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WHITE PAPER

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Best Practices for Emissions Monitoring in the Energy Sector

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Introduction

The global economy is moving towards a decarbonized energy system. This conversion, commonly known as the "Energy Transition," is being driven by key stakeholders including regulators, legislators, investors and the public. The word transition implies a change, and in this case the Energy Transition implies a shift away from fossil fuels to greater use of renewable energy sources.

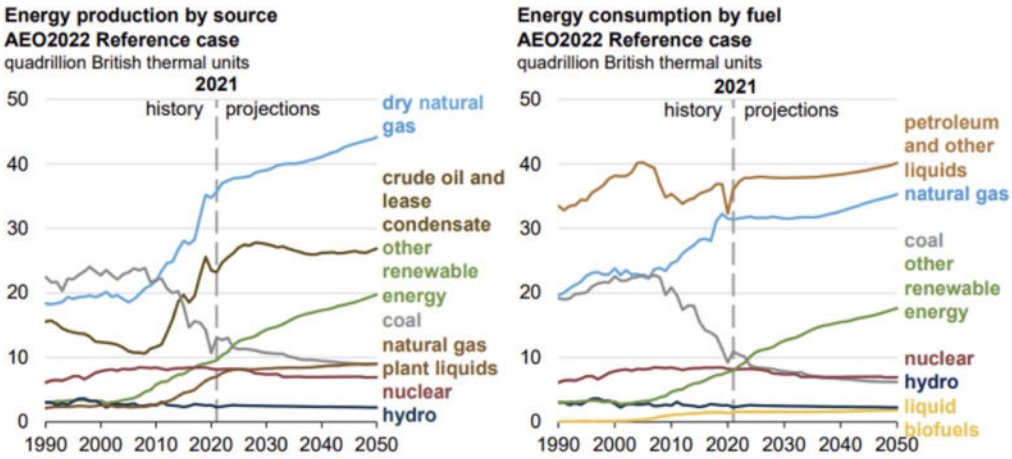
As a result, the Oil & Gas industry, including upstream producers, oilfield service companies and midstream transporters, have come under heightened pressure to reduce emissions across the entire energy supply chain.

At the heart of the Energy Transition is a focus on reducing emissions of Greenhouse Gasses (GHG) (i.e., methane (CH4) and carbon dioxide (CO2)) and other substances released to the atmosphere from unintended leaks and system processes (aka fugitive emissions);development of oil & gas assets as well as storage and transportation of natural gas and crude oil (and subsequent refining operations) further necessitates the need to decarbonize. Consequently, emissions monitoring has emerged as central to this campaign which Energy companies will need to master to satisfy existing and future environmental performance regulations and standards.

In this white paper, we cover the essential role of natural gas in meeting future energy needs and the best practices operators can employ to develop an effective emissions monitoring and mitigation strategy.

The Role of Natural Gas in Meeting Future Energy Demand

Renewable energy sources grab the majority of headlines advocating the Energy Transition for the obvious reason that the common alternatives, wind and solar, emit zero emissions (in theory). The U.S. Energy Information Agency (EIA) reports that although renewable sources today make up less than 10% of total energy consumption in the United States, their share of the overall energy supply is rising rapidly.



Note: Biofuels are shown separately and included in petroleum and other liquids.

SOURCE: U.S. EIA, Annual Energy Outlook 2022

A major obstacle to greater development and adoption of renewable energy sources, however, is thermodynamic variability. Wind turbines do not generate electricity in calm conditions and solar panels do not operate efficiently on cloudy days or at night. On a cold and snowy day, a homeowner or business wants reliable and affordable heat instantaneously, something renewable energy sources often struggle to provide.

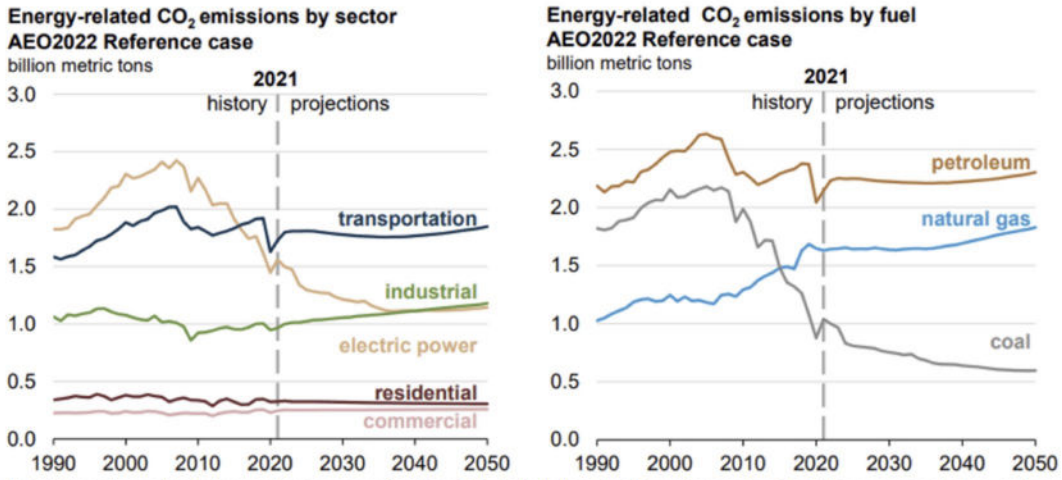
One solution regarding the concept of thermodynamic variability is the advent of battery storage capacity. Numerous battery storage projects are currently under development to provide long-term storage of electricity generated by renewables during ideal conditions (e.g., a bright sunny day for solar panels), so it can be delivered to the grid during peak demand (a multi-day snowstorm).

Battery storage projects, however, are not a complete panacea. EIA currently forecasts that renewable energy will supply only 20% of total energy demand by 2050. **The implication for the Energy Transition is clear - renewable energy sources alone cannot be relied upon to satisfy future energy demand.**

That means natural gas will continue to play a critical role in the domestic and global energy portfolio. EIA acknowledges as much, forecasting that natural gas consumption will grow through 2050 and retain its second-place market share behind petroleum.

Natural Gas
is Good for Emissions

In addition to providing reliable and affordable energy, natural gas plays an important role in reducing emissions of GHGs.



Note: Series does not include greenhouse gases other than CO_2. Industrial sector CO_2 emissions do not include process emissions, such as the emissions from cement clinker production.

SOURCE: U.S. EIA, Annual Energy Outlook 2022

Coal-fired power plants are significant GHG emitters, primarily of CO2. Consequently, plants relying on coal feedstocks are being replaced by those powered by natural gas. EIA reports that coal-to-gas switching for power generation has been a major factor in the decline of GHG emissions from the electric power sector.

The Emergence of Emissions Monitoring

One downside of natural gas is that its primary component, methane, is considered to be a more potent GHG than carbon dioxide. Some sources estimate that over a 20-year period, methane is 80 times more effective at warming than CO2. As a result, reducing fugitive emissions of methane from energy systems, typically the result of unintended leaks and venting, is a strategic environmental performance initiative.

Before we begin fixing things that are not broken, however, executives need to know what the current level of fugitive emissions are from their company's operations. The essential question for Oil & Gas operators must answer then, is what are the actual levels of emissions from their operations?

For over a decade, EPA emissions factors have been accepted as the primary variable in quantifying emissions volumes from Oil & Gas equipment and operations; and are used in air permit applications for

air-quality representations under state and federal regulatory programs. While the EPA recognizes limitations regarding the representativeness of these factors, more recent emission investigations have demonstrated that there is a significant difference between the reported volumes estimated by EPA emissions factors and actual emissions observed in the field.

If an operator can secure an air permit using EPA emissions factors, then why should anyone care about monitoring actual emissions in the field? As emissions data is being consumed increasingly by audiences outside the industry and regulatory agencies (e.g., investors, media, legislators, etc.), the advantages are clear:

1. Monitoring actual emissions helps operators identify where they can make meaningful and actual improvements in emissions performance, not just relegated to compliance programs. This also includes enhanced maintenance and reliability (M&R) which translates to an increase in uptime performance.
2. Provide an affirmative defense using empirical data and scientifically-proven methodologies.
3. Enhance corporate reputation with investors and the public.
4. Respond/adapt to future regulatory requirements.

Emissions Monitoring Methods

Energy companies have many options for emissions monitoring, classified generally as Continuous and Scheduled monitoring methods.

Continuous Emissions Monitoring Options

Continuous emissions monitoring methods evaluate air quality at well sites, production facilities, pipelines and other infrastructure with a real-time or near real-time temporal frequency.

Blind Sensors

Blind sensors are often employed for “fence line” monitoring because they are installed at multiple locations at the perimeter of well site or facility (on a “grid” system in certain other types of applications). Blind sensors typically use metal oxide (MOx) technology, which is relatively cheap to manufacture and install. Blind sensors, however, are just that – blind. They simply detect the presence of certain substances, similar in the way a fire alarm detects the presence of smoke particulates to indicate a potential fire. Blind sensors are not particularly effective in identifying specific emissions sources, describing individual plume components, or quantifying the volumes of an emissions event (i.e., source localization and quantification).

They are concentration sensitive (low minimum detectable concentration limits); however, higher sensitivity without localization may be an operational limiter. For example, a blind sensor on a well site may be registering an emissions detection from a loose thief hatch on a tank battery located on a lease operated by a different company (transient emissions event). Without proper localization, the operator may be searching for a needle in a haystack.

Secondly, blind sensors require meteorological data and complex dispersion post-processing algorithms which may succumb to error propagation.

AI-Enabled Optical Gas Imaging (AI-OGI)

AI-enabled Infrared Optical Gas Imaging (AI-OGI) offers a significantly higher quality of visual analysis of emissions components during both daytime and at night. AI-OGI cameras can identify various emissions gasses, including methane, CO2 and VOCs.

Key benefits of AI-OGI cameras are their autonomous and unsupervised operation combined with their ability to precisely identify leak sources, detect emissions with low false alarm rates, quantify emission flow rates and their duration to determine aggregate emissions on a specific site with a high level of granularity.

AI-OGI cameras can be deployed on the ground or via satellite; the technology has emerged as the platinum standard for emissions detection, quantification and data quality.

While AI-OGI cameras tend to cost more, they produce more actionable results and enhance the effectiveness of LDAR crews by dispatching them to sites with confirmed leaks and helping them locate specific emissions sources quickly. This keeps more natural gas in the pipe and improves field safety.

Lasers

Fixed laser-based detection methods use the science of light to scan wide areas and capture data indicating emission plumes. The primary drawback for laser systems that rely on mirrors is that resolution (and accuracy) is contingent on how many mirrors are deployed. The mirrors themselves are vulnerable to the elements and/or jostled around by livestock/wildlife or becoming obscured (think of six-foot high snow drifts in North Dakota). Additionally, well pads and facilities located in variable terrain (or complex scenes) with significant vegetation can be problematic for mirror placement and instrument resolution.

EmVision™ Mobile

AI-Enabled Optical Gas Imaging (AI-OGI)

Scheduled Emissions Monitoring Options

Scheduled monitoring options provide monitoring at periodic intervals and provide a "snapshot in time" of the emissions profile.

Legacy Satellites

Low Earth Orbit (LEO) satellites using legacy technology are effective for research and identifying large leaks over a wide expense, especially over restricted and/or remote locations. In recent years, sensor quality and resolution have improved signifcantly.

Handheld IR Cameras

Leak Detection and Repair (LDAR) teams use handheld IR cameras for periodic inspections of well sites, facilities and infrastructure on an intermittent basis. When used by a trained operator, they are effective tools for detecting and locating leaks on site.

Drones

Drones are less expensive to operate than aircraft but are limited by short battery life and Federal Aviation Administration (FAA) regulations around operating within line of sight, which may constrain or limit operability. Furthermore, drones suffer from the same weather-related drawbacks and survey frequency disadvantages as aircraft.

Aircraft

Aircraft using Light Detection and Ranging (LiDAR) offer more specific data than satellites but are plagued with some of the same downsides as space-based satellites. Airborne monitoring is difficult if the weather is unsafe for flying and is typically more expensive and difficult to scale. The primary downside of airborne surveys is time between data collection, processing and interpretation. By the time you receive the data, the leak profile has probably changed.

Satellite (iSIM, VHR and UHR Technology)

iSIM (integrated Standard Imager for Microsatellites) and Very High Resolution (VHR) technology represents the latest generation of satellite sensor technology, capable of Very High-Resolution imaging with video capability. iSIM and VHR can be further enhanced to Ultra-High Resolution (UHR), which is a technique used to retrieve a high spatial resolution image from a series of low spatial resolution images, without loss of information. Importantly, iSIM monitoring technology offers Agility, the uniqe capability of allowing the camera to follow a non-linear structure on Earth, such as a pipeline, as the satellite travels above. Without Agility, the camera would have only a fixed view of the land surface along the satellite's path.

Although typically more expensive than aerial surveying options, the higher revisit frequency of satellites gives them an advantage by providing more current data.

Classifications of Emissions Monitoring Methods

Sorting through the variety of emissions monitoring methods can be a confusing and a time-consuming task. To simplify the emissions monitoring landscape, we created the graphic below.

The relative position of each emissions monitoring method considered in this paper is plotted on the comparison matrix below using “Continuous” vs. “Scheduled” methods on the y-axis and “Precision” vs. “General Detection” methods on the x-axis.

Precision is a combination of several factors, including a method’s ability to differentiate between substances (e.g., methane, VOC, CO2 or water vapor), specificity in identifying the source(s) of emissions (localization) and the quality of emissions quantification.

Continuous Monitoring is a function of sample frequency, or in the case of AI-OGI image frequency, hours of effective operation and other factors. Methods that are “always on” 24/7 and that provide effective monitoring in daylight and at night will necessarily rank higher than those that must be scheduled or are intermittent.

Considering the technological positioning and overall utility, AI-OGI offers the best precision of all methods, and can be used in both continuous (on-site cameras) and scheduled applications (mobile AI-OGI Platform and Satellites).

Best Practices for Emissions Monitoring in the Energy Sector

We believe the following seven factors represent the best practices for emissions monitoring for Oil & Gas production and transportation operations.

Step One: Define Your Emissions Monitoring and Reporting Goals. Ideally, the emissions monitoring technologies and methods you employ will support your environmental performance and reporting goals. In our experience, there is no one "do-it-all" method or technology. The needs of meeting certified gas standards, regulatory compliance requirements, and sustainability reporting combined with your operational footprint and characteristics all have implications for the technologies you select and the data strategy / methodologies you adopt. Publicly traded Energy companies with large, geographically distributed operations (disparate assets) and active drilling programs will have different objectives than privately held operators managing a small number of older wells. Tailor your emissions monitoring initiative to meet your near-term and long-range strategic objectives.

Keep Monitoring Equipment Maintained and Clean! Although sensor equipment is designed for all-weather operation, even the most rugged designs can succumb to inclement weather or unexpected events. Following the manufacturers maintenance schedule and keeping sensors clean and clear of obstructions is important for getting accurate data. Additionally, routine instrument linearity evaluations help maintain system integrity (i.e., prevent instrument "drift") and improves reliability (uptime) – which may vary based upon local/region climate (i.e., humidity, temperature, snow cover, etc.)

AI-OGI Technology. AI-Enhanced Optical Gas Imaging (AI-OGI) offers the best combination of visualization, ability to discern key substances (i.e., discriminate between methane, CO2, and other substances), and quality of detection and quantification. Blind sensors act like fire alarms; they can detect the presence of emissions, but do not offer the kind of data reliability and specificity (localization) that provide meaningful insights into how one can reduce emissions and then efficiently report to investors, regulators and the public with a measurable degree of confidence.

Mobility for on-ground methods. All methods, including AI-OGI, should have a high degree of portability (especially with regard to upstream operations). Blind sensors are easy and simple to move; however, given their many drawbacks they are not the preferred monitoring choice. Fixed cameras are more difficult to move, but a trailer-mounted solution resolves the problem – especially for shorter-term emissions performance baselining.

Context is Everything (Use Multiple Data Ingestion Points). Although emissions monitoring identifies symptoms, it does not explain the root cause of fugitive emissions events. We suggest it is important to look at the entire emissions profile by employing the right monitoring and analysis tools specific to your operations and goals. Combined with your team's knowledge of operations from an emissions perspective, you can better interpret what your emissions symptoms are telling you.

Data validity, traceability and reproducibility. Emissions results should be traceable by independent third parties. Emissions reports based on proprietary data models have the potential to defeat the intended purpose of monitoring. Data that cannot be replicated independently creates a level of opaqueness inconsistent with the primary tenets of monitoring, which is intended to provide greater transparency, not less.

It is recommended that you incorporate industry and regulatory methods/practices (i.e., API, ASTM, EPA, ISO, etc.) into your decarbonization program in order to substantiate data and climate-related claims.

Establish a single source of emissions truth (data). Inconsistency between data used for compliance purposes and reporting environmental performance in sustainability reports can lead to confusion and lack of trust among data consumers. Having one source of actual emissions data can go a long way to establishing confidence in reported data and claims based on it. Data centralization brings together all data into a single (one) place so it can be more effectively managed and accessed. As businesses rely on a larger number of data sources that ever before, the importance of having a centralized approach to store and manage it has never been greater.

Benefits

There are a variety of compelling benefits for pursuing an emissions monitoring program that incorporates the best practices identified above.

Maximize ROI. Good environmental performance is good business. Mitigating methane emissions and proving environmental performance increases revenue by keeping product in the pipe and leveraging certified gas markets; and reduces costs by avoiding carbon taxes, reducing purchases of carbon offsets, avoiding fines, enhancing your corporate reputation and even generating carbon credits.

Improved environmental performance. An emissions monitoring and management program that incorporates best practices has the best potential to generate material reductions in emissions from energy production and distribution. Optimizing environmental performance is essential to the success of the Energy Transition – for both compliance and operational differentiation.

Increased revenue and resource conservation. Responding to leaks fast and mitigating emissions across your entire operation will keep more product in the pipe creating more revenue and preventing the waste of a valuable resource.

Evidence your environmental performance. The better enhanced and more contextualized your emissions data, the easier it will be to provide and substantiate actual environmental performance, strengthening your corporate reputation and ability to defend against attacks using anecdotal and improperly interpreted data and information (affirmative defense). The more visible and immediate the detection is, the lower the impact of leaks and the cost to remediate them.

Actionable and auditable data. Eventually, emissions data will find its way into nearly every facet of reporting. From sustainability reports to air quality permits, financial statement filings, debt covenants and more, emissions data will have to meet the same quality standards as audited financial statements.

Improved access to capital. Institutional investors are using environmental performance in general, and emissions data specifically, to screen the debt and equity of public companies. Those operators that develop a reputation for reliability and transparency have an opportunity to build and maintain trust with investors and access capital on more favorable terms than those who do not.

Support M&A activity. Smaller operators seeking to be acquired by larger companies will have an easier time selling their assets if they can prove good environmental performance and that their emissions profile does not represent a risk to the acquiror's environmental performance record. This has implications for both private independents, private equity backed E&Ps and midstream operators.

Leverage carbon credits. Valid and actionable emissions data helps demonstrate carbon capture and reduction performance. Having a complete (and transparent) emissions profile can help you to identify institutional problems which can highlight areas of material reduction. Establishing a proper baseline of emissions performance combined with post-reduction measurements can be beneficial for those wishing to generate carbon offsets/credits.

Enhance mechanical integrity. Detecting leaks in near real-time means problems can be fixed faster, minimizing their potential for causing additional operational issues. Certain types of instruments (i.e., AI-OGI) can provide operational intelligence beyond emissions as they are capable of identifying heat loss, assessing storage tank levels and identifying energy flows. A properly designed/maintained system will be operating at a higher efficiency which generally translates to a lower emissions profile.

Safety. Reducing fugitive emissions improves the safety profile for workers on site, helping reduce the potential for lost time injuries and unplanned production interruptions. Optical technologies now have security and risk mitigation features (i.e., visualization intelligence combined with AI) which may alert the operator to employees entering hazardous areas (i.e., Class 1 Division 1).

Capitalize on certified gas markets. Emissions monitoring is a requirement for known natural gas certifications, and certified gas can fetch a higher price than generic gas. As the market matures, it is believed that certified gas will eventually become the standard; meaning that, as gas quality improves (lowered carbon emissions value), more pressure will be placed on operators to improve their emissions performance to maintain and capture market share (remain competitive).

Greater ROI on LDAR investments. Detection and near real-time alerts of emissions events provides LDAR teams with the specific information they need to immediately respond to leaks where they are occurring, keeping more product in the pipe and substantially mitigating the release of methane into the atmosphere.

The Encino Advantage

Encino is a pioneer in emissions monitoring in the Energy sector, providing clients with a complete range of environmental services. Because of our broad range of capabilities and services, partnering with Encino can help you improve efficiencies and productivity by reducing the number of vendors, enabling synergies between operations and sustainability and providing opportunities to bundle and work with a company that can be a more comprehensive partner. Getting a true view of your emissions profile is required to evidence environmental performance and keep more product in the pipe.

Empirically Driven, Not Sales Driven. Encino was founded by scientists, engineers, and Energy professionals in 2010 who thrive on getting it right.

Truth in Transparency. Whether our data is used for compliance, operations analysis or ESG reporting, it is transparent and can be independently verified.

Comprehensive Emissions Ecosystem. We offer a vertically-integrated emissions measurement ecosystem; from continuous monitoring of individual sites to emissions performance testing of combustion sources (e.g., engines, heaters, boilers, etc.), Leak Detection and Repair (LDAR) services and wide-area satellite surveillance combined with expert analysis.

AI-Enabled Optical Gas Imaging Technology. We have made a commitment to using AI-OGI wherever feasible to provide the best emissions Quantification, Monitoring, Reporting and Verification (QMRV) possible.

Mobile Monitoring Systems. Encino's patented Mobile Systems for monitoring emissions provides for rapid mobilization of accurate continuous emissions monitoring, including methane intensity. Extendable masts make on-site deployment in the field fast and easy, without construction permits (i.e., confined space, hot work, etc.) which are typically required for securing fixed camera units at a well site, pipeline location or production facility (management of change notwithstanding).

Accessible, Verifiable Data. We don't hide behind IP or proprietary algorithms. Our data is auditable, and our analytics can be independently reproduced and verified.

Additionally, Encino has developed calibration/linearity evaluation systems to appropriately assess the capabilities (and limitations) of our systems. This is important not only for meeting data quality objectives, but to (also) provide a roadmap for advancing our technologies.

Bringing Multiple Data Sets Together. Encino can collect critical environmental data via multiple methods to provide you with a unified, visual emissions "Mosaic" for analysis and decision making. We bring the broadest range of emissions monitoring and mitigation technologies to the table and collect full-spectrum GHG data from all of our emissions performance testing projects (and have since day one). By using Fourier-Transform Infrared (FTIR) instruments combined with spectral reprocessing software, we can recount GHG measurements from any project data package.

Laboratory Accreditation. Our laboratory operations maintains accreditation (through an accredited regulatory body), ensuring our processes and methodologies follow industry best practices.

Contact us today at (281) 201-3544 or support@encinoenviron.com for a free consultation and evaluation of how Encino can help you achieve environmental performance that generates economic results.

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About Encino Environmental

Founded in 2010 to meet the growing demand for environmental regulatory compliance solutions, Encino Environmental Services, LLC specializes in environmental compliance and performance support for the energy industry. Our field-proven services include emissions testing and compliance initiatives. As technology has evolved, so have our services, with continuous emissions monitoring systems and data systems increasingly in demand.

With more than 150 years of combined engineering, project management, and environmental compliance experience, Encino has the capability to assess, design, and implement an array of strategies for simple to complex environmental projects.

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