LongPath Technologies, Inc.
10/15/2021

Dear Office of Management and Budget,

LongPath Technologies is a continuous methane monitoring service. As such, we have a direct interest in the development of the EPA methane emissions regulations. Thank you very much for your work on these rules and for the opportunity to visit with you.

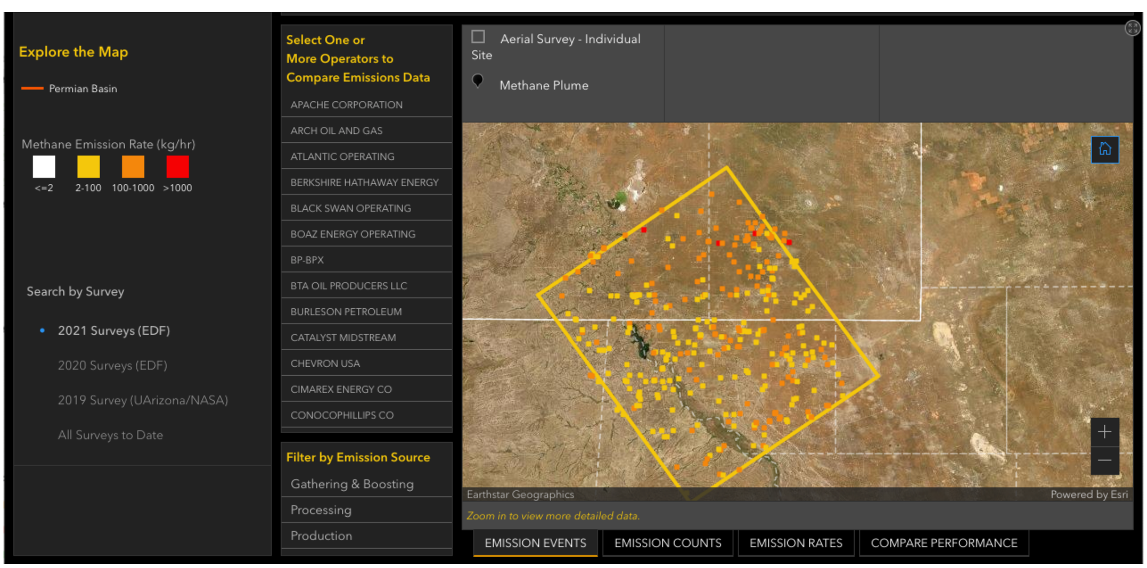
We have submitted a deck describing our technology and will be referencing that during this meeting.

Before we do that, we'd like to take a moment a provide a series of recommendations to OMB as it reviews the pending EPA rules and AMEL process.

Our observations and recommendations are directed toward improving the regulation's policy provisions and streamlining the processes by which new technologies can be employed by oil and gas operators. We will submit all referenced resources as part of our post-meeting materials.

Recommendation 1: for Quad Oa updates to move away from LDAR based on OGI or other spot-check methodologies.

If you were to open the webpage www.permianmap.org and select "explore the data", you would see evidence that the methods undergirding Quad Oa are not working. Tanks, unlit flares, and intermittent venting and emissions persist, despite Quad Oa's LDAR requirements. As we will speak to below, these issues likely cannot be fixed with current LDAR methods, whether the visit frequency is once per year or 12 times per year.



From: https://data.permianmap.org/pages/operators

David Tyner and Matthew Johnson's paper from July of this year in the journal ES&T, describing repeat OGI and aerial surveys at the same sites, demonstrates that "regulations relying on OGI surveys alone may risk missing a significant portion of emissions". Publication DOI: https://doi.org/10.1021/acs.est.1c01572.

The first finding this paper illustrates is that OGI surveys and aerial surveys do not record the same emission sources. OGI surveys in this study found many small sources but far, far fewer large sources than were found with aerial surveys. See Figure 4 from that work.

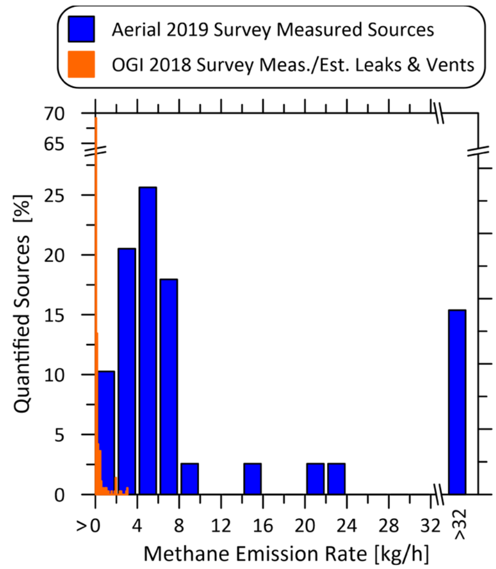


Figure 4. Contrast of source distributions measured in the aerial survey (blue) and prior OGI survey (orange) for the common set of 140 sites (comprising 198 wells and 60 batteries) covered by both surveys.

The second finding this paper illustrates is that OGI surveys are missing important emission sources. "For emitting tanks, the difference between the ground survey estimated mean emission rate of 1.3 kg/h and the aerial measured rate of 48.3 kg/h is readily attributed to the unreliability of visual estimates from OGI camera images. Similarly, unlit flares at height are not readily detected by an OGI camera…". See Figure 5 from that work.

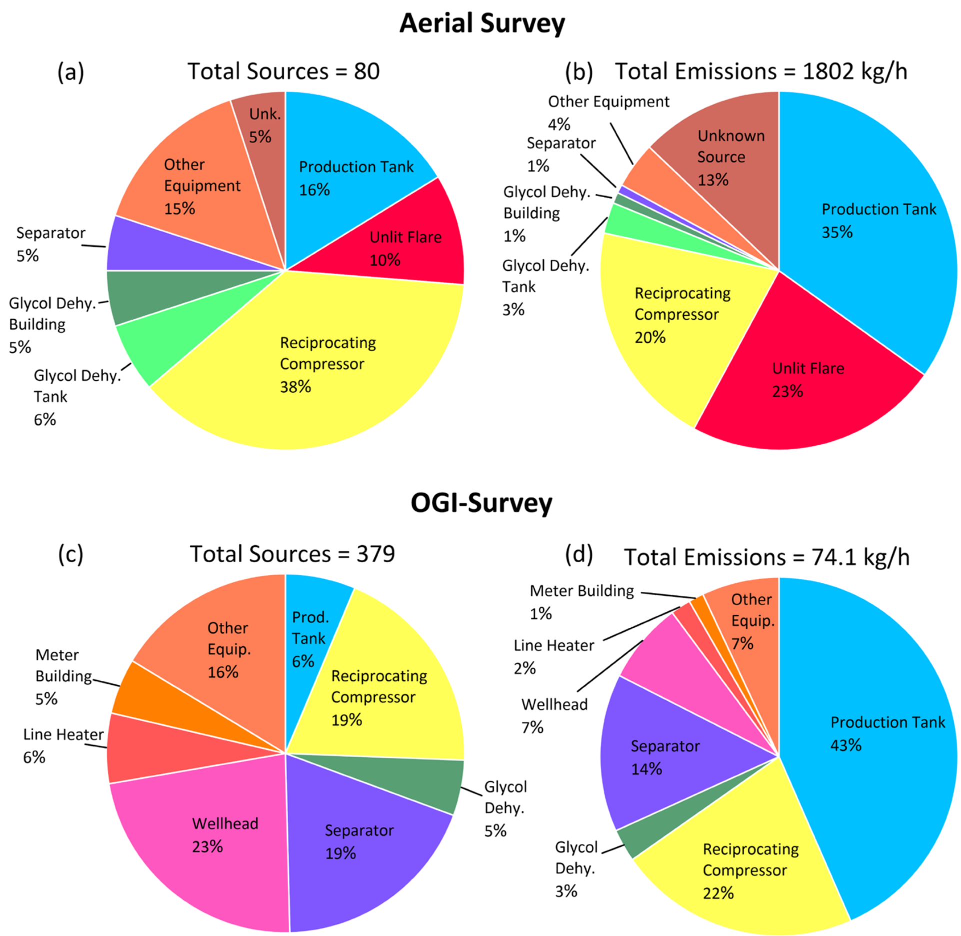


Figure 5. Contrast of aerial and OGI survey source frequency (a, c) and contribution to total measured emissions (b, d) by major equipment type at the same set of sites.

The third finding that this paper illustrates is that, while OGI surveys found many smaller emission sources, they missed many substantial, large emission sources. Neither required vent reporting nor OGI surveys caught the largest emission events seen with aerial survey. See Figure 7 from that work.

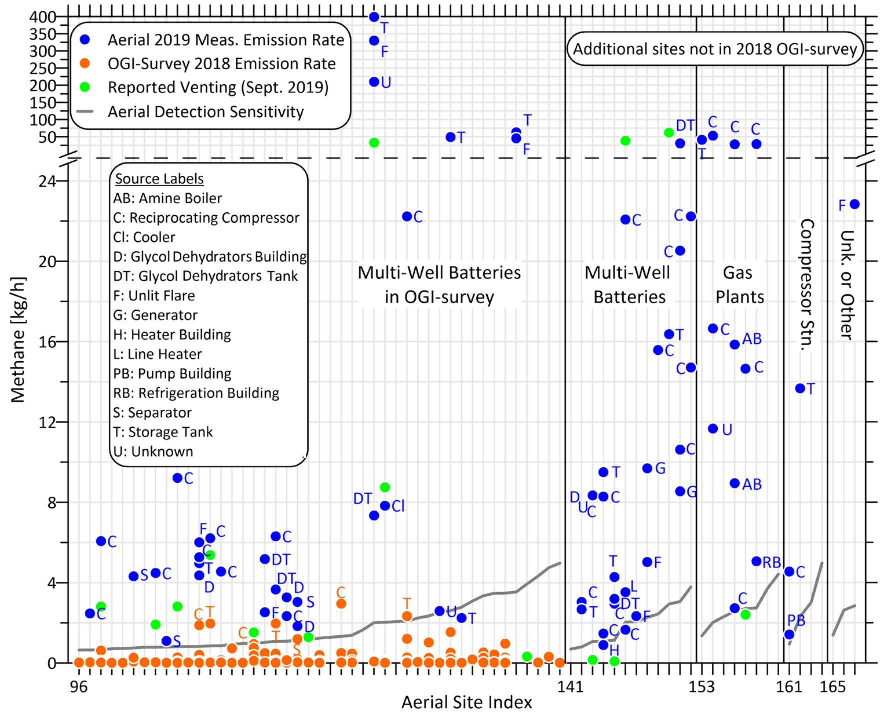


Figure 7. Site-by-site measured emissions for larger facilities in the aerial survey with identified individual source types labeled in blue. The comparison with OGI survey emissions (orange) is shown for the 45 multiwell batteries in both surveys. The estimated GML lower sensitivity at the time of survey based on local wind speed at 3 m elevation above the ground is shown as a gray line (see Johnson et al.[18]), where sites have been ordered by wind speed. The methane contribution from reported venting during the month of the airborne survey (if any) is shown in green for comparison. Note the broken scale on the vertical axis.

Together, these three findings indicate that policy, inventories and regulations built around OGI will likely not achieve stated goals.

Recommendation 2: for the AMEL process to be streamlined, simplified and broadened such that a single AMEL application can be applied across operators and basins.

During the development of OOOOa, EPA agreed that development of cost-effective alternative technologies should be encouraged and accommodated.

EPA also stated that their process would allow for use of alternative approaches and committed to rapid review of applications.

However, despite major improvements to the process in 2020, there remain issues with the AMEL process with respect to speed, efficiency and clarity of the process.

As we understand it, an application for an AMEL would apply only to the sites identified in a specific application. If an operator constructed new well sites in the same field, the applicant would have to start the process all over again. And if another operator wanted to use the same technology in the same geographic area, that also would require an entirely new application. Imagine the cost to submit - and for EPA to process - thousands or tens of thousands of permit applications for a basin-wide monitoring network such as we propose.

Here, we recommend that EPA reconsider its current “definition of source” – doing so would address the process problems noted and could allow for the measurement and monitoring of individual facilities within a basin wide source area. For example, a source could be the region covered by a given LongPath node (20 square mile area).

In a similar vein, we ask that EPA streamline the process for a particular technology after it has been approved once.

The most meaningful adjustment to the AMEL process would be to offer “Type Approval”, in which the technology, system and components are approved. Then, as long as it were verified that the system is set up according to documented specifications, the monitoring system would be considered approved. In this scenario, a technology and method would be approved nation-wide rather than on an operator- or site-specific basis.

Our final recommendations would be to preserve excellent 2020 improvements, such as 1) allowing the vendor to apply, 2) allowing modeling to demonstrate equivalency, and 3) allowing for testing in controlled environments like METEC.

Recommendation 3: for Quad Oa to become performance-based rather than prescriptive.

Current LDAR rules are prescriptive and labor intensive to implement. Today, the only broadly allowed compliance methods are Hand-held Cameras (Optical Gas Imaging, or OGI) and Hand-held Sensors (Organic Vapor Analyzers, or, Sniffers). For certain kinds of leaks (but not all – see earlier comment), these methods can identify emissions while on site. However, they are labor intensive, and, because of the positive skew of emission rates from fugitive and unregulated venting events, these point-in-time evaluations miss the bulk of total emissions. Furthermore, emissions that intermittent in nature can be missed or misinterpreted without continuous monitoring. Further, some important and problematic issues such as unlit flares cannot be reliably seen with OGI cameras or sniffers (see comments above).

By EPA’s own numbers, Quad Oa has not accomplished its goals. President Biden’s emissions reduction targets will not be met with any simple expansion of the old and ineffective methods for leak detection.

We therefore encourage EPA **not** to double down on these technologies in its rulemaking but to consider leveraging the significant advancements of newer, more efficient and more effective measurement and monitoring technologies. Many of the newer technology offerings can provide quantification of emission rates. If the new rules are written to specify that performance is measured rather than estimated (e.g., with inventories, which, because of the skewed nature of emissions, are all but guaranteed to be incorrect at a given site and at a given time), then all stakeholders will benefit: society, the environment and industry.

LongPath’s technology can monitor everything within a 20 square mile area. It would only take 1000 of our sensors, or a $30-40M investment, to cover the entirety of the Permian basin with continuous monitoring through time and with sensitivity akin to or better than what is currently required for LDAR.

We believe sensors that provide continuous and scalable detection have the potential to significantly reduce the cost of compliance and result in greater benefits to the environment.

Obviously, regulations can never keep pace with technological advancement. But EPA has an opportunity now to allow the utility of proven technologies to be leveraged for the best possible metrics via actual, direct measurement of emissions.

We encourage EPA to write the rules with emission (or intensity) targets based on metrics defining detection frequency and sensitivity, so that proven continuous measurement and monitoring technologies can guide action that will meet President Biden’s ambitious emission reduction goals.

www.LongPathTech.com

LongPath Technologies was founded by a team of engineers and atmospheric scientists to bring the best new technologies and methodologies to bear on the issue of methane loss from the oil and gas supply chain.

LongPath Recommendations for OOOOa & AMEL

- Technology always moves faster than regulations… *but* rules that are too open-ended do not work. Performance-based rules can solve this issue.
  - **Define metrics:** what must be detected and how fast (e.g., must find emissions of rate/size X within Y days)
- To deal with fat-tailed problems like methane emissions (find and fix big emitters fast) it is important to monitor
  - Everywhere
  - All of the time
  - With fine enough thresholds of detection
- Companies like ours are AMEL-limited by facility-by-facility requirements
  - Can we ask for flexibility in this – e.g., facility definitions or "Type Approval" for adoption across operators and sites

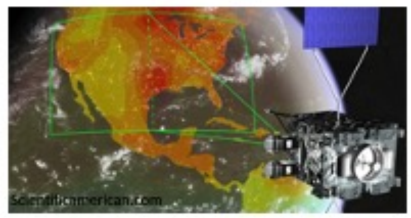
Continuous Monitoring Matters

Spot check approaches

- Emissions from O&G are fat-tailed: a small portion of large leaks cause most emissions
- Inspections and aircraft can locate large leaks, but suffer sparse coverage (no temporal context; miss / misinterpret intermittency)
- Satellite methods provide intermittent coverage at coarse resolution

Current approach

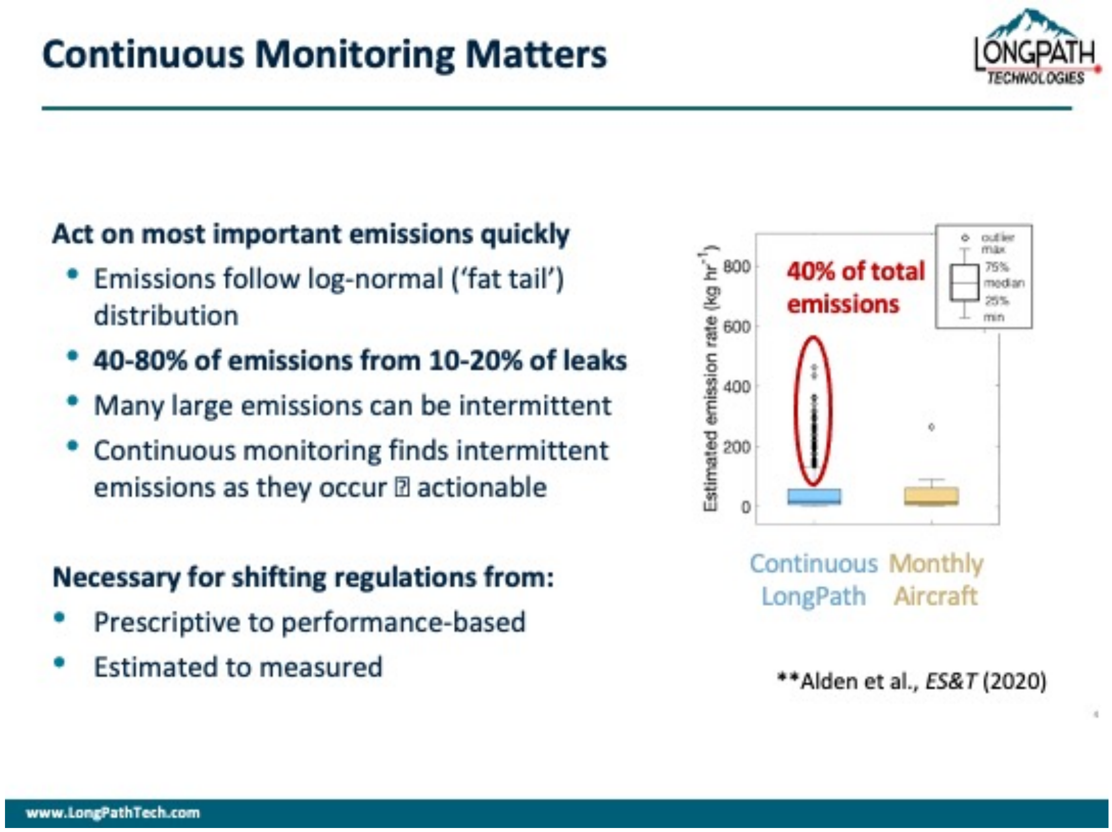
Aircraft & satellite platforms



This presentation briefly covers two important aspects of methane detection: first, why continuous monitoring is critical, and second, why the ability to quantify emissions with an appropriate threshold of detection is important.

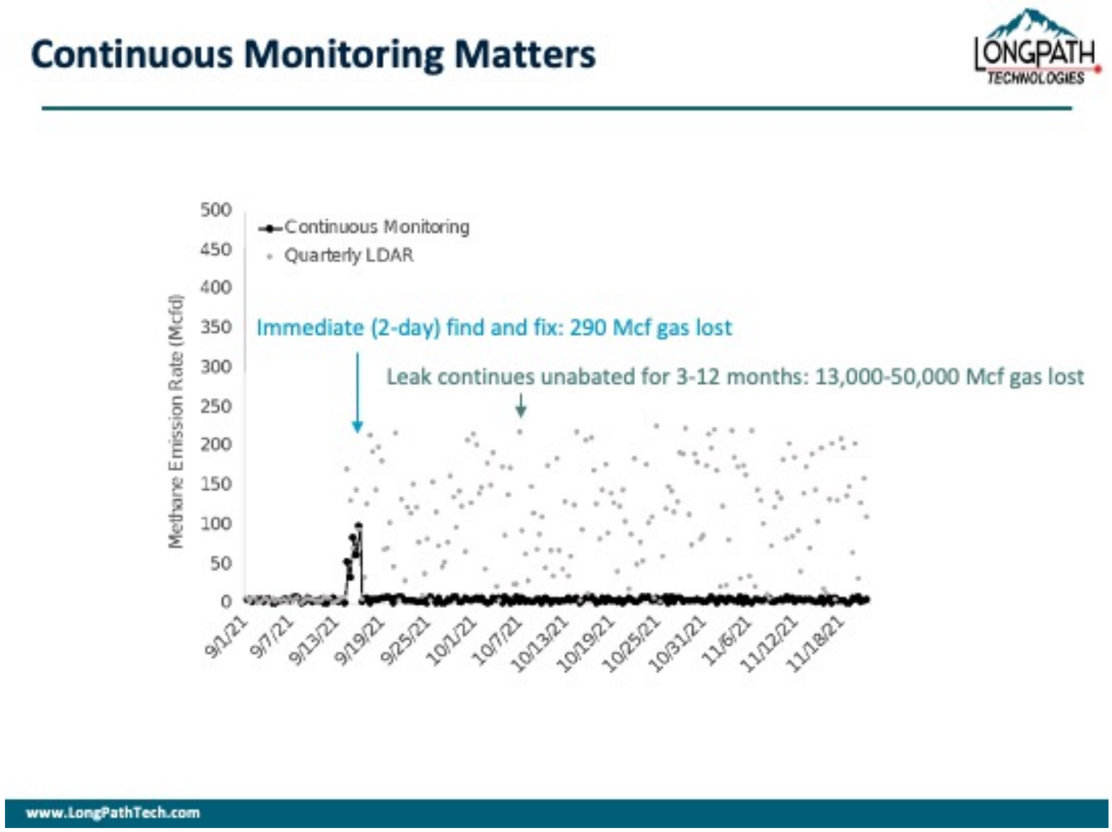
Emissions from oil and gas operations are fat tailed, meaning that a few large and unpredictable fugitive events cause the bulk of overall emissions. The infrequent, unpredictable, and sometimes intermittent nature of these emissions means that spot-check approaches to monitoring or measurement would need to occur with extremely high frequency to be effective.

OGI visits and aircraft and satellite fly-bys can locate large leaks, but they lack the temporal context that can help operators diagnose issues. In particular, snapshot-in-time approaches can either miss or misinterpret intermittent events.

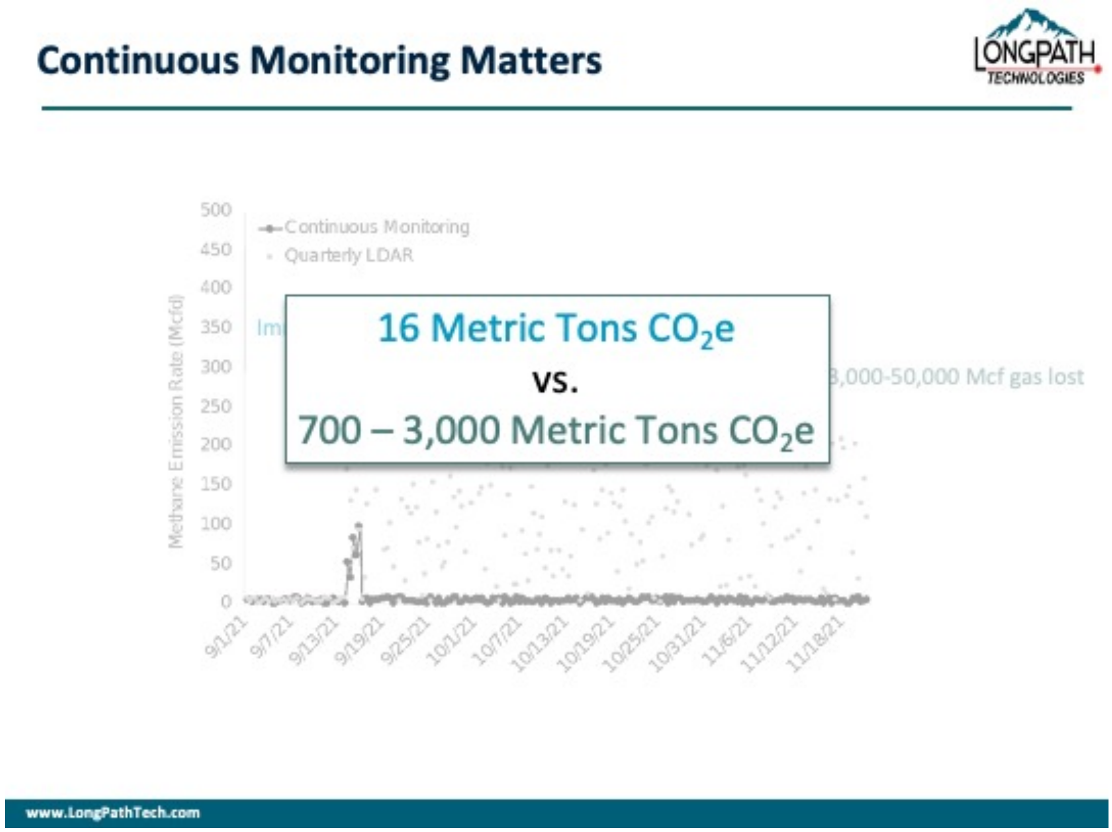


A year-long continuous monitoring study at an underground natural gas storage facility, performed by this team, proves out this concept: 40% of total emissions came from 10% of emission events. Even very frequent aircraft fly-bys only managed to detect one of these events.

Simply put, continuous monitoring is the check engine light for the oil field -- it allows us to use the 80/20 rule to our advantage and solve the biggest piece of the emissions pie by using the lowest-cost and easiest-to-integrate methods out there.



The simulated (modeled, not measured) data shown here is based on real emission events that have been found and fixed using LongPath Technologies continuous monitoring. Here you can see that a simulated fugitive event began on 9/16. Using continuous monitoring equipment, the emission would immediately (within hours to days) be identified as being abnormal, and a field crew would be able to fix the problematic equipment within 2 days. The black line shows that, using continuous monitoring, emissions would return immediately to the baseline value. The gray dots show what would have happened if the malfunction had not been detected until a routine quarterly or annual LDAR visit.



The difference in gas lost equates to thousands of metric tons of CO2e. Given that continuous monitoring technologies are widely commercially available, there is no reason that this should not be the de facto modality for saving industry money and saving society the impacts of emissions. Aircraft fly-bys, satellite sweeps, mobile methane monitors and routine or even highly frequent OGI visits would have resulted in massive gas losses compared with continuous monitoring.

Detection Thresholds Matter

LONGPATH TECHNOLOGIES

"Super Emitter" Threshold[1] = 26 kg/hr
Regulated Vent Limits = 12 - 14 kg/hr

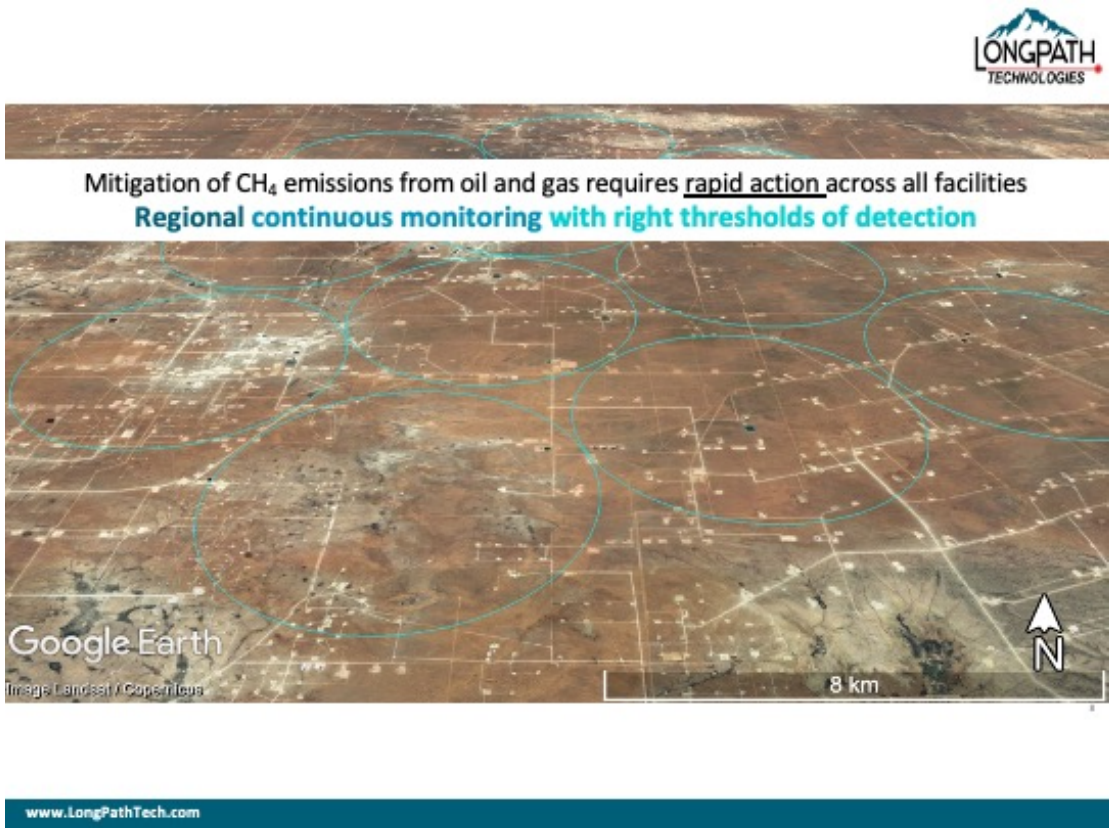
Monitoring Platform	***Mcf/day***	***kg/hr***
Satellite[2]	130	100
Flyover[2*]	45	35
LongPath[3]	**0.2**	**0.2**

Blind tests and field data demonstrate LongPath's ability to identify emissions across the spectrum, from small emissions to large leaks and vents

[1]Zavala-Araiza et al., Nature Communications (2017)
[2]Presentations at CH_4 Connections, November 2020
[3]Field testing & Alden, et al., Env. Sci. & Technol. (2019)
*Lower limits have been recently published with low wind speeds

In addition to continuity of measurements, it is critically important to consider a technology's threshold for emissions detection. The scientific literature defines very large unintended emissions, or super-emitter events, as greater than or equal to 26 kg/hr. Several major platforms for methane detection have detection thresholds that are not sensitive enough to see even these large events, much less offer a nuanced view of total emissions and how they change through time.

Blind tests and field data demonstrate LongPath's ability to identify emissions across the spectrum, from small to large leaks and vents.



In summary, to provide the maximum cost savings and societal benefit, emissions monitoring should be everywhere, all the time, and with the right thresholds of detection.

Scalable, Quantitative Continuous Monitoring

LONGPATH TECHNOLOGIES

Unique, proven technology:

- Nobel Prize laser, DOE backed, 8 years development & testing
- Only peer-reviewed, 3rd party blind tested continuous technology
- 13,000 acres of coverage per system

Field proven: 11 E&P partners (170+ facilities) by Q4 2021

End-to-end, networked solution: Install / Maintain / Upgrade / Locate

Our Goal: Basin-wide continuous monitoring networks

www.LongPathTech.com

LongPath has been backed by two ARPA-E awards (through the MONITOR and later SCALEUP programs) as well as a DOE Office of Fossil Energy award to study emissions from underground natural gas storage facilities. We are an end-to-end solution, covering everything from installation to maintenance and communications to the final leak locate. We are a proven tech, with third party blind testing and with customer/operator field data.

LongPath Technologies, Inc.

- LongPath's solution is based on Nobel Prize-winning laser technology
- Jointly developed by the University of Colorado and NIST
- Recipient of multiple ARPA-E grants
- Only blind-test validated & peer review published continuous monitoring solution
- Monitoring 200+ square miles by end of 2021
- Poised for rapid scaling in 2022

www.LongPathTech.com

LongPath Technologies serves this need in a networked fashion that offers high-value monitoring to the industry for a very low cost.

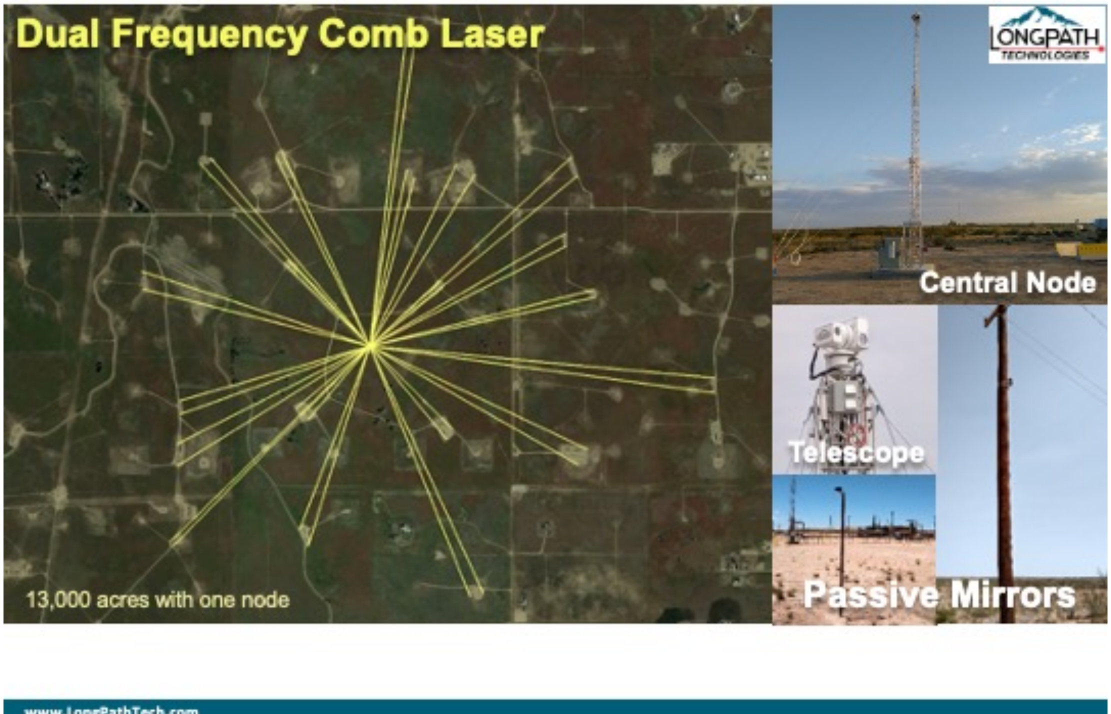
Our solution is based on Nobel Prize winning Dual Frequency Comb Laser Spectroscopy that was jointly developed by the University of Colorado and NIST, coupled with inversion algorithms jointly developed by the University of Colorado and NOAA.

We are the recipients of multiple Department of Energy ARPA-E grants, first to develop the tech and later to commercialize and scale.

We are the only continuous monitoring solution that has published our blind-validation testing results in the peer reviewed literature. This means that there will be no surprises when it comes time for regulatory approvals and demonstrating quality control of monitoring and data.

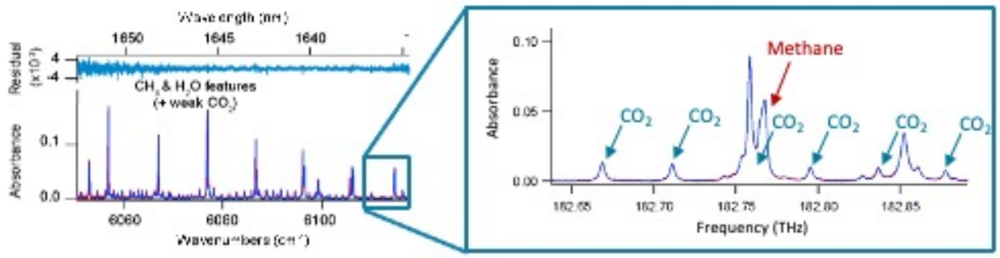
LongPath is out in the field with multiple E&P partners, with monitoring of over 180 facilities by the end of 2021.

We are poised for rapid scaling in 2022, both in terms of our financial backing and our production capabilities.



LongPath Technologies uses a single centralized node to deploy a laser spectrometer on a small tower. All power and communications occur at that one location. The eye-safe and invisible laser light fans out across distances of 2.5 miles. It is bounced back to the detector with tiny passive (no power or communications needed) mirrors put on existing infrastructure or small posts placed on the edges of pads.

Dual Frequency Comb Sensor



Frequency comb: 50,000+ wavelengths of eye-safe infrared light

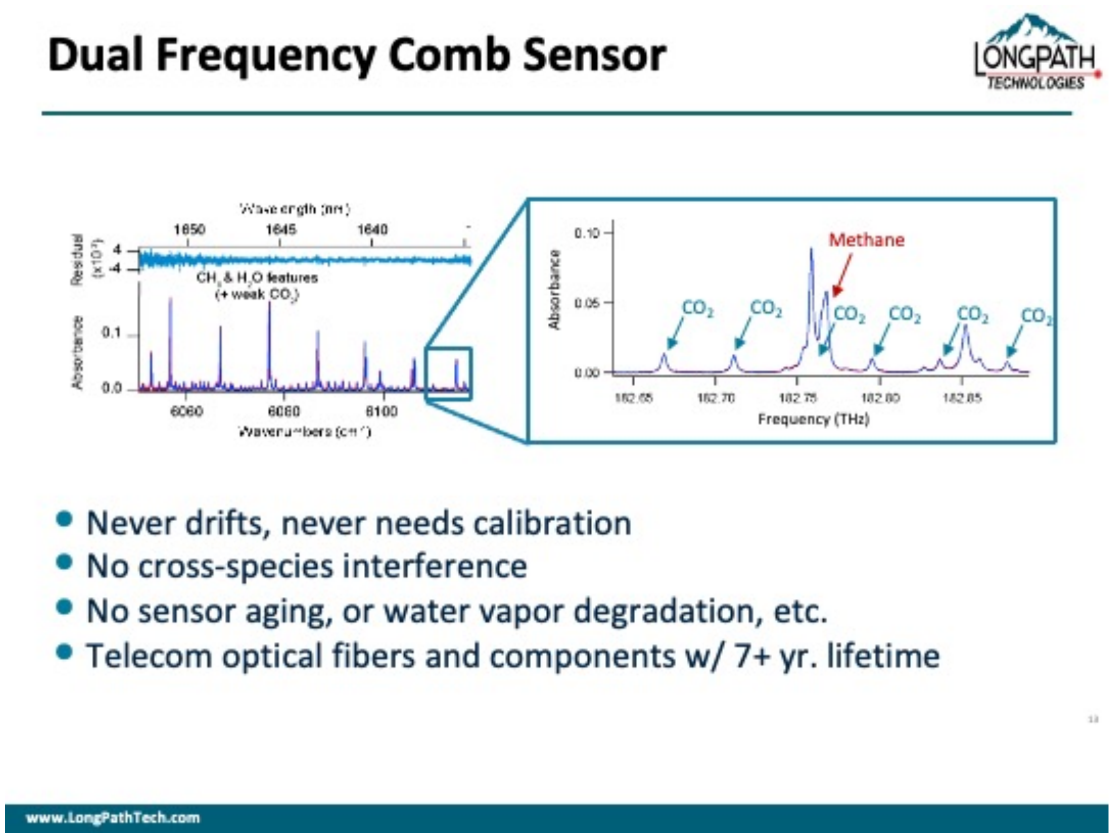
Senses unique pattern of absorption by quantum energy level transitions in molecules

Same frequency comb technology in optical clocks at NIST

This slide demonstrates how frequency comb technology, originally the recipient of a Nobel Prize, and later developed out by our team for rugged and remote use in the field, provides unprecedented precision and stability for methane sensing.

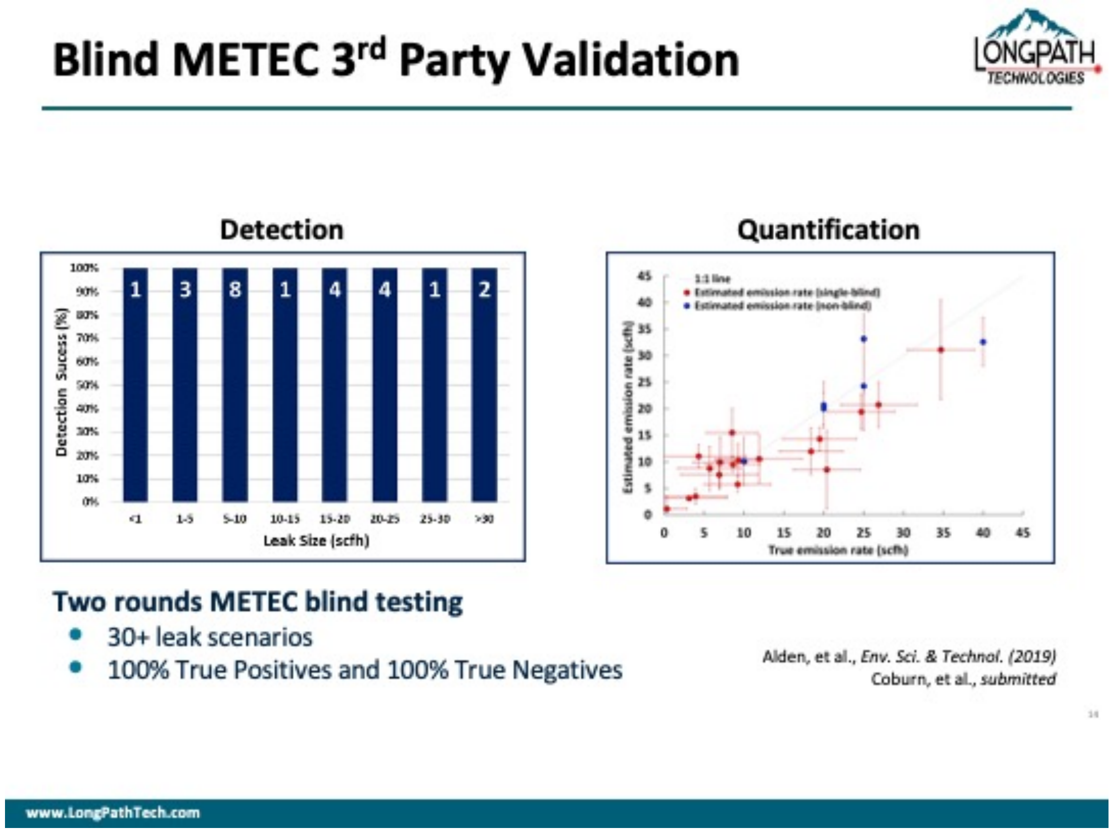
Frequency combs emit tens of thousands of different wavelengths of eye-safe infrared light. All elements of the laser are low-cost and easy to procure, because the technology is based on telecom industry fiber materials.

The laser senses unique patterns of absorption, leading to extremely precise, direct measurement of methane, water vapor and carbon dioxide.

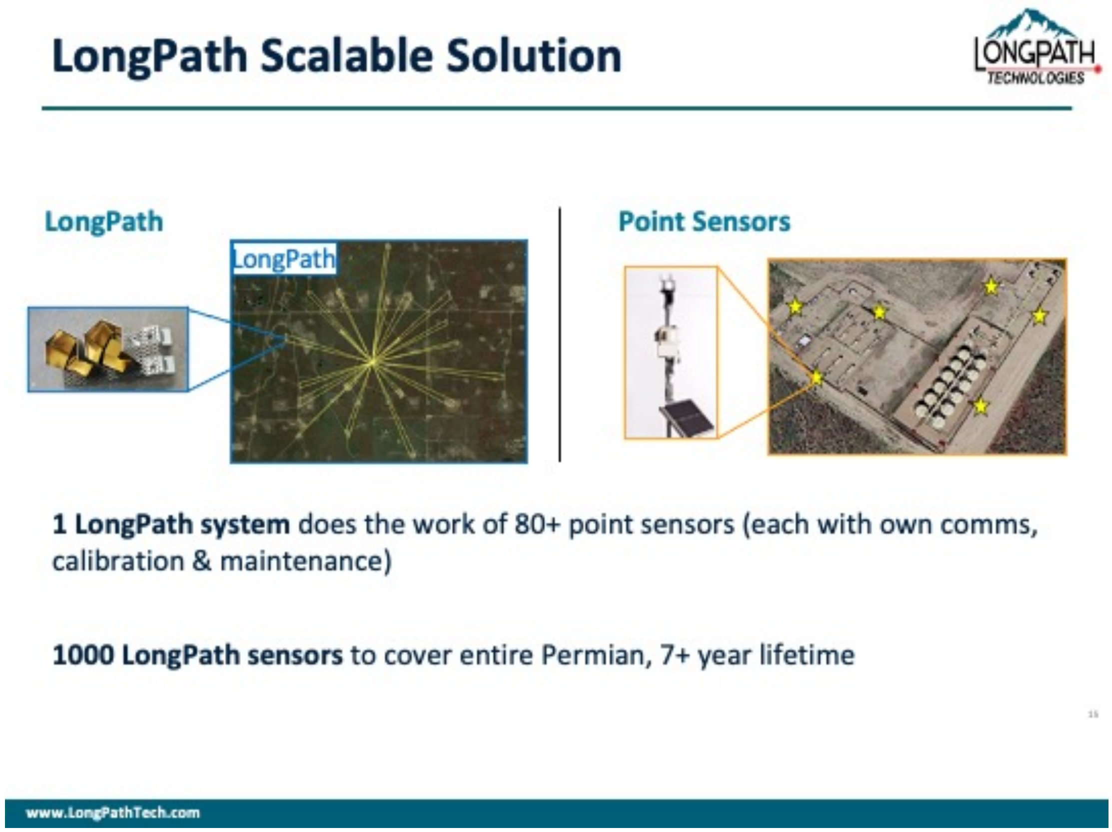


This means that the sensor never drifts and never needs calibration. It can remain in the field for many years with no degradation.

This also means that there is no cross-species interference – water vapor is measured directly, and so it does not produce interference signals in the ways that, for example, metal oxide sensors must contend with.



We have published blind validation testing results in the peer reviewed literature, demonstrating the detection and quantification capabilities of the system as robust and verified.



The way that we deploy this laser means that the already low cost of the laser is spread across many many facilities, enabling a highly scalable solution in a ”network” of coverage. Each single laser system does the work of 80+ point sensors. There is only one point for power and communications with our system, and the tower can provide societal co-benefits such as broadband networking support for rural communities.

It would only take 1000 LongPath sensor to cover the entirety of the Permian Basin – the cost and logistics of this would be a tiny drop in the bucket for oil and gas.

Lowest Cost to the Industry

	LongPath	Other Continuous
Calibration	Never	Mixed / Yes
Sensor Aging	Never	Mixed / Yes
H_2O interference	No	Mixed / Yes
Published, peer-review Blind-test	Yes	No
Daily cost per facility (over 2-yr deployment)	**<$22/day**	**~$23* to $60/day**

*Does not include maintenance

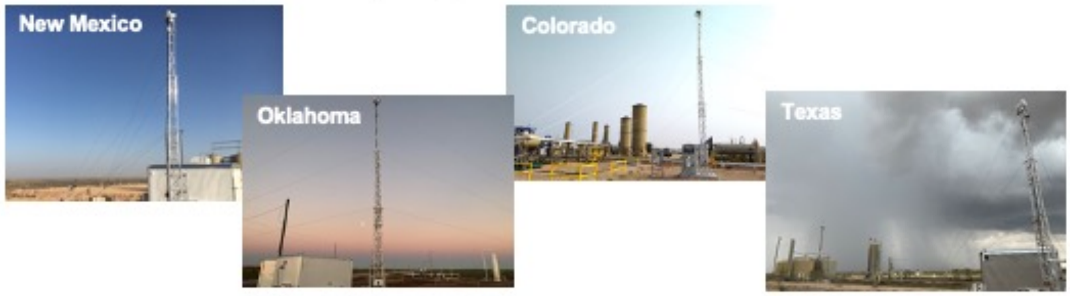
Includes install, lifetime maintenance & final leak locate

Not only does LongPath provide the most robust data in terms of sensor performance and validation testing, but it is also at or below the cost of other continuous monitoring technologies.

Permian/Anadarko Pilots: Overall Performance

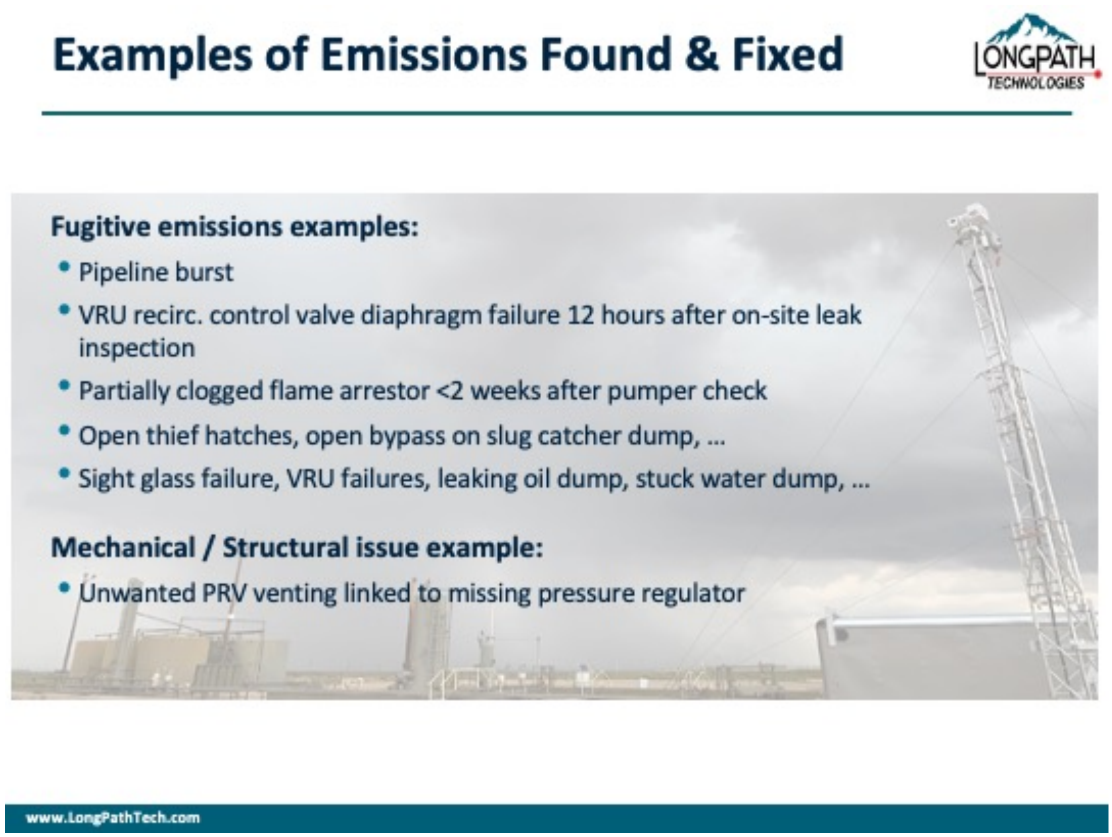
LONGPATH TECHNOLOGIES

40+ months of monitoring across multiple deployments

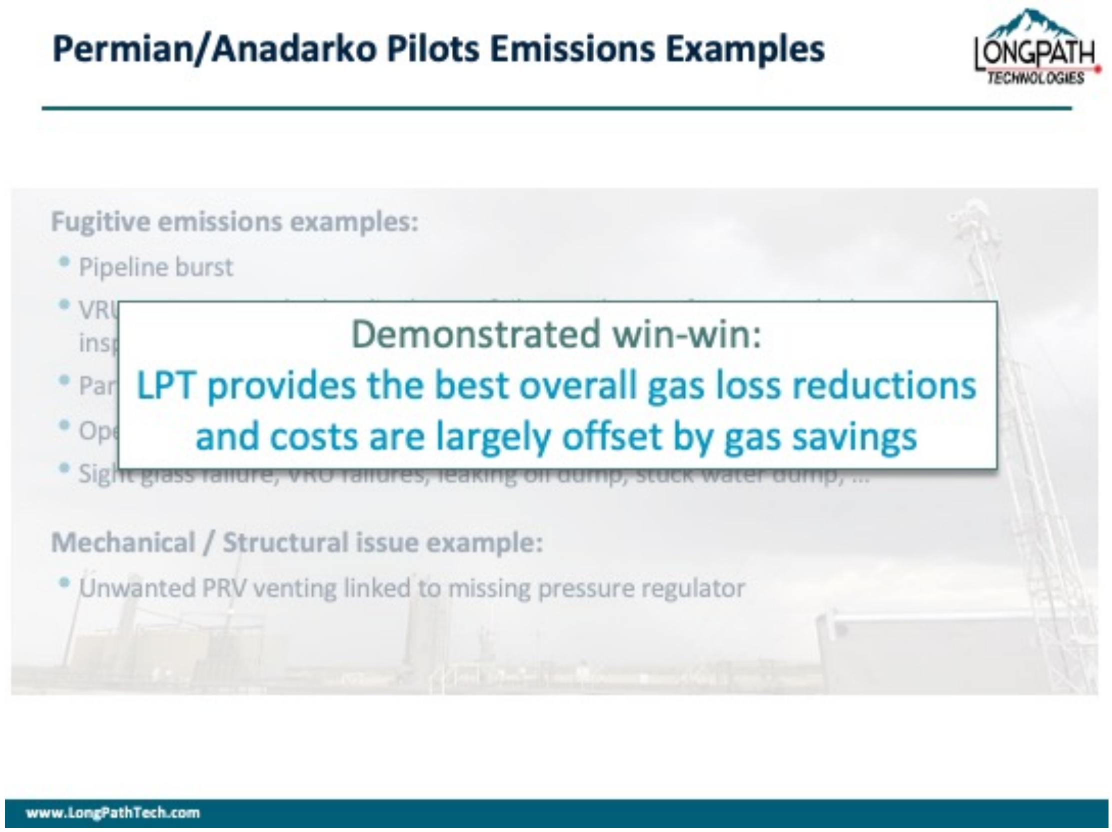


- Many facilities perform well on a day-to-day basis
- Avg. <1 Significant Event / Facility / 12 months
- Avg. Mcf saved / Facility / Month covers monitoring cost, even vs. monthly surveys

We are out in the field with multiple E&Ps and in multiple basins. Field data shows that continuous monitoring can drastically reduce emissions by targeting truck rolls – not necessarily by increasing them for repairs. This monitoring quickly pays for itself in terms of lost product saved. With monthly visits you are going to catch more than quarterly, and not let large emissions accumulate. But even then, the gas savings before monthly detection pays for the system.

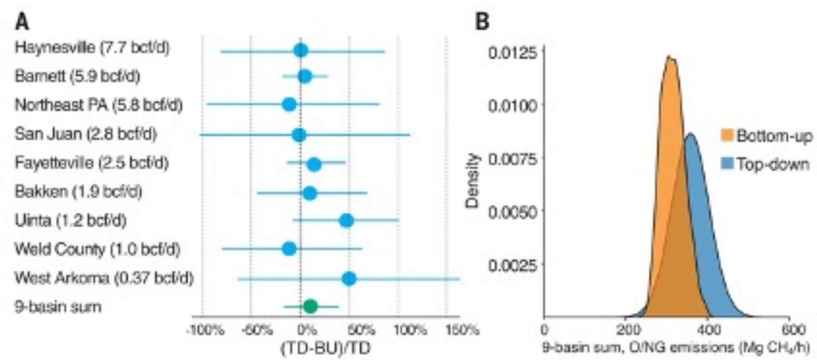


This slide shows a few examples of the kinds of emissions – both fugitive and structural – that LongPath has been able to mitigate.



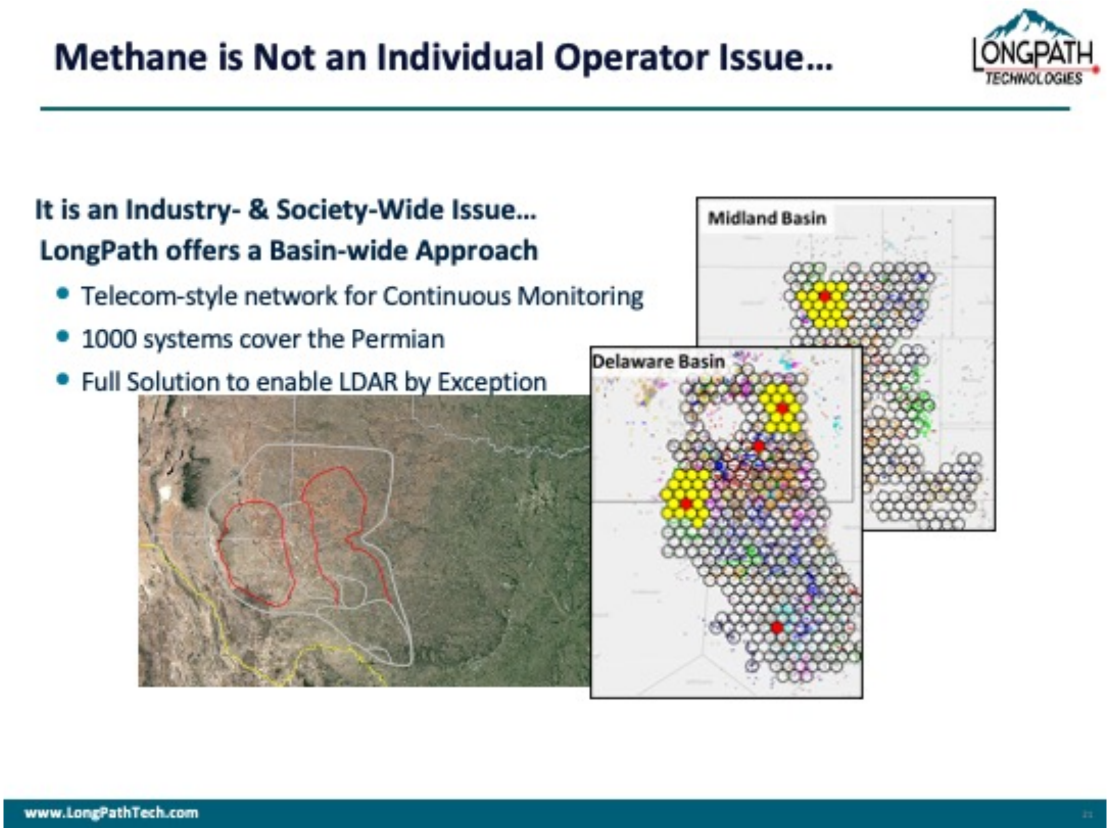
In short, LongPath provides the best overall gas loss reductions, with its networked coverage of continuous and sensitive detection threshold monitoring, and the monitoring costs are largely offset by the gas savings provided to the customer.

LongPath Enables Performance-Based Rules



Alvarez et al., Science (2018)

Given that inventories are not accurately representing emissions, it is critical to have regulations reflect the fact that we can now measure emissions directly and therefore directly gauge and improve performance rather than following prescriptive rules.



LongPath offers basin-wide solutions to this issue, allowing industry, regulators and other stakeholders to work together in support of a monitoring network that can provide a win-win to all parties.