Highwood Emissions Management

Leveraging Technology to Tackle Methane Emissions

Commissioned by

Environmental Defense Fund

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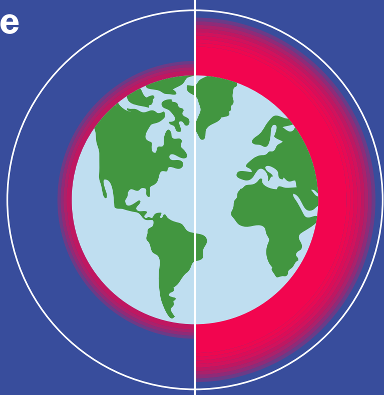
The Imperative and Benefits of Oil and Gas Methane Mitigation

Reducing Methane Now is The Fastest Way to Slow Global Warming



100 YEAR TIMELINE

Methane's global warming potential is **28-34 times** that of CO_2

20 YEAR TIMELINE

Methane's global warming potential is **84-86 times** that of CO_2

Low Hanging Fruit

25%

of total anthropogenic methane emissions came from the oil and gas industry.

0.1°C

of global warming increase could be avoided by 2050 by addressing oil and gas methane emissions.

90m

U.S. homes' annual natural gas need could be met by the methane emitted by the oil and gas industry globally.

75%

of oil and gas methane emissions can be eliminated by existing technology, and 50% at net zero cost.

Improved Air Quality and Public Health

can be achieved by reducing oil and gas methane and comingled pollutants.

Anthropogenic methane sources. Source: https://www.iea.org/data-and-statistics/charts/main-sources-of-methane-emissions

The Importance of Methane Detection and Quantification (D&Q)

Methane is invisible to the human eye and odorless. It rises quickly, disperses rapidly, and can originate from various sources, making detection challenging without effective detection technology.

Accurate measurement of methane emissions needs the right technology and is critical for oil and gas companies to:

- Target emissions reduction efforts, e.g., aiming for "net-zero."
- Identify operational improvements that reduce emissions, e.g., phasing out routine venting and flaring.
- Accurately track methane emissions reduction improvements, and provide accountability and transparency to stakeholders.

A Diverse Technology Landscape

The technology landscape for methane detection and quantification is diverse, and rapidly evolving. Understanding the features of these technologies is crucial for an effective measurement, detection and quantification strategy.

Key Sources of Oil and Gas Sector Methane Emissions

Categories of Methane Emissions

Addressing methane emissions requires consideration of their variability in both space and time. This variability is driven by several factors, including the type and condition of equipment, operational practices, and environmental conditions. A helpful starting point in this assessment is the three following methane emission source type categories.

CATEGORY 1

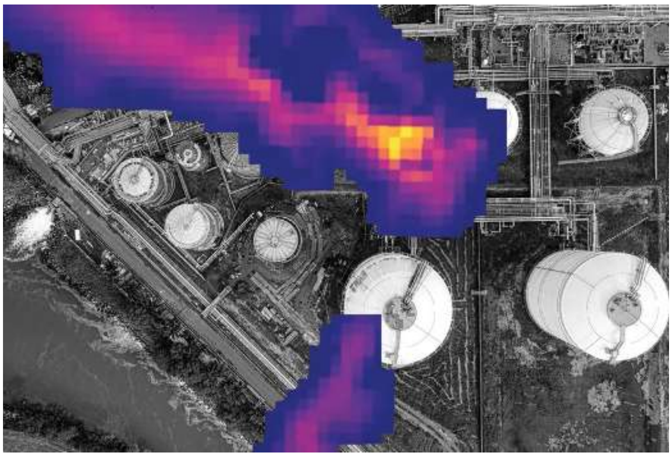
Fugitive Emissions

Unintentional methane emissions, including component leaks (failures of connectors and valves), process failures (unlit flares), and human errors (thief hatches left open, improperly-set pressure relief valves).

CATEGORY 2

Venting

The intentional release of methane into the atmosphere during normal operations, maintenance activities, or for safety reasons.



CATEGORY 3

Incomplete Combustion

Methane emitted as a byproduct of incomplete combustion in engines, turbines, boilers, or flares.

Understanding Emissions Sources

Key Emission Behaviors to Consider Before Selecting Methane D&Q Technology:

KNOWN VS UNKNOWN SOURCES

Do I know the sources I want to measure, or do I need to identify sources first?

Some emissions sources, such as fugitive emissions which are unintentional, could occur across the oil and gas supply chain, so detecting them is a crucial first step. In contrast, venting and combustion emissions are generally due to engineering design. Their reduction efforts typically focus on emission rates quantification through a combination of engineering calculations and direct measurement.

EMISSION SIZE

Do I need a highly sensitive technology?

Methane D&Q technologies have different emission size detection limits. If most emissions are known to be smaller than what a potential methane D&Q technology is known to able to detect, then it is not suitable.

TEMPORAL VARIABILITY

How long do my emissions last?

If sources are intermittent, more frequent surveys or continuous monitoring would be best approaches.

FREQUENCY

How often are emissions expected to arise?

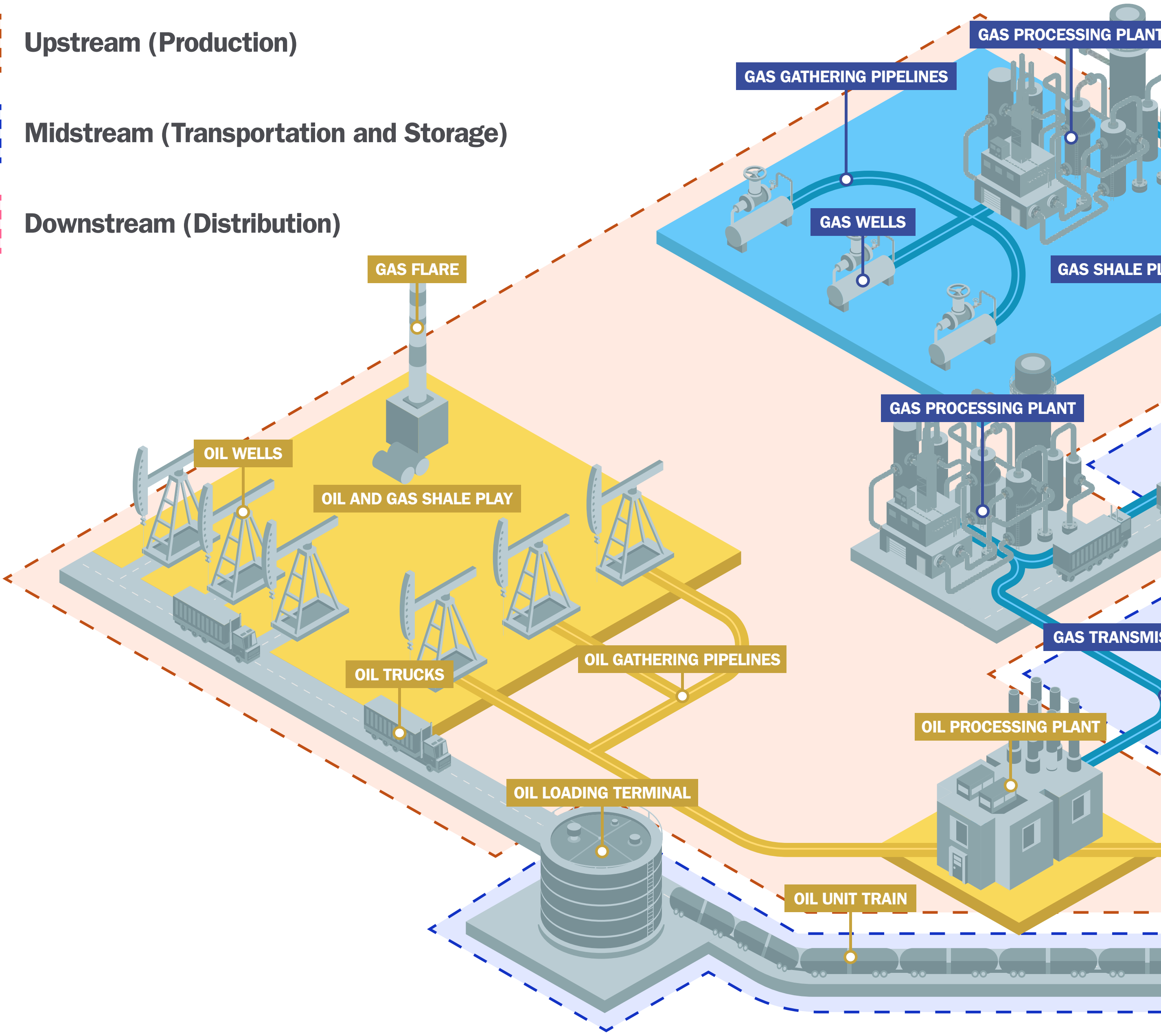
Emissions frequency can help determine how often to monitor certain sources.

How do Methane Emissions Behave Across the Oil and Gas Supply Chain?

Upstream (Production)

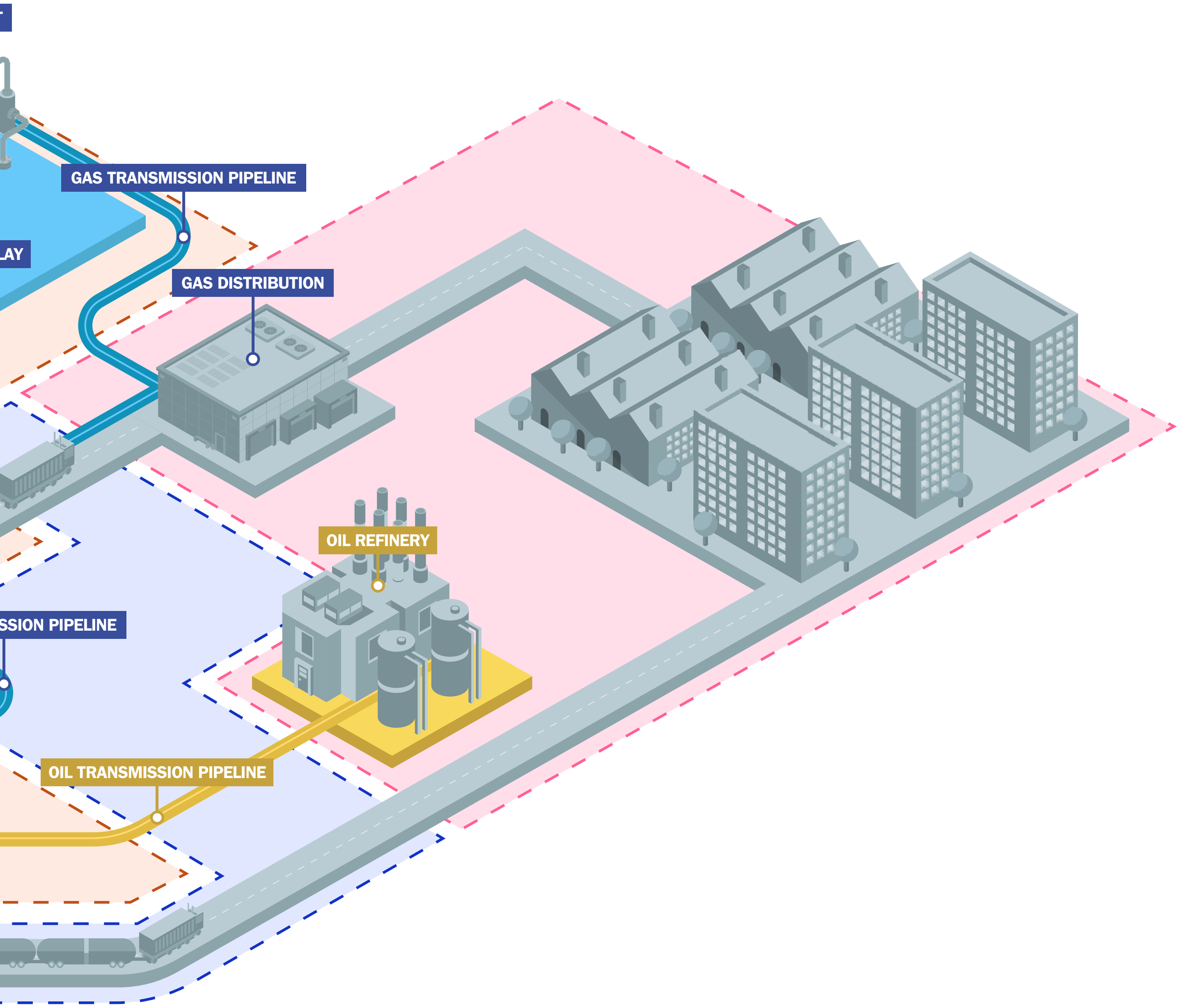
Midstream (Transportation and Storage)

Downstream (Distribution)



Upstream (Production)

Facilities	Onshore and offshore oil and gas wells, separation facilities, gas processing facilities and gathering pipelines
Source Types	Fugitives, Venting, Incomplete Combustion
Emission Size	Small (<1 kg CH4/hr) to large (>100 kg CH4/hr)



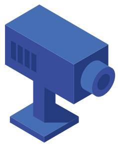
Midstream (Transportation and Storage)	Downstream (Distribution)
Transmission pipelines, compressor stations, LNG facilities and storage	Distribution pipelines, customer meter sets
Fugitives, Venting, Incomplete Combustion	Fugitives, Venting
Small (<1 kg CH4/hr) to large (>100 kg CH4/hr)	Small (<1 kg CH4/hr) to medium (<50 kg CH4/hr)

Attributes of Methane D&Q Technology to Consider

KEY ATTRIBUTE 1

Technology Platform

Methane D&Q technologies are typically grouped according to the platform which houses the methane sensor(s) and ancillary instruments. As these technologies have evolved, the key platforms have emerged as:

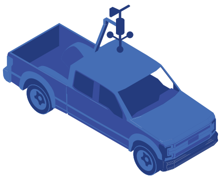


Handheld Devices

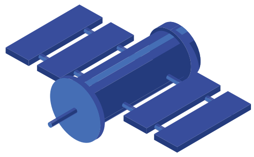
Aircraft

Drones / UAVs

Continuous Monitoring



Ground-Based Vehicles



Satellites

Technology Platform is a Good Starting Point in Decision Making

Questions to consider when comparing the wide range of methane D&Q tech

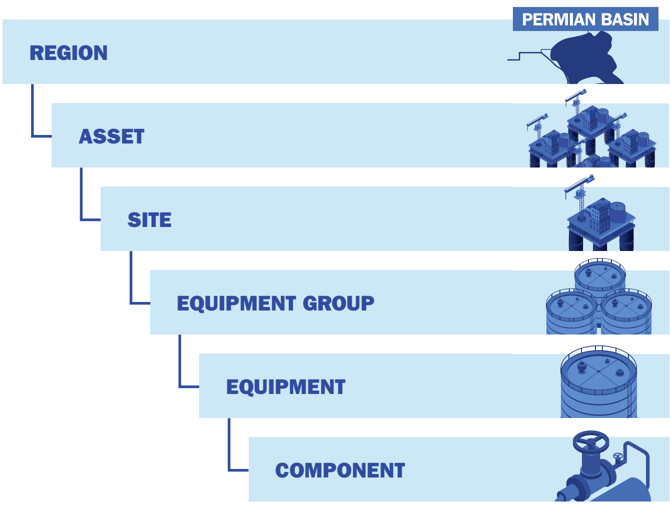
- How far apart are sites?
- Are sites difficult to access?
- Are emissions known to be small or large?

Once the ideal platform(s) are understood, further decision making will be around the particular vendor.

KEY ATTRIBUTE 2

Spatial Resolution

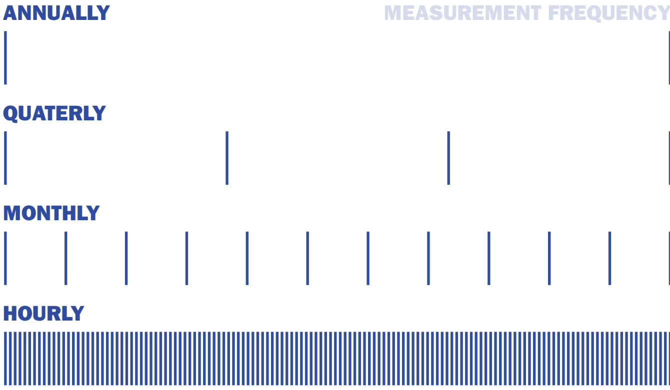
The granularity at which methane detection and quantification technology can localize emissions within oil and gas infrastructure.



KEY ATTRIBUTE 3

Temporal Resolution

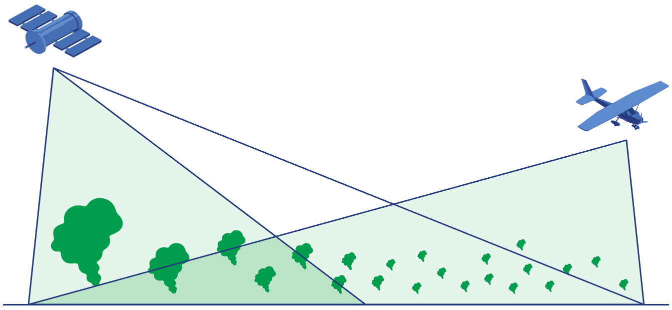
The frequency at which a methane D&Q technology conducts screenings and/or measurements. These screenings and/or measurements are typically taken at least annually.



KEY ATTRIBUTE 4

Sensitivity

The ability of a technology to detect methane emissions, is typically discussed in terms of its minimum detection limit, or a probability of detection (PoD). Simply put, selected technologies must capture the vast majority of emissions. When evaluating technologies, consider the PoD as well as quantification uncertainty (see below). This information is not always available, so operators should ask vendors for proof of performance. Organizations like the United Nations Environment Programme's International Methane Emissions Observatory (IMEO) are working to improve technology performance transparency through open testing.

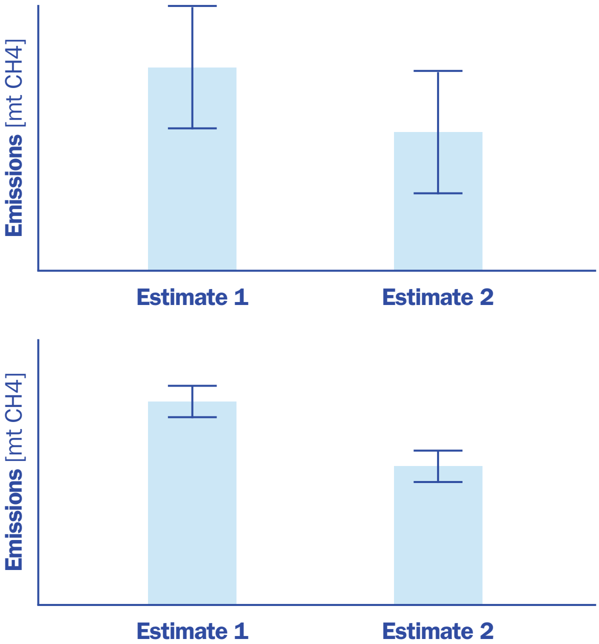


A visual representation of the impact of varying sensitivity by different technologies. Source: Ayasse, et al. (2024) Probability of Detection and Multi-Sensor Persistence of Methane Emissions from Coincident Airborne and Satellite Observations.

KEY ATTRIBUTE 5

Quantification Error and Uncertainty

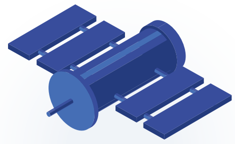
Quantification refers to estimating a source's emission rate. Quantification error is the difference between the estimated and actual emission rates. Sources of error include limited spatial or temporal coverage, and environmental conditions like wind speed and temperature. Quantification uncertainty represents the overall impact of such errors. The figure to the right shows two bar charts, each representing hypothetical results of collected emissions measurements of the same source. Error bars represent quantification/measurement error. The error of the measurements from the top bar chart are much larger whereas the error from the bottom bar chart is smaller. In this case, we can assume we have two different estimates in the bottom bar graph as the error bars do not overlap, but not so on the top bar graph as the error bars do overlap.



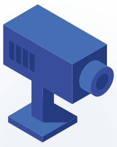
Technology Platforms: Trade-offs in Sensitivity, Scale and Accessibility

	Handheld Devices	Continuous Monitoring
Spatial Resolution	Region/Asset Site Equipment Component	Region/Asset Site Equipment Component
Ability to Detect Small Emissions (<2 kg/hr)	Many Vendors	Some Vendors
Ability to Detect Large, Intermittent Emissions (>100 kg/hr)	Some Vendors	Many Vendors
Ability to Quantify Component or Equipment-Level Emissions	Some Vendors	Some Vendors
Ability to Quantify Site-Level Emissions	No Vendors	Some Vendors
Unique Technology Companies Available	Many Vendors	Some Vendors
Industry Adoption Level	Many Vendors	Some Vendors

Few Vendors — Some Vendors — Many Vendors

			
Ground-Based Vehicles	**Drones / UAVs**	**Piloted Aircraft**	**Satellites**
Region/Asset Site Equipment Component	Region/Asset Site Equipment Component	Region/Asset Site Equipment Component	Region/Asset Site Equipment Component
Few Vendors	Some Vendors	Some Vendors	No Vendors
Some Vendors	Some Vendors	Some Vendors	Many Vendors
Some Vendors	Some Vendors	Some Vendors	Few Vendors
Some Vendors	Some Vendors	Some Vendors	Some Vendors
Some Vendors	Some Vendors	Some Vendors	Some Vendors
Some Vendors	Some Vendors	Some Vendors	Some Vendors

Technology Platforms: Trade-offs in Sensitivity, Scale and Accessibility



Handheld Devices

Operation

Used by technicians in walking surveys to manually survey for emissions. Handheld technologies are Optical Gas Imaging (OGI) cameras, and portable analyzers.

Use Cases

Regulatory Requirements: Handheld devices are the legacy method for meeting leak detection and repair regulations, there is a high level of familiarity with these devices.

Vendor Examples

e.g., FLIR, Gazomat, Health Consultants, Li-COR, Opgal

Continuous Monitoring

Operation

Permanently installed at site, either around perimeter or at a central observation location depending on sensor type, these devices continuously monitor emissions and communicate results through a dashboard.

Use Cases

Rapid Emissions Detection: Continuous monitors excel at rapidly identifying emissions, allowing rapid repairs of leaks.

Vendor Examples

e.g., CleanConnect, Earthview.io, Honeywell, Kuva, LongPath, Mirico, Opgal, Project Canary, Qube, Sensia, Sensirion, SLB, SOOFIE

Ground-Based Vehicles

Operation

Ground-based vehicles with methane sensors drive the perimeter of an upstream facility, or through the streets of a distribution network collecting measurements.

Use Cases

Downstream (Distribution): Ground-based vehicles are emerging as the go to technology for distribution networks as they are highly sensitive, can get close to potential emissions, and are able to rapidly cover ground.

Vendor Examples

e.g., ExACT, Geovera, Pergam, Picarro, PoMELO

The International Association of Oil & Gas Producers has developed a tool methane detection and quantification technology filtering tool which can be helpful for decision making. Find the tool at https://www.iogp.org/workstreams/environment/environment/methane-emissions-detection-and-quantification/methane-detection-and-quantification-technology-filtering-tool/

Drones / UAVs

Operation

Drones are flown by an experienced, trained and qualified pilot in a grid based pattern around a site. Often, drones are flown slightly down wind of the facility when collecting site level measurements.

Use Cases

Offshore: Drones are often deployed for offshore operations as the point sensors typically used on drones can detect over water.

Vendor Examples

e.g., ABB, AUSEA (TotalEnergies), Boreal Laser, SeekOps, Sniffer Robotics

Piloted Aircraft

Operation

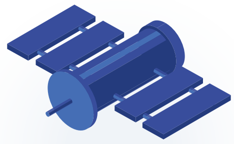
Piloted aircraft are flown over oil and gas infrastructure collecting methane measurements. Results are processed on the ground and sent to the operators.

Use Cases

Quantification: Piloted aircraft are currently one of the most established technologies for initiatives which require site-level emissions quantification.

Vendor Examples

e.g., Bridger Photonics, CHARM, GHGSat, Insight M, Lasen, Pergam



Satellites

Operation

In orbit above earth, satellites collect raw methane measurements which are sent back to earth for processing and reporting.

Use Cases

Global, Regional, and Point Source Detection: Some advanced satellite technologies can detect and quantify large emissions from distinct point sources, whilst others can quantify diffuse sources over larger areas.

Instrument Examples

e.g., EMIT, EnMAP, GHGSat, GOSAT, MethaneSAT, PRISMA, Sentinel-5P, Tanager-1

Guiding Questions

1. What are your technology deployment goals?

Am I trying to meet regulatory requirements? Achieve voluntary initiative certification? Collecting data to build out company-specific emissions factors? Or some combination of these goals.

2. What oil and gas infrastructure is within scope of the technology deployment?

Define sites within scope. Categorizing sites by segment and facility type can help clarify specific requirements and emission sources.

3. Are there any specific deployment challenges?

These may include power availability, weather conditions, or regulatory restrictions (for example, drones are prohibited in some regions).

4. What types of emissions sources are likely present?

Different emission sources require different types of technologies. For example, continuous monitoring or handheld devices, may be more suited for detecting smaller leaks from valves, while aerial surveys are typically used for emissions from flares, as their elevated nature makes ground-level monitoring less effective.

5. What are the available options in the region of interest?

What technologies are available and what are their deployment requirements? Do I need multiple technologies to tackle detection and quantification?

6. What are the technology attributes of available technologies? Do they align with current needs?

For example, given the typical size of emissions at your infrastructure in scope, will a given technology be sensitive enough to detect them?

7. Are there preferred data attributes?

Define the data types, formats, and integration to align with existing organization workflow. For example, the large flux of continuous monitoring data can be valuable and will require allocation of sufficient people power for analysis.

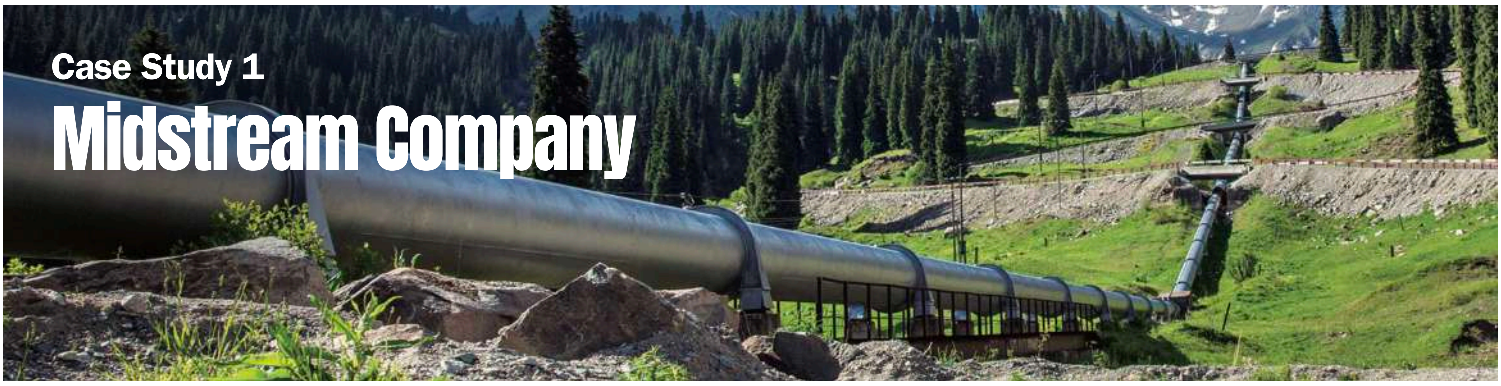
8. Do multiple technologies fit the above requirements?

How do I zero-in on the best technology if multiple ones meet my need? Pilot programs and simulation modeling can help narrow down the best options.

9. What is the available budget?

For example, how can I meet my goals within my budget by optimizing screening? How do the costs of similar vendors compare?

For a more comprehensive database, check out the **methane detection and quantification technology tool**, developed by the International Association of Oil & Gas Producers (IOGP), OGCI, and Ipieca. The online database features detailed technology data sheets covering over 50 technologies, and decision trees to guide technology deployment.



Case Study 1

Midstream Company

A midstream company seeks to proactively monitor emissions of their transmission lines to stay ahead of evolving regulations and prevent significant emission events and product loss. Indicators point to updated regulations calling for frequent screening using "advanced technology" (aerial, satellites, etc.), and the company is preparing for change.

The company's primary goal is to detect and address leaks quickly to avoid costly repairs, regulatory penalties, and reputation damage associated with large emissions.

Questions		Answers
WHAT IS THE INFRASTRUCTURE SCOPE?	→	Transmission pipelines
↓		
WHAT IS THE TECHNOLOGY DEPLOYMENT GOAL?	→	Quickly react to significant emissions events and pilot technologies in preparation of updating regulations
↓		
ARE THERE ANY SPECIFIC DEPLOYMENT CHALLENGES?	→	Extensive geographic area. Ground-based access is difficult due to lack of access roads. This eliminates drones, ground-based vehicles, handheld devices, and continuous monitoring based solutions
↓		
WHAT TYPES OF SOURCES ARE PRESENT?	→	Mainly fugitive emissions. Venting from a few routine operations
↓		
WHAT ARE THE AVAILABLE OPTIONS IN THE REGION OF INTEREST?	→	Wide variety of platforms and sensitivity
↓		
WHAT ARE THE TECHNOLOGY ATTRIBUTES OF AVAILABLE TECHNOLOGIES? DO THEY ALIGN WITH CURRENT NEEDS?	→	Transmission line fugitive emissions are rare, but can be larger than 100 kg/hr.
↓		
ARE THERE PREFERRED DATA ATTRIBUTES?	→	No specific requirements
↓		
MULTIPLE TECHNOLOGIES FIT THE ABOVE REQUIREMENTS?	→	Aircraft and satellites are potential options. There will be a trade-off in cost and sensitivity. To find the most cost effective solution pilot studies and modelling are recommended.

Case Study 2

Remote Well Sites

An upstream oil and gas company currently monitors remote well pads quarterly using handheld devices to meet LDAR requirements. The company is interested in deploying technology to collect site-level measurements in the upcoming year to A.) meet OGMP 2.0 Level 5 requirements,* and B.) Incorporate site-level measurements for a more accurate understanding of emissions.

Recent LDAR campaigns revealed small leaks at most sites, prompting questions about the efficiency and safety of their quarterly surveys which involve significant driving. The company is exploring alternative technologies to minimize on-site visits, enhance safety, optimize resource allocation, and quantify emissions at the site level.

Questions	Answers
WHAT IS THE INFRASTRUCTURE SCOPE?	Upstream wellpads
WHAT IS THE TECHNOLOGY DEPLOYMENT GOAL?	Monitor fugitive emissions and perform site and source-level emissions quantification (collect site and source-level measurements).
ARE THERE ANY SPECIFIC DEPLOYMENT LIMITATIONS OR CONSTRAINTS?	Ground-based access is difficult. Drone, ground-based vehicle, handheld device-based solutions will be resource intensive.
WHAT TYPES OF SOURCES ARE PRESENT?	Fugitives, venting and incomplete combustion
WHAT ARE THE AVAILABLE OPTIONS IN THE REGION OF INTEREST?	Wide variety of platforms and sensitivity
WHAT ARE THE TECHNOLOGY ATTRIBUTES OF AVAILABLE TECHNOLOGIES? DO THEY ALIGN WITH CURRENT NEEDS?	Frequency and emission size is variable, but most emissions are less than 100 kg CH_4/hr.
ARE THERE PREFERRED DATA ATTRIBUTES?	No specific requirements
MULTIPLE TECHNOLOGIES FIT THE ABOVE REQUIREMENTS?	Aircraft and continuous monitoring are potential options as additional technology to the handheld devices already used by the company. Here, the operator needs to carefully consider evolving OGMP 2.0 recommendations in tandem with technology advancement in the performance of technology such as satellite and continuous monitoring.

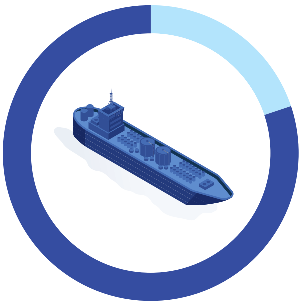
*For an introduction to OGMP 2.0 please visit https://www.ogmpartnership.org/frequently-asked-questions

Raising the Bar on Methane Reporting

Background

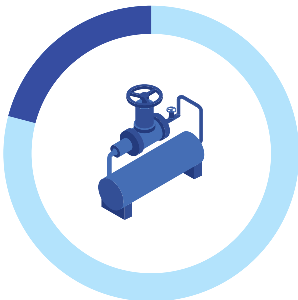
The Oil and Gas Methane Partnership (OGMP) 2.0 is a comprehensive methane reporting framework for the oil and gas industry, administered by the United Nations Environment Programme (UNEP). OGMP 2.0 requires the implementation of measurement-based technologies both at the source level and site level and their reconciliation.
Participating companies commit to reporting their methane emissions from operated and non-operated assets across the value chain each year. OGMP 2.0 provides members a platform to credibly report on methane emissions performance, identify best mitigation options,and engage with and contribute to the leading process for methane management globally. OGMP 2.0 has 153 oil and gas signatories in 2024.

OGMP 2.0 Member Companies Represent

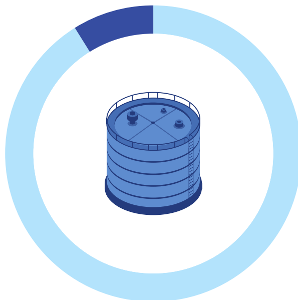


Over
80%
of liquefied natural gas (LNG) flows

Over
40%
of the global oil and gas production



Over
20%
of global natural gas transmission and distribution pipelines



Over
10%
of global storage capacity

OGMP 2.0 Levels

OGMP 2.0 has five levels that require progressively more rigorous emissions estimation techniques and more comprehensive measurement, culminating in reconciliation. Each year in May, member companies report their emissions and UNEP staff provide review.

TOP-DOWN	Level 5 ↑ GOLD STANDARD	**Site Level - Measurement & Reconciliation** Intended to reconcile source level emission estimates, providing improved confidence in reported emissions
BOTTOM-UP	Level 4 ↑ GOLD STANDARD	**Source Level - Measurement based EFs** Based on representative sampling of sources in measurement studies. For some sources, engineering calculations or simulation software may be appropriate
BOTTOM-UP	Level 3 ↑	**Source Level - Generic Emission Factors** e.g., API GHG Compendium
BOTTOM-UP	Level 2 ↑	**Simplified Source Level** i.e., vents, flares, fugitive, combustion and other per asset
BOTTOM-UP	Level 1 ↑	**Asset Level** i.e., one emission figure for whole of asset

OGMP 2.0 REPORTING FRAMEWORK

May 2025

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