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# Spotlighting Opportunity:

How artificial intelligence is accelerating methane action

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# Executive summary

Photo credit: Canva

**Artificial intelligence (AI) is a rapidly evolving technology with significant potential for accelerating climate action, by processing vast environmental data sets and informing decision-making.**

**Methane offers a key opportunity for AI applications. Reducing methane emissions is the fastest, most cost-effective way to slow near-term global warming as broader decarbonization efforts continue. Thanks to a new generation of methane-tracking satellites and other technologies, the world is experiencing a methane data revolution, with an unprecedented amount of information now available on how much, and precisely where, methane is emitted. Targeted methane action requires context and transforming this information into meaningful emission insights, which involves substantial data processing and analysis.**

The United Nations Environment Programme (UNEP)'s International Methane Emissions Observatory (IMEO) conducts this processing and analysis as part of its work to provide data and insights to the individuals across government and industry who can take action to reduce methane emissions. IMEO's use of AI has profound implications for methane mitigation, accelerating analysis to support methane reductions at a global scale. Leveraging UNEP's global reach across governments, companies and civil society, IMEO is uniquely positioned to ensure that AI-enhanced insights reach the decision-makers with the authority and responsibility to act upon them.

IMEO has implemented AI at the core of its Methane Alert and Response System (MARS), which detects major methane emission events and notifies governments and companies to catalyse mitigation response. The first global tool of its kind, the system empowers IMEO's team of remote-sensing specialists to process between 12-15 times more data than without AI models, dramatically scaling up its potential to identify methane mitigation opportunities.

Since MARS became fully operational in 2024, the system has enabled the handling of over 1.3 million satellite measurements, triggering over 40 on-the-ground emission reductions to date. Together, these emission sources are estimated to have released 1,200,000 tonnes of methane before they were mitigated, a volume comparable to the annual emissions of nearly 24 million gasoline-powered passenger cars (UNEP 2026).

This report comes on the heels of UN Secretary-General António Guterres's call for urgent action to scale up methane mitigation. With less than four years to go to meet the Global Methane Pledge's target of a 30 per cent reduction in methane emissions from 2020 levels by 2030, the window to seize this climate opportunity—and rein in 1.5°C overshoot—is narrowing.

This report demonstrates how AI can be responsibly deployed to meet urgent global environmental challenges with rapid impact, as well as illustrates the breadth of IMEO's work across the AI development spectrum, from mature, operational use cases to foundational data curation that will support future innovation. As new satellite missions come online and the volume of environmental data grows, IMEO's work in this space will increasingly serve as a model for environmental monitoring.

# Introduction

**Methane is responsible for approximately a third of today's global warming (UNEP and Climate and Clean Air Coalition 2021). With more than 80 times the warming power of carbon dioxide in the two decades after it reaches the atmosphere, this potent greenhouse gas has an outsized impact on near-term warming. As a result, reducing methane emissions can immediately slow global warming.**

According to the UNEP-convened Climate and Clean Air Coalition (CCAC), up to 80 per cent of oil and gas mitigation measures, and up to 98 per cent of coal, could be implemented at negative or low cost (2021). Since natural gas is largely composed of methane, most methane emissions represent a wasted product that can otherwise be captured and sold, generating additional revenue and enhancing energy security.

In 2021, UNEP established IMEO to provide open, reliable and actionable data to individuals with the agency to reduce methane emissions. IMEO is a core implementing partner for the Global Methane Pledge, through which more than 150 country signatories aim to reduce global methane emissions by at least 30 per cent from 2020 levels by 2030. The pledge is consistent with the Paris Agreement's climate goals, which, if met, would avert the worst impacts of climate change.

Photo credit: Energy & Emissions Research Lab (EERL), Carleton University

IMEO fosters transparency through open methane data access. With accurate data, policymakers, industry leaders and researchers can develop and implement targeted mitigation strategies, as well as track progress toward global targets.

An unprecedented amount of information is now available on how much, and exactly where, methane is emitted. But there is an insight gap: The volume of data now streaming in from methane-tracking satellites and other technologies far exceeds what any team of analysts can make sense of manually. AI makes closing this gap at a global scale possible.

IMEO uses AI to enhance and accelerate its methane detection, monitoring and data-sharing systems. Using AI to process methane data marks a significant leap in environmental monitoring. Already, AI is increasing IMEO's capacity to provide actionable data and thereby support countries to deliver on the ambition of the Global Methane Pledge.

With less than four years left to meet the targets set by the Global Methane Pledge, the window to act on methane is narrowing. At the same time, as more satellite missions come online in the coming years, the availability of methane data grows ever richer. Whether that data translates into climate action will depend on whether the AI tools to efficiently interpret it are built and utilized.

This document describes how IMEO uses this rapidly evolving technology, a transformative tool that is contributing to climate stability.

# A multi-source picture of methane

**IMEO collects methane data from three primary sources:**

- **Satellite monitoring:** IMEO's Methane Alert and Response System (MARS) is a global satellite detection and notification system that provides actionable data alerts to governments and companies to enable rapid response. MARS integrates data from over 30 satellite instruments to monitor the globe for major emission events.

- **Industry reporting:** Through UNEP's Oil and Gas Methane Partnership (OGMP) 2.0, oil and gas companies measure and report their emissions according to a five-tier reporting framework. The framework requires regular improvements in data quality, helping companies evolve from rough estimates towards measurement-based reporting.

- **Scientific research:** IMEO manages an extensive programme of multi-year Methane Science Studies that have considerably advanced the state-of-the-art of empirical methane observations (i.e. from a variety of sensors: satellite, airborne, ground-based and in situ) and novel data analysis methodologies. Results are published in peer-reviewed scientific journals.

IMEO makes data publicly available on its Eye on Methane data platform. Stakeholders across research firms, governments, the private sector, media, academic, finance, civil society and more have requested access to the platform's data via Application Programming Interface (API), demonstrating the breadth of its reach across methane decision-making.

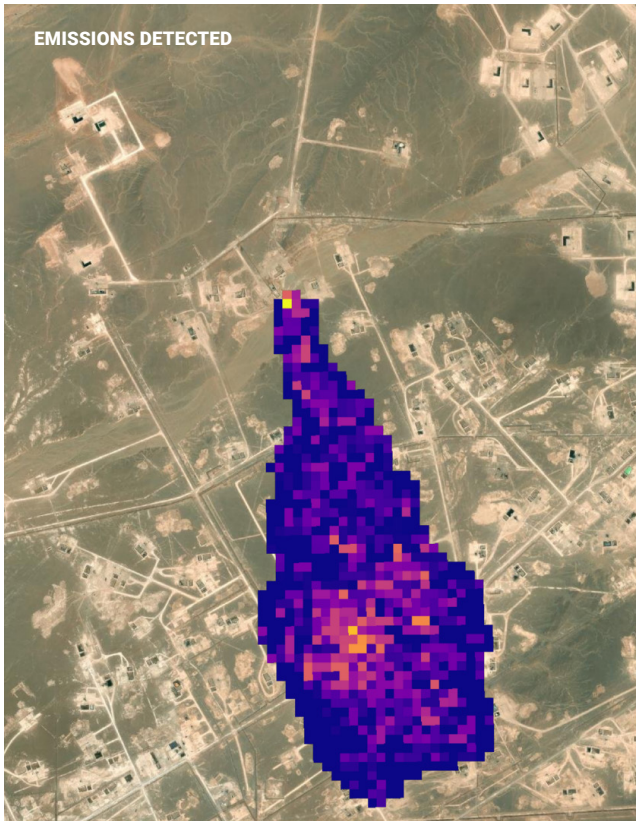




Photo credit: NASA's EMIT

# AI tools to accelerate methane monitoring

The scale and disparate nature of IMEO's primary data streams—which vary in resolution, coverage, methodology, and time and spatial scales—present precisely the kind of challenge where AI techniques can add significant value.

IMEO develops AI tools to augment its work, from automating methane detection in satellite data to recognizing patterns and anomalies. What makes IMEO's approach distinctive is not only the technology, but the network. UNEP's relationships with governments, companies and civil society ensure that AI-enabled insights reach those with the agency to reduce emissions and transform such insights into action.

IMEO's development of AI tools also demonstrates the UN's commitment to leveraging emerging technologies, as described in the UN 2.0 vision, which offers a roadmap to enhance the organization's impact and effectiveness in addressing global challenges (2023).

## Sustainability by design

Using AI requires serious consideration of the technology's environmental impacts. The environmental impact of AI is largely shaped by its use of computational resources. Training large-scale models often requires data centers, powerful chips for processing graphics and many hours of processing. This takes energy, water, critical minerals and metals, and produces carbon emissions and electronic waste (UNEP 2024).

IMEO prioritizes tools with which AI can deliver measurable, high-impact environmental benefits. This means carefully weighing the resource demands of AI systems against the gains they enable. In this way, environmental responsibility is embedded in IMEO's approach to AI tool development.

The methane monitoring system that underpins MARS is lightweight and energy efficient. Models are trained on a single graphic processing chip. Once they are trained, regular use of the models doesn't require a graphic processor at all, instead relying on standard processors that use much less power.

The sections that follow examine IMEO's most mature AI use case, MARS's AI-enhanced models.

### Box 1. **IMEO's data curation work**

The quality of AI models depends on the quality of the data they are trained on. Across many disciplines where AI has advanced rapidly, a key enabler has been the availability of large-scale, well-structured data sets. These expertly curated data sets, combined with clearly defined problem statements, allow AI developers to focus on building and refining novel AI frameworks. In the methane space, IMEO is helping to establish this foundational capability. For example, IMEO is developing open-access, labelled data sets of satellite observations for training AI models to detect emission plumes (see page 10, "Open data and code").

Methane measurement data is scattered across thousands of scientific publications, collected through different sensor technologies, and reported in different formats or units. Methane data themselves also vary widely in terms of reliability, including uncertainty ranges, as well as their spatial and temporal resolution. At the cutting-edge of IMEO's research is an effort to integrate data from these different sources in order to build a comprehensive picture of global emissions across the highest-emitting sectors, energy, agriculture and waste.

This data integration effort will be key to turning disparate data sets into resources that can either train AI models or validate their outputs, and it requires extensive expert curation. IMEO's Repository of Empirical Methane Emissions for Data Integration (REMEDI) database, housed on IMEO's data platform, exemplifies this approach. The database will compile science-grade, empirical methane emission measurements beyond the super-emitters observed by MARS.

The value of this work extends well beyond IMEO. Any organization seeking to develop AI tools for methane monitoring and mitigation requires access to high-quality, expertly curated methane emissions data sets. IMEO welcomes engagement with data providers and the research community to expand access to the data sets that will power the next generation of methane-monitoring tools.

By investing in data curation now, IMEO is helping to lower the barrier to entry for the global community and supporting future innovation.

# AI transforms satellite data into actionable intelligence

MARS draws on data from more than 30 satellite instruments to deliver alerts that enable rapid response.

The volume of data flowing in from these satellites far exceeds what any team of analysts could review manually on a global scale. As of April 2026, MARS has ingested and analysed over 1.3 million satellite images since the system become fully operational in 2024, covering an area of 302 million square kilometres, equivalent to twice Earth's entire land surface.

The challenge of processing this raw data is compounded by the fact that satellite methane data is inherently noisy. Variations in terrain, weather and surface reflectivity can produce false signals that resemble real methane emission plumes. Filtering these out manually requires both scientific expertise and considerable effort.

AI helps solve these problems. Trained on large data sets, MARS's AI models can distinguish genuine methane emission events from false signals across a wide range of landscapes and conditions (Allen *et al.* 2026; Růžička *et al.* 2026).

These models do not replace expert judgment. Instead, they act as a filter, narrowing down a vast data stream to a short list of potential detections for analysts to review. This keeps human expertise focused where it is most valuable, without compromising the rigor that underpins MARS's scientific credibility.

## Two AI model types for comprehensive global monitoring

MARS takes in data from two kinds of space-based sensors: multispectral and hyperspectral. Together, they offer complementary strengths well suited for global monitoring. IMEO has developed two classes of AI models, each designed to work with a specific data type.

Both types of models feed into MARS's overall workflow. Together, they make MARS the first tool of its kind that operates at a global scale; previous AI-enhanced methane detection tools were built for specific regions. This capability is transforming methane monitoring from a patchwork of regional efforts to a global system for transparency and accountability.

**Table 1: Multispectral and hyperspectral sensors**

IMEO drives methane mitigation using data sets from global space agencies, including the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA).

| Sensor type | Key characteristics | Sensors |
|---|---|---|
| Multispectral | Scans broad swathes of the globe frequently | ESA's Sentinel-2<br><br>NASA/U.S. Geological Survey's Landsat |
| Hyperspectral | Captures more detailed information on specific locations | NASA's EMIT<br><br>Italian Space Agency's PRISMA<br><br>German Aerospace Center's EnMAP |

Source: IMEO

The multispectral class of AI models was trained on a manually curated data set of over 80,000 images (Allen *et al.* 2026, see Figure 1). They are built to perform under the specifications of these instruments: higher global spatial and temporal cover, but lower spectral resolution and higher background noise (see Table 1).

The multispectral AI models are most effective at detecting larger emission sources, those above 1 metric ton per hour. They work best in arid and semi-arid regions where the surface is more reflective and stable, such as the Permian Basin in the United States of America or the Arabian Peninsula. Within these parameters, the models achieve a detection rate of 78 per cent with a false positive rate of just 8 per cent at previously unseen sites (Allen *et al.* 2026). Multispectral instruments' combined ability to revisit the same location every two to three days makes them ideal for monitoring emissions at the facility level.

The second class of models handles data from hyperspectral satellites. These instruments capture richer spectral information, making them useful for detecting emissions across a wider range of landscapes and conditions.

These models were developed on a large and globally diverse annotated data set from three satellite missions, listed in Table 1 (Růžička *et al.* 2026). They use an ensemble approach, combining the outputs of multiple models, which reduces false detections by over 74 per cent compared to previous methods. Recent advances in plume vetting introduce an additional physics-based validation step expected to further reduce false positives (Růžička *et al.* 2026); this approach is currently under development within MARS.

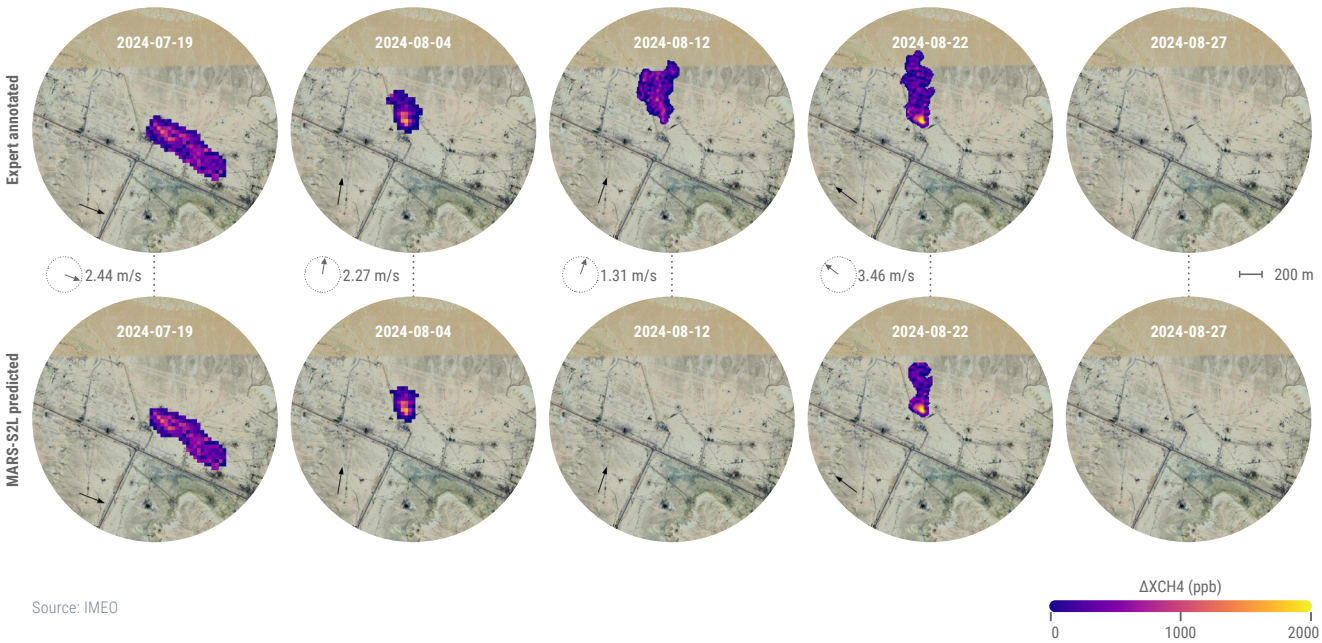
Currently, roughly half of validated detections originate from each instrument type. Hyperspectral instruments also conduct targeted follow-up observations to verify whether mitigation has occurred at sites that MARS previously flagged.

Both model families were designed with energy efficiency as an explicit goal, reflecting IMEO's commitment to sustainable AI development. Training each model requires only a single graphic processing chip, and day-to-day operation runs on standard processors with minimal power consumption.

**Open data and code:** To help others build on this work, IMEO is making select elements of the multispectral code repository and data set, as well as the hyperspectral code repository and data set, openly available. These resources are intended to promote equitable access to AI tools across diverse groups, including women and underrepresented communities, support further innovation, enable stronger algorithm development and accelerate progress across the wider methane research and mitigation community.

While these resources provide a foundational contribution, they are intended to be adapted and expanded by the wider community in combination with other data, tools and methodologies.

**Figure 1: Annotated plumes used to train the MARS models**




Source: IMEO

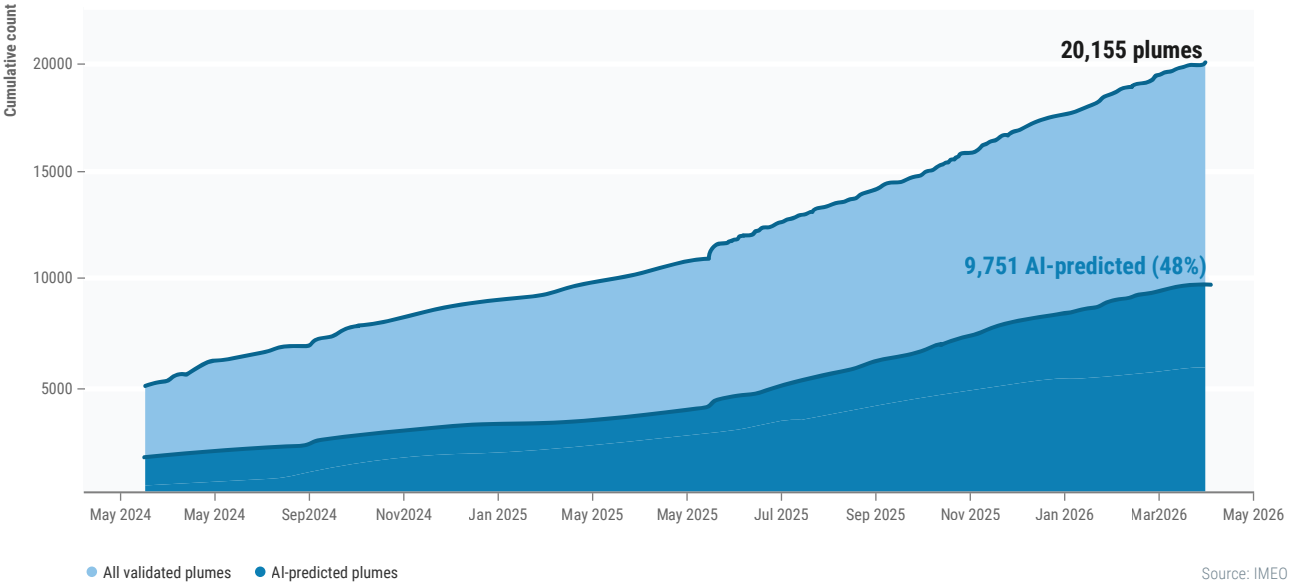
## Flagged by AI, validated by experts

AI model outputs are the result of statistical inferences, not conclusive judgment. When identifying methane emission sources across diverse landscapes, each case presents unique characteristics that require human judgment to interpret and act on.

MARS analysts verify all AI-flagged detections, following a strict protocol that requires at least two analysts' independent review. This hybrid human-machine system, also known as "human in the loop", is designed to improve accuracy and speed, at the same time preserving scientific rigour.

AI allows IMEO to process between 12-15 times more data with the same level of human effort, significantly enhancing a single analyst's reach and scaling MARS's impact (Allen *et al.* 2026).

**Figure 2: MARS detections since the deployment of the AI-enhanced models, including total detections and plumes flagged by AI tools.**




Source: IMEO

Since the models' deployment in 2024 to April 2026, 85 per cent of confirmed detections from multispectral sensors and 80 per cent from hyperspectral sensors were initially flagged by AI before analysts' review (Allen *et al.* 2026; Růžička *et al.* 2026). The AI models produce an order of magnitude less of false positives than physics-based models.

During this time, the multispectral models have processed over 900,000 images, contributing to the verification of 847 distinct methane leaks and 650 MARS notifications (see Figure 2). The hyperspectral models processed nearly 37,500 images in the same period, yielding 2,996 verified leaks and 546 notifications.

Analysts also revisit detections that the AI system misses. These detections arise during regular monitoring, in which analysts track specific sources or facilities with high emission potential.

Analysts typically conduct this "manual" monitoring in regions that have high surface variability or limited samples in the data set used to train the AI models. The models also often miss plumes from persistent or frequently emitting sources located in areas with unfavourable conditions for satellite detection, such as strong winds that quickly break up plumes.

Importantly, detections that analysts identify without an AI flag are not a lapse in the system. These feed directly into ongoing model refinement, helping the models improve over time.

Occasionally, IMEO's work encounters pushback from industry or government stakeholders regarding the interpretation of satellite data or credibility of emission estimates. In such cases, IMEO engages directly with concerned parties, walking them through the analysis, including plume detection, validation and emission

quantification. IMEO remains open to revising estimates for which stakeholders can provide higher-quality empirical data and demonstrate discrepancies in the analysis.

IMEO's scientific credibility is rooted in peer-reviewed methods, collaboration with leading research institutions, and public controlled release experiments, which are supported by IMEO and invite private sector and academic entities alike to test different methane measurement technologies.

## From detection to verified mitigation

Detection is not the endpoint, but the entry to a system that engages stakeholders to reduce methane emissions. When MARS identifies an extreme emission event, UNEP notifies the relevant government and, where applicable, OGMP 2.0 company focal points. IMEO is available to provide support as governments determine an appropriate response.

In most cases, the same satellite instruments and AI models that flagged the original emission can be used to confirm whether mitigation action was successful.

This verification depends on a concept that is easy to overlook: the value of a non-detection. When a site that previously showed a detectable plume is subsequently observed without one, that absence itself is often evidence of change.

The absence of methane detection is not enough to confirm an emission event has been mitigated, however. Many emission events are sporadic. Or emissions may have simply fallen under the threshold for satellite detection. UNEP requests feedback from governments and companies, including information on the detected emissions, their underlying cause and any mitigation plans or actions taken. These responses provide critical, complementary information on mitigation that satellites cannot.

The impact of this approach is significant. To date, IMEO has confirmed more than 40 instances of mitigation action that MARS facilitated or verified. Together, these sources are estimated to have released 1,200,000 tonnes of methane before they were mitigated, a volume comparable to the annual emissions of nearly 24 million gasoline-powered passenger cars (UNEP 2026).

## Case study: Mitigation in Kazakhstan

One such case from Kazakhstan illustrates how the MARS system works in practice, from detection to mitigation (see Figure 3). In June 2023, the hyperspectral EMIT sensor first observed a sporadic plume at a source in the Middle Caspian Basin. A year later, MARS's multispectral AI system started detecting persistent emissions at the same site. Over a two-month period between June and August 2024, the AI model detected seven plumes. The source is estimated to have had an average emission rate of 1.79 metric tons of methane per hour.

UNEP notified the government and company focal points. An on-site inspection traced the emissions to a malfunctioning valve, which the operator subsequently replaced. On 14 October 2024, observations from multiple hyperspectral instruments confirmed that emissions had ceased.

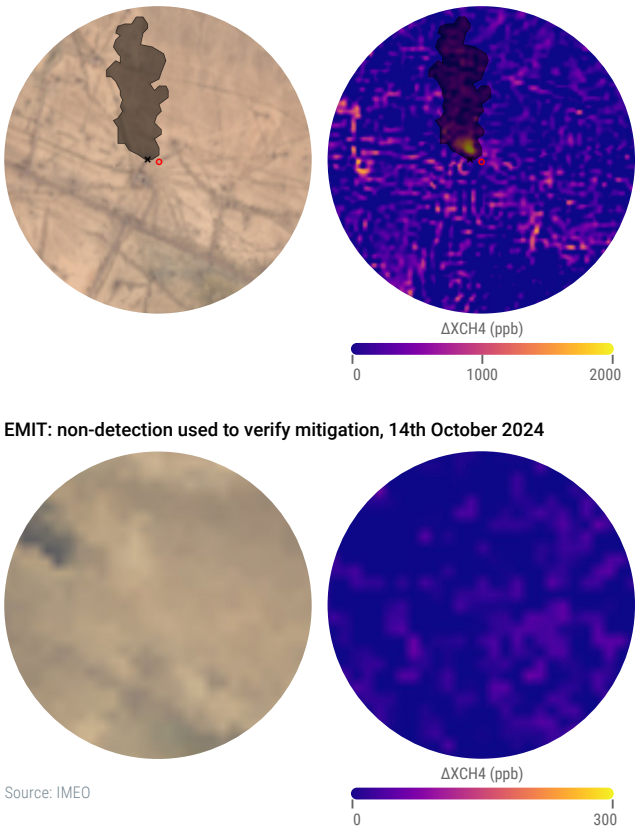
The case illustrates the complementary strengths of each instrument type, from enabling the initial detection to tracking emissions and confirming that corrective action was taken.

The case also demonstrates MARS's lightweight yet high-impact approach, one that delivers verifiable climate results without requiring resource-intensive tools.
The credibility of this approach rests on satellite detection, AI models rigorously validated with established science, a human review protocol ensuring no detection reaches a stakeholder without expert confirmation, and a verification process that links notification and response.

In most cases, the same satellite instruments and AI models that flagged the original emission can be used to confirm whether mitigation action was successful.

This verification depends on a concept that is easy to overlook: the value of a non-detection. When a site that previously showed a detectable plume is subsequently observed without one, that absence itself is often evidence of change.

**Figure 3: A plume detected in Kazakhstan, followed by the non-detection in October 2024, confirming that emissions had ceased.**




Source: IMEO

## Box 2. AI accelerates methane data integration

Building on the success of UNEP's Oil and Gas Methane Partnership 2.0, IMEO is scaling its industry engagement approach to the metallurgical coal sector. Steel production depends on metallurgical coal, the mining of which produces methane. These emissions increase the climate footprint of blast furnace steel, the majority of steel, by on average a quarter, yet it could be substantially reduced with proven, cost-effective technology (UNEP 2025).

In spring 2026, IMEO launched the Coal Methane Database, the first public database of mine-level methane emissions that combines multiple data sources. It aims to bring unprecedented transparency to the steel supply chain and draw attention to metallurgical coal's untapped mitigation potential.

Creating this database includes testing an AI-based statistical method for integrating empirical and non-empirical methane data, such as coal mine emission estimates from satellite measurements, local scientific studies, inventories, and company and government reporting.

UNEP has confirmed more than

**40**

cases of mitigation action through MARS

Find more mitigation cases here and explore the data on IMEO's Eye on Methane data platform

Photo credit: Canva

# Future directions

IMEO continues to explore how AI can enhance operational efficiency and advance methane mitigation outcomes.

This includes developing AI tools to process complex data sets, streamline prioritization and translate data into actionable insights across other IMEO workstreams. Across its digital platforms, including the Eye on Methane data platform, IMEO is examining how users access and apply data to decision-making, as well as how AI could be used to make insights more actionable for users.

These explorations reflect IMEO's commitment to continuously evolving its use of state-of-the-art technology to offer high-quality data and insights to stakeholders for methane mitigation.

Equitable access to AI-enabled tools is essential for effective, inclusive climate action. However, gaps remain in the capacity of government and industry stakeholders to translate data into targeted decision-making and action. IMEO addresses these challenges through its Methane Training Series, which provides training and support to governments and national oil companies. Across this program, IMEO has trained nearly 2,000 diverse stakeholders, including women in leadership and technical roles, to ensure that capacity-building efforts reach those best positioned to drive informed, equitable action.

UNEP will continue to strengthen collaborations and partnerships to pursue these developments. Support from Google.org, the Global Methane Hub and Bloomberg Philanthropies, among others, reflects a range of technical and philanthropic actors aligned on the goal of turning satellite data into climate action. IMEO welcomes engagement from potential partners who share this ambition.

Photo credit: Canva

# Conclusion


Photo credit: UNEP

**UNEP's integration of AI into its methane mitigation work represents a significant step forward in global environmental monitoring. IMEO's Methane Alert and Response System (MARS) illustrates what this approach can look like in practice: machine learning deployed not as a research prototype, but as an operational system informing decision-making at a global scale. This deployment offers lessons that extend beyond methane monitoring.**

**AI tools can help responsibly and rigorously accelerate global climate progress when sustainability is embedded by design.** Through initiatives like MARS, UNEP is demonstrating how AI tools can be scaled up to address a major climate challenge. The result is greater efficiency, speed and scale amidst a rapidly evolving methane data landscape, without undercutting the climate benefits that MARS can catalyse.

**Integration of AI technology is critical for tapping into the full value of space-based data.** As new satellite missions and data collection sources become available in the coming years, the volume of space-based, environmental data continues to grow rapidly. Translating this data into climate action will depend on the development and utilization of AI-enabled tools and data sets. AI models and AI-enhanced analysis are essential for deriving actionable intelligence from raw satellite observations.

**Human supervision remains indispensable.** AI systems synthesize patterns based on training with historical data, but lack contextual understanding needed for decision-making. When addressing critical, site-specific environmental problems, human verification and judgment is needed before stakeholders act on AI outputs.

As the world faces mounting climate challenges, continued innovation and strengthened collaboration will be essential to achieve meaningful methane reductions and secure a healthier planet for future generations.

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