FIND MEASURE FIX

JOBS IN THE U.S. METHANE EMISSIONS MITIGATION INDUSTRY

A REPORT BY DATU RESEARCH

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ABOUT THIS REPORT

This work was prepared on behalf of Environmental Defense Fund.
edf.org

ABOUT DATU RESEARCH

Datu Research is an international consulting firm that provides the right data to the leading foundations, NGOs and governments that are working to solve humanity's most important challenges, including food security, soil health, and climate change.
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AUTHORS

Marcy Lowe and Robin Lowe-Skillern

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notchcode.com

COMPANIES AND POLICY VIEWS

Inclusion of company names in this report does not imply a position on federal or state policies regarding methane emissions.

None of the opinions or comments expressed in this study are endorsed by the companies mentioned or individuals interviewed. Errors of fact or interpretation remain exclusively with the authors. We welcome comments and suggestions.

CONTACT

Inquiries can be directed to: mlowe@daturesearch.com

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EXECUTIVE SUMMARY

The following report introduces policy makers, firms, researchers, and the general public to the growing methane emissions mitigation industry, describing its recent innovations, growth potential, and ability to provide U.S. jobs. These manufacturing and service firms offer solutions to oil and gas companies across the United States by finding, measuring, and mitigating methane emissions. Recent advances in emerging technology and advanced data analytics are making it possible to do so in ways never before possible.

Our research updates and builds upon two similar reports released in 2014 and 2017 — demonstrating that this growing industry:

Creates U.S. Jobs. Firms in the industry offer well-paid employment opportunities across the country that provide upward mobility and often involve fieldwork that cannot be offshored.

Saves Operators Money. Methane emissions mitigation reduces waste by keeping otherwise lost product in the sales line.

Improves Environment and Climate. Addressing natural gas leaks across the country reduces emissions of a highly potent greenhouse gas, while contributing to cleaner air in surrounding areas.

SEVEN KEY RESEARCH FINDINGS ABOUT THE METHANE EMISSIONS MITIGATION INDUSTRY

1) The industry is growing rapidly. Today it includes at least 101 manufacturing firms (a 33-percent increase over our 2014 count) and 114 service firms (a 90-percent increase over our 2017 count). Together, these firms have at least 748 employee locations nationwide.

2) The industry comprises dozens of job types, with annual salaries ranging from $37,150 to $140,960 (as compared to the U.S. annual mean wage of $56,310 for all occupations).[1] Common entry-level jobs such as assemblers and fabricators offer opportunity for upward mobility.

3) Most of the firms (70 percent) are small businesses, known to serve as an economic engine for new job growth.

4) Nearly 25 percent of the manufacturing firms and over 40 percent of the service firms were founded in the past 12 years, indicating a fast-growing industry.

5) Firms are adding new U.S. employee locations. In 2021, we identified a total of 748 employee locations for manufacturing and service firms, an increase of 26 percent over the number previously identified.

6) Firms anticipate growing jobs. Of 57 firms that responded to our survey, 75 percent of the manufacturing firms and 88 percent of the service firms reported that if future state or federal methane emission rules were put in place, they would anticipate hiring more employees.

7) These jobs appear poised to grow soon, since the current Administration and at least eight states are preparing either to introduce new methane rules or expand the scope of existing ones.

INTRODUCTION

PURPOSE

The purpose of this research is to describe and understand the growing industry of firms that provide methane emissions mitigation services and equipment to the oil and gas industry. Provided is an inventory of relevant companies, including size, maturity stage, and technologies used. Also documented are the geography, roles and wages of the methane emissions mitigation workforce. Through this research, we seek to answer key questions such as: What kinds of jobs are created by methane emissions mitigation? Where is the work performed? What kind of growth do these firms anticipate as a result of existing and potential state and federal regulations?

IN THIS 2021 FOLLOW-UP STUDY, WE UPDATE AND EXPAND THE INVENTORY OF RELEVANT FIRMS THAT PLAY EITHER A MANUFACTURING OR SERVICES ROLE IN METHANE EMISSIONS MITIGATION.

This report is a follow-up to two previous Datu Research reports. First, *The Emerging U.S. Methane Mitigation Industry* (2014) documented the manufacture of existing methane control technologies, analyzed the size and geographic distribution of the industry, and assessed future growth potential. The 2014 study found that the methane mitigation industry included at least 72 manufacturing firms, with over 500 locations across the United States. Second, *Find and Fix: Job Creation in the Emerging Methane Leak Detection and Repair Industry* (2017), identified 60 service firms that provided methane leak detection and repair (LDAR) services to oil and gas companies in 45 states.

In this 2021 follow-up study, we update and expand the inventory of relevant firms that play either a manufacturing or services role in methane emissions mitigation. This time, we include two added industry categories: Advanced Data Analytics (firms that use Artificial Intelligence (AI) and other advanced data techniques to detect and measure methane emissions) and Strategic Advisory (consulting firms that help operators plan for reducing or eliminating their methane emissions). Also new in this 2021 edition are several evolving technologies — for instance, those that enable operators to monitor emissions continuously, analyze methane data from satellites, and capture "associated" gas from oil sites either for use onsite or for distribution elsewhere.

METHODOLOGY

We identified 389 potentially relevant firms through purposive sampling and online research. Vetting this large list based on primary and secondary data collected in January and February 2021, we identified a total sample of at least 215 firms that comprise the U.S. methane emissions mitigation industry. To analyze this industry's contribution to job creation and its ability to provide methane emissions mitigation nationwide as demand grows, we reached out to firms via interviews and phone and email surveys. For six representative firms, we prepared brief profiles by conducting interviews with company executives and managers, followed by several additional communications to collect further information. Inclusion of company names in this report does not imply a position on federal or state policies regarding methane emissions.

WHY METHANE?

THE INTERNATIONAL ENERGY AGENCY ESTIMATES THAT 75% OF TOTAL METHANE EMISSIONS FROM OIL AND GAS OPERATIONS COULD BE AVOIDED WITH TECHNOLOGIES THAT ARE AVAILABLE TODAY.

MITIGATING CLIMATE CHANGE AND AIR POLLUTION

Methane is the largest component of natural gas. It has an extraordinarily high heat-trapping potential, making it a potent factor in global warming. To illustrate, in 2019, methane represented 10% of all greenhouse gas emissions in the United States, second only to carbon dioxide (CO_2).[2] However, in comparison to carbon dioxide, methane has a warming potential that is significantly higher: for the first 20 years after it is released into the atmosphere, methane has 84 times the heat-trapping effect of carbon dioxide and 28 times after 100 years.[3] The largest industrial source of methane emissions is the oil and gas industry, accounting for 33% of all U.S. methane emissions.[4] In addition to global warming, co-pollutants released by oil and gas operations contribute to smog formation and ozone, threatening public health on a global scale.

The International Energy Agency estimates that 75% of total methane emissions from oil and gas operations could be avoided with technologies that are available today — and since the captured gas can be sold, an estimated 40% of total emissions could be avoided at no net cost, based on 2019 natural gas prices.[5] This report takes inventory of the U.S. manufacturing and service firms that stand ready to help operators achieve these dramatic, often profitable reductions.

CREATING GOOD JOBS

Methane emissions mitigation means jobs. A wide and steadily expanding range of skills are required, from field technicians to chemical engineers to data scientists. Interviews with firms indicate that these jobs offer upward mobility. Many firms expect to expand their workforce if new federal and/or state methane rules are put into place. Of the eight states that either have methane rules or are considering them, seven are among the top states for employee locations in the methane emissions mitigation industry, including California, Colorado, Pennsylvania, New York, Wyoming, New Mexico, and Ohio. This would suggest that employee locations are poised to grow if the federal government and/or states roll out new rules on methane emissions.

TURNING WASTED NATURAL GAS INTO REVENUE

Methane is released into the atmosphere from equipment leaks and malfunctions in oil and gas operations and infrastructure. These methane emissions represent lost product for the oil and gas industry. When captured, this resource can be sold, leading to an increase in the amount of gas available to power U.S. homes, factories, and more. Reducing methane emissions capitalizes on previously lost revenue for the industry.

METHANE EMISSIONS MITIGATION INDUSTRY: FOUR CATEGORIES

HOW AND WHERE EMISSIONS OCCUR

Methane is emitted throughout the oil and gas supply chain, which consists of four stages: production; gathering and processing; transmission and storage; and distribution (see Figure 1). Production, gathering and processing occur at or near the site of the well. In these phases, companies drill, build (or "complete") and operate wells to produce natural gas. Once the gas is produced, compressors gather and "boost" it, sending it to plants where it is processed before moving to the next phase. In the transmission and storage phase, a series of compressors move the gas from the well site through pipelines to customers or storage facilities. Distribution occurs in the end market area, where natural gas is delivered to end users of various sizes.

Methane emissions in the supply chain occur in two ways — vented emissions and fugitive emissions. Vented emissions are intentional and occur by product and/or process design. For instance, many sites have pneumatic devices that use energy from pressurized gas to operate mechanical equipment; these devices vent gas continuously or intermittently to modulate a process. Fugitive emissions, by contrast, are unintentional, primarily in the form of leaks — such as those caused by failing seals or corroded material, or valves that are stuck open.

FIGURE 1. FOUR STAGES OF THE NATURAL GAS SUPPLY CHAIN

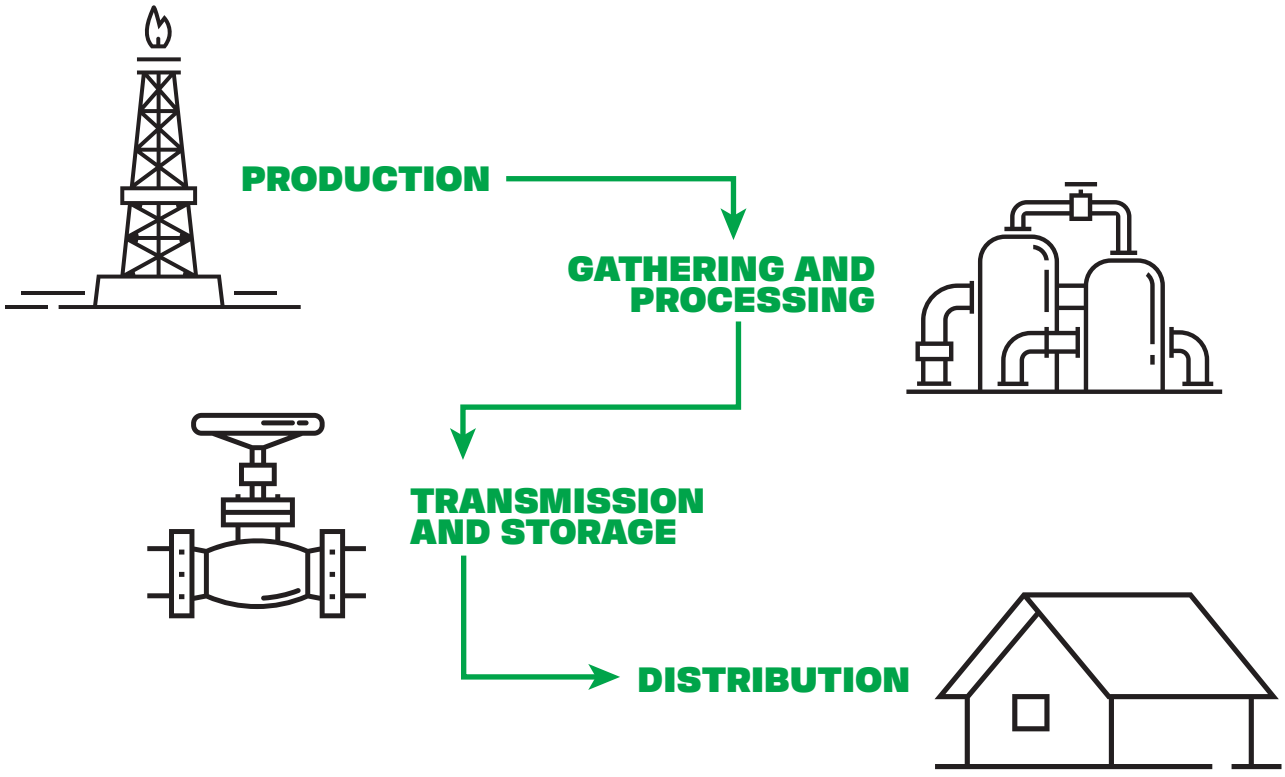


TABLE 1. FOUR CATEGORIES OF METHANE EMISSIONS MITIGATION FIRMS

LEAK DETECTION, MEASUREMENT & REPAIR	ADVANCED DATA ANALYTICS	MITIGATION TECHNOLOGIES	STRATEGIC ADVISORY
These firms provide leak detection, measurement, and/or repair services, using optical gas imagery, handheld sensors, fixed sensors, or sensors mounted on vehicles, drones, or aircraft.	These firms use big data, artificial intelligence, and machine learning techniques to find and/or measure methane emissions based on data from a range of sources, in some cases including satellite data.	These firms manufacture technologies that replace or add to existing devices to reduce emissions by preventing leaks, reducing venting, mitigating flaring, and/or capturing gas for use either on- or off-site.	These firms help oil and gas operators prepare their plans for reducing methane emissions from their operations, including net-zero commitments, energy transition, greenhouse gas verification markets and other opportunities.

Both vented and fugitive methane emissions occur in all stages of the natural gas supply chain, and they are nearly all avoidable. The methane emissions mitigation industry consists of firms that address avoidable emissions either by manufacturing equipment or providing services. These firms fall into four major categories: leak detection, measurement and repair; advanced data analytics; mitigation technologies; and strategic advisory, as summarized in Table 1.

The following section discusses each of these four categories in greater detail, along with the relevant technologies and promising innovations that have emerged in recent years.

1) LEAK DETECTION, MEASUREMENT, AND REPAIR

Methane is a colorless, odorless gas, which makes it challenging for oil and gas operators to detect methane leaks. Many operators find it cost effective to outsource leak detection services. Common leak detection technologies and platforms are summarized in Table 2. Leak detection is most commonly performed with handheld devices. Traditionally, the most-frequently-used devices have been infrared cameras and tunable diode lasers. Infrared or Optical Gas Imaging (OGI) cameras have become dominant in recent years; since they translate methane emissions into an easy-to-see gas plume, they make leak detection intuitive and user-friendly.

Many service firms amplify the coverage that is possible with handheld (or close-range) detection technologies by mounting them to road vehicles, unmanned aerial vehicles (UAVs, also called drones), helicopters, or airplanes. This enables them to cover much more of a facility in a shorter time. And to maximize the frequency of inspection, two additional approaches provide continuous screening, particularly useful to detect intermittent sources: fixed sensors installed throughout a facility, and even methane-sensing satellites.[6]

Continuous screening via fixed sensors is especially useful in high-risk areas, and can include an alarm that triggers if methane emissions exceed certain levels. Also promising is the prospect of satellite methane detection. Today, satellites can detect and measure methane concentrations in specific basins, but they are typically not yet capable of screening below the level of a particular facility. Governments and the private sector are making rapid progress, however, such that some researchers believe that facility-scale screening based on satellite data will be available in the near future.[7]

Since screening and close-range devices each have unique advantages, in the future they increasingly could play complementary roles in methane leak detection.

TABLE 2. METHANE LEAK DETECTION AND MEASUREMENT TECHNOLOGIES AND PLATFORMS

OPTICAL GAS IMAGING (OGI)
OGI cameras are thermal devices that create infrared images of methane plumes. Because they display results in a visual and intuitive manner, they enable operators to quickly and safely expose gas leaks. In recent years they have become the dominant close-range method.
NON-OGI CLOSE-RANGE INSTRUMENTS
Another widely used, effective close-range technology is laser spectroscopy. The device points a laser beam towards a suspected leak, and the target reflects back a diffused beam. The device then measures the absorptivity of the beam and calculates its methane column density.
FIXED SENSORS
Fixed sensors are installed in a facility — typically in high-risk areas — to provide continuous, real-time readings of methane concentration. These devices will trigger an alarm if concentrations exceed certain limits.
MOBILE GROUND LABS
Consisting of a vehicle with a global positioning system and a methane sensor, this enables an operator to generate a map of methane concentrations along the vehicle's path. Because it is limited to the path (usually a road), this method collects data in a two-dimensional space.
UNMANNED AERIAL VEHICLES (UAVS)
Also called drones, these can reach dangerous or hard-to-reach places and can fly very close to the source of plumes. They can be equipped with OGIs and other relatively small, lightweight sensor devices and, like aircraft, can operate in three-dimensional space.
AIRCRAFT
Various sensor types can be mounted on helicopters and small airplanes to detect methane emissions over relatively long periods while covering longer distances. Like drones, aircraft can collect data in three dimensions.
SATELLITES
Satellites can be equipped to measure methane concentrations in the troposphere. These readings can be combined with other data to identify large sources of emissions.

Source: Fox et al., "A review of close-range and screening technologies for mitigating fugitive methane emissions in upstream oil and gas." Note: Here, the source's original first category, "handheld instruments," is divided into OGI and non-OGI categories.[8]

Although screening technologies can cover larger areas and provide continuous monitoring, for instance, they cannot identify specific components that are leaking. But in a combined approach, screening technologies would quickly find high-emitting sites, and close-range devices would then follow up and identify the precise source of each leak.[9]

Once leak detection and repair firms have located leaks, their clients can choose to have them send out professionally certified technicians to perform the needed repairs. These boots on the ground help an operator's facility avoid wasting lost product and stay in compliance. Some firms even provide preventative maintenance and repair, such as detailed valve inventories and specialty valve repair.

IN A COMBINED APPROACH, SCREENING TECHNOLOGIES WOULD QUICKLY FIND HIGH-EMITTING SITES, AND CLOSE-RANGE DEVICES WOULD THEN FOLLOW UP AND IDENTIFY THE PRECISE SOURCE OF EACH LEAK.

2) ADVANCED DATA ANALYTICS

In this age of explosive growth in data availability, oil and gas operators can now collect and interpret data in different ways to identify leaks and quantify them. This newly emerging category within the methane emissions mitigation industry represents jobs quite different from those typically associated with the industry, including new skillsets required for data science, design thinking, artificial intelligence, and related approaches.

The role of data is evolving quickly. Not only does today's data help to detect more leaks in less time; it also makes it possible to detect leaks early, continuously monitor much larger spatial areas, and increasingly, even predict where future leaks are likely to occur.

Several relevant technologies and advanced data analytics techniques are summarized in Table 3. Drones are used to perform remote sensing, making it possible to cover much more territory than is possible with manual inspection, and to go into areas that may be dangerous or hard to reach. Continuous monitoring generates large amounts of useful data, helping operators manage their physical assets and make informed decisions about when to inspect, repair or replace them.

All of this data can be analyzed with AI techniques to create specific, actionable information that often exceeds what can be achieved with sensors alone. The potential to harness AI is greatest in operations that invest in IoT communication and extensive instrumentation — for example, to record and analyze temperatures, pumping rates, flow rates, and numerous other variables — although many upstream oil and gas facilities currently lack such instrumentation.

TABLE 3. ADVANCED DATA ANALYTICS IN METHANE EMISSIONS MITIGATION

REMOTE SENSING
Leak inspections can be done via remote sensing with the use of drones and other aircraft, which can expand the quantity and frequency of leaks found and repaired.
CLOUD COMPUTING
Moving to the cloud helps operators gain access to cutting edge technology applications, undertake enormous analytic workloads, and perform complex modeling to help identify and quantify methane emissions.
ARTIFICIAL INTELLIGENCE
AI is the umbrella over several "thinking" techniques that computers are now capable of performing. For instance, remote sensing data can be combined with AI algorithms to create smart methane emissions detection. AI experts are developing additional ways to perform high-level tasks that involve prediction or problem solving.
MACHINE LEARNING
A common AI technique is machine learning, in which the machine learns from experience, as opposed to being programed to follow specific instructions. For instance, the machine can be trained to "learn the shape that a methane leak takes as it is released and spreads."[10]
DEEP LEARNING
In Deep Learning, the machine finds hidden patterns in the data and combines them to come up with efficient decision rules. The machine can recognize images and sounds, enabling it, for instance, to reliably identify a methane plume.
INTERNET OF THINGS
IoT enables a system of computing devices (mechanical and digital) to transfer data over a network without requiring human participation. In oil and gas facilities, the data generated and shared in this way can be used to provide efficient and early leak detection.
PREDICTIVE MODELLING
Historical data can be used to "train" a model on the relationships between methane concentrations and certain variables. Those variable values can then be applied to real-time data to predict methane concentration values.

3) MITIGATION TECHNOLOGIES

Methane mitigation technologies are long established and well known in the oil and gas industry. In many cases they pay for themselves via the natural gas they save; the International Energy Agency (IEA) estimates that 40% of total emissions could be avoided with measures that have no net cost.[11] The main technologies, along with a description for each, are found in Table 4.

TABLE 4. METHANE EMISSIONS MITIGATION TECHNOLOGIES

LOW-EMISSION ROD PACKING AND DRY SEALS
Compressors are used to pressurize and transport natural gas; replacing typical seals with these low-emission seals and rod packing helps prevent compressor leaks.
LOW-EMISSION VALVES
Various valves are used to vent excess gas pressure for safety, or to stop the flow of gas when a line is severed or a pilot light is unlit. To avoid leaks, operators can replace failing valves early, preferably with low-leak valves.
ALTERNATIVES TO PNEUMATIC DEVICES
Pneumatic devices such as actuators, controllers and pumps use energy from pressurized gas to operate equipment. They vent gas to modulate pressure, flow, and more. Sites with electricity can replace gas-driven devices with compressed instrument air, electric, and solar alternatives.
REDUCED EMISSIONS COMPLETIONS (GREEN COMPLETIONS)
At sites that use hydraulic fracturing, excess fluid and produced water must be removed before routine production can begin. During the process, a large amount of methane escapes. Instead, temporary REC equipment can be brought to separate the gas and send it to the sales line.
LIQUIDS UNLOADING: PLUNGER LIFTS AND VELOCITY TUBING
A well's productivity can be impeded by accumulating liquids, often removed via a "blowdown," which allows the gas under pressure to push out the liquids--releasing large amounts of methane. Plunger lifts and velocity tubing can be used to release far less methane.
VAPOR RECOVERY UNITS
Vapor recovery units (VRUs) collect gas vapors from storage tanks. Methane vaporizes and collects between the liquid and the top of the tank, creating emissions that are often vented or flared. VRUs can capture them for on-site generators or compress them into a sales pipeline.
CAPTURE OF ASSOCIATED GAS FOR USE OR DISTRIBUTION
Instead of venting and flaring natural gas associated with oil operations, operators can use it as fuel for oil field activities by compressing it, or convert it to electric power using small-scale generators, or convert it to methanol or LNG.[12]
IMPROVED COMBUSTION FOR FLARING
If flaring is used, technologies can optimize combustion efficiency and ensure flares stay lit.

Significant emission reductions can come simply from replacing devices such as compressor rods and seals before they can corrode or get clogged, leading to gas leaks. Ideally, compressor rods and wet seals can be replaced with low-emission rod packing and dry seals, which further reduce emissions.

Some devices used in natural gas production emit methane routinely as part of everyday operations, including pneumatic devices (those that use energy from pressurized gas to operate equipment). At sites with electric power, gas-driven devices can be replaced with instrument air, electric, and solar alternatives. Also available are devices that exist expressly to cut emissions, such as vapor recovery units (VRUs), which recover gas found near the top of storage tanks that is otherwise vented or flared.

Large opportunities exist to reduce or even eliminate methane emissions from routine venting and flaring, especially at remote facilities — or at oil sites, where natural gas is not considered a product, but rather only "associated" with oil production. The World Bank's estimates from satellite data show that in 2019, global gas flaring increased to 150 billion cubic meters (bcm), equal to the total annual gas consumption of Sub-Saharan Africa.[13] This wasted gas could instead be used for energy, even while reaching net-zero emissions. For instance, several technologies capture associated natural gas and either use it onsite as fuel, or convert it to electricity or liquid fuels for distribution off-site. Others can improve flare combustion performance to achieve 99.99% efficiency, also using the waste heat to generate power.[14]

4) STRATEGIC ADVISORY

Oil and gas companies have long engaged the services of third-party service firms to help them with compliance and reporting. Many of the same firms that perform leak detection services also offer services to do this compliance work with their oil and gas clients. But in recent years, along with climate awareness, a new type of consulting has emerged, to help operators make strategic plans to reduce their methane emissions. These strategic advisory services go far beyond regulatory compliance and instead help operators envision how they can manage methane emissions to create a future business model that could differ considerably from a company's current configuration.

Much of the growth in this type of strategy consulting is motivated by investors' increasing embrace of Environmental, Social, and Governance (ESG) factors in their analysis of the financial metrics of a company. ESG has become an important aspect of risk assessment and investment decisions. The general public is also becoming more discerning, as climate awareness increases, and likelier to hold oil and gas operators accountable for their emissions.

Oil and gas companies that are focusing on ESG may work with traditional environmental consulting firms to set ambitious goals, such as those to reduce or even eliminate fugitive emissions — treating them not as an unavoidable downside of operations, but rather as an opportunity to recover lost product and to improve their greenhouse gas footprint.

THE WORLD BANK'S ESTIMATES FROM SATELLITE DATA SHOW THAT IN 2019, GLOBAL GAS FLARING INCREASED TO 150 BILLION CUBIC METERS (BCM), EQUAL TO THE TOTAL ANNUAL GAS CONSUMPTION OF SUB-SAHARAN AFRICA.

One of the largest opportunities to address methane emissions is to reduce or eliminate venting and flaring — two practices that are increasingly avoidable, given improvements in flaring alternatives, including efficient combustion technology.

Consultants can help by offering not only technical advice but also modifications to a company's business model, including how to make productive use of the recovered gas.

CHARACTERISTICS OF THE U.S. METHANE EMISSIONS MITIGATION INDUSTRY

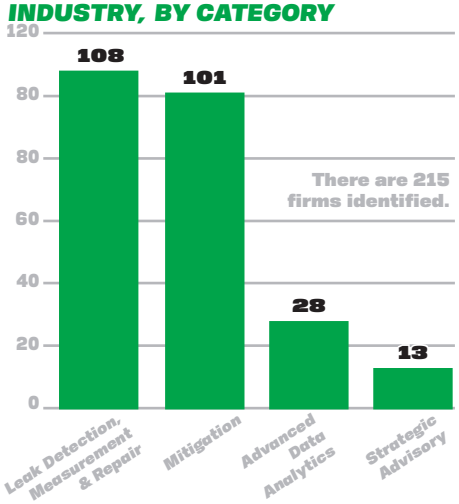
COUNT OF FIRMS

Our research identified a total of 215 firms that either manufacture technology for, or provide services to the oil and gas industry to manage methane emissions. This total is nearly evenly split between mitigation manufacturing firms (101) and service firms (114), as shown in Figure 2.

The industry appears to be growing rapidly. For the manufacturing firms, our 2021 total is a 33-percent increase over our 2014 count. For service firms, our current total is a 90-percent increase over our 2017 count. Service firms are mostly performing leak detection, measurement and repair (108 firms), while 28 service firms provide advanced data analytics, and 13 provide strategic advisory to oil and gas operators. Not exhaustive, this research is almost certainly an undercount in all manufacturing and service categories.

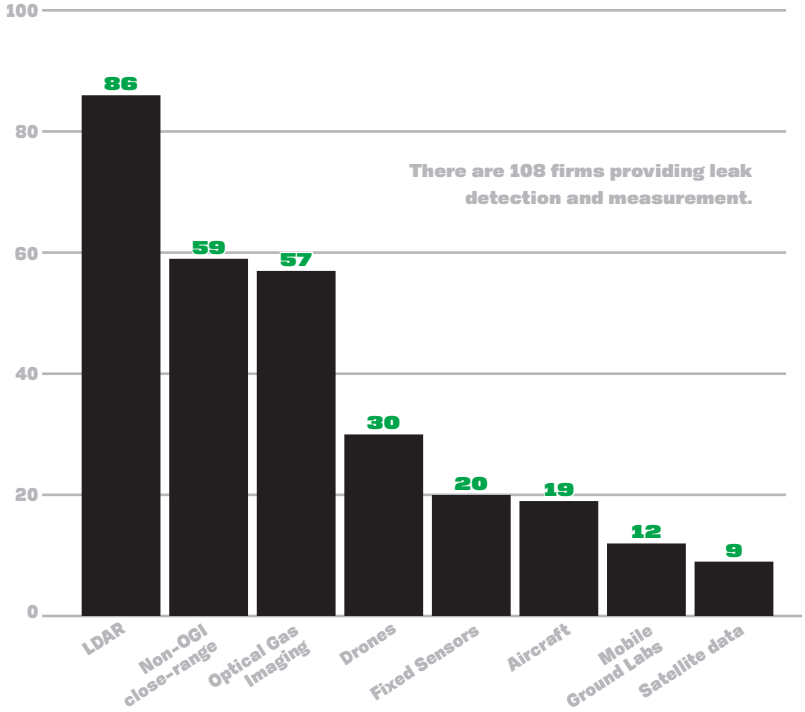
For two of our industry categories — Leak Detection, Measurement and Repair; and Mitigation — we assigned a number of relevant subcategories. Leak Detection, Measurement and Repair comprised eight subcategories, found in Figure 3. We chose to treat LDAR services (86 firms) as its own subcategory to distinguish these firms from the growing number of service firms that provide other detection- and measurement-related services. These include, for instance, New York-based start-up Bluefield Technologies, which uses artificial intelligence and machine learning techniques to analyze methane emissions data from ground sensors and satellites. Among firms

FIGURE 2. NUMBER OF FIRMS IN U.S. METHANE EMISSIONS MITIGATION INDUSTRY, BY CATEGORY



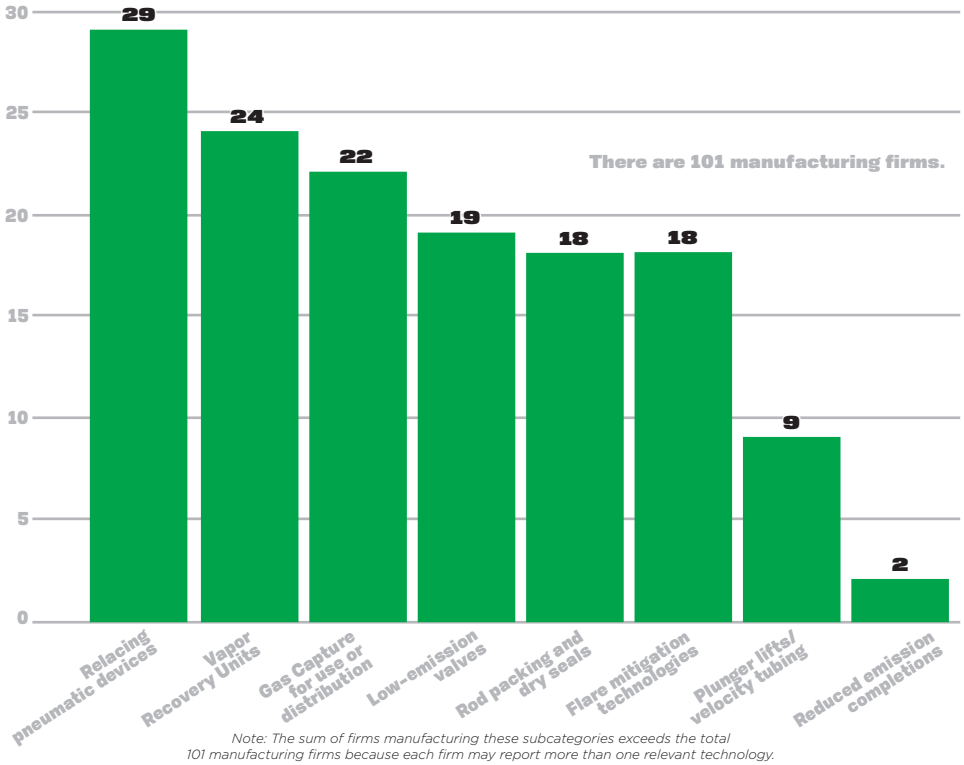
Note: The sum of firms in each category exceeds the total 215 firms because each firm may be active in two or more categories.

FIGURE 3. NUMBER OF FIRMS PROVIDING LEAK DETECTION & MEASUREMENT, BY TECHNOLOGY



Note: The sum of firms in these subcategories exceeds the total 108 firms providing leak detection and measurement services because each firm may report more than one relevant technology.

FIGURE 4. NUMBER OF FIRMS PROVIDING METHANE EMISSIONS MITIGATION, BY TECHNOLOGY



Note: The sum of firms manufacturing these subcategories exceeds the total 101 manufacturing firms because each firm may report more than one relevant technology.

that do perform traditional LDAR, 57 reported using OGI technology, roughly equal to those using all other handheld or close-range technologies (59 firms). This reflects how dominant infrared cameras have become in recent years, in part because of regulatory requirements like EPA's 0000a rulemaking.

Within Mitigation, we divided the manufacturing firms also into eight technology subcategories, found in Figure 4. The largest number of firms (29) reported that they manufacture alternatives to pneumatic devices, followed by vapor recovery units (24), and technologies to capture gas for use or distribution (22). Together, these three categories accounted for 74 percent of the 101 mitigation firms identified, meaning that nearly three-fourths of the firms in the mitigation space are manufacturing one or more of these three technologies. This is in sharp contrast to the two smallest categories; plunger lifts and velocity tubing are provided by only nine manufacturing firms, and reduced emission completion technology, only two.

FIRMS' EMPLOYEES, REVENUES, AND MATURITY STAGE

Most firms identified in this study are small businesses. The U.S. Small Business Administration (SBA) provides varying definitions of small businesses according to the characteristics of each sub-industry. The definitions are usually based on number of employees. For this study, we use 500 employees as the upper benchmark for small manufacturing firms, and 200 employees for service firms, which tend to have smaller staffs. According to these criteria, 62 manufacturing firms and 78 service firms — that is, 70% of identified firms, qualify as small businesses (see Figure 5).

Similar to the size ranges for number of employees, the size ranges for sales begin much higher at the low end for manufacturing firms than for service firms. Accordingly, the lowest sales range for manufacturing, $1M to $38.5M, applied to 48 firms. Six firms were in the highest range, those topping $10B in sales. Service firms had a steep drop-off between the 0-$15M range (61 firms) and the $15M-50M range (18 firms). The highest sales range for manufacturing and services--$10B and above — applied in several cases to firms that perform both manufacturing and services, such as ABB Group, Ball Corporation, and Schlumberger.

FIGURE 5. NUMBER OF EMPLOYEES, METHANE-RELEVANT MANUFACTURING AND SERVICE FIRMS

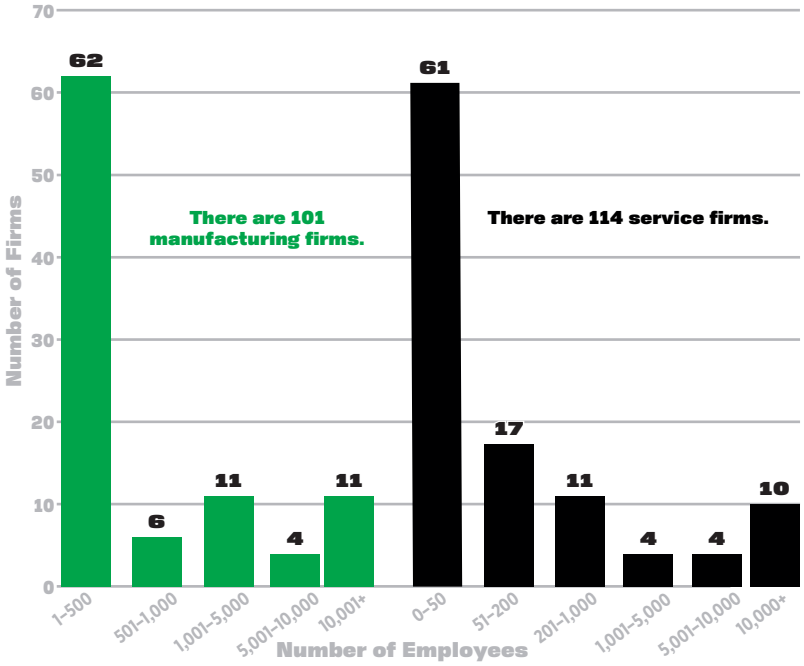
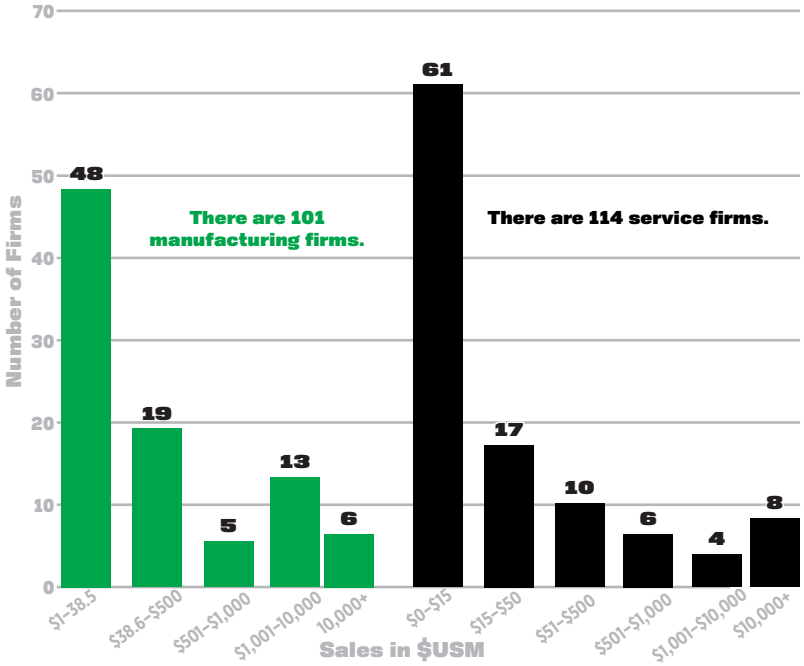
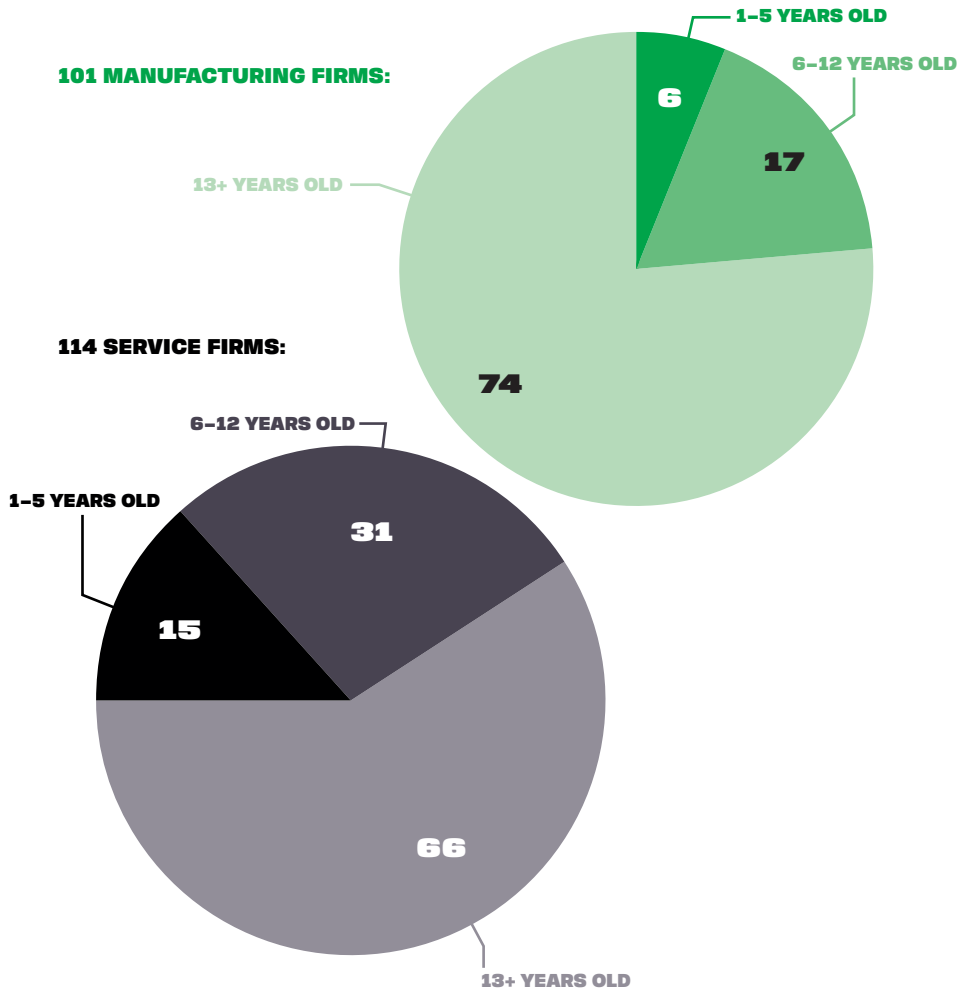


FIGURE 6. ANNUAL SALES, METHANE-RELEVANT MANUFACTURING AND SERVICE FIRMS



Most of the manufacturing firms we identified are mature firms (see Figure 7); 74 of 100 are at least 13 years old, and 12 — including National Oilwell Varco, Siemens Energy, and Gardner Denver — were founded before 1900. Only six of the manufacturing firms are startups. In contrast, the service firms we identified tend to be younger. Mature service firms constitute just 66 of the total of 114, and startups account for 15 firms. To meet demand for methane-related services, new service firms are emerging in states where the natural gas industry is prevalent. Since 2010, nine new firms have established headquarters in Texas alone, opening a total of 13 employee locations in the state.

FIGURE 7. MATURITY STAGE, METHANE-RELEVANT MANUFACTURING AND SERVICE FIRMS



Note: Founding year was unavailable for a few of the identified firms.

REGULATORY LANDSCAPE

FEDERAL REGULATIONS

A summary of federal methane LDAR regulations is found in Table 5. In 2016, the Environmental Protection Agency (EPA) adopted rules that serve to reduce methane emissions, local air pollution, and natural gas waste from new and modified oil and gas facilities. While these rules were weakened under President Trump, EPA's New Source Performance Standards[15] currently require new and modified non-low production well sites and gathering and boosting compressor stations to conduct semiannual leak detection and repair.[16] President Biden recently directed EPA to review these amendments and move forward with emission standards for older, existing oil and gas facilities.[17] Through agency action, EPA methane rules could be expanded and strengthened to reduce more emissions.

With strong federal emissions standards, operators would waste less product and generate greater economic returns for taxpayers, states and tribes, and royalty owners. At the same time, deep reductions of methane, a potent greenhouse gas, are critical to meeting the United States' climate goals.[18] Federal standards designed to achieve ambitious emissions reductions will necessitate large-scale investment in the methane mitigation industry.[19]

TABLE 5. FEDERAL METHANE LDAR REGULATIONS

JURISDICTION	REGULATORY AGENCY	REGULATION NAME	REGULATION STATUS	SOURCES ADDRESSED	LDAR TESTING FREQUENCY	REQUIRED LDAR TECHNOLOGY	PATHWAY FOR INNOVATIVE TECHNOLOGIES	NOTABLE EXCLUSIONS
Federal (All Lands)	Environmental Protection Agency	Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources[20]	In effect without methane regulation;[21] under agency review at time of report release	New and modified sources in production and gathering and boosting	Semi-annual for non-low production well sites, gathering and boosting compressor stations	OGI or portable analyzers	Yes, per agency approval; criteria and process provided	Low-production well sites; transmission and storage (exclusions new to Trump amendments)

STATE REGULATIONS

Various states established or improved their own methane LDAR standards while Federal rules were in a state of uncertainty. Leaders like Colorado and California expanded the scope of their regulations to include low-producing sources and the transmission segment, respectively. Pennsylvania took the significant step of proposing a rule for existing sources, while Ohio has started early stakeholder outreach to do the same. Maryland started requiring quarterly LDAR in late 2020 for the gathering and processing and transmission segments, with well sites to follow in a second phase of the rulemaking. And New York has begun the stakeholder outreach process for quarterly LDAR at new and existing sources.

STATE REGULATIONS CAN NOT ONLY PROVIDE AN OPPORTUNITY FOR THE METHANE MITIGATION INDUSTRY TO GROW AND INNOVATE, BUT ALSO TO SERVE AS CASE STUDIES FOR WHAT IS VIABLE ECONOMICALLY AND POLITICALLY AT THE FEDERAL LEVEL.

Most significantly, New Mexico has proposed its first regulation on fugitive emissions in the oil and gas industry. The proposal addresses both new and existing sources and focuses on areas with high reported ozone levels (although proposed exemptions have raised questions about stringency). Equipment leaks are the largest reported source of emissions in the state's oil and gas industry.[22] A summary of the status of state methane LDAR regulations is found in Table 6.

Currently, some states with methane LDAR regulations have included exemptions of some kind — often for low producers, even though the relationship between production levels and total fugitive methane emissions is not necessarily direct, meaning that small producers are still capable of large emissions. In fact, a September 2020 study in Ohio found that "oil and gas wells in this lowest production category emit approximately 11% of total annual CH_4 from oil and gas production in the EPA greenhouse gas inventory, although they produce about 0.2% of oil and 0.4% of gas in the US per year."[23] Exemptions based on good results in previous emissions are another vulnerability, as consistent and frequent inspections are key for catching new leaks.[24]

States can also help improve emissions reductions by allowing the use of alternative technological innovations and providing clear criteria and directions for the approval process. This can in turn reduce compliance costs for operators. Currently, Maryland, New York, New Mexico, and Colorado have such provisions. California has no such provision for most of its regulated facilities but has acknowledged that it may revise its rule in the future to do so.[25] Wyoming, Ohio and Pennsylvania have provisions for alternative monitoring methods, but without a clearly defined approval pathway. Such a pathway will make the regulatory landscape more inviting to investment.

Though a patchwork of LDAR requirements for fugitive methane emissions at the state level cannot substitute for a consistently defined and implemented federal policy, nor ensure the uniform conditions that would encourage large-scale investment, state regulations can not only provide an opportunity for the methane mitigation industry to grow and innovate, but also to serve as case studies for what is viable economically and politically at the federal level.

TABLE 6. STATE METHANE LDAR REGULATIONS

JURISDICTION	REGULATORY AGENCY	REGULATION NAME	REGULATION STATUS	SOURCES ADDRESSED	LDAR TESTING FREQUENCY	REQUIRED LDAR TECHNOLOGY	PATHWAY FOR INNOVATIVE TECHNOLOGIES	NOTABLE EXCLUSIONS
California	California Environmental Protection Agency	GHGs Emission Standards for Crude Oil and Natural Gas Facilities[26]	In effect	New and existing sources	Quarterly	OGI or portable analyzers (must use analyzers at least once)	No	Equipment already under local standards
California	California Public Utilities Commission	Natural Gas Leak Abatement Program	In effect	New and existing sources	Triennial, or more frequent for high-risk equipment	No specific technology required	Yes	
Colorado	Colorado Department of Public Health and Environment	Reg. 7 Control of Ozone via Ozone Precursors and Control of Hydrocarbons via Oil and Gas Emissions[27]	In effect	New and existing sources	Annual, semi-annual, quarterly or monthly based on facility type, output capability and emissions over previous year	OGI or portable analyzers based on facility type, output capability and emissions over previous year	Yes, per agency approval; process and criteria pending	
Maryland	Maryland Department of the Environment	Control of Methane Emissions from the Natural Gas Industry[28]	In effect	New and existing sources	Quarterly	OGI or portable analyzers	Yes, per agency approval; process and criteria pending	Well sites (to be addressed in Phase 2 rule)
New Mexico	New Mexico Environment Department	Oil and Natural Gas Regulation for Ozone Precursors[29]	Preliminary draft released at time of report release	New and existing sources in high-ozone areas	Annual, semi-annual, quarterly or monthly based on emissions potential	OGI or portable analyzers	Yes, per agency approval; process and criteria pending	Low producers and low projected emitters
New York	New York State Department of Environmental Conservation	Oil & Natural Gas Sector Emissions in New York[30]	Early stakeholder outreach in 2018	New and existing sources	Quarterly	OGI, or portable analyzers at a certain threshold level	Yes, per agency approval; process and criteria pending	

TABLE 6. STATE METHANE LDAR REGULATIONS, CONTINUED

JURISDICTION	REGULATORY AGENCY	REGULATION NAME	REGULATION STATUS	SOURCES ADDRESSED	LDAR TESTING FREQUENCY	REQUIRED LDAR TECHNOLOGY	PATHWAY FOR INNOVATIVE TECHNOLOGIES	NOTABLE EXCLUSIONS
Ohio	Ohio Environmental Protection Agency	General Permit 18.1[31]	In effect	New and modified major sources	Quarterly for one year with step-downs if <2% of equipment leaked over previous year	OGI or portable analyzers	No; option for individual has been requested	Conventional well sites, transmission and storage segment
Ohio	Ohio Environmental Protection Agency	New Rules Regulating Emissions from the Oil and Gas Industry[32]	Early stakeholder outreach in 2018	New and existing sources	Quarterly with stepdown for production sites if <2% of equipment leaked over last two inspections	OGI or portable analyzers	TBD	Transmission and storage segments
Pennsylvania	Pennsylvania Department of Environmental Protection	General Permit 5 and 5A[33]	In effect	New and modified sources	Quarterly with stepdown if <2% of equipment leaked over last two inspections	OGI or portable analyzers	Yes, per agency approval; process and criteria pending	Conventional well sites
Pennsylvania	Pennsylvania Department of Environmental Protection	Control of VOC Emissions from Oil and Natural Gas Sources[34]	Rule proposed	New and existing sources	Quarterly with stepdown if <2% of equipment leaked over last two inspections	OGI or portable analyzers	TBD	Transmission segment; low producers
Wyoming	Wyoming Department of Environmental Protection	Air Quality Standards and Regulations Ch. 6 Section 2[35]	In effect	New and modified sources, existing sources in Upper Green River Basin	Semi-annual or quarterly based on area, source type, previous emissions	OGI or portable analyzers, or AVO for existing sources in Upper Green River Basin	Yes, per EPA criteria; process not provided	Conventional sources, transmission and storage segment

JOBS

Reducing methane emissions from the oil and gas industry not only protects the climate and reduces product loss; it also creates jobs. These are good jobs that pay well and offer upward mobility. Many of them require on-site work, so they are not at risk of being offshored.

The manufacturing and service firms described in this study represent a large number of occupations, including engineers, designers, technicians, assemblers, fabricators, and many others (see Table 7 and Table 8). Compared to as recently as five years ago, software and data-related occupations are increasingly prominent, especially in the service firms. This is consistent with a digitalization process underway throughout the oil and gas industry.[37]

TABLE 7. U.S. MEDIAN WAGES OF KEY OCCUPATIONS IN METHANE MITIGATION MANUFACTURING[36]

OCCUPATION	MEDIAN ANNUAL SALARY ($US)
Chemical Engineers	$ 140,960
Electrical Engineers	$ 126,520
Civil Engineers	$ 119,500
Mechanical Engineers	$ 114,520
Software and Web Developers, Programmers, and Testers	$ 109,560
Computer Programmers	$ 108,280
Electronics Engineers, Except Computer	$ 104,110
Environmental Engineers	$ 102,680
Industrial Engineers, Including Health and Safety	$ 101,250
Industrial Engineers	$ 97,570
Occupational Health and Safety Specialists and Technicians	$ 84,740
Commercial and Industrial Designers	$ 82,470
Electrical and Electronic Engineering Technologists and Technicians	$ 73,050
Control and Valve Installers and Repairers	$ 71,510
Engineering Technologists and Technicians, Except Drafters	$ 70,780
Drafters, Engineering Technicians, and Mapping Technicians	$ 68,780
Industrial Machinery Mechanics	$ 68,290
Environmental Engineering Technologists and Technicians	$ 67,210
Industrial Machinery Installation, Repair, and Maintenance Workers	$ 67,020
Installation, Maintenance, and Repair Occupations	$ 64,560
Industrial Engineering Technologists and Technicians	$ 63,070
Drafters	$ 58,210
Assemblers and Fabricators	$ 37,150

TABLE 8. U.S. MEDIAN WAGES OF KEY OCCUPATIONS IN METHANE MITIGATION SERVICES[38]

OCCUPATION	MEDIAN ANNUAL SALARY ($US)
Computer and Information Research Scientists	$ 126,410
Chemical Engineers	$ 110,840
Computer Hardware Engineers	$ 108,140
Health and Safety Engineers	$ 104,740
Atmospheric and Space Scientists	$ 102,060
Electrical and Electronics Engineers	$ 99,800
Electrical Engineers	$ 96,600
Information Security Analysts	$ 95,830
Software and Web Developers, Programmers, and Testers	$ 95,610
Materials Engineers	$ 92,000
Mechanical Engineers	$ 90,560
Environmental Engineers	$ 88,420
Chemists and Materials Scientists	$ 86,810
Computer and Information Analysts	$ 85,290
Commercial and Industrial Designers	$ 84,990
Industrial Engineers	$ 84,700
Computer Systems Analysts	$ 83,640
Computer Programmers	$ 83,060
Geoscientists	$ 82,190
Management Analysts	$ 81,740
Environmental Scientists and Geoscientists	$ 75,240
Web Developers and Digital Interface Designers	$ 74,570
Physical Scientists	$ 71,170
Business and Financial Operations Occupations	$ 66,880
Designers	$ 63,240
Aircraft Mechanics and Service Technicians	$ 60,730
Precision Instrument and Equipment Repairers	$ 60,640
Drafters, Engineering Technicians, and Mapping Technicians	$ 54,290
Calibration Technologists and Technicians	$ 52,820
Computer Support Specialists	$ 52,640
Environmental Engineering Technologists and Technicians	$ 48,800
Environmental Science and Geoscience Technicians	$ 43,160
Installation, Maintenance, and Repair Occupations	$ 40,030
Drone operators	$ 40,000
Assemblers and Fabricators	$ 38,900

GEOGRAPHY

The distribution of jobs that comprise the methane emissions mitigation industry is robust, with at least 748 employee locations spread across 47 states, plus Puerto Rico and the District of Columbia. The only states without employee locations in our 2021 count are Hawaii, Idaho and Mississippi. In total, we identified 210 headquarters, 111 manufacturing/assembly locations, and 473 other employee locations (see map in Figure 8).

FIGURE 8. U.S. EMPLOYEE LOCATIONS OF FIRMS IN METHANE EMISSIONS MITIGATION INDUSTRY

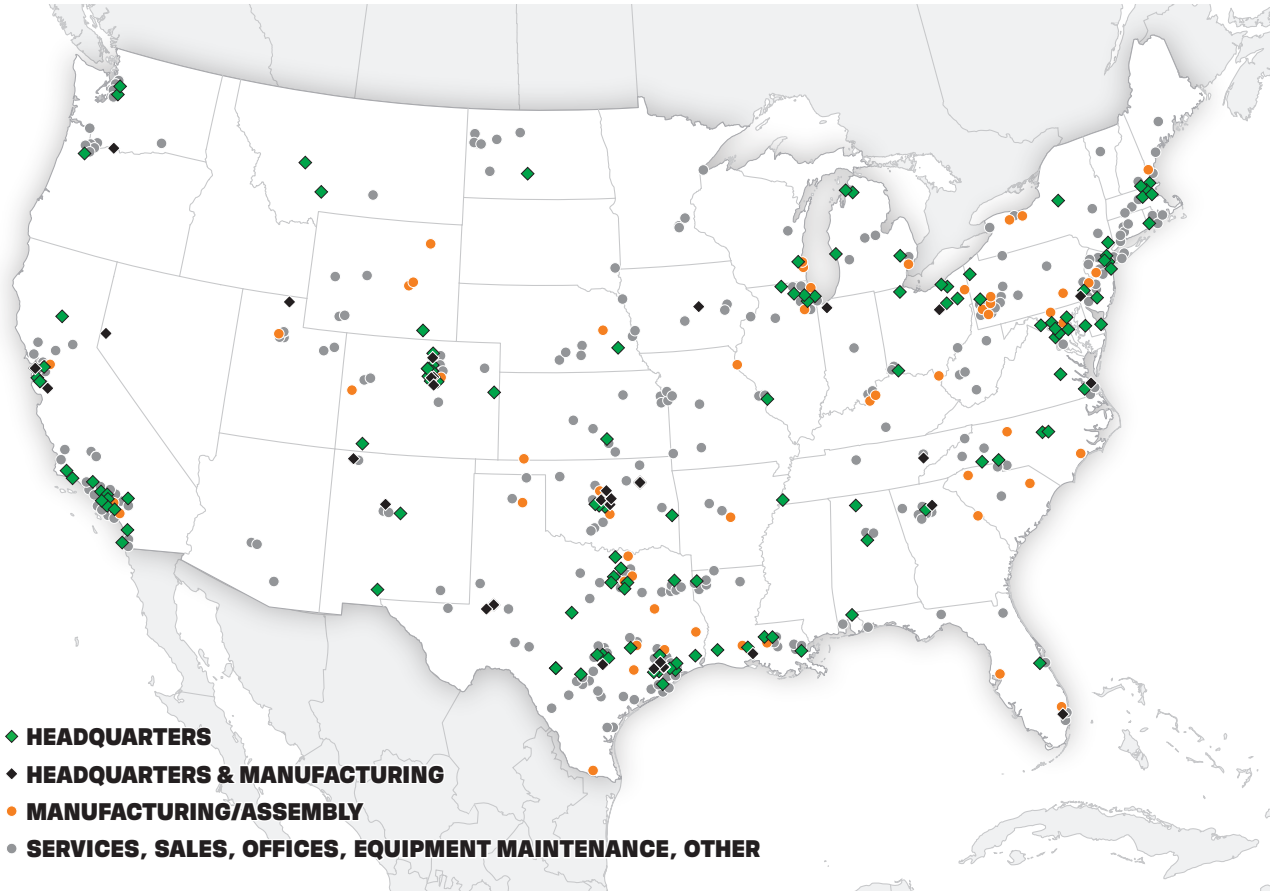
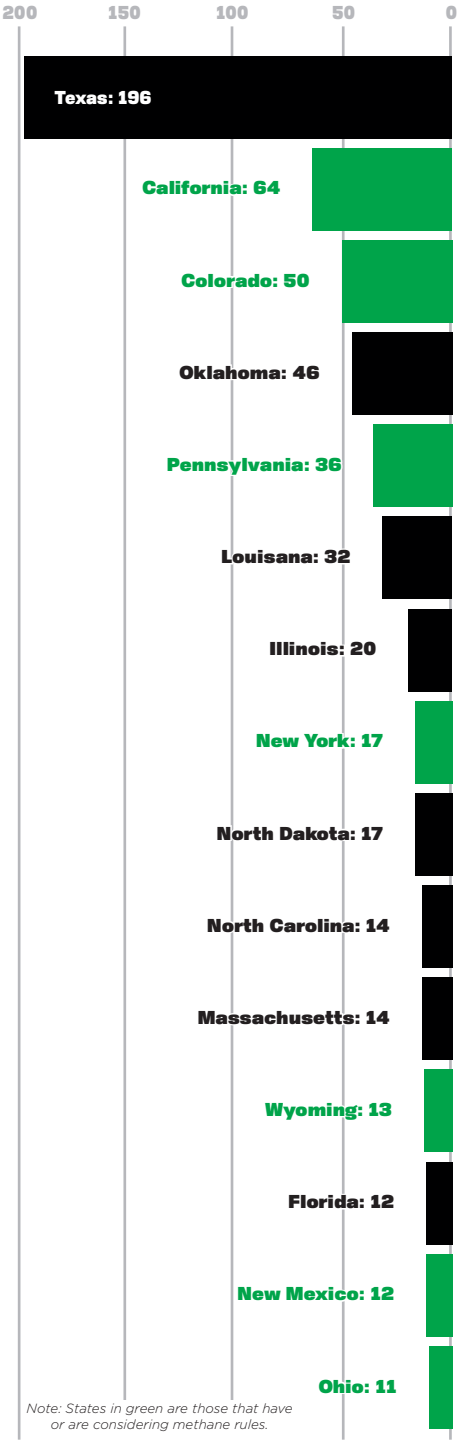


FIGURE 9. TOP 15 STATES IN US EMPLOYEE LOCATIONS, METHANE EMISSIONS MITIGATION, 2021



Note: States in green are those that have or are considering methane rules.

Unsurprisingly, the heaviest concentrations of employee locations are found in oil and gas-producing states (see Figure 9). Of the 748 locations identified nationwide, 392 of these sites, or 52 percent, are in the five states of Texas, California, Colorado, Oklahoma, and Pennsylvania. One state that has seen especially high growth is California — relevant employee locations in California have grown 167 percent since our previous counts — perhaps an indication of the fast-growing role of data and information technology firms in detecting and measuring methane emissions. Such California-headquartered firms include Kelvin, which uses AI for process control in order to predict future leaks; Orbital Sidekick, which builds and launches hyperspectral imaging satellites; and Planet, which builds satellites and operates a platform that downloads and processes 11+TB of data daily.

Also not surprising is that nearly half of the top 15 states (shown in Figure 9) are states that either have methane rules in place or are considering them. Of the eight such states, seven are in this top-state list, including California, Colorado, Pennsylvania, New York, Wyoming, New Mexico, and Ohio. This would suggest that employee locations are poised to grow if the federal government and/or states roll out new rules on methane emissions.

ANTICIPATED GROWTH

We reached out to all 215 identified firms with a brief survey in which we asked, "Do you feel that future state or federal methane emission rules would likely help grow your company — and if 'yes,' in what ways?" A total of 57 firms responded. Among manufacturing firms, 75 percent (18 out of 24) reported that if future state or federal methane emission rules were put in place, they would anticipate hiring more employees. For service firms, this figure was 88 percent (29 out of 33). Full survey results are found in Figure 10. A sample of comments by surveyed firms that reported anticipating future growth is found in Figure 11.

FIGURE 10. GROWTH ANTICIPATED BY METHANE EMISSIONS MITIGATION FIRMS

Manufacturing Firm Responses: 24 **Service Firm Responses: 33**

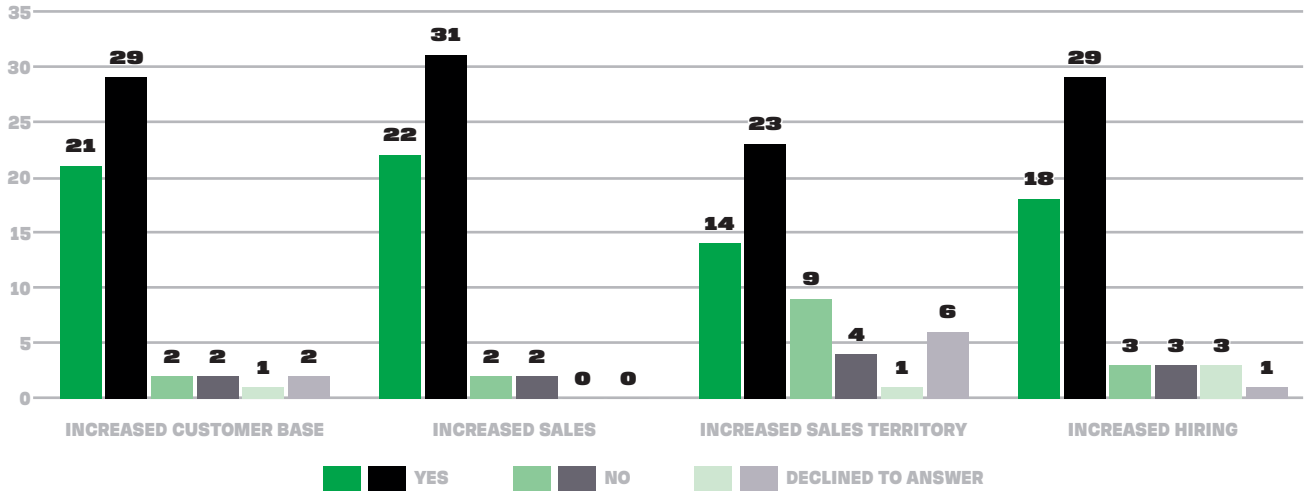


FIGURE 11. COMMENTS ON ANTICIPATED GROWTH, SELECTED METHANE EMISSIONS MITIGATION FIRMS

Yes - we would need to increase our engineering payload, payload operations, analysts/ data processing, and flight operations teams.

Also, pressure from investors. Customers seem to be adopting wholesale (faster than anticipated). Currently hiring data positions.

Yes, we already feel the increase and phone calls. We are looking to add as many as 15 to 20 back for patrol and data processing.

With additional methane emissions rules we believe that there will be more companies looking for ways to provide disclosure and transparency. We would plan to hire and grow our teams to meet those needs.

It is game on in the US now that methane emission reductions are back on the table. Canadian market is already taking off. Yes, we will more than triple in size if our sales forecasts are correct.

Additional employees: perhaps in the long run depending on what the new rule requirements might be.

There are thousands upon thousands of valves and controls leaking natural gas today ... We would expand customer base, increase sales and expand our sales territory.

COMPANY PROFILE: LASEN

An extraordinarily sensitive laser technology mounted on a helicopter can survey hundreds of miles of pipeline in a day, detecting even the smallest of leaks.

LaSen is a leak detection firm that provides precision remote sensing of pipelines using aerial LiDAR survey. Its unique system has detected more than 40,000 leaks along 500,000 miles of pipeline, preventing nearly 45 billion cubic feet of methane from escaping into the atmosphere.

Developed in-house, LaSen's differential absorption LiDAR system sends two laser beams down to the ground — one that's tuned to the methane spectrum, and a reference beam that's not tuned to anything. When the methane-spectrum beam passes through any amount of methane, its power is diminished, so when it bounces back to the sensor, it's much different from the reference beam, indicating the presence of methane. The amount of difference between the two beams is then used to determine the size of the leak.

THE LASEN SYSTEM IS THE ONLY ONE ON THE MARKET THAT WORKS IN THE MID-IR SPECTRAL REGION, A DISTINCTION THAT MAKES IT EXTREMELY SENSITIVE.

The LaSen system is the only one on the market that works in the mid-IR spectral region, a distinction that makes it extremely sensitive; it can detect methane concentrations as low as four parts per million. LaSen president Tim Goolsby notes that, while competitors' technology finds only larger leaks, "Ours finds all of them."

BENEFITS TO OPERATORS AND COMMUNITIES

LaSen provides its clients the distinct advantage of much faster inspection than is possible with traditional methods. "Surveying on foot or by vehicle," says Goolsby, "they have issues with access to properties, safety issues, logistics. They can only cover, on a good day, maybe five or six miles of pipeline, where we cover about 400 miles a day." Goolsby notes that this time savings is crucial for managing emissions. "Instead of it leaking for two months while their technicians are out there looking for it, our clients can go straight to getting it fixed."

Along with the leak detection, LaSen's clients also receive photographs and video footage of each inspection flight, giving them a near-real-time view of their right-of-way. These aerial views help an operator identify construction activities that could potentially affect the pipeline. They also help locate fallen or outdated "pipeline markers," required indicators installed along the right-of-way that serve as a warning that a buried pipeline is nearby.

EMPLOYMENT OPPORTUNITIES

Because LaSen develops and manufactures its technologies in-house, it requires a wide range of job types and skill sets. These include a PhD researcher, software engineer, lab technicians, and "jacks of all trade" who can weld, do precision machining, create PCB boards, design laser packages, and do 3-D printing. The 12 pilots and 12 LiDAR sensor technicians fly pipelines seven days a week. One-quarter of the staff are military veterans, and one-quarter are of Hispanic origin.

"From 2017 until now," says Goolsby, "we've doubled the number of employees, revenue, and the number of miles we've inspected." He sees that trend continuing. The company's five-year plan calls for adding another 20 or 30

employees. To handle this growth, they will soon break ground on a new 37,000-square-foot facility with a full machine shop, a dedicated laboratory, and ample office space.

FUTURE DEVELOPMENTS

Innovating continuously to improve leak detection, LaSen plans to keep adding new technologies and services. It is now working to create an "active" pipeline marker. Markers currently in use are not always easy to see. They can fall or get knocked down, and on older pipelines, their recorded locations may be inaccurate. LaSen's marker will be capable of detecting and reporting whether it is up or down; it will have its GPS coordinates encoded in it; and a reflector, small light, and strobes will improve its visibility at night. In the second phase of development, it will include a methane sniffer.

As for new services, the company is adding drones so it can inspect facilities, well pads, and compressor stations, using a third-party methane sensor to pinpoint leaks and an OGI camera to help clients see them on video. Another new service is detecting leaks over water. LaSen is working with Pacific Gas & Electric (PG&E) to test a new drone-mounted sensor that will enable them to inspect all their waterways from the air — an efficient replacement for the current process, which is done by boat.

Perhaps most exciting, LaSen is expanding its footprint beyond the United States. The company recently received its Standard Type Certificate from the Federal Aviation Administration to fly in Canada, the European Union, and Australia.

COMPANY PROFILE: AVITAS SYSTEMS

Thanks to immense data sets collected via drones and continuous monitoring — combined with advanced data techniques such as machine learning and computer vision — operators can identify and mitigate emissions more safely and cost-effectively than ever before.

Avitas is a 100% Baker Hughes-owned company, created in 2017 on the expectation that oil and gas operators can vastly improve their inspection processes by taking a digital approach to what is currently done by hand. Drawing on Baker Hughes' industry expertise and scale, Avitas helps its clients maintain asset integrity, with a strong focus on detecting, localizing and quantifying greenhouse gas emissions.

IT IS PERHAPS THE GROWING NEED FOR CUTTING EDGE, DATA-RELATED SKILLS THAT EXPLAINS WHY AVITAS IS CONSISTENTLY STAFFING UP.

Avitas offers both continuous monitoring and unmanned aerial systems (drones) to detect and characterize emissions. Having invested considerable resources in cyber-physical technology, advanced data analytics, and a powerful cloud-based platform, the company can cover more extensive assets across a wider geography than before. It can also gather data reliably and safely in remote or high-risk locations. Once gathered, the monitoring data is ingested and analyzed using proprietary algorithms and analytics that enable the Avitas team to pinpoint fugitive emission sources and quantify them. The Avitas end-to-end digital approach can continually learn, making future inspections even more accurate.

Jennifer Stewart, Avitas Vice President of Strategic Growth, notes that the company shares all this information gathered by aerial surveys with each client via an easy-to-use, cloud-based platform that provides not only an emissions profile, but also a 3D digital twin of the asset, including a detailed inventory of the componentry. The client can at any time pull up a report that is refreshingly intuitive and actionable. "A lot of companies use tabular data," Stewart says, "but it's our visual analysis that makes it easy to grasp and act on. We can tell them, 'Hey, hatch number five is leaking, see that? Here's the outline of the plume, and here's the quantification.'"

BENEFITS TO OPERATORS

Clients find that Avitas' aerial survey technology enables them to focus their methane emission efforts cost-effectively. Stewart attributes this to the data analytics looking not just backward, but forward. To illustrate: after six months of monitoring a large commercial operation via aerial surveys, the Avitas team identified a clear trend of certain components being the biggest emitters. "So the client then realized, 'I don't need to focus over there, I need to focus right here, because it's where a leak is likely to develop,'" says Stewart.

Another benefit important to clients is timeliness. So, notes Stewart, if you're using continuous monitoring, you can find a leak and fix it very quickly, as opposed to not knowing about it until the next semi-annual inspection.

And, for operators interested in demonstrating they are actively controlling their emissions, the use of continuous monitoring and aerial inspection technologies can

demonstrate — to investors, lenders, certifiers, and the general public — that they have a lower-emitting product.

In addition to benefiting its own clients, Avitas seeks to have a significant impact on the oil and gas industry as a whole. The company has developed an Emissions Reduction Potential (ERP) metric, which is used to assess the efficiency of an inspection program; it provides operators the information they need to more quickly reduce their emissions. "That's what we want to deliver," says Stewart, "whether or not we're the one that's going out there and closing the valve." The team keeps this big picture in mind as it makes strategic decisions because the industry's continued viability, access to capital, and public acceptance depend in large part on reducing its greenhouse gas emissions.

EMPLOYMENT OPPORTUNITIES

The company has two technical groups. The engineering group comprises electrical, mechanical, and robotics engineers. The software and analytics group includes data engineers (who extract, collect, and integrate data); data scientists (who analyze the data provided by the data engineers). Among the data scientists are those specializing in computer vision, machine learning, and other artificial intelligence techniques. All have very different skills, and much of the expertise they require for their jobs is evolving rapidly, as new technologies and methods emerge.

It is perhaps this growing need for cutting-edge, data-related skills that explains why Avitas is consistently staffing up. "I manage our LinkedIn site," says Stewart, "and I keep posting, 'We're hiring, we're hiring. We need data scientists. We need drone pilots. We need program managers." The company expects to keep expanding its workforce as more and more oil and gas operators recognize the benefits of automating and improving how they manage their physical assets.

FUTURE DEVELOPMENTS

Avitas, and Baker Hughes as a whole, anticipate continuing to serve operators with new and better ways to ensure a smooth and profitable energy transition. IoT devices alone constitute a backbone for communications that has enormous potential for expansion, to monitor and improve nearly any aspect of a facility's operations. Stewart notes that, as the push for reductions in methane emissions intensifies — not just from policymakers, but also from financial stakeholders and an increasingly vigilant public — more operators will choose to address their fugitive emissions. "I believe," says Stewart, "that with or without regulation, our industry knows we have to do better."

COMPANY PROFILE:
BAUER COMPRESSORS

For methane mitigation, manufacturers can draw on valuable expertise from outside the oil and gas industry to find ways to reduce gas leaks and to capture gas for use on-site or distribution.

BAUER IS STRONGLY FOCUSED ON DEVELOPING A DIVERSE WORKFORCE, A PRIORITY THAT COMES THROUGH CLEARLY IN THE NUMBERS: THE STAFF IS 48 PERCENT NON-WHITE AND 52 PERCENT WHITE.

Since its founding in Germany in 1946, Bauer has been manufacturing high-pressure compressors for various uses, such as breathing apparatuses for firefighters, divers and others. Bauer compressors are used widely in animal agriculture, at over 200 biogas installations worldwide; they serve transportation fleets in 2,000 installations with compressed natural gas. Today, Bauer is increasingly serving oil and gas operators with cutting-edge application of technologies it pioneered in these other sectors.

As an alternative to venting and flaring, the company's gas recovery units capture well gas and flash gas and compress it into the sales pipeline. Every gas-capture system is equipped with IoT remote telemetry, so clients can control and monitor it from offsite, using computer, mobile phone, or any smart device. Bauer's instrument air systems provide oil and gas operators an alternative to methane-emitting pneumatic devices.

Bauer further benefits its oil and gas customers by providing a patented system for reducing oxygen content in storage tanks to below hazardous levels, an approach that improves safety and reduces gas leaks. Designed to each client's specific tank configuration, the technology uses nitrogen to displace air in the tanks' headspace. By limiting oxygen, it decreases rusting of the tanks and reduces leaks over time — and it keeps tanks safe in the event that lightning hits the location, a relevant risk in thunderstorm-prone regions such as the Permian Basin in Texas.

Among the larger opportunities for methane mitigation is pipeline maintenance. Every interstate pipeline is required to be tested every five years, explains Brice Jones, Vice President of Industrial Sales. If an issue is found, says Jones, you have to pull out that section and fix it. "Instead of venting all that gas to the atmosphere, we can pull it out of the pipeline at very low pressure and store it in high-pressure cylinders, usually mobile units." The client can then either use the gas onsite, or transport it for use or distribution elsewhere, avoiding methane emissions and saving product that would otherwise be lost.

EMPLOYMENT OPPORTUNITIES

Bauer is strongly focused on developing a diverse workforce, a priority that comes through clearly in the numbers: the staff is 48 percent non-white and 52 percent white. The company not only ensures diversity in its hiring practices but also emphasizes a corporate culture that reflects all the communities within its workforce. The diversity inclusion committee, known informally as "Bauer Strong," works to cultivate diverse leadership within the company.

Upward mobility is a priority; it is typical, for instance, for an employee to start as a service tech and within a few years become a customer service manager. The current director of manufacturing began on the line putting together compressors. Employee benefits include not only vacation time and health insurance, but also a hot lunch, on-site doctor, and gym facilities. Perhaps the clearest indicator that Bauer provides good jobs is employee anniversaries. Sales team members stay on average for 20 years. Recently, the company celebrated four people who each have worked at the company for 45 years.

COMPANY PROFILE: QUESTOR

Existing technologies enable operators to eliminate emissions from flaring and venting. The key is to guarantee clean combustion and to put the resulting waste heat to use.

Questor is a public, international cleantech firm with headquarters in Calgary and over 90 percent of its sales in the United States. President and CEO Audrey Mascarenhas says that since its founding in 1995, the company has relied on innovation and holistic thinking to help the oil and gas industry become more sustainable.

A chemical engineer who has worked in oil and gas in production, operations, joint venture, facilities, and corporate development, Mascarenhas noticed early on that most flares she encountered were "black and smoky," belying the industry's standard assumption that flares burn at 98 percent efficiency. "Research shows it's as low as 60 percent," says Mascarenhas. "And many flares don't even stay lit, so they vent 100 percent into the atmosphere."

IMPROVING FLARE COMBUSTION AND USING THE RESULTING WASTE HEAT

In 2020, Questor became the first company in North America to receive ISO 14034 Environmental Technology Verification, and the first one in the world to receive it for combustion efficiency. Questor's thermal oxidizer combusts gas in an enclosed chamber with no smoke, no odor, and no visible flame — at an efficiency of 99.99%.

This combustion process results in a clean stream of hot exit gases, which, if an operator chooses, can then be used to provide process heat, generate power, or purify wastewater. Questor's power generators transform high- and low-temperature heat into electricity that can be used on-site or sent to a power grid. Once the heat is extracted, the CO_2 can be easily captured from the stack. This arrangement enables clients to get to net-zero, or even net-negative, while also protecting communities from harmful pollutants.

ELIMINATING VENTING DURING MAINTENANCE

Inefficient flares aren't the only huge opportunity to reduce methane emissions, says Mascarenhas. Also neglected are the industry's frequent blowdowns, completions, and pipeline maintenance — activities that can easily become super emitters. "We've got thousands and thousands of engine-compressor combinations," notes Mascarenhas. "Just like your car, after so many hours, they need to be overhauled. And what are we doing? We're venting the entire stream at over 1,000 pounds pressure."

Instead of venting during such tasks, clients can turn to Questor's 120-unit rental fleet of 99.99-percent-efficiency combustors. Each unit is designed with no fans, blowers or moving parts. It arrives on a patented trailer and sets up in 10 minutes, ready to go, easy to move. The units seldom need maintenance; some have been in operation for 20 years and have hardly been touched. Clients use them for pipeline work, coil tubing jobs, well tests, and green completions, all with impressive results. So much so, in fact, that Dominion Energy, a utility

provider in 16 states, wrote Questor's technology into its specifications.

BENEFITS TO OPERATORS AND COMMUNITIES

Steps to address venting and flaring take on greater urgency as communities increasingly voice their concerns about health, safety and the environment. One such concern is blowouts, especially at sites near residential neighborhoods. Questor's equipment has been on jobs where a well blew out and only the combustor people knew — because there was drilling mud in the unit. If that had happened with an open flare instead, the burst of mud, liquids and gases could have put the community at risk.

Clients also benefit in other ways by achieving zero methane hydrocarbon emissions. Regulators in Colorado and North Dakota now allow operators to assume that their Questor units achieve 100-percent efficiency, bringing the well-pad site below VOC limits. This is important to operators because it gives them permission to increase oil production under Title V of the Clean Air Act — welcome news for the operator and a win for the community.

Mascarenhas notes that clients seldom calculate the money saved through clean combustion; nor do they make a fair comparison with flaring. "They overlook the fact that you've got to space flares far away, you've got to have a bigger lease, you've got

to have a high-pressure flare and a low-pressure flare. Our one unit does both." To illustrate, at a typical site in Colorado, a client used to have 30 or 40 small combustors and 30 to 40 small vapor recovery units. By eliminating all of those, the Questor technology reduced the size of the lease by 30 percent and reduced the well-pad cost by 20 percent.

EMPLOYMENT OPPORTUNITIES

Questor is rapidly creating US jobs. The company was identified by SelectUSA, a US Department of Commerce program that searches for promising international firms with potential to create employment in the United States. In 2017, SelectUSA called Questor a success story for creating such jobs, an honor it has continued to earn. In fact, even this past year, despite the COVID-19 pandemic, the company has expanded its staff by 30 percent.

STEPS TO ADDRESS VENTING AND FLARING TAKE ON GREATER URGENCY AS COMMUNITIES INCREASINGLY VOICE THEIR CONCERNS ABOUT HEALTH, SAFETY AND THE ENVIRONMENT.

The company is remarkable for its diversity, with personnel from all over the world serving in engineering, management, technical sales, maintenance, accounting, and administration. A corporation whose president and CEO is a woman of color, Questor reports that 30 percent of its staff are women (compared with 15 percent across the oil and gas industry as a whole). "In this space, you need to be diverse, Mascarenhas explains. "Because you need to be innovative, you need to think on your feet, you need to shift, to persevere, and be resilient."

FUTURE DEVELOPMENTS

What is next for Questor? Mascarenhas envisions further innovations to help clients get to net-zero. Viewed from a whole-system perspective, she says, flaring is not just a problem, but an opportunity. She would like to turn the industry's attention to the vast potential for solving super emitters like flowbacks and completions and lack of pipeline takeaway capacity. These could be the biggest wins, especially if combined with waste heat to power. "We don't have to wait till 2050 to reach net zero. We can actually be there right now."

COMPANY PROFILE:
SLR INTERNATIONAL

Climate change is altering the whole landscape of hydrocarbon energy, and many oil and gas operators need expert help in forging new paths to success.

SLR International is a traditional environmental consulting firm with deep expertise across seven key industry sectors, including a large practice in the oil and gas industry. Founded in 1994 in the U.K. as SECOR Ltd., the company now operates in five global regions. It changed its name to SLR in 2000, when U.S. operations opened.

Today, SLR helps its oil and gas clients set ESG goals and achieve them. As investors, regulators and the general public increasingly demand that operators commit to address climate change, a growing part of SLR's strategic advisory focuses on helping oil and gas operators reduce their methane emissions.

An important niche for SLR consists of mid-size operators that are now realizing they need to get onboard with what several of the major oil and gas companies have embraced: achieving net-zero greenhouse gas emissions by 2050. Unlike the BPs and Shells of the industry — which have internal staff devoted to planning for a net-zero future — some mid-size operators need professional advisory services. What is an ambitious, yet feasible, goal? What are the intermediate steps? Today, there is enough pressure coming from shareholders and stakeholders that many more companies — including those that are not necessarily in the public spotlight — are asking for SLR's help navigating complex choices so they can make informed decisions.

BENEFITS TO OPERATORS

SLR is particularly suited to helping clients keep up with rapidly changing technology, notes Tim Quarles, U.S. Air Program Manager. "We draw on a breadth of experience on the engineering side, and we take every opportunity to team with cutting-edge researchers, whether in field measurement, national studies, or pilots of new technologies." Matt Harrison, Senior Principal, agrees, adding that SLR enables its clients to benefit in a timely way from the newest developments. "Things are changing so fast," says Harrison, "if you take a week vacation, you've missed three critical papers that came out. Clients want help putting their arms around the quickly changing landscape of measurements, mitigations, and standards."

Detailed technical strategies to reduce methane emissions create value for SLR clients. For instance, when operators realize that periodic snapshots of fugitive emissions are not adequate, Harrison's team can help them find and test suitable ways to perform alternate monitoring or continuous monitoring, and do it affordably. But perhaps even greater value lies in helping clients design their overall climate strategies. "So you could say we're not only helping operators today," he notes. "We're also, in the big picture, helping them maintain the confidence of their stakeholders, investors and the general public, extending their social license to operate."

SLR IS PARTICULARLY SUITED TO HELPING CLIENTS KEEP UP WITH RAPIDLY CHANGING TECHNOLOGY.

EMPLOYMENT OPPORTUNITIES

SLR consistently hires scientists and engineers as well as positions in design, accounting, management, and administrative roles. Because of SLR's focus on research, the staff includes a number of graduate scientists. As with other environmental consulting firms, SLR finds it a continuing challenge to find talented candidates capable of embracing the oil and gas industry's increasingly high-level, complicated issues. Yet Harrison is seeing an encouraging trend at the universities it partners with on research projects. "What's interesting to me is the growing number of newly minted PhDs that I see coming on with a methane specialty," he says. "If you looked back even a few years ago, we didn't have anything like that."

FUTURE DEVELOPMENTS

Methane is a large growth opportunity, and the role of data is huge. Quarles notes that the public is demanding more and more data in real time. "We have more information on what is really happening, and there's more pressure for oil and gas operators to reduce their greenhouse gas emissions, so we are in a constant growth mode."

How can one company solve the large issues at stake? It can't, says Harrison. It's bigger than that, which is why SLR works hard to support the science, participate in research, and think collaboratively on the coming energy transition. "We are doing things in partnerships that couldn't be done just with one company or one institution."

COMPANY PROFILE:
BALL AEROSPACE

Drawing on NASA-mission expertise, an aerospace firm is building a remote sensing technology that will detect and measure methane emissions across the globe, doing so with unprecedented coverage and precision.

In 2018, the Environmental Defense Fund surprised a TED Talk audience by unveiling an ambitious undertaking: a new satellite that will locate and quantify sources of methane pollution worldwide. Data gathered by the mission, called MethaneSAT, will enable humanity to make the interventions needed to cut global methane emissions by 45 percent by 2025.

Dr. Makenzie Lystrup, an astrophysicist at Ball Aerospace & Technologies Corp., remembers being intrigued by the project's urgency.

"Space is not easy," she said. "You don't go there to measure something unless you have to."

Lystrup serves as Ball Aerospace's VP and General Manager of Civil Space. A wholly-owned subsidiary of Ball Corporation (a leading sustainable packaging company specializing in an infinitely recyclable material, aluminum), Ball Aerospace manufactures spacecraft, defense technologies, and instruments for scientific research. It has a long track record of performing remote sensing—of the Earth, of other planets, and bodies beyond our solar system.

After a 10-month competitive process, Ball Aerospace won a contract from MethaneSAT LLC, a newly-created branch of EDF. Lystrup's team set out to develop MethaneSAT's imaging spectrometer, the instrument that would identify and measure methane emissions across the planet.

GLOBAL COVERAGE, GREATER ACCURACY

Methane and other gases emit and absorb light at very specific wavelengths, what's known as their spectral signature. The MethaneSAT spectrometer will use the spectral signatures of methane and oxygen. Taking these two measurements simultaneously, on the same focal plane, generates a rich stream of data. This information, when combined with atmospheric data, will enable scientists to create a detailed global map of methane emissions and their sources.

MethaneSAT is a unique endeavor, says Lystrup. But Ball Aerospace is no stranger to complex, envelope-pushing challenges. She cites the company's work on the Hubble Telescope as an example. "When you think of a telescope, really, it's remote sensing. You're looking out, characterizing the light, looking for those spectral signatures, and then trying to understand the physics from them. With MethaneSAT, we're just looking for a different phenomenon."

Even within the realm of targeted methane-sensing efforts, MethaneSAT can do

things no other satellite can. First, while other satellites can either detect emissions across large geographic areas or measure them at specific locations, MethaneSAT will do both. Second, it will do so with extraordinary precision (the Ball Aerospace instrument can pick up a methane concentration as low as three parts per billion), including large point sources as well as cumulative emissions from thousands of smaller sources across the globe. Third, the information it collects will be public and free, enabling citizens, government, and corporations to take action.

MEANINGFUL IMPACT

For nearly all of Ball Aerospace's 65-year history, it has been engaged in monitoring Earth. Increasingly, the company's clients are seeking to understand ways in which the planet is changing. These include record-breaking weather events such as hurricanes, floods, droughts, and heat waves—disasters that have profound effects on people's lives.

Everyone wants to do work that is meaningful, Lystrup notes, and methane presents an extraordinary opportunity to alter the course of climate change. "The team is really engaged. It's exciting to work on something that matters to people, and that has potential for real positive impact."

WHAT'S NEXT?

Does Ball Aerospace see more projects like MethaneSAT in its future? Hard to say, says Lystrup. As a private, non-profit venture, this one is unlike any of the company's numerous government and corporate clients.

At the same time, more and more decision makers are realizing that addressing climate change within our lifetime will require us to cut methane emissions. The first step is knowing where the sources are. Since the data from MethaneSAT will be free to the public, there will certainly be more opportunities to do so.

APPENDIX: 215 FIRMS IN THE U.S. METHANE EMISSIONS MITIGATION INDUSTRY

101 MANUFACTURING FIRMS

MANUFACTURING FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
ABB Group*	1988	DMR, ADA	CR, FS, UAV, A, S	10,001+	$10,000+	NC, CA, OH, OK, PA, TX
A. W. Chesterton	1884	M	RPS, V	1,001-5,000	$501-$1,000	MA, GA, IL, LA, TX, WV
Advantage Midstream	2017	M	FM, GC	1-500	1-$38.5	TX
AESSEAL	1979	M	RPS	1,001-5,000	1-$38.5	TN, CA, IA, ME, WA
Ametek	1930	DMR, M	CR, APD	10,001+	$1,001-$10,001	PA
Baker Hughes*	1987	DMR, M, ADA	LDAR, OGI, CR, FS, MGL, UAV, RPS, V, APD, REC, PLVT, FM, GC	10,001+	$10,000+	TX, CA, CO, KS, LA, MA, MI, OK
Ball Corporation*	1880	DMR, ADA	A, S	10,001+	$10,000+	CO
Bauer Compressors	1946	M	RPS, VRU, GC	1-500	$38.6-$500	VA, CA
Bray	1986	M	V, APD	501-1,000	$501-$1,000	TX, AL, CA, IL, LA
Calscan	1995	DMR, M	FS, V, APD	1-500	1-$38.5	TX
Calvert Energy	2014	M	GC	1-500	1-$38.5	MD
Capstone Turbines	1988	M	GC	1-500	$38.6-$500	CA
Certarus	2012	M	GC	1-500	1-$38.5	TX, CO
CI Systems	1977	DMR	OGI	51-200	$15-$50	TX
Cimarron Energy*	1984	DMR, M	LDAR, OGI, FS, PLVT, VRU	1-500	$38.6-$500	TX, CO, KY, OH, OK
Circor Energy	1999	M	V, APD	1,001-5,000	$501-$1,000	MA, FL, KY, NC, NY, TX, UT
Clarke Valve	2011	M	V	1-500	1-$38.5	RI
ComAp	1991	M	GC	1-500	$38.6-$500	IL
COMM Engineering USA	1991	M	VRU, FM	1-500	1-$38.5	LA, CO, OK, TX
Compressor Engineering Corporation	1964	DMR, M	CR, RPS	1-500	1-$38.5	TX, AL, LA
Compressor Products International	1897	M	V	501-1,000	$38.6-$500	TX
Cook Compression	1888	DMR, M	CR, FS, RPS	1-500	1-$38.5	TX, CA, CO, IN, LA, OK, TN
CORKEN	1924	M	VRU	1-500	1-$38.5	OK
Crusoe Energy*	2018	SC, M	FM, GC	1-500	1-$38.5	CO

KEY TO RELEVANT TECHNOLOGIES

LDAR: Leak Detection & Repair | **MGL:** Mobile Ground Labs | **RPS:** Rod Packing & Dry Seals | **PLVT:** Plunger Lifts/Velocity Tubing | **OGI:** Optical Gas Imaging

UAV: Unmanned Aerial Vehicles

V: Low-emission Valves | **VRU:** Vapor Recovery Units

CR: Non-OGI Close Range | **A:** Aircraft

APD: Alternatives to Pneumatics

FM: Flare Mitigation | **FS:** Fixed Sensors

S: Satellites | **REC:** Reduced Emission Completions

GC: Gas Capture For Use Or Distribution

** Firm offers relevant manufacturing and relevant services.*

MANUFACTURING FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
Curtiss-Wright	1990	M	APD	1-500	1-$38.5	MN, NC
Custom Compression Systems	2010	M	VRU	1-500	1-$38.5	LA
Dresser Natural Gas Solutions	1879	M	APD	501-1,000	$38.6-$500	TX, PA
EagleBurgmann	1977	M	RPS	1-500	$1,001-$10,000	TX, CA, LA, MI, NC, NJ, OH
ECOTEC	2015	DMR	CR, FS, MGL	1-500	1-$38.5	CA
EcoVapor Recovery Systems	2010	M	VRU, FM, GC	1-500	1-$38.5	CO, TX
ElectraTherm	2005	M	FM, GC	1-500	1-$38.5	GA
Emerson	1890	DMR, M, ADA	OGI, CR, FS, RPS, V, APD, VRU	10,001+	$10,000+	MO, AK, FL, GA, IA, LA, MN, NC, NJ, NM, TX, WA, WI
Endurance Lift Systems	2014	M	PLVT	1-500	1-$38.5	TX, AR, CO, ND, NM, PA, TX, WY
Engineered Concepts	1959	M	VRU, GC	1-500	<$38.5	NM
Enovation Controls	2009	M	APD	1-500	$38.6-$500	OK, TX
Exterran	2007	M	VRU, GC	1,001-5,000	$501-$1,000	TX, CO, OK, PA
FCI-Fluid Components International	1964	DMR	CR, FS	1-500	$38.6-$500	CA
Flex Energy Solutions	2011	M	APD, VRU, FM, GC	1-500	$38.6-$500	CO, ND, NY, TX
FLIR Systems	1978	DMR	OGI, CR, FS, MGL, UAV	1,001-5,000	$1,001-$10,000	OR, CA, MA, MD, NH, VA
Flogistix*	1996	DMR, M	LDAR, OGI, CR, FS, UAV, VRU	1-500	$38.6-$500	OK, NM, TX, WY
Flowserve	1997	M	RPS, V, APD, VRU	10,001+	$1,001-$10,000	TX, KY, MD, NC, PA, SC, VA, WV
FLSmidth	1882	M	V, VRU	10,001+	$1,001-$10,000	PA, GA, UT
Galileo Technologies	1987	M	GC	1-500	1-$38.5	CA, NJ
Gardner Denver	1859	M	RPS	5,001-10,000	$1,001-$10,000	WI, AL, CA, CT, IL, LA, MO, ND, OK, PA, TX, WA
Garlock	1887	M	RPS, V, APD	1-500	$38.6-$500	TX, NY
GasTechno Energy & Fuels	2004	M	FM, GC	1-500	1-$38.5	MI
Generon	2006	M	VRU	501-1,000	$38.6-$500	TX, CA
GTUIT	2011	M	FM, GC	1-500	1-$38.5	MT, ND, TX
Hoerbiger	1895	M	RPS, V	501-1,000	$1,001-$10,000	FL, CA, IL, KS, LA, OH, OK, TX, WY
Honeywell*	1906	DMR	OGI, CR, FS	5,001-10,000	$1,001-$10,000	NC, GA, NJ, PA, SC, WA
Hycomp	1986	M	RPS	1-500	1-$38.5	UT

101 MANUFACTURING FIRMS, CONTINUED

MANUFACTURING FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
ICI Infrared Cameras Inc	1995	DMR	OGI	1-500	1-$38.5	TX
InstrumentAir	2007	M	APD	1-500	1-$38.5	CO
John Crane	1917	M	RPS	5,001-10,000	$1,001-$10,000	IL, AK, AL, CA, CO, GA, IA, IL, IN, KS, LA, MI, MN, MO, ND, NE, NJ, NY, OK, OR, PA, RI, TX, UT, WI
Kaydon Ring & Seal	1986	M	RPS			MD
Kimray	1948	M	V, APD, GC	1-500	$38.6-$500	OK, PA, TX
KUVA	2015	DMR	OGI, FS, MGL	1-500	1-$38.5	MA
Mesa Natural Gas Solutions	2014	M	FM	1-500	$15-$50	CO, WY
Microdrones GmbH	2005	DMR, SC	CR, UAV	1-500	1-$38.5	NY, GA
MSA	1914	DMR	CR, FS	1,001-5,000	$1,001-$10,000	PA, CA, IL, NC, TX
National Oilwell Varco	1841	M	APD, PLVT, VRU	10,001+	$1,001-$10,000	TX, ND, OK
NevadaNano	2004	DMR	FS	1-500	1-$38.5	NV
Neway Valve	1997	M	V, APD	1,001-5,000	$38.6-$500	TX
Norriseal	1981	M	V, APD	1-500	1-$38.5	TX, LA, OK
Orbital Sidekick*	2016	DMR, ADA	S	0-50	$0-$15	CA
Pacific Advanced Technology	1988	DMR	OGI	1-500	1-$38.5	CA
PCS Ferguson	1985	M	PLVT	1-500	1-$38.5	CO, LA, NM, OK, PA, TX, UT, WY
Petrogas Environmental Systems	1975	M	VRU, GC	1-500	1-$38.5	TX
Pioneer Energy	2006	M	FM, GC	1-500	1-$38.5	CO
Planet*	2010	ADA	S	201-1,000	$51-$500	CA
Platinum Vapor Control	2012	M	VRU	1-500	1-$38.5	TX, NM
Primus Green Energy		M	FM, GC	1-500	1-$38.5	TX, NJ
Production Lift Systems	1989	M	PLVT	1-500	1-$38.5	TX
PSG Blackmer		M	VRU	1,001-5,000	$38.6-$500	IL, CA, CO, MI, PA, VA

KEY TO RELEVANT TECHNOLOGIES

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V: Low-emission Valves | **VRU:** Vapor Recovery Units **CR:** Non-OGI Close Range | **A:** Aircraft **APD:** Alternatives to Pneumatics **FM:** Flare Mitigation | **FS:** Fixed Sensors

S: Satellites | **REC:** Reduced Emission Completions **GC:** Gas Capture For Use Or Distribution

** Firm offers relevant manufacturing and relevant services.*

MANUFACTURING FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
Questor Technology*	1995	SC, M	VRU	0-50	$0-$15	TX, CO, FL, ND, PA
Quincy Compressor	1920	M	RPS, VRU	1-500	$38.6-$500	AL, CT, MA, NJ, NY, PA
Remediation Service International		M	VRU, FM	1-500	1-$38.5	CA
Rotork	1957	M	APD	1,001-5,000	$501-$1,000	NC, CA, NY, PA, RI, TX, WI
SAFCell	2009	M	APD	1-500	1-$38.5	CA
Schlumberger*	1926	DMR, M, ADA	LDAR, CR, V, APD	10,001+	$10,000+	TX, AR, OK
SeekOps*	2017	DMR	LDAR, CR, UAV	1-500	1-$38.5	TX, CA
Sensit	1980	DMR	CR, FS, MGL	51-200	$15-$50	IN
Shore Pipeline Solutions	2020	M	GC	1-500	1-$38.5	MD
Siemens Energy	1847	M	RPS, APD	10,001+	$10,000+	DC
Sierra-Olympic Technologies	1995	DMR	OGI	1-500	1-$38.5	OR
Solar Injection Systems	1992	M	APD	1-500	1-$38.5	TX
Solar Turbines	1927	M	APD, FM	1,001-5,000	$1,001-$10,000	CA, FL, IL, LA, NJ, PA, TX, UT
Stewart & Stevenson	1902	M	APD	1-500	$38.6-$500	TX, CO, WY
Swagelok	1947	M	V, APD	5,001-10,000	$1,001-$10,000	OH, AK, CA, KS, OR, TX, WA
TCI USA	1988	M	FM	1-500	1-$38.5	CO
Tech Tool Ohio	1990	M	PLVT	1-500	1-$38.5	OH
TechnipFMC	2015	M	RPS, V, APD, REC	10,001+	$10,000+	TX, AK, CA, CO, LA, ND, OK, PA, TX, UT, WY
Tenaris	2001	M	PLVT	10,001+	$1,001-$10,000	TX, OK, PA
Tescorp	1987	M	VRU	1-500	1-$38.5	OK
TPE Midstream	2014	DMR, M	CR, FM	1-500	1-$38.5	OK
TXAM Pumps	1986	M	APD	1-500	1-$38.5	TX, AR, CO, ND, NM, OK, TX, WV, WY
Weatherford	1992	M	APD, PLVT	501-1,000	$38.6-$500	TX, CA, LA, OK, PA, UT, WY
Well Master	1984	M	PLVT	1-500	1-$38.5	CO, NM, TX
Whirlwind Methane Recovery Systems	2007	M	APD, VRU, FM	1-500	1-$38.5	OK
Zahroof Valves	2019	M	V	1-500	1-$38.5	TX
Zeeco	1979	M	VRU, FM, GC	1,001-5,000	$38.6-$500	OK, CT, KS, KY, TX

114 SERVICE FIRMS

SERVICE FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
A.R.T. Aviation Services	2010	DMR	LDAR, CR, A	0-50	$0-$15	
ABB Group*	1988	DMR, ADA	CR, FS, UAV, A, S	10,001+	$10,000+	NC, CA, OH, OK, PA, TX
AECOM	1990	DMR, SA		10,001+	$10,000+	CA
Aerial Production Services	2014	DMR	LDAR, OGI, UAV	0-50	$0-$15	MD
Alliance Emission Monitoring	2020	DMR, SA	LDAR	51-200	$15-$50	AL, CA, TX
Altamira	1994	DMR	LDAR, OGI	51-200	$15-$50	OK, TX
American Aerospace Advisors	2002	DMR, ADA	UAV	0-50	$0-$15	PA
Amerigo	2012	DMR	LDAR, OGI	0-50	$0-$15	TX
AmeriTek Environmental Services	1999	DMR	LDAR, OGI, CR	51-200	$0-$15	TX
Antares Technology Solutions	1988	DMR, ADA		0-50	$0-$15	LA
Apex Companies	1988	DMR	LDAR, OGI, CR, UAV	201-1,000	$51-$500	MD
Apogee Scientific	1993	DMR	LDAR, CR, A	0-50	$0-$15	CO
Aster Global	2019	SA		0-50	$0-$15	OH
Atlas Technical Consultants	2006	DMR	LDAR, OGI, CR	51-200	$15-$50	TX
Atmosfir Optics	2011	DMR	LDAR, CR, FS	0-50	$0-$15	NC
Atmospheric Corrosion Specialists	2003	DMR	LDAR, CR, UAV	0-50	$0-$15	VA
Avitas	2017	DMR, ADA	LDAR, OGI, UAV	0-50		TX, CA, MA
Baker Consulting	2010	DMR	LDAR, OGI	51-200	$15-$50	ND
Baker Hughes Company*	1987	DMR, ADA, M	LDAR, OGI, CR, FS, MGL, UAV, RPS, V, APD, REC, PLVT, FM, GC	10,001+	$10,000+	TX, CA, CO, KS, LA, MA, MI, OK
Ball Corporation*	1880	DMR, ADA	A, S	10,001+	$10,000+	CO
Beacon Energy Services	2008	DMR	LDAR, OGI, CR	51-200	$15-$50	CA, UT

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** Firm offers relevant manufacturing and relevant services.*

SERVICE FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
Belmont Technology	2017	DMR, ADA		0-50	$0-$15	TX
Bison Engineering	1980	DMR	LDAR, OGI	0-50	$0-$15	MT, AZ
Bluefield Technologies	2017	DMR, ADA	S	0-50	$0-$15	NY, CA
Bridger Photonics	2006	DMR, ADA	LDAR, CR, UAV, A	51-200	$15-$50	MT
Business Technical Services	2010	DMR	LDAR, CR	0-50	$0-$15	OH
C3.ai	2009	DMR, ADA		51-200	$15-$50	CA, NY
Cameron-Cole	2001	SA	OGI, CR	51-200	$15-$50	CO, CA, FL, MA, TN
Cegal	2000	DMR, ADA		201-1,000	$51-$500	TX
Chem-Air	1973	DMR	A	0-50	$0-$15	LA
Chesapeake Bay Helicopters	1998	DMR	LDAR, CR, A	0-50	$0-$15	VA
Cimarron Energy*	1984	DMR, M	LDAR, OGI, FS, PLVT, VRU	1-500	$38.6-$500	TX, CO, KY, OH, OK
Colorado Heli-ops	2009	DMR	LDAR, CR, A,	0-50	$0-$15	CO
Corridor Field Services	2016	DMR	LDAR, OGI, UAV	0-50	$0-$15	AL
Crusoe Energy*	2018	SA, M	FM, GC	1-500	1-$38.5	CO
Custom Stack Analysis	1965	DMR	LDAR, CR, FM	0-50	$0-$15	OH, IL, NY, PR, SC
Cyberhawk	2008	DMR	LDAR, UAV	51-200	$15-$50	CO, TX
Dan Fitzgerald & Associates	1979	DMR	LDAR, CR, MGL	0-50	$0-$15	CA, IA, SD
Darbonne Services	1983	DMR	LDAR, OGI, CR	0-50	$0-$15	LA
Dataiku	2013	DMR, ADA		201-1,000	$51-$500	NY
DeNovo Global Technologies	2007	DMR	LDAR, CR	0-50	$0-$15	TX
DG Consulting	2014	DMR	OGI, CR	0-50	$0-$15	WV
EcoTest Energy Services	2014	DMR	LDAR, OGI, CR	0-50	$0-$15	OK, PA, TX
Emission Monitoring Service	1986	DMR	LDAR, OGI, CR	201-1,000	$51-$500	TX
ENCOS	1994	DMR	LDAR, OGI, CR	0-50	$0-$15	LA
Environmental Compliance & Testing	2014	DMR	LDAR, OGI, CR	0-50	$0-$15	TN
ERM	1971	DMR, SA	LDAR, OGI	5,001-10,000	$501-$1,000	CA

114 SERVICE FIRMS, CONTINUED

SERVICE FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
Flogistix, LP*	1996	DMR, M	LDAR, OGI, CR, FS, UAV, VRU	1-500	$38.6-$500	OK, NM, TX, WY
Gas Detection Services	2017	DMR	LDAR, CR, MGL, UAV, A	0-50	$0-$15	CO
Gas Ops Leak Detectives	2014	DMR	LDAR, OGI, CR	0-50	$0-$15	CO
Gas Technology Institute	1941	DMR, M	APD	201-1,000	$51-$500	IL, CA, DC, TX
GHD	1928	DMR, SA	LDAR, OGI, CR	10,001+	$1,001-$10,000	NM
Heath Consultants	1933	DMR	LDAR, OGI, CR, FS, MGL, UAV	1,001-5,000	$501-$1,000	TX, AZ, PA
Honeywell*	1906	DMR	OGI, CR, FS	5,001-10,000	$1,001-$10,000	NC, GA, NJ, PA, SC, WA
Huco Consulting	2008	DMR		0-50	$0-$15	TX
HydroChemPSC	1977	DMR, M	LDAR, OGI, CR, VRU	5,001-10,000	$1,001-$10,000	TX
IBM Thomas J. Watson Research Center	1911	DMR, ADA		10,001+	$10,000+	NY, MA
Insight Environmental	2004	DMR	LDAR, OGI, CR, FS, UAV	51-200	$0-$15	TX, AK, MN, ND, WI
IRT Consult		DMR	LDAR, OGI	0-50	$0-$15	FL
K&K Services	2007	DMR	LDAR, CR	0-50	$0-$15	IL
Kairos Aerospace	2014	DMR, ADA	LDAR, OGI, A	0-50	$0-$15	CA
Kayrros	2016	DMR, ADA	S	51-200	$15-$50	NY, TX
Keitu Engineering	2001	DMR	LDAR, OGI	0-50	$0-$15	ND
Kelvin	2013	DMR, ADA		51-200	$15-$50	CA, CO, TX
L&M Environmental Response	2016	DMR	LDAR, OGI, CR	0-50	$0-$15	LA
LaSen	1989	DMR	LDAR, OGI, UAV, A	0-50	$0-$15	NM
Leak Finder	2009	DMR	LDAR, OGI	0-50	$0-$15	OH
Leak Imaging	2010	DMR	LDAR, OGI	0-50	$0-$15	TX
Leak Surveys	2004	DMR	LDAR, OGI, A			TX
Lesair Environmental	2000	DMR	LDAR, OGI, CR	0-50	$0-$15	CO
M&R Industrial Services	2005	DMR	LDAR, OGI	0-50	$0-$15	TX
Montrose Environmental	2012	DMR	LDAR, OGI, CR, FS, MGL, UAV	201-1,000	$51-$500	CA, CO, IL, PA, TX

KEY TO RELEVANT TECHNOLOGIES

LDAR: Leak Detection & Repair | **MGL:** Mobile Ground Labs | **OGI:** Optical Gas Imaging | **UAV:** Unmanned Aerial Vehicles | **CR:** Non-OGI Close Range **A:** Aircraft | **FS:** Fixed Sensors | **S:** Satellites

** Firm offers relevant manufacturing and relevant services.*

SERVICE FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
My Drone Services	2016	DMR	LDAR, OGI, CR, FS, UAV	0-50	$0-$15	DE, FL
Olsson Associates	1956	DMR	LDAR, OGI, CR	1,001-5,000	$501-$1,000	NE, AR, AZ, CO, IA, KS, MO, NE, OK, TX
Omark Consultants	1987	DMR	LDAR, CR	51-200	$15-$50	MA
Orbital Sidekick*	2016	DMR, ADA	LDAR, A, S	0-50	$0-$15	CA
Otech Aerial Drone Service		DMR	LDAR, OGI, UAV	0-50	$0-$15	MI
Pergam Technical Services	2005	DMR	LDAR, CR, FS, UAV, A	1-500	<$38.5	WA
Picarro	1998	DMR, ADA	LDAR, CR, FS, MGL	1-500	<$38.5	CA
Planet*	2010	DMR, ADA	S	201-1,000	$51-$500	CA
Project Canary	2013	DMR, ADA, SA	FS, MGL	0-50	$0-$15	CO, TX
Questor Technology*	1995	DMR, ADA, SA, M	FM	0-50	$15-$50	TX, CO, FL, ND, PA
Ravan AIR	2018	DMR	LDAR, OGI, UAV	0-50	$0-$15	PA
Reces Environmental Consulting	2003	DMR	LDAR, CR	0-50	$0-$15	TX, CA
Red Hen Systems	1997	DMR	LDAR, OGI, CR, A	0-50	$0-$15	CO
Satelytics	2015	DMR, ADA	LDAR, FS, UAV, A, S	0-50	$0-$15	OH
Sceye	2015	DMR	LDAR, A	0-50	$0-$15	NM
Schlumberger *	1926	DMR, M, ADA	LDAR, CR, V, APD	10,001+	$10,000+	TX, AR, OK
Scientific Aviation	2010	DMR, ADA	LDAR, CR, FS, MGL, UAV, A	0-50	$0-$15	CO
SCS Engineers	1970	DMR	LDAR, OGI, CR, FS, MGL, UAV	201-1,000	$51-$500	CA
SEALTEC	1983	DMR	LDAR, CR	0-50	$0-$15	NJ
SeekOps Inc.*	2017	DMR	LDAR, CR, UAV	1-500	1-$38.5	TX, CA
SLR International	1994	SA		1,001-5,000	$501-$1,000	WA, AK, AZ, CA, CO, CT, GA, IL, IN, KY, LA, MA, ME, NH, NY, OK, OR, PA, SC, TN, TX, UT, VA, VT, WV
Southern Cross Corporation	1946	DMR	LDAR	201-1,000	$51-$500	GA
Southwest Research Institute	1947	DMR, ADA	LDAR, OGI, MGL, UAV, S	1,001-5,000	$501-$1,000	TX
Spectral Sensor Solutions	2012	DMR	LDAR, FS, UAV	0-50	$0-$15	IN, NM

114 SERVICE FIRMS, CONTINUED

SERVICE FIRM	FIRST YEAR	INDUSTRY CATEGORY	RELEVANT TECHNOLOGIES	EMPLOYEES RANGE	SALES RANGE (MILLIONS)	U.S. EMPLOYEE LOCATIONS (HQ APPEARS FIRST)
Spherical Analytics	2017	DMR, ADA	S	0-50	$0-$15	MA
Stantec	1954	SA		10,001+	$1,001-$10,000	FL
Stranded Solutions	2013	M	FM, GC	0-50	$0-$15	MI
Strata	1997	DMR	LDAR, OGI, CR	0-50	$0-$15	KS, OK
Team Inc	1973	DMR, M	LDAR, OGI	5,001-10,000		TX, CO, CT, IL, LA, NJ, WA
Tern Technologies	1984	DMR	LDAR, OGI	0-50	$0-$15	AK
The Sniffers	1991	DMR, SA	LDAR, OGI, CR, FS, MGL, UAV	51-200	$15-$50	TX
Think Environmental	1984	DMR	LDAR, OGI, CR	51-200	$15-$50	TX
Tricord Consulting	2013	DMR	LDAR, OGI, CR	0-50	$0-$15	TX, CA, IL, LA, NC
Trihydro	1984	DMR	LDAR, OGI, CR	201-1,000	$15-$50	WY
Trinity Consultants	1974	DMR		201-1,000	$51-$500	TX
UM Inspections	2015	DMR	LDAR, CR, UAV	0-50	$0-$15	TX
Urbint	2015	DMR, ADA	LDAR	51-200	$15-$50	NY
Viper Drones	2015	DMR	LDAR, OGI, UAV	0-50	$0-$15	FL, AL
Well Data Labs	2014	DMR, ADA		0-50	$0-$15	CO
Westshore Consulting	1982	DMR	LDAR, OGI, CR	0-50	$0-$15	MI
Wood	1912	SA		10,001+	$10,000+	GA, TX
WSP	1885	DMR	LDAR, OGI, CR, FS	10,001+	$10,000+	NY

KEY TO RELEVANT TECHNOLOGIES

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ABBREVIATIONS AND REFERENCES

ABBREVIATIONS

ABBREVIATION	NAME
ADA	Advanced Data Analytics
AI	Artificial Intelligence
bcm	billion cubic meters
CH_4	Methane
CO_2	Carbon dioxide
EPA	Environmental Protection Agency
ESG	Environmental, Social, and Governance
IEA	International Energy Agency
IoT	Internet of Things
IR	Infrared
ISO	International Organization for Standardization
LDAR	Leak Detection and Repair
LiDAR	Light Detection and Ranging
LNG	Liquified Natural Gas
ML	Machine Learning
OGI	Optical Gas Imaging
PCB	Printed Circuit Board
SA	Strategic Advisory
TB	Terabyte
UAV	Unmanned Aerial Vehicle (drone)
VRU	Vapor Recovery Unit

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