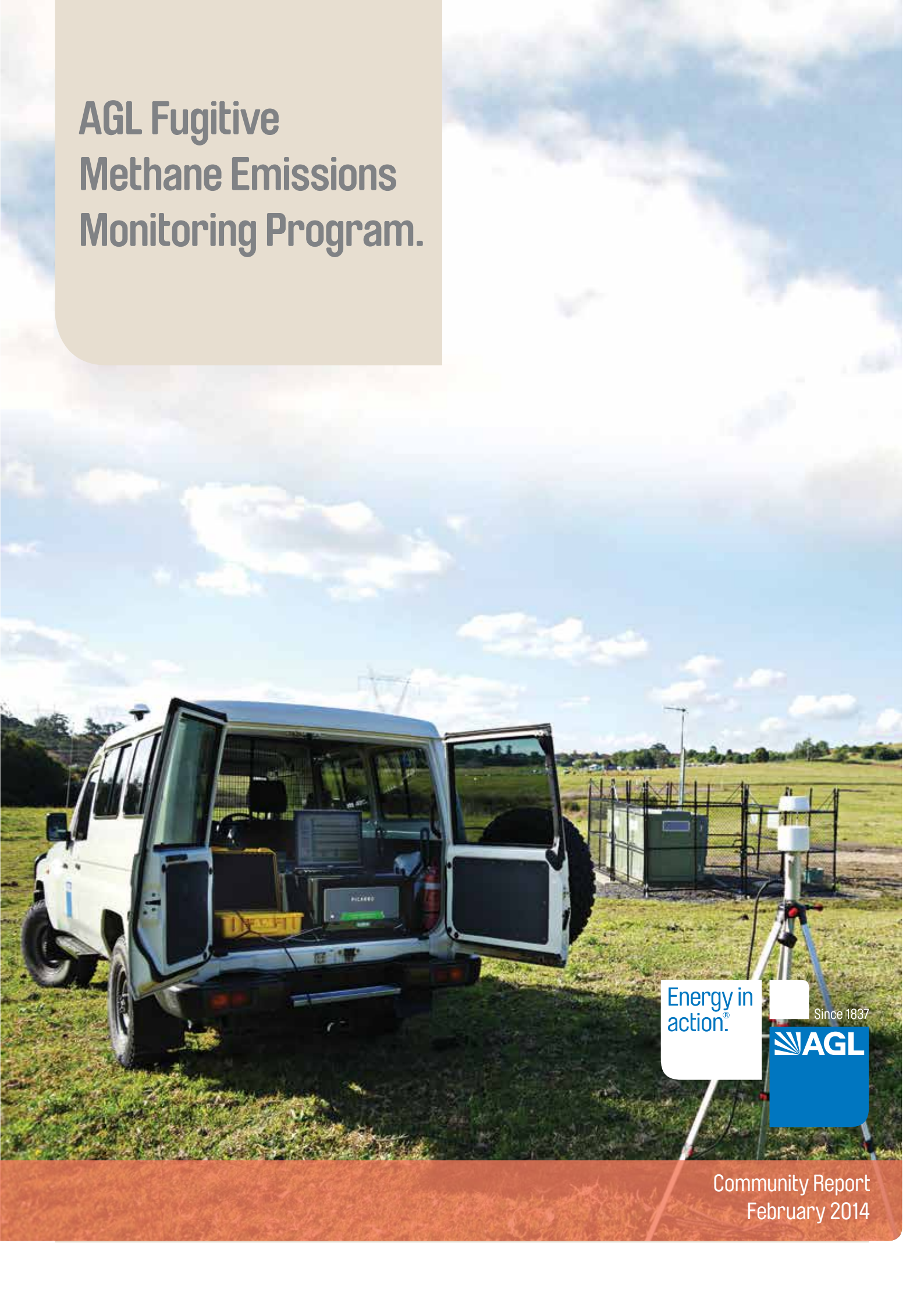


AGL Fugitive Methane Emissions Monitoring Program.



Energy in
action.®

Since 1837

AGL

Community Report
February 2014

Camden Gas Project background.

AGL's Camden Gas Project has been producing natural coal seam gas since 2001. It supplies around five percent of NSW's gas needs, providing families and businesses with an essential energy source for manufacturing, power generation, cooking, heating and providing hot water for baths and showers.

The project includes 144 gas wells, 100km of low-pressure underground gas gathering lines and the Rosalind Park Gas Plant.

AGL works to ensure it makes a valuable contribution to local families, businesses and community groups. Eighty percent of AGL's 60 full time employees at the Camden Gas Project are from the Macarthur region, and 40 percent of its suppliers and contractors are locally-based businesses. AGL invests in local infrastructure and community projects such as the AGL Lakeside Pavilion at the Australian Botanic Gardens, Mount Annan.

Did you know:

- Coal seam gas is natural gas, and Australians use it every day.
- Natural coal seam gas supplies 35 percent of eastern Australia's gas needs.
- AGL's Camden Gas Project supplies five percent of NSW natural gas needs. The remaining 95 percent is sourced from interstate supplies.
- 95 percent of Queensland's natural gas supply comes from coal seam gas.

Sharing the results of AGL's Fugitive Methane Emissions Monitoring Program.

AGL is part of the Macarthur community. We work here, we live here, we employ local people, support local businesses and invest in community initiatives. Our Camden Gas Project is producing safe, natural gas that supplies families and businesses across NSW with a vital source of energy.

AGL is committed to protecting and supporting the Macarthur community. It's important that what we do is safe – for our employees, for the community and for the environment. That's why AGL conducts ongoing monitoring and reporting on our operations and voluntarily invests into research that goes beyond our regulatory requirements. Our latest research project involved measuring fugitive methane emissions in the air across the Camden Gas Project and in surrounding areas with one of the world's best pieces of equipment, the Picarro G2201-i. This is the first study of its kind in NSW.

Representatives from the community and government agencies were involved in identifying the monitoring locations both within the Camden Gas Project and in areas the community uses each day. We kept this Community Consultation Group, the Camden Community Consultative Committee, government and government agencies up to date with our progress throughout the program, and we've also briefed all groups on the study outcomes and sought their feedback. AGL also sought advice on the study from the CSIRO, and its comments have been incorporated into the final report.

The results are provided in the report *AGL Fugitive Methane Emissions Monitoring Program – Technical Report (Pacific Environment Limited) 2014* and explained in this Community Report.

They show that methane concentrations in the Macarthur region are close to global averages and in line with methane concentrations measured in urban areas. This confirms that AGL operates in accordance with best industry practice and that the Macarthur community can confidently live, work and play side by side AGL's activities.

I encourage you to read this Community Report and to please contact us if you have any questions. The technical report can be found at www.agl.com.au/Camden. I'd also like to remind you that we hold regular Open Days at the Camden Gas Project and we would be delighted if you would join us for a tour of our operations. You can call and book on ph (02) 9963 1318. We hope to see you soon.



Mike Moraza
Group General Manager,
Upstream Gas, AGL

Glossary.

Term	Definition
AGL	AGL Upstream Investments Pty Ltd, a wholly owned subsidiary of AGL Energy Limited.
Anthropogenic	Anthropogenic is a term used to describe activities that are human induced (i.e. farming, coal seam gas activities).
Biogenic	Biogenic is a term used to describe substances that are generated through life processes (i.e. produced by living organisms or biological processes).
Camden Gas Project	The Camden Gas Project is located approximately 60 kilometres south west of Sydney. It is 100% owned and operated by AGL and comprises 144 coal seam gas wells, 100km of gas gathering lines, and the Rosalind Park Gas Plant.
Coal seam gas (CSG)	Coal seam gas contains methane that naturally occurs in coal seams below the surface of the earth. Coal seam gas from the Camden Gas Project comprises, on average, 96 percent methane with the remaining 4 percent mainly carbon dioxide and nitrogen.
Fugitive Emissions	Fugitive emissions refer to unintended or irregular gas releases that are not captured or controlled through an emission point such as an exhaust stack or vent.
Isotopic ratio ($^{13}\text{C}-\text{CH}_4$)	$^{13}\text{C}-\text{CH}_4$ is a measure of the stable isotopes of carbon (13C:12C) within the methane sampled.
Isotopic signature	The isotopic signature can be used to analyse $^{13}\text{C}-\text{CH}_4$ measurement and distinguish between different sources of methane in the atmosphere. The Picarro has the ability to differentiate biogenic methane that is generally 'lighter' than thermogenic methane.
Methane (CH_4)	Methane or CH_4 is a naturally occurring gas that is present in the atmosphere at trace concentrations. The global average methane concentration is 1.8 parts per million (ppm) in 2009 ¹ . Methane can also be anthropogenically released through activities such as landfill, agricultural practices (i.e. livestock) and CSG projects. In urban areas, methane concentrations are found to be slightly higher, with observations commonly ranging between 1.8ppm and 3.0 ppm ³ .
Parts per million (ppm)	A measure of very diluted concentrations of substances. Just as percent means out of a hundred, so parts per million, or ppm, means out of a million.
Parts per billion (ppb)	A measure of very diluted concentrations of substances. Just as percent means out of a hundred, so parts per billion, or ppb, means out of a billion.
Picarro	<p>The Picarro G-2201-i Cavity Ring Down Spectrometer (CRDS) uses a near-Infrared laser to measure sample gas passed through an optical measurement cavity. The instrument has an effective path length of up to 20 kilometres inside the cavity, which results in high precision, and low-volume cavity to ensure better temperature stability, faster gas exchange, lower noise and higher sensitivity. The stability of the system means that minimal calibration is required (Picarro, 2012)⁸.</p> <p>The G2201-i is based on Picarro's CRDS technology, but also measures isotopic carbon ratios. Origins of methane (i.e. biogenic and thermogenic) have a characteristic ratio of 13C to 12C. The Picarro G2201-i makes precise 13C/12C ratio measurements that can potentially be used to distinguish between methane from different sources. This capability can be useful in measuring CH_4 in the vicinity of coal seam gas operations. This is since the isotopic carbon ratio of CH_4 generated from, say, cattle, will typically have a different signature from that of fugitive coal seam gas.</p> <p>It should be noted that there are limitations associated with the use of the Picarro equipment and the determination of $^{13}\text{C}-\text{CH}_4$ values. The higher the concentration of CH_4 observed (i.e. the stronger the signal), the more effective the use of $^{13}\text{C}-\text{CH}_4$ as a metric of CH_4 source. Therefore, at low, well mixed CH_4 concentrations (such as those observed during the study period) interpretation of the $^{13}\text{C}-\text{CH}_4$ results are considered indicative.</p>
Thermogenic	Thermogenic is a term used to describe hydrocarbons (i.e. methane) created via the thermal breakdown of heavier hydrocarbons under high temperature/pressure conditions. Such conditions occur where hydrocarbons are buried deep below the surface of the earth (i.e. due to the breakdown of fossil fuels), and may be taken as meaning 'associated with coal seam gas' in the context of this report.

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AGL would like to acknowledge and thank the following groups and organisations:

- **NSW Department of Planning and Infrastructure, NSW Environment Protection Authority, NSW Chief Scientist & Engineer's Office** for providing feedback during development of the study scope and methodology.
- **Community Consultation Group** for providing feedback on preferred site monitoring locations and effective ways to communicate the report findings to the Macarthur community.
- **Commonwealth Scientific and Industrial Research Organisation (CSIRO)** for providing feedback on the study methodology and reviewing the Technical Report.

Quick guide

- 12 week program to measure methane levels in the air.
- Ran from 29 April 2013 to 17 July 2013.
- Completed by air quality specialists, Pacific Environment.
- 20 locations within the Camden Gas Project area.
- Five background locations outside the Camden Gas Project area.
- Air readings taken weekly at different times of day and night.
- 75 hours of methane concentration and isotopic ratio measurements recorded.
- Over the 12 week monitoring program the average methane concentration was 2.1 ppm.
- **This value is just above the global average of 1.8 ppm² and in line with methane concentrations measured in urban areas commonly ranging between 1.8 ppm and 3.0 ppm.³**

Why undertake a fugitive methane emissions study?

It's our responsibility – to the community, our employees, our shareholders and other stakeholders like the NSW Government – to ensure our operations are consistently operating in accordance with best practice. It's important to us that the community recognises AGL operates to rigorous safety and environment standards.

So when the Macarthur community told us there was concern about fugitive methane emissions, and whilst fugitive emissions monitoring is not a regulatory requirement, we knew we needed to provide solid data and research to assure you our operations are to industry best practice.

The 12 week fugitive methane emissions monitoring program aimed to find out the concentration of methane that is typically experienced at 25 locations within and around the Camden Gas Project. In consultation with the community, 20 sites within the Camden Gas Project and five background locations were selected. These sites were monitored for an aggregate period of 15 minutes each week, where readings of methane concentration and the isotopic ratio were recorded.

The study was undertaken by external air quality specialists, Pacific Environment. AGL purchased one of the world's best pieces of measuring equipment, the Picarro G-2201-i Cavity Ring Down Spectrometer (the Picarro), to be used in the study.

This study is considered to represent an indicative screening analysis of the current conditions in the vicinity of the Camden Gas Project.

What are fugitive emissions?

Fugitive emissions refer to unintended or irregular gas releases that are not captured or controlled through an emission point such as an exhaust stack or vent. Emissions from livestock and wetlands are considered fugitive emissions as they are not captured first, while emissions from a compressor engine exhaust stack is considered a point source, as the emission is planned and controlled. In relation to AGL's Camden Gas Project, fugitive methane emissions are commonly considered those that are due to leaks and pressure release valves (essentially a designed leak).



AGL staff working with landowners

What is methane (CH_4) and isotopic ratios ($^{13}\text{C}-\text{CH}_4$)?

Methane is a naturally occurring gas that is present in the atmosphere in low concentrations. It's non-toxic and has no known health effects at the concentrations typically experienced in the environment. Some natural sources of methane are wetlands, oceans and animals. Man-made sources include agricultural operations, landfill and wastewater treatment, rice paddies and oil and gas production.

The coal seam gas from the Camden Gas Project comprises, on average, 96 percent methane with the remaining 4 percent mainly carbon dioxide and nitrogen, which is why the study focuses on methane emissions.

An isotopic ratio ($\delta^{13}\text{C}-\text{CH}_4$) is a methane sources' unique signature. The isotopic ratio can be used to analyse methane measurements and distinguish between different sources of methane in the atmosphere.

By using sensitive measurement equipment, like the Picarro, the study could determine the methane from the Camden Gas Project had a different identity – or isotopic ratio – to methane from other sources, such as the local landfill or agriculture. This gave an indication of the most likely source of the methane. The Picarro is a laboratory-grade analyser, able to detect changes in methane at concentrations in the parts per billion (ppb) range (where 1ppb is equal to 0.001 ppm).

Sources of methane.

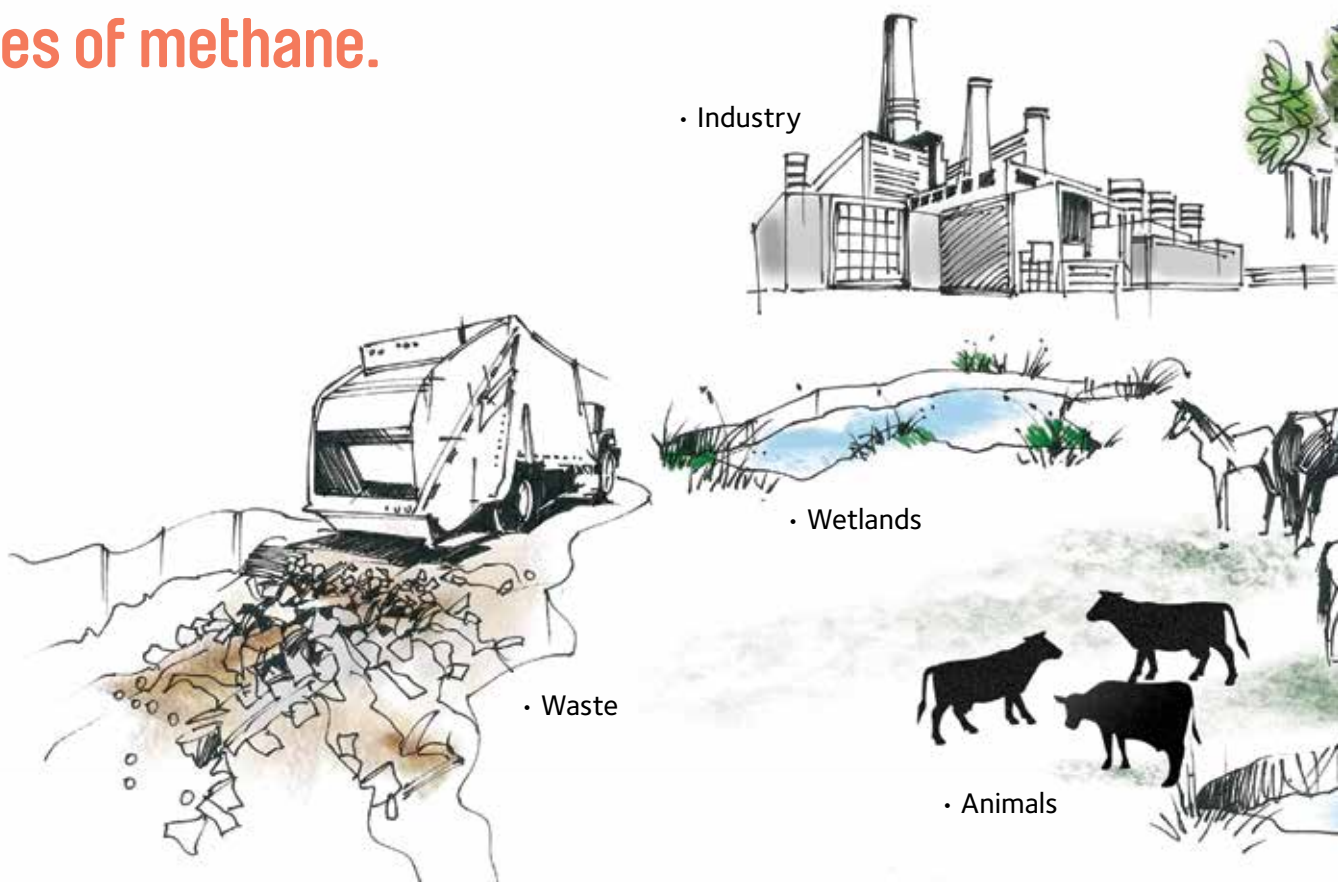


Table I: Isotopic ratio of common methane sources.^{1,4}

Source	$\delta^{13}\text{C}-\text{CH}_4$ (‰)
Natural sources	
Wetlands (swamps)	-55±3
Wetlands (bogs and tundra)	-65±5
Oceans	-59
Mud volcanoes	-40
Termites	-57
Wild animals	-62
Anthropogenic sources	
Biomass burning (C4 vegetation)	-17±3
Biomass burning (C3 vegetation)	-26±3
Enteric fermentation (C4 vegetation)	-49±4
Enteric fermentation (C3 vegetation)	-70±4
Landfill	-53±2
Domestic sewage	-57±3
Rice paddies	-62±3
Coal extraction	-35±3
Gas extraction (North Sea)	-34±3
Gas extraction (Siberia)	-50±3
Residential	-38



• Residential

• Rice paddies

• Oceans

Is methane safe?

Methane is a non-toxic, naturally occurring gas.

The global average methane concentration is 1.8 ppm¹. Whilst methane is non-toxic, at 500,000 ppm methane becomes unsafe for human health. This is because the amount of methane would displace oxygen, making it very difficult to breathe. This concentration is highly unlikely to occur in open air, but may occur in a confined space where there is a significant methane source.

Internationally, the (United States) National Institute for Occupational Safety and Health (NIOSH) references a maximum recommended safe methane concentration for workers during an eight hour period (referred to as a Threshold Limit Value, or TLV) of 1,000 ppm⁶.

- The coal seam gas from the Camden Gas Project is 96 percent methane.
- The global average methane concentration is currently 1.8 ppm.
- In urban areas, methane concentrations are generally slightly higher, commonly ranging between 1.8 ppm and 3.0 ppm³.

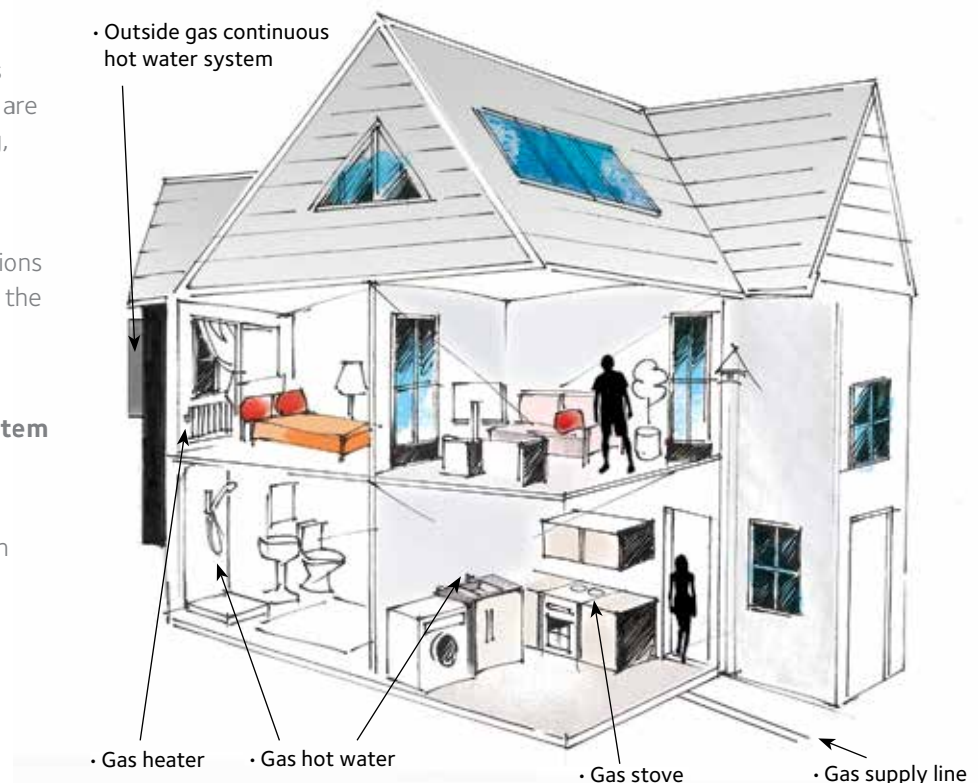
How do we use methane in our homes?

Coal seam gas is natural gas, and Australians use it every day in their homes. Typical uses are for heating water for bathing and showering, providing warmth through gas heaters and energy for cooking.

Methane was monitored from several emissions points around a typical household located in the Macarthur region.

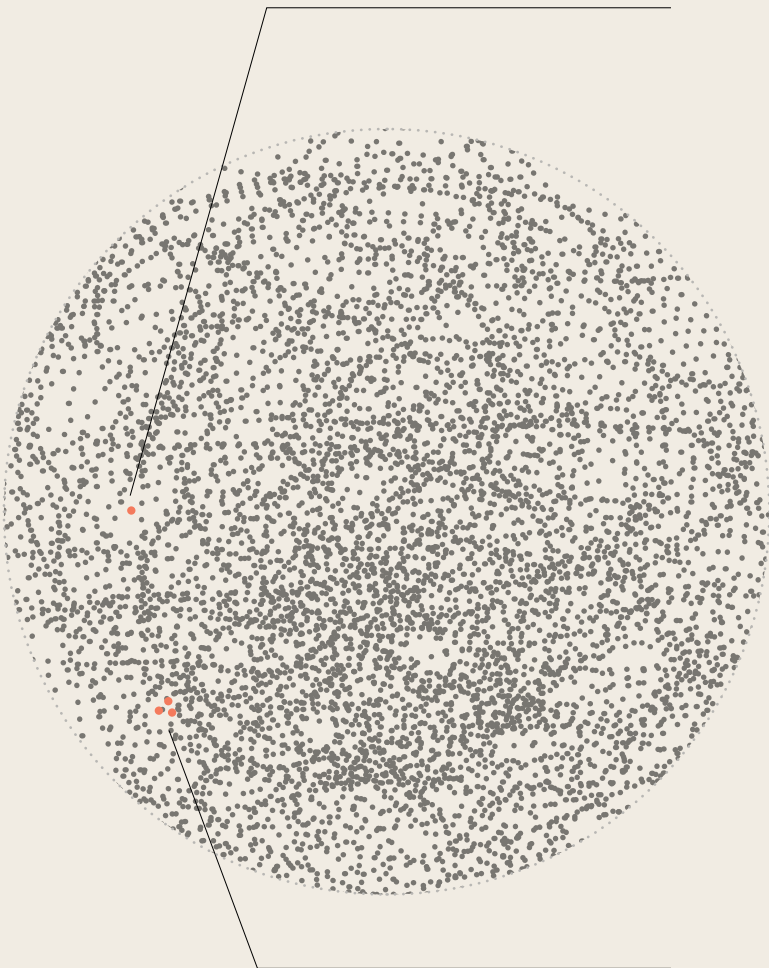
Approximate readings at these sources are:

- **Outside gas continuous hot water system** – 100cm from vent 9-10.0 ppm
- **Gas heater** – 50cm from vent 2.4 ppm
- **Gas stove** – 50cm from cooker 10.2 ppm



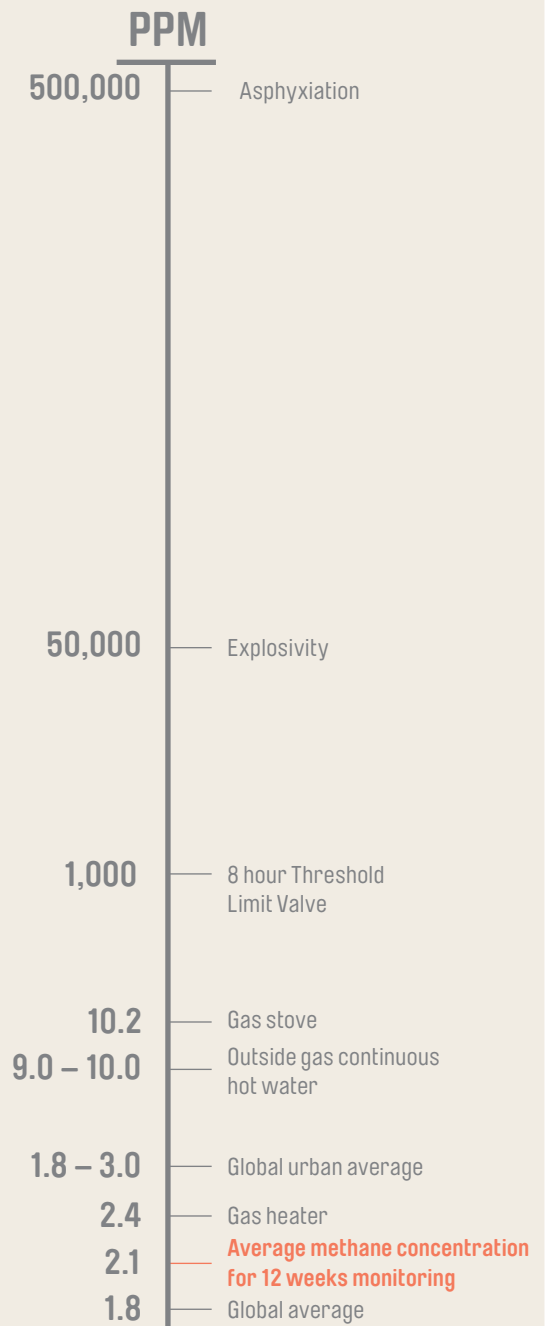
What does parts per million look like?

The global average methane concentration is 1.8 ppm.



In urban areas, methane concentrations are generally slightly higher commonly ranging between 1.8 ppm and 3.0 ppm³.

Monitoring result in comparison to other methane concentration.



Not to scale

AGL consulted with key stakeholders in developing the study.

- NSW Department of Planning and Infrastructure (DP&I)
- NSW Environment Protection Authority (EPA)
- NSW Chief Scientist and Engineer's Office
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Community Consultation Group

The fugitive methane emission monitoring program.

The AGL Fugitive Methane Emissions Monitoring Program ran for 12 weeks from 29 April 2013 to 17 July 2013.

Each week, representatives from air quality specialists Pacific Environment monitored at each of the 25 locations for 15 minutes. To cover all 25 sites, the monitoring was completed over two weekdays per week on different days and times of day to ensure that the potential for systematic bias in the sampling did not occur. Additional night time monitoring was also completed to identify if there were diurnal changes in the methane. Over the duration of the 12 week monitoring period, 75 hours of one second measurements of methane concentration and isotopic ratio were recorded.

Monitoring locations.

How were the monitoring locations chosen?

Each monitoring site was selected to ensure it was representative of the geographical area and met good sampling practices as per those described in Australian Standard AS/NZS 3580.1.1: 2007 *Methods for the Sampling of Ambient Air – Part 1.1: Guide to siting air monitoring equipment*.

The selected monitoring sites within the Camden Gas Project boundary are located within reasonable proximity to a Camden Gas Project well site with consideration given to where the nearest potential sensitive receptor (e.g. residence, business, school, retirement village, recreation areas, etc.) is located. That is where the community works, lives and plays.

Locating the monitoring sites near wells allowed for potential fugitive methane emissions to be captured in the data that was gathered. The background monitoring locations were selected using the criteria that each site be located at least two kilometres from the nearest well site and be representative of air quality that would be experienced in the Macarthur region.

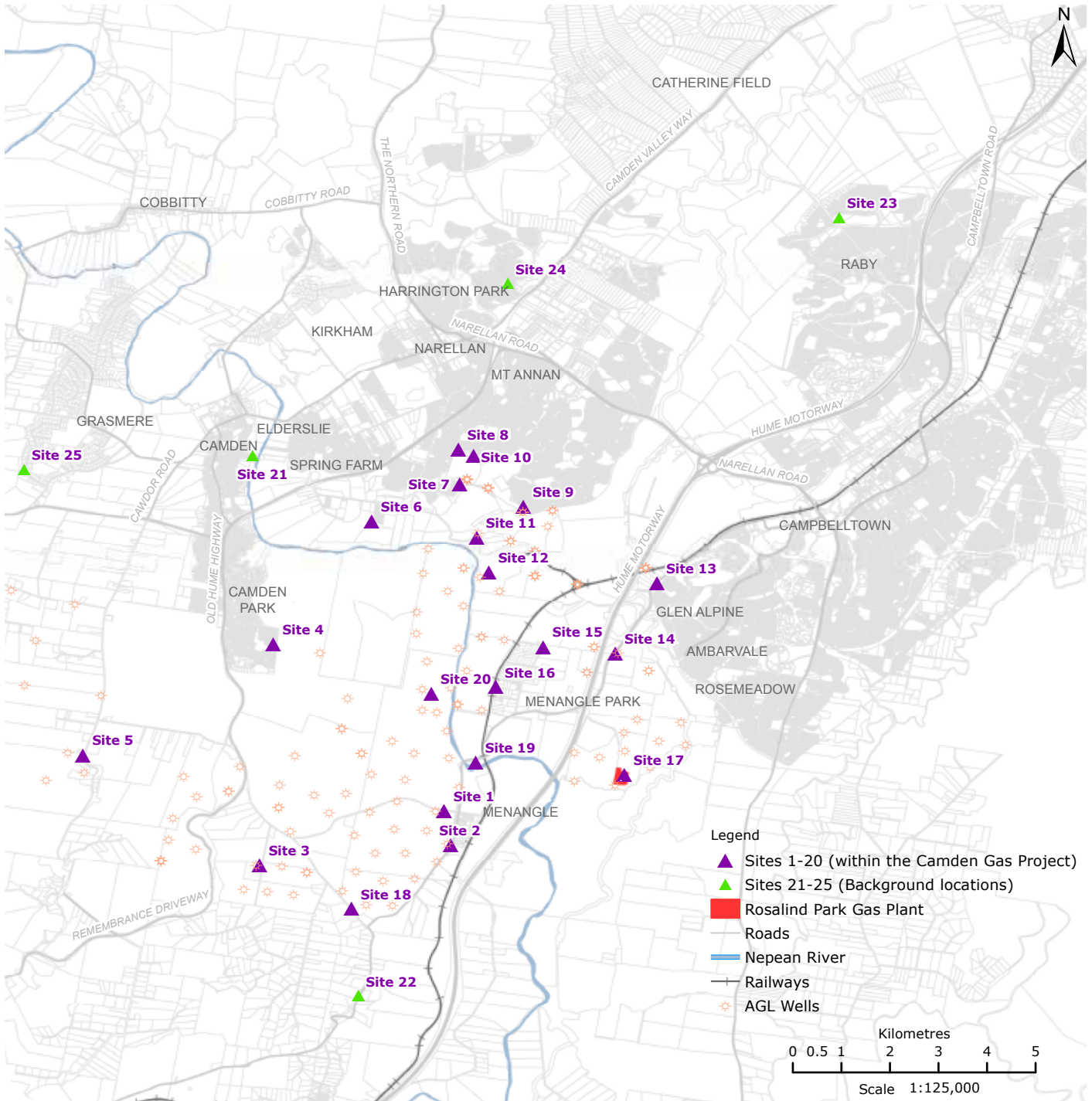
It was also important for AGL to engage with the Macarthur community. Before the monitoring program started, AGL met with a wide range of community members – the Community Consultation Group – representing local families, government and industry to brief them on the program and gain input into the number of monitoring sites and their locations. These representatives asked for additional monitoring sites, and so the number increased from 17 to 25 at the community's request.

The selection also covered varying land uses to ensure a range of potential sources of fugitive methane emissions were included – for example, agriculture, urban and industry.

Table II: Description of monitoring locations

Site number	Site description	Purpose	Distance to nearest well (km)	Distance to Rosalind Park Gas Plant (km)
Site 1	Woodbridge Road, Menangle	Camden Gas Project	0.2	3.1
Site 2	Menangle Road, Menangle	Camden Gas Project	0.1	3.2
Site 3	Dawson Road, Menangle	Camden Gas Project	0.1	6.4
Site 4	Macarthur Circuit, Camden Park	Camden Gas Project	0.8	6.5
Site 5	Old Razorback Road, Cawdor	Camden Gas Project	0.3	9.1
Site 6	Spring Farm Drive, Spring Farm	Camden Gas Project	1.1	6.8
Site 7	Holland Drive, Spring Farm	Camden Gas Project	0.2	6.7
Site 8	Welling Drive, Narellan Vale	Camden Gas Project	0.6	7.4
Site 9	Alchornea Circuit, Mt Anan	Camden Gas Project	0.1	5.9
Site 10	Mary Howe Reserve, Narellan Vale	Camden Gas Project	0.5	7.2
Site 11	Glenlee Road, Glenlee (Landfill)	Camden Gas Project	0.1	5.6
Site 12	Glenlee Road, Glenlee (Coal washery)	Camden Gas Project	0.2	4.9
Site 13	Menangle Road, Glen Alpine	Camden Gas Project	0.4	4.1
Site 14	Menangle Road, Menangle Park	Camden Gas Project	0.1	2.6
Site 15	Fitzpatrick Street, Menangle Park	Camden Gas Project	0.7	3.1
Site 16	Menangle Park Station, Menangle Park	Camden Gas Project	0.5	2.9
Site 17	AGL Rosalind Park Gas Plant, Menangle	Camden Gas Project	0.2	0.2
Site 18	Finns Road, Menangle	Camden Gas Project	0.3	5.3
Site 19	Nepean River, Menangle	Camden Gas Project	0.5	2.5
Site 20	Elizabeth Macarthur Agricultural Institute, Menangle	Camden Gas Project	0.2	3.7
Site 21	Chellaston Street, Camden	Background	3.5	9.2
Site 22	Menangle Road, Douglas Park	Background	2.0	6.3
Site 23	Raby Road sports field, Raby	Background	7.6	12.2
Site 24	Harrison Reserve, Harrington Park	Background	4.6	10.4
Site 25	Benwerrin Reserve, Grassmere	Background	2.5	12.1

Monitoring locations.



Measurement and analysis with the Picarro.

The Picarro is one of the world's best air quality measurement and analysis instruments. Its monitoring system has been configured for field monitoring, measuring methane concentration and isotopic ratios, as well as wind speed, wind direction and GPS coordinates. AGL purchased the Picarro specifically for this fugitive methane emissions study.

The system components were housed within an AGL Toyota Landcruiser Troop Carrier which was redesigned to meet the recommendations of the Picarro Mobile Kit User's Guide.⁸

A weather station, placed outside the Landcruiser, provided data including wind speed and wind direction in addition to data received via the GPS receiver mounted on the vehicle which measured GPS coordinates. This information can be measured simultaneously with the methane concentrations and assist in determining the source of potential fugitive emissions measured (e.g. from a gas well). For example, if a spike in methane concentration is observed, it is possible to look at what activities were upwind at the time, to help identify the source. Looking at the wind speed and direction can also be useful in discounting known fugitive emission sources and identifying new ones based on the prevailing wind direction.

The Picarro analysed the samples over a 15 minute monitoring period at each monitoring location to measure the methane concentrations and corresponding isotopic ratio.

The Picarro has been used in other studies overseas⁷ and in Australia as outlined in the *Initial report on the Independent Review of Coal Seam Gas Activities in NSW*.⁹



Picarro monitoring equipment.

What are the results?

- The methane concentrations measured in the study area are considered to be close to the global average background concentrations².
- Over the 12 week monitoring program the average methane concentration was 2.1 ppm. This value is just above the global average of 1.8 ppm² and in line with methane concentrations measured in urban areas commonly ranging between 1.8 ppm and 3.0 ppm³.
- The range of 15-minute average data was between 1.7ppm and 16.6ppm with a maximum one second methane concentration of 23.2ppm for the monitoring period.
- Review of the data for monitoring sites located in close proximity to AGL gas wells does not indicate significant fugitive methane emissions were present during the monitoring period.
- The highest methane concentrations were observed at Site 11, adjacent to the landfill. Findings indicate that the landfill is possibly a contributor to fugitive methane emissions in the study area.
- The coal washery was not shown to be a source of fugitive methane emissions in the study area, assumed to be due to the age of the coal.
- Elevated methane concentrations were also measured at Site 17, the closest monitoring site to the Rosalind Park Gas Plant. The Rosalind Park Gas Plant comprises a number of pressure relief valves and regulators that are designed to periodically release coal seam gas. It is therefore expected that somewhat elevated methane concentrations may be found at this location.
- Based on the low concentrations of methane observed, it is not possible to draw clear conclusions as to the contribution of agriculturally sourced methane in the study area.
- The background methane concentrations also fall within reasonable approximation of the global average² with 15-minute average concentrations, with the average concentration for sites 21-25 across the 12 week monitoring period being 2.0 ppm.
- When sites potentially influenced by fugitive emissions from landfill are removed from the dataset, the statistical analysis showed no significant difference between those methane concentrations measured inside of the Camden Gas Project and those located outside (i.e. background locations).
- Methane concentrations in urban areas were observed to be 0.2 ppm higher than those measured in rural areas. Statistical analysis of the data gathered within this study supports these findings. Reference to scientific literature also indicates that methane concentrations are typically higher in urban areas ^{7,3}.

Table III: Summary of 15 minute data by site

Monitoring site	Average	Minimum	Maximum
Site 1	2.1	1.8	3.3
Site 2	2.0	1.8	2.9
Site 3	1.9	1.7	2.6
Site 4	1.9	1.7	2.8
Site 5	1.8	1.7	2.2
Site 6	2.0	1.7	2.5
Site 7	2.0	1.8	2.7
Site 8	2.0	1.7	2.9
Site 9	2.4	1.7	4.2
Site 10	2.1	1.8	3.5
Site 11	3.8	1.8	16.6
Site 12	2.0	1.7	2.7
Site 13	2.2	1.7	3.2
Site 14	2.0	1.7	2.5
Site 15	2.0	1.7	2.8
Site 16	2.0	1.7	2.4
Site 17	2.2	1.7	3.5
Site 18	1.9	1.7	2.8
Site 19	2.1	1.7	3.1
Site 20	2.1	1.7	3.0
Site 21	1.9	1.7	2.5
Site 22	2.0	1.7	2.6
Site 23	2.1	1.7	2.9
Site 24	2.3	1.8	4.7
Site 25	1.9	1.7	2.5

What other testing does AGL do for fugitive methane emissions?

AGL also operates a Leak Detection And Repair Program which includes an annual leak detection survey conducted by external specialist consultants.

The leak detection survey is conducted at each well location of the Camden Gas Project as well as along the entire length (approximately 100 kilometres) of gas gathering lines and the Rosalind Park Gas Plant. Any identified leaks are repaired within a prescribed timeframe and the findings are reported to the NSW Environment Protection Authority.



Camden Gas Project coexisting with the community

Summary.

It is AGL's responsibility to the community, our employees, our shareholders and other stakeholders, like the NSW Government, to ensure our operations are consistently operating at best practice. It's important to us that the community recognises AGL operates to rigorous safety and environment standards and in accordance with applicable legislative requirements.

So when the Macarthur community told us there was concern about fugitive methane emissions, we knew we needed to provide solid data and research to assure the community we operate in accordance with best practice.

AGL's Fugitive Methane Emissions Monitoring Program provided a detailed 12 week study that measured methane levels across changing meteorological conditions and time of day, and accounted for the influence of other common sources of methane in the study area. This is the first study of its kind in NSW.

Over the 12 week monitoring program the average methane concentration was 2.1 ppm. This value is just above the global average of 1.8 ppm² and in line with methane concentrations measured in urban areas commonly ranging between 1.8 and 3.0 ppm.³

The range of 15-minute average data was between 1.7ppm and 16.6ppm with a maximum 1 second CH₄ concentration of 23.2ppm for the period.

Review of the data for monitoring sites located in close proximity to AGL gas wells does not indicate significant fugitive methane emissions were present during the monitoring period.

Throughout the study we ensured the Community Consultation Group, the Camden Community Consultative Committee, government and government agencies were up to date with our progress, and we've also briefed all groups on the study outcomes and sought their feedback. AGL has also shared the results of the study with the CSIRO. AGL has consulted with the CSIRO during the study and taken their comments into account during the development of the monitoring programs methodology and technical report.

AGL understands that fugitive methane emissions are an important issue for the community and will continue consultation with the community as future studies are developed and completed.

-
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