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Fugitive emissions from unconventional gas

What the latest scientific research is telling us about fugitive methane emissions from unconventional gas.

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What does science tell us about fugitive methane emissions from unconventional gas?

KEY POINTS

- Fugitive emissions are losses, leaks and other releases of methane to the atmosphere that are associated with industries producing natural gas, oil and coal. They also include CO_2 emissions associated with flaring of excess gas to the atmosphere.
- In Australia, fugitive emissions from oil and gas production are estimated to account for about 6.0% of greenhouse gas emissions.
- To accurately measure fugitive emissions, natural background biological and geological sources must be separated from human sources. CSIRO studies aim to separate these sources.
- CSIRO has a range of research programs underway in Queensland, New South Wales, Western Australia and the Northern Territory using measuring and monitoring techniques, life-cycle analysis methods and industry activity data to provide accurate and comprehensive estimates of natural and and fugitive emissions in Australia.
- A recent CSIRO study on GHG emissions from a CSG-LNG company in Queensland estimated total GHG direct and indirect emissions (scope 1 and scope 2) of the production chain of about 5 Mt CO_2-e/year. These GHG emissions amounted to 1.4 % of CSG production (576 PJ). A further 40 Mt CO_2-e/year were generated by shipping LNG, regasification and combustion in Asia.
- Another CSIRO study using 'top down' atmospheric inversion of methane concentration data in the central Surat Basin coupled with a 'bottom-up' inventory of methane sources for the same region suggested that fugitive methane emissions from upstream gas production infrastructure is less than 0.5% of CSG production (576 PJ). This study also found the largest contribution to total methane emissions in this region was cattle grazing (54%), followed by feedlots (24%) and CSG processing (8%) (Luhar et al., 2018).
- The median fugitive emissions from measurements of CSG wells in Queensland and NSW is less than 1kg/day with 1% of wells releasing 63 kg/day. Well completion and workover measurements show releases of 200 kg/day and 20 t/day, respectively. Measurements made at a CSG water treatment plant were between 18 and 32 kg/day and from a CSG compression plant, emissions were 780 kg/day. To put these measurements into context, methane fluxes measured from an urban sewerage treatment plant were 45 kg/day, a medium sized waste land fill were 400 kg/day and from a cattle feed lot were 2,600 kg/day.

This factsheet sets out what the science tells us about methane emission sources from coal seam gas (CSG) wells, pipelines, compressors and other infrastructure associated with CSG production; and their importance in contributing to warming of the earth's climate.

What is methane and where does it come from?

Methane, a colourless, odourless, non-toxic gas, originates from two sources:

- the decomposition of organic matter, such as in lakes, rivers, wetlands and soils, or
- from deep beneath the earth's surface where gaseous methane has formed geochemically under elevated temperature and pressure conditions.

Globally, it is estimated that more than 300 million tonnes (Mt) of methane is emitted each year from natural sources such as wetlands, soils, biomass burning and geological sources and another 330 million tonnes (Mt) of methane is produced by human activities such as agriculture; mainly rice and beef production (Kirschke et al., 2013). However, large uncertainties remain in these estimates (Schaefer et al., 2016). Of the natural sources, about 16% is seeping naturally from sedimentary basins such as from coal seams and shale basins, rising from geological structures beneath the earth's surface. About 29% of human sources of methane emitted to the atmosphere arise from fossil fuel combustion (Kirschke et al., 2013). However, these estimates are still subject to significant uncertainty. The Commonwealth Government estimates that fugitive emissions from natural gas production are about 6.0% (Commonwealth Government, 2018).

How much does methane warm the atmosphere?

Like all greenhouse gases, methane absorbs infra-red radiation from the earth and then radiates this heat back into the surrounding atmosphere, warming it. However, methane is a more potent greenhouse gas than carbon dioxide. About 20% of the total warming of the atmosphere since 1750 is due to methane emissions from human activities, which has increased global average temperatures by about 1 degree Celsius (Kirschke et al., 2013).

The relative capacity of different gases to warm the atmosphere, taking into account their 'lifetimes', is called the global warming potential. Methane remains in the atmosphere on average for between eight and twelve years (Lassey et al., 2007), whereas 50% of carbon dioxide emitted to the atmosphere is lost in about 30 years (Inman 2008). The global warming potential of methane, when compared to carbon dioxide over a 100-year lifetime, is about 28 times greater (Saunois et al., 2016; IPCC 2014 Fifth Assessment Report).

Measuring fugitive emissions at a CSG well in the Surat Basin, Queensland

How much methane is coming from gas production?

Global atmospheric methane concentrations have risen from about 0.7 parts per million (ppm) in 1750 to about 1.8 ppm today. To accurately measure fugitive emissions, natural background biological and geological sources must be separated from human sources.

It is estimated that between between 69 and 88 Mt of methane is emitted by the global oil and gas industry annually. In comparison, emissions from agricultural production of beef and rice are about 135 Mt/yr (Saunois et al., 2016).

Over the past three decades, the rate of global oil and gas methane emissions from gas production have declined from 8% to 2%, as shown by the isotopic composition of methane in the atmosphere (Schwietzke et al., 2016).

How are fugitive methane emissions from the gas industry measured?

CSIRO research underway in Queensland, NSW, Northern Territory and WA uses a range of methods to build a comprehensive picture of natural background and fugitive gas industry emissions in Australia.

To understand methane emissions from the CSG industry, multiple approaches are needed, including:

1. A 'bottom-up' approach which directly measures methane fluxes from individual wells, compressors, pipelines, and other infrastructure. The rate of flow, or 'flux', of methane from wells and other infrastructure is estimated using a range of measurement techniques. One CSIRO approach is to measure methane concentrations downwind of a well or other source and calculate the emission flux based on knowledge of plume dispersion and local wind speeds. A second method uses a tracer gas that is released at a known rate at the methane source. The relationship between known flux and measured concentration of the tracer allows us to infer the flux of methane from co-measured concentrations. These flux measurements are used by the Commonwealth Government to generate Australia-specific emissions factors which are then used to estimate total fugitive emissions from gas production. Fugitive emission estimates for the industry are reported in the Commonwealth Government's National Greenhouse Gas Accounts to the United Nations Framework Convention on Climate Change.

   CSIRO's 'bottom-up' research (Day et al., 2012; Day et al., 2013; Day et al., 2014; Day et al., 2015; Day et al., 2016; Day et al., 2017) consists of sensitive methane measurements adjacent to gas infrastructure, combined with meteorological measurements of wind speed and direction. Researchers use a Picarro spectrometer, sensitive to concentrations of parts per billion, mounted in a vehicle to undertake measurements along access roads. These gas concentration measurements are combined in a physical model of gas plume dispersion to provide methane fluxes estimates.

   In another approach, researchers use three-metre high towers equipped with methane sensors and meteorological equipment to provide concentration measurements, meteorological observations and estimates of methane fluxes over a wider area of the size of a farmer's field.

2. 'Top-down' methods calculate emissions rates by measuring atmospheric concentrations of methane at different times and using meteorological information on wind speed and direction. Typically, 'top-down' methods are applied at a much larger scale than 'bottom-up' measurements up to the size of an entire gas producing region.

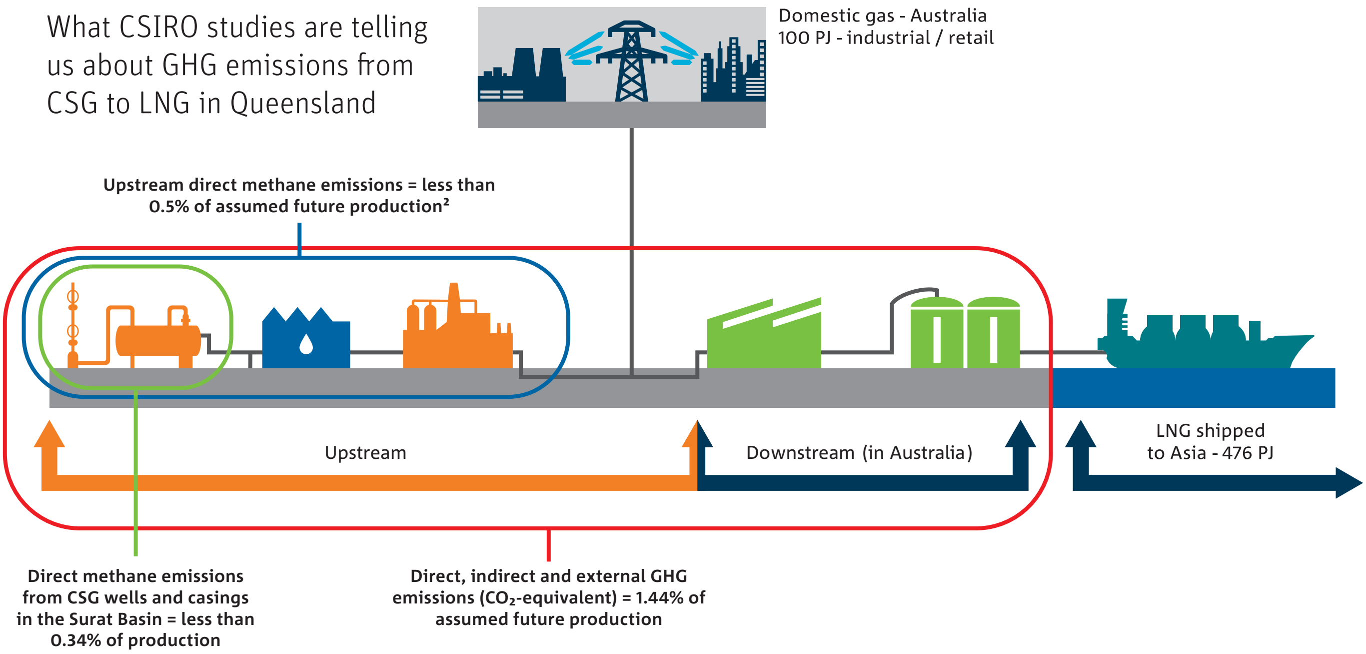
   CSIRO's 'top-down' projects (Etheridge et al., 2016; Luhar et al., 2018) use 10-metre towers situated upwind and downwind of the gas production fields in the Surat Basin, Queensland. These two towers measure changes in methane concentrations as air passes across the gas production field and, when combined with a physical model of atmospheric transport, can tell us about methane fluxes coming from areas of a few square kilometres. Repeated measurements combined with meteorological observations and a physical model of atmospheric transport are used to determine fluxes over many tens of square kilometres.

3. A CSIRO study on GHG emissions from different components of the natural gas supply chain that includes upstream infrastructure (well heads, compression plants, water treatment facilities, pipelines and downstream operations (liquefaction, shipping, regasification and combustion). This analysis allows comparison of GHG emissions from natural gas with other forms of electricity generation such as coal and renewables.

What is CSIRO research showing?

Here is a snapshot of CSIRO research on methane emissions in gas development regions:

- A CSIRO study examining GHG emissions associated with the CSG-LNG production chain showed that the total direct and indirect (scope 1 and 2) emissions were around 5 Mt CO_2-e/year with between 52 and 55% of these emissions associated with upstream CSG production (Schandl et al, 2019). Nearly 40 Mt CO_2-e/year in emissions are generated by shipping LNG, regasification and combustion of gas in Asia. GHG emissions from CSG-LNG production in Australia represented 1.4% of total natural gas production for this company (576 PJ).
- Top down' atmospheric inversion of methane concentration data in central Surat Basins (Luhar et al. 2018) coupled with a 'bottom-up' inventory of methane sources for the same region suggests that methane fugitive emissions from approximately 4600 wells, casings, water treatment plants compressor stations and other infrastructure (not including flaring) due to venting and leaks were between 13.9 and 15.0 kt CO_2/year. Extrapolating this figure to 18,500 production wells suggests that fugitive methane emissions from upstream gas production infrastructure is less than 0.5 per cent of maximum capacity CSG – LNG production in the Surat Basin (Schandl et al., 2019).
- An examination of in situ leaks from well heads and casings over 43 wells in the Surat Basin (Day et al., 2014) found that the mean emission rate was about 7 m^3/day (maximum less than 100 m^3/day) compared to mean gas production per well of 29,600 m^3/day, suggesting that fugitive GHG emissions directly from CSG wells and casings in the Surat Basin, even at a maximum rate, is less than 0.34% of production.
- Detailed 'bottom-up' measurements of fluxes from 67 CSG wells in Queensland and NSW over time showed 88% of the CSG wells monitored produced less than 4.3 kg/day of methane, equivalent to about 30 cows[1]. Median fugitive emissions from all wells was less than 1 kg/day, although the maximum emission rate detected, representing about 1% of wells examined to date, was significantly higher at 63 kg/day. These wells, known as 'super-emitters', have been shown in the US to account for most fugitive methane emissions by the gas industry (Brandt et al., 2014).
- Research has shown that during well 'completion' and 'workover' activities there is greater potential for temporary but significant methane emissions. (Day et al., 2017). Measurements revealed releases of methane lasting for about an hour were nearly 200 kg per well completion. A single well workover, on the other hand, showed that more than 20 tonnes of methane was released during a 24-hour operation (Day et al., 2017). Once the workover procedure was complete, subsequent methane emissions reverted to the median rate of production wells of about 1 kg/day. These well workover fluxes are less than half the 50 tonnes of methane per well released during hydraulic fracturing operations based on estimates for 4000 shale gas wells in the US (O'Sullivan and Paltsev, 2012).



1. A 'standard cow' is based on beef cattle producing 0.17 kg of methane daily per animal.
2. Assumed future production = 576 PJ (100 PJ consumed in Australia and 476 PJ send as feedstock to LNG facility for export as LNG)

CSIRO atmospheric monitoring tower at Ironbark, near Tara (photo: D. Etheridge)

- A study completed for the Commonwealth Government to improve knowledge of fugitive methane emissions estimates from gas wells also included emissions from other gas infrastructure, including water treatment facilities. Fugitive emissions measured from CSG compression plants in Queensland were about 780 kg/day. Measurements taken near CSG water treatment works in NSW showed methane emissions were 18 and 32 kg/day (equivalent to about 200 cows). These emissions were about the same as measurements from an urban sewage treatment plant (about 40 kg/day) and about 20 times less than from a moderate sized urban land-fill in New South Wales (400 kg/day). The methane emissions from the compression plant was about a third the methane emissions from a cattle feedlot (Day et al., 2015).
- Measurements near coal exploration bores drilled between 1960 and 1980 found that a very small number were producing up to 1000 kg/day of methane emissions (equivalent to 5,700 cows). It is possible that these legacy bores have been producing methane for decades. The Queensland Government is undertaking a program to plug leaking boreholes to prevent ignition during bushfire (Queensland Government, 2013).
- In the Surat Basin, natural gas seeps associated with fissures and fractures, where the coal seams approach the surface, have recorded methane fluxes of up to 100 kg/day. It is likely that these vents have been emitting methane at this rate for many millenia.
- Analysis of remote sensing data over the Surat Basin, using data from the satellite-based sensors, has revealed no difference in the average atmospheric methane concentrations between 2001 and 2011 (Day et al., 2015) when compared to the remainder of Australia. CSIRO is also undertaking an analysis of higher precision satellite data to determine whether any methane can be detected by satellites in Queensland and NSW gas production regions (Day et al., 2015).

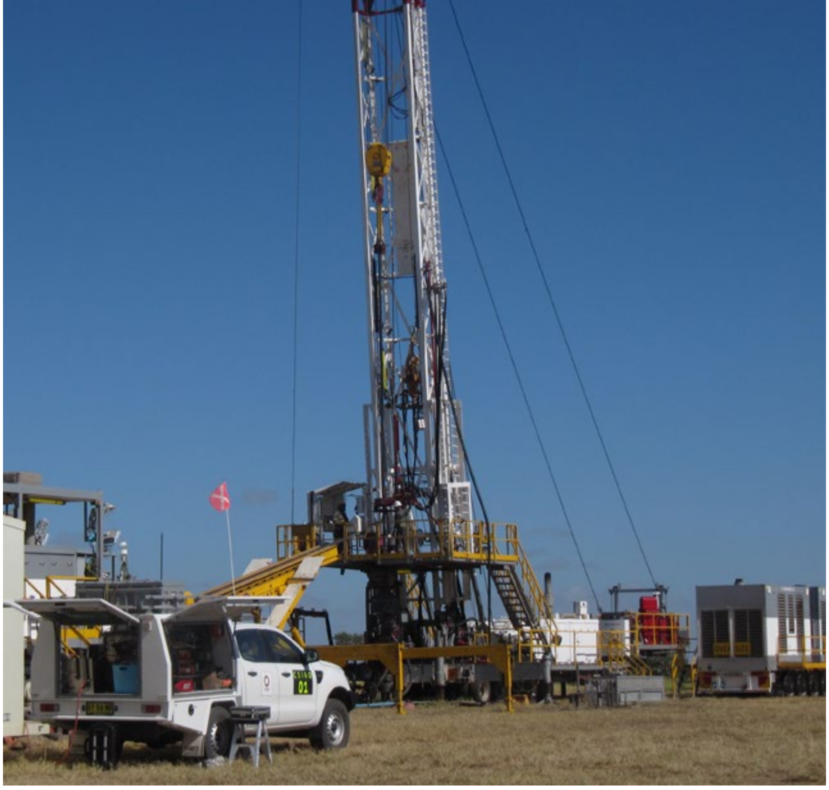
What is research in the United States showing?

Gas production in the US has many differences compared to Australia due to history of gas development, size of the industry, dominance by shale gas over CSG production, differences in environmental regulatory controls and laws governing land owner rights over resources.

US research on fugitive emissions from the petroleum sector has focussed on reconciling different estimates from both national inventories (Environmental Protection Agency data and the Emissions Database for Global Atmospheric Research) and from regional measurement and modelling studies focussed on individual production fields. Recent research on long term trends (2006-2015) in oil and gas methane emissions United States suggest small increases (~3.4% per year) over this period (Lan et al, 2019). Despite regional 'hotspots' of methane emissions in some oil and gas regions, overall US inventory estimates of fugitive emissions are lower than simple extrapolation of these regional studies would suggest (Miller et al., 2013) because these regional discrepancies are not representative of nationwide natural gas leakage rates (Allen et al., 2013). Also, part of the discrepancy may be due to the regional studies not adequately separating background emissions, such as natural seeps of methane, from fugitive emissions (Brandt et al., 2014).

The US Environment Protection Authority has estimated that fugitive methane emissions are 1.4% of US gross national natural gas production (Alvarez et al, 2018). Other estimates using 'top down' comparisons with 'bottom up' inventories suggest this figure may be 2.30 to 2.85% of production (Zavala et al, 2015; Alvarez et al, 2018). However more recent studies (Vaughn et al 2018) have demonstrated that these discrepancies are in part due to (1) failure to account for coincidence of intermittent work-related emission events with 'top down' measurements; (2) inaccuracies in emissions factors associated with high flow events; and (3) under-representation of high emitting sources.

Abandoned wells may also be a source of methane in the US, where 130 years of oil and gas production has led to significant legacy issues from old wells in regions such as the Marcellus Shales in Pennsylvania, which was constructed under less strict environmental regulatory controls than in place in Australia today. Based on measurements of 19 abandoned shale gas wells (Kang et al., 2014), a median methane emissions rate of 0.0013 kg/day was observed (mean = 0.27 kg/day), well below a single cow's daily methane emissions.



CSIRO research provides Queensland-specific results for well completions and well workovers in the Surat Basin

A CSIRO researcher inspects an atmospheric monitoring tower in the Surat Basin (photo: D. Etheridge)

Instrumentation from the top of a CSIRO atmospheric monitoring station

A CSIRO researcher measures fugitive emissions at a CSG well pad. Results from a study of 47 wells in the Surat Basin suggest direct fugitive emissions are less than 0.34% of mean well production

CSIRO methane surveys completed in the Northern Territory provide baseline methane measurements across the dry, fire and wet seasons

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