UN environment programme

Invisible but not unseen

How data-driven tools can turn the tide on methane emissions – if we use them

An Eye on Methane 2024

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Abbreviations

COP	Conference of the Parties
EU	European Union
GFMR	Global Flaring and Methane Reduction Partnership
GMP	Global Methane Pledge
IEA	International Energy Agency
IMEO	International Methane Emissions Observatory
IPCC	Intergovernmental Panel on Climate Change
LNG	liquefied natural gas
MARS	Methane Alert and Response System
metcoal	metallurgical coal
MENA	Middle East and North Africa
OGMP 2.0	Oil and Gas Methane Partnership 2.0
UNEP	United Nations Environment Programme

Foreword

Slashing methane emissions is an emergency brake to rapidly slow global warming while we work toward a net zero future. And it is past time we pulled it. Methane is responsible for roughly one-third of the warming our planet is currently experiencing, and the science is clear: cutting methane is the fastest and most cost-effective way to mitigate near-term warming and avoid worsening climate damage.

The fourth edition of *An Eye on Methane* arrives at a critical juncture, as global efforts to address methane emissions must transition from aspiration to action. While once difficult to detect and hard to measure, the technologies and systems to manage methane emissions have arrived. Methane may be invisible, but it is not unseen—and there is no longer an excuse for inaction.

The United Nations Environment Programme (UNEP) International Methane Emissions Observatory (IMEO) provides data and context to empower individuals who can act to reduce methane emissions. This year's report finds that while the data-driven tools provided by UNEP's IMEO are ready to be put to use to cut emissions, stakeholders must increase their engagement and follow-through.

For example, through its work leveraging data from the world's growing array of methane-detecting satellites via the Methane Alert and Response System (MARS), UNEP's IMEO has notified governments and companies of over 1,200 major emission events, but only received substantive responses in one per cent of these cases. This underscores that data alone is not enough. With the window to address climate change rapidly closing, action to reduce emissions must follow.

In parallel, UNEP's Oil and Gas Methane Partnership 2.0 (OGMP 2.0), a voluntary initiative for oil and gas companies to measure and reduce their methane emissions more effectively, has expanded to 140 members covering more than 40 per cent of global production. OGMP 2.0 is transitioning companies from imprecise emissions estimates to the measured data needed to reduce emissions. But as pledges to act mount from the oil and gas sector, OGMP 2.0 participation must expand to ensure these are backed by credible data to drive accountability and reduce emissions.

This year's report also shines a light on the untapped potential to reduce methane emissions in the steel industry and announces how UNEP can help the sector harness credible data from IMEO to drive swift mitigation. This is essential as methane contributes about one-third the climate footprint of steel production, but could be significantly reduced at about one per cent of the price of steel.

The coming years will be critical for delivering on methane reduction promises. Stakeholders must make the leap from ambition to action to keep within reach the objectives of the Paris Agreement and the Global Methane Pledge, through which over 150 countries aim to reduce global methane emissions by at least 30 per cent from 2020 levels by 2030. UNEP, through IMEO and other partnerships, stands ready to support countries, companies and stakeholders in achieving rapid and credible methane mitigation. The tools are ready, the targets are set—now it is time to act.

Dechen Tsering
Director a.i., Climate Change Division
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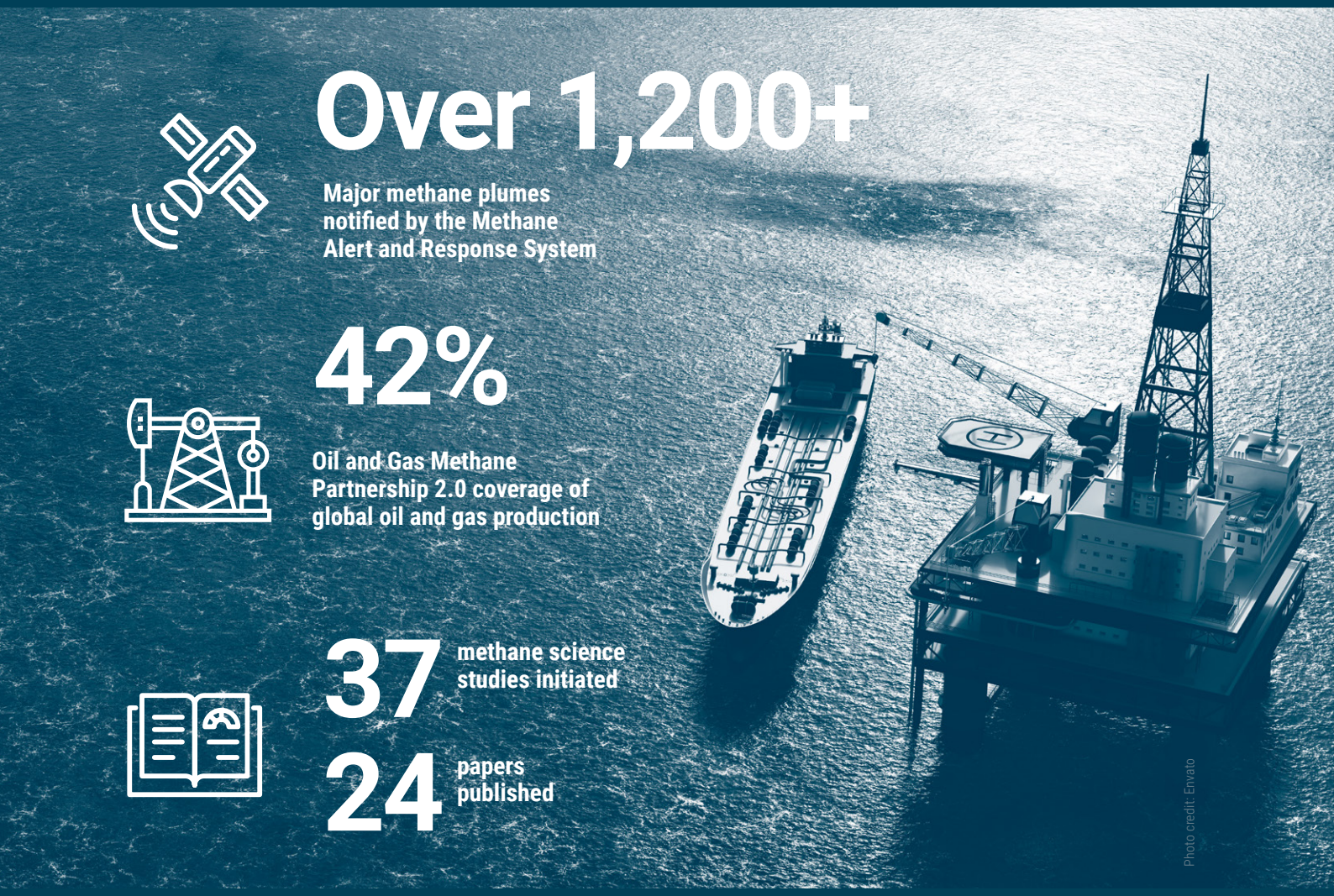
IMEO at a glance



Over 1,200+

Major methane plumes notified by the Methane Alert and Response System

42%

Oil and Gas Methane Partnership 2.0 coverage of global oil and gas production

37 methane science studies initiated

24 papers published

Photo credit: Envato

Methane emissions from human activity drive roughly one-third of the warming being experienced on our planet today.

Reducing methane emissions is the fastest, most cost-effective way to slow the current rate of warming, as we further decarbonize.

Rapid advances in monitoring technology and heightened global attention now allow us to determine how much methane is entering the atmosphere and where these emissions are occurring.

UNEP's International Methane Emissions Observatory is catalysing a methane data revolution, and has created the tools to ensure that better data accelerates methane action.

Executive Summary

Human-caused methane emissions are responsible for roughly one-third of the planet's current warming. Reducing these emissions is the fastest, most cost-effective way to slow global warming in the near-term—and is essential to averting critical climate damages.

The fourth edition of the United Nations Environment Programme (UNEP) International Methane Emissions Observatory (IMEO) publication, *An Eye on Methane: Invisible but not unseen*, takes stock of the progress made to harness a methane data revolution that can accelerate methane reduction at a global scale.

UNEP's IMEO provides data and context to the individuals who can act to reduce emissions. To do this, IMEO collects and publishes data through rigorous industry reporting via the Oil and Gas Methane Partnership 2.0 (OGMP 2.0), from satellites via the Methane Alert and Response System (MARS), from its series of global methane science studies, and from national emissions inventories.

This report finds that engagement with the systems built to reduce emissions has not kept pace with the mounting pledges to act. The tools for a methane data revolution are ready—governments and companies must now deliver. As UNEP's 2024 Emissions Gap Report warns that climate goals are slipping out of reach, data-driven action on methane represents a clear opportunity.

1. Enabling oil and gas sector transparency and mitigation

OGMP 2.0 sets the global standard for methane accountability and transparency in the oil and gas sector, and has expanded to 140 members covering 42 per cent of global production in 2024. This marks an increase of over 20 companies since last reported in 2023.

This is also the first year that OGMP 2.0 has begun awarding its "Gold Standard reporting" to companies that report their emissions at the partnership's highest data quality levels. Moving all companies to Gold Standard emissions reporting is necessary to effectively track and target mitigation with measurement-based data. In 2024, 55 companies achieved Gold Standard reporting, out of OGMP 2.0's first cohort of 68 companies that joined in 2020 and 2021.

OGMP 2.0's other 72 member companies that reported data in 2024 (OGMP 2.0 companies are expected to submit their first report the year after they join) are earlier on their journey. Forty-one companies met the agreed Gold Standard pathway as they roll out empirical measurements across their operated and non-operated portfolios. One company achieved Gold Standard reporting ahead of the deadline, demonstrating to the rest of the partnership what is possible.

2. Understanding the oil and gas methane emissions reporting gap

UNEP's OGMP 2.0 provides data to guide and track methane reduction in the oil and gas sector. To do this, its member companies report their emissions through a measurement-based framework. Notably, the past two IMEO reports found that emissions reported by OGMP 2.0 companies were significantly less than the corresponding amount of methane observed in the atmosphere.

This year's report clarifies this gap—and confirms that UNEP's OGMP 2.0 is shifting the sector from imprecise estimates to credible measured data. Analysis by UNEP's IMEO reveals the methane volumes estimated with generic emissions factors, rather than measurements, underestimate emissions, while assets of OGMP 2.0 companies remain unreported. In addition, the available data indicates that significant differences in the types of oil and gas assets operated by OGMP 2.0 vs. non-OGMP 2.0 companies begin to plausibly explain why OGMP 2.0 companies would have lower emissions intensity.

OGMP 2.0 companies' implementation plans provide assurance that the gap will continue to narrow in the coming years as companies provide more verified data. Expanding OGMP 2.0 participation across the sector is necessary to shed more light on the actual sources of emissions—and where mitigation efforts must be targeted.

3. The Methane Alert and Response System (MARS): Ready for action

Through MARS, IMEO draws data from over a dozen satellite instruments to alert countries and governments of major emissions. To date, UNEP has issued over 1,200 MARS notifications and enhanced the system's capabilities with new AI tools and an expanded engagement network.

So far, MARS has catalysed and verified action to mitigate emissions across four continents. However, while the system's capabilities and notifications have grown, response and action by operators and governments has not kept pace.

Of the more than 1,200 MARS notifications issued, just over one per cent have received any substantive response. Given this low response rate, there is a clear climate opportunity for countries and governments to engage and increase mitigation action.

4. Methane emissions in the steel supply chain

Methane emissions from the steel supply chain offer a major but overlooked opportunity for climate action. Production of metallurgical coal (metcoal) accounts for one-tenth of energy sector methane emissions and contributes around one-third of the near-term climate footprint of steel. The majority of these emissions can be mitigated at less than one per cent of the price of steel. With the vast majority of steel produced using blast furnaces fueled by metcoal, addressing these emissions is consistent with industry's effort to curb the cost of lower-carbon alternatives.

Through IMEO, UNEP is working to incorporate methane mitigation into the steel industry's climate strategies, advancing a suite of scientific studies and expanding MARS to cover metcoal facilities.

At the core of this work is the IMEO Steel Methane Programme, which sets ambitious targets and promotes emissions measurement in metcoal production. This initiative builds on OGMP 2.0's success in the oil and gas sector, and offers a practical, cost-effective way to lower the climate footprint of steel while the industry adopts cleaner technologies.

5. Evolving IMEO's methane science

As of 2024, IMEO has launched 37 methane science studies across 19 countries. Initial IMEO methane science studies have successfully filled key knowledge gaps, including by providing the first empirical studies of offshore oil and gas infrastructure and liquefied natural gas facilities, as well as research campaigns in regions lacking empirical data.

Now, a new generation of satellites and monitoring approaches that provide policy-relevant data is creating new opportunities. IMEO is evolving its scientific efforts to capitalize on these changes. While initial studies sought to obtain a basic understanding of emissions in regions without reliable data, moving forward, all studies will prioritize four main objectives.

1. Advancing reconciliation and data integration approaches for multi-scale emissions data
2. Validating measurement-based approaches
3. Supporting data assurance and characterization of regions and sources with high uncertainty or discrepancies in the integrated data
4. Furthering science studies in support of countries targeting methane mitigation.

6. Assembling the methane data puzzle

Accurately estimating the full picture of methane emissions requires integrating data from diverse sources. The number of variables involved—including how emissions change over time, differing operational conditions and measurement instruments' range of detection thresholds and applications—means that relying on a single data source to obtain a complete picture of emissions is not possible.

Through IMEO, UNEP is expanding its efforts to synthesize data so that decision makers are empowered to take targeted action through informed choices. This includes products like the Methane Supply Index, which will enable gas buyers, governments and civil society to compare the methane content of different oil and gas imports. This index will integrate empirical data from IMEO's scientific studies, satellite data and OGMP 2.0 reporting to provide transparency and accountability.

7. Building capacity for methane action

IMEO is driving collaboration between governments, industry and other key players to address systemic barriers to methane reduction. By engaging policymakers and regulators who shape the conditions for mitigation, UNEP aims to facilitate action, particularly by those with direct agency to reduce emissions.

UNEP's IMEO Methane Training Series has nearly doubled the number of government officials and industry professionals empowered to identify and implement strategic actions by leveraging methane data. To date, these trainings have been provided to over 1,000 individuals across 30 countries.

Further, IMEO is ensuring major scientific efforts are paired with engagement, including in its Colombia and Nigeria country-wide baseline studies as well as work in Turkmenistan, where IMEO has provided analysis and scoping of a major in-country mitigation project with the potential to reduce four million tonnes of methane annually.

Making the leap from ambition to action for global methane reduction

Achieving global climate goals hinges on a decisive shift from ambition to action, and the tools to make that shift are already available. UNEP has laid the foundation for global methane progress with cutting-edge initiatives like OGMP 2.0, MARS, its new Steel Methane Programme and a growing suite of data products. But real progress will only come when stakeholders across governments, industries and civil society embrace these resources and turn them into action.

The path to a more sustainable future is clear—by harnessing the power of data and collaboration, we can dramatically cut methane emissions, slow global warming and deliver on the promise of the Global Methane Pledge and the Paris Agreement.

The time to act is now.

01

Enabling oil and gas sector transparency and mitigation

OGMP 2.0 makes the leap to global measured data

Photo credit: EDF

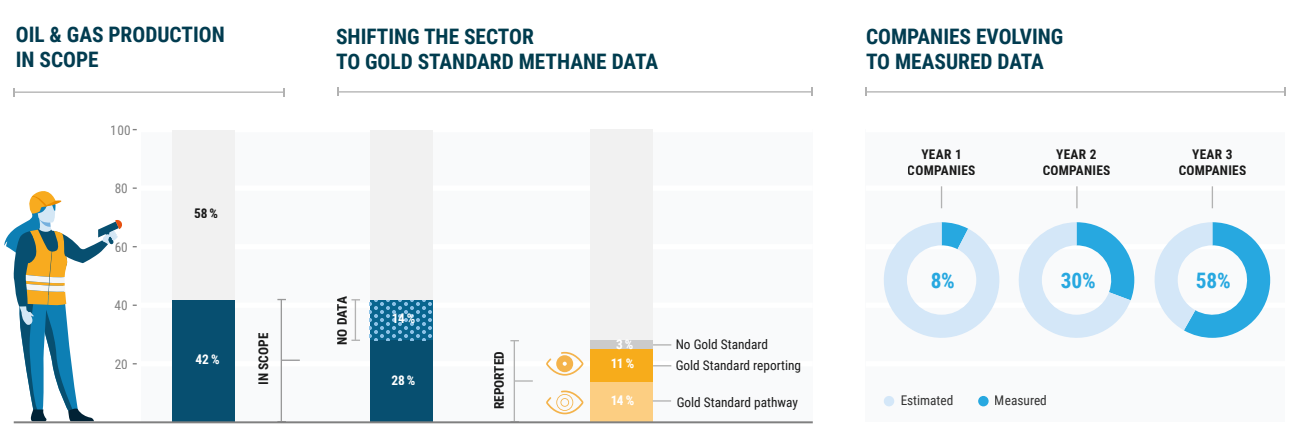
The shift from Gold Standard pathway to Gold Standard reporting

In the oil and gas sector, UNEP's Oil and Gas Methane Partnership 2.0 (OGMP 2.0) transparency and accountability initiative continues to set the global standard with its comprehensive, measurement-based reporting framework and community of practice, accelerating industry-wide action to empirically measure and mitigate emissions.

OGMP 2.0's framework is driving transparency in methane emissions reporting within the oil and gas industry.

2024 marked a significant milestone as the first group of OGMP 2.0 company members have started to reach Gold Standard reporting, the highest level of reporting, for the first time (see Figure 1). While still in its infancy, this ambitious measurement and reconciliation of emissions at both source and site levels is providing invaluable insights for mitigation action. By building experience and creating collective learning through OGMP 2.0, these Level 5 measurements are instrumental in fast-tracking the efforts of others aiming to achieve similar performance in emissions measurement and in focusing action at the scale and speed required by the climate crisis.

Figure1: The transition to measured data



Through increasingly accurate emissions measurement, member companies are identifying significant sources of methane emissions and implementing effective mitigation strategies. In 2024, of the 122 member companies eligible to report, 118 submitted reports, while four companies did not. OGMP 2.0 recognized 56 companies with Gold Standard reporting and 41 companies with Gold Standard pathway. A further 21 companies reported their methane emissions, though did not meet the Gold Standard.

An additional 18 companies that joined OGMP 2.0 in 2024 will be eligible to report for the first time in 2025.

During this year's grading of company emissions reporting, UNEP recognized the diverse challenges companies faced in achieving Level 5 reporting for the first time. However, with improved data quality and collective learning, greater adherence to Level 5 reporting standards is anticipated and expected next year.

Box 1. **OGMP 2.0 reporting levels**

OGMP 2.0 reporting levels 1, 2 and 3 are estimated based on generic emission factors, contrasting with levels 4 and 5 which are based on empirical measurements:

Level 1 – Country, venture or asset level reporting – Emissions reported for a venture at the asset or country level (i.e. one methane emissions figure for all operations in an asset or all assets within a region or country).

Level 2 - Emissions category – Emissions reported in consolidated, simplified source categories (based on the International Association of Oil and Gas Producers' five categories for upstream emissions and on MARCOGAZ's three categories for midstream and downstream emissions), using a variety of quantification methodologies.

Level 3 – Generic emission source – Emissions are reported by detailed source type, based on generic emissions factors.

Level 4 – Specific emission source – Emissions reported by detailed source type using specific emissions and activity factors derived from direct measurements or advanced engineering calculations.

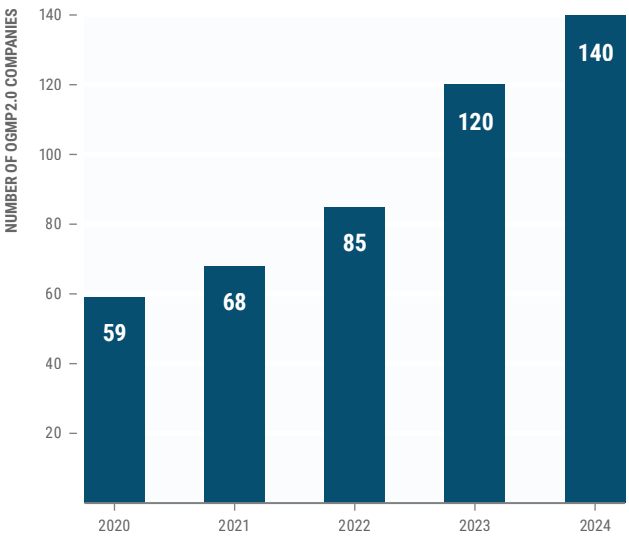
Level 5 – Specific emission source level + site-level measurement – Emissions reported similarly to Level 4, but with the addition of site-level measurement reconciliation (site-level measurements characterize site-level emissions distribution for a statistically representative population).

For more on OGMP 2.0's reporting journey, timelines and commitments, see the OGMP 2.0 website.

An expanding partnership

Launched in 2020 with 62 member companies, OGMP 2.0 has more than doubled to 140 members (see Figure 2). OGMP 2.0 has seen a significant regional diversification in its membership, welcoming Indonesia's Pertamina, Azerbaijan's SOCAR and Nigeria's NNPC, United States of America majors Chevron and Exxon, Australia's Woodside, Canada's Kiwetinohk and Japan's Inpex Corporation. Coverage includes assets in Central Asia and China, and significant midstream assets were added in the United States of America in the 2023 reporting year.

Figure 2: OGMP 2.0 membership growth

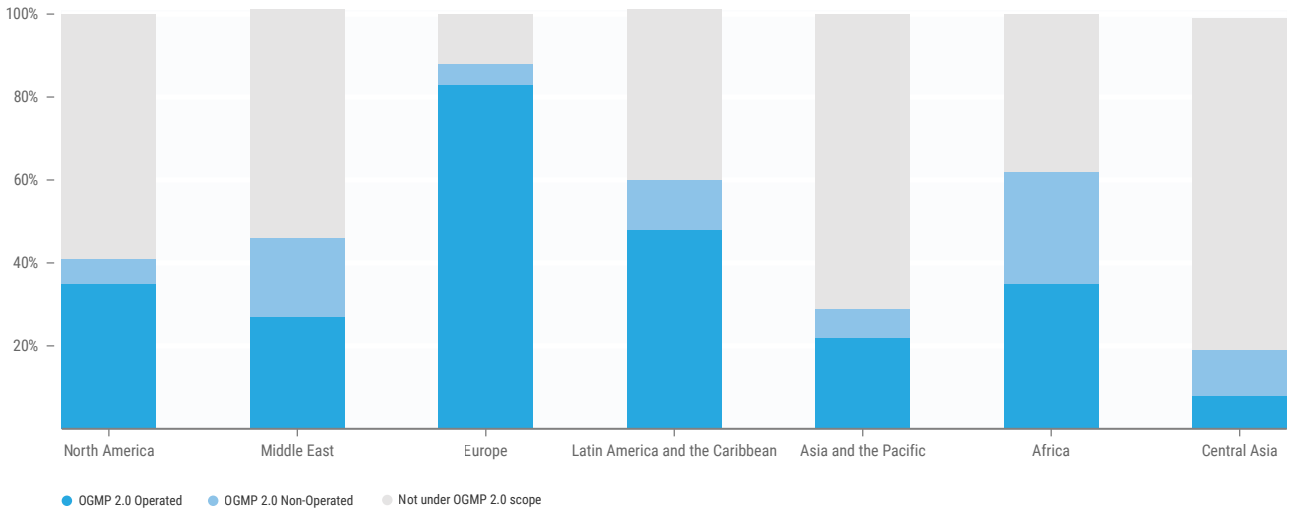


OGMP 2.0 now covers around 42 per cent of global oil and gas production (see Figure 3), over 80 per cent of liquefied natural gas (LNG) flows, and over 20 per cent of global gas storage capacity. In the midstream and downstream segments, the partnership includes the vast majority of European operators, the dominant Chinese downstream operator and a major American transmission operator, enabling it to drive measurement-based progress across these parts of the sector.

OGMP 2.0 has seen engagement from major buying markets such as the European Union (EU), Republic of Korea and Japan, with an interest in transparent emissions disclosure to inform purchasing decisions. OGMP 2.0's measurement-based framework is also the basis for the EU Regulation on methane emissions reduction in the energy sector (EU/2024/1787). These regulations require companies in Europe to measure, monitor, report and verify their methane emissions in line with OGMP 2.0 reporting standards and its Technical Guidance Documents. In addition to setting requirements and obligations for the EU-based oil, gas and coal industry, EU law regulates methane emissions from fossil-fuel imports.

OGMP 2.0 is also receiving growing interest from institutional investors (see Box 2) and banks who can apply OGMP 2.0 Gold Standard reporting as a simple yet effective indicator of companies' methane performance.

Figure 3: OGMP 2.0 members share of production by region



Box 2. **Recognizing investor engagement**

Nordea Asset Management received the Principles for Responsible Investment 2024 award for *Recognition for action—climate*. Nordea's efforts focused on engaging sectors that are major contributors to anthropogenic methane emissions. For the energy sector, Nordea targeted companies' achievement of near-zero methane emissions backed by the Oil and Gas Methane Partnership 2.0 (OGMP 2.0) Gold Standard reporting. Nordea's engagement has delivered substantive results influencing the investor community and companies to act to mitigate methane emissions and helping recruit 14 major oil and gas companies, including ExxonMobil, Chevron and Petrobras, to join OGMP 2.0 and commit to granular methane emissions reporting.

In 2024, the World Bank Group formally joined OGMP 2.0 as a non-company member as part of its revamped Global Flaring and Methane Reduction Partnership (GFMR). A prerequisite for companies to qualify for financing under the GFMR is now OGMP 2.0 membership. This is a further example of collaboration between OGMP 2.0 non-company partners to bring accountability to methane commitments and drive mitigation.

OGMP 2.0 is both a reporting and mitigation framework as well as a community of practice. As part of the latter, OGMP 2.0 hosts an annual in-person implementation conference, regular experience-sharing webinars, and collaboratively develops technical guidance documents to support implementation of the OGMP 2.0 reporting framework. This year also saw the launch of the first global Asset Managers Network to strengthen the connections among individuals in this group of change agents, and a peer-to-peer mentoring programme for company members.

Data uncertainty, reconciliation and assurance

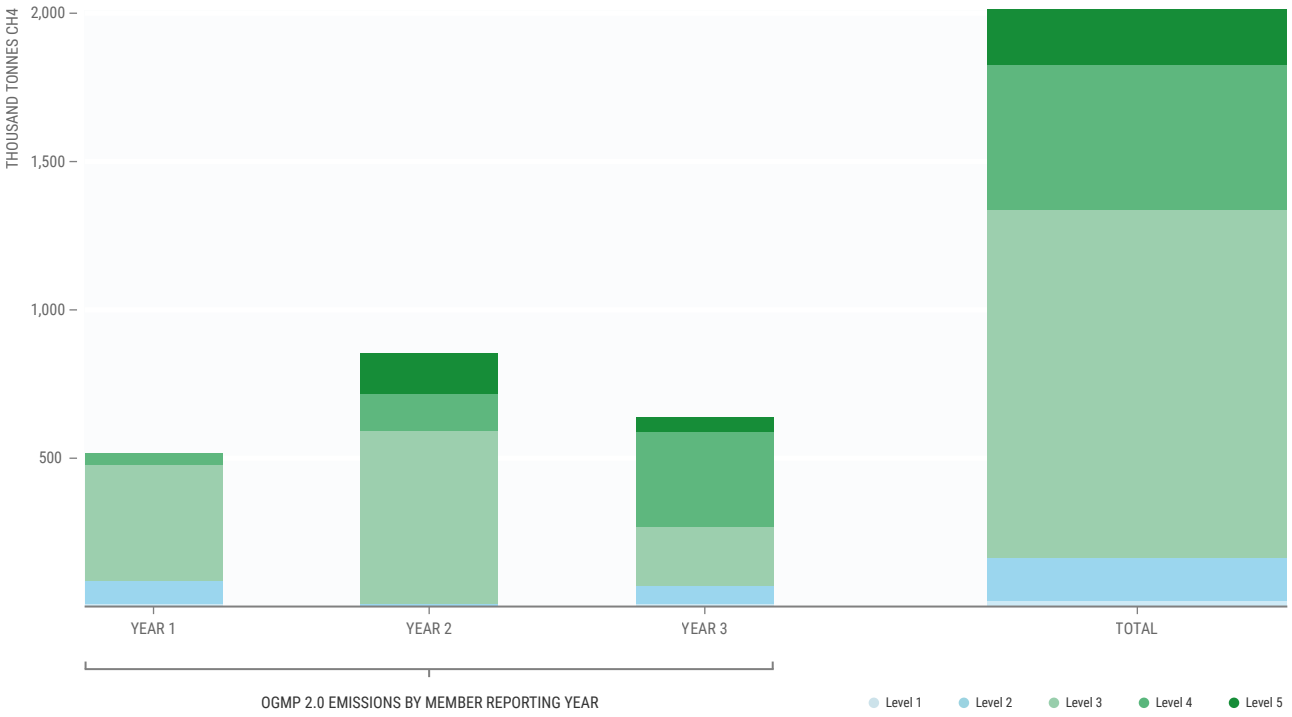
Accurate quantification of methane emissions is necessary to target and track mitigation actions and to inform decisions by governments, regulators and investors. Methane emission quantification efforts require multi-scale data and a robust reconciliation process. This is the basis of OGMP 2.0's Level 5 assessment of emissions. The granularity and completeness of OGMP 2.0 data gives its members an integrated picture of their emission sources to create a focussed mitigation plan.

The OGMP 2.0 framework requires companies to progressively improve data quality, with IMEO providing four levels of data assurance. First, it evaluates company-reported data quality, conducting data quality checks to ensure accurate reporting. The framework standardizes asset size and type definitions and verifies all submitted asset lists against external databases to ensure completeness. Second, using advanced statistical techniques, IMEO analyses data patterns to observe trends and anomalies. This allows for an assessment of data quality shortfalls and suggestions for improvement. Third, IMEO integrates additional sources of data, such as from science studies or from MARS. Finally, in specific cases, IMEO may commission focused science studies or measurements to assess specific assets.

These levels of assurance enable IMEO to add value to the company-reported data, and to share those insights with OGMP 2.0 partners and the broader methane ecosystem to clarify reasons for differing estimates. This leads to improved measurement quality, and of course more effectively mitigate emissions—the primary goal of measurement and reporting.

Photo credit: Pexels - Ganesh Ramsumair

Figure 4: Reported emissions by OGMP 2.0 levels



What the data tell us

Extracting patterns

The data provided by OGMP 2.0 companies indicates how much various segments emit and the major sources within each (see Figure 5). According to the data, upstream assets emit 83 per cent of total reported emissions, with production assets accounting for nearly 90 per cent of reported emissions within the upstream sector. Venting is the major source, followed by fugitive emissions and incomplete combustion from poor quality flaring.

Of reported midstream emissions, LNG liquefaction, shipping and regasification plants constitute over 40 per cent of the segment's emissions, transmission systems over 50 per cent, and underground storage systems represent the balance of approximatively seven per cent of emissions.

The OGMP 2.0 reporting framework requires companies to progress from estimating emissions using emission factors to measuring actual emissions within three years for operated assets and five years for non-operated assets. This improvement is evident in Figure 4, comparing companies in year 1 of their OGMP 2.0 journey that have reported largely factor-based estimated emissions, and companies in year 3 that have empirically measured over 90 per cent of emissions for operated assets, (achieving Level 4 and in some cases Level 5) thereby providing more credible, reliable and actionable data. Notably, a single company, ConocoPhillips, achieved Level 5 for nearly 100 per cent of its operated assets in year 2, an outstanding achievement and demonstration of the art of the possible.

There continues to be a consistent increase in average reporting levels across sectors for operated assets over the last three years, as indicated in Table 1.

Table 1: Emissions-weighted average reporting level for operated assets for companies reporting over the years 2021 through 2023

Industry segment	Average reporting level		
	2021	2022	2023
Upstream	3.2	3.4	3.9
Midstream	3.3	3.7	4.0
Downstream	3.0	3.6	4.0

Figure 5: Top emission sources by segment

Challenges in performing at Level 5

This year, some companies successfully achieved Level 5 reporting at numerous assets. Others attempted to do so, gaining insights into the performance of their operations.

Differences in companies' approaches to reporting the temporal and spatial variability and intermittency of emissions sources and a lack of robust documentation on methods used presented challenges in the evaluation of companies' Level 5 reports. In some cases, companies were unable to undertake site-level measurements or to adequately extrapolate them. In other cases, emissions assessments were not properly adjusted to reflect measurement findings, resulting in a possible underreporting of emissions.

Companies in the downstream segment continue to face challenges in assessing their emissions at Level 5. As part of its methane science studies (see Evolving IMEO's methane science), UNEP through IMEO is collaborating with the University of Utrecht to define the Level 5 methodologies that OGMP 2.0 downstream companies will be able to apply.

In this first year, IMEO has evaluated OGMP 2.0 Level 5 reporting and recognized those companies that successfully reconciled source and site-level measurements with Gold Standard reporting. Those who did not achieve reconciliation but learned lessons through their attempts were still granted Gold Standard reporting, however their assets were recognized at Level 4. IMEO's assessment of companies' data reconciliation efforts will become more stringent over the coming years.

Lessons learned will help to evolve the definition of Level 5, while guidance on topics such as managing uncertainty and data reconciliation will increase the collective learning of members and lead to greater adoption of successful approaches by others.

Responsibility for emissions beyond operated assets

Under the OGMP 2.0 framework, companies are required to use their influence with joint venture partners (e.g. via their governance capacity and operational relations) to determine a path to achieving the highest levels of reporting for their non-operated assets over the agreed five-year timeframe. Engagement efforts by member companies have resulted in numerous joint venture companies joining OGMP 2.0 as direct members. There is some evidence of higher quality data for non-operated assets reported by the same operator year on year. The direct connection of joint venture companies to OGMP 2.0 is desirable and efficient, but of course does not alter the OGMP 2.0 commitments of their shareholders. In general, a greater effort is required by all stakeholders to improve measurement performance in these assets.

A total of 28 operated and non-operated assets were divested by member companies in 2023, five of which were divested to other OGMP 2.0 members. These divested assets will continue to be tracked by OGMP 2.0 and be subject to a separate analysis.

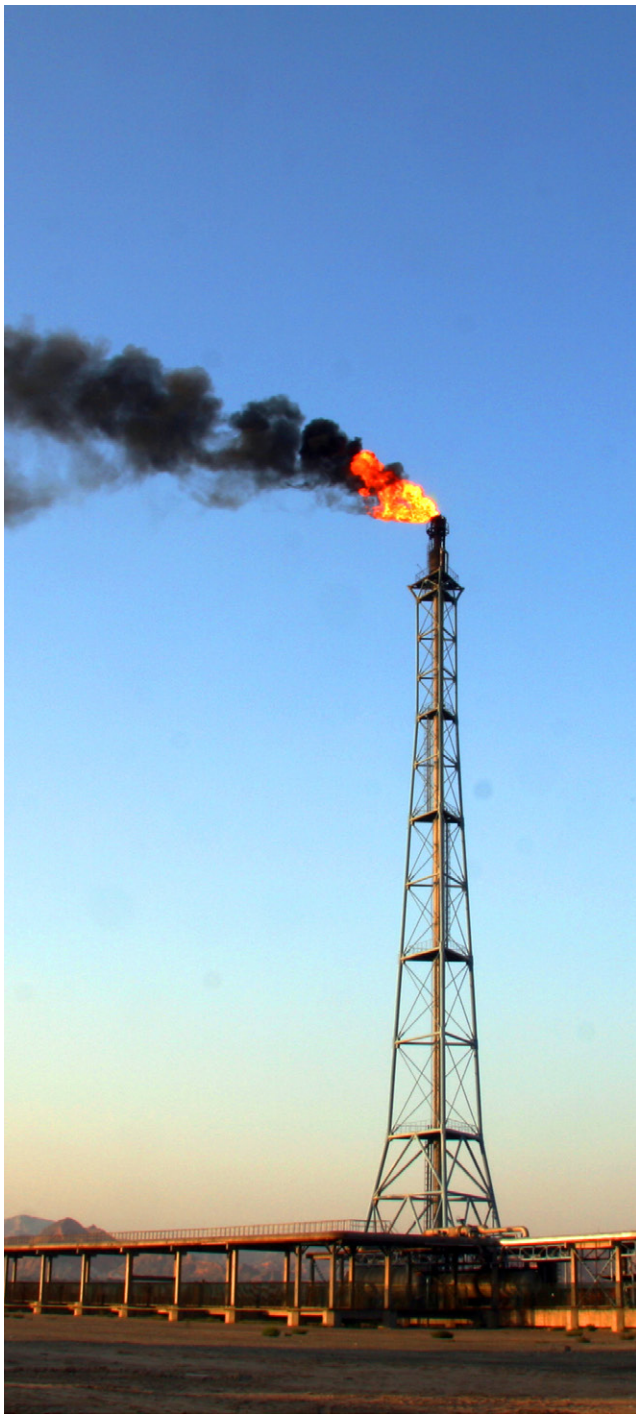


Photo credit: Flickr Adam Cohn

Stories of progress in OGMP 2.0 partner companies

Transparency at asset level

UNEP's goal is to dramatically increase transparency, and for this to happen companies must ultimately achieve emissions disclosure at the asset level. Increasingly this is what external stakeholders expect. It is also frequently the level of granularity at which Level 5 reconciliation must occur. While there are acknowledged fiduciary issues with disclosing asset level data at Levels 1–3 OGMP 2.0 reporting, these concerns do not apply at Levels 4–5. For 2023 data, disclosure at asset level was encouraged and voluntary.

As a result, eleven companies agreed to disclose their emissions data for 55 specific assets. These companies are Bahia De Bizkaia Gas, DESFA, Enaon, Equinor, eustream, Fluvius, Italgas, Nederlandse Gasunie, Oman LNG, Presidio Petroleum and Uniper Energy Storage. A total of 28.6 thousand tonnes of emissions were disclosed. Half of these emissions came from upstream assets. In terms of data quality, nearly 60 per cent of these emissions were measured at Level 4 and Level 5, with the remainder estimated using emission factors at Level 3.

Performance in measurement improvement

- **TotalEnergies** has undertaken an extensive drone-based measurement campaign across sources and assets globally. The programme has resulted in a better understanding of emission distribution from various sources, as well as leading to emissions mitigation.

- **ADNOC** committed to a robust implementation plan that documented the comprehensive measurements it has undertaken to determine its Level 4 source-level inventories. Following a site-level survey, ADNOC identified an opportunity to enhance the accuracy of its emissions quantification from a specific source. By revising its methodology, ADNOC has improved its ability to capture the full range of emissions more effectively, critical for effective mitigation.

- **PETRONAS** conducted site-level measurements and attempted Level 5 reporting at one of its assets this year (Year 2), a year ahead of the requirements. Although PETRONAS ultimately decided not to report the asset at Level 5, the learnings provide PETRONAS a strong advantage for the next reporting year and valuable insights for mitigation action.

- **Cheniere** is leading a research and development programme with scientists from different universities, technology providers and operators to assess the capabilities of methane emissions measurement technologies and improve the analysis and characterization of methane emissions in the upstream, midstream and shipping segments of the supply chain. The results of these programmes will be publicly available in peer reviewed journals, and so inform effective public policies and corporate programmes to monitor, report and mitigate emissions.

- **Italgas** conducted a thorough and extensive measurement campaign across its distribution network, which offers a good example of uncertainty assessment of emissions measurements. Italgas attempted data reconciliation and although some limitations were identified, the effort offers insights into prioritizing analysis and reduction of high-emitting sources that account for most emissions. Italgas is collaborating with a group of scientists to organize controlled gas releases in a new test field with the aim of improving understanding of sources not accounted for during the measurement campaigns.

Photo credit: QatarEnergy

Leading performance at Level 5

- **ConocoPhillips**' reporting is best in class this year. The company conducted an outstanding data reconciliation analysis that yielded a robust Level 5 estimate of their emissions for all material operating assets. This is noteworthy as it was achieved in year 2, ahead of the required deadline for operated assets and a strong signal to other companies of what is possible.

- **Jonah** took a thorough approach to site-level measurements, conducting both facility-wide surveys and whole-site flux measurements. They performed a comprehensive reconciliation, first comparing the source-level inventory with facility-level drone measurements, followed by comparing facility-level totals with full-field measurements. These additional insights will enable Jonah to target mitigation efforts to the largest sources.

- Taking into account the specific operating conditions at the time of the measurements, **GASCADE Gastransport** carried out a robust estimation of the uncertainties of the measurement methods. To get a clear picture of their emissions—essential to inform mitigation—the company carried out a comprehensive data reconciliation.

- **GRTgaz** conducted an extensive source-level uncertainty assessment, considering and quantifying all relevant sources of uncertainty in assembling their Level 4 inventory. The company was also exceptionally transparent in their calculation methodologies.

- **Storengy France** conducted a comprehensive uncertainty analysis for all their sources and provided a nuanced representation of the uncertainties to reflect the full range of potential variability in emissions. Although they encountered some challenges to quantifying the discrepancies between site-level measurements and Level 4 estimates for some assets, the company made considerable efforts to understand these discrepancies.

Performance in transparency and planning

- **SierraCol** provided a best-in-class implementation plan from the year 1 companies, with robust documentation of its methane reduction target and mitigation plans, the technologies and methodologies it intends to use for source-level measurement and a clear, credible plan for achieving Level 4 and Level 5 reporting at its material assets.

- **Williams** submitted a robust and comprehensive implementation plan to achieve Gold Standard reporting, including detailed technical information about their operated assets and their plans to quantify each material source and perform site-level measurements and reconciliation.

- **2iRete** has a very ambitious implementation plan for its assets. In 2023, the company tested different technologies and carried out measurement campaigns in various areas with the goal of reconciling collected data. 2iRete has shared the issues and limitations identified, as well as its plan for addressing these, an essential element of any mitigation strategy.

Photo credit: Flickr Juan Carlos Martins

02

Understanding the oil and gas emissions reporting gap

New IMEO analysis now allows for a plausible explanation of the difference between reported emissions and atmospheric observations

Photo credit: Fluxys Belgium - David Samyn

Reconciling the emissions reporting gap through measurement data

There is a significant challenge in reconciling data reported by OGMP 2.0 member companies with the estimates of global oil and gas emissions based on atmospheric observations. In the last two *Eye on Methane* reports, UNEP's IMEO highlighted that early data from companies seemed to underestimate emissions, especially compared to their industry's share. This discrepancy was later confirmed by the International Energy Agency (IEA). This suggested either that OGMP 2.0 companies were underreporting emissions or that non-OGMP 2.0 companies had much higher emissions intensities. Now, within the uncertainty of the data, it plausibly appears to be a mix of both. Companies striving for the most comprehensive measurement-based reporting tend to underreport emissions, especially those just starting their OGMP 2.0 journey, while non-OGMP 2.0 companies are indeed likely to have higher emissions intensities.

In 2024, OGMP 2.0 companies reported data at higher quality levels (see Figure 1), providing new insights. Tracking emissions at specific assets over several years provides new understanding of the differences in emissions profiles between OGMP 2.0 and non-OGMP 2.0 companies as well as among OGMP 2.0 companies reporting at various levels.

Based on atmospheric observations, global oil and gas emissions are estimated at 80-140 MT per year (Schwietzke *et al*. 2016; Hmiel et al. 2020; Saunois *et al*. 2020).[1] The lower value in this range is consistent with the IEA's estimate for global oil and gas emissions in 2023 based on the 2024 Global Methane Tracker (IEA 2024). For the purpose of this analysis, this report focuses on this range's lower bound and on the oil and gas emissions from the industry's production, or upstream, segment—as it provides the most direct comparison in terms of asset types and coverage in current OGMP 2.0 reporting. This segment is estimated to emit approximately 60 MT/yr.[2]

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1 This range is derived from inverse modeling and isotopic source apportionment (Schwietzke *et al*. 2016; Hmiel *et al*. 2020; Saunois *et al*. 2020).
2 According to IEA data (2024), upstream emissions account for approximately 80 per cent of total oil and gas methane emissions. Excluding the midstream segment from the IEA upstream data (Scarpelli *et al*. 2020) leaves approximately 60 MT/yr for upstream only.

Upstream OGMP 2.0 companies that reported data to UNEP represent 28 per cent of global oil and gas production and accounted for 1.1 MT of methane emissions in 2023. That total is 1.8 per cent of the approximately 60 MT of global oil and gas emissions attributed to the upstream segment, revealing the aforementioned gap between reported OGMP 2.0 emissions and their expected share of atmospheric methane.

Analysis by IMEO allows a comparison of the methane emissions intensity of OGMP 2.0 companies vs. that of companies outside the partnership. The data shows that the asset portfolios of these two groups differ significantly, which partially explains the difference in their respective emissions intensities. This report's analysis starts to partially explain the variance in methane emissions intensities between these groups of companies.

While IMEO data is the most comprehensive measurement-based data available, it only allows for an initial approximation of the gap mentioned above. The positive takeaway is that each subsequent year of reporting will improve the analysis and reduce uncertainty. As the share of global oil and gas production covered by OGMP 2.0 increases as more companies join the partnership and reporting quality improves, this reporting gap is projected to narrow.

Photo credit: EDF - ROMEO

Material underreporting from OGMP 2.0 company assets

Five factors contribute to underreporting of emissions by companies:

- Underreporting at lower reporting levels: IMEO data helps assess underreporting by companies at lower levels of reporting (OGMP 2.0 Levels 1–3, see Box 1 for more detail). Over time, emissions data reported by source and asset reveal quantitative trends in the evolution of measured data. Levels 1–3, based on generic emissions factors, report higher emissions intensity than Level 4, based on direct measurements. Although Level 5 data, which requires reconciliation between source and site-level measurements, is sparse and somewhat mixed in reliability, emissions significantly increase again at this stage. These trends align with the range of intensities reported in several scientific studies where measurement-based data is compared to different types of inventories. It confirms that the committed progression to Level 5 will provide a significantly better understanding of emissions.

- Outsourcing emissions: OGMP 2.0 data cross-checked with industry databases shows that many upstream emissions lie beyond the wellpad, and instead originate from sources such as gathering, boosting and processing, or are outsourced to non-OGMP 2.0 companies, leading to underreporting of full upstream production emissions.

- Missing data from key assets and new member companies: Some major assets, especially in Iraq and the Russian Federation, have not submitted data. Reporting companies represent 28 per cent of global production, with an additional seven per cent in their first year of OGMP 2.0 reporting and seven per cent providing no data.

- Reducing emissions: Anecdotal reports indicate that companies are mitigating emissions as they find them and using the reduced emissions rates in their reporting. One example is the replacement of pneumatic controllers with lower emissions equipment. This is encouraging as the goal is to reduce emissions and this also suggests that over time we should see the desired decrease in global emissions. Independent measurement-based and accurate data at regional and country-level will be key to confirm this expected downward trend from mitigation.

Portfolio differences between OGMP 2.0 and non-OGMP 2.0 companies

A detailed comparison of OGMP 2.0 company assets highlights three key differences compared to assets of non-OGMP 2.0 companies. These differences can be assessed by analysing their impact on various assets within the OGMP 2.0 portfolio:

- Higher proportion of deep-offshore assets: OGMP 2.0 companies have a larger share of deep-offshore assets. Data from companies and scientific studies show that onshore assets (and shallow offshore) typically have higher emissions intensities, likely due to the greater operational demands of offshore operations. This difference partly explains the variation in emissions intensity between the OGMP 2.0 and non-OGMP 2.0 companies.

- Fewer wellpads per unit of production: Non-OGMP 2.0 companies operate a higher number of wellpads per unit of production than OGMP 2.0 companies do. Studies have indicated that dispersed wellpads tend to have higher emission intensities when compared to more integrated production units.

- Commitment to emissions management: It is reasonable to assume that companies participating in OGMP 2.0, with their commitment to measuring emissions at the highest quality level, are more focused on managing methane emissions and therefore plausibly have lower emissions intensity.

Tightening the reporting gap in the future

In conclusion, the available data support the plausible assumption that non-OGMP 2.0 companies have emissions intensities higher than OGMP 2.0 companies. A material part of this difference is explained by variations in the asset portfolios of these groups.

The continued collection of measurement-based data by IMEO—through programmes like OGMP 2.0, the Methane Alert and Response System (MARS) and scientific studies—and upcoming data integration products will enable an increasingly refined assessment of emissions intensity distribution.

As OGMP 2.0 expands its coverage and improves reporting quality, the uncertainty surrounding emissions intensity will decrease. Additionally, IMEO's ongoing integration of additional independent empirical data—such as that from next-generation satellites—will further reduce uncertainty. This shift will mark the end of reliance on generic emission factors and replace them with widespread, measurement-based data needed to drive targeted emissions reduction.

Photo credit: UNEP

03

The Methane Alert and Response System: Ready for action

Leveraging AI, the system is ready but the response is lagging

Photo credit: Canva

Over the past year, IMEO has made significant strides to enhance the capabilities of MARS. MARS is the first global system that provides actionable and transparent data from the world's methane-detecting satellites directly to governments and companies so they can take action to reduce emissions.

IMEO's latest improvements to MARS have enhanced the precision and speed at which the system detects methane emissions and provides stakeholders timely and actionable data.

About a dozen diverse satellite instruments produce a high volume of data on methane emissions. Interpreting and leveraging the data can be challenging, so UNEP provides the required expertise through MARS. The service allows governments and companies to receive an accurate set of data, using integrated emissions observations from multiple instruments. When an emission is detected and validated, the identified government contact point is notified, as well as the company if the facility in question is assessed to belong to a member of OGMP 2.0.

However, the power of MARS data lies not just in its accuracy, but in its ability to enable follow-up action to reduce emissions from specific sources. While the system's capabilities and outreach to companies and governments has substantially grown, action from these stakeholders has not kept pace. This may result from capacity issues, technical barriers and a lack of accountability.

As the window for mitigating climate change narrows, it is imperative that governments, industries and communities alike leverage MARS' insights to enact swift and decisive measures to curb methane emissions.

The system is in place and the network is growing

MARS entered 2024 fully operational, marking a major milestone. Since then, as noted above, the system's detection capabilities have significantly increased, leading to a steady rise in the number of methane plumes detected (see Table 2). In parallel, IMEO has substantially expanded its network of MARS contact points, helping ensure the timely delivery of data to those who can act on it.

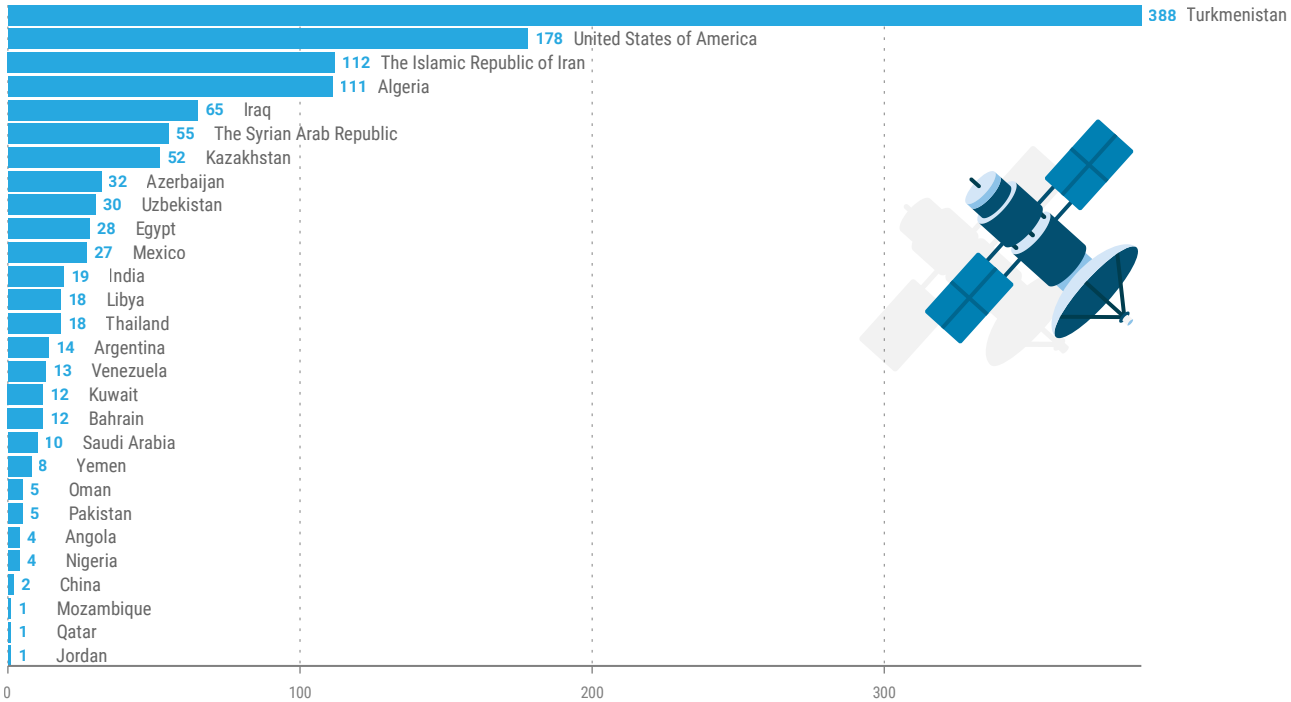
With the integration of new satellites and enhanced AI capabilities to process the growing volumes of data, the detection capability and efficiency of MARS will continue to increase.

Beginning in mid-2024, IMEO scaled up its ability to notify all relevant stakeholders about detected methane plumes that are notifiable. Since its launch, MARS has notified governments and companies of over 1,200 major emission events in the oil and gas sector (see Figure 6). When a MARS notification is issued, IMEO requests that the recipient share information about the detected plume in question such as the source or whether any mitigation action was taken.

Table 2: Total number of detected plumes from January 2024 to 30 September 2024, by sector [3]

Sector	Total # of plumes	# of high-resolution plumes
Oil and gas	2,618	2,036
Coal	582	365
Waste	563	155

Figure 6: Notified plumes by country [4]



3 Through MARS, IMEO only notifies plumes that are: from high-resolution satellites, attributable to a facility and validated by MARS remote sensing experts within 15 days of image acquisition.

4 Note that satellite detection capabilities are not equally distributed in all countries. Some countries are more difficult to detect emissions from via satellite, due to surface conditions, cloud coverage and environmental conditions, among other factors. Therefore, the number of notified plumes per country should not be construed as a definitive ranking of countries' total methane emissions, as some may be underrepresented.

Harnessing artificial intelligence to drive efficiency

A key driver of MARS' growth is its cutting-edge integration of AI to support UNEP's scientific expertise with machine learning. This has enabled monitoring of over 2,000 global locations for methane emissions with unprecedented efficiency.

MARS utilizes numerous high-resolution satellites and receives hundreds of images daily of monitored locations. To enable rapid and robust emissions detection, IMEO data scientists have trained an AI model on over 53,000 multispectral images to automatically identify the presence of emissions at these locations. Based on this training, the AI model processes daily images, flagging potential emissions for the MARS team. Every potential emissions event is analysed by a remote sensing expert at IMEO who confirms its accuracy.

Compared to previous methane-detecting AI models which accurately detected plumes 24 per cent of the time, IMEO has produced a working model that improves detection accuracy by over 200 per cent. In its first six months, this improved AI model correctly identified over 400 methane plumes across 22 countries. Experts verify each of the AI model's findings, but this automated process significantly reduces human input and enables MARS to monitor thousands of potential emission sources daily. This has cost-effectively expanded the level of global coverage possible.

These efforts build upon UNEP's leading research to assimilate, filter and efficiently utilize the thousands of satellite images obtained every day over emitting regions. Scientists at IMEO have published peer-reviewed research on this technology (Vaughan *et al.* 2024), with another manuscript currently under review in a leading scientific journal. These advances are transforming how we detect and respond to methane emissions, streamlining the work of experts and driving impact at a global scale.

Tapping into new observation systems

The MARS AI model is currently optimized for images obtained from the Sentinel-2 and Landsat satellites, which currently provide the largest amount of global methane emissions data. In the future, IMEO plans to expand its AI capabilities to process imagery from a wider range of satellites and space sensors, thereby increasing the frequency and accuracy of actionable data.

IMEO is actively building AI models to analyse data from instruments such as PRISMA, EnMAP and EMIT. While MARS already uses data from these instruments, expanding AI capabilities to these sensors will reduce false positives and enhance the system's efficiency. Additionally, IMEO is preparing to incorporate data from newer satellites such as MethaneSAT and Carbon Mapper's Tanager-1. The growing system of satellites from which MARS draws data is improving the characterization of point sources and expanding spatial coverage.

With the launch of Environmental Defense Fund's MethaneSAT and Carbon Mapper's Tanager-1 in 2024, the outlook for methane detection from space has become even more promising. In 2025, the GOSAT-GW and Sentinel-5 missions will be launched, further increasing the availability of accurate global methane data.

At the same time, a growing number of high-resolution, methane-specific satellites are being launched by private organizations (e.g. Satlantis, Absolut Sensing and AIRMO), most of which IMEO is collaborating with. The increasing deployment of commercial satellites underscores the rising interest in methane beyond academia, accelerating the availability of information and expanding mitigation opportunities.

The advanced sensitivity of these purpose-built satellites presents a valuable opportunity to detect smaller emissions and cover complex regions currently under-monitored by the world's existing remote-sensing capabilities.

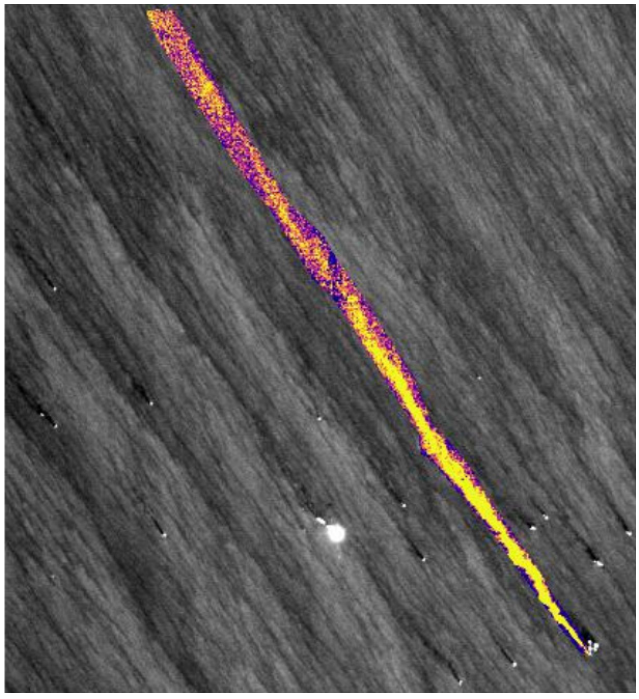


Photo credit: Universitat Politècnica de València

Engaging stakeholders to enable action

IMEO provides MARS data directly to governments and company members of OGMP 2.0. Engaging individuals with the agency to use the data is as important as continually increasing its accuracy. UNEP's existing in-depth and technical dialogue with the 140 oil and gas company members of OGMP 2.0 has proven an efficient pathway to obtain feedback on potential mitigation actions.

To facilitate effective information sharing, governments are encouraged to nominate "focal points" to receive notifications directly from IMEO. These individuals work closely with IMEO to interpret alerts, identify barriers to action, and ultimately work to reduce emissions from these events.

Table 3: Overview of MARS notifications from pilot through 30 September 2024

	# notified plumes	# notified governments or companies	# acknowledged plumes [5]	# governments or companies that acknowledged	# plumes feedback received
Governments	1,225	29	433	11	7
Companies	141	24	80	21	8
Total	**1,225**	**N/A**	**523**	**N/A**	**15**

To date, 20 countries have appointed dedicated focal points to collaborate directly with UNEP on MARS, covering nearly two-thirds of countries where MARS has frequently detected emissions. These focal points play a critical role in responding to emissions notifications, engaging stakeholders and enabling timely and effective mitigation efforts. This partnership helps ensure MARS's impact can be both immediate and far-reaching.

Countries with nominated MARS focal points:

- Algeria
- Azerbaijan
- Argentina
- Bahrain
- Bosnia and Herzegovina
- Brazil
- Colombia
- Iraq
- Kazakhstan
- Kuwait
- Malaysia
- Mexico
- Mozambique
- Nigeria
- Oman
- South Africa
- Turkmenistan
- Ukraine
- United States of America
- Uzbekistan

While emissions occur around the world, IMEO is deepening engagement in regions where emissions are particularly frequent or persistent:

Middle East and North Africa (MENA)

The MENA region is highly conducive to satellite-based methane detection given its large areas of arid and flat topography and lack of cloud cover. MARS has consistently identified and brought detected emissions to the attention of national focal points and companies.

Several countries are taking steps to improve their response to MARS notifications: IMEO is working closely with the government of Iraq, alongside the UNEP-convened Climate and Clean Air Coalition, IEA, and the Clean Air Task Force to support the Ministry of Environment, the Ministry of Oil and various oil and gas companies to develop best practices for responding to MARS notifications. In Bahrain, efforts are underway to coordinate a response action between various entities, focusing on a persistent source of methane emissions in the country.

5 Stakeholders to date have been asked to acknowledge receipt of notifications. Going forward, IMEO will no longer track this metric. Focus will narrow to whether feedback was received—meaning whether IMEO received information about the emissions event or mitigation action taken from the government or company. This information will be made public in the IMEO Eye on Methane data platform on detected plumes starting in December 2024.

The Americas

In Latin America and the Caribbean, cloud cover, dense vegetation and challenging topography limit satellite monitoring capabilities. Despite these obstacles, MARS focal points have been nominated in Brazil, Mexico and Argentina. IMEO is working with the Latin American Energy Organization and its Methane Emissions Observatory for Latin America and the Caribbean to align regional efforts with those of MARS and expand the system's reach.

In North America, MARS has frequently detected emissions in the United States of America, where a national focal point has been appointed alongside the first sub-national focal point in the state of New Mexico.

Central Asia

Central Asia is a region with high potential for satellite monitoring, and one with frequent emissions detections. Azerbaijan, Kazakhstan, Turkmenistan and Uzbekistan have all nominated focal points to engage with MARS data. The region has become a focus area for IMEO, especially in the lead up to COP29 hosted by Azerbaijan in Baku. In Turkmenistan, MARS detections have laid the groundwork for a multi-million-dollar, UN-led joint programme to support the government and national oil companies' efforts to reduce methane emissions utilizing data from IMEO to prioritize actions and monitor results. The joint programme was recently endorsed by the government and is awaiting final approval to begin implementation.

Africa

Although satellite monitoring is limited in some tropical zones of Africa due to dense vegetation and frequent cloud coverage, IMEO is working to expand its engagement in several high-production countries such as Nigeria. A baseline measurement study is being advanced there, and efforts are focused on integrating MARS data with on-the-ground measurement and capacity-building initiatives to catalyse action. This has already resulted in mitigation, as MARS documented a mitigation case following a notification in Nigeria.

Asia and the Pacific

Asia has seen the detection of several very large and persistent methane plumes between Malaysia and Thailand that have been the focus of UNEP's engagement in the region through IMEO. This has focused on working with companies that are members of OGMP 2.0 and can take direct action when they receive a MARS emission notification.

Photo credit: Pexels

Satellites are enabling successful mitigation

The use of satellite technology has already begun to deliver tangible results in methane mitigation. Since the first documented MARS mitigation in Argentina last year, a number of other successful interventions have been confirmed:

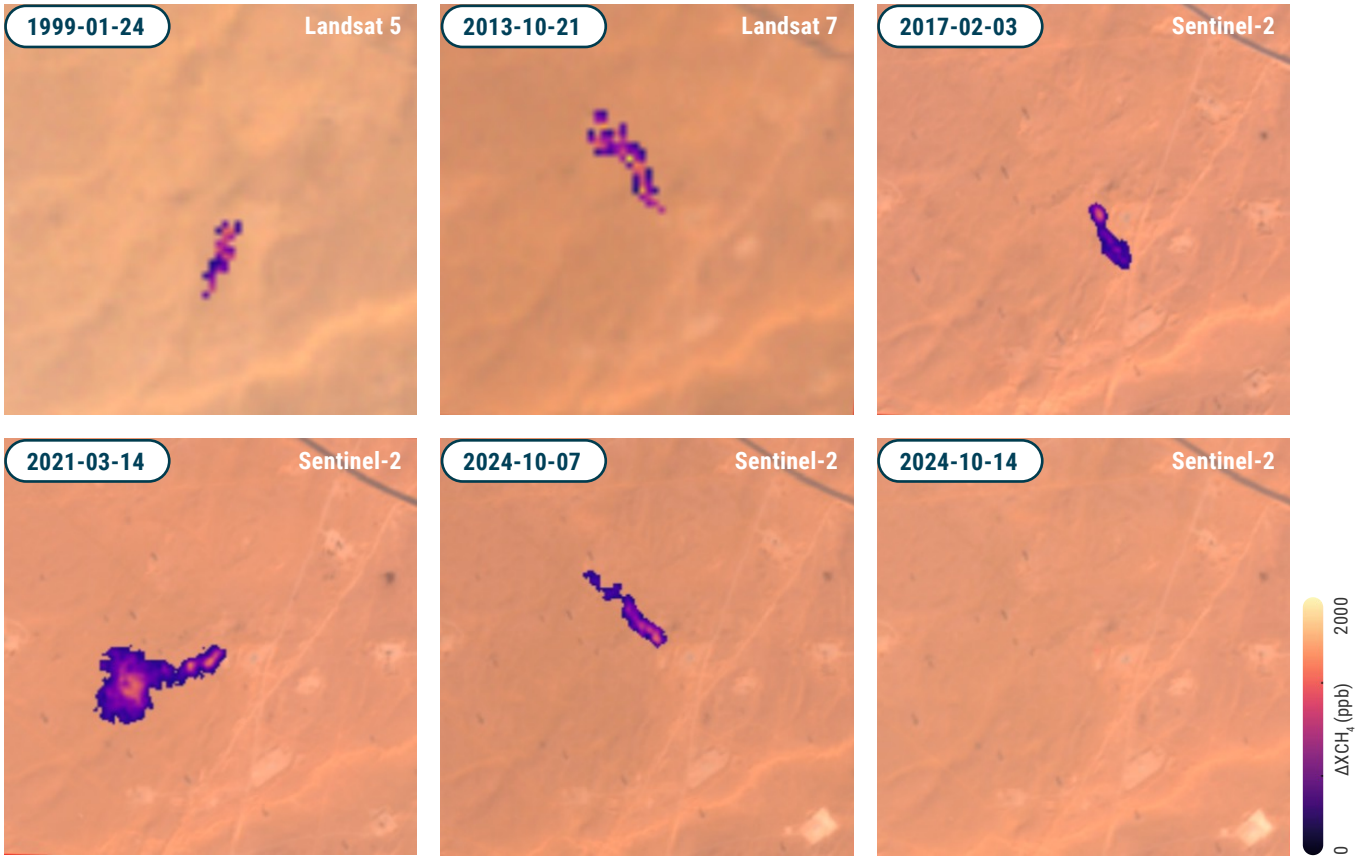
Emissions in Hassi Messaoud, Algeria (see Figure 7). Through MARS, IMEO detected continuous methane emissions from a gas disposal facility linked to an oil extraction well in the Hassi Messaoud oilfield. According to historical satellite data, the source was emitting since at least 2013, when the earliest high-quality satellite data is available from Landsat 8. However, evidence of emissions at the site dates as far back as 1999 from observations from another satellite, Landsat 5. It is likely that the source was constantly emitting methane, as emissions were detected in every high-quality satellite observation of the site (up to nearly 200 images per year).

IMEO issued several MARS notifications of these emissions over the course of 2024 and has engaged with the Algerian government and its national oil company, Sonatrach, on methane emissions reduction more broadly. At a methane training hosted by IMEO in September 2024 for Algerian stakeholders, this emission source was brought to the attention of government and company representatives. Subsequently, on 14 October 2024, IMEO no longer detected emissions from the location for the first time.

The elimination of this emissions source is a significant demonstration of climate action, as the leak was one of the oldest persistently emitting sources on record. It is estimated have emitted approximately 27,500 tonnes of methane per year. That amount of methane has the same near-term climate impact as almost 500,000 passenger vehicles driven for a year.

The satellite images in Figure 7 identify plumes detected in the Hassi Messaoud oilfield between 1999 and 2024. The final image shows the same location in October 2024 with no plume detected for the first time.

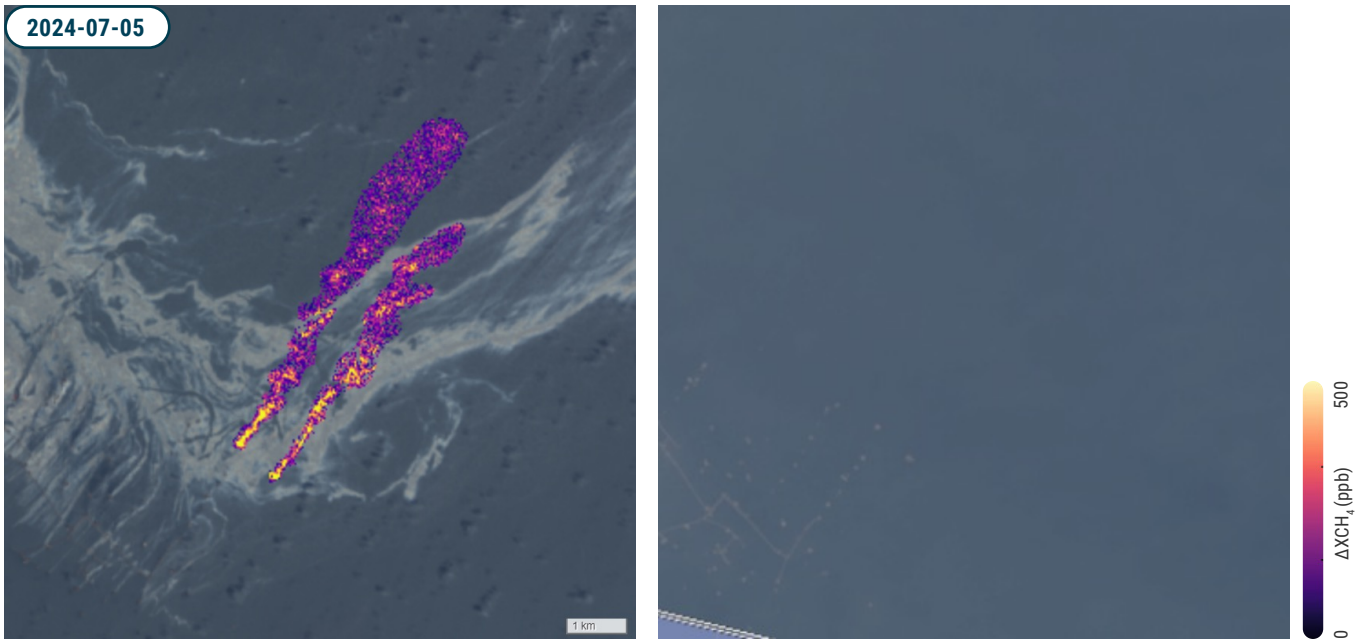
Figure 7: Observations of emissions in Hassi Messaoud, Algeria



Emissions in Neft Daşları, Azerbaijan (see Figure 8).
In July and August 2024, IMEO detected several methane plumes from the Neft Daşları offshore complex in Azerbaijan. This information was provided via MARS notification to the government's designated focal point and to SOCAR, as an OGMP 2.0 member company.

Subsequently, SOCAR confirmed that a low-pressure gas line had been installed, enabling the company to export additional associated gas that had previously been vented. IMEO confirmed through satellite observation on 17 October that no further emissions were detected at these two production platforms.

Figure 8: PRISMA satellite observations of emissions in Neft Daşları, Azerbaijan



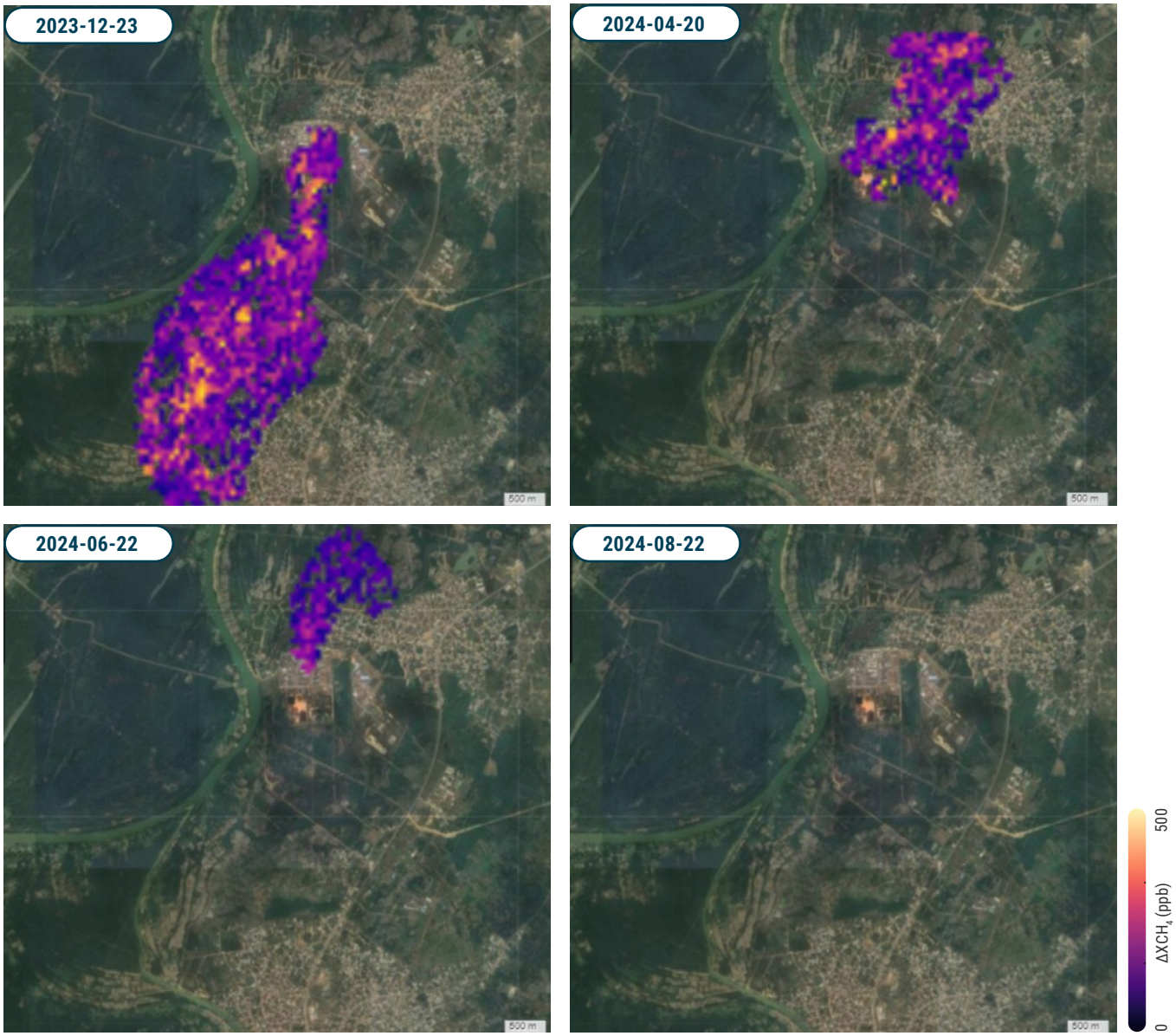
The image on the left from PRISMA dated 5 July 2024 identifies two plumes detected from an offshore facility in Neft Daşları, Azerbaijan. The image on the right shows no plume detected at the same location.

Emissions in the Niger Delta, Nigeria (see Figure 9). In June 2024, IMEO detected methane emissions in the Niger Delta using data obtained from NASA's EMIT instrument mounted to the International Space Station. IMEO analysed archival data and identified two previous high-quality images from December 2023 and April 2024 that showed emissions originating from the same gas plant.

Analysis showed the facility was emitting approximately 4.5 tonnes of methane per hour on average. Every hour, that amount of methane has the same near-term climate impact as over 80 passenger vehicles driven for an entire year.

UNEP promptly notified both the Nigerian government and the operator at the time, Eni, a member of OGMP 2.0, on 26 and 27 June 2024. Within a few weeks, the operator confirmed that the emissions were caused by a leak from the inlet scrubber of a sales gas compressor unit. Eni responded to the leak by shutting down the compressor station and replacing the ring joint responsible for the emission.

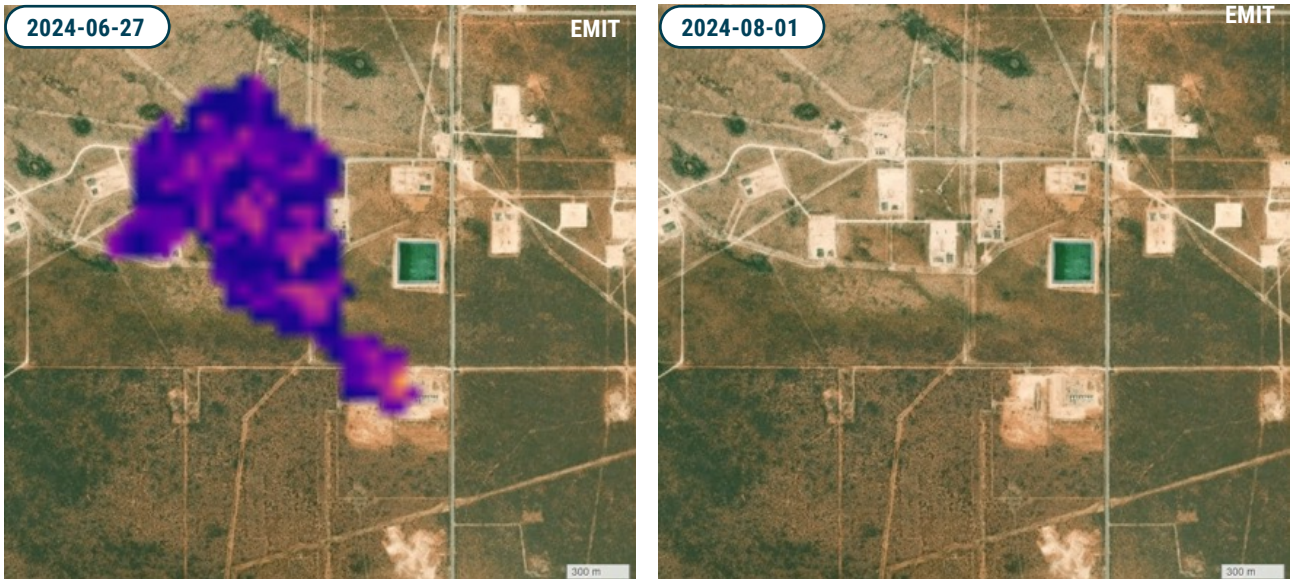
Figure 9: NASA's EMIT space sensor observations of gas plant in Niger Delta



The images above from EMIT dated December 2023 to June 2024 identify an emissions plume coming from the gas plant. The EMIT image from August 2024 shows that emissions are no longer detected at the same location.

Emissions in Permian Basin, United States of America. On 27 June 2024, methane emissions were detected in the Permian Basin in the state of New Mexico using data from NASA's EMIT instrument (see Figure 10). After further investigation and communication with government officials, the facility operator confirmed that the emissions originated from a faulty Pressure Safety Valve (PSV). The leaking PSV allowed natural gas to escape via the atmospheric vent header. When informed, the facility operator took action, shutting down the unit and repairing the defective valve, effectively halting the emissions.

Figure 10: NASA's EMIT space sensor observations of emissions in New Mexico Permian Basin



The image on the left from EMIT, dated 27 June 2024, shows a plume in the Permian Basin, New Mexico. The image on the right, from EnMAP, shows no further plume is detected as of 1 August 2024.

These examples of incidents highlight the value of satellite monitoring in quickly identifying methane emissions and prompting corrective action to deliver swift mitigation.

Based on satellite data used by MARS, it is not possible to confirm the presence of minimal methane emissions at a given location. Rather, this data can confirm the absence of emissions at levels higher than a given satellite's detection limit, which varies based on the technology, ground conditions and the weather.

A shift in response rate to alerts

Despite examples of mitigation enabled by MARS data, the limited response to notifications remains a significant concern. Through MARS, IMEO provides data that allows stakeholders to take prompt and informed action regarding specific methane emissions sources. It has demonstrated its ability to provide this data and build on advances in remote sensing and AI in service of its mission.

Although MARS delivers critical information, the agency to take action lies with the governments and companies receiving that information. To date, action following notifications has been limited and represents a missed opportunity for climate action (see Figure 11). The data is available, but without adequate stakeholder response, its potential remains largely untapped.

Out of the over 1,200 emission notifications that MARS has sent to governments and companies, fewer than half have been acknowledged by the recipients. Of those, IMEO has received only 15 responses providing information about the source of the emissions and whether any mitigation action was considered or taken. This low engagement rate highlights the critical gap between receiving data and taking timely action to reduce emissions, particularly in the absence of a comprehensive framework for methane management such as OGMP 2.0.

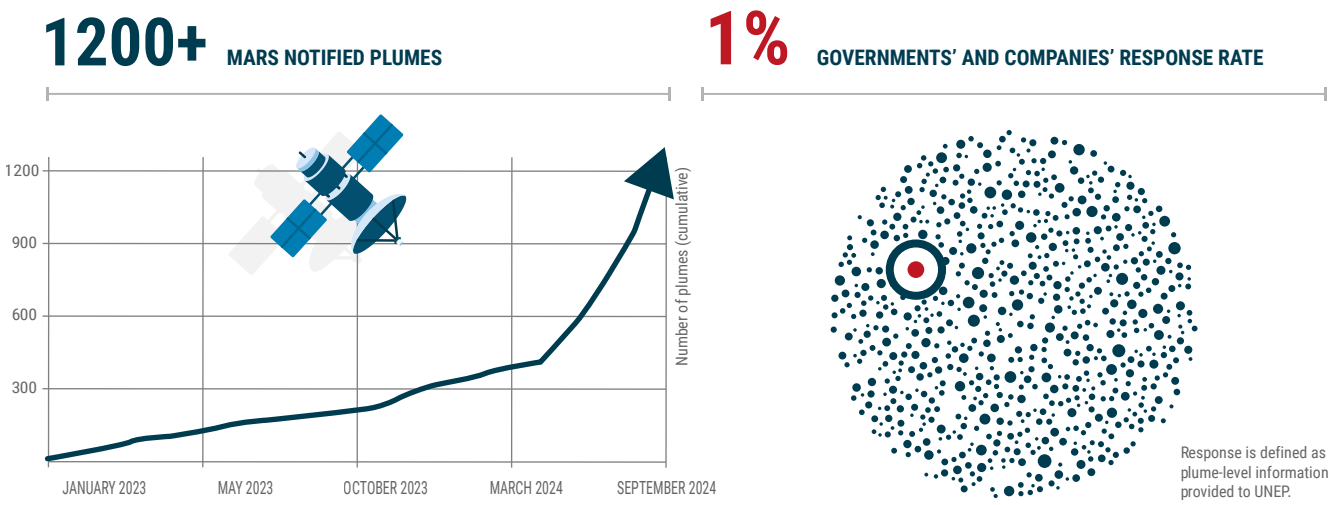
IMEO and its MARS partners, including the UNEP-convened Climate and Clean Air Coalition, the World Bank Group, the IEA, the government of the United States of America and and the European Commission, have stated their willingness to help stakeholders act on the mitigation opportunities identified by MARS. Some countries have expressed a need for additional support developing MARS response mechanisms and technical capabilities. This is an area for additional collaboration in the growing international methane ecosystem.

However, the core issue remains: stakeholders must engage with MARS data. This requires more than simply acknowledging notifications; it involves actively identifying what additional stakeholders must be engaged, what questions must be answered and what solutions must be deployed to cut emissions. UNEP hopes to see additional stakeholders —particularly those committed to the Global Methane Pledge—deepen their engagement with MARS. Expanding OGMP 2.0 membership appears to be a particularly productive route to securing a higher response rate, so it needs to be an integral part of this effort.

As the methane data revolution advances, accountability is shifting from being optional to becoming the norm, driven by systems like MARS and the growing network of satellites that support it. UNEP is committed to providing convenient access to the expanding body of methane data, and looks forward to partnering with governments and OGMP 2.0 companies to secure a rapidly increasing response rate.

As the window for mitigating climate change narrows, it is imperative that governments, industry and communities alike leverage MARS insights to enact swift and decisive measures to curb methane emissions.

Figure 11: Low MARS response rate from governments and companies



Expanding to the steel supply chain

Building on the success of MARS in detecting and notifying oil and gas sector emissions, UNEP's IMEO is expanding detection activities to metallurgical coal mines in the steel industry's supply chain.

As described in Section 4, metallurgical coal, or "metcoal", presents an important opportunity for climate action. The use of metcoal in steelmaking is expected to persist for decades, so it is crucial to reduce emissions from mines now. Mitigation is also highly cost-effective, estimated to be achievable at just one per cent of the price of steel.

MARS is piloting two distinct detection methods for different types of metcoal mines:

For open-pit metcoal mines, MARS will primarily use data from the TROPOMI sensor on the Sentinel-5P satellite. TROPOMI is able to detect diffuse emissions sources, which are typical of open-pit mines. Emissions estimates for these mines will be made using flux inversion models, which analyse emissions data collected at different time scales. This method allows for comparisons with bottom-up inventories and enables monitoring of emissions trends over time. In cases where high-resolution data is available, this will be integrated with TROPOMI readings to pinpoint specific areas of a mine responsible for emissions.

For underground metcoal mines, where emissions are often concentrated at point sources like venting shafts and draining stations, MARS will rely on high-resolution hyperspectral instruments, including EnMAP, MethaneSAT, Carbon Mapper's Tanager-1 and EMIT. These sensors are more adept at detecting emissions in complex areas with dense vegetation, complex infrastructure and varied terrain.

As part of this expansion, IMEO will also explore an adapted notification system for the metcoal sector, with the goal of helping companies and governments make informed near- and long-term mitigation decisions.

Photo credit: Airborne Research Australia

04

Methane emissions in the steel supply chain

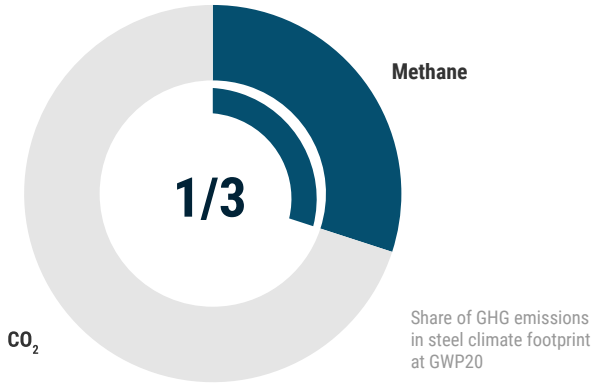
Cutting 30 per cent of the climate footprint of steel at one per cent of the cost

Photo credit: Pixabay

An unknown, known opportunity

Metallurgical coal (metcoal), essential in steelmaking, is estimated to generate one-tenth of all methane emissions from the energy sector and one-third of emissions from coal (see Figure 12). These emissions occur as methane trapped in the porous structure of coal is released to the atmosphere as the coal is mined, processed or the structure of a coal seam is disturbed.

Figure 12: Methane averages to one third of steel's climate footprint



Differentiating metcoal from thermal coal used for power generation is a first step. The two products are part of vastly different economic systems and need to be considered separately. Under any steel decarbonization scenario, short-term mitigation of methane emissions is required.

In the near-term, methane emissions from metallurgical coal represent on average 30 per cent of the climate footprint of steel produced through conventional routes.

The production of iron, which is critical for steelmaking, is heavily dependent on blast furnaces that utilize metcoal as both a fuel and a reactant. Over 90 per cent of the world's iron production follows this method. Low carbon alternatives, such as using hydrogen or carbon capture and storage, exist, but they require cost reductions through "learning by doing" to become competitive. This cost reduction will take time to bring down the current price premium and bring about the desired goal of a deep decarbonization of steel. While recycling steel presents an opportunity to reduce the climate impact of the raw material, the available supply of scrap steel falls well short of demand. Consequently, blast furnaces are expected to remain dominant in steel production for many years, even under the most ambitious decarbonization plans.

As a result, mitigating methane must be an integral component of any pathway towards greener steel.

Despite its significant impact, this opportunity does not receive wide recognition. UNEP's work through IMEO on metcoal methane emissions extends beyond the metcoal industry, engaging steel producers as well as buyers to ensure the entire value chain recognizes the climate opportunity of reducing methane emissions in steel production.

Engaging the steel supply chain

Throughout the past year, IMEO has focused on the need to involve the steel industry and steel buyers in coal mine methane mitigation efforts. In Q4 2023, UNEP collaborated with WorldSteel, the World Trade Organization and other stakeholders to ensure that methane was explicitly identified in the Steel Standards Principles—a declaration signed by steel industry representatives, individual companies and steel buyers. Through IMEO, UNEP has since been actively working to translate these principles into actionable strategies. One goal is to include supply chain methane emissions in assessments of steel production's climate footprint.

These emissions are part of scope 3 for the steel industry, but it is unreasonable to exclude them given their size and companies' ability to influence action to mitigate them. In addition, they can also be cost effectively mitigated, reducing the climate footprint of steel products. Just like for the oil and gas sector, IMEO emphasizes the need for empirical measurements of methane emissions which, unlike carbon dioxide, cannot be accurately inferred through emission factors or volumes of input material. Emission measurements are essential to focus mitigation efforts.

In addition to the work on the Steel Standards Principles, IMEO has collaborated with NGOs to share expertise on coal mine methane emissions. These efforts are focused on ensuring that methane emissions are considered within the broader steel decarbonization agenda and that methane is included in the overall emissions budget for the steel industry.

Coal science studies

While methane emissions in the oil and gas sector have historically been poorly understood, the coal mining industry has long recognized methane as a critical safety concern due to its explosive nature at higher atmospheric concentrations. This has led to significant expertise in methane emissions management within coal mining operations. UNEP's engagement with coal mining companies through IMEO leverages this expertise to deepen understanding of the nature of methane emissions and assess the precision of various measurement practices used in estimating coal mine methane emissions with the objective of accelerating mitigation. To learn more about IMEO's coal science studies, see Evolving IMEO's methane science.

MARS metcoal pilot project

In addition to ongoing scientific studies, IMEO is extending the application of MARS to metcoal mines. In a scoping phase, both surface and underground mines across different geographies and geologies are being examined to better understand how satellite measurements can support methane mitigation for steel as part of UNEP's engagements with countries and companies. Metcoal has far fewer emission sources and assets than the oil and gas sector, and its production is concentrated in a small number of countries. This allows for a focused and potentially more complete inventory of emissions. More details are presented in The Methane Alert and Response System: Ready for action.

A solution—the Steel Methane Programme

In collaboration with governments, NGOs and both metcoal and steel companies, IMEO has developed a Steel Methane Programme (SMP) framework comparable to OGMP 2.0, to help the sector move from estimating emissions through factors to high quality Level 5 measurements to enable methane emission reduction. There are obvious and relevant differences between these two sectors, which have been accounted for in the SMP's framework by collaborating with companies and independent metcoal experts. The programme's framework outlines methane measurement standards for metcoal methane sources and sets ambitious reduction targets. The aim of the programme is to drive metcoal methane reduction efforts in the steel supply chain so that methane's share in the steel climate footprint is reduced while the industry transitions to green alternatives.

05

Evolving IMEO's methane science

Focusing science study efforts on new goals

Photo credit: UNEP

IMEO's approach to mitigation-relevant science

Through IMEO, UNEP's methane science studies have improved understanding of both the magnitude and the location of key anthropogenic methane emissions sources. The studies provide the empirical data needed to determine changes in emissions over time and identify mitigation opportunities.

IMEO is expanding its scientific efforts beyond oil and gas to cover other sectors such as coal, waste and agriculture. Each sector is unique and demands different approaches, produces data with its own characteristics and has specific needs for unlocking policy-relevant insights.

As these science studies facilitate more accurate monitoring and reporting of methane emissions, making the resulting data accessible and actionable is essential. IMEO is now creating different pathways to quickly share lessons learned from its science studies with governments and companies. This is achieved through IMEO engagement with governments, its capacity building and training work, and by making data available on IMEO's Eye on Methane data platform.

All science studies continue to follow core principles ensuring that research is comprehensive, transparent and of the highest quality:

1. Studies are led by academic/research scientists.
2. Studies employ multiple measurement and emission quantification methodologies whenever possible.
3. The full scientific process—from scoping of the study to publication—is reviewed by an independent panel of scientific experts in IMEO's Scientific Oversight Committee, including UNEP's Chief Scientist.
4. All emission measurement data are made publicly available.
5. Results are published in peer-reviewed journals.

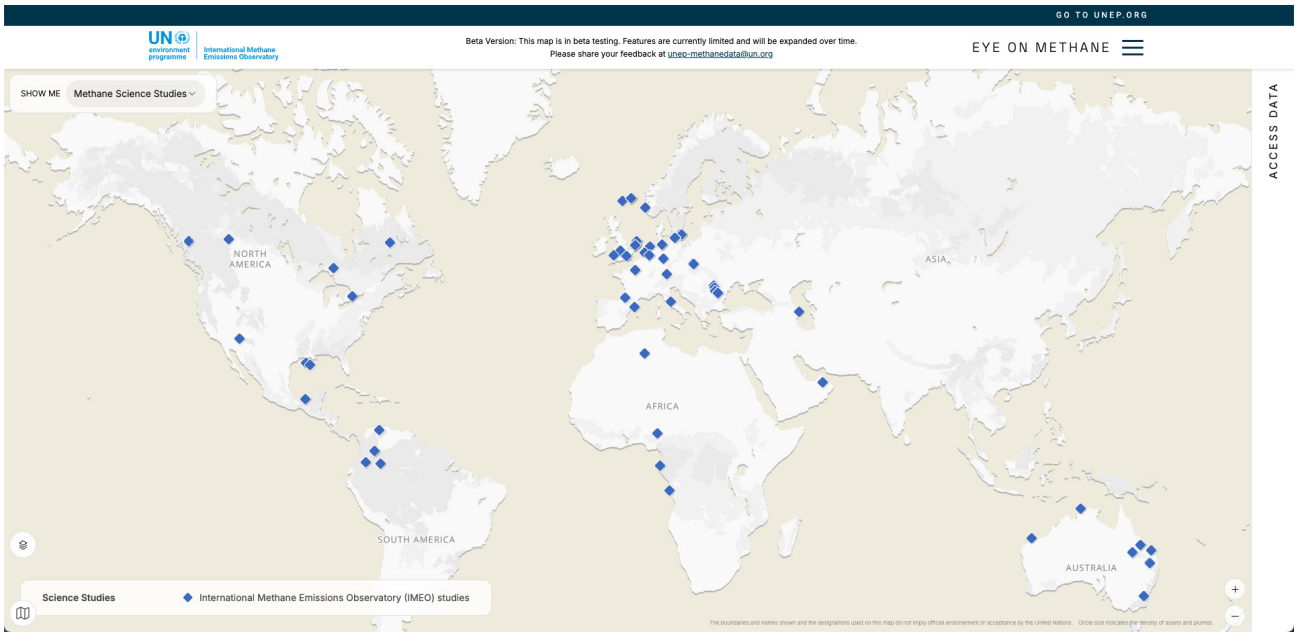
To date, IMEO has initiated 37 studies across 19 countries in collaboration with more than 30 academic and research institutions (see Figure 13). To date, this has resulted in the publication of 24 peer-reviewed papers. Twenty-six studies are still under way with outcomes expected in 2025 and 2026.

So far in 2024, IMEO's Scientific Oversight Committee has approved four new science studies, and a total of five papers have been published since the last IMEO annual report. An additional 15 papers are expected to be submitted for publication by the end of 2024.

A core principle of UNEP's methane science effort is collaboration. This spirit of open and transparent engagement extends to partners like the IEA, the European Space Agency, the World Meteorological Organization and academic research teams around the world. Alongside scientific partners, IMEO initiates new research, builds on existing knowledge from peer scientific institutions and builds capacity within research centres and fosters new scientists through PhD studies.

This work also actively engages and supports women scientists in its research and governance efforts. Women comprise forty per cent of IMEO's Scientific Oversight Committee and thirty per cent of its methane science studies are led by women scientists. Engagement with industry is another feature of many projects, providing unique access to operational data and knowledge as well as the transfer of new methods necessary to better assess methane emissions and potential mitigation solutions.

Figure 13: Science studies map



Four objectives to focus science work on methane action

UNEP's methane science studies managed through IMEO have successfully filled key knowledge gaps, including by providing the first empirical studies of offshore oil and gas infrastructure and LNG facilities, as well as multi-scale campaigns in regions lacking empirical data.

But the landscape for methane science studies is changing.

This shift is being driven by a new generation of satellites and monitoring approaches that provide policy-relevant data at different scales. IMEO is evolving its scientific efforts to capitalize on these changes, and while initial studies sought to obtain a basic understanding of emission magnitudes in regions that lack reliable data, moving forward, all studies will prioritize four main objectives.

1. Integrate and reconcile multi-scale empirical data (in support of IMEO's data integration workstream described in the following section, Assembling the methane data puzzle).

2. Characterize, assess and validate measurement-based approaches—including the new wave of remote sensing data.

3. Initiate science studies in support of data assurance and efforts to characterize regions and sources with high uncertainty or discrepancies in the integrated data.

4. Support the understanding and development of national emission inventories and support countries in identifying mitigation opportunities.

Each of these objectives is described in greater detail below.

While the collective understanding of some emission sources (e.g. oil and gas) and regions (e.g. North America) is detailed, it remains limited for other sources (e.g. agriculture) and regions (e.g. Africa). In sectors and regions where understanding is more limited, UNEP's IMEO will continue to support sector-based studies to reconcile methane emission estimates derived from different approaches.

Objective 1: Advance reconciliation and integration of multi-scale emissions data

IMEO is prioritizing studies that combine emissions data from different scales, such as large areas and individual point sources, over various time periods within specific regions. The goal is to better understand how much high-emitting point sources contribute to overall regional emissions. This research is critical for improving IMEO's Eye on Methane data platform, which will need to integrate information from both point-based and area-based measurements. Developing transparent methods for combining these types of data will make the platform more effective.

Multi-scale characterization of emissions in Romania: Emissions from the oil and gas sector have been assessed at multiple scales, from individual pieces of equipment and wellpads to basin- and country-wide characterization of emissions. A study by Stavropoulou et al. (2023) in Romania enhanced inventory estimates that were originally based on simple emission factors (IPCC Tier 1). The study used comprehensive field data from aerial and ground measurements and showed the value of incorporating multiple measurement methods at different scales to improve the accuracy of emissions estimates. An overall synthesis paper summarizing the main findings from the measurement campaigns will be submitted for publication late 2024.

Offshore measurement study in Gabon and Angola: Methane emissions from 30 offshore oil and gas facilities in Angola were quantified using airborne techniques as part of IMEO's METHANE-To-Go Africa scientific campaign. The region has been identified as a flaring hotspot, but methane emissions data from offshore facilities has so far been limited. The study will generate a comprehensive new dataset, greatly improving the understanding of emission sources and patterns in the region. The results are expected to aid operators and policymakers in understanding the scale and origin of methane emissions, particularly from flaring and fugitive sources.

Aerial and ground-based measurements of coal methane emissions in Poland: IMEO initiated a series of field campaigns in the Upper Silesia Basin from 2022 to 2024, focused on characterizing mine-level ventilation air methane, the main emission source in the coal sector. These campaigns employed a range of measurement techniques to quantify emissions rates, including ground-based (static and mobile), airborne (remote sensing and in situ) and satellite remote sensing methods. The results will provide insights into the behaviour of coal mine methane sources across space and time, while assessing the effectiveness of measurement techniques. This is a critical first step towards validating emissions reported by inventories and mine-based methodologies.

Objective 2: Validate measurement-based approaches

IMEO-led scientific initiatives have helped drive a shift within the oil and gas industry and among regulatory agencies towards measurement-based reporting. As this shift progresses, validating monitoring technologies becomes critical. IMEO is evaluating measurement approaches that can be universally applied across sectors, as well as those designed for particular challenges within a given sector.

Validation of methane quantification technologies for the oil and gas industry: In the summer of 2024, IMEO coordinated a set of controlled release experiments in the EU (France), building upon similar experiments conducted in the United States of America. These covered a wide range of technologies and testing conditions. Additional controlled release experiments are being planned for Asia in 2025. Over the next few years, IMEO-led controlled release experiments will expand to include not only satellite point-source mappers—in addition to the range of ground-based and aerial technologies already being assessed—but also area mapping satellites. IMEO is also working closely with the international metrology community to develop a set of guidelines for testing and validating new measurement technologies.

Assessment of top-down measurement approaches to characterize emissions from the coal sector: IMEO coal science studies are deploying ground-based, airborne (remote sensing and in situ) and satellite remote sensing methods to measure methane emissions from coal mines. This work has already begun in the Upper Silesian Basin of Poland and Australia's Bowen Basin. Building on prior research in Poland that evaluated a suite of top-down methods, studies underway aim to validate emission estimates from inventory approaches by comparing these to satellite detections and in-mine safety sensor data. Selected locations throughout the world, including China, the United States of America and Australia, will be targeted by satellites and compared with the finest scale of inventory-based or in-mine sensor data available. The potential for using continuously operating underground mine safety sensors to report emissions is also being explored, especially in countries that solely rely on inventory calculations (e.g. IPCC Tier 1). By synchronizing high-resolution bottom-up data with top-down measurements, IMEO aims to reduce uncertainties in emissions reporting.

Objective 3: Data assurance and characterization of high uncertainty regions

As IMEO develops integrated data products such as the Methane Supply Index (see Assembling the methane data puzzle) it will focus on new science studies to understand major data discrepancies. This includes investigating significant discrepancies between OGMP 2.0 Level 5 emissions reported for a specific region or assets and satellite remote sensing estimates. As OGMP 2.0 companies begin reporting at Gold Standard level and key discrepancies or sources of interest are identified, IMEO will commission targeted field studies to address these gaps.

Objective 4: Support the understanding and development of measurement-based emission inventories

Many countries face challenges in setting methane reduction targets, tracking progress and identifying priority areas for mitigation due to a lack of measurement-based data on emissions across sectors. To address this, in 2023 IMEO conceptualized the Baseline Science Studies—multi-sector, multi-scale measurement studies designed to support country efforts to estimate annual methane emissions at the national level. A key focus in 2024 has been on project scoping, gaining stakeholder buy-in and advancing study proposals, contracting and campaign planning. These studies require robust coordination between researchers and government agencies to succeed. Specifically, IMEO is collaborating with the governments of Colombia and Nigeria and research institutions to achieve stakeholder approval and develop detailed study proposals. Pending approval by IMEO's Scientific Oversight Committee, the campaigns are expected to begin in 2025.

The Baseline Science Studies will utilize both satellite and direct measurement methods, working with local experts, to assess methane emissions from the agriculture, waste and energy sectors. Throughout the process, stakeholders—including governments and private operators—will be actively engaged, and findings will be published in peer-reviewed journals, with aggregate data made publicly available.

Countries will benefit from the Baseline Science Studies in several ways: 1) improved understanding of methane emissions at both national and sectoral levels; 2) enhanced ability to set realistic targets and track progress toward emission reductions; 3) identification of priority areas for mitigation efforts; 4) more comprehensive and contextualized data to support national reporting to the UNFCCC.

The Baseline Science Studies will be tailored to each country's needs, integrating available national and sub-national data. Waste sector measurements have already begun in Colombia and Oman, and planning is underway in Colombia and Nigeria for major multi-sector measurement campaigns. In the Netherlands, a baseline study will synthesize existing data to verify and improve national inventory estimates and serve as a model for scaling up measurements and deriving national emission factors from atmospheric observations to be applied in other countries.

As the Baseline Science Studies move from planning to execution, principal investigators will share their feedback and experience, creating greater consistency and effectiveness in future studies. IMEO's baselining efforts will help governments, civil society, industry and other stakeholders to prioritize actions to reduce methane emissions. The outcomes will support the development of methane policies and strategies, improve estimates for nationally determined contributions and assist in integrating atmospheric observation data into national inventories.

06

Assembling the methane data puzzle

Integrating multiple sources of data for new insights

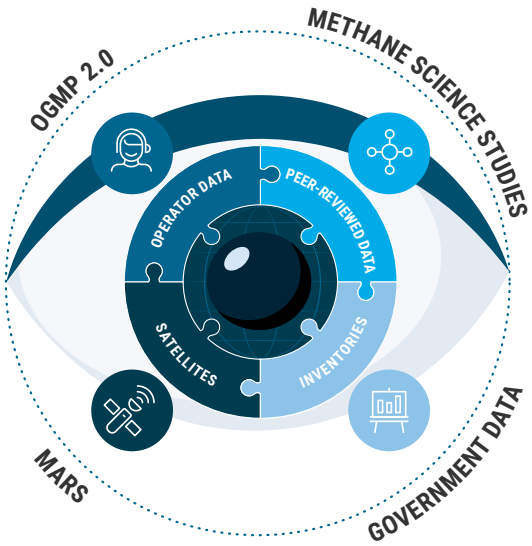
Photo credit: Flylogix

IMEO's mission is to provide open, reliable and actionable data to the individuals that can act to reduce methane emissions. Substantial strides have been made through OGMP 2.0 and MARS, which already involve integrating multiple sources of data—OGMP 2.0 through integration of source and site level data at Level 5 (see Box 1), and MARS via its use of AI techniques to analyse and integrate data from multiple satellite instruments. However, a dedicated focus on data integration is needed to harness the increasing number and variety of measurement tools and methods available across sectors.

This focus will deliver two outputs. One is a robust methodology anchored in scientific insights to ensure the results of data integration efforts are credible, transparent and accessible.

The second output is a set of data products that will synthesize data so that decision makers are empowered to take targeted action and make informed choices.
One example is the IMEO Methane Supply Index, which will integrate all available sources of data to provide information on the methane emissions associated with a given oil and gas supply chain. As a science-based method, it will be transparent about the range of uncertainty associated with each data element. Another important product will be an additional layer of assurance for OGMP 2.0 data, by integrating company-reported data with all other relevant sources of emissions data for a particular asset.

Figure 14: **IMEO data integration**



Building consensus on data integration methods

Currently, there are a wide range of empirical and non-empirical methane data sources, measurement approaches and methane emission data platforms. This results in fragmented data availability and limited transparency, and frequently leads to an apparent inconsistency across data streams, which impedes effective mitigation efforts.

A poignant example of this is the Nord Stream emission event, which illustrates the value and the challenges of integrating heterogenous data sources. Nord Stream was an extreme case, both in terms of the level of emissions and the number of different detection technologies that provided empirical data on the release. It is nevertheless a very good laboratory for understanding challenges and providing analytical solutions.

In this case, IMEO collaborated with over 60 scientists globally to integrate the various types of data. The data types included, for example, original pipeline parameters, pipeline fracture observations, marine advection and methane concentration measurements, local aerial atmospheric methane measurements, routine background methane concentration measurements and satellite data.

After carefully integrating all data sources, IMEO and co-authors were able to produce an upward revision of the initial plausible range to 410-480 kilotonnes of methane (Harris et al. 2024), almost tripling the initial central estimate (UNEP 2023). While Nord Stream will hopefully continue to remain a rare and extreme event, it has provided invaluable lessons on integrating diverse data sources.

Further methodology development is planned.

Delivering value from assembling the puzzle

The ultimate goal of IMEO's data effort is to provide those with the power to act better information to enable mitigation. This includes oil and gas asset managers, policymakers, investors and gas traders, all of whom share a need for data that is as accurate as possible. The analysis presented in Understanding the oil and gas emissions reporting gap regarding the inconsistency between reported and observed emissions is an example of how multiple sources of data can be brought together to provide unique insights. The ability to provide this insight will increase significantly as the accuracy of emissions data increases and becomes more common internationally.

Assurance for OGMP 2.0 Level 5 data

As reported in Enhancing oil and gas sector transparency and mitigation, many companies have struggled to integrate source and site level information for specific assets. The fact that some have succeeded is an encouraging signal that progress is achievable as robust efforts continue. As described in Evolving IMEO's methane science, one of IMEO's roles is providing additional levels of assurance for the data reported by OGMP 2.0 companies. Continuing to grow IMEO's capability to integrate multiple data sources with the OGMP 2.0 Level 5 dataset is an imperative in this respect.

Continuing to evolve MARS

The year 2025 will witness a rapid expansion of satellite detection capacity for methane emissions, in particular now that the Environmental Defense Fund's MethaneSAT and Carbon Mapper's Tanager-1 are starting to deliver data. Using these new sources and integrating them with MARS will allow IMEO to provide more accurate and granular information to OGMP 2.0 companies and to governments.

Methane Supply Index

The objective of the Methane Supply Index is to provide information on the methane emission intensity of individual oil and gas supply chains, integrating all available measured data. The results of pilot studies will be available in the first half of 2025.

An early example of a comparison of supply chain data is the contribution of UNEP's IMEO to the CLEAN initiative, launched in July 2023 by JERA Co., Inc., the Korea Gas Corporation, and the Japan Organization for Metals and Energy Security (Japan Organization for Metals and Energy Security 2024). This analysis illustrates how putting together multiple sources of data can improve comparison of supply chains.

In 2023, 87 per cent of Japan's LNG supply was covered by OGMP 2.0 company emissions reporting (indicated in bold in Table 4). Of the Japanese LNG supply data reported to OGMP 2.0, 11 per cent was measured at Level 4 and 5, 62 per cent estimated at Level 1, 2 and 3, with the balance of 27 per cent to be reported for the first time next year.

The weighted average data quality from Japan's suppliers will improve over the coming years, based on the implementation plans provided by the respective companies to IMEO through OGMP 2.0. Japan's gas suppliers have a

weighted average performance target of a 0.2 per cent loss rate, which was derived from the complete portfolio targets of each shareholder and applied to each supplying asset. Table 4 summarizes all the empirical data that is currently known about methane emissions associated with Japan's LNG supply. Over 2023, the weighted average quality of the reported data was OGMP 2.0 Level 3.2 (out of 5). Users can explore this data via IMEO's Eye on Methane data platform.

The upcoming Methane Supply Index product will be able to add substantial additional information to such analyses by integrating many more sources of data.

Table 4: Available empirical data on methane emissions in the Japan LNG supply

Asset	2023 mmpta	Operator	Owners
MLNG	10,23	Petronas	Petronas, Mitsubishi, Sarawak state government, ENEOS Corporation, Diamond Gas, ENEOS Corporation, PTT
Wheatstone LNG	7,07	Chevron	Chevron, KUFPEC, Woodside, JOGMEC, Mitsubishi, Kyushu Electric, NYK, JERA
Sakhalin 2	5,82	Sakhalin Energy LLC	Sakhalin Energy LLC (Gazprom, Novatek, Mitsui, Mitsubishi)
Ichtys LNG	5,44	Inpex	INPEX, TotalEnergies, CPC, Tokyo Gas, Kansai Electric, Toho Gas, Osaka Gas, JERA
North West Shelf	5,40	Woodside	BP, Chevron, Woodside, Shell, Mitsubishi, Mitsui
Gorgon	5,31	Chevron	Chevron, ExxonMobil, Shell, Osaka Gas, Tokyo Gas, JERA
PNG LNG	3,98	PNG LNG	PNG LNG (Santos, ExxonMobil, Kumul Petroleum, JX Nippon Oil & Gas Exploration, Marubeni, MRDC)
Qatargas, Rasgas	2,91	QatarEnergy LNG	Qatar Energy, et al
Cameron LNG	2,72	Cameron LNG	Sempra, TotalEnergies, Mitsui, Japan LNG Investment (a joint venture between Mitsubishi and NYK)
Pluto LNG	2,65	Woodside	Woodside, Kansai Electric, Tokyo Gas
Brunei LNG	2,52	Brunei LNG Sendirian Berhad	Brunei Government, Shell, Mitsubishi
Oman LNG, Qualhat LNG	2,26	Oman LNG	Government of Oman, Shell, TotalEnergies, Korea LNG, Mitsubishi, Mitsui, PTTEP, Itochu, ENI, Naturgy, Osaka Gas
Donggi-Senoro LNG	1,34	PT Donggi-Senoro LNG	PT Donggi-Senoro LNG (Mitsubishi, Pertamina, KOGAS, Medco)
QCLNG	1,19	Shell	Shell, CNOOC, Tokyo Gas
Cove Point LNG	1,10	Cove Point LNG, LP	Cove Point LNG, LP (Berkshire Hathaway, Brookfield Infrastructure Partners)
Freeport LNG	1,07	Freeport LNG	Freeport LNG Liquefaction, LLC
Tangguh	0,91	Tangguh LNG	Tangguh LNG (BP, Mitsubishi, INPEX, CNOOC, JX Nippon Oil & Gas Exploration, Kansai Electric)
ADNOC LNG	0,82	ADNOC	ADNOC LNG (ADNOC, Mitsui, BP, TotalEnergies)
APLNG	0,56	ConocoPhillips	ConocoPhillips, Origin Energy, Sinopec Group
Prelude FLNG	0,55	Shell	Shell, INPEX, KOGAS, CPC
Bontang LNG	0,50	PT Badak NGL	Government of Indonesia / (Pertamina 55%,PHSS 20%, PNA 15%, TotalEnergies)
Calcasieu Pass LNG	0,41	Venture Global Calcasieu Pass	Venture Global Calcasieu Pass
Sabine Pass	0,39	Cheniere Energy	Sabine Pass Liquefaction (Cheniere)
NLNG	0,27	NLNG	Nigeria LNG (NNPC, Shell, TotalEnergies, ENI)
Peru LNG	0,27	Hunt Oil	Hunt Oil, Shell, SK Innovation, Marubeni
PFLNG Satu	0,26	PFLNG Satu (FLNG)	Petronas
Corpus Christi Liquefaction	0,25	Cheniere Energy	Corpus Christi Liquefaction (Cheniere)
Darwin LNG	0,18	Santos	Santos, SK E&S, INPEX, ENI, JERA, Tokyo Gas
PFLNG Dua	0,16	PFLNG Dua (FLNG)	Petronas
Egyptian LNG	0,15	Egyptian LNG	Egyptian LNG (Shell, Petronas, EGPC, EGAS, TotalEnergies)
Coral FLNG	0,14	Eni	Coral South LNG (CNPC, Eni, ExxonMobil, ENH, Galp, KOGAS)
Yamal LNG	0,14	Yamal LNG	Yamal LNG (Novatek, CNPC, TotalEnergies, Silk Road Fund)
EG LNG	0,14	EG LNG	EG LNG (Marathon, Sonagas, Mitsui, Marubeni)
GLNG	0,11	Santos	Santos, Petronas, TotalEnergies, KOGAS
Atlantic LNG Terminal	0,07	Atlantic LNG	Shell, BP, NGC Trinidad
Arzew GL3Z (Gassi Touil)	0,07	Sonatrach	Sonatrach

In 2023, 92 per cent of the Republic of Korea's LNG supply was covered by OGMP 2.0 company emissions reporting (indicated in bold in Table 5). Of the Korean LNG supply data reported to OGMP 2.0, 29 per cent was measured at Level 4 and 5, 61 per cent estimated at Level 1, 2 and 3, with the balance of 10 per cent to be reported for the first time next year.

The weighted average data quality from the Republic of Korea's suppliers will improve over the coming years, based on the implementation plans provided by the respective companies to IMEO through OGMP 2.0. The Republic of Korea's gas suppliers have a weighted average performance target of a 0.2 per cent loss rate, which was derived from the complete portfolio targets of each shareholder and applied to each supplying asset.

Table 5 summarizes all the empirical data that is currently known about methane emissions associated the Republic of Korea's LNG supply. Over 2023, the weighted average quality of the reported data was OGMP 2.0 Level 3.3 (out of 5). Users can explore this data via IMEO's Eye on Methane data platform.

Table 5: Available empirical data on methane emissions in the Korean LNG supply

Asset	2023 mmpta	Operator	Owners
Qatargas and Rasgas	8,80	QatarEnergy LNG	Qatar Energy, et al
MLNG	5,74	Petronas	Petronas, Mitsubishi, Sarawak state government, ENEOS Corporation, Diamond Gas, ENEOS Corporation, PTT
Oman LNG, Qualhat LNG	5,19	Oman LNG	Government of Oman, Shell, TotalEnergies, Korea LNG, Mitsubishi, Mitsui, PTTEP, Itochu, ENI, Naturgy, Osaka Gas
Gorgon	3,03	Chevron	Chevron, ExxonMobil, Shell, Osaka Gas, Tokyo Gas, JERA
GLNG	2,76	Santos	Santos, Petronas, TotalEnergies, KOGAS
Sabine Pass	2,41	Cheniere Energy	Sabine Pass Liquefaction (Cheniere)
Sakhalin 2	1,59	Sakhalin Energy LLC	Sakhalin Energy LLC (Gazprom, Novatek, Mitsui, Mitsubishi)
Tangguh	1,46	Tangguh LNG	Tangguh LNG (BP, Mitsubishi, INPEX, CNOOC, JX Nippon Oil & Gas Exploration, Kansai Electric)
Freeport LNG	1,44	Freeport LNG	Freeport LNG Liquefaction, LLC
North West Shelf	1,28	Woodside	BP, Chevron, Woodside, Shell, Mitsubishi, Mitsui
Prelude FLNG	1,15	Shell	Shell, INPEX, KOGAS, CPC
Peru LNG	0,86	Hunt Oil	Hunt Oil, Shell, SK Innovation, Marubeni
Bontang LNG	0,83	PT Badak NGL	Government of Indonesia / (Pertamina,PHSS, PNA, TotalEnergies)
Cameron LNG	0,76	Cameron LNG	Sempra, TotalEnergies, Mitsui, Japan LNG Investment (a joint venture between Mitsubishi and NYK)
Wheatstone LNG	0,72	Chevron	Chevron, KUFPEC, Woodside, JOGMEC, Mitsubishi, Kyushu Electric, NYK, JERA
Donggi-Senoro LNG	0,71	PT Donggi-Senoro LNG	PT Donggi-Senoro LNG (Mitsubishi, Pertamina, KOGAS, Medco)
Ichtys LNG	0,70	Inpex	INPEX, TotalEnergies, CPC, Tokyo Gas, Kansai Electric, Toho Gas
NLNG	0,66	NLNG	Nigeria LNG (NNPC, Shell, TotalEnergies, ENI)
PNG LNG	0,61	PNG LNG	PNG LNG (Santos, ExxonMobil, Kumul Petroleum, JX Nippon Oil & Gas Exploration, Marubeni, MRDC)
Brunei LNG	0,55	Brunei LNG Sendirian Berhad	Brunei Government, Shell, Mitsubishi
Corpus Christi Liquefaction	0,45	Cheniere Energy	Corpus Christi Liquefaction (Cheniere)
Pluto LNG	0,41	Woodside	Woodside, Kansai Electric, Tokyo Gas
ADNOC LNG	0,38	ADNOC	ADNOC LNG (ADNOC, Mitsui, BP, TotalEnergies)
Coral FLNG	0,38	ENI	Coral South LNG (CNPC, Eni, ExxonMobil, ENH, Galp, KOGAS)
EG LNG	0,35	EG LNG	EG LNG (Marathon, Sonagas, Mitsui, Marubeni)
APLNG	0,34	ConocoPhillips	ConocoPhillips, Origin Energy, Sinopec Group
QCLNG	0,34	Shell	Shell, CNOOC, Tokyo Gas
PFLNG Dua	0,33	PFLNG Dua (FLNG)	Petronas
Calcasieu Pass LNG	0,28	Venture Global Calcasieu Pass	Venture Global Calcasieu Pass
Darwin LNG	0,21	Santos	Santos, SK E&S, INPEX, ENI, JERA, Tokyo Gas
PFLNG Satu	0,20	PFLNG Satu (FLNG)	Petronas
Egyptian LNG	0,15	Egyptian LNG	Egyptian LNG (Shell, Petronas, EGPC, EGAS, TotalEnergies)
Damietta	0,14	Damietta LNG	SEGAS (ENI, EGAS, EGPC)
Arzew GL3Z (Gassi Touil)	0,14	Sonatrach	Sonatrach
Yamal LNG	0,07	Yamal LNG	Yamal LNG (Novatek, CNPC, TotalEnergies, Silk Road Fund)

07

Building capacity for methane action

Knowledge sharing and capacity building for increased agency

Photo credit: UNEP

Reducing methane emissions at the speed and scale needed to address the climate emergency requires more than just better data; it requires collaborative action from stakeholders across governments, industry academia and civil society. IMEO is actively working to engage these stakeholders by fostering partnerships and initiatives that aim to address the complex challenges of methane mitigation.

While employees at operating companies in the fossil fuel sector are often the ones who physically address and repair methane leaks, they are typically constrained or influenced by a broader system. From discussions with these asset managers, it is clear that a broad array of factors influences their behaviour. This includes a lack of accurate emissions data. But it also includes corporate culture, the relationships between the corporate centre and field operations, priorities in capital expenditures and operating expenses, factors related to nearby communities and more. IMEO seeks to engage all stakeholders within this system to facilitate action on the ground.

Government policies and action play an important role in shaping the priorities and operational practices of companies. In particular, this applies to state-owned enterprises, which often rank among the world's largest and potentially highest-emitting companies, and are closely tied to government actions and priorities. Government involvement is therefore essential in laying the groundwork for effective and sustained methane reduction initiatives.

Knowledge networks to meet needs, expand reach

Across the board, stakeholders are requesting more information and training about methane emissions and mitigation actions. This demand reflects a positive trend, indicating growing awareness and a stronger focus on addressing methane emissions.

In response, IMEO's Methane Training Series continues to expand and now offers information on methane sources, measurement techniques, quantification methods and mitigation options. The series also includes specialized modules on satellite data, flaring and LNG.

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Over 1,000 oil and gas professionals including regulators, policymakers and company employees from more than 30 countries have received this training. The courses have encouraged participants to pursue strategic methane action within their countries and regions. Notably, the series has been instrumental in bringing methane emissions to the forefront in countries such as Algeria, Libya and Turkmenistan.

While these trainings represent a useful foundation, IMEO emphasizes that capacity building is just the beginning. It must not be viewed as an end goal or used as a reason to delay reducing emissions. IMEO trainings are designed to equip stakeholders with the skills to interpret and act on methane data, ensuring that this data leads to meaningful action.

Building on major scientific studies to connect data with mitigation efforts

One goal of IMEO's Baseline Science Studies (see Evolving IMEO's methane science) is to identify opportunities for methane mitigation. To ensure that those opportunities are effectively implemented, IMEO is actively engaging government entities throughout the lifecycle of each study. In support of Baseline Science Studies planned in Colombia and Nigeria, IMEO is fostering collaboration across governmental, academic, scientific and industrial communities, while also activating local and international civil society networks.

In Colombia, IMEO has already executed aerial measurements of 60 per cent of oil and gas activities as well as a number of landfills. Now, it is expanding its efforts to include ground-based measurements, as well as extending studies into the coal, waste and agriculture sectors. Throughout the study process, IMEO has been leading direct stakeholder engagement, working closely with government entities and companies. By working with local scientists leading the study, IMEO ensures that all relevant stakeholders are informed and positioned to apply the study's findings.

In Nigeria, IMEO is building capacity for measurement-based data and conducting a feasibility study on total and sector-specific emissions through multi-scale measurements under the Nigeria Methane Emissions Reduction Pilot Programme funded by the EU Delegation to Nigeria. In October 2024, IMEO convened a workshop that brought together Nigerian government representatives and asset managers in the Nigerian oil and gas industry to deepen their understanding of methane emissions and discuss how to utilize empirical data to improve ongoing measurement and mitigation efforts. To strengthen regional scientific capacity, IMEO is involving Nigerian scientists in the study process, first by inviting these scientists to visit other IMEO study locations to learn about methodologies and technologies to gain hands-on experience with advanced measurement tools and analytical methods.

Box 3. **Connecting scientific findings with mitigation support**

In both Colombia and Nigeria, IMEO is in discussions with the World Bank Group regarding its Global Methane Flaring Reduction Trust Fund, which may directly fund mitigation opportunities around the world. By connecting results from IMEO's studies to organizations poised to fund action, IMEO is ensuring that better data leads to targeted mitigation, catalysing the deep reductions in methane needed.

Satellites guiding major reduction efforts on the ground

Methane emissions in Turkmenistan are particularly frequent, persistent and readily observed via satellites. Recognizing the major opportunity for emissions reduction in the country, IMEO devoted significant resources to bridging the gap between remote sensing findings and in-country action.

IMEO has led the design of an initiative to translate satellite data into direct mitigation in Turkmenistan to be implemented by the UN Office for Project Services (UNOPS), in collaboration with the United Nations Economic Commission for Europe and the UN Resident Coordinator's Office for Turkmenistan. Altogether, this joint programme has the potential to reduce an estimated four million metric tonnes of methane per year.

To provide a scientific basis for the programme, IMEO conducted an in-depth analysis of all satellite observations of Turkmenistan over a four-month period. This analysis identified over 240 large and persistent point sources of methane emissions.

The joint programme aims to drive deep reductions in methane emissions in Turkmenistan's oil and gas sector by improving policies, regulation and enforcement of methane emissions activities. The programme will also support the government's access to international finance to enable the large infrastructural improvements needed to address the methane emissions problem in Turkmenistan.

The programme was endorsed by the government in October 2024, with UNEP acting as an independent technical advisor and validator of progress through satellite monitoring.

Box 4. **Asset manager engagement**

Asset managers responsible for day-to-day operations of specific oil and gas facilities possess the knowledge and access needed to reduce methane emissions, but they face real world constraints. To understand this group's needs and enable action, in 2024 IMEO launched the OGMP 2.0 Asset Managers Network. The network engages asset managers to identify barriers and co-design scalable solutions, while building and sharing collective knowledge.

Box 5. **NGO engagement**

Non-governmental organizations (NGOs) play a crucial role in pushing governments and companies to set ambitious mitigation targets and adopt empirical methane measurements as standard practice.

In 2024, IMEO worked to build stronger, more direct communication channels with NGOs engaged in its IMEO Advisory Council. This effort includes monthly updates on relevant IMEO activities and data, as well as meetings to explore collaboration and share knowledge. One notable event, "How Methane Data Can Support Legal Action", featured prominent speakers who shared their experiences using better methane emissions data to challenge environmental permits and corporate reporting.

We encourage any NGOs interested in joining this community to reach out for further information (imeo@un.org).

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