White Paper

Emissions Measurement

An Innovative Approach Included in P-Cubed® Rev. 6.4

Methane emissions are at the center of the current climate crisis due to methane's outsized contribution to global warming. Methane is one of the most potent greenhouse gases, being approximately 86 times more negatively impactful on climate change than carbon dioxide within the first 20 years in the atmosphere. It represents as much as 25% of the historic warming that can be attributed to human activities and is considered the greenhouse gas most responsible for driving warming in the near-term. Methane also represents a great opportunity for countries across the globe to drastically reduce their overall carbon footprint. This opportunity is owed to the fact that much of the methane that enters our atmosphere is from sources that may be mitigated effectively. Further, due to methane's short lifespan in the atmosphere (just 12-15 years versus >100 years for carbon dioxide), meaningful reduction in atmospheric greenhouse gases may be realized within a single generation. With the proper protocols and technology, mankind can win the fight against fugitive methane emissions and thus drastically affect the warming trend of our planet. Methane emissions reporting and reduction is the single greatest lever that may be pulled today to slow down the warming of the planet, and Picarro has the reporting application that should be the bedrock of every utility's emissions management and reporting process.

The Emissions Measurement application provides a necessary solution to the difficult problem of generating a complete and accurate inventory of a gas distribution company's total emissions across their geographies and over time. This innovative application hosted on the P-Cubed® analytics platform creates a measurement-based emission factor inventory which represents a substantially more accurate record of total emissions. Without understanding total methane emissions on a utility network it becomes very challenging to undertake a meaningful emissions reduction program – if you haven't measured your network emissions it is hard to know where to begin in reducing them. A utility can use the application to efficiently monitor, quantify, and report their emissions and their emissions reductions year over year and by geography. This paper will summarize the necessary steps to achieve a viable methane emissions

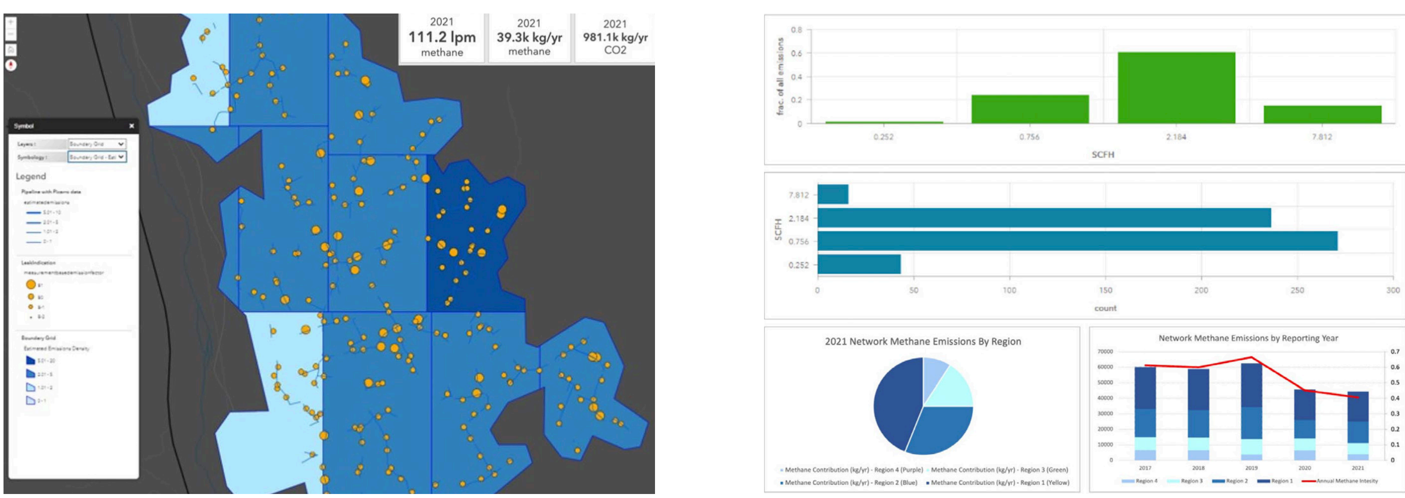

Figure 1. Emissions-related data can be operationalized rapidly using performance dashboards. This dashboard includes information on total network emissions, emissions trends over time, emission intensities, measurement-based emission factors, and specific emission point sources.

management and reporting system, step by step, and provide information on how Picarro technologies can deliver a robust emissions reporting system.

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Enabling ESG Goals

In considering fugitive methane emissions from industry, it is important to highlight that the entire value chain of natural gas – upstream, midstream, downstream, and distribution – are receiving a mandate to accurately measure and report their emissions. Further, they must produce and implement a plan to meaningfully reduce their emissions over time. This mandate comes from global trade organizations, governments, regulators, communities, shareholders, and financial markets. Reducing methane emissions is a major environmental, social, and governance (ESG) goal for many companies today, and those companies who are performing against these methane emissions reduction KPIs are finding better funding, being lauded by the public, and are likely outperforming the market. Distribution System Operators (DSOs) managing national, regional, and even local distribution networks are no exception to the mandate, and are, in fact, critical to helping the broader oil and gas industry reduce methane emissions in an impactful way, as distribution represents a meaningful percentage of total emissions for the industry in the US. Finally, there is a significant opportunity around implementing effective emissions management and reduction programs, which help operators to achieve improved safety results, reduce operational impacts on the environment, boost capital efficiency, and transform gas networks in order to achieve net zero operations, paving the way for sustainable and safer natural gas distribution in the future.

Key to understanding and tackling the methane emissions problem is to identify, measure, quantify, and finally, reduce, the methane emissions from our business activities. Firstly, we know that some emissions are the inevitable outcome of natural gas systems and processes; it is critical to identify these sources so that they may later be mitigated or offset. Design-based sources include things like flares or over-pressure vents that are part of the natural gas processing and transportation value chain. The real culprit in methane emissions' impact on global warming are the unexpected or fugitive emissions; these emissions are not inherent to the natural gas system design and are therefore not only hugely negative to the environment, but also represent lost revenue and profit. Fugitive emissions are a major contributor to overall DSO emissions globally. Examples of fugitive emissions include leaks in our pipelines, a faulty valve, or an inefficient flare.

Effectively Mitigating and Reducing Emissions

Identifying and measuring fugitive leaks is the first step to mitigating or reducing emissions. It can be very challenging to account for fugitive emissions in a distribution network which may contain millions of pipe segments and other assets representing potential point emitters. There are many technologies on the market today that can identify leaking infrastructure, these include handheld devices, advanced mobile leak detection solutions (vehicle- and drone-based), aerial methods (LIDAR), continuous monitoring sensors, and satellite. Not all technologies are up to the task for measuring and reducing emissions on a natural gas distribution system; a good measure of suitability for use on distribution networks is the minimum detection limit (MDL) as compared to the lognormal emissions rate versus cumulative leak distribution curve. As evidenced in Figure 2, the very skewed nature of the plot means that

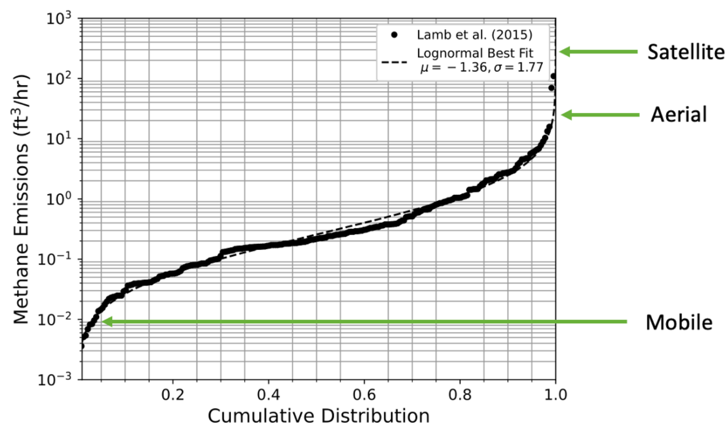

Figure 2. Graph showing methane emission versus cumulative distribution including a representation of what portion of the curve is visible to various technologies by MDL. AMLD is the only technology sensitive enough to measure the entirety of a distribution network.

very few leaks comprise a large percentage of total emissions (i.e. <10% of total leaks may comprise 40-50% of total emissions). Unfortunately, many technologies simply don't have a low enough MDL to see the vast majority of leaks on a distribution network; in some cases their "blind-spot" includes even large leaks of >10-20 scfh, and if the technology cannot measure the leak because it exists below its minimum detection limit, then the operator cannot know to go and mitigate it, resulting in both a less-safe network and a lost emissions reduction opportunity. In order to accurately report baseline emissions and promote meaningful emissions reduction efforts, it is important to be able to measure leaks of all sizes contained in the network. In the Highwood Emissions Management technical report, "Leak detection methods for natural gas gathering, transmission, and distribution pipelines" [1], the firm seeks to compare various technologies in order to provide some direction for operators interested in utilizing them for emissions measurement, reporting, and abatement programs. Using this report and other industry evidence one could conclude:

- **Handhelds –** generally not sensitive enough and too slow (not scalable for entire network measurement in meaningful timeframe), poor find rate
- **Satellites –** poor spatial resolution, ultra-high MDL
- **Aerial-based LIDAR –** expensive to deploy, weather-dependent, may not be able to gain access to all areas (FAA regulations, no-fly zones, etc), high MDL
- **Drones –** good for specific use cases (mainly upstream and downstream processing, potential for midstream), high operating costs, limited range
- **Vehicle-based AMLD –** Very low MDL (down to .01 SCFH utilizing PPB sensor), scalable to entire network, cost effective

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Clearly, vehicle-based AMLD may be the most powerful way to gather the emissions data necessary to compute a network-wide, measurement-based emissions estimate. Picarro's AMLD is a proven technology and methodology which is used for compliance leak survey in 10 US states and has been adopted by 30+ customers from around the globe. Now with Picarro's Advanced Leak Detection 4th generation (ALD 4.0) algorithm, customers can expect unrivaled performance with >90% leak find rate, <10% false positives, and >90% field of view. Further, Picarro's flow rate estimate accuracy has been validated over eight years through multiple controlled-release studies with operators, as well as being leverage extensively in production workflows around the world. Using Picarro's AMLD, a local distribution company can cover the entirety of their network annually, with high accuracy of the measured methane concentrations, a clear understanding of what assets are leaking, and the ability to clearly report on changes in their network performance over time and with meaningful granularity.

After a leak is detected, it must be measured, and that is where the sensitivity and accuracy of the technology really begins to matter. Accurately measuring the leak is the critical process that allows us to later quantify the emissions at the site or on the individual asset. Along with being able to accurately measure leaks, it is very important to have enough coverage of the infrastructure in

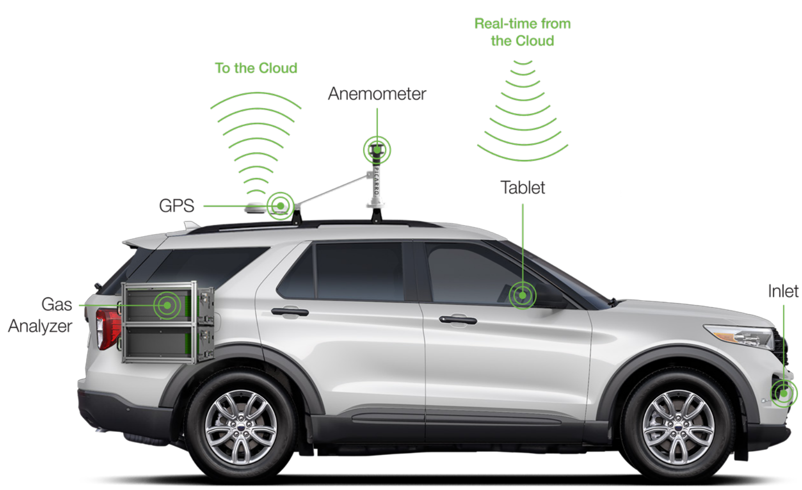

Figure 3. The Picarro AMLD solution showing the various components, including industry-leading minimum detection limit (MDL) methane-ethane sensors, which allow Picarro to identify, measure, and quantify fugitive methane leaks and emissions.

order to truly understand how leaky it is (how great is the fugitive emissions problem). This need for accuracy and efficiency (scalability) is the ultimate arbiter of technology in the quest to accurately quantify emissions at a large scale. Looking forward, suitable technologies underpinning an emissions reporting and reduction program must be measurement-based and enable operators to detect their leaks, measure those leaks, and quantify the emissions represented by those leaks in an operationally-effective and scalable way.

Quantification of Leak Flow Rates

Following the identification and measurement of leaks found on a distribution network, there are a variety of potential methods to choose from in order to quantify the leak flow rate. These methods range from direct measurement of the flow of gas from the ground, to calculating flow from concentration in the air, all the way to optical imaging techniques attempting to quantify methane emissions based on plume volume and spectral absorption. Once a DSO has the flow rates of individual leaks in hand, the next step is to increase scale up to site-level, geography-level, and ultimately network-level in order to produce an organization-scale quantification of methane emissions. Traditionally, network-scale quantification could be accomplished in two ways; both methods are estimates and neither are particularly accurate. First, a top-down estimate is generally accomplished by aggregating measurements (or a combination of measurements and emission factors) for large-scale geographic units, such as an entire town, city, or region. Often these sorts of estimates miss emission events that are non-continuous, potentially includes methane sources which are not cogent to the calculation (i.e. gas from another operator, a dairy farm, or similarly misappropriated gas), and doesn't generally offer actionable insights that an operator may use to improve their network performance due to the scale of visibility or measurement. Second, a bottom-up estimate takes measurements or emission factors for small-scale assets, such as pumps, pipes, meter sets, etc., and then adds them together to produce a total emissions volume. This method struggles due to the generic nature of emission factors, inaccuracy in the measurement of methane emissions below the site or asset level, the difficulty in measuring large geographies in a timely manner, and the error creep associated with the additive process used to quantify the total network emissions. It should be noted that the vast majority of current coefficient-based bottom-up methodologies are not based on direct measurements.

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They do not accurately represent true emissions and do not locate nor quantify individual emitters (limiting their usefulness in leak abatement and emissions reduction); therefore, they are not particularly suitable for meaningful emissions reporting or emissions reduction programs.

Leveraging Machine Learning to Accelerate Measurement

In 2022 Picarro is taking a massive step forward in helping the oil and gas industry reduce emissions by releasing the Network Emissions Measurement application for the P-Cubed® platform. Powered by the new 3rd generation Emissions Quantification (EQ) algorithm, Emissions Measurement allows for a top-down emissions estimate that is based on true measurements from point sources, similar to a bottom-up calculation. It uses a unique leak-based, time-averaged approach which has been commercially proven with more than four years of successful implementation. Using Emissions Measurement, operators will be able to build a full inventory of network emissions sources, ranked and binned from .01 SCFH up to 100+ SCFH. The application outputs measurement-based emission factors which are calibrated and optimized for each operator, an enormous step-change over generic emission factors which may be unrepresentative of specific assets. Our protocols and methodology fully support the existing and upcoming voluntary methane emissions reporting schemas, including OGMP 2.0, Project Veritas, NGSI, Marcogaz, and OneFuture. Finally, Emissions Measurement is already used by multiple distributors to report emissions and drive emissions reduction efforts; these operators include Italgas and PG&E, with many others also moving to adopt this technology in 2022.

To power our emissions measurement and reduction efforts we are introducing several GISbased visualization tools. The first tool being released in 2022 is the Network Assessment Viewer (NAV). The NAV is an intuitive and interactive representation of all measured methane sources and their associated emissions in a DSO network. It computes leak and emissions densities and total methane emissions for pipe assets. It further aggregates this data to different geospatial (zoom) levels, from local, to regional, up to total network scale. The NAV will power multiple applications, including emissions measurement and reporting. In development are a suite of dashboards that will allow operators to track their emissions across regions and over time. Later in 2022 Picarro will expand the measurement and reporting concept to all operator assets and sources of emissions, leading to a comprehensive emissions reporting engine.

Figure 4. The NAV image shown represents a plot of emissions density versus leak density with high-emitting point sources and pipeline segments overlain. The NAV allows for rapid analysis of complex data in order to make empowered decisions regarding network infrastructure.

Outlining a Clear Pathway for Emissions Reduction

If a distribution network can be surveyed every year, as multiple operators are doing today with Picarro, it is possible to accomplish a full-scale, enterprise emissions quantification utilizing a single technology and quantification methodology. Measuring the entire network annually with Picarro allows an operator or local distribution company (LDC) to manage their ESG goals, shareholder expectations, and be ahead of future regulatory reporting requirements through a data-centric network emissions quantification and reporting schema. If measuring the entire network annually is not possible, having data-driven and measurement-based emission factors for asset classes, which are optimized to their infrastructure,

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would still allow for a more complete and correct view of network emissions and should lower total network emissions when compared to the generic emission factors generally used (i.e. EPA's GHGRP EFs) in a quantification methodology such as NGSI or OGMP 2.0. Going deeper into voluntary reporting, Emissions Measurement provides a clear path forward to achieving Level 4 or Level 5 "Gold Standard" in OGMP 2.0 and the top-tier in many of the other voluntary reporting schemas, as it is based on direct measurement at both the site- and source-level.

There is a clear pathway to seizing control of fugitive methane emissions for any organization, and it is time to embark on the journey. Having the roadmap to success coupled to the right tools to support the endeavor is the path forward. Hopefully this whitepaper has helped to provide a clear picture of the methane emissions issue, the path to implement a solution, provided some tools that could be used, and finally shown the value in the process. Knowing the total emissions volume of your organization is a critical step toward being able to meaningfully reduce emissions and take credit for those reductions. Use Picarro's new Network Emissions Measurement application; measure the emissions, report the outcome, and reduce over time to a sustainable future.

References:

[1] M. Strange, T. Fox, A. Hayman, B. Moorhouse (2022, January). Technical Report: Leak detection methods for natural gas gathering, transmission, and distribution pipelines. Highwood Emissions Management. https://highwoodemissions.com/reports/leak-detection-methods-for-natural-gas-gathering/

[2] Brian K. Lamb, Steven L. Edburg, Thomas W. Ferrara, Touché Howard, Matthew R. Harrison, Charles E. Kolb, Amy Townsend-Small, Wesley Dyck, Antonio Possolo, and James R. Whetstone. 2015. "Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States." Environmental Science & Technology 49 (8): 5161-5169. DOI: 10.1021/es505116p

LIT CODE: V1.0-230406
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