

SCIENTIFIC INSIGHTS

Permian Basin Survey: An array of aerial surveys in the Permian Basin to acquire the baseline distribution of methane emission rates and sources

Background and Objectives

The Collaboratory to Advance Methane Science (CAMS) is an industry-led research collaboration administered by GTI and dedicated to improving the scientific understanding of methane emissions, including emissions detection, measurement, and quantification. As part of its mission, CAMS evaluates new tools and emerging technologies to improve the detection of methane leaks and characterization of emissions. In 2020, the CAMS group commissioned a project to assess the capabilities of an airborne Light Detection and Ranging (LiDAR) technology for methane leak detection, localization, and quantification.

For the work performed in this study, CAMS contracted with Bridger Photonics, Inc. (Bridger) to deploy their commercially available Gas Mapping LiDAR[™] (GML) technology to scan a statistically significant number of production facilities within the Permian's Delaware and Midland Basin to detect, locate, and quantify sources of methane emissions. This work was performed over a two-week period during which aerial images of methane plumes were captured for five targeted areas in the Permian Basin.

This white paper highlights results from two of the objectives from that project:

- · Acquire anonymous baseline leak rate data on assets.
- Associate identified leaks and leak rates with equipment type to conduct a statistical analysis of both frequency and volume of emissions for each equipment type.

An aerial method that provides data on net methane emission rates...

- allows an owner or operator to prioritize the source types that should be tackled first;
- can, with repeat surveys, uncover trends useful for emission reduction tracking;
- can lead longer-term to verification assurance that significant leaks are addressed and that net emissions are dropping over time.

An aerial method that provides data on emission rates allows an owner or operator to prioritize which source types should be addressed first. In the aerial surveys performed in the Permian Basin, 5,361 pieces of equipment were identified on 1450 facilities over 250 square miles using Gas Mapping LiDAR[™] (GML) remote sensor technology. Out of these 5000+ pieces of observed equipment, 6.0% were identified as emitters on the first pass. For this study, emitters are defined as equipment observed to be releasing methane into the atmosphere, irrespective of whether that equipment is exhibited as routine or unintended emissions.

The aggregate results of the GML survey for all surveyed areas, grouped by equipment type (Figure 1), show that tanks resulted in the most significant volume (40%) of methane emissions released from the target areas. This result is consistent with findings from previous aerial studies, such as those conducted by helicopter flyover with Forward Looking Infrared (FLIR) Cameras which found most detectable emissions were from tanks.^{1,2} The survey also found that compressors were responsible for 19% of total detectable emissions, and more than 25% of the compressors in the survey area showed detectable methane emissions. Equipment on or near a separator was also identified as a significant source of emissions. contributing 15% of all detectable emissions. Note that only a small fraction of the separators (fewer than 5%) resulted in detectable emissions. Flares contributed 12% of emissions, and approximately 13% of the flares identified had detectable methane emissions. Equipment not including tanks, such as buried pipe and unknown or unclassified assets, also represented a considerable source of detected methane emissions (around 12%). Wellheads, on the other hand, were found to be a minor source of overall detected emissions, contributing only 2% of all detected emissions.



Figure 1. Percent share by equipment type of total methane emissions (from the GML data and aerial photography gathered during two weeks by Bridger-Photonics) Figure 2. Percent share by equipment type of total emitter sources (from the GML data and aerial photography gathered during two weeks by Bridger-Photonics)



Figure 3. The measured emissions for the Midland/Delaware basins as a function of observed emission rate.

Another notable finding of this study is that the detected emissions data collected by LiDAR can be utilized to determine emissions distribution as a function of detection sensitivity (*Figure 3*). Emission distributions can be readily used to determine the maximum percentage of detected basin emissions for other technologies with weaker detection sensitivities.

Aerial Surveys of Elevated Hydrocarbon Emissions from Oil and Gas Production Sites, Lyon et al, Environmental Science and Technology, April 5, 2016. DOI: 10.1021/acs.est.6b00705.
Aerial and ground-based optical gas imaging survey of Uinta Basin oil and gas wells, Lyman et at, Elementa, November 2019. https://doi.org/10.1525/elementa.381.

Technology and Methods



Bridger's GML technology is based on wavelength modulation spectroscopy (WMS) using a laser wavelength near 1650 nm to determine the path-integrated methane concentration between the aircraft and the ground-based topographic back-scatterer. Bridger also acquires digital aerial photography and topographical LiDAR, which is used for equipment association and accurate determination of the distance between the sensor and the surface topography for their internal data processing. Bridger acquires all data from an airborne platform and all their data is geo-registered to a common global coordinate system. The controlled release rates were selected and administered by an independent third-party SLR Consulting (SLR). Bridger's



stated emission rate detection sensitivity is 3.6 Mscfd (150 scfh, 95% detection probability) in this study. This detection sensitivity is supported by Bridger's detection of all SLR-facilitated blind controlled releases down to 0.9 Mscfd (37 scfh). Bridger uses proprietary processing techniques that include the lateral and vertical gas concentration profiles to match vertically varying wind speed profiles, and other factors and parameters, to quantify emission rates. For the current project, Bridger used their standard operating conditions for the production sector which include a single-engine fixedwing aircraft with a flight altitude between 500' and 750' AGL and a typical flight speed of 100 mph.

To collect the data for this study, a single-engine fixed-wing aircraft equipped with GML remote sensor technology was deployed to scan facilities in five target areas, marked red in *Figure 4*. The target areas were selected by CAMS to be representative of typical operations in the Permian's Midland and Delaware basins to include both older and newer operations as well as both gas and oil production. The target areas encompassed approximately 1,450 facilities over 250 square miles in west Texas. Some of the facilities were known to be owned by CAMS members, while the ownership of the remaining facilities was unknown and remained anonymous.

During the scans, Bridger detected and quantified methane emissions, and associated the emission sources with equipment types. An example of the GML data from one of the sites surveyed, including associated aerial photography, gas plume imagery, and equipment identification markers is shown in 5.

In Figure 5, 3D gas concentration measurements with vertical wind speed profiles were used to accurately determine the volumetric flow rate of methane from a leak or emissions unit. Results are returned in units of standard cubic feet per hour of methane released, converted from actual conditions using recorded ambient temperature and pressure. The minimum detection limit (MDL) for GML depends on the altitude and speed of the aircraft as well as on wind speed. Bridger estimates a minimum detection limit (>95% detection confidence), accounting for variable wind conditions, of be-



Figure 4. The five representative regions in the Delaware and Midland basins (highlighted in red) were selected for scanning with Bridger's Gas Mapping LiDAR[™].

tween 100 scfh and 150 scfh, for altitudes between 500 ft and 750 ft, respectively.

The histogram in Figure 6 illustrates that for these survey areas there are few "very large" sources of methane emissions (emissions >1600 scfh) and that the single largest source detected was approximately 17,800 scfh. Tanks are responsible for almost half (47%) of emissions from all sources that have an emission rate exceeding 2000 scfh. Compressors, separators, flares, and other sources are responsible for 21%, 17%, 9%, and 6%, respectively, of emissions from sources with emission rates exceeding 2000 scfh. The red curve in Figure 6 shows the cumulative emission rate as a function of the emitter size. A controlled release was conducted to verify Bridger's detection sensitivity and the accuracy of Bridger's quantification during the GML survey. Details of this controlled survey are provided in the Appendix.



Figure 5. Example data products from Bridger's Gas Mapping LiDAR[™] including digital aerial photography, equipment identification, and gas plume imagery, geo-registered and overlaid on Google Earth satellite imagery.



The aerial survey produces valuable results that allow the analysis of the distribution of emission source locations. Based on the results of this Permian Basin survey, the largest portion of methane emissions (~40%) from oil and gas production facilities in the Permian Basin are generated by tanks. It is important to note that without additional information on tank control systems and permitted quantities, it cannot be determined whether the observed emissions from tanks were expected versus anomolous. However, an operator with access to permitted emissions data would have the information needed to make such a determination. Emissions also have a skewed distribution: the top 20% of the detected tank emitters contribute more than half (63%) of all detected tank emissions. This skew is useful in that it could allow an operator to prioritize their emission reduction efforts to address the largest detected sources first.

Compressors were also significant contributors to the total detectable emissions and a single compressor resulted in the maximum emission rate recorded during the survey, at 17,802 scfh. Given that this study did not simultaneously collect operating data (such as what mode the compressor was in, and whether there was an emitting event such as a blowdown, a compressor start, etc.), the cause of that largest compressor emission is unknown.

Flares are another considerable source of emissions, and over 13% of the flares identified had detectable methane emissions. Although flares burning natural gas usually have a very high combustion efficiency (98%+)³, a flare burning natural gas could emit plumes with a peak methane concentration of 20,000 ppm (2% uncombusted methane). Under typical operating conditions, such a plume would very likely be detectable by the GML instrumentation. An operator could use information from this type of survey to investigate all flares from which methane emissions are detected.

Emissions from equipment on or near a separator were also a major source of emissions. Since only a small fraction of the separators, less than 5% of those surveyed, resulted in detectable emissions, an aerial survey appears to be a fast, comprehensive method to find the few emitting sources among the larger population of non-emitting sources.

Other, unidentified sources resulted in 12% of total detected emissions, meaning there exists a population of methane sources that do not fall into the other five equipment type classifications or that could not be readily classified from the aerial photograph. A further owner or operator cooperation may be required to assign an equipment type.

Persistency of emissions revealed that the persistency varies by equipment type. 29% to 70% of emissions sources detected on the first pass were detected again on the second pass, depending on the source type. Compressors showed the highest persistence, with nearly 70% of compressors still producing detectable emissions when the second pass of GML was made. Wells showed the lowest persistence at only 29%. The remaining source categories (separators, flares, tanks, and "other") all revealed 44% to 56% persistency.

Equipment Type	Percent Persistent
Compressor	69.7%
Flare	55.6%
Other	46.8%
Tank	44.6%
Separators	44.3%
Well	29.4%

Table 1. Percentage of identified emitting equipment still generating emissions on second flight

An aerial method that provides data on emission rates allows an owner or operator to prioritize which source types should be addressed first. With repeat surveys, it can also provide trends useful for emission reduction tracking, and in the long term, may provide verification assurance that significant leaks are addressed and that net emissions are dropping over time.

³ EPA Greenhouse Gas Reporting Rule 40 CFR 98, Subpart W, assumes 98 % flare combustion efficiency for natural gas, unless a higher combustion efficiency is specified by the flare manufacturer.

The controlled release rates were selected and administered by an independent third-party SLR Consulting (SLR). The location of the release was known but Bridger was blind to the release rates.

During the controlled release testing, Bridger's aircraft, equipped with GML, flew in figure-eight patterns and acquired data over an anonymous CAMS volunteer facility near Midland, Texas during a series of controlled emission releases. SLR used the valving associated with the site's pipeline transfer meter as an emissions source to simulate an uncontrolled release of methane emissions. SLR controlled the emission rate and monitored it using a flow meter during a series of flight passes.



The controlled emissions consisted of 11 different emissions rates ranging from 0.9 Mscfd (37.5 scfh) to 59.5 Mscfd (2,480 scfh) for the testing. The wind speed was measured by SLR using an on-site anemometer and reported to Bridger to evaluate the sensitivity of the resultant emissions estimates to the use if MeteoBlue in the Bridger emissions estimating methodology. Additionally, Bridger accessed interpolated wind speed data based on regional weather station data (MeteoBlue) with a 1-hour temporal resolution. The average wind speed varied during the testing between 9 mph and 18 mph with gusts exceeding 30 mph as

measured by the onsite anemometer. Bridger acquired and processed the data and delivered their estimates for each emission rate to SLR without knowledge of the actual controlled emission rates. Results of the blind-controlled release testing are shown in Figure 7. The left side of the figure shows example gas plume imagery for four of the 11 emission rates. The right side of the figure shows plots of the emission rate measured by Bridger versus the emission rate measured at the controlled ground flow meter. The orange data represents Bridger's emissions rate estimates when using the on-site anemometer wind data while the blue data represents emission rate estimates when using the interpolated weather station data. The

result should not be interpreted to necessarily indicate GML's lower detection limit because it would be possible for Bridger to reduce the detection threshold with little concern for false alarms in a highly confined geographic area. Nevertheless, the field testing described in the next section also indicates that Bridger detected emissions well below their stated 3.9 Mscfd (95% probability of detection) production-sector sensitivity.

The second result of the testing determined by SLR is that, in comparison to recorded ground data, Bridger quantified the blind controlled emissions with an aggregate bias of +25% based on a linear fit and standard deviation of relative error for a

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Onsite Data

5833



Figure 7. Left: Example plume imagery. Right: Plots of the emission rate measured by Bridger from the air versus that measured by SLR at controlled release on the ground. The yellow line represents the "ideal" 1:1 ratio.

top plot shows a zoom of the data below 15 Mscfd while the bottom plot shows all the data. The yellow line in each plot represents the "ideal" 1:1 ratio.

The first important result of the testing is that Bridger's GML measured all controlled releases for all flight passes down to the lowest controlled emission rate (0.9 Mscfd, measured with an average wind speed of 18 mph for that release rate). However, because Bridger was aware of the emission source location, this sensitivity

single measurement of 47%. This bias is influenced greatest by the largest methane emission rates. However, for the highest emission rate (59.9 Mscfd), SLR noted that the high emission rate resulted in condensation of the emitted gas, the impacts of which are unknown on the accuracy of the flow meter value that is used as 'truth' in the above plots, or on Bridger's ability to quantify emissions. Other studies have independently addressed GML surveys detection sensitivity^{4,5}.

⁴ https://www.bridgerphotonics.com/sites/default/files/inlinefiles/BridgerPhotonics_HighControlledReleaseRates.pdf

⁵ Matthew R. Johnson, David R. Tyner, Alexander J. Szekeres, "Blinded evaluation of airborne methane source detection using Bridger Photonics LiDAR", Remote Sensing of Environment, Volume 259, 2021.