IEF METHANE INITIATIVE

Methane Mitigation in the Energy Sector

New Methodology and Opportunities

IEF | KAYRROS

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About the International Energy Forum

The International Energy Forum (IEF) is the world's largest international organization of energy ministers from 71 countries and includes both producing and consuming nations. The IEF has a broad mandate to examine all energy issues including oil and gas, clean and renewable energy, sustainability, energy transitions and new technologies, data transparency, and energy access. Through the Forum and its associated events, officials, industry executives, and other experts engage in a dialogue of increasing importance to global energy security and sustainability.

About Kayrros

Kayrros is a leading geospatial analytics company. Harnessing satellite imagery and multiple sources of unconventional data with machine learning, and advanced mathematics, Kayrros monitors and measures energy and natural resource activity worldwide. Kayrros' mission is to give energy and industrial actors the data tools they need to optimize operations, tackle the climate challenge, navigate the energy transition, and stay on top of fast-changing markets.

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Executive Summary

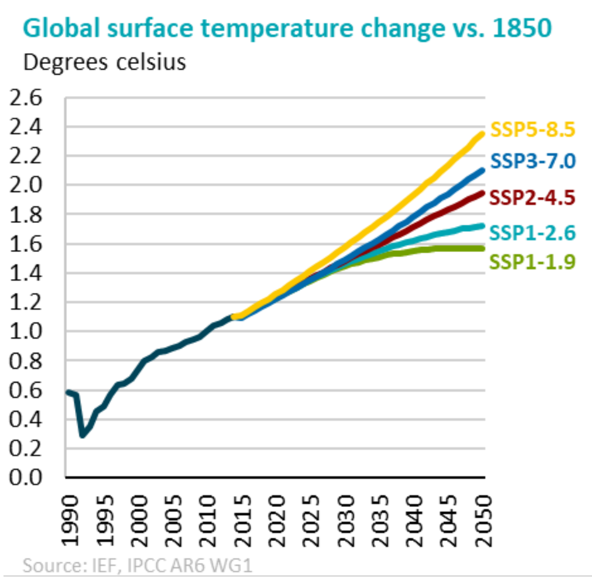
- Urgent mitigation of methane emissions is essential to achieving climate goals. Methane is more efficient at capturing heat than many other gases, including carbon dioxide. In the latest IPCC report, the 'sustainability' path assumes methane emissions will fall by more than 45% by 2050.
- Measuring methane emissions is technically challenging, and the use of emission factors can understate total emissions by a factor of 10 relative to atmospheric measurements and global methane inventories. Better data and a standardized measurement methodology are necessary to establish a consistent, accurate baseline, and define realistic mitigation targets.
- The International Energy Forum (IEF) partnered with Kayrros, a leading geospatial analytics company, to develop a common approach for accurately estimating methane emissions in the energy sector. The production and transport of hydrocarbons is the second largest source of anthropogenic emissions, and energy-related methane is widely considered the low-hanging fruit of climate action.
- Satellite monitoring technology has matured over the past two years and can be used to identify, monitor, and assess (1) methane intensities of hydrocarbon production across the supply chain, (2) super-emitter events, and (3) flaring intensities. These three metrics are core to the proposed methodology to estimate methane emissions and can be used by countries to define emission baselines and credible mitigation targets.
- While satellites bring unique benefits in terms of coverage and data transparency, the current technology also has limitations; tropical regions and offshore areas are out of scope, and small methane sources can only be detected using local sensors. Therefore, an integrated process that considers bottom-up estimates from company reporting, ground observations, and country consultations is also essential.
- The proposed standardized methodology, built through a series of consultations with IEF member countries, considering their specific circumstances, empowers countries to estimate emission levels more accurately. It enables them to present credible mitigation plans in their Nationally Determined Contributions (NDC), while supporting industry initiatives to integrate top-down and bottom-up technologies. Eighty percent of countries have included methane in their greenhouse gas targets of their NDC, but only five percent have set specific targets for methane reductions.
- It is critical for the proposed methodology to be low cost. This initiative used data from the European Union's Sentinel-5P. As a public satellite, raw atmospheric measurements are provided free of charge. This data set can be complemented with ground sensors, aerial campaigns, and commercial satellites, but deploying these technologies at scale along the entire supply chain can be cost prohibitive. By prioritizing public satellite data, the methodology is affordable and can be widely adopted.
- More broadly, an era of greater transparency should result in a much-needed collaboration between energy stakeholders around a common understanding of methane sources and mitigation opportunities along the entire energy supply chain. The perfect is the enemy of the good. Despite the limitations, raising awareness and providing tools to more accurately measure and track methane emissions at production, transport and consumption can only spur accountability and mitigation action.

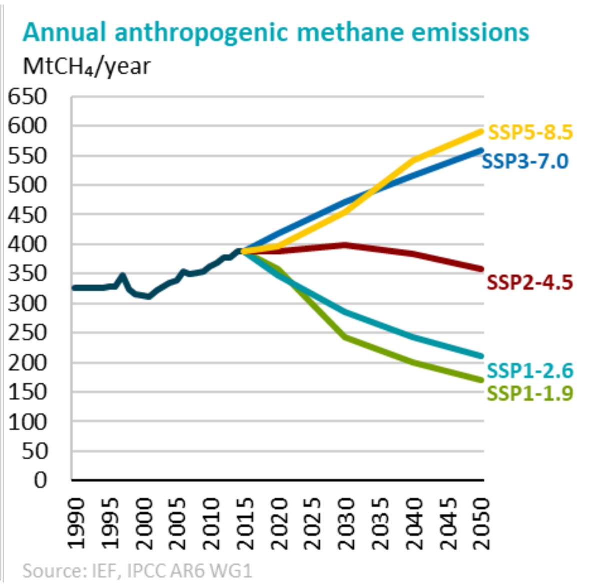
Introduction

Why methane and why now?

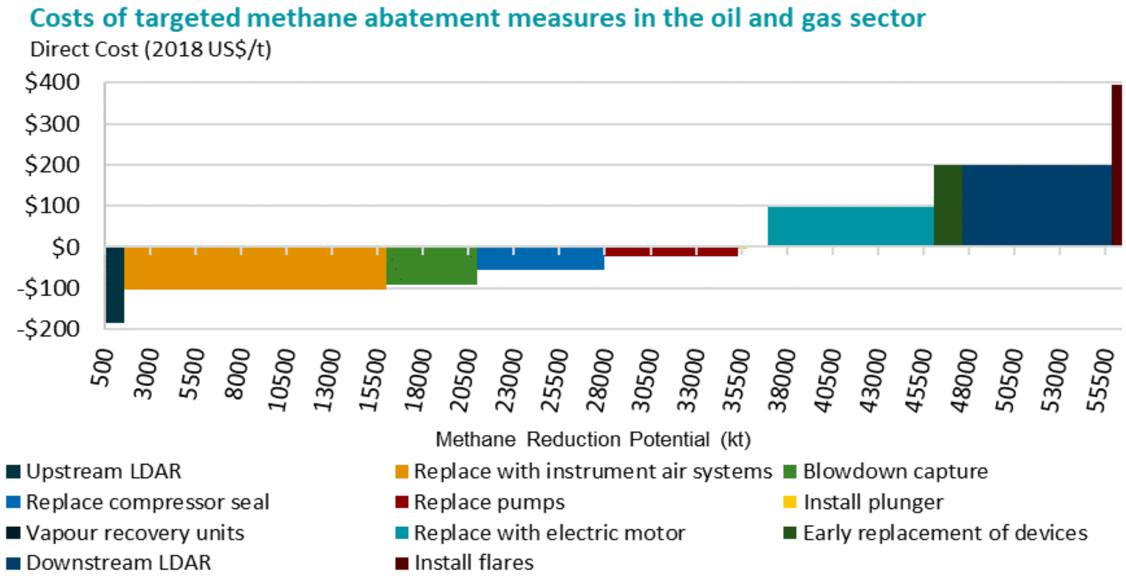
Scientists and policymakers increasingly recognize that reducing methane (CH_4) emissions is crucial to achieving short-term climate goals. The latest Intergovernmental Panel on Climate Change (IPCC) report, published in August 2021, notes that “addressing methane mitigation appears even more important” now and that methane mitigation “increases the feasibility of achieving the Paris Agreement goal.”

IPCC’s SSP2 (‘middle of the road’ path) assumes annual anthropogenic methane emissions plateau at ~400 Mt/year through the end of the decade before falling by ~13% to ~350 Mt/year by the middle of the century. Meanwhile, the more ambitious SSP1 (‘sustainability’ paths) show an immediate reversal in methane emissions with rates falling by nearly 20% between 2015 and 2025 and by more than 45% by 2050.





Unlike carbon dioxide (CO_2) emissions, which are easier to estimate but harder to address, methane emissions have been elusive to identify but, once detected, offer considerable low-hanging fruit for climate action. The United Nations Environment Programme reports that the energy sector can reduce methane emissions from oil, gas, and coal by 50 percent at a low cost, and deliver 0.1℃ in avoided warming by 2030 (UNEP, 2021). While some upfront costs are necessary and may need to be shared, the graphic below shows that more than 60% of methane emissions from oil and gas can be abated at a net negative cost.



Source: IEF, UNEP *Global Methane Assessment*, CCAC

Eighty percent of countries have included methane in their greenhouse gas targets of their NDC, but only five percent have set specific targets for methane reduction. While methane mitigation is garnering momentum among government and industry leaders, there is still not a standardized method for measuring methane emissions.

New technologies enable more accurate emission tracking

Satellite data, artificial intelligence, and advanced modeling are now being harnessed to track methane hotspots worldwide, enabling energy stakeholders to take immediate action on mitigation efforts. This increasingly affordable technology offers a more accurate view of aggregate methane emissions and reveals traditional bottom-up intensities and reporting frequently underestimate emissions by a significant order of magnitude.

Satellite monitoring is complementary to bottom-up sensors and reporting. An effective monitoring system must meet the following criteria:

- **Frequency**: taking frequent measurements is critical to accurately define inventories and account for large emission events that cannot easily be detected or measured with other means
- **Coverage**: comprehensive geographical coverage is necessary to benchmark and define context
- **Resolution**: high resolution is needed to detect smaller sources and attribute to the right asset

Whereas ground sensors can detect small local methane sources and aerial campaigns provide a detailed snapshot of a region, public satellites can measure and attribute large, intermittent emission events than cannot easily be detected and quantified by other means. Public satellites provide the widest coverage at a very low cost, albeit with lower spatial resolution.

The cost and capabilities of different sensor types varies greatly. Ground sensors can cost c.$1,000 per facility per year, while the cost of aerial and commercial satellite analytics can range from $5,000 to $150,000 depending on the type of asset, resolution and number of revisits required. Scaling these technologies is challenging given the number of facilities in a company's operations, and to date they have been deployed only sparingly. As a result, they provide only a partial view of the supply chain and fall short of a comprehensive monitoring system.

Providing a standardized measurement methodology

The IEF, in partnership with Kayrros, launched the Methane Initiative in June 2021 to develop a common approach for estimating methane emissions. The new methodology allows IEF member countries to consider the best available data on methane emissions from the energy industry, define their historical methane baseline, and set mitigation goals in a transparent and consistent manner.

The methodology was formulated through an iterative, consultative process with IEF members and combines top-down satellite measurements with bottom-up company reporting and contextual data. The methodology provides countries and the sector with a range of tools to match their capabilities and needs for reducing emissions.

IEF's Methane Initiative complements other projects

Since 2004, there have been many initiatives targeting methane emissions. Existing initiatives use a variety of tools and serve different goals. Some initiatives rely solely on company provided bottom-up data (eg. OGCI, OGMP 2.0). Other initiative harness methane-focused satellite data and plan to provide the data freely (eg. EDF's MethaneSAT, planned to launch in late-2022).

The IEF initiative proposes a methodology using publicly available global satellite data from the European Space Agency's Copernicus Programme paired with an inversion model and ground-level context. IEF's initiative is different due to the availability of better data, the inclusive approach, and the focus on country-level emissions, and not only at the corporate-level.

The IEF commends the work of other programs and encourages its member countries to use existing and future tools to better understand and measure their climate impact and mitigation options. The table below includes initiatives already in place and expected to launch in the next year. Additional initiatives are expected in 2023 and beyond.

Note: The recent Global Methane Pledge, proposed by the current US administration with the European Union, was not included in the table as it is yet to be launched at COP-26 in November 2021 and the parties are currently engaging with various countries to join the Pledge as signatories.

Initiative		Public/Private, for/non-profit	Launch	Goal	Data Availability	Methodology
IEF METHANE INITIATIVE	IEF Methane Initiative	IGO led, non-profit, 71 member countries	June 2021	Create a common approach for accurately estimating methane emissions	Methodology provided; confidential data was provided to select countries during the initiative	Consultative, iterative, top-down supported by global satellite data/advanced analytics, and bottom-up company reporting and country contextual data
Global Methane Initiative	Global Methane Initiative	Government led, public-private initiative, non-profit, 45 member countries	2004	Abate methane with a focus on recovery and use	Historical US EPA emission data provided	Technical support to deploy methane-to-energy projects
MethaneSAT	MethaneSAT (EDF)	NGO led, non-profit	Planned 4Q22	Locate and measure methane emissions from oil & gas operations	Raw data publicly available	Top-down, targeted area mapping (not global) by satellite
OGCI OIL AND GAS CLIMATE INITIATIVE	OGCI	Industry driven, CEO led, for-profit, 12 companies as members	2014	Reduce methane intensity and eliminate routine flaring; Advocacy	Aggregate statistics of member companies available	Members provide bottom-up data; verified by third-party
UN environment	IMEO (UNEP)	IGO led, non-profit, 193 member countries	Announced March 2021	Collect and verify methane emissions data to improve targeted abatement	Public dataset of empirically verified methane emissions, with an initial focus on fossil fuel sources	Aggregating company reporting, satellite data, and data from scientific studies
OGMP Oil And Gas Methane Partnership 2.0	OGMP 2.0	Public-private initiative, led by UNEP, EDF, & EC, and has 67 companies as members	2014	Improve reporting accuracy and transparency of methane emissions in the oil and gas sector	Company data remains confidential	Member companies provide bottom-up emission data of assets
METHANE GUIDING PRINCIPLES	Methane Guiding Principles	Industry led, 24 companies as members	2017	Focus on reducing emissions across natural gas supply chain; Advocacy	Companies publicly report	Companies report how they are meeting the intent of reducing emissions & improving data

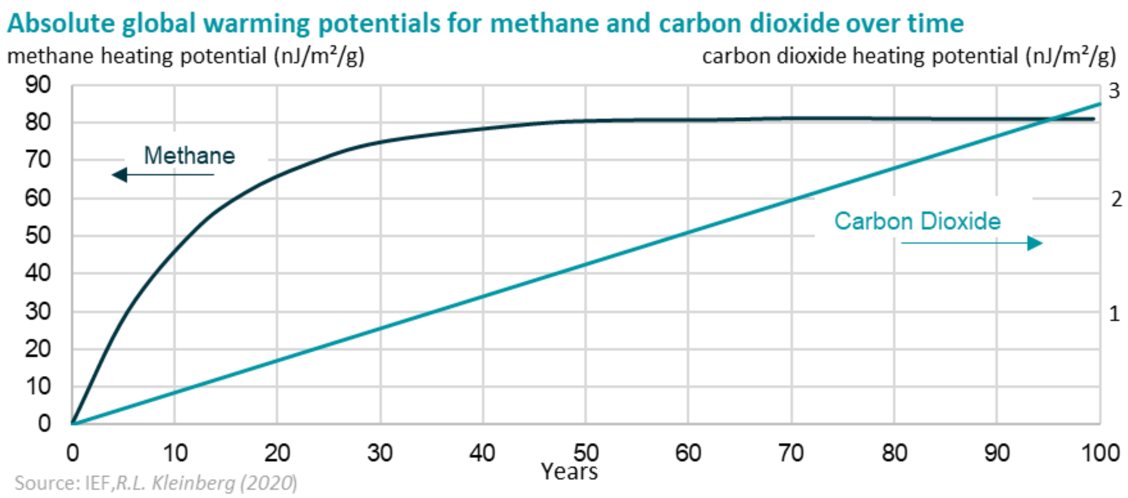
Background

Methane 101

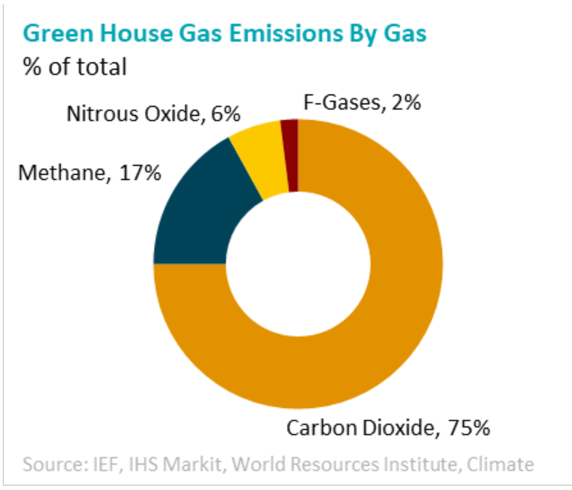
Methane is an odorless, colorless, and highly flammable gas. It is the main component of natural gas and the second highest contributor to global warming after carbon dioxide (Saunois et al, 2020). Methane leaks are challenging to monitor using traditional methods and are frequently underreported or even left out of emissions inventories. Yet at least 25 percent of today's global warming is driven by methane produced through human activity (UNEP, 2021).

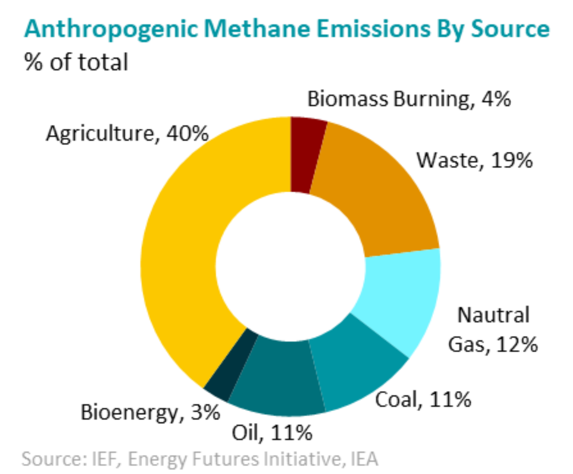
The amount of methane in the atmosphere has more than doubled since pre-industrial times (Nisbet et al, 2019). However, methane’s atmospheric lifetime is around 12 years, whereas carbon dioxide lingers for centuries (IPCC, 2021). A reduction in methane emissions should have an immediate and palpable impact on methane-driven warming.

Methane is more efficient at capturing heat than many other gases (Kleinberg, 2020). In the first 20 years after being released into the atmosphere, methane is 82 times more potent than carbon dioxide at trapping heat. Over the lifetime of carbon dioxide, methane is 28 times more potent than carbon dioxide (IPCC, 2021).



Today, nearly 60% of methane emissions are driven by human activity, including rice production, landfills, raising domestic livestock, and energy generation (Schiermeier, 2020). Methane leaks can happen anywhere along the natural gas supply chain or can also be released during oil and coal production. Major natural sources of methane emissions include wetlands and oceans.

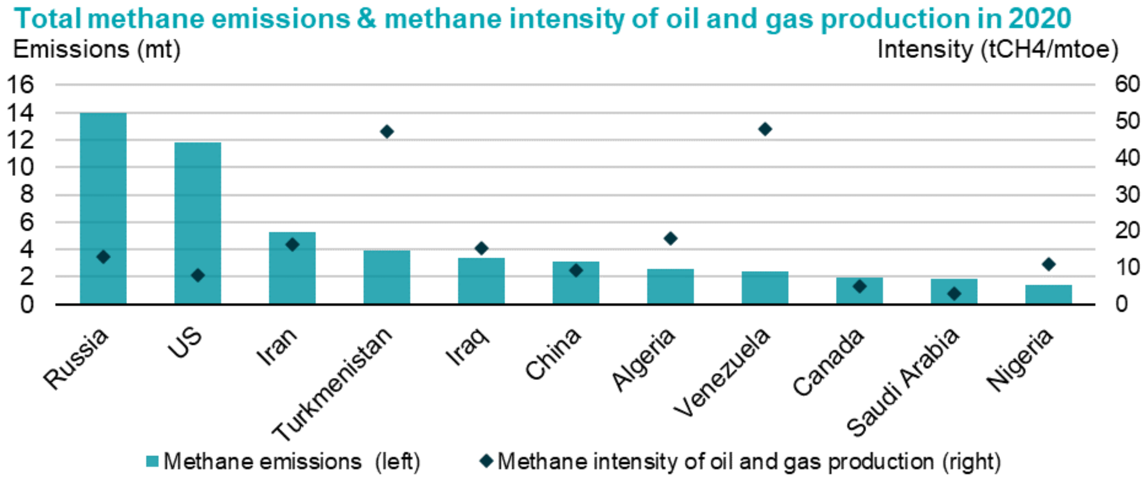




Methane emissions and the energy sector

Current estimates show oil, gas, and coal operations contribute to more than a third of all anthropogenic methane emissions. Yet, many researchers argue that this these measurements severely underestimate true emissions. For example, Schwietzke et al. found that “fossil fuel methane emissions are 60–110% greater than current estimates” (Schwietzke et al, 2016). Improving the accuracy of data and reporting is essential to creating and implementing credible mitigation plans.

Data from countries and production basins show that methane emissions are not always directly proportional to the amount of energy being produced. As the chart below illustrates, the emissions intensity of oil and gas production can be more than 10 times higher among the lower performing countries compared to higher performing ones. Turkmenistan, for example, sits at the high end of methane intensity, defined as the ratio of methane released to energy produced. Meanwhile, some of the top producing countries, including Saudi Arabia, are among the lowest emitters in intensity and absolute terms.



Source: IEF, IEA *Methane Tracker 2021*

The good news is that emissions from energy infrastructure are among the easiest and cheapest sources of methane emissions to reduce – once located and quantified.

The methodology outlined below proposes using satellite detection systems and artificial intelligence algorithms in concert with existing systems, aerial monitoring, and ground-based surveillance to estimate a more accurate methane emission rate.

Satellite imagery can provide high-frequency global measurements

There are two main categories of satellites able to estimate methane emissions – monitoring satellites and tasking satellites. Monitoring satellites scan the entire atmosphere and generate large volumes of data, which in the case of public satellites (such as Sentinel-5P) is freely available in raw, unprocessed form. Meanwhile, tasking satellites only scan specifically requested areas, and in the case of commercial satellites, the data is provided only to clients.

The IEF initiative used data from the European Space Agency’s Sentinel-5P satellite carrying the TROPOspheric Monitoring Instrument (TROPOMI). The satellite covers ~95% of the earth surface daily. Data from the satellite can reveal individual cases of very large methane emission events and regional basin-wide anomalies.

Satellites are an important tool to measuring methane as only they can provide the large-scale coverage and high temporal resolution of daily revisits that are essential to both address the intermittency of large methane vents and the multitude of potential emission sources.

Instrument	Agency/ Company	Public Data?	Launch	Smallest leak rate detectible (kg/h)	Pixel size (km x km)	**Coverage**
SCIAMACHY	**ESA**	**Yes**	**2003**	**70,000**	**30 x 60**	**Global (every 6 days)**
GOSAT	**JAXA**	**Yes**	**2009**	**7,100**	**10 x 10**	**Global (every 3 days)**
GHGSat	**GHGSat, Inc**	**No**	**2016**	**1,000**	**0.05 x 0.05**	**Targeted (revisit every 14 days)**
Sentinel-5P	**ESA, NSO**	**Yes**	**2017**	**4,000**	**7 x 7**	**Global (daily)**
GOSAT-2	**JAXA**	**Yes**	**2018**	**4,000**	**10 x 10**	**Global (every 6 days)**
PRISMA	**ASI**	**Yes**	**2019**	**1,000**	**30 x 30**	**Global (every 7 days)**
GHGSat-C1	**GHGSat, Inc**	**No**	**2020**	**70-250**	**0.05 x 0.05**	**Targeted (revisit every 14 days)**
MethaneSAT	**EDF**	**Yes**	**2022**	**100**	**1 x 1**	**Targeted (revisit every 10 days for most sites)**
GeoCARB	**NASA**	**Yes**	**2022**	**4,000**	**4 x 5**	**Limited to Americas (revisit every 2-8 hours)**
GHGSat-C2	**GHGSat, Inc**	**No**	**2022**	**100**	**0.025 x 0.025**	**Targeted (revisit every 14 days)**
Sentinel-5	**ESA, NSO**	**Yes**	**2022**	**4,000**	**7 x 7**	**Global (daily)**
Bluefield	**Bluefield Technologies**	**No**	**2023**	**70**	**0.02 x 0.02**	**Targeted**
TANGO	**ESA**	**Yes**	**2024**	**500-1,000**	**0.3 x 0.3**	**Targeted**
CO2M	**ESA**	**Yes**	**2026**	**1,000**	**2 x 2**	**Global (every 7 days)**

Source: IEF, *Elkind et al. (2020), UNEP GMA (2021), Carbon Limits (2020)*

IEF – Kayrros Methodology

Key metrics: Methane intensities, super-emitters, and flaring

The methodology described in this report is focused on defining three quantitative metrics whose evolution can be measured over time: the methane intensity of production, the number of super-emitters, and the flaring intensity.

These metrics were designed so that:

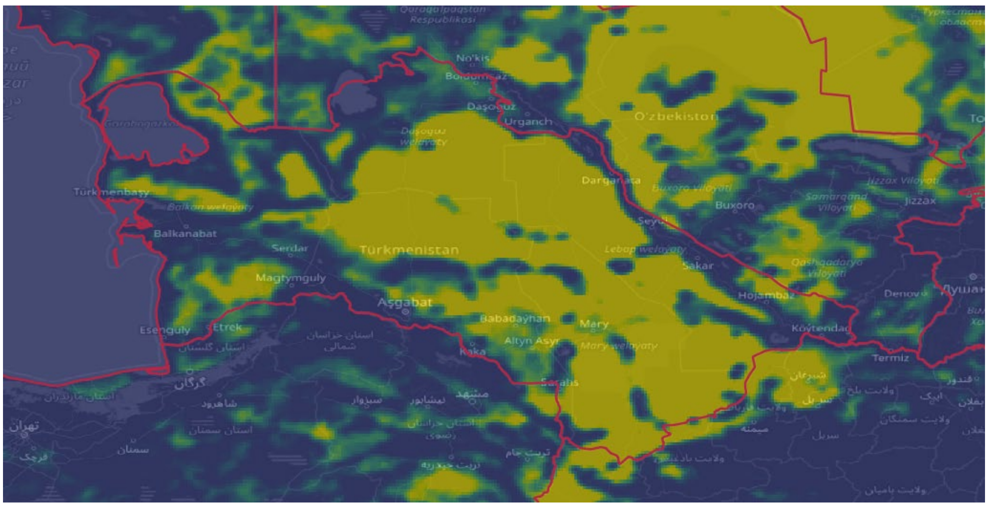
- A first assessment can be run with satellite measurements, helping build a baseline without requiring higher-cost surveillance tools
- Realistic actions can be put in place for mitigation and the effectiveness of these actions can be measured
- These metrics can be refined by running an integrated model and by ground-truthing

The regional application of the tools outlined in this white paper will vary due to different access to data and monitoring systems and country circumstances. However, all regions can prioritize the three key metrics below.

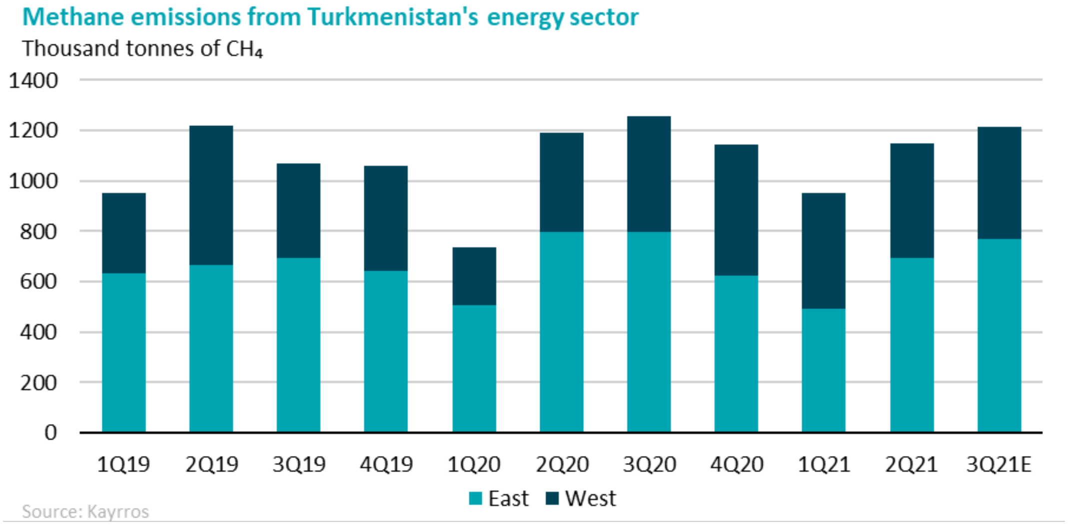
1. **Methane intensities:** Methane intensity is the ratio of methane leaked and/or vented to hydrocarbon output. The intensity of methane emissions varies widely across energy producing countries. As highlighted previously, emissions intensity can be more than 10 times higher among the lower performing countries compared to higher ones. Countries can use methane intensities to rate the relative efficiency of its production. This underscores the opportunity that many countries have to rapidly achieve huge improvements in reducing emissions and progressing toward climate goals.

   For example, there is excellent satellite coverage over Turkmenistan, as illustrated in the first graphic below. The satellite data confirms other estimates that show Turkmenistan's methane intensity of production at nearly 50 tCH_4/mtoe – well above the global average of ~10.6 tCH_4/mtoe.

   Sentinel-5P coverage in Turkmenistan
   (bright yellow >100 observations per year; dark purple: zero)

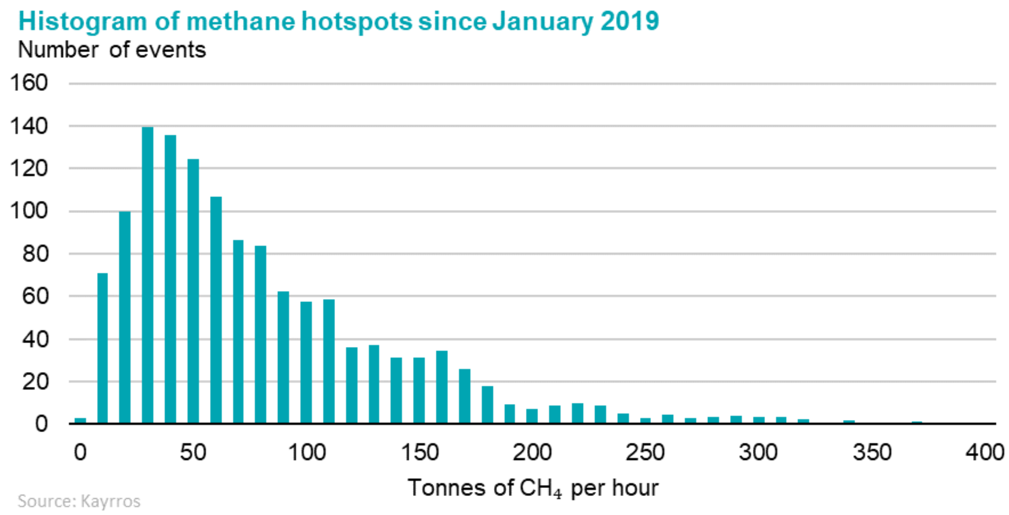


Source: Kayrros analysis of Sentinel-5P data

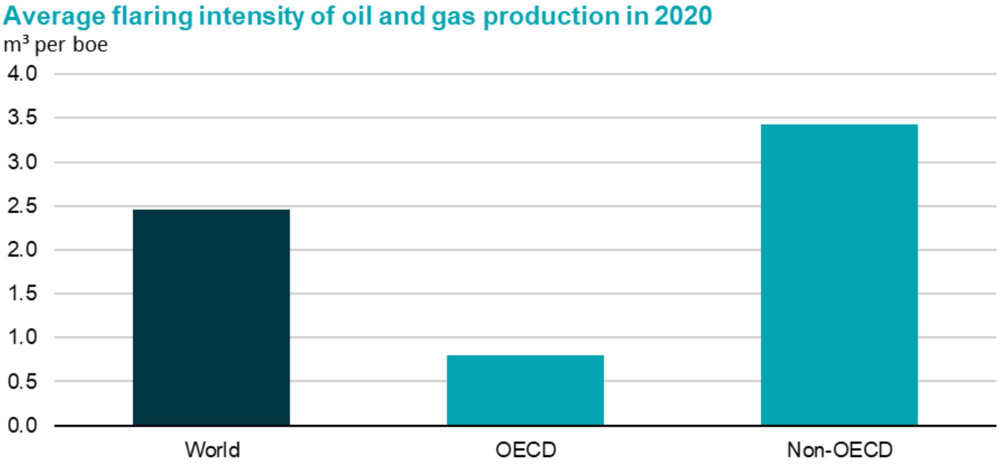


2. **Super-emitters:** A small number of major events—known as super-emitters—represent a significant portion of emitted volumes. It has been estimated that these leaks can contribute up to half of total emissions for some countries and that there are around 100 high-volume methane leaks happening in the world, at any one time. High-frequency monitoring is necessary to quickly detect these abnormal events.

   In recent months, media outlets have used satellite data to highlight super-emitters in countries including Russia, South Africa, US, Bangladesh, Iraq, and Canada.



3. **Flaring:** Studies show that flaring is generally underreported (Leyden, 2019). Flaring gas should combust methane and release only carbon dioxide into the atmosphere. However, flares are often inefficient and combust incompletely, releasing methane instead of carbon dioxide into the atmosphere. Malfunctioning or unlit flares can also occur. Satellite imagery is best positioned to monitor flaring intensities to assess the efficiency of the flare and whether excess methane is released.



Source: Kayrros

Satellite imagery: Simulating emissions with artificial intelligence and inversion model

To quantify, attribute and analyze methane emissions from the raw satellite data, weather conditions, wind direction, and other ground factors must be considered. Inversion models based on Sentinel-5P developed by Kayrros quantify approximately 30% of global methane emissions on a monthly/quarterly basis. The super-emitters detected and quantified using this methodology showed rates ranging between 5 tons per hour and several hundred tons of methane per hour.

The **methane intensity of production** can be estimated by combining a full inversion model, giving total methane emissions over a given area, and production of this same region. A full inversion model is a statistical measure based on satellite images and atmospheric simulations. The model should consider:

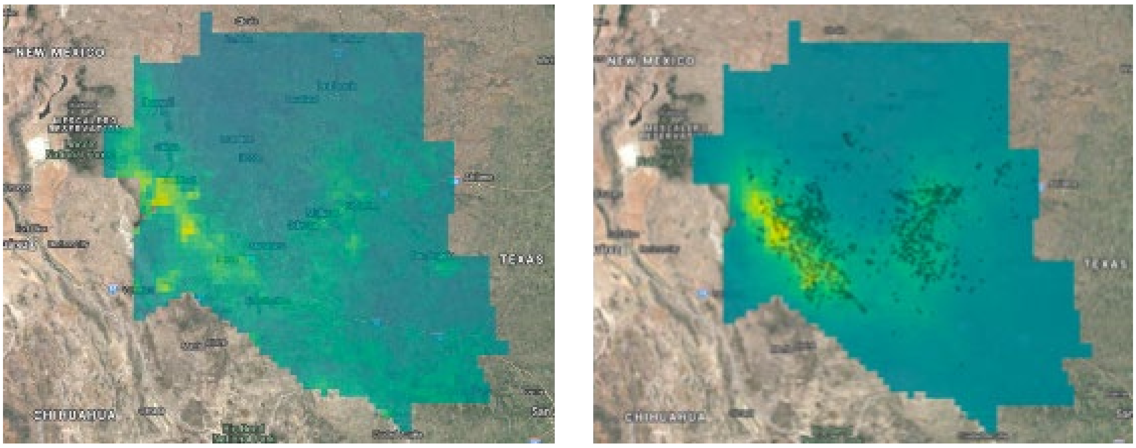
1. Methane concentration grids from satellite images need to be corrected for atmospheric conditions and ground reflections affecting satellite measurements.

2. Background methane concentrations are filtered to distinguish anthropogenic emissions from ambient methane concentrations in the atmosphere. Gas diffusion models are used to correct the methane grids, which have their own uncertainty linked to parameters of the transport model (simulation duration, wind data, etc.).

3. Finally, on-ground operational data (well completions, flaring intensity, etc.) are used to discriminate between potential emission sources identified by the inversion model, hence statistically attributing methane emissions to specific areas. These operational metrics, used as inputs in the model, are calculated from satellite, geolocation data and country input.

Inversion models are best suited to upstream areas with significant methane volumes from many concentrated sources. This applies to some of the most prolific onshore oil and gas production basins in the world, from the well head down to “first mile” transportation systems (compressor stations, gathering pipeline valves, etc.) and nearby storage facilities.

Satellite measurement of methane concentrations (left) and inversion model based on new wells as a proxy for potential methane sources (right)



Source: Kayrros analysis of Sentinel-5P data

Flaring intensity can be measured by assessing the radiant heat of the flare in the infrared, for instance from the VIIRS sensor onboard the Suomi-NPP satellite. This radiant heat is proportionate to the amount of gas burnt.

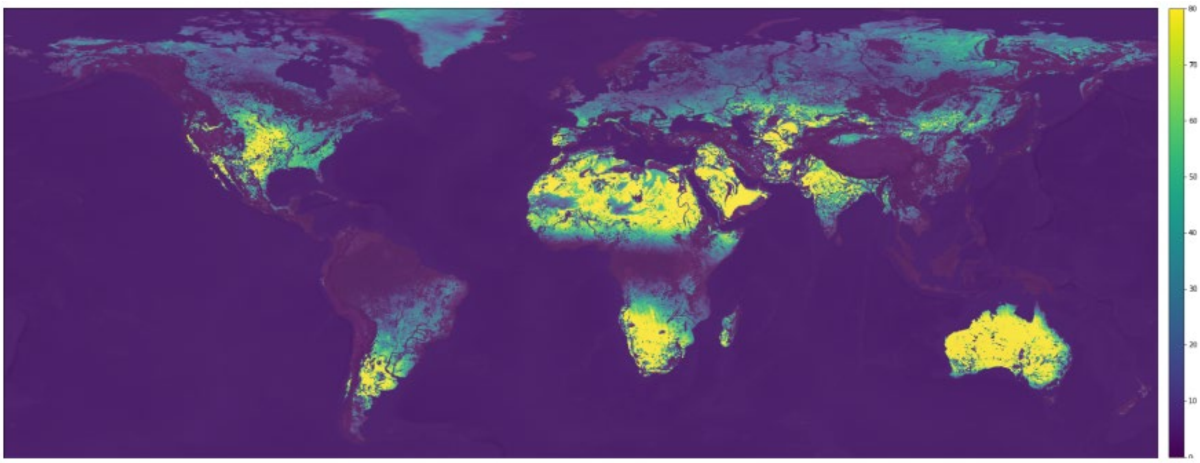
Satellite data limitations

Criticisms of a top-down approach includes temporal issues (measurements limited to cloudless days with limited wind, leading to a “blue sky bias”), issues related to the attribution of emission events (inability to discern the exact source of a given event when there may be overlap of multiple potential sources, e.g. agriculture and energy infrastructure), and geographic limitations (inability to accurately measure over wetlands, snow, offshore installations or along the equator).

The image below shows the number of usable pixels per year available from the Sentinel-5P TROPOMI, with yellow indicating the highest number of pixels and dark purple no available data.

Currently, satellite monitoring cannot be used to monitor offshore or regions near the equator. However, several planned satellites will use sun-glint technology to provide some measurements over water.

Sentinel-5P TROPOMI coverage: Usable pixels in a year (2020-2021)



Source: Kayrros, modified Copernicus Sentinel data

In areas with limited or no satellite coverage, increased on-the-ground monitoring is critical. In addition, countries can monitor flaring intensities and estimate methane intensities by benchmarking to regions with satellite visibility that has similar geology and operations.

For example, while there is substantial production and processing in Mexico that cannot be seen clearly with current satellite technology (due to satellite limitations for offshore production and high humidity and tropics in southern Mexico), one recent study supplemented what can be seen by satellite with airplane flyovers and ground-level monitoring. It revealed methane emissions were ten times higher than government reporting (Zavala-Araiza et al, 2021).

Similarly, while satellite imagery is limited in Nigeria due to its location near the equator, flaring intensities and aircraft/drone technologies can be used to identify potential emissions.

Integrated model: Leveraging technology and ground-level data

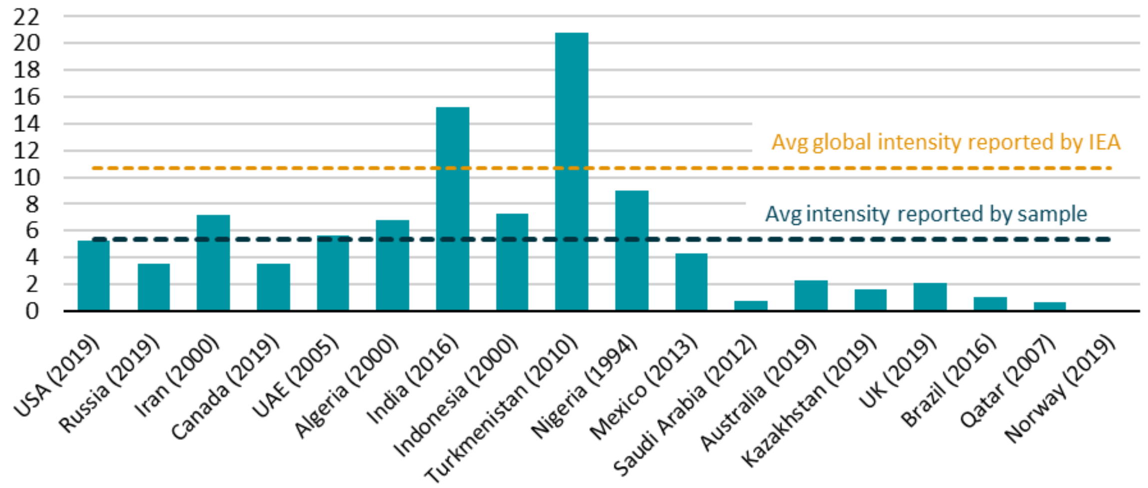
Methane emissions are generally quantified in one of two ways: "bottom-up" or "top-down" accounting. Bottom-up accounting sums the individual component emissions to reach a total estimate while top-down measures the concentrations in ambient air. Neither top-down nor bottom-up estimates is perfect on its own. However, if the methodologies can be reconciled and informed by region-specific operational data, the ultimate result is as accurate as possible with current technology.

Studies show that bottom-up emission estimates using emission factors for energy asset components alone consistently underestimate the amount of methane leaked into the atmosphere. The largest emission events are due to abnormal conditions while emission factors only account for normal operations.

The chart below shows the implied methane intensities of production calculated using country-reported emissions from the oil and gas sector (UNFCC) and BP's estimate of oil and gas production. Of the 18 countries sampled (representing >70% of global oil and gas production), only two have an implied methane intensity above the IEA Methane Tracker's estimate of average intensity for the sector. The average intensity estimated by the IEA is nearly double the production-weighted average intensity reported for the group of countries in the below sample.

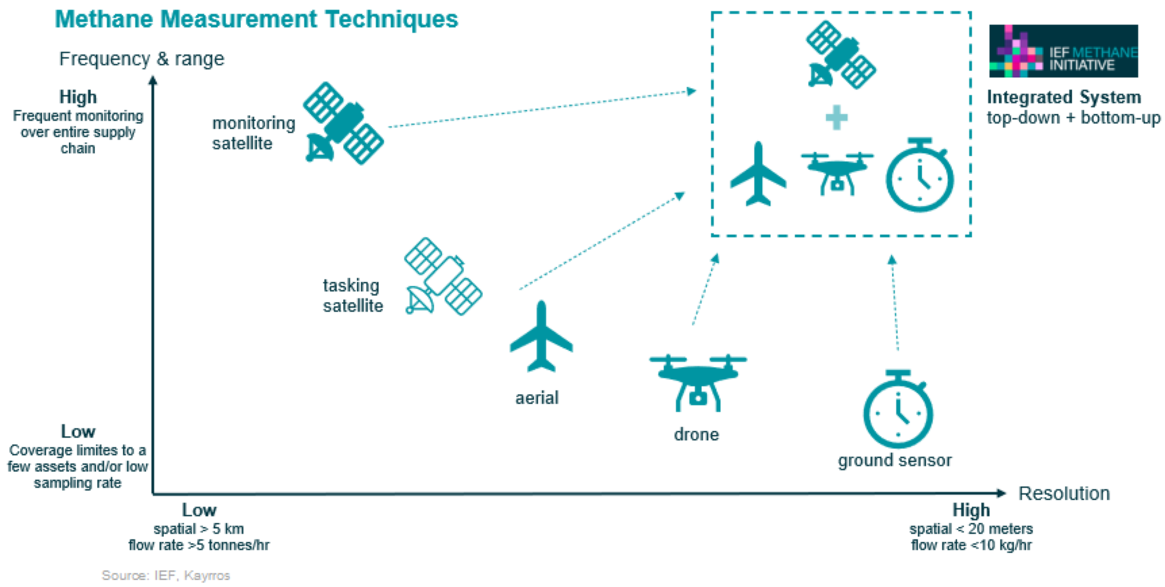
Methane emission intensities from the oil & gas sector reported by major producing countries

Tonnes CH_4 per mboe oil and gas produced



Source: IEF, UNFCC, BP World Energy Statistics

To be able to capture a large share of emissions, a monitoring system must combine frequent measurements, wide geographical coverage, and high sensitivity. Since no single technology can meet this challenge on its own, an effective monitoring system must combine different types of observing strategies.



Each method has its own operational envelope:

- **Satellite imagery** allows for continuous monitoring (up to daily revisit of entire regions), but the spatial resolution limits the attribution process, and the technology remains ineffective over specific areas (offshore facilities, cloudy tropical regions).
- **Aerial campaigns** have been successful in quantifying basin-level emissions, but specific facilities need to be targeted to attribute and quantify individual emissions (Lavoie et al., 2015, Gasbarra et al., 2019). Flyovers provide a snapshot in time, with one plane covering around 200 sq km in a day. These operations require permission to access the airspace and can miss intermittent emissions.
- **Drones** are becoming more serviceable as the weight of methane sensors decrease and drone technologies improve rapidly, but their coverage is more limited than airplanes. Equipped drones are effective on offshore fields and platforms where satellite coverage is limited, and access remains difficult.
- **Tower networks** efficiency depends on the density of sensors within the area and can be limited by the lack of existing infrastructures to deploy continuous analyzers.
- **Mobile campaigns** (automobiles) are the best solution to lower the detection threshold to ~10kg per hour and to precisely attribute the observed emissions to the source, but deployment remains operationally limited.

Satellites can play a central role because of their global coverage and high frequency of monitoring. However, airborne (planes, drones) and mobile sensors (ground sensors) will provide the precision required for a comprehensive system capable of assessing the majority of methane emissions in a cost-effective manner.

In regions with multiple potential methane sources, it is advised to leverage the lower detection threshold of high-resolution satellites and the increased number of measurements. The use of mobile sensors can also help attribute emissions between companies, and even sectors, operating in the same area.

An interesting example we encountered in this study is India. Although there are no satellite-based measurements of methane emissions from Indian coal, data available from other regions can be used as a benchmark. This, together with studies on the methane content of coal relative to its rank and seam depth, can be used to estimate emissions in Indian coal basins. The latter are likely to have a methane intensity well below the world average of 5kg per tonne.

Large-scale monitoring satellites can also help optimize the use of other more-expensive, focused technologies (tasking satellites, aerial campaigns, drones, and ground sensors) by guiding them to the right targets.

At the basin level, where monitoring satellites can detect more than 90% of total emissions, more local technologies play a critical role by identifying high-risk areas before leak detection and repair campaigns.

Conclusion

Lessons learned and next steps

The momentum for methane mitigation has never been this strong. Scientists and policymakers recognize the importance of reducing methane emissions to achieve near-term climate goals efficiently and effectively. The energy sector is responsible for nearly 40% of anthropogenic methane emissions, with most emissions coming from a disproportionately small number of events that can be remedied at little-to-no net cost. Methane emissions are truly the low-hanging fruit for climate action. Given the urgency, there are two main lessons from this initiative: (1) less is more, and (2) perfection can be the enemy of the good.

However, credible mitigation plans can only be made once baseline data and reporting have reached an acceptable level of accuracy. Methane emissions estimated using traditional bottom-up intensities and reporting alone are significantly lower than what is observed by satellites. The reporting gap needs to be addressed by ground-truthing satellite data.

The IEF, in partnership with Kayrros, is proposing one standardized, low-cost methodology to use available technology and data to supplement and bolster measurement techniques. The results of the model can be improved further with additional regional insights complementing the three metrics used: (1) methane intensities, (2) super-emitters, and (3) flaring intensities. While every region and country are unique in terms of data availability and energy systems, each can improve the accuracy of its methane emission estimates by leveraging public free satellite data and AI technologies with ground-level assessments and benchmarking.

The perfect is the enemy of the good. The proposed integrated approach can overcome the shortcomings of the available technologies to provide an acceptable level of accuracy, so countries can invest resources in mitigation rather than debating the numbers. Raising awareness and providing tools to more accurately measure and track methane emissions at production, transport and consumption can only spur accountability and mitigation action.

As for next steps:

1. **IEF members can engage with their trade partners to agree on monitoring and verification standards**. Since this methodology provides energy producers and consumers with a basis for a common view of methane emissions and mitigation targets along the energy value chain, the IEF can facilitate these discussions in collaboration with the other international initiatives engaged on methane.
2. **The integration of top-down and bottom-up data will be an important milestone that allows energy players to identify and eliminate the majority of methane emission sources**. While the type of local sensors may vary between operators and regions, IEF members should continue to encourage these efforts, which are consistent with OGMP 2.0 Level 5 reporting guidelines.
3. **The methodology described in this report will evolve as the volume of data grows and as more advanced technology become available**, making it possible to cover a wider range of methane sources and fine-tune the results of the model. The IEF proposes to engage with its member countries to review on an annual basis the opportunities created by innovations in satellite analytics and update the methodology.

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