*Working paper – December 2025*

# Improving the Control of Methane Emissions Using Satellite Data: Context and Considerations for Policymakers

***Edward Parson, Cara Horowitz, Juan Pablo Escudero, Tiffany Deguzman*[1]**

## I. Introduction and background

There is a rapid expansion underway in the availability of atmospheric methane data. A suite of existing satellite-borne methane detection instruments—with more on the way—is measuring methane emissions in new ways, from new places, with new degrees of precision. However, most government regulators around the world working to control methane emissions do not yet fully understand this new data or what else is coming down the pike; what form(s) it will come in; how to access it; or how to best employ this data concretely in regulatory settings to maximize methane emission reductions. Although considerable work is being done at academic institutions and elsewhere to advance methane regulation generally, very few efforts are carefully examining the implications of this technological revolution for regulators. This paper—the latest in a series by the UCLA Emmett Institute on Climate Change and the Environment—is aimed at helping fill this gap by summarizing important information relevant to policymakers and assessing the ways that satellite data can support and enhance control of methane emissions.

To advance this project, the Emmett Institute first convened a two-day exploratory workshop at UCLA—featuring technical and policy experts, regulators and legislators, and satellite industry representatives—to discuss current and future applications of new remote sensing technologies in methane regulation. Panelists and participants at this convening discussed challenges, opportunities, current regulatory focuses, and visions for the future of methane regulation, particularly as these topics relate to improved methane remote sensing technology. Then, UCLA hosted an event at COP28 with the purpose of reviewing insights from the workshop, seeking broader consultation, selecting relevant case studies, and further developing lessons learned. Following these discussions, the Emmett Institute worked with partners on a series of publications and convenings aimed at making the technological advances in monitoring technology understandable for policymakers and other non-scientific audiences, especially those from developing jurisdictions.

[1] Edward Parson is the Dan and Rae Emmett Professor of Environmental Law and Faculty Director of the Emmett Institute on Climate Change and the Environment at UCLA School of Law. Cara Horowitz is the Executive Director of the Emmett Institute. Juan Pablo Escudero is a project affiliate based at the Universidad Adolfo Ibáñez. Tiffany Deguzman is the Shapiro Fellow in Environmental Law at the Emmett Institute. The authors particularly thank Ruthie Lazenby and Katelyn Zou for research assistance in support of this paper. All views in this paper are the authors' own and not those of the institutions with which they are affiliated; all errors are their own.

This paper highlights lessons from this work and shares two new case studies drawn from jurisdictions that are reforming their methane regulatory controls in ways designed to take advantage of advances in remote-sensing technologies, including satellites. We find that the data-to-action pipeline is not as straightforward as one might expect, for reasons that can relate to lack of access, lack of understanding, lack of trust, lack of capacity, lack of authority, lack of sufficient motivation, or other reasons. Nonetheless, we find and explore many opportunities to strengthen methane controls using data from satellites. Among our findings:

- We note commonalities in the incentives that can motivate actors to cut emissions once they know about them, which typically fall into three broad buckets: economic, legal or regulatory, and reputational.
- We discuss the advantages of integrating satellite observations with other validated technologies capable of directly capturing site-level emissions.
- We share lessons from a developing jurisdiction, the province of Chubut, Argentina, for ways to approach the creation of a flexible methane regulatory regime from scratch.
- We highlight opportunities for use of satellite data to improve the regulation of methane sources from the oil and gas and landfill sectors—giving an example of a jurisdiction, the U.S. state of Colorado, doing both.
- And we pay particular attention to emerging opportunities to employ satellite data for use cases beyond the improvement of jurisdiction-scale inventories or the detection of large point-source leaks, concluding that scales between point sources and entire jurisdictions can be important for policy and control.

## II. High-level summary of methane control strategies globally

To understand how new forms of satellite data may enhance the regulation of methane emissions, it is important to start with a strong understanding of the existing regulatory landscape. Global methane regulations can be grouped into two primary categories: (1) cross-sector regulatory policies and (2) sector-specific methane regulations.[2] Cross-sector regulations include jurisdiction-wide methane emissions reductions policies, methane emissions inventory and reporting policies, and market-based methane emissions policies.[3] Meanwhile, sector-specific regulations include fossil fuel methane policies, agricultural policies, and waste and landfilling policies.[4]

### A. Cross-sector methane policies

Jurisdiction-wide methane emissions reductions policies most often look like international, non-binding commitments or "pledges" establishing specific emissions reductions goals. At COP26 in November 2021, more than one hundred countries signed onto the Global Methane

[2] Gabriel Greif & Ruthie Lazenby, *Global Methane Regulation: A Summary*, UCLA EMMETT INSTITUTE, Nov. 2024, at 1, https://tinyurl.com/GlobalMethaneSummary.
[3] *Id.* at 1-7.
[4] *Id.* at 7-22.

Pledge.[5] The Global Methane Pledge constitutes a non-binding commitment to achieve a 30 percent reduction in methane emissions from 2020 levels by 2030. In support of this goal, the United States ("US"), European Union ("EU"), Japan, Canada, Norway, Singapore, and the United Kingdom ("UK") also released a Joint Declaration committing to advance new policies to achieve the methane reductions laid out in the Global Methane Pledge, with a specific aim of reducing methane emissions throughout the fossil fuel supply chain.[6] Later, in anticipation of the COP28 conference, the governments of the State of California; Queretaro, Mexico; Gauteng, South Africa; Espirito Santo, Brazil; Cross-River State, Nigeria; Yucatan, Mexico; and Delhi, India launched the Subnational Methane Action Coalition, which supports members in efforts to adopt methane action plans, set methane reduction goals, and establish methane inventories.[7]

In the time since these commitments were made, several jurisdictions—including the EU, Canada, and China—have enacted or are developing methane policies that aim to fulfill the goals of the Global Methane Pledge. For instance, the EU's plan leverages its buying power to require extraterritorial importers to submit source-level monitoring, reporting, and verification ("MRV") information and to abide by leak detection and repair protocols.[8] China's National Methane Action Plan, on the other hand, focuses on coal methane reduction and utilization, which is responsible for about 40 percent of China's methane total emissions.[9]

Policies of this nature, and methane emissions inventory and reporting policies in general, take advantage of the fact that nearly all countries and many subnational jurisdictions periodically issue greenhouse gas ("GHG") emissions inventories that include methane.[10] Parties to the United Nations Framework Convention on Climate Change ("UNFCCC"), for example, are required to report a GHG emissions inventory that provides an estimate of national emissions and of removals of direct GHGs (including methane).[11]

[5] *Global Methane Pledge* (Dec. 2021), https://www.ccacoalition.org/sites/default/files/resources//Global%20Methane%20Pledge.pdf.
[6] *Joint Declaration from Energy Importers and Exporters on Reducing Greenhouse Gas Emissions from Fossil Fuels,* EUROPEAN COMMISSION (Nov. 11, 2022), https://ec.europa.eu/commission/presscorner/detail/en/statement_22_6827.
[7] *California Enlists Governments Around the World to Fight Methane Pollution*, OFFICE OF GOVERNOR GAVIN NEWSOM (Sept. 20, 2023), https://www.gov.ca.gov/2023/09/20/california-enlists-governments-around-the-world-to-fight-methane-pollution/.
[8] *See* Pascal Canfin & Jutta Paulus, *May 2023 Amendments 001-267 to the EU Methane Proposal*, COMMITTEE ON THE ENVIRONMENT, PUBLIC HEALTH AND FOOD SAFETY (May 3, 2023), https://www.europarl.europa.eu/doceo/document/A-9-2023-0162-AM-001-267_EN.pdf; *see also* Tim Boersma & Robert Kleinberg, *Prospects for EU Extraterritorial Reduction of Methane Emissions From Its Natural Gas Supply*, COLUMBIA CENTER OF GLOBAL ENERGY POLICY (June 15, 2023), https://www.energypolicy.columbia.edu/publications/prospects-for-eu-extraterritorial-reduction-of-methane-emissions-from-its-natural-gas-supply/.
[9] David Stanway, *China Announces Plan to Curb Rising Methane Emissions But Challenges Await*, REUTERS (Nov. 9, 2022), https://www.reuters.com/business/cop/china-announces-plan-curb-rising-methane-emissions-challenges-await-2022-11-09/.
[10] *See* Greif and Lazenby, *supra* n. 2, at 4.
[11] United Nations Framework Convention on Climate Change, *Reporting and Review* (last visited Nov. 6, 2024), https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/reporting-requirements.

These forms of methane emissions inventories are generally produced using "bottom-up" emissions estimates, which are calculated by assigning emissions factors to activities that may release methane into the atmosphere (accounting for facilities, equipment types, production volume, herd sizes, and so on).[12] Due to the imperfections of bottom-up reporting, however, methane emissions inventories that countries submit to the UNFCCC often report far lower emissions than the International Energy Agency ("IEA") estimates based on its data.[13] Discrepancies are especially apparent where National Emissions Inventories are compared against "top-down" methane measurements, which are calculated by using remote sensing technology to detect atmospheric methane and infer methane emissions. Accordingly, several jurisdictions have since adopted or proposed more robust reporting and monitoring practices than the UNFCCC requires.

Several market-based emissions trading schemes ("ETS") also control methane emissions, either directly (by requiring compliance obligations for methane emissions) or indirectly (by allowing methane-control projects to generate offsets).[14] Permitted offset programs generally award credits—either to obligated or non-obligated parties—for voluntary methane emission reductions, including from agricultural and landfilling facilities. In addition to ETS programs, jurisdictions also incentivize methane emissions reductions using positive incentives (like subsidies or tax credits) or fees.

For example, California's ETS program (commonly referred to as cap-and-trade) covers a range of greenhouse gas emissions, including methane.[15] Under this program, covered sources, such as refineries and other large industrial facilities, must include methane emissions in their inventories and secure compliance instruments to cover those emissions. Other sources, such as facilities producing biogas and biomethane, are not subject to compliance obligations for those emissions, but claimed methane emissions reductions from these projects may be credited as offsets and transferred to (or used by) obligated parties to meet their compliance obligations.[16] In the EU ETS, although methane emissions have not historically been covered, recent amendments require the inclusion of methane emissions from the shipping sector beginning in 2026.[17] Similarly,

---

[12] Veldman, et al., *Remote Sensing of Atmospheric Methane: A Primer for Policymakers on the Science of Methane Satellites,* UCLA EMMETT INSTITUTE, 4 (Aug. 2025), https://tinyurl.com/SatellitesPrimer [hereinafter "Remote Sensing Primer"].
[13] *See* Int'l Energy Agency, *Understanding Methane Emissions*, 2023, https://www.iea.org/reports/global-methane-tracker-2023/understanding-methane-emissions; Penwadee Cheewaphongphan et al., *Exploring Gaps Between Bottom-Up and Top-Down Emissions Estimates Based on Uncertainties in Multiple Emission Inventories*, 11 J. SUSTAINABILITY 2054 (Apr. 9, 2019), https://www.mdpi.com/2071-1050/11/7/2054.
[14] *See* Greif and Lazenby, *supra* n.2 at 6.
[15] 17 Cal. Code Regs. § 95802, 95810; Katelyn Roedner Sutter, *California's Cap-and-Trade Program Step By Step*, ENVTL. DEF. FUND, 2 (2018), https://www.edf.org/sites/default/files/californias-cap-and-trade-program-step-by-step.pdf.
[16] 17 Cal. Code Regs. § 95852.1.1(a).
[17] *Directive (EU) 2023/959 of the European Parliament and of the Council*, EUROPEAN PARLIAMENT & THE COUNCIL OF THE EUROPEAN UNION (May 10, 2023), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023L0959&qid=1693429745420.

the UK recently announced its decision to expand its ETS to include methane emissions from the maritime sector beginning in July 2026.[18]

### B. Sector-specific regulations

According to the IEA, oil, coal, and natural gas operations accounted for more than 129 million tonnes of methane emissions in 2023, amounting to just over a third of anthropogenic global methane emissions.[19] Several jurisdiction-wide mandates exist to reduce emissions from the oil, coal, and natural gas sector.[20] For example, the State of Colorado, which is the fifth-largest producer of oil and gas in the US, adopted regulations requiring oil and gas producers to utilize direct emissions monitoring instruments and submit detailed emissions inventories to the state, which must then be certified by an independent, state-accredited auditor.[21] Other fossil methane policies generally regulate one of several sources of fossil fuel methane, including: (1) flaring and venting; (2) leak detection and repair; (3) orphaned and abandoned wells; and (4) coal and coalbeds.[22]

Agriculture is the world's leading anthropogenic source of methane emissions and is responsible for more than a quarter of total global methane emissions.[23] However, agricultural methane regulations are often less stringent than fossil fuel-focused methane abatement policies. Most policies that target methane from the agricultural sector utilize financial incentives and taxes or charges to abate agricultural emissions, rather than using prescriptive controls. Agricultural methane policies can generally be broken into three categories: (1) policies promoting digesters and biogas; (2) alternative manure management strategies; and (3) approaches to enteric emission reductions.[24]

Organic waste—particularly waste deposited in landfills—represents the third largest source of anthropogenic methane emissions.[25] Emissions from this sector are likely routinely underestimated because emissions models fail to account for underperforming gas collection systems, leaks, and incomplete flaring.[26] Much like dairy and livestock manure, methane is produced when organic waste decomposes anaerobically—outside the presence of oxygen—which typically occurs when waste is compacted at a landfill. Therefore, agencies generally regulate landfill methane through some combination of two strategies: (1) implementing methane

[18] UK Emissions Trading Scheme Scope Expansion: Maritime, 8 (July 2025), https://assets.publishing.service.gov.uk/media/687de724a5561a5a7e726bd9/uk-ets-maritime-interim-authority-response.pdf.
[19] Int'l Energy Agency, *Methane Tracker 2023* (updated March 13, 2024), https://www.iea.org/data-and-statistics/data-tools/methane-tracker.
[20] *See* Greif and Lazenby, *supra* n.2, at 8.
[21] Steve Hanley, *Colorado Adopts New Rules To Curb Methane Emissions*, CLEANTECHNICA (July 24, 2023), https://cleantechnica.com/2023/07/24/colorado-adopts-new-rules-to-curb-methane-emissions/.
[22] *See* Greif and Lazenby, *supra* n.2, at 9-16.
[23] Int'l Energy Agency, *Methane and Climate Change* (last visited Nov. 8, 2024), https://www.iea.org/reports/methane-tracker-2021/methane-and-climate-change.
[24] *See* Greif and Lazenby, *supra* n.2, at 16-19.
[25] Int'l Energy Agency, *Understanding Methane Emissions* (last visited Nov. 8, 2024), https://www.iea.org/reports/global-methane-tracker-2023/understanding-methane-emissions.
[26] Ellie Garland et al., *Mitigating Landfill Methane*, ROCKY MOUNTAIN INST. (June 9, 2023), https://rmi.org/wp-content/uploads/dlm_uploads/2023/06/landfill_monitoring_memo_series.pdf.

mitigation and utilization strategies at landfills; and (2) reducing landfilling of waste and encouraging composting.

### C. Challenges

Although the continued development and expansion of the methane regulatory landscape is promising, effective control of methane emissions has been hindered by the limited ability to reliably observe emissions directly. As mentioned above, historically, emissions estimates have used "bottom-up" methods, in which an observed level of some emissions-producing activity – e.g., volume of oil produced or number of cows – is multiplied by an "emissions factor" derived from prior research – e.g., methane emitted per barrel of oil produced or per cow – to yield an estimate of total methane emitted.[27] These types of estimates often fail to capture the full extent of methane emissions due to: (1) limits in the accuracy of production data, especially in the waste and agricultural sectors, and (2) reliance on emissions factors that neglect variation over time, location, and activity and are thus outdated and unrepresentative.[28] Accordingly, many direct observations have shown bottom-up estimates of methane emissions to be inaccurate, and in most cases, to seriously under-estimate actual emissions.

For these reasons, it is useful to supplement bottom-up estimates with direct observations of methane emissions, but until recently, direct observations of atmospheric methane required costly, limited-duration field campaigns with airborne or ground-based instruments.[29] This is where current advances in satellite-borne instruments and remote sensing can most transform our ability to observe methane directly and to improve methane emission estimates. Satellite instruments now enable more precise, complete, and reliable observations of atmospheric methane and estimates of emissions, and capabilities are advancing rapidly.[30] As detailed further throughout this paper, these advances will both strengthen current approaches to controlling methane emissions and enable new approaches not previously available or considered.

## III. The basics of satellite methane monitoring

### A. What is remote sensing?

Remote sensing is the process of gathering information (sensing) about an object of interest at a distance (remote) from the object. Remote sensing ("RS") can be used to observe a wide range of objects at a distance, including pollutants in the air.[31] RS instruments operate by sensing light that travels to the instrument from the thing being observed. RS instruments can be designed to see light of one wavelength, or several, or a wide continuous range of wavelengths. Remote sensing instruments are used to observe many characteristics of the Earth's surface, oceans, and

---

[27] Remote Sensing Primer, *supra* n.12, at 4.

[28] Shukla, et al., *Hunting Methane Using Satellites: A Guide for Policymakers*, UC BERKELEY CLEE & UCLA EMMETT INSTITUTE, 7 (Apr. 2025), https://tinyurl.com/HuntingMethane [hereinafter "Hunting Methane Guide"].

[29] *See* Remote Sensing Primer, *supra* n.12 at 5; *see also* Esparza, et al., *Analysis of a tiered top-down approach using satellite and aircraft platforms to monitor oil and gas facilities in the Permian Basin,* RENEWABLE & SUSTAINABLE ENERGY REVS., 178 (2023). https://doi.org/10.1016/j.rser.2023.113265.

[30] *See* Remote Sensing Primer, *supra* n.12 at 5. This summary of the science of methane detection satellites and how they work draws significantly from that earlier work in our series.

[31] *Id.* at 6.

atmosphere, and can be carried on a wide range of platforms. The most important environmental remote sensing is done from airborne or space-borne instruments carried on aircraft, balloons, drones, or satellites.[32]

Satellite instruments measure the brightness (or "radiance") of light reaching the instrument at each wavelength that the instrument is able to see.[33] Nearly all RS of atmospheric methane observes sunlight that has scattered from the target to the instrument. Methane and other atmospheric constituents can be seen by this method because their molecules interact strongly with light at highly specific wavelengths, affecting the brightness of light scattered back to the instrument at these wavelengths. Because each molecule of methane is identical, each one absorbs wavelengths of light in the same way, sometimes referred to as "the molecule's spectral signature or spectral fingerprint."[34] RS instruments can identify how abundant specific molecules are in the atmosphere by seeing their spectral fingerprints in the mix of wavelengths scattered back to the instrument.[35]

## B. Capabilities

Unlike with traditional bottom-up approaches, top-down approaches like remote sensing enable direct observation.[36] Airborne and satellite instruments are now capable of detecting and quantifying methane emissions at unprecedented scales. These instruments utilize infrared light to measure methane concentrations, which can be used to estimate emissions volumes and rates from a range of sources.[37] Satellites can observe vast areas, including regions previously inaccessible to efficient ground-based monitoring. They can also detect intermittent emissions, such as those resulting from maintenance events or sporadic leaks, and spot high-emitting point sources with precision. By combining satellite, airborne, and ground-based observations, it is now possible to create detailed pictures of methane emissions over large regions. Accordingly, by providing more accurate, widespread, and timely information, satellites allow policymakers and industry leaders to take more immediate action, thereby seizing major economic, health, and climate benefits.[38]

## C. Types of data

As mentioned previously, what these instruments actually measure is the brightness (or "radiance") of light reaching the instrument at specific wavelengths (determined by the instrument's spectral scope and resolution), at specific pixels at known locations ([39] by the instrument's spatial scope and resolution), at specific times.[40] From these measurements of wavelength-specific radiance, the first computational step toward making the data useful involves

---

[32] *Id.*
[33] *Id.* at 8.
[34] *Id.* at 9.
[35] *Id.*
[36] *See* Hunting Methane Guide, *supra* n.28 at 7.
[37] *See id.*; *see also* Remote Sensing Primer, *supra* n.12 at 7.
[38] *See* Hunting Methane Guide, *supra* n.28 at 8.
[39] *See* Remote Sensing Primer, *supra* n.12 at 16.

calculating how much methane is in the atmospheric column between the instrument and the Earth's surface. This can be expressed as the total number of methane molecules in that column of air (column abundance), or as the fraction of methane in that air column. The latter form – methane fraction or average concentration – is easier to understand and use, because it does not vary with land elevation, air pressure, or humidity.[41]

This calculation depends on knowing how radiation of different wavelengths is absorbed and re-emitted by all the gases in the vertical column of air the instrument is observing. These processes are represented by quantitative "radiative-transfer models."[42] In their normal use, radiative-transfer models take as inputs how much of each gas is present at each height in the atmosphere and calculate the resultant radiation. In the case of methane, we don't know how much methane is present in the atmosphere but instead must calculate it from the observed radiation. This calculation, reversing the model's outputs and inputs, effectively runs the model backwards in a process called inverting the model or retrieving the column methane.

Then, turning the map of column methane produced by this retrieval process into an estimate of methane emissions from particular sources requires a second computational step.[43] For larger areas, from tens of kilometers square to continental or global scales, the aim is usually to quantify average emissions and trends over periods from weeks to years. These estimates can be used to attribute emissions to area sources, to make or check jurisdictional emissions inventories, or to measure trends to assess effectiveness of emissions-control measures. Since area source emissions are more consistent over time than leaks or point sources, estimates for these larger areas can be based on many repeated observations.[44]

## D. Limitations

Although there are many advantages to remote sensing, this method of information gathering is not without its limits. The primary limitation comes from the uncertain spatial coverage of satellites—meaning that the quality of measurements depends on surface, weather, and sun-angle conditions, measurements cannot be made at night or in polar winter, and they can fail due to clouds or surfaces that are too bright (ice and snow) or too dark (water, except with special viewing techniques).[45] These conditions introduce consistent regional and seasonal limits to reliable observations. Other limitations include: (1) the intermittency of observations, and related challenges of consistently integrating diverse data sources to reduce intermittency; (2) data availability, timeliness, and cost, as well as policy-makers' capacity to utilize it; (3) policy-makers' willingness to rely on and respond to data produced by diverse entities (national governments, IGOs, non-profits, private firms) based in multiple jurisdictions; (4) industry cooperation and engagement in developing, interpreting, and responding to new data; and (5) reliability of continued availability of data and terms of access.[46]

---

[41] *Id.*
[42] *Id.* at 17.
[43] *Id.*
[44] *Id.*
[45] *Id.* at 23.
[46] *See* Remote Sensing Primer, *supra* n.12 at 23.

## E. Typical use cases

There are many opportunities for governments and policymakers to use the data collected by methane-detecting satellites, including: (1) the development of new emissions inventories informed by direct observation, (2) the verification of existing inventories based on new and refined data, (3) fast reporting to help authorities and businesses respond to leaks, (4) identification of major point sources, and (5) refining descriptions of emissions variability across time, location, and source activity.[47]

More specifically, remote-sensed data can improve the accuracy of jurisdictional emissions inventories by incorporating observed leaks or other uncounted emissions and by correcting emissions factors.[48] Satellite or other remote sensing data can supplement and improve inventories by incorporating omitted sources, correcting emissions factors, and providing a stronger understanding of temporal variation of emissions, both daily and seasonal. Nonetheless, remote sensing, alone, cannot give a reliable and complete picture of regional emissions. This is due to challenges associated with emissions sources that are intermittent or spatially diffuse, as well as barriers presented by weather, surface conditions, and sun angle. There is growing interest, however, in hybrid estimates that combine multi-pass aerial measurements with bottom-up measurements of sources that are challenging or costly to measure directly. While researchers continue to integrate remote sensing data with *in situ* and bottom-up data, ongoing advances will provide new opportunities to improve emissions transparency, identify profitable opportunities to cut emissions, and help jurisdictions tailor their reduction efforts to their individual needs.[49]

Another well-developed use case involves leak detection and notification.[50] As remote sensing technologies have advanced, governments have recognized their utility to detect previously hidden methane leaks, particularly from high-emitting events. Satellite operators and others are now sharing information about major emissions events with source operators and governments. For example, NASA has historically used methane detection instruments, including satellites and airplanes, to notify operators and authorities of large methane plumes. In 2015 and 2016, for instance, NASA employed satellites to detect gas during a major methane leak near Porter Ranch, California.[51] Today, such efforts have become more widespread and regularized. The United Nations' International Methane Emissions Observatory ("IMEO") operates the Methane Alert and Response System ("MARS"), which regularly notifies jurisdictions about major emissions events detected by a network of satellites, with the goal of prompting leak repair.[52]

---

[47] *See* Hunting Methane Guide, *supra* n.28 at 17-20; *see also* Parson, et al., *Advancing Methane Regulation: Implications of New Monitoring Technologies Discussion Paper*, UCLA EMMETT INSTITUTE, 1 (Dec. 2023), https://tinyurl.com/TechDiscussionPaper [hereinafter "Advancing Methane Regulation Discussion Paper"].
[48] Advancing Methane Regulation Discussion Paper, *supra* n.46 at 8.
[49] *See* Hunting Methane Guide, *supra* n.28 at 19-20; Advancing Methane Regulation Discussion Paper, *supra* n.46, at 8; *see also* Environmental Defense Fund, Comments to US EPA: Docket No. EPA-HQ-OAR-2023-0234, 17-18 (2023), https://www.edf.org/sites/default/files/2023-10/EDF%20CATF%20et%20al.%20Subpart%20W%20Comments%2010.2.2023%20FINAL.pdf.
[50] *See* Hunting Methane Guide, *supra* n.28 at 20.
[51] *Id.*; *see also* Earth Observatory, *Imaging a Methane Leak from Space* (2016), https://earthobservatory.nasa.gov/images/88245/imaging-a-methane-leak-from-space; Earth Observatory, *Mapping Methane Emissions in California* (2020), https://earthobservatory.nasa.gov/images/148806/map-ping-methane-emissions-in-california.
[52] United Nations Environment Programme, *About IMEO* (2024), https://www.unep.org/topics/energy/

The California Air Resources Board ("CARB") has also developed a sophisticated leak detection and notification process.[53]

## IV. Case studies: Colorado's and Chubut's approaches to using satellite data to improve methane control through regulation

Data from methane monitoring satellites are increasingly being incorporated into policy, legal, and regulatory contexts. Analyzing examples of how governments are starting to use this technology to enhance methane control through regulation gives us a better idea of how to support local, state, and national governments in these efforts going forward. Below, we look particularly at work underway in the U.S. state of Colorado and in the Argentinian province of Chubut. Examining efforts across these two jurisdictions is useful because the two case studies provide insights into the impact and utility of these data at different stages of regulation and in different social and economic circumstances.

Colorado, in particular, offers an interesting middle-ground use case for satellite data in methane regulation. In contrast to the two most common use cases that have been seen in other contexts—to support broad jurisdictional emissions inventories on the one hand, or detection of point-source leaks on the other—Colorado uses satellite monitoring at a scale in between those two, to help implement an emissions intensity limit imposed by regulation on clusters of upstream sources in the oil and gas industry. In so doing, Colorado is pioneering a new approach to using satellite data to advance and improve regulatory limits on industrial pollution.

Our second case study examines the Province of Chubut, a subnational jurisdiction in Argentina that has recently taken pathbreaking steps toward regulating methane emissions from the hydrocarbon sector. Unlike Colorado, which has a more mature regulatory framework, Chubut provides an important example of a jurisdiction in the very early stages of regulatory development.

### A. Colorado's oil & gas and landfill regulations

The U.S. state of Colorado has developed a unique regulatory approach to controlling methane emissions from certain segments of the oil and gas industry, an approach designed to take advantage of ongoing improvements in methane observation technology. We describe that approach here and draw lessons for other jurisdictions, especially those with significant regulatory capacity. At bottom, Colorado's approach adopts an emissions-intensity limit for certain clusters of oil and gas facilities—those associated with the production of oil and gas—and creates incentives for operators to develop and use newer and more reliable emission observation and validation techniques to comply with the regulation, including, potentially, techniques using remote observation and satellite data. This regulatory design is clever, creative, and well positioned both to overcome the limits of traditional bottom-up methane emission inventories and to encourage—and exploit—advances in remote sensing capabilities.

---

methane/international-methane-emissions-observatory/about-imeo.

[53] *See* Hunting Methane Guide, *supra* n.28 at 20.

Notably, Colorado is now also turning to the task of updating its landfill regulations to better control methane emissions. As with its oil and gas control programs, and as described further below, its proposed landfill regulations are being developed to accommodate uses of satellite data in novel ways.

### 1. Socio-economic and regulatory background

Colorado is the eighth largest state in the United States and has a population of nearly six million. The state has abundant oil and gas resources, concentrated in the Niobrara Shale Formation in the northeastern part of the state. Though Colorado has vast rural regions, the state's population is primarily concentrated in areas developed enough to be considered "urban" by the U.S. Census. In both population and area, it is similar in size to New Zealand.[54]

The fossil fuel industry's presence in Colorado is robust, but the state's economy is nevertheless diverse: finance, insurance, real estate, professional and business services, and government are the largest contributors to the state's GDP.[55] Additionally, the state has a strong technology industry. Most of the state's methane emissions come from the oil and gas and agricultural sectors. According to Colorado's Greenhouse Gas Roadmap, the combination of oil and gas systems and enteric fermentation contribute 86% of methane across the state and 26% of all greenhouse gas emissions.[56] The oil and gas sector is the third largest source of greenhouse gas emissions overall in Colorado and the largest source of the state's methane emissions, followed by enteric fermentation.

The primary legal authority for the state's greenhouse gas emissions program is Colorado House Bill 19-1261, which sets greenhouse gas targets for the state and requires a state environmental agency, the Colorado Air Quality Control Commission ("CAQCC"), to promulgate implementing regulations. CAQCC has developed a multi-part program to reduce emissions from the oil and gas industry, relying on its general state statutory authority and specific mandates to meet evolving statewide targets, alongside some U.S. federal authority through the federal Clean Air Act.

### 2. Use case application: Colorado's upstream oil and gas regulations

Colorado regulates methane emissions from many segments of the oil and gas industry, including upstream, midstream, and downstream sources. This case study focuses on Colorado's regulation of methane from oil and gas production equipment and operations, which state law refers to as the "upstream" segment. The upstream segment covers production sites, where operators drill wells to bring oil and gas to the surface and collect it using equipment like wellheads, separators, storage tanks, and compressors. Emissions from the upstream sector are primarily fugitive emissions and can be dispersed over many small sites and come from a range of sources, including pneumatic devices that can bleed; storage tanks that can leak; wells themselves,

[54] U.S. Census, *Colorado Quick Facts*, https://www.census.gov/quickfacts/fact/table/CO/PST045224.
[55] US Energy Info. Admin., *Colorado State Profile*, https://www.eia.gov/state/analysis.php?sid=CO.
[56] *See* Colo. Dep't of Pub. Health and Env't, Colorado Greenhouse Gas Inventory, https://cdphe.colorado.gov/environment/air-pollution/climate-change/GHG-inventory.

which can produce gas before infrastructure is ready to receive it; and leaky equipment like valves, flanges, and pumps.

Colorado's methane rules for the upstream sector impose a binding emissions intensity standard that applies across all such equipment. An emissions intensity standard caps emissions per unit of production (expressed in $CO_2e$/BOE) for upstream operators. Under this standard, upstream operators must meet specific greenhouse gas intensity targets for their pre-production and production emissions[57] and demonstrate their compliance with those targets using emissions inventories.[58] Upstream operators must comply with the greenhouse gas intensity targets each year or achieve additional emissions reductions in the following year to address the difference.[59]

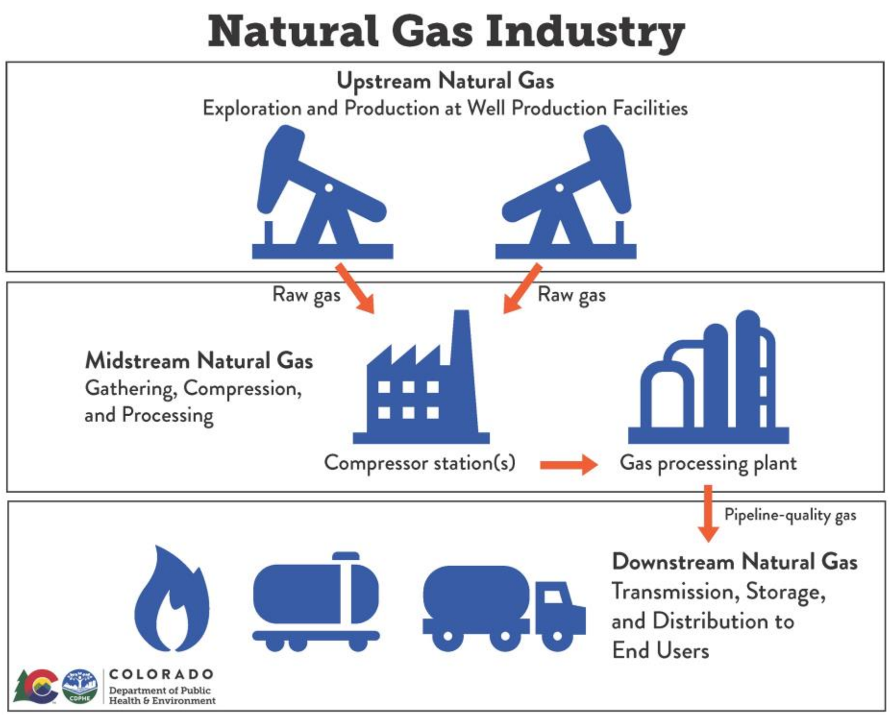


Figure 1 from Colo. Dep't Pub. Health & Env't

Relevant to the use of satellite data, Colorado's real regulatory innovation comes from its rules around how operators must inventory and report their emissions to document compliance with emissions intensity caps. Colorado's rules call for operators to produce a so-called "measurement-informed inventory" of their upstream emissions, used to calculate the greenhouse

[57] Pre-production refers to emissions that occur "during the construction and operation of the oil or natural gas well until the well commences operation, including from the drilling through the hydrocarbon bearing zones, hydraulic fracturing or refracturing, drill-out, and flowback of the oil and/or natural gas well." 5 Colo. Code Regs. § 1001-9:B.VIII.A.26. Production emissions are emissions generated "after the well commences operation." 5 Colo. Code Regs. § 1001-9:B.VIII.A.27.

[58] 5 Colo. Code Regs. § 1001-9:B.VIII.

[59] 5 Colo. Code Regs. § 1001-9:B.VIII.B.1 ("An intensity operator that fails to achieve any of the applicable targets in Section VIII.B. must achieve additional reductions in preproduction and/or production emissions in the subsequent calendar year to address the difference between the intensity operator's reported greenhouse gas intensity for that calendar year and the applicable target.")

gas intensity of their operations. Measurement-informed inventories differ from ordinary, bottom-up emissions estimates in ways that are designed to increase their accuracy. Under Colorado's rules, a measurement-informed inventory can be developed in one of two ways: Either (1) by starting with a traditional bottom-up estimate of emissions and multiplying that estimate by a numerical factor, set by Colorado, aimed at correcting for typical emission undercounts; or (2) by designing a custom, higher-quality inventory methodology that more precisely shows an operator's actual emissions, potentially by making use of remote-sensed or other direct observations.[60]

Under the first of those methods, Colorado sets an appropriate multiplication factor—which it calls a default verification factor—based on information available to it, with the goal of making emissions estimates more accurate. In essence, default verification factors are evidence-based multipliers applied to operations' bottom-up emissions estimates, intended to help correct typical emissions underestimates.[61] If the state's default verification factor is unfavorable relative to the uncertainty range of actual emissions, operators have every incentive to use the second inventory method instead, taking advantage of more sophisticated methane-detection techniques to create a more accurate inventory. In each case, CAQCC's Verification Protocol details the specific methods and measurement technologies that are permitted.[62]

At bottom, Colorado's measurement-informed inventory rules are intended to enhance and improve the accuracy of emissions estimates, including through the use of direct measurement techniques.[63] The measurement-informed inventory is a particularly novel feature of Colorado's greenhouse gas intensity program, designed to respond to well-founded critiques of bottom-up estimates by supplementing them with data to improve precision and to account for emissions that bottom-up accounting might miss.

These inventory rules have several key design features relating to satellite monitoring that are worth mentioning. First, the rules currently allow for the use of satellite monitoring, although only in limited ways. Colorado may use data from satellites, for example, to help determine its default verification factor, alongside other methods.[64] And operators may design and use custom intensity verification programs that incorporate satellite data as a supplement to other measurement strategies. For the current reporting period, the Protocol allows for the supplemental use of satellite data "to build upon the data collected from other technologies specified in their measurement strategy,"[65] while prohibiting from relying on satellite monitoring as a sole or central strategy for their measurement-informed inventories.

Second, the rules are structured to reflect evolving technologies, including improvements in satellite detection capabilities. Generally, if operators opt for the custom approach, the Verification Protocol puts the onus on the operators to determine their systemwide emissions and

---

[60] 5 Colo. Code Regs. § 1001-9:B.VIII.F.3.b.
[61] *Id.*
[62] Oil and Natural Gas Methane Intensity Verification Protocol at 6 (May 2024), [https://cdphe.colorado.gov/oil-and-gas-greenhouse-gas-intensity-program](https://cdphe.colorado.gov/oil-and-gas-greenhouse-gas-intensity-program) [hereinafter Verification Protocol].
[63] Verification Protocol at 5. "Parametric Measurement" means regional, local, stationary source, or air pollution source monitoring of pressure, temperature, flow rate, control efficiency, or other operational characteristics used to inform quantification of greenhouse gas emissions.
[64] *Id.* at 10, 12.
[65] *Id.* at 22.

design a measurement strategy to capture these emissions.[66] Operators using custom verification programs must develop a measurement strategy and are subject to third-party audits. While operator-specified programs in the current reporting period must use one of three approved measurement strategies developed by the state, in later years operators will be permitted to design their own programs, drawing on whatever best technology is fit for purpose and justifiable. It is anticipated that those programs may incorporate satellite data in the future, as the technology advances.

Indeed, the Verification Protocol explicitly acknowledges rapidly evolving satellite technology, stating, "the division recognizes that existing and soon-to-be-operational satellites will be providing worldwide coverage of large emission sources ≳100 kg/hr. The majority of these have been validated with appropriate testing27 [sic]."[67] Starting in 2027, operators will have the freedom to develop their own measurement strategies beyond the state-approved measurement strategies currently in place. The Division must review and approve those customized strategies on an annual basis, and this new freedom could open up space for the incorporation of satellite monitoring, if operators can justify its use.[68]

Lastly, the measurement-informed inventory, by design, incorporates an incentive for industry to invest in improving methane control and monitoring technologies over time. Colorado's novel regulatory design gives operators incentives to conduct observations, validation, and control activities to show overall compliance that may include effective or low-cost options that the regulator could not have directly required them to do. It thus leverages operator incentives to extend otherwise incomplete regulatory authority.

#### 3. Use case application: Colorado's landfill regulations

Colorado is now also exploring the use of satellite methane data to help refine its regulation of landfills. In April of 2025, Colorado proposed a new rule related to methane emissions from landfills, which contribute about 1.1% of the state's methane emissions.[69] The new rule, if adopted,

---

[66] *Id.* ("Because the methane detection and measurement world is evolving, the division cannot provide a complete set of decision points for operators to consider when developing a measurement strategy. Instead, operators should review division-developed measurement strategies, relevant guidance from the division or otherwise, published materials on technologies and methods, and operational experience to develop a measurement strategy appropriate to their operations. The division recommends operators consider utilizing multiple measurement techniques and/or technologies to account for various measurement scenarios and variables."), 24 ("Emissions occur due to a variety of factors. Some are steady-state, others intermittent. Some are seasonal, others year-round. Operators must consider how to effectively monitor the range of operations to capture unpredictable events. The measurement strategy must account for the potential in variations (e.g., frequency, duration, magnitude, seasonality, etc.) of emissions from operations and activities. Any assumptions about facility type emission profiles must be documented and explained.")

[67] *Id.*

[68] *Id.* at 22.

[69] Tim Taylor, *Colorado Landfill Methane Rule Proposal Presentation, Speaker Session III: Colorado's Energy and Waste Methane Strategy,* SUBNATIONAL METHANE ACTION COALITION, 3 (Dec. 18, 2024), https://oitco.hylandcloud.com/cdphermpop/docpop/docpop.aspx?docid=34183151 [hereinafter Taylor Presentation]; Colo. Dep't Public Health & Env't, *Landfill Methane Reductions in Colorado*, https://cdphe.colorado.gov/landfill-methane-reductions-in-colorado.

would permit the use of satellite monitoring as part of a remote monitoring program aimed at improving the estimation of methane emissions coming from the state's landfills.[70]

Under federal U.S. EPA rules, landfills in Colorado are already required to install and control emissions with gas collection and control systems if they meet certain criteria based on design capacity (the maximum quantity of waste they are designed to accept) and when non-methane organic compound emissions reach certain thresholds.[71] Colorado's proposed rule would expand the criteria for the use of gas collection and control systems. The proposed Colorado rule is expected to require gas collection and control systems based, in part, on a trigger that depends on current methane emissions generated by the landfill. Overall, the effect of the rule will be to expand the number of landfills operating gas collection and control systems.

The new Colorado rule is expected to include a role for alternative monitoring technologies, including remote monitoring by satellites, in determining landfill methane emissions. According to state agency staff designing the rule, alternative monitoring technologies "can allow for quicker and more comprehensive monitoring of landfills, and monitoring of difficult or dangerous areas of a landfill that previously may have been exempt from monitoring."[72] Staff also acknowledge that recent studies have "demonstrated the effectiveness of remote methane monitoring in identifying emissions from MSW landfills."[73] Under the proposed rule, remote monitoring, including satellite monitoring, would need to be conducted by approved third party monitoring entities.[74]

If adopted, Colorado's potential use of monitoring technologies,[75] both surface emissions monitoring and remote monitoring, would be distinctive. Indeed, the remote monitoring requirements were described in a December 2024 public workshop on the rule as a "somewhat unique" requirement, since remote monitoring is not currently found in other state or federal rules.[76] The regulatory design expected from the landfill rule has several similarities with the oil and gas rule discussed above. Like the oil and gas measurement-informed inventory, early discussions of the landfill rule include both bottom-up estimates of methane emissions based on the amount of waste in the landfill, along with actual measurements of methane emissions onsite. Also as in the gas context, the proposed approach provides flexibility for regulated parties to adopt a default approach to emission estimates or to conduct their own monitoring. Not only would this provide flexibility for operations, but it could create an incentive for operations to develop methods and technologies to conduct such monitoring.

### 4. Lessons for other jurisdictions

[70] 5 Colo. Code Regs. § 1001-33 (Proposed Rule), 65, *available at* https://drive.google.com/file/d/1hGoGAy76PV6EzOhPlR8NnrCJeMEYFpZp/view.
[71] Taylor Presentation at 4.
[72] *Id.* at 11.
[73] *Id.*
[74] *Id.*
[75] Colorado plans to include a broader range of alternative monitoring technologies. One proposal includes adapting Colorado's Approved Instrument Monitoring Method from the oil and gas sector for landfill use. Taylor Presentation at 21. In the December 2024 public workshop, speakers expressed interest in adapting new technologies to the use of landfill monitoring.
[76] Taylor Presentation at 13.

The Colorado example provides a few lessons for other jurisdictions considering whether and how to incorporate methane data from satellites into their regulatory regimes.

### a. Creative and highly customized approach

Colorado has creatively designed regulatory approaches that account for the strengths and weaknesses of satellite data, tailored to Colorado's unique characteristics. Colorado regulators carefully hewed their regulatory proposals to their legal authorities to ensure legal defensibility, while using those legal authorities creatively to maximize co-benefits. This approach was made possible in Colorado in part due to strategic use of the state's enforcement authority over many years. In designing these novel approaches, Colorado regulators gathered data through enforcement settlements to learn more about regulatory gaps and how to strengthen the state's air quality regime.

### b. Strategic use of an emissions intensity standard

Emissions intensity-based regulations can be more politically palatable than absolute emissions caps in some circumstances. They could be a good option for jurisdictions with powerful, high-emitting industries and strong political obstacles to absolute caps. An emissions intensity standard can also help encourage emissions reductions from parts of a system not typically governed by regulation or where statutory authority for direct regulation is absent. Satellite monitoring can help backstop intensity-based programs by groundtruthing bottom-up estimates with actual, localized emissions data across a set of tightly-spaced equipment.

### c. Adoption of strong default verification factors to improve emissions estimates, encourage better performance, and incentivize advances in measurement technology

By setting strong default verification factors—that is, evidence-based multipliers of typical bottom-up emissions estimates, applied to help correct emissions underestimates and avoidable only through individualized verification that meets certain evidentiary standards—Colorado goes fairly far toward solving the problem of inaccurate bottom-up emissions estimates. It simultaneously encourages oil and gas operations to develop their own verification strategies and to invest in improvements in measurement and monitoring technologies. Operations have an incentive to avoid the use of default factors through better measurement. And as default verification factors change and potentially increase over time, they also create an incentive for improved operations.

### d. Uses beyond the oil and gas sector

Colorado's proposed landfill regulations show the benefit of looking beyond the oil and gas sector when considering how to use satellite data to improve methane regulation. Landfills present an especially strong case for satellite observations, because emissions from landfills: (1) tend to be difficult to measure accurately in other ways; (2) are relatively geographically isolated from other distinct sources of emissions, due to landfill size; and (3) are sufficiently persistent and constant over time to be reliably captured by satellite overpasses.

## B. Chubut

Chubut is a province in Argentina that is among the first in its region to create a regime for control of methane emissions from the oil and gas sector. We use this case study to explore how subnational governments in emerging economies can begin to craft rules for methane control. First, we describe Chubut's economic and industrial context, highlighting its importance as one of Argentina's most significant oil producing regions. Second, we review the scope and provisions of the province's newly adopted methane regulation, paying particular attention to how the rule is structured as a framework that requires further implementing regulations. Third, we assess the challenges and opportunities of applying satellite and remote sensing data in Chubut's regulatory environment. Finally, we consider what lessons can be drawn from Chubut's early regulatory efforts for other jurisdictions in Latin America and beyond, especially where capacity and resources to enforce methane rules remain limited.

### 1. Background (general info, geography, economic activities)

Chubut is one of Argentina's 23 provinces and one of the five Patagonian provinces. It covers 224,686 square-kilometers and has a population of about 62,000.[77] As with the other provinces, Chubut has its own constitution and legislative powers. The province of Chubut represents 2.2% of the Argentinean GDP. The most significant productive activity is hydrocarbon extraction. Chubut is the second-largest oil producer in Argentina (behind Neuquén), and it is responsible for up to 27% of the country's total production. Chubut is Argentina's largest conventional crude oil producer, producing 40% of the country's total. It is Argentina's fifth-largest jurisdiction in gas production and its only aluminum-producing province. Chubut is the first province in Argentina, and one of the few jurisdictions in Latin America, to regulate methane emissions from the oil and gas sector.[78]

### 2. Emissions profile

Chubut does not yet holistically measure or inventory its methane or GHG emissions. Emissions estimates for the province come only from disaggregating the national greenhouse gas inventory. However, this inventory includes only those emissions sources and sinks for which information is available, in accordance with Intergovernmental Panel on Climate Change (IPCC) principles. Therefore, many sources are not captured in these measurements—e.g., abandoned

[77] Official information about the Province of Chubut is available at: https://www.argentina.gob.ar/chubut

[78] Ministerio de Economía de la Argentina, *Informe Productivo Provincial de Chubut* (2022), chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.argentina.gob.ar/sites/default/files/40_2022_chubut.pdf

wells—and the inventory does not account for potential emissions from leaks in aging infrastructure, nor the actual condition and scale of all facilities in the province.

The nonprofit organization Climate Trace provides estimates of GHG emissions worldwide and makes the data publicly available. According to Climate Trace, methane emissions estimations from fossil fuel operations from the Province of Chubut, measured in tons of methane emitted, are: 4.75Kt for 2021, 4.67Kt for 2022, 4.91Kt for 2023, and 4.67Kt for 2024.[79] For context, according to Climate Trace, the Province of Neuquen—Argentina's largest oil and gas producer—has significantly higher methane emissions, reaching up to 900Kt for 2024.[80] The energy sector is responsible for at least 50% of Argentina's GHG emissions, and it is the second-largest methane emitter after agriculture.[81]

Although its methane emissions are not as high as in some other provinces, Chubut is taking quite seriously opportunities to better assess its emissions and to further reduce them. It is making remarkable efforts in understanding its methane emissions from oil and gas. For example, the provincial government, through the Secretariat of Environment and Sustainable Development Control, has launched a campaign to measure fugitive methane emissions in the Golfo San Jorge Basin, in collaboration with the IMEO and McGill University. Thus far, the campaign has surveyed more than 60 abandoned oil wells operated by major companies in the basin.[82]

### 3. Laws and regulations

#### a) Federal regulations

The federal government in Argentina has made some, though limited, efforts to regulate methane emissions. For example, Resolutions 236/1993 and 143/1998 set maximum permissible gas-to-oil ratios for production wells. If emissions exceed these ratios, companies are required to flare excess gas rather than vent it directly into the atmosphere. The gas-to-oil threshold established is 1,500 $m^3$ of gas per $m^3$ of oil produced. These rules apply to all holders of exploration permits and exploitation concessions and allow for exceptions only under defined circumstances. Provinces, which hold jurisdiction over hydrocarbon resources, may adopt stricter standards. The Province of Neuquén, for example, has established stricter standards with a gas-to-oil limit of 1:1.[83]

---

[79] $CH_4$ emissions from fossil fuel operations: Province of Chubut, Argentina, CLIMATE TRACE, https://climatetrace.org/explore#admin=Chubut--%20ARG:375:ARG.4_1:state&gas=ch4&year=2023&timeframe=100&sector=fossil-fuel-operations&asset=3588595

[80] *Id.*

[81] Munno Dithurbide, G., *Mitigación de emisiones de metano desde el sector energético en Argentina. Avances, desafíos y propuestas frente a la emergencia climática,* BUENOS AIRES, FUNDACIÓN AMBIENTE Y RECURSOS NATURALES (2025), https://farn.org.ar/wp-content/uploads/2025/04/Mitigacion-de-emisiones-de-metano-desde-el-sector-energetico-en-Argentina.pdf.

[82] Secretaría de Ambiente y Control del Desarrollo Sustentable del Chubut, *Chubut avanza en el control de emisiones de metano en la cuenca del Golfo San Jorge*, (May 20, 2025), https://ambiente1.chubut.gob.ar/2025/05/20/chubut-avanza-en-el-control-de-emisiones-de-metano-en-la-cuenca-del-golfo-san-jorge/.

[83] Munno, *supra* n.81.

The Argentinean parliament is currently discussing a bill on methane control called "Minimum Environmental Protection Standards for Methane Emissions Management in the Hydrocarbon Sector."[84] The bill aims to establish minimum protection standards for managing methane emissions from the oil and gas sector, specifically in the exploration, exploitation, transport, and refinement of these products, with the intention of reducing their environmental impact. The specific goals of the bill are to: (i) improve air quality, (ii) prevent, quantify, control and reduce methane emissions; (iii) reduce flaring; and (iv) improve and promote transparency. The bill establishes a National Methane Emissions Reduction Plan ("PNREM") that must be developed within 1 year of the law's enactment. This plan will define sector-specific emission intensity limits, outline required technologies and practices for methane mitigation, and establish methodologies for detection, quantification, and emission factors.

b) **Chubut's methane rule**

In October 2024, the Province of Chubut published Resolution No. 58/2024, establishing guidelines for detecting, controlling, monitoring, quantifying, and reducing methane emissions from the oil and gas sectors.[85] Its objectives include improving air quality and public health, strengthening leak detection and control, contributing to methane-reduction commitments across sectors, and improving data provision and public access to information.

The Resolution applies to hydrocarbon exploration, exploitation, and transportation in continental areas and jurisdictional waters, and to all natural and legal persons conducting such activities. It prohibits venting from oil or gas well testing except in exceptional, temporary, and authorized safety cases, in which vented gas must be burned. Obligated parties must submit a Methane Emissions Management Plan within twelve months of the Resolution's passage and periodically thereafter. Management plans must include an asset inventory, identification and classification of emission sources, annual quantification of methane emissions, measurement methodology, and a natural gas flaring program.

It also requires an annual Leak Detection and Repair ("LDAR") program for new and existing facilities, with monitoring, leak identification and classification, repair or replacement plans, and annual reporting. Leak detection must use optical gas imaging, infrared cameras, or equivalent equipment, complemented by technical, visual, or tactile inspections, and supported by aircraft, drones, or other techniques. Equipment found leaking must be labeled; non-repairable equipment must be replaced under a defined plan; and inspection records must be kept for 5 years.

The regulation names the Secretariat of Environment and Sustainable Development as the enforcement authority, responsible for overseeing compliance, approving and supervising reports, developing inventories, administering a public website on methane emissions, and establishing technical regulations, including possible emission-intensity limits, reduction programs, and

[84] More information about this bill is available at the website of the Cámara de Diputados Argentina: https://www.hcdn.gob.ar/diputados/mmaquieyra/proyecto.html?exp=2898-D-2024
[85] Province of Chubut, Resolution 58/2024, https://www.marval.com/archive/a_newsletters/Chubut-%20Resoluci%C3%B3n-%2058-2024.pdf.

offsetting schemes. The Secretariat may conduct audits and must publish information on emissions, collected funds, and sanctions.

Since the Resolution's publication, all obligated parties have submitted emission reports by September 2025, though the methodologies differ in some cases. In response, the provincial authority is developing and implementing regulations to standardize reporting and ensure effective control. The Province is currently drafting the regulations needed to implement the methane rule, with government and stakeholders discussing priorities, including defining mechanisms for quantifying and reporting emissions.

Importantly, Chubut's scheme is designed in a manner that could allow for the use of satellite data over time. The Resolution does not include specific provisions regarding the use of satellite data, but it is expected that forthcoming implementing regulations will allow satellite monitoring to be used as one of the technologies for site-level methane emission quantification, provided that satellite observations are integrated with other validated technologies capable of directly capturing site-level emissions. Exclusive reliance on satellite data to meet site-level measurement obligations would not be permitted.

Looking beyond the Resolution, Chubut has already served as a successful example of satellite technology being applied to mitigate significant methane leaks. In November 2024, IMEO's MARS triggered an alert for a methane leak in a well in the Province of Chubut, emitting at a rate estimated at approximately 4.2 tons per hour. The alert was subsequently verified through an on-site inspection, and the leak was repaired by the owner of the facility within weeks. This case represents the first successful example in Argentina of methane-emission mitigation resulting from the detection of an event via satellite monitoring.[86]

### 4. Takeaways for other jurisdictions

The regulatory process in Chubut is in its early stages, with practical implementation steps still underway. Nevertheless, it is significant that Chubut is pushing forward with the first regulation on methane emissions in a major Latin American oil-producing country. Although the scale of Chubut's methane emissions is not as significant as those of other provinces like Neuquén, Chubut's efforts will serve as an example for other provinces, so its success is crucial. A central challenge will be ensuring that companies comply with the regulation and contribute constructively to its implementation, particularly medium and smaller-sized operators, many of which have entered the province in recent years. Without sufficient support, such operations may struggle to comply with the Regulation's provisions because of lack of capacity.

Other developing-country jurisdictions could follow in Chubut's footsteps in important ways. For provinces without a history of regulating methane, Chubut illustrates the utility of beginning the work with a general framework that establishes guidelines for detecting, monitoring, quantifying, and reducing methane emissions from the oil and gas sectors. Putting in place basic monitoring requirements, annual reporting obligations, and a Leak Detection and Repair program is a robust start. Further, it is useful for regulations to leave the door open to the adoption of

[86] UNEP, *Satellite alerts spur methane cuts but room for progress remains* (July 23, 2025), https://www.unep.org/technical-highlight/satellite-alerts-spur-methane-cuts-room-progress-remains.

emerging monitoring tools that could facilitate compliance in the future, even if such tools are not fully deployable at present. Relatedly, and especially in light of the growing use of satellite technologies, it would be valuable to grant the provincial authorities the ability to request clarifications or challenge company reports in cases where independent satellite data indicate discrepancies with what the companies report, and to establish a mandatory response procedure to ensure accountability.

## V. Reflections for policymakers going forward

### A. From data to action

The rapid expansion underway in availability of atmospheric methane data represents a major advance in our ability to effectively reduce emissions. This is because remote observations of atmospheric methane, mainly from satellite-based and airborne instruments, have made visible many emissions that were formerly invisible. Insofar as a lack of information about emissions has constrained effective controls, the continuing expansion of visibility significantly aids in resolving this challenge. But the structures and systems that connect information about emissions with action to reduce those emissions are more complex and less direct than one might expect from focusing just on advances in data coverage and quality.

For data on emissions to move effective control action, the data must be received, understood, and trusted by the right actors – those who have the authority, operational capacity, and motivation to take actions to effectively reduce emissions, in widely varied contexts and settings worldwide.

The world maps of methane emissions available on multiple data portals – e.g., those of Carbon Mapper, IMEO, and Kayrros – suggest a global uniformity in the observation, interpretation, and importance of emissions. Viewed in geophysical terms, this sense of uniformity is valid. Methane is one of the "well mixed" greenhouse gases, those that reach relatively uniform concentration and thus have climate effects independent of where they are emitted.[87] But for these data to promote actions to reduce emissions, they must act upon social, economic, and legal/policy systems that vary widely among settings.

Indeed, even the requirement that data be received, understood, and trusted by the relevant actors depends on conditions that vary widely. Data may be produced and validated by scientific processes and standards that are globally uniform, but the processes by which information is received, affirmed, and used in most decision processes are diverse, local, and often parochial. For example, corporate decisions rely heavily on information generated and vetted internally or by trusted associates, expressed in terms that fit internal processes and are explainable to senior decisionmakers in terms that resonate with their interests and sense of organizational identity. Legal and regulatory decisions rely on their own evidentiary standards, rules of procedure, and processes to resolve uncertainty and reach closure. While these processes to receive, validate, and

[87] Not entirely uniform, of course. There are limits in observing conditions that are spatially variable. In addition, methane is often co-emitted with other pollutants that are more chemically active and thus have shorter lifetimes, so these have regional environment and health impacts that do depend on the location of emissions.

use information may be pulled toward consistency by factors such as global capital markets, technical or accounting standards, or consistently applied legal principles, they could still diverge widely due to the non-binding nature of these forces.

Similarly, the additional factors that determine emissions actions and outcomes – the identity of relevant actors, their authorities and capabilities, what it takes to capture their attention, and what incentives and constraints shape their decisions – can vary widely across sectors, legal settings, levels of development, and specific jurisdictions. It is crucial that policymakers keep the variability of these aspects in mind when aiming to act upon the increasingly accessible methane emissions data.

### B. Incentives to cut emissions in diverse jurisdictional settings

In view of this diversity of decisions settings, one can't assume that data on emissions will simply and straightforwardly lead to control action in every setting. Nor, however, does every emissions source need a custom-fitted system to communicate and motivate action. Reality lies between these extremes. For particular emissions sources and sectors – e.g., oil and gas operations, landfills, coal mines – there are commonalities across locations in emissions patterns and causes, technologies involved, options for control, and the organizations or professional communities involved. There are also commonalities in the incentives that can motivate actors to cut emissions once they know about them, which typically fall into three broad buckets: economic, legal or regulatory, and reputational.

Economic incentives can operate when emissions represent an unnecessary cost, a loss of potential revenue, or a symptom of technical or management failures that may be causing other harm to the operator. These incentives can apply, for example, for leaks in oil and gas production or processing facilities where the operator could have sold the gas rather than let it escape, or for point sources, such as landfills or concentrated livestock operations, that have an available connection to gas distribution networks.

Legal or regulatory incentives can operate when a release represents a violation of permitted operating conditions, a basis for a charge or fine, or a source of potential liability. Whether this is the case for a particular release will depend on what specific regulatory requirements and potential sources of liability are actually operative. These incentives might not apply even to a large release, for example, if regulations only require specific technology, or the release is permitted for safety, routine maintenance, or other allowed purposes. These incentives can be strengthened if the emissions trigger risks of liability for resultant damage, particularly from co-emitted pollutants. They would also be strengthened by regulations that target actual emissions. Most current regulations do not do this, but this could change as the availability of and access to emissions data continue to rapidly expand. Targeting regulations more directly on observed emissions represents a significant opportunity for new, stronger approaches to emissions control.

Reputational incentives are the most diffuse and open-ended type of incentive, and in some cases, they may overlap with the other types. Any emitting facility depends on the good graces of some collection of actors who provide the needed social or political license to operate, whether these are formal legal or governmental authorities, customers or other business partners, or others with formal or informal power in the relevant jurisdiction. Even if it carries no immediate material consequence, being publicly identified to these groups as causing harm, breaking commitments, or operating recklessly may represent a diffuse threat of future harm, whether through economic mechanisms (e.g., loss of customers or business relations) or legal and political ones (e.g., facing stricter scrutiny or enforcement, or new stricter requirements). Those responsible for emitting facilities thus generally prefer to avoid such public naming and shaming.

### C. Theories of change: Deploying atmospheric observations to move action

Based on these loose commonalities in emissions, reduction opportunities, and incentives, several approaches have been tried and proposed to motivate reductions, working at various spatial scales from individual point sources to complete jurisdictions. Some of these early efforts have shown varying degrees of success, but more development is needed. Other approaches have been proposed, with early exploratory efforts underway, and still others –including ways to use the new data to drive large reductions – remain early aspirations.

The most direct path from data to action operates where an instrument with fine spatial resolution observes a large point source, given certain favorable conditions: the release can be confidently attributed to an identified responsible party; and that party has the authority, the technical and administrative capability, and the incentive to take action to stop the release. In a leading example of this intervention model, Carbon Mapper reports that when it shares information about large U.S. point-source releases in the oil and gas sector with the responsible operator, Carbon Mapper receives a substantive response and can later verify that the source was fixed about half of the time.

Even in this seemingly simple case, however, there can be various incentives at play. Not all large releases are violations of applicable regulations and permits, so legal and regulatory incentives may or may not apply. But even absent these incentives, sources may correct emissions to save money or avoid bad publicity. They may value information about their emissions enough that they are willing to pay for proprietary or early access, as in the business models of GHGSat or Planet's commercial sale of methane data during the 30-day window before Carbon Mapper is authorized to disclose it publicly.

There are additional ways to use point-source emissions information to promote action, beyond either releasing the information publicly or providing it directly to operators. For example, a regulator can acquire emissions data from an instrument operator, as the California Air Resources Board does from Carbon Mapper.[88] This gives the regulator discretion to decide how to respond – whether to consult informally with the source, provide advice and support for reductions, make formal compliance determinations, or take enforcement action.

On the other hand, large point-source events detected and communicated may not lead to effective reduction action, for various reasons. Depending on the specific regulatory environment, large emissions events, particularly in the oil and gas sector, may involve high release rates for short periods that are allowed within permit conditions for safety, maintenance, or other purposes.

[88] CARB, *California Satellite Methane Project*, https://ww2.arb.ca.gov/our-work/programs/california-satellite-methane-project.

These may already be known to operators and regulators, such that reporting them does not induce, or require, any change.

Alternatively, attribution can pose various challenges. If the difficulty comes from multiple sources close together but there is a responsible regulatory authority, that authority can use the initial observation to allocate enforcement resources and follow up by other means, including on-site inspection. More severe attribution challenges can arise when facilities are closed or abandoned (e.g., old oil and gas facilities or coal mines) or in jurisdictions with thin regulatory authorities or none. In such cases, identifying responsible actors may be complex or for practical purposes impossible at any smaller scale than the national government.

Such limitations are clear in the low reported response rates to UNEP's MARS system, a program that notifies designated national contacts when a large plume is detected.[89] Such a globally uniform notification system faces clear challenges. National contacts, usually in the foreign ministry, typically have limited knowledge or authority over the identified emissions event, and such a globally uniform reporting system can provide no context for the observed emissions to help assess their causes, legality, or impact. Additional contextual information is required.

A final approach based on large point-source emissions is that taken by the UCLA STOP Methane project: simply identifying and publicizing the largest emitters in various categories – by sector and/or nation – and disseminating the information broadly, with no particular assumption about which actors or action channels will be most relevant.[90] The aim is to either directly motivate operators or regulators, or to provide the basis for other potentially influential actors to apply whatever incentives they have available to motivate reductions.

Beyond large point sources, remote observations of methane can also be used to support action at larger scales, but the technical and computational requirements are more complex, and the methods to do so are at earlier stages of exploration and development. At the scale of entire jurisdictions, nations and some subnational jurisdictions prepare regular inventories of GHG emissions including methane, as tools for promoting accountability, monitoring trends, and assessing impacts of mitigation policies.[91] National governments are also required to report emissions inventories under the FCCC and Paris Agreement,[92] using guidelines promulgated by the IPCC.[93] As per the guidelines, most inventories are prepared with bottom-up methods based

---

[89] UNEP, *An Eye on Methane 2024*, https://www.unep.org/resources/eye-methane-2024; UNEP, *An Eye on Methane 2025*, https://www.unep.org/resources/eye-methane-2025-measurement-momentum.
[90] UCLA Law, *Announcing the UCLA Emmett Institute's STOP Methane Project*, https://law.ucla.edu/academics/centers/emmett-institute-climate-change-environment/announcing-ucla-emmett-institutes-stop-methane-project.

[91] *See, e.g.*, EPA, *Inventory of US Greenhouse Gas Emissions and Sinks*, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks; CARB, *California greenhouse gas emissions inventory*, https://ww2.arb.ca.gov/ghg-inventory-data; Gov. of Canada, *Canada's greenhouse gas inventory*, https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html.
[92] *See* UNFCCC, *Greenhouse Gas Data from UNFCCC*, https://unfccc.int/topics/mitigation/resources/registry-and-data/ghg-data-from-unfccc; UNFCCC, *National Inventory Submissions 2025*, https://unfccc.int/ghg-inventories-annex-i-parties/2025.
[93] IPCC, *Task Force on National Greenhouse Gas Inventories*, https://www.ipcc-nggip.iges.or.jp.

on observed levels of emissions-related activities and standard emissions factors. These methods have been increasingly found to be inadequate and there are increasing efforts to integrate satellite-based and other direct observations to strengthen inventories by incorporating omitted sources, correcting emissions factors, and providing a stronger understanding of how emissions vary spatially and over time.[94]

Scales between point sources and entire jurisdictions can also be important for policy and control. At these scales – on order tens to hundreds of kilometers – large discrete point sources may represent small contributions to the total or none, but large numbers of smaller or distributed sources can add up to large total emissions. Satellite instruments can characterize total emissions at these scales with high precision given repeated observations over extended periods, typically weeks to months.[95]

A frequent challenge in using observations at these scales for emissions action or control is attributing emissions to a responsible actor or actors. Typically under current regulatory approaches, the aim is to attribute emissions to a single facility, a site, or a business enterprise or other organization. There are several types of approach to overcoming this challenge in operation or being developed or proposed.

Colorado's regulation of emissions from the upstream gas production sector provides an example of such a system in operation. As described in our case study above, Colorado's approach combines an emissions intensity limit for enterprises operating in the upstream sector, with a menu of options operators may use to verify compliance. They may opt for custom verification and reporting that may include remote-sensed or other direct observations, or alternatively, they may accept a default estimate that is based on information available to the regulator and is typically somewhat unfavorable relative to the uncertainty range of actual emissions. This structure gives operators incentives to conduct observations, validation, and control activities to show overall compliance that may include effective or low-cost options that the regulator could not have directly required them to do. It thus leverages operator incentives to extend otherwise incomplete regulatory authority.[96] Similar structures that combine data from multiple sources in the context of enterprise-level regulations could be developed in other jurisdictions and for other emissions sectors.

In addition to their potential use in diverse legal and regulatory settings, such multi-dimensional measurement and estimation systems can also be used outside formal regulatory settings, by various soft-law processes to inform and motivate reductions. For example, such systems can be used to provide accountability for declared plans or pledges, by individual

---

[94] Lu Shen et al, *Quantifying National Emissions*, NATURE (2023), https://www.nature.com/articles/s41467-023-40671-6.
[95] *See, e.g.*, Schneising, et al., *Atmospheric Chemistry and Physics*, 9169-9182 (2020); Zhang et al, *Quantifying methane emissions from the largest oil-producing basin in the United States from space*, SCI. ADVS. 6 (2020), https://www.science.org/doi/pdf/10.1126/sciadv.aaz5120; Lauvaux, et al., *Global Assessment of Oil and Gas Methane Ultra-Emitters*, 375 SCIENCE 6580 (Feb. 3, 2022), https://www.science.org/doi/10.1126/science.abj4351.
[96] *See supra* Section IV.a.2.

enterprises, industry groups or others.[97] Alternatively, such systems can be sued to attribute emissions associated with specific products, to inform action by purchasers, importers, or others. The most prominent example at present is in the EU, where efforts are underway to assign emissions intensities to imported fuels and other products, in the context of their methane regulation and carbon border adjustment mechanism. [98] There are also efforts underway to characterize emissions intensity of internationally traded LNG, in hope of persuading major importers to act collectively to limit the emissions intensity of internationally traded fuels. These all involve integration of multiple types of observation, including remote-sensed observations at various scales, direct on-site measurement, and engineering or operational data of parameters associated with emissions that may vary with emissions sectors and specific activities or types of equipment.[99]

## VI. Conclusion

As data from methane monitoring satellites are increasingly incorporated into policy, legal, and regulatory contexts, even more work could and should be done to support local, state, and national governments in these efforts. Lessons from the early efforts described in this paper should help strengthen the impact and utility of these data at different stages of regulation and in different social and economic circumstances.

[97] Clean Air Task Force and CERES, *Benchmarking Methane and other Greenhouse Gas Emissions of oil and gas production in the United States* (June 2024), https://cdn.catf.us/wp-content/uploads/2024/05/31103518/oil-gas-benchmarking-2024.pdf.

[98] EU Regulation 2024/1787 (June 13, 2024), https://eur-lex.europa.eu/eli/reg/2024/1787/oj/eng.

[99] *See* Dan Zimmerle, Anna Hodshire, & Arthur Santos, *Strategy for effective reporting of methane emissions at the producer level*, METEC, COLORADO STATE UNIVERSITY (March 2025), https://metec.colostate.edu/wp-content/uploads/sites/37/2025/04/EU-White-Paper-v3-clean.pdf; Brandon Locke & David McCabe, *Harnessing data-driven accountability: How "following the money" can track fossil fuels across the supply chain,* CLEAN AIR TASK FORCE (Feb. 2025), https://www.catf.us/resource/harnessing-data-driven-accountability-following-money-track-fossil-fuels-across-supply-chain/.