jorg M. Hacker[3,4], Xinyi LU[2] and Stefan Schwietzke[5,†]

[1]MetAir AG, Airfield LSZN, Switzerland
[2]School of Biological, Earth and Environmental Sciences, UNSW

"…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**…"

Atmos. Chem. Phys., 20, 15487–15511, 2020
https://doi.org/10.5194/acp-20-15487-2020

Atmospheric Chemistry and Physics
Open Access
EGU

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

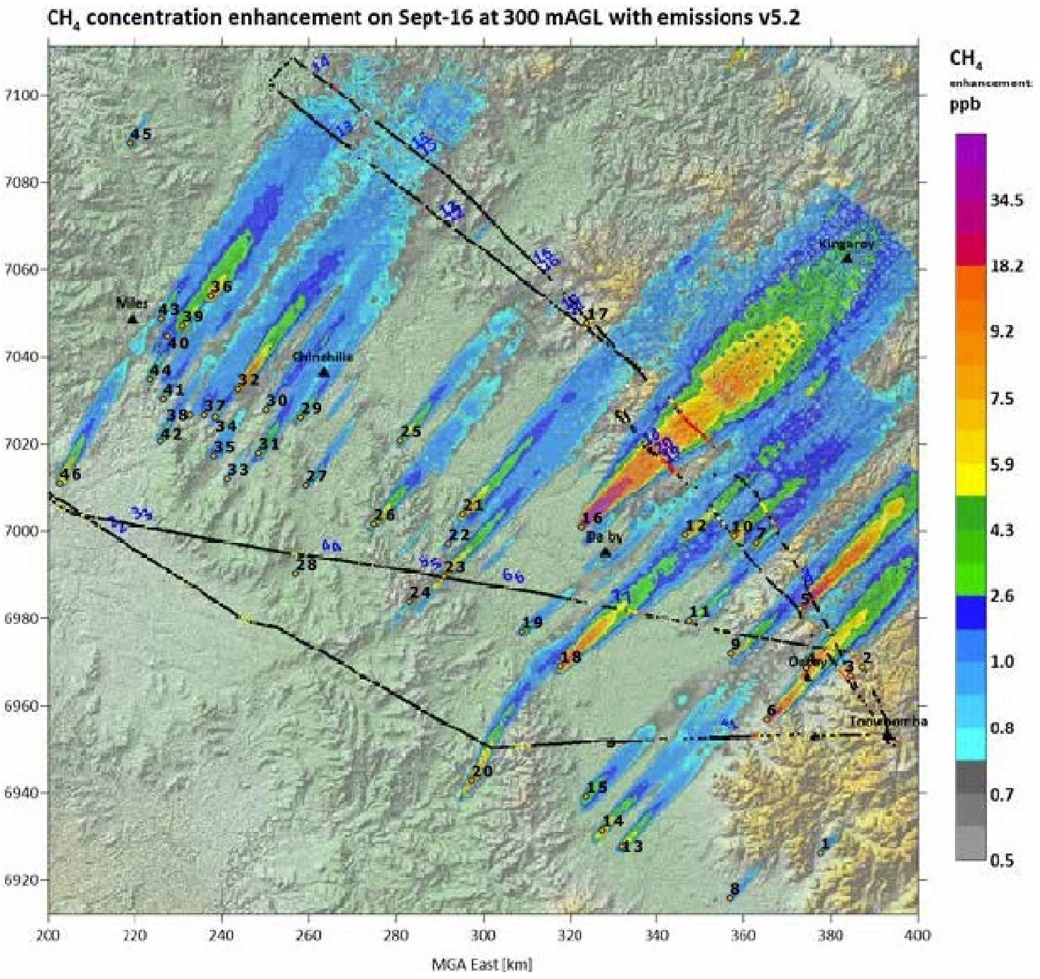
Ashok K. Luhar[1], David M. Etheridge[1], Zoë M. Loh[1], Julie Noonan[1], Darren Spencer[1], Lisa Smith[2], and Cindy Ong[3]

[1]CSIRO Oceans and Atmosphere, Aspendale, 3195, Victoria, Australia
[2]Katestone Environmental Pty. Ltd., Milton, 4064, Queensland, Australia
[3]CSIRO 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



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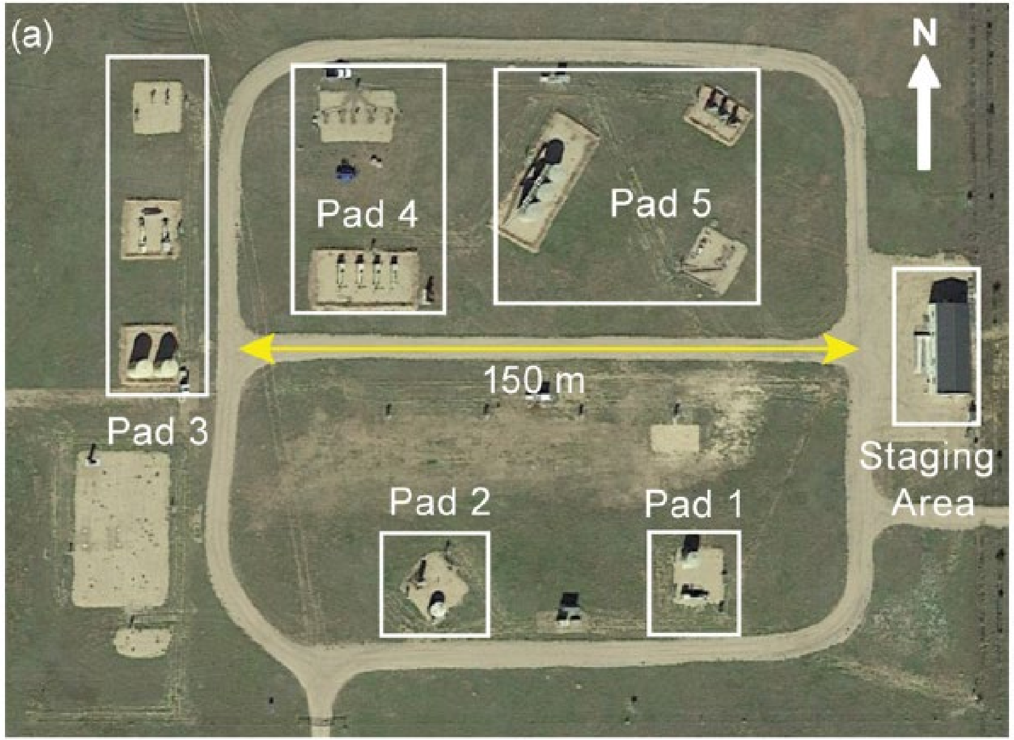
Possible sources?

1	'mega' plume (#16, mainly ag. but maybe coalesced)
17	feedlots (most of the active ones)
16	gas "facilities" (small proportion, mainly comp. stns)
3	coal mines
3	towns
1	water body
2	piggeries

Quantifying fugitive methane emissions

Single-blind inter-comparison of methane detection technologies – results from the Stanford/EDF Mobile Monitoring Challenge. *Elementa Science of the Anthropocene, 7: 37. 2019*



- 10 teams, drone-, vehicle-, plane-, helicopter-based
- Mobile Monitoring Challenge:
  - ❑ 1 hidden CH_4 source per pad
  - ❑ Random pad allocation
  - ❑ Teams to measure and estimate, report back

Quantifying fugitive methane emissions

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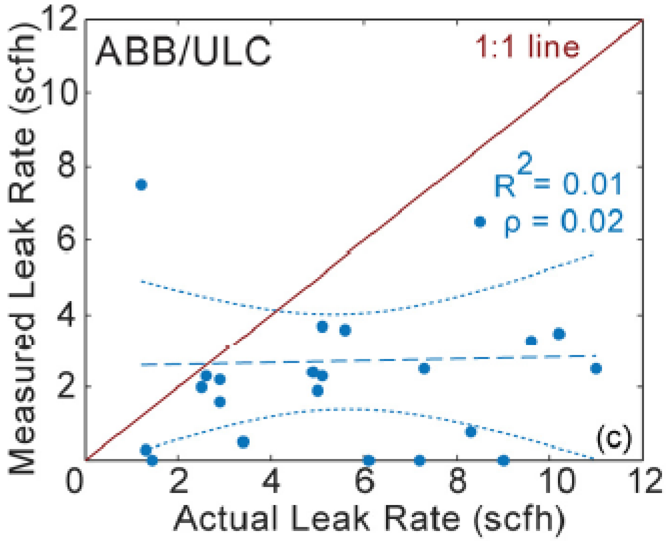
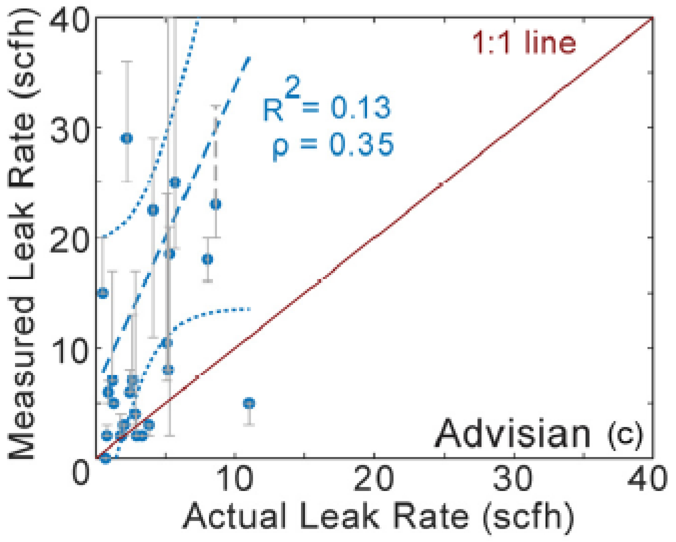
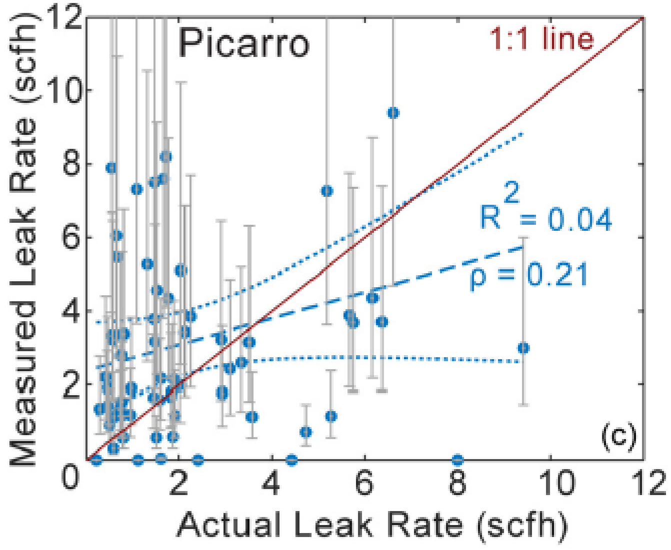
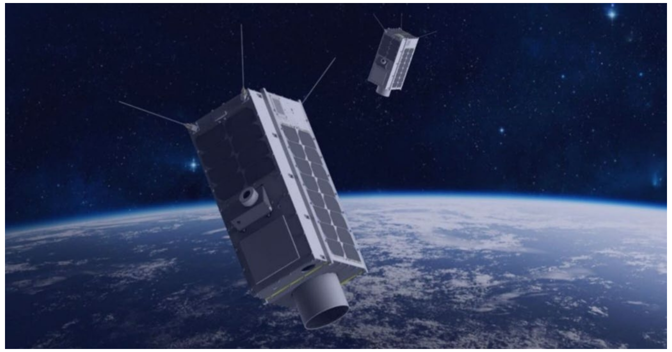






Quantifying fugitive methane emissions

The University of Queensland
Australia



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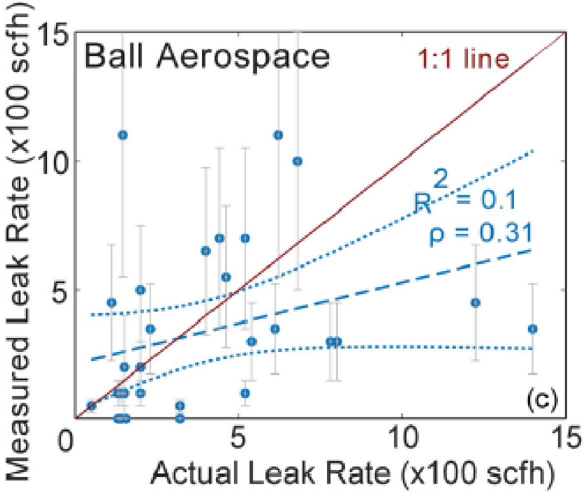
Source: https://pergamusa.com/

Source: www.terrasanaconsultants.com

Source: *The APPEA Journal* 57(2) 561-566
https://doi.org/10.1071/AJ16098

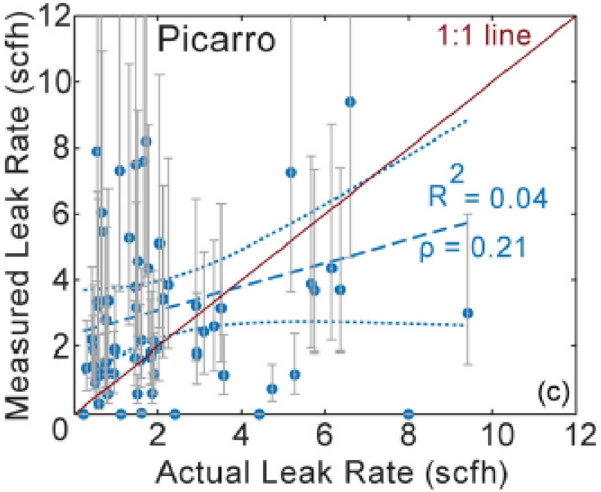
No data available!

$R^2 \approx 0.8$ (super-emitters)



Sherwin, ED, et al. 2021. Single-blind test of airplane-based hyperspectral methane detection via controlled releases. Elem Sci Anth, 9: 1. DOI: https://doi.org/10.1525/elementa.2021.00063

$R^2 < 0.2$



Single-blind inter-comparison of methane detection technologies – results from the Stanford/EDF Mobile Monitoring Challenge. *Elementa Science of the Anthropocene, 7: 37. 2019*

Flux estimation accuracy

UQ-CNG AQIRF

Novel statistical estimation of fugitive methane emissions using drones

Source: www.terrasanaconsultants.com

Source: www.terrasanaconsultants.com

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Queensland Government

AUSTRALIA PACIFIC LNG

Operated by origin

TERRA SANA CONSULTANTS

Santos

arrow

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

The University of Queensland Australia

Queensland Government

Australia Pacific LNG

Operated by origin

Terra Sana Consultants

Santos

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Acknowledgments

The author gratefully acknowledges support of the Queensland Government through the Advance Queensland Industry Research Fellowship Scheme and industry (Arrow Energy, APLNG, Santos, and Terra Sana Consultants) through The University of Queensland Centre for Natural Gas (natural-gas.centre.uq.edu.au).

Thank you!

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