GTI ENERGY

GTI ENERGY NZIP Net Zero Infrastructure Program

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WHITE PAPER

Industry Wide Strategies: Emissions Management and Infrastructure Integrity

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Pipeline Image Credit: Institute of Energy Research

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Introduction

GTI Energy launched the Net Zero Infrastructure Program (NZIP) in June of 2023 to communicate and improve understanding of how current gas infrastructure can provide the foundation for future, decarbonized energy systems. The emissions management and integrity of these systems are critical elements that underpin the continued use of gas systems. This paper highlights some of the key solutions to emissions mitigation and integrity management of gas systems, specifically Leak Detection and Repair (LDAR), strategies to improve energy and operations efficiency, and emerging technologies to reduce methane slip of natural gas systems. The aforementioned reduction strategies are discussed in terms of potential emission reduction magnitudes, and deployment considerations across the natural gas industry.

Leak Detection and Repair (LDAR)

LDAR is an emissions reduction strategy involving systematic inspections aimed to efficiently identify and mitigate fugitive emissions. LDAR programs have become crucial in supporting the continued reliability of natural gas infrastructure, as well as promoting more effective planning of decarbonization strategies. According to the California Air Resources Board (CARB), in California LDAR surveys resulted in approximately 2,200 metric tons of methane reduction, or 23% of total emissions, from components subject to LDAR in 2020.[1] This represents an improvement from 2019 as a result of the implementation of CARB's Greenhouse Gas Emission Standards for Crude Oil and Natural Gas Facilities. Currently, 23 federal standards require facilities to have LDAR programs.[2] LDAR programs include leak detection, monitoring, repair, and recordkeeping.

Leak Detection

Methane leakage is detected using technologies such as optical gas imaging cameras (OGI), fixed monitors, handheld gas detectors, laser-based sensors, unmanned aerial vehicles (UAV) mounted sensors, manned aircraft, and satellite imagery. Each of these detection technologies have unique detection thresholds, and Figure 1 illustrates the strengths and weaknesses of various detection methods based on detectable emission rate and emissions frequency. Initially, regulatory LDAR programs primarily used OGI or Method 21 leakage detection technologies; however, due to their detection rate limits, other technologies considered more cost effective are now in use.[3,4] Given that the detection technology used is dependent on the use-case, scope, location, and equipment most LDAR programs necessitate the use of several leak detection technologies for muti-scale surveys.

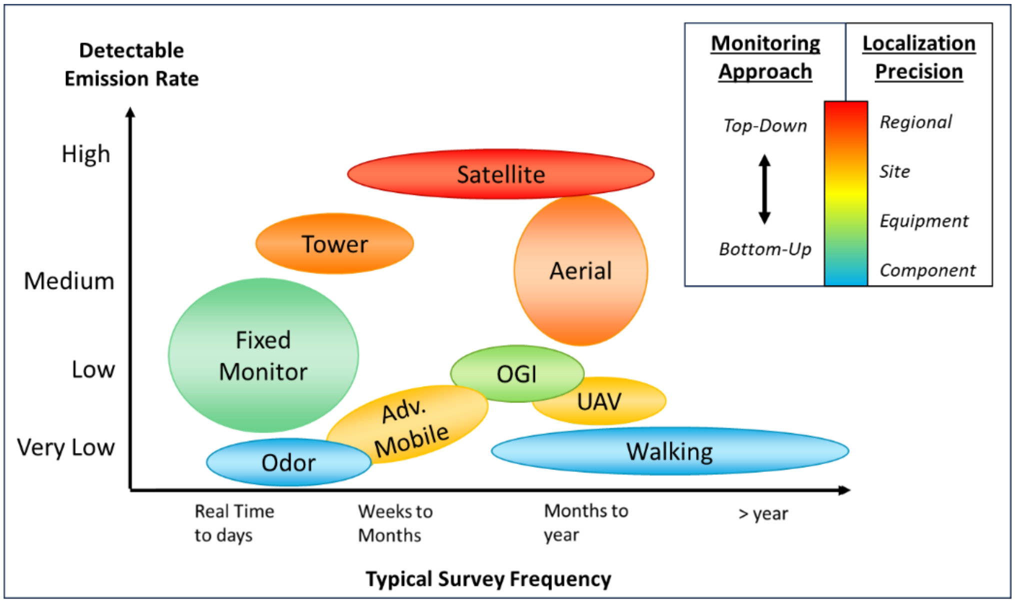

Figure 1: Leakage detection methods and their respective use (Sourced from OTD report: Emissions Quantification and Reduction Strategies Report)[5]

Repairs

Post-emissions detection repair includes equipment repairs, retrofits, or complete replacement. Aging infrastructure is more prone to leaks, making it essential to prioritize repairs and replacements to mitigate methane emissions effectively. From 1990 to 2021, the transmission, storage and distribution segments of the U.S natural gas industry observed emissions reduction of 31% and 70%, respectively, driven by pipeline upgrades, improved material maintenance, and an increased focus on emission detection and monitoring leak repair programs.[6] Aging pipelines still represent 29% of distribution pipelines and 53% of transmission pipelines.[7] LDAR programs significantly reduce the number of corrosion-prone pipelines in service, while increased detection further support emissions reduction. Based on current pipeline replacement rates, distribution and transmission pipeline replacement programs are estimated to fully replace corrosion-prone pipes in the next 73.5 to 100 years.[6] Additionally, replacements can cost up to $10 million per mile. LDAR programs can improve efforts to prioritize the replacement of the most leak-prone sections and accelerate emission reductions. By identifying and addressing high-risk areas first, these programs can maximize their impact and efficiency.

Energy & Operations Efficiency

Energy Efficiency

Energy efficiency programs aim to minimize or reduce energy use during operations and for downstream users. This effort can include changes to appliance standards and building codes, commissioning and retro-commissioning, decoupling rates from utility earnings, education and behavior modification, energy benchmarking and disclosure, and financial incentives.[8] According to Consortium for Energy Efficiency (CEE) surveys, over 80% of U.S. natural gas efficiency programs have been active for over a decade. As of 2020, these investments resulted in a reduction of 1.7 million metric tons of greenhouse gas emissions reduction (equivalent to a 70% greenhouse gas emissions reduction) from the natural gas distribution system since 1990.[9]

The primary energy efficiency measures taken by members of the CEE in the commercial sector include upgrades to air conditioning (AC), heat pumps, and boilers. In the residential sector, heating, ventilation, and air conditioning (HVAC) initiatives have received the most attention. CEE currently has a total of 175 members for commercial AC, 70 members for commercial boilers, and 176 members for residential HVAC programs. Although these programs represent a fraction of the natural gas industry's efforts to improve energy efficiency, Figure 2 highlights high-priority strategies in the residential and commercial sectors for natural gas end users and the respective number of companies involved.

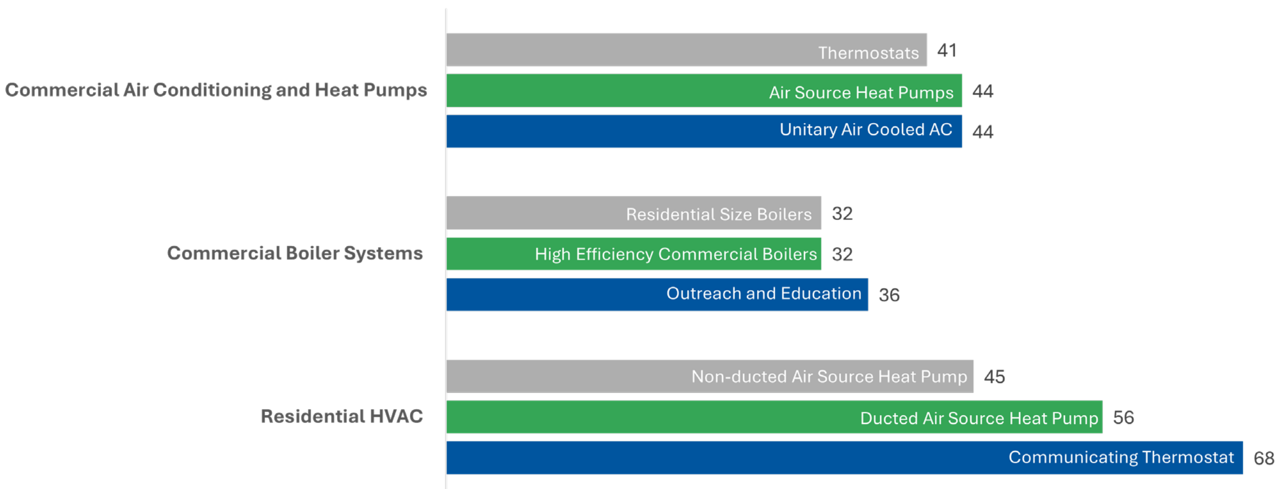

Figure 2: Top energy efficiency strategies deployed by CEE program participating natural gas companies in 2022 (Number of companies)[10]

In the industrial sector, strategic energy management programs, serving 2,662 sites and 883 customers, have accomplished approximately 736 million cubic feet, or 30%, of natural gas savings from 2021 to 2022. Furthermore, natural gas companies participate in CEE initiatives associated with industrial pump systems, which target efficiency improvements of current pump systems and opportunities to accelerate the market adoption of high efficiency alternatives. Energy efficiency programs have made significant strides in reducing methane and other greenhouse gas emissions through necessary upgrades. As these initiatives continue to evolve, they will offer increased value to decarbonization efforts.

Operations Efficiency

There are various opportunities to reduce emissions associated with the operations of natural gas systems, such as by eliminating vented methane. In times of emergency, equipment shut offs, or planned maintenance, upstream and midstream natural gas operators will often depressurize affected equipment by implementing controlled atmosphere releases known as blowdowns along pipelines or compressor stations. According to the U.S Environmental Protection Agency (EPA) Inventory of Greenhouse Gas Emissions and Sinks (GHGI), equipment and pipeline blowdowns were collectively responsible for 6% of total oil and gas methane emissions in 2022, which equates to approximately 11.4 million metric tons of carbon dioxide equivalent.[11] Common strategies to reduce or eliminate blowdown emissions include: [12]

- Segment isolation: using valves, squeezing off plastic pipe, branch connections, and stoppers
- Installation of vapor recovery systems: can achieve up to 100% reduction in fugitive methane emissions
- Drawdown: reduce pressure, divert gas, temporary compression
- Gas flaring and/or Purging

However, the implementation of these mitigation technologies is subject to operational, regulatory, and economic constraints. [9] Consequently, avoiding blowdown events is sometimes the best opportunity to eliminate associated emissions.

In 2022, Best Management Practice (BMP) and ONE Future partners within the Natural Gas STAR program reported emission reduction of approximately 4 million and 6 thousand metric tons carbon dioxide equivalent from transmission pipeline blowdowns and distribution pipeline blowdowns, respectively.[13] These emissions are primarily reduced through pipeline pump-down techniques, Emergency Shutdown tests (ESDs), operating practice changes, vent gas recovery (VGR) systems.[14]

Improvements to energy and operational efficiency present a wide range of opportunities for mitigating methane emissions in the natural gas industry. Continuing to optimize the operations of natural gas systems and efficient delivery of natural gas will be critical to achieving a sustainable, decarbonized natural gas industry.

Emerging Technologies: Methane Slip

The global natural gas industry continues to integrate new methane abatement technologies to tackle hard-to-abate emission sources, like combustion equipment. Fugitive methane emissions, known as methane slip, result from undesirable methane migration through combustion equipment and incomplete combustion with natural gas-powered combustion equipment (i.e. engines, turbines, burners, boilers, and flares). Methane slip emissions are predominantly a concern in the upstream and midstream segments of natural gas systems.

The EPA recently noted that current GHGRP reporting requirements likely underestimate methane slip emissions and thus proposed revised methodologies for quantifying methane slip from reciprocating engines and gas turbines.[15] Several studies have also indicated that methane slip emissions are poorly accounted for across natural gas systems, especially from flare equipment. A 2022 field measurement campaign conducted in three production basins found flare efficiencies to be approximately 90%, compared to their reported 98% efficiencies.[16] Flares can have lower combustion efficiencies due to poorly operating and defective components, e.g., damaged starters. The Energy Information Administration (EIA) estimates approximately 270,000 million ft^3 was either flared or vented in 2022, which represented 0.5% of gross withdrawals.[17] The full-scale emission impacts from defective or inefficient flare equipment are yet to be understood for natural gas systems. According to the National Petroleum Council, combustion emissions associated with natural gas equipment are projected to be 50% of natural gas system emissions in 2050, 26% of which attributed to methane slip.[18]

A recognized need for improved quantification and mitigation of methane slip generated across natural gas systems has been met with the development of research initiatives such as the Collaboratory to Advance Methane Science (CAMS), a research consortium including GTI Energy and numerous leading energy companies.[19] CAMS has set out to identify opportunities to reduce methane slip in the exhaust of natural gas compression engines and further understand the impacts of methane slip to natural gas systems.

Reducing Methane Slip

The most effective reductions of methane slip from natural gas combustion engines will incorporate methods to improve efficiency, rather than capture and recovery of the fugitive methane. The replacement of gas-powered engines with electric equivalents can completely eliminate methane slip. Higher efficiency engine designs, which promote complete combustion and reduced fuel usage, can also significantly promote the reduction of methane slip (i.e., 98% methane slip reduction with ARPA-E research reciprocating engine design).[20]

Cost is a major hurdle to scaling combustion engine replacements across the natural gas industry. It is estimated that most reciprocating engines (~3,600) currently operating across the natural gas industry are between 30 and 60 years old and have been maintained and retrofitted to accommodate changing site operations.[21] Many of these engines have extensive lifespans with continual maintenance, with total operation lifespans estimated to be nearly 100 years.[21] Hence, there are more immediate opportunities for the natural gas industry to reduce methane slip, such as with the use of combustion efficiency controllers, increased monitoring, and direct treatment of exhaust emissions.

Exhaust treatment of combustion engines via catalytic oxidation or regenerative thermal oxidizer equipment has gained interest as a method to reduce exhaust methane. There are still significant challenges with exhaust treatment solutions to reduce fugitive methane from combustion engines. Although catalytic treatment of exhaust to reduce methane is stated to highly effective (100% exhaust methane reduction), catalysts can be easily damaged by undesirable constituents such as H_2S in natural gas.[22] Mitigation of exhaust methane via additional treatment equipment also does not address methane slippage through other components of combustion equipment.

Methane slip associated with flare equipment can be mitigated by improving combustion efficiencies and reducing maintenance response times. Remote continuous data collection to monitor flare stack performance can allow operators to more quickly address faulty components that contribute to poor flare combustion efficiencies. Flares can also be retrofitted to be air assisted, which can improve combustion efficiency (to

98%) or treated and repurposed with a flare gas recovery system. Flaring is a valuable method to reduce methane releases from safety and maintenance of natural gas systems. However, advanced monitoring of flare equipment is a necessary emission mitigation measure to address methane slip.

Increased site measurement data is critical to addressing equipment with higher rates of methane slip emissions. ONE Future participating natural gas companies have mitigated methane slip via increased voluntary aerial LDAR surveys to identify and address inefficient combustion equipment of natural gas facilities.[23] Methane stack testing is another opportunity identified by ONE Future to reduce methane slip from reciprocating compressors. Advanced methane monitoring solutions can reduce methane slip across natural gas systems, by enabling faster, targeted maintenance of combustion equipment.

Conclusion

There are a variety of emission mitigation strategies to be deployed across natural gas systems. Programs which target LDAR, and energy efficiency improvements have demonstrated value in reducing emissions over the last few decades, as well as promoting the reliability of natural gas systems. There are still considerable efforts to be made to reduce methane emissions generated by the operations of natural gas systems. Emerging technologies such as more efficient combustion engines or electric equivalent engines, exhaust refinement, and continuous emissions monitoring are opportunities that can reduce methane over natural gas systems in the future. The implementation of LDAR, energy efficiency improvements and long-term mitigation of hard-to-abate methane emissions generated by natural gas systems will be essential as additional decarbonization pathways such as hydrogen, renewable natural gas, and carbon capture are considered and deployed.

For more information, please visit the NZIP website.

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