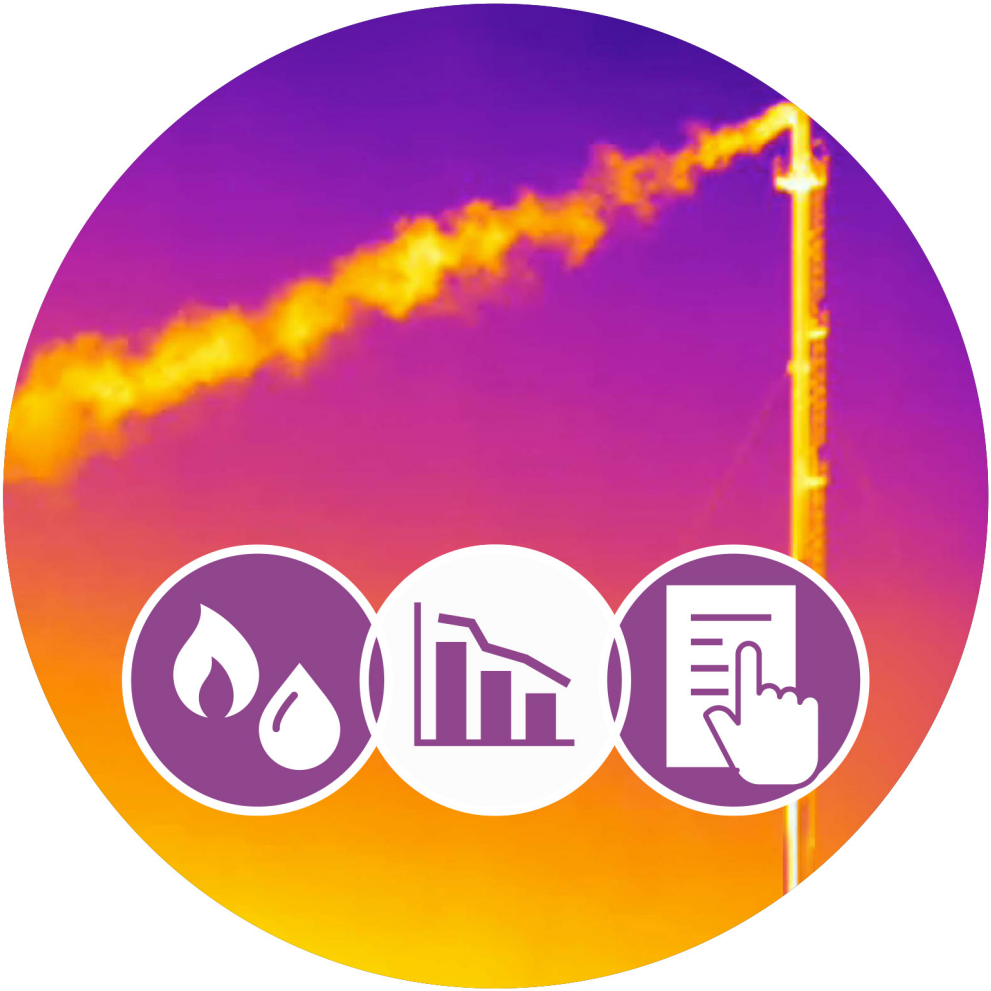
Methane Abatement for Oil and Gas

Handbook for Policymakers



Opening Letter From Secretary Raimondo

Climate change is a profound and global challenge. The United States has risen to meet this challenge. In Executive Order 14008, the Biden-Harris Administration recognized that now is the moment to act to avoid the worst impacts of the climate crisis as well as to seize the opportunity that tackling climate change presents. The U.S. Department of Commerce is part of this whole-of-government effort to meet the climate moment and ensure a just and rapid transition to a lower carbon, sustainable, and prosperous future.

Methane emissions are a major contributor to climate change. Abating methane emissions are also a unique opportunity. For that reason, in 2021, the United States and its international partners established the Global Methane Pledge. Under the Pledge, countries commit to collectively reduce methane by 30% by 2030 from 2020 levels. The U.S. and its partners are working now to help countries adopt methane abatement policies, mobilize methane financing, deploy abatement technologies and practices, and reform laws and regulations.

At the U.S. Department of Commerce, the Office of the General Counsel's Commercial Law Development Program (CLDP) has assisted countries to update their commercial laws and regulations for over 30 years. Now, CLDP has organized a free, accessible, fit-for-purpose guide for policymakers and regulators to abate methane emissions from the oil and gas value chain.

In developing the handbook, CLDP convened a group of experts on methane abatement from the U.S. Government, multilateral institutions, non-governmental organizations, industry, and academia. These many authors and many other supporters of the handbook collectively volunteered innumerable hours. The result is a guide that legislators, ministry officials, and regulators

worldwide can use right now to draft, adopt, and enforce new legislation that will rapidly and effectively reduce methane from oil and gas processes.

This handbook also expands the scope of series developed by CLDP under Power Africa, called *Understanding Power*: an open-source and plain-language knowledge library of handbooks explains a range of essential topics in power project contracts, financing, and procurement. In addition to supporting the Global Methane Pledge and the United States' climate goals, the handbook furthers U.S. Department of Commerce climate and clean tech trade objectives.

I am grateful to CLDP and the authors, sponsors, and supporters for developing this important contribution to our collective effort to take climate action. Working together, we can address the climate crisis, seize economic opportunities, and rise to the challenge.

Gina M. Raimondo
U.S. Secretary of Commerce

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A Guide to the Handbook

Who Is This Book For?

The international community has committed to rapidly reducing methane emissions from oil and gas operations to meet climate change objectives and enhance economic and energy security. Many countries, however, still need to understand how to achieve these objectives. This handbook introduces government officials to a range of options for methane abatement in the oil and gas sector and guides the design and implementation of regulations. It builds on lessons learned from regulatory schemes in various countries. Government officials involved in all oil and gas sector aspects can benefit from this handbook.

What Is the Scope of This Book?

This handbook explains methane abatement opportunities, methane abatement technologies, and how to develop and implement effective methane abatement policies and regulations. It provides useful examples and case studies of recent methane abatement regulations adopted by countries worldwide. This handbook only covers some of the specific methane abatement technologies in-depth and focuses on salient points on the topic. It summarizes points that individual authors feel are particularly important when considering methane abatement regulations and implementation. This handbook is not intended to advocate for a particular suite of methane abatement policies but provides an overview of options.

Who Wrote This Book?

The authors are diverse energy sector practitioners, including government officials, engineers, public policy experts, lawyers, and academics. This handbook seeks to capture their collective practical experience and current knowledge. However, it may not represent policy positions of the organizations, institutions,

countries and/or companies with which the individual authors are or have been affiliated. For such views, please refer to the publications and websites of the respective organizations, institutions, countries, and/or companies.

Abating methane emissions is a complex issue informed through continued learning by many stakeholders and technological advancements. The authors' varied areas of specialization allowed the handbook to address this complexity in a digestible format — pointing out the issues and alternatives with the authors participating or not on certain topics given their individual expertise. The authors hope this handbook will advance the development and implementation of methane abatement policies and regulations and contribute to lowering global methane emissions from the oil and gas sector.

How Was This Book Developed?

The handbook was produced using the Book Sprints (www.booksprints.net) method, which allows for the drafting, editing, and publishing of a complete product in just five days. The authors sincerely thank our Book Sprint facilitator Barbara Rühling for her patient guidance and unwavering leadership throughout the nearly 75-hour drafting process. The authors also thank Henrik van Leeuwen and Lennart Wolfert for turning our rushed scribbles into beautiful and meaningful illustrations. We would also like to recognize the tireless work of Book Sprints copy editors, Raewyn Whyte and Christine Davis.

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How May I Use This Book?

In the tradition of open-source knowledge sharing, this handbook is intended to reflect the vibrant nature of the Book Sprint process and serve as a reference and a jumping-off point for further discussion and scholarship. It is issued under the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (**CC BY NO SA**). In selecting this publication license, anyone is welcome to copy, excerpt, rework, translate, and re-use the text for any non-commercial purpose without seeking permission from the authors, so long as the resulting work is also issued under a Creative Commons License. The handbook is initially published in English. Translations may soon follow. It is available in electronic format at *https://cldp.doc.gov/resources* and in print format. In addition, the handbook can be used as an online interactive resource. Many of the contributing authors are also committed to working within their institutions to adapt this resource for use as the basis for training courses and technical assistance initiatives.

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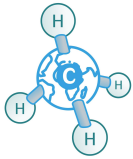
1. The Methane Opportunity

Why Countries Should Abate Methane from the Oil and Gas Sector Now

Key Takeaways

- Methane, a key component of natural gas, is both a global commodity and a greenhouse gas (GHG) that contributes to climate change.
- Near-term methane reduction across all economic sectors, including oil and gas, is vital to achieving global climate goals.
- Methane abatement can generate revenue, improve energy access, create jobs, enhance energy security, provide access to investment, enhance safety, advance community health, and showcase leadership.
- Governments can design effective oil and gas methane abatement policies to achieve these win-wins.
- Governments should seize the methane opportunity, abating emissions and advancing their economic and social goals.

The Changing Role of Methane in the Oil and Gas Sector



Methane, with the chemical formula of CH_4, is the primary component of natural gas. The role of natural gas in the energy system has changed dramatically over time.

When oil was first discovered and produced, natural gas was viewed as a hazard — an undesired product found alongside oil deposits. At that time, natural gas was a nuisance to be managed. To market the oil, many producers disposed of the natural gas by venting it into the air or burning (i.e., "flaring") the gas.

Today, natural gas plays a significant role in the energy mix of many countries. It is used in power generation, industry, and cities for heating and is also a critical feedstock for manufacturing fertilizer, ammonia, and other chemical and petrochemical goods. It has largely replaced coal and liquid fuel in some markets in homes, industries, and power plants —

improving air quality in cities worldwide and reducing carbon dioxide emissions. However, studies have shown that a coal-to-gas substitution only produces a net climate benefit,[1] when methane leak rates are below 2.4-3.4 percent.[2]

The advent of large-scale transportation of natural gas liquefaction in the 1950s meant that natural gas no longer could only be moved by pipeline. Instead, countries facing a decline in their domestic natural gas reserves, or lacking options for new power generation, could take advantage of imported liquefied natural gas (LNG).

Natural gas — once only an annoyance and a hazard — is now a key energy and revenue source for numerous countries relying on it for economic growth. Even now, some countries are increasing the use of natural gas for economic development or supplanting more carbon-intensive fuel sources such as coal. Conversely, other countries are evaluating future decreases in natural gas use as part of their energy transition planning. The International Energy Agency finds that pathways consistent with meeting net-zero by 2050 require halving the emissions intensity from the oil and gas sector by the end of the decade while reducing total oil and gas consumption.

Methane and the Climate Challenge

Methane is a potent short-lived greenhouse gas (GHG), and breaks down in the atmosphere in around 12 years. According to the 5th Assessment Report from the IPCC, methane's impact is estimated as ~84 times greater than carbon dioxide when averaged over 20 years and ~28 times more powerful when averaged over 100 years.[3] Per the National Oceanic and Atmospheric Administration, the atmospheric concentration of methane has more than doubled since pre-industrial times (~715 parts per billion (ppb) to ~1912 ppb in 2022), and methane from all sources, natural and anthropogenic, is the second most abundant GHG.[4]

As noted in the Global Methane Pledge "readily-available cost-effective methane emission measures have the potential to avoid over 0.2 degrees C of warming by 2050."[5] Solutions to reduce methane emissions must be pursued in tandem with reductions of other GHG emissions, particularly carbon dioxide, to address global climate goals meaningfully.

Near-term methane reduction is a vital component to achieving global climate goals and could limit the rate of global warming. The IPCC recommends "strong, rapid, and sustained" cuts to methane emissions.[6]

Methane in the Oil and Gas Value Chain

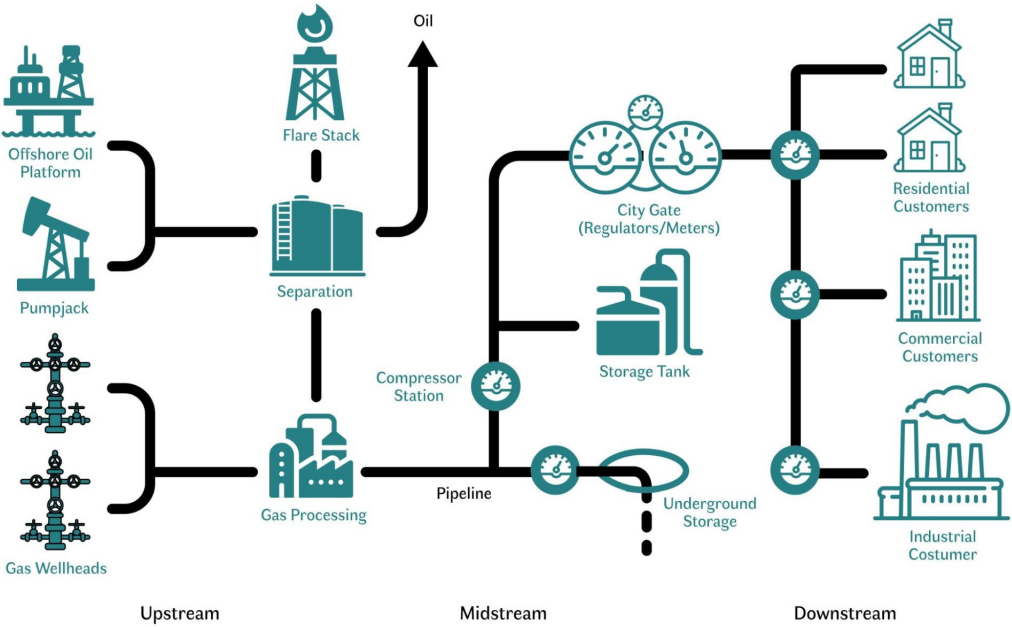


Figure 1.1: Illustration of the different segments of the oil and gas value chain.

Methane can be emitted across the entire oil and gas value chain, which consists of three segments:

- **Upstream.** Production, gathering, and processing of oil and gas.
- **Midstream.** Gas transmission by pipelines or as LNG and storage activities.

➔ **Downstream.** Transport and refining of oil and systems for local gas distribution to consumers.

Most methane emissions from oil and gas operations fall into one of three categories:

Flaring. The intentional burning of natural gas to relieve pressure in upset conditions or when sending gas to sales is not feasible. When flares combust natural gas, most methane is converted to CO_2, but some methane remains uncombusted.

Venting. The intentional release of natural gas arising from a process or activity directly into the air.

Fugitive emissions. The unintentional release of methane from leaks, for example, from valves or flanges. Since methane is colorless and odorless, leaks can go undetected without regular inspection.

The International Energy Agency (IEA) estimates global methane emissions from oil and gas activities were 82 million metric tonnes in 2022.[7] Figure 1.2 shows the relative proportion of methane emissions between flaring, venting, and fugitive emissions.

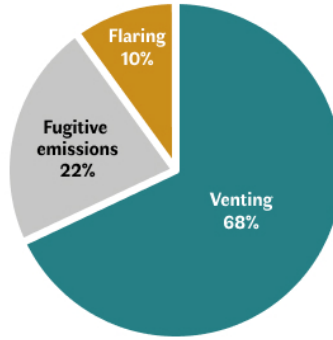


Figure 1.2: Sources of methane emissions in the petroleum and natural gas sectors (2021).[8]

The Opportunity: Methane Abatement from Oil and Gas

Governments have begun to prioritize near-term methane reduction in light of the growing knowledge in the area. More than 150 countries have joined the Global Methane Pledge as of the writing of this handbook. The Global Methane Pledge includes, among other things, commitments to "work together to collectively reduce global anthropogenic methane emissions across all sectors by at least 30 percent below 2020 levels by 2030." Other international fora have recognized methane as a priority issue as well.[9]

The oil and gas sector is not the only or largest source of anthropogenic methane emissions. Three main sectors make up most human-caused methane emissions in the world: energy, agriculture, and waste. Each of these will need its own approach

to methane abatement. While this document focuses on oil and gas methane, governments can maximize the benefits of methane abatement by considering simultaneous actions in other sectors.

Recent developments in remote sensing have shown that the energy sector has opportunities to reduce methane emissions in the near term. In 2022, the IEA estimated that the worldwide oil and gas sector emitted ~82 million tonnes of methane and that ~70 percent of methane emissions from global fossil fuel operations could be reduced with well-known technology that is currently available.[10]

Methane abatement in the oil and gas sector can be a win-win. Rapid methane reduction from oil and gas is possible, and it can and should promote broad economic growth, job creation, community health, worker safety, and international competitiveness. Oil and gas methane abatement is a climate change mitigation and economic development opportunity.

But the "how" matters. How methane is abated will determine how much a country can reap the economic and social benefits. Methane abatement will require adjusting the regulatory and operating environment for oil and gas investment. Important questions to consider include:

- **Costs.** Who will bear the burden of the costs of new technologies and practices?
- **Revenues.** Will revenues to the treasury or National Oil Company (NOC) be reduced?
- **Capacity.** Will governments, NOCs, and private companies develop sufficient expertise and staffing to meet the new regulatory and operating requirements to abate methane?
- **Jobs.** What impact will methane abatement have on jobs? Will it have uneven impacts across communities?

- **Technology.** Will abatement technologies be available and affordable?

While these concerns are real and must be confronted, methane abatement from oil and gas activities can unlock significant benefits:

- **More Revenue.** Governments can monetize methane that is now being wasted. This may produce more revenues for the treasury and better stewardship of public resources.
- **Improved Energy Access.** Governments and operators can improve energy access for populations by capturing and using methane for power, heat, and cooking.
- **Job Creation.** Methane abatement technologies require trained personnel, stimulating new jobs.[11]
- **Enhanced Energy Security.** Eliminating methane waste ensures less reliance on imported and sometimes expensive energy sources.
- **Access to Investments.** Companies, including NOCs, are looking to access climate or green financing, but to do so, they need to show they have strong climate and Environmental Social and Governance (ESG) metrics.
- **Better Public Safety.** Methane abatement activities may reduce hazards to the public and workers.
- **Improved Air Quality.** Methane emission reductions can have co-benefits around improved local air quality.
- **Climate Leadership in the Region and Worldwide.** Reducing methane emissions is a top global priority and countries that show progress will be recognized as leaders regionally and globally.

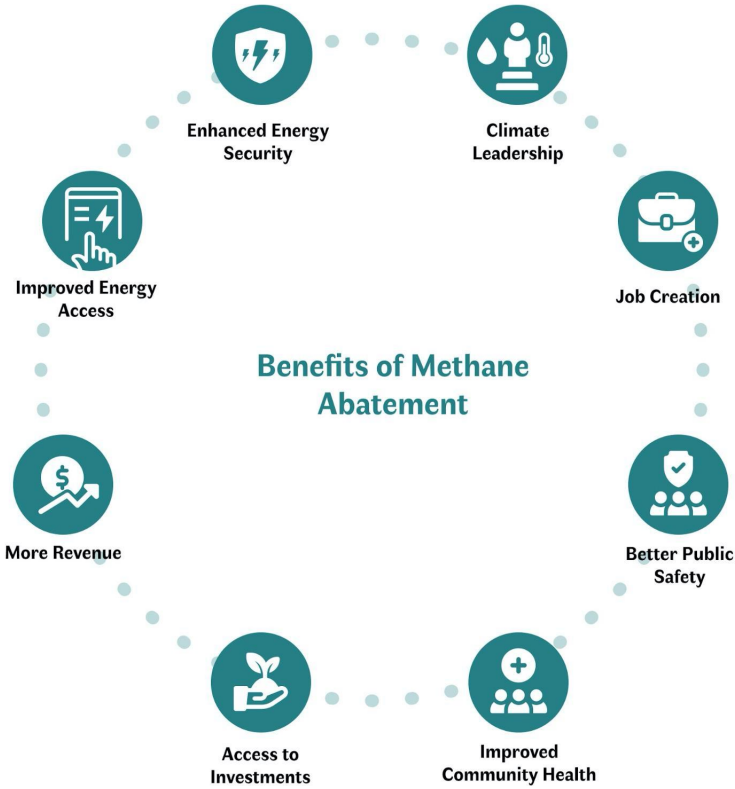


Figure 1.3: Illustration of the benefits of methane abatement.

More Revenue, More Power: How Governments Can Benefit From Using Gas Instead of Flaring It

Some governments and NOCs are missing an opportunity by allowing associated gas to be flared. Reducing flaring allows additional gas to be piped to consumer markets or used to generate electricity. These gas-to-pipeline and gas-to-power projects are win-win for governments, the industry, and the public. In some cases, these projects require few, if any, government budget outlays: they are all delivered by private operators who stand to profit. Moreover, in gas-to-power projects, the new electricity can increase grid stability and reduce air emissions from the electrification of operations.

Two examples from Egypt illustrate the potential opportunity. In one, a UK-based independent oil company, Pharos Energy, reduced gas flaring by 30 percent in its oilfield operations by installing two new gas-fired power generators. This also significantly reduced diesel combustion pollution and costs. Based on the estimates from Capterio's FlareIntel, the avoided flaring and diesel air emissions from these projects reduced approximately 42,000 CO_2-equivalent tonnes per year.

In a separate oilfield, the Ukrainian State-owned company, Naftogaz, installed new equipment to recover natural gas that would have been flared and ship it to market using a nearby pipeline. This reduced emissions by up to 800,000 CO_2-equivalent tonnes per year. FlareIntel estimates nearly 15 million standard cubic feet per day of natural gas is being commercialized instead of flared due to this gas-to-pipeline project.[12]

Will Countries Seize the Opportunity?

What will the future look like for oil and gas? This will depend on how countries seize the opportunity of methane abatement in the sector. Countries that embrace the groundswell of new analyses, tools, standards, practices, and commitments can rapidly reduce methane emissions from the oil and gas sector. There are opportunities to grow methane reduction ambitions and implementation.

2. Planning to Reduce Methane Emissions from the Oil and Gas Sector

Key Takeaways

- National and subnational governments are planning to abate methane by setting high-level targets and goals for methane across all sectors in a national methane action plan. Dozens of countries have adopted or are developing methane action plans.
- Countries developing national action plans and sector-specific measures can look to other countries for useful examples of what can be included.
- International development partners for the oil and gas sector have resources for developing oil and gas methane abatement plans, detailed roadmaps, and specific regulations.
- When developing a methane abatement policy covering the oil and gas sector, policymakers and regulators should tailor the policy to their circumstances.
- Methane abatement options depend on the three industry segments — upstream, midstream, and downstream.

National Methane Action Plans

National methane action plans set forth economy-wide ambitions for controlling emissions. A national action plan is a good place to set high-level targets and goals for methane across all sectors, including oil and gas, coal, waste, and agriculture. These may include high-level numerical targets, a list of specific mitigation measures that the government will take, or both.

- **Ghana's** National Action Plan to Mitigate Short-Lived Climate Pollutants (2018) identifies specific measures to reduce methane and other pollutants across all sectors.[13]
- The **United States** Methane Emissions Reduction Action Plan (2021) details several regulatory and non-regulatory steps the government is taking to reduce methane from oil and gas, landfills, coal mines, agriculture, and other industries and buildings.[14]

- **Norway's** National Methane Action Plan (2022) does not establish a separate target for methane but instead notes that methane is covered by Norway's overarching GHG emissions reduction goal of 55 percent by 2030 and 90-95 percent by 2050 (compared to 1990 levels).[15]
- **Canada's** Methane Strategy (2022) outlines abatement measures and supporting programs to reduce domestic methane emissions by more than 35 percent by 2030 (compared to 2020). For the oil and gas sector, Canada has committed to reducing emissions by 75 percent by 2030 compared to 2012.[16]

As countries track progress toward their policy goals, they can revise targets and plans to reflect new learning.

Countries developing new action plans can look to other countries for useful examples of what can be included. As of May 2023, an estimated 50 countries have adopted or are working on methane action plans.[17]

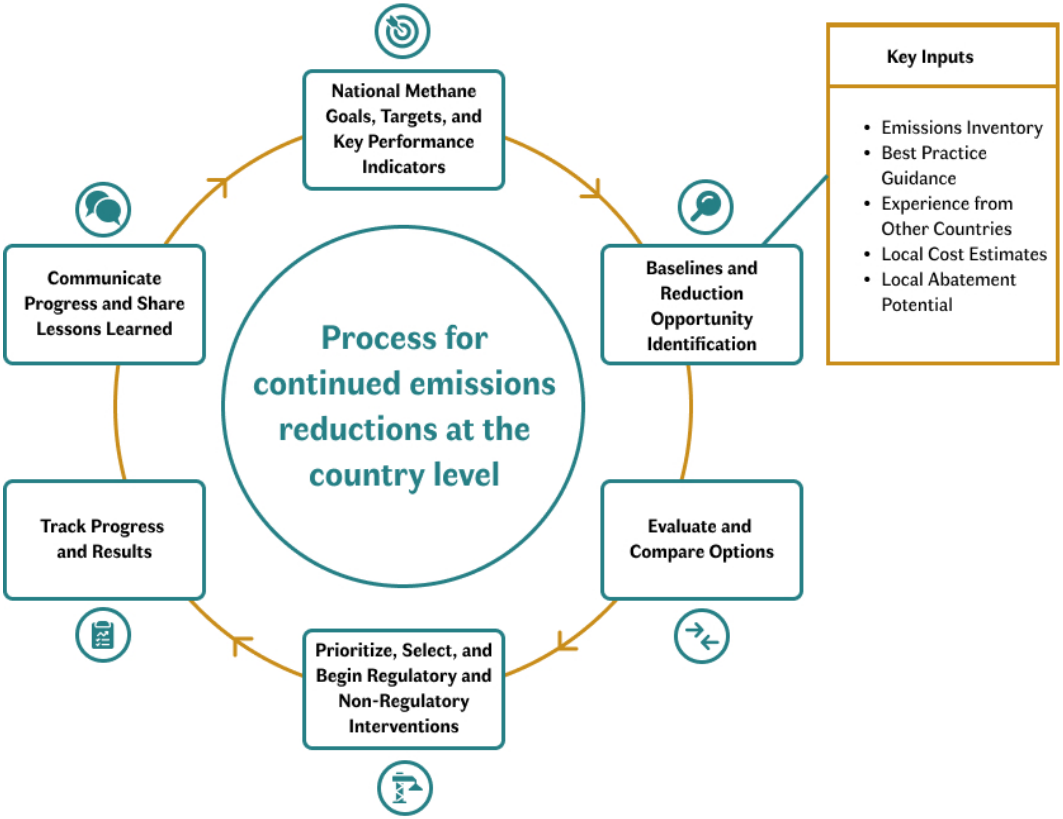


Figure 2.1: Process for continued emission reductions at the country level.

There are resources available to assist countries in this process, including the Climate and Clean Air Coalition's (CCAC) Methane Roadmap Action Program (M-RAP).[18]

Case Study: Vietnam Methane Action Plan 2030

A methane action plan can demonstrate the intent and lay out the processes of developing a more detailed roadmap. Vietnam's Methane Action Plan 2030 establishes targets to reduce overall emissions by at least 30 percent below 2020 levels by 2030, with specific targets for the agriculture, waste, and energy sectors.

Vietnam's Methane Action Plan states that "Methane emission reductions must be made on the basis of cost-benefit analysis according to a set forth roadmap that ensures the legitimate rights and benefits of both institutional and individual entities and promotes innovations serving Vietnam's sustainable socio-economic development". This roadmap includes provisions to:

- ➔ Promote technology transfer and adoption to support the installation of abatement solutions.
- ➔ Set up the regulatory framework for managing carbon credits from methane reduction and support emitters to access domestic and international carbon markets.

The Plan also mandates that action to curtail methane align with existing policies, instructing ministry officials to include methane emissions reduction in climate change response strategy, national green growth plan, and sectoral and provincial master plans.

Abatement Plans for the Oil and Gas Sector

In support of an economy-wide national action plan, many countries are developing more detailed policies and roadmaps

that outline specific actions to address emissions from the oil and gas sector. The IEA has developed a Regulatory Roadmap and Toolkit to assist policymakers by identifying the steps governments can take to design and implement new methane policies and regulations.[19]

These can be grouped into three broad phases: understanding the setting, regulatory design, and implementation. These steps may be carried out in a sequence or occur concurrently.

Figure 2.2: IEA's roadmap for effective methane policy design.[20]

Evaluating Methane Abatement Costs and Benefits

When establishing oil and gas sector-specific targets and plans, countries can prioritize the most significant sources of emissions or the most cost-effective abatement options. The IEA's Global Methane Tracker is a good starting point for this information.[21] The Tracker provides IEA estimates of methane emissions, abatement options, and costs on a country-by-country basis. This information can help identify the areas with the most mitigation potential, even without detailed country-level information.

Over time, countries can work towards country-specific information on potential emissions sources and costs. The Clean Air Task Force's Country Methane Abatement Tool (CoMAT) is

designed to aid regulators in developing estimates of current emissions and the abatement potential of various policy options.[22] Eventually, a detailed marginal abatement cost curve (MACC) can help show where reductions can be made at the lowest cost, thereby guiding prioritization among different mitigation options.

Making a Marginal Abatement Cost Curve

A country-level marginal abatement cost curve (MACC) shows the abatement opportunities in relation to cost, which can inform choices about what mitigation options to prioritize.

Many tools are available to help develop MACCs and experts from organizations such as CATF and others can advise on properly creating them.[23]

Key inputs into this process include:

- The annual amount of emissions reduced by the opportunity, typically expressed in tonnes of methane or CO_2 equivalent emissions.
- Capital cost estimates.
- Annual recurring costs for activities, including labor or maintenance.
- A discount rate to help determine a net present value or other economic indicators considering the relative value of current versus future spending.
- Considerations regarding the useful life of the equipment.
- The value of cost savings, such as lower maintenance costs for interventions, including the potential value of recovered natural gas.

A MACC may change as technologies evolve and become more widely available. New monitoring technologies are still being developed, which may reduce the cost of finding and repairing fugitive emissions (*See Chapter 9: Monitoring*). However, most of the design considerations discussed in this chapter are already well-established.

Given that solutions to methane emissions will need to be pursued in tandem with carbon dioxide reductions, governments will need to consider how to prioritize methane actions alongside

mitigation actions aimed at other greenhouse gas (GHG) emissions and adaptation efforts. Costs can be a critical factor in making these decisions, particularly where resources are limited.

Global Warming Potential: What Policymakers Need to Know

Policymakers can estimate the effect of global warming using Global Warming Potential (GWP), which expresses a tonne of greenhouse gas emitted in CO_2-equivalent terms to provide a single measure of total greenhouse-gas emissions (in CO_2-equivalent). The IPCC has indicated "a GWP for methane between 84-87 when considering its impact over a 20-year timeframe (GWP20) and between 28-36 when considering its impact over a 100-year timeframe (GWP100). Accordingly, one tonne of methane can be considered equivalent to 28 to 36 tonnes of CO_2 if looking at its impact over 100 years."[24] Under the UNFCCC, Parties agreed to use 100-year GWPs (or GWP100) for national reporting and tracking progress under Article 13 of the Paris Agreement, and the reporting guidelines specify use of GWP100 values from IPCC's Fifth Assessment Report.[25] The IPCC guidelines provide multiple metrics from which countries may report greenhouse gas emissions. Under the Paris Agreement, countries would use GWP100 from the Fifth Assessment Report.

Tailoring Methane Policies to Local Contexts

An oil and gas methane policy will be most effective if it is tailored to a jurisdiction's local situation, including the political and regulatory context, the nature of the industry, the size and location of emissions sources, and the jurisdiction's policy goals.

A key consideration can be the maturity of the country's oil and gas sector: whether it is a new producer, an existing producer, or a late-stage producer.

Table 2.1: Comparison of starting points vs. opportunities for oil and gas methane abatement.

Different Starting Points	Opportunity for Methane Avoidance and Abatement for Countries
New producers Countries with no or limited current production may develop regulations simultaneously as they develop their understanding of oil and gas operations.	Require new facilities to be designed to a near-zero methane emissions standard — getting it right at the outset can avoid more costly retrofits and work best practices into the design phase.
Early- and mid-stage producers Circumstances vary based on the scale and complexity of the industry. For example, an island nation with a single offshore field vs. countries with onshore, offshore, conventional, and unconventional gas production.	Focus first on the largest emitters (super-emitters) to get the most reductions with the lowest possible investment. Prioritization can be designed with a focus on cost-effectiveness.
Late-stage producers May need ongoing production, and wells approaching decommissioning or abandoned.	Seek continuing abatement opportunities for active production, which may require going further than initial regulatory measures. Policies can develop programs for properly plugging and abandoning wells to mitigate potential methane emissions.

There are many important considerations when developing an oil and gas methane abatement policy.

Local considerations. The costs of goods or equipment may significantly differ worldwide. Similarly, goods and services may be subject to local content requirements that may not have the manufacturing capacity for specific methane abatement technologies.

Supply chains and logistics. Several countries are currently adopting methane regulations and control requirements. While the market will ultimately balance supply and demand for these technologies, there may be short-term challenges in obtaining specific equipment pieces, possibly necessitating reasonable phase-in timelines for engineering controls. For example, the American Petroleum Institute (API) recently cited back-order times of 1 year for compressed air systems and 1.5-2 years for solar panels, which are important methane abatement technologies. However, a recent report by Datu Research, based on interviews with providers of zero-emitting technologies, states that suppliers are well equipped to meet anticipated demand in the U.S. Regulators can learn about the state of play of the supply chain from the local oil and gas sector and technology providers.

Local services and training. For certain types of methane abatement opportunities, operators and contractors will need training on procedures or maintenance practices to reduce methane emissions effectively. Local availability of maintenance personnel and ongoing sourcing of replacement parts and materials is vital for effectively implementing other abatement options.

Resilience to local weather conditions. Local weather conditions, such as extreme temperature or precipitation levels, will affect the design standards for equipment. Case studies and reduction solutions developed for one operation or location may not apply to another.

New versus existing sources. The costs of methane emission controls in designing new facilities may be lower than for retrofitting existing sources for various reasons. Some examples include ensuring that on-site power generation is sized for the electrical load associated with air compressors or vapor recovery units or the availability of deck space on an offshore platform for an additional process unit needed for methane abatement. New

producers can leverage local and international partners and adopt best regulatory practices from more established markets, adapting to local circumstances. If new facilities are designed with the best available mitigation technologies, it is possible to attain near-zero methane emissions.

Useful Resources

Oil and Gas Methane Partnership: Guidance documents and templates. *https://ogmpartnership.com/guidance-documents-and-templates/*

The Environmental Partnership: Taking Action — Environmental Performance Programs. *https://theenvironmentalpartnership.org/what-were-doing/taking-action/*

Methane Guiding Principles: Resources — Best Practice Guides and Toolkits. *https://methaneguidingprinciples.org/resources-and-guides/*

Natural Gas Star Program: Recommended Technologies to Reduce Methane Emissions. *https://www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions*

ExxonMobil Corporation: Mitigating Methane Emissions from the Oil and Gas Industry: Model Regulatory Framework. *https://corporate.exxonmobil.com/-/media/Global/Files/newsroom/publications-and-reports/Mitigating-Methane-Emissions-from-the-Oil-and-Gas-Industry-Model-Regulatory-Framework.pdf*

Assistance from The Climate and Clean Air Coalition. *https://www.ccacoalition.org/en/content/methane-technical-assistance*

Guidance from the Clean Air Task Force. *https://www.catf.us/methane/international-oil-gas/*

IEA Report: Driving Down Methane Leaks from the Oil and Gas Industry. *https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry/regulatory-roadmap*

3. Getting Started on Methane Abatement Regulations

Key Takeaways

- Understanding the measures that can be applied to reduce methane emissions is a good starting point in developing new regulations.
- There are four main approaches for methane regulation — prescriptive, performance, economic, and information. They are not mutually exclusive; a regulatory regime will likely include elements from multiple approaches.
- The existing legal and regulatory framework will determine what regulatory actions are possible and who has the authority to develop new policies.
- Engaging key stakeholders in methane abatement policy development gives them a voice in decisions that affect them and informs policy-making.
- Industry actors may already be taking voluntary actions that regulatory measures can build on and reinforce.
- Looking at existing regulations in other countries can yield insights into the most effective regulatory options. For example, existing regulations commonly include leak detection and repair requirements, flaring and venting restrictions, and standards for specific equipment and processes.

Potential Policy and Regulatory Strategies

A good starting point in developing a new policy or regulation is understanding the different types of regulatory strategies that could be applied to methane abatement. Following a survey of existing oil and gas methane regulations, the IEA has classified different approaches that could apply to oil and gas methane emissions.[26]

- **Prescriptive** measures directly require entities to undertake or not undertake specific actions or procedures. These include leak detection and repair (LDAR) requirements, equipment standards, and bans or moratoriums.

- **Performance** measures establish a mandatory performance standard for regulated entities but do not dictate how the target must be achieved. These can be set at a high scale (e.g., facility-wide performance standards) or a more limited scale (e.g., performance standards for flare efficiency).
- **Economic** measures induce action by applying fees or introducing financial incentives for certain behaviors. These range from relatively specific incentives, such as taxes on flaring and venting or direct subsidies for emissions reduction actions, to broader measures that link methane reductions to multi-sector carbon markets.
- **Information** measures are designed to improve the state of information about emissions and may include requirements that regulated entities estimate, measure, and report their emissions to public bodies. These can range from simple reporting of existing sources and facilities to detailed reporting of emissions rates and measured data. For example, this system could include publishing the list of top emitters or complete emission data available for public consumption. Information measures can themselves be powerful tools to reduce emissions when the data is made public and companies face public accountability.

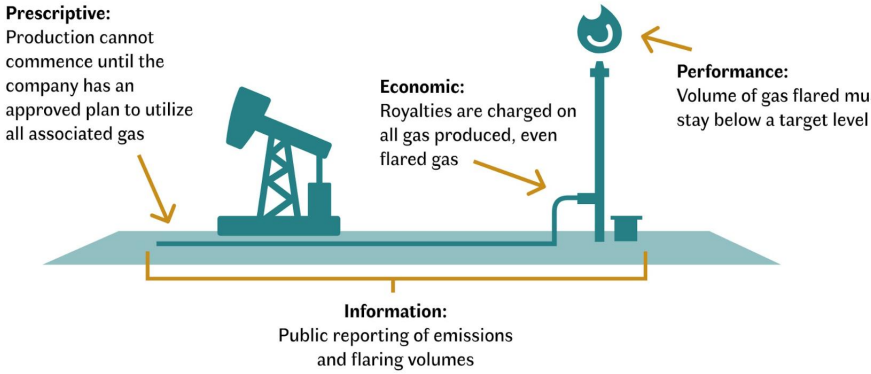


Figure 3.1: Illustration of different potential regulatory approaches using an example of associated gas.

These four approaches are not mutually exclusive and a given regulatory regime will likely include elements from multiple approaches. For example, one country's regulatory measures may include a mandatory LDAR requirement (a prescriptive measure), a tax on flaring (an economic measure), and a reporting standard requiring companies to report the volume of flared gas and the specific outcome of each LDAR campaign (an information measure).

Comparative Advantages

Across the world, there are many examples of oil and gas methane regulations from each of these four main types of regulation. In selecting the approach and elements to use, many different considerations are relevant depending on the specific situation in a country.

Ease of implementation. Well-designed, prescriptive regulations are generally relatively easy for regulators and companies to implement because they are unambiguous, and the reporting and compliance framework can be simple. For this reason, most existing methane abatement regulations are prescriptive. This consideration may be crucial for jurisdictions with limited regulatory resources. On the other hand, economic instruments can be more challenging to implement, particularly if they rely on external factors like a broader carbon pricing scheme or international framework for offsets.

Effectiveness. Different approaches may be more effective depending on specific national circumstances. For example, information-based regulations can enable economic or performance-based instruments, but they do not generally lead to reductions in and of themselves.

Need for high-quality data. The type of data needed, whether emissions or other data, is an important consideration. A tax on flaring only functions to reduce emissions if companies can be sure that reducing flaring will reduce their tax bill. Such a program could require the metering of flare volumes and reporting that metered data to the relevant government agency.

Flexibility or rigidity in the regulatory regime. Prescriptive approaches tend to be limited to technology options that exist when the regulation is finalized. In contrast, performance and economic approaches allow companies to choose how to comply as new technologies become available.

While these are common considerations for selecting a regulatory regime, other factors related to international norms, market dynamics, geopolitical shocks, domestic complications, and stakeholder acceptability also be considered.

Table 3.1: Table from IEA on regulatory approaches, drawbacks, and benefits.[27]

Regulatory approach	Transaction costs	Rigidity	Preconditions	Consider when...	Examples
Prescriptive	**Low** Simple to administer for both regulators and firms	**High** Only prescribed changes will take place	**Moderate** Knowledge of facilities' emissions needed	You have identified key abatement opportunities	Prohibition (Equatorial Guinea[28])
Performance- or outcome-based	**Moderate** Monitoring, measurement, and follow-up are needed	**Low** Encourages different solutions	**High** Requires information on baseline and overall emissions	You have a reasonable understanding of emissions and monitoring capabilities	Facility limits (Alberta, Canada[29])
Economic	**High** Requires robust verification systems	**Low** Enables company-specific abatement strategies	**Moderate** Requires knowledge of baseline emissions and related methane contributions	A monitoring system is in place and you want to mobilize different solutions	Royalties (Brazil[30])
Information-based	**High** Demands collecting, analyzing and transmitting information	**Moderate** Allows for other solutions in some cases	**Low** No need of previous information	You need a better understanding of methane emissions and abatement opportunities	Measure and report (Saskatchewan, Canada[31])
Often different approaches are combined, e.g., Vietnam[32] has put in place a regulation with restrictions on flaring (prescriptive), entitling the government to grant the right to use, free of charge, gas that would be flared (economic) and requiring gas loss reporting (information-based).					

Assessing Existing Laws and Institutions

Some countries may already have laws, regulations, standards, or other policies that address or could address methane abatement in the oil and gas sector. These legal frameworks, however, may vary in the type of legal instruments, procedures, and standards for addressing methane emissions. Some countries may need to develop new regulations to address methane emissions.

In some countries, the inherent authority to protect national resources and their beneficial use may be particularly broad. Other jurisdictions may need precise statutory provisions to provide legal authority to address specific sources of methane emissions. Some countries may pilot interim policies to inform the development of a statutory body to address methane emissions from the oil and gas sector.

Case Study: How Sri Lanka is Evolving its Regulatory Framework

Sri Lanka is an example of how a government can evolve its approach to regulating oil and gas development and how it is prepared to integrate methane emissions abatement into its current regulatory framework. The history of Sri Lanka's oil exploration dates back to the 1960s. From 1960 to 1984, substantial volumes of 2D seismic data were acquired, and seven wells were drilled off the northwest coast. The exploration efforts were renewed with a Norwegian seismic operator developing high-quality 2D seismic data in 2001 and 2005 in the Mannar Basin. During this time, however, it was unclear whether Sri Lanka had any environmental regulations or guidelines for petroleum operations. In place of such regulations, the Government of Sri Lanka (GOSL) ensured operators would use best oilfield practices by reviewing and approving the operators' Standards of Procedures (SOP).

Encouraged by the outcome of the above operations, GOSL has since decided to enact a new legal and regulatory framework and adopt new guidelines for petroleum operations. As a result, the Petroleum Resources Development Secretariat (PRDS), established under Petroleum Resources Act No. 26 of 2003, issued geophysical, geological, environmental, and geotechnical program guidelines for petroleum operations in 2008 and guidelines for offshore drilling programs in 2011. In addition, the Marine Environmental Protection Authority, the agency responsible for environmentally clearing petroleum operations, issued the Offshore Exploration for and Exploitation of Natural Resources Including Petroleum (Marine Environment Protection) Regulation No. 1 of 2011. Under those regulations, several offshore 2D and 3D seismic surveys were conducted, and four offshore wells were drilled, resulting in two gas

discoveries. In 2020, the Sri Lankan Cabinet approved its National Policy on Natural Gas of Sri Lanka to support the natural gas commercialization process.

The GOSL has recently enacted a new Petroleum Resources Act No. 21 of 2021 and established a new entity to regulate all upstream petroleum operations in Sri Lanka, the Petroleum Development Authority of Sri Lanka (PDASL). The PDASL has published several regulations to establish procedures for entering exploration programs, data generation, and licensing. In addition, the PDASL is expected to formulate new technical regulations for upstream petroleum operations, including health, safety, and environmental-related areas considering methane emission abatement and gas utilization.

Subnational efforts also play a key role in emission management in some jurisdictions. These include regulations in several U.S. states, such as California, New Mexico, and Colorado, as well as Canadian provinces, such as Alberta and British Columbia. In addition, climate-focused initiatives such as the C40 Cities network and Under2 Coalition have united subnational entities around the world in addressing methane emissions.

Project approval procedures can be critical for assessing methane emission management options along with feasibility, impacts, and mitigation. Some jurisdictions require consideration of expected methane emissions prior to project approval, for example, as part of an Environmental Impact Assessment or a GHG management plan. The approval may include conditions to mitigate the environmental impacts, including monitoring, operational procedures, or limits on methane emissions.

Stakeholder Engagement

Stakeholder engagement gives affected communities a voice in decisions and informs decision-making. This process may consist of public notice and an opportunity to comment and provides transparency. Effective stakeholder engagement can promote buy-in.

Figure 3.2: Stakeholders in methane abatement regulation.

Civil society groups and environmental agencies may be interested in methane emissions as part of a national or subnational GHG reduction strategy. They may also seek to ensure that steps are taken to ensure that underserved communities have opportunities for meaningful participation and are protected in the decisions that affect them.

The industry may be particularly interested in costs and leeway for innovation as technologies evolve. In many cases, the sector has vital information which regulators need to ensure that

regulations are feasible and practical. If operators designate a point of contact, these individuals can support addressing a later emission event. Agencies and operators should maintain up-to-date contact lists of representatives to ensure timely and responsive communication.

Government agencies that manage natural resources or finances or oversee oil and gas operators may be interested in wasted natural gas as a result of practices such as flaring and venting. Energy agencies may be particularly interested in ensuring and expanding energy access.

Leveraging Voluntary Action by the Industry

In some instances, policymakers and regulators can leverage existing industry initiatives on methane abatement. Countries with fewer resources and lower initial capacity may begin their methane policy journey by working with the industry to promote voluntary actions and learn about methane policy options and best practices.

Joint industry efforts such as the Oil and Gas Climate Initiative Aiming for Zero Methane Emissions Initiative introduce standard guidelines, standards, and codes to share best practices and improve industry performance. Other examples include:

- ➔ The Environmental Partnership.
- ➔ Methane Guiding Principles.
- ➔ Oil and Gas Climate Initiative.
- ➔ Oil and Gas Methane Partnership 2.0.

Given the shared goal of near-term global methane emission reduction, many governments are actively considering all available tools for methane abatement, voluntary and otherwise,

by incorporating them into their regulatory programs. Governments should consider the possibility that policy choices have unintended consequences on voluntary methane emissions activities.

Common Approaches in Existing Regulations

Over the past few years, many countries have implemented methane reduction regulations which may provide practical examples for other jurisdictions. These include Canada, Colombia, Mexico, Nigeria, Norway, the United States, and the European Union. As discussed above, subnational jurisdictions have also developed methane regulations in some countries, including Alberta (Canada) and California, Colorado, and New Mexico (U.S.). These examples can also be a good starting point for understanding what options may be effective.

Most current methane regulations focus on prescriptive or information approaches. Existing regulatory schemes commonly include (1) LDAR requirements; (2) flaring and venting restrictions; and (3) standards for specific equipment and processes. These are discussed in detail in subsequent chapters. The effectiveness of these and other regulatory schemes are, in turn, supported by an evolving inventory of methane (and GHG) emissions founded on a program of monitoring, reporting, and verification (MRV). Chapters on inventories and MRV follow the discussion of the three regulatory schemes.

4. Methane Sources by Oil and Gas Market Segment

The three methane value chain segments have unique equipment, components, and processes. The specific abatement actions and their costs vary significantly. For example, flaring is generally associated with upstream production activities and is much less common in the mid and downstream segments. For these reasons, the specific make-up of a country's industry can inform the priority-setting among different mitigation options.

Case Study: Retrofitting Gas Distribution Systems (Bangladesh)

For Bangladesh, the midstream and downstream gas segments are priorities. It is currently modernizing its gas distribution system. Bangladesh has noticed many methane leakages in the old gas distribution pipelines. These pipelines were first built decades ago.

Natural gas was discovered in 1962, and two years later, the Titas Gas Transmission and Distribution Company (TGTDCL) was established. TGTDCL began construction on a gas distribution network then. It is still today the largest gas distribution company, providing more than 50 percent of the total natural gas supply to consumers.

Leaks of natural gas from the distribution grid came into sharp focus when Bangladesh started importing LNG in late 2018 to meet increasing energy demand. LNG is expensive, and so were losses of that LNG in the gas pipeline system. Primarily for energy efficiency and cost savings, TGTDCL decided to modernize the system.

Since then, TGTDCL has prepared a project to replace or upgrade its old gas network in the Dhaka and Narayanganj city corporation areas. The network services of TGTDCL have about 2.8 million residential consumers.

TGTDCL undertook a feasibility study for some 2750 kilometers of pipeline to be constructed or replaced and 18 natural gas stations to be modified. Importantly, the project will include geographic information systems (GIS) mapping, supervisory control and data acquisition (SCADA), and defect identification systems in the upgraded network. Ultimately TGTDCL will bring this modernized network under the energy sector automation system.

For Bangladesh, then, the downstream sector is a priority. And although TGTDCL is carrying out its gas pipeline modernization for operational efficiency and to improve financial safeguards, the reduced leakages will help climate goals, conserve resources, and improve the local environment and public safety.

The tables below outline key sources of methane emissions in the upstream, midstream, and downstream segments. They describe familiar emissions sources, the primary abatement options to address them, and potential trade-offs.[33]

Upstream

The upstream segment consists of oil and gas wells (both onshore and offshore), oil separation facilities, gas processing facilities, and gathering and short-distance pipelines between these facilities.

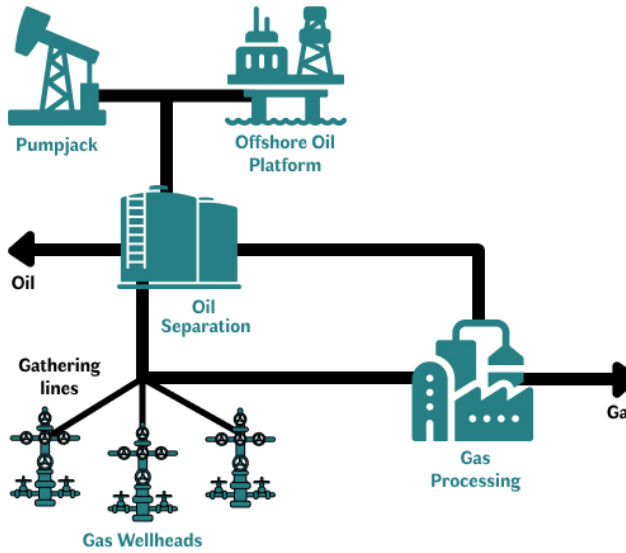


Figure 4.1: Illustration of upstream oil and gas infrastructure.

Table 4.1: Selected methane abatement sources/opportunities in upstream oil and gas.

Pneumatic controllers and pumps. Devices that use pressurized natural gas for process control actions or pumping fluid when electricity is unavailable.

Abatement Option	Description	Considerations
High Bleed Retrofits or Replacements.[34]	Replace certain types of high-emitting controllers with options that vent less natural gas.	None identified.
Inspection of Intermittent Vent Controllers.[35]	Ensure intermittent vent controllers do not vent gas outside active actuation periods.	Requires the existence of an LDAR program for fugitive emissions.
Replacement with compressed air (can replace any / all high bleed, intermittent bleed, low bleed, and pumps).[36]	Replace pressurized natural gas with compressed air.	Requires access to or on-site generation of electricity, which may be achieved by on-site solar.

Manual liquid unloading. Temporary diverting of the well to a lower pressure location to remove accumulated water.

Abatement Option	Description	Considerations
On-site personnel during unloading operation.[37]	The operator remains on-site until unloading is completed and the well is returned to production.	None identified.

Hydrocarbon storage tanks. Gas emissions associated with pressure drop and liquid movement activities in storage tanks.[38]

Abatement Option	Description	Considerations
Route to a control device like a flare.	Flare rather than vent gas.	Select situations where supplemental gas would be needed to combust vapors.
Route to a vapor recovery system.	Capture gas for sale or beneficial on-site use.	Some tank designs are not compatible with vapor recovery systems; inadequate design to handle emissions.

Centrifugal compressor wet seals. Methane becomes entrained in oil-based (wet) seal systems that must be purged to maintain compressor function.

Abatement Option	Description	Considerations
Re-route gas.	Capture gas via vapor recovery or routing to the compressor suction.	Convert to a lower-emitting dry seal technology.
Convert to a lower-emitting dry seal technology.	Replace or design the seal system with lower-emitting technology.	Conversion of some older compressor designs is not feasible.

Midstream

The midstream segment includes transportation infrastructure, such as long-distance pipelines and associated compressor stations, liquefied natural gas facilities and tankers, and storage facilities.

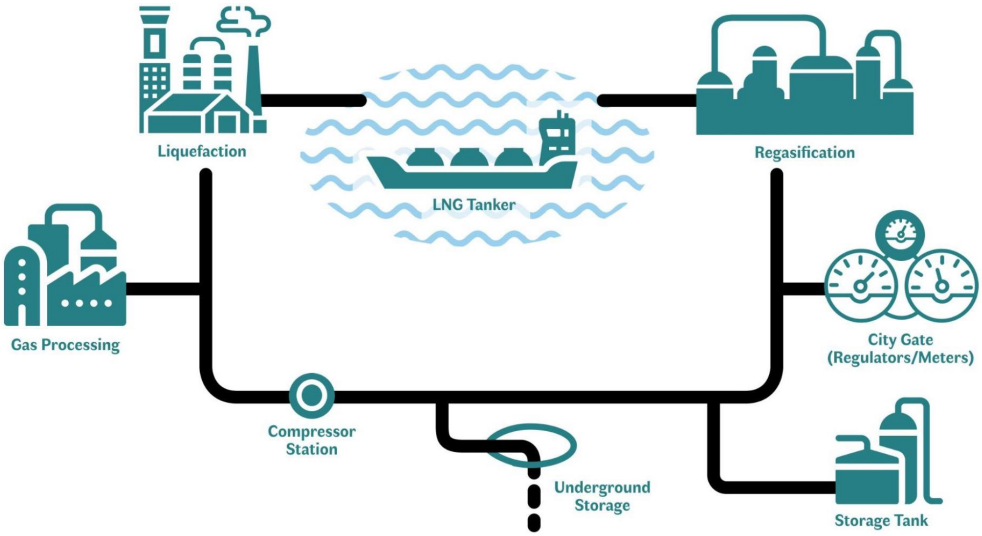


Figure 4.2: Illustration of midstream oil and gas infrastructure.

Table 4.2: Selected methane abatement sources/opportunities in midstream oil and gas.

Pneumatic devices. Devices that use pressurized gas for process control actions or pumping fluid when electricity is unavailable.

Abatement Option	Description	Considerations
High Bleed Retrofits or Replacements.[39]	Replace high-emitting controllers with those that vent less gas.	None identified.
Inspection of Intermittent Vent Controllers.[40]	Ensure intermittent vent controllers are not venting outside of active actuation periods.	Requires the existence of an LDAR program for fugitive emissions.
Replacement with compressed air (can replace any / all high bleed, intermittent bleed, low bleed, and pumps).[41]	Replace pressurized gas with compressed air.	Requires access to or on-site generation of electricity, which may be achieved by on-site solar.

Hydrocarbon storage tanks. Gas emissions associated with pressure drop and liquid movement activities in storage tanks.[42]

Abatement Option	Description	Considerations
Route to a control device like a flare.	Flare, rather than vent, gas.	Select situations where supplemental gas would be needed to combust vapors.
Route to a vapor recovery system.	Capture gas for sale or on-site beneficial use.	Some older tank designs are not compatible with vapor recovery systems.

Centrifugal compressor wet seals. Methane becomes entrained in oil-based (wet) seal systems that must be purged to maintain compressor function.

Abatement Option	Description	Considerations
Reroute gas.	Capture gas via vapor recovery or routing to the compressor suction.	Engineering design studies are needed to ensure safe operation.
Convert to a lower-emitting dry seal technology.	Replace or design the seal system with lower-emitting technology.	Conversion of some older compressor designs is not feasible.[43]

Reciprocating compressors – rod packing vent. Rod packing emissions typically do not occur around the rings but through the nose gasket around the packing case, between the packing cups, and between the rings and shaft. As the rings wear, or if the fit between the rod packing rings and the rod is too loose, more gas can escape.

Abatement Option	Description	Considerations
Replacing rod packing based on a fixed predetermined time frame or hours of operation.	Replace reciprocating compressor rod packing every 26,000 hours or every 36 months.	Scheduling downtime ensures the station meets reliability and demand requirements, especially if connected to a public utility or critical infrastructure.

Abatement Option	Description	Considerations
Capture, flare, or control vented gas.	Route packing vent to capture system for beneficial use or route to flare to achieve at least a 95 percent reduction in methane emissions.	Scheduling downtime as described above, potential space constraints, and possible disruptions with associated systems.
Conditions-based monitoring.	Use continuous monitoring or testing data to track emissions and develop a predictive maintenance program.	Start-up costs; Initial configuration of sensors and associated software; and learning curve for a new system.

Transmission pipeline blowdowns between compressor stations. Blowdowns are the release of gas from a pipeline that causes a reduction in system pressure or a complete depressurization. They are typically required for maintenance.

Abatement Option	Description	Considerations
Capture vented gas.[44] .	Route gas to a compressor or capture system for beneficial use, route to flare, or leverage existing piping connections between high and low-pressure systems.[45]	Extensive planning and coordination with Gas Control to minimize downtime; some route opportunities may not be available due to safety concerns; hot tapping adds new infrastructure, increasing maintenance and leak points.

Compressor station, transmission meter, and regulator stations or above ground facilities. Fugitive and vented gas associated with above-ground facilities.

Abatement Option	Description	Considerations
Periodic LDAR; re-design venting or emergency blowdown systems to simulate or re-direct gas back into the system during testing; install continuous monitoring.	Conduct routine inspection and maintenance programs or LDAR programs at defined intervals; install continuous monitoring at compressor stations; and incorporate the ability not to vent gas during safety testing of emergency blowdown systems.	Re-designs of emergency blowdown systems can be capital intensive and disrupt other operations; cost-effectiveness of continuous monitoring systems if the low risk of large emission events; integrating new infrastructure will have initial up-front costs and ongoing maintenance.

Engines or other on-site combustion devices (e.g., flares). Incomplete combustion allows methane to slip into flue gas in the atmosphere.

Abatement Option	Description	Considerations
Periodic Tune-up and Maintenance Programs; Process Monitoring and Control optimization systems.	Periodic maintenance programs to ensure the engine or combustion device is operating as designed and per specs; install monitoring and control systems for optimal combustion efficiency.	New skills to learn how to properly tune and maintain equipment for optimal combustion efficiency or learn new process monitoring and control systems.

Pipelines. Transmission pipelines can leak via integrity failures from corrosion and unintentional damages from weather events (e.g., landslides) or third-party (dig-ins).

Abatement Option	Description	Considerations
Pipeline Integrity Program; LDAR programs; Continuous Monitoring Systems.	Pipeline integrity programs with internal and external inspection; periodic LDAR surveys (aerial and walking); installing Continuous Monitoring along pipeline routes.	Integrity programs require diligence and expertise in evaluating and addressing identified threats with good data management tools; new training and skill may be required.

Downstream

The downstream gas segment consists primarily of distribution networks designed to reach end consumers, whether residential, commercial, or industrial.

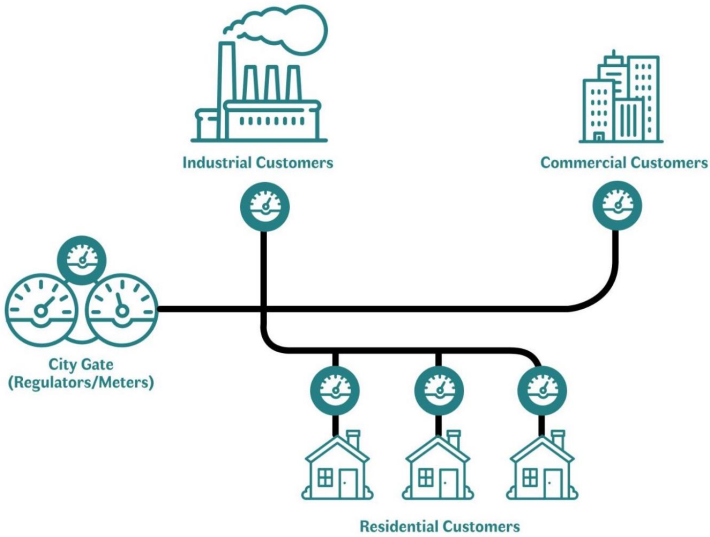


Figure 4.3: Illustration of downstream gas infrastructure.

Pipelines (mains and services). Distribution pipelines can leak via integrity failures (typically from corrosion of the steel at the joints for cast iron and cracking from non-state-of-the-art plastic materials) or inadvertent damages from third-party dig-ins.

Table 4.3: Selected methane abatement sources/opportunities in downstream gas.

Abatement Option	Description	Considerations
Pipeline Integrity Programs.	Distribution Integrity Management Programs to identify threats and monitor ongoing performance. Use aerial and mobile surveys and continuous point-sensing monitoring technologies. Prioritize repair on bigger leaks. Accelerate replacement of leak-prone pipe systems.	Rehabilitating and replacing pipelines can take years and require significant upfront capital. Demonstrating reductions will require alternatives to traditional emission factor methods — new methods to link emissions to actual leaks and their duration before repair. Developing cost-effectiveness or marginal abatement cost curves are critical to ensuring enhanced LDAR can be prioritized for maximum impact.
Enhanced LDAR Programs.	Enhanced LDAR programs increase surveys in poor-performing areas. Use decision tree analysis to find the bigger leaks.	Capital and operating costs. Developing cost-effectiveness or marginal abatement cost curves is critical to ensuring enhanced LDAR can be prioritized for maximum impact.

Abatement Option	Description	Considerations
Damage Prevention Programs (e.g., Call Before You Dig 811).	These programs reduce the risk of pipeline ruptures from digging activities by maintaining an easily accessible system for developers to get information about the location of pipelines before they dig.	It may be difficult to obtain the GIS data of pipeline locations. Have to build the information database. Time and cost of building public awareness of the program.

Customer meters. Fugitive emissions from leaking components (e.g., loose-fitting) or venting from pressure regulators. Commercial/ industrial meters may have pneumatic devices and a higher potential to emit because they operate at higher pressures than residential meters.

Abatement Option	Description	Considerations
Enhanced leak detection and accelerated repair.	Enhance leak detection through aerial and mobile surveys and installation of point sensing where data analytics can be used to find leaks. Accelerate or prioritize repair based on leaks from higher-pressure systems (if not safety-sensitive).	Funding and human capacity constraints. Similar to pipelines, a need exists to move from traditional emission factors to leaker-based factor methods to demonstrate reductions and to develop more accurate emission profiles.

Abatement Option	Description	Known Implementation Challenges
Installation of advanced meter networks.	Advanced meter networks can use data analytics on the customer side of the meter to find leaks through anomalies in hourly consumption rates.	Capital and operating costs. Training costs and integration into IT infrastructure.
Re-design of meter to reduce leak points.	Re-design of meters may involve changing from displacement to sonic meters for residential or eliminating leak points where possible.	Capital and operating costs.

5. Leak Detection and Repair (LDAR)

Key Takeaways

- Leak Detection and Repair (LDAR) programs are designed to identify and address unintended or fugitive emissions from equipment.
- LDAR requirements can be implemented without extensive data on or specific measurements of the level of fugitive emissions.
- Important design features of LDAR regulations include:
  - Scope of facilities to be inspected.
  - Detection technologies to be used and detection threshold to set.
  - Frequency of inspections.
  - Repair requirements, including deadlines.
  - Reporting, recordkeeping, and certification.
- Canada's federal LDAR regulation is discussed as an illustration of these design features.

Fugitive emissions, or leaks, are unintentional losses of methane. Leaks typically occur at several connection points, like values, throughout the value chain. While emissions from an individual leak may not be significant, the collective methane emission rates from fugitives are one of the largest sources of emissions from the oil and gas sector.

LDAR programs involve periodic on-site surveys by qualified personnel. If leaks are detected, the operator is required to fix those leaks within a specified period. In addition, operators are generally required to document the LDAR process and report regularly to the government.

LDAR programs do not require robust upfront methane emission data to function. Operators can begin conducting leak detection surveys and fixing leaks, which leads to methane reductions, even before extensive data is collected. However, data compiled

by operators during LDAR programs, such as the type and frequency of certain leaks, can be valuable information to help inform future actions.

LDAR Regulation Features

Figure 5.1: Features of LDAR regulation.

Several design considerations determine the effectiveness of LDAR programs:

Scope of inspected facilities. LDAR requirements can specify which facilities must be inspected. Exclusions can be based on size, throughput, or other characteristics. For example, smaller facilities may be excluded or have different requirements. The frequency of surveys may be lower for very remote facilities. LDAR programs may include exceptions for components designated as unsafe to monitor.

Leaks can occur at all types of facilities, whether large or small. A program focused on a subset of emission sources may address

fewer leaks but be more cost-effective. If a regulation covers only a subset of sources, covering the sources most likely to leak will be essential.

Detection technology and detection threshold. LDAR regulations may require specific methods or technologies to conduct the source survey. These include, but are not limited to, audio, visual, and olfactory (smell) inspections (AVO), various portable monitoring instruments like sniffers for EPA Method 21, and optical gas imaging (OGI) cameras. For instruments and OGI cameras, regulations may specify calibration and operational requirements for the device. These can include a specific detection threshold for the size of a leak that the instrument can detect. However, LDAR regulations might not necessarily require quantifying individual leaks beyond whether they are above the detection threshold.

AVO inspections are inexpensive as they are grouped among other routine duties at a facility and do not require special equipment. However, their effectiveness at detecting leaks is best at sites with simple equipment (like wellheads) and low noise levels. OGI cameras, which require specialized training to operate and use, are more effective at detecting leaks.

There is an ongoing discussion over how to ensure that LDAR regulations encourage innovation and development of advanced technologies, such as aerial surveys from airplanes or drones, satellites, and continuous monitoring. Some jurisdictions have created processes for operators to petition to use an alternative approach by proving that it can achieve at least the same level of emissions reductions as the detection technologies specified in the regulation. Other potential options include developing a common framework to evaluate the equivalency of emerging monitoring technologies for identifying emissions reductions.

Given the number of different detection options and the fact that the technology is advancing rapidly, some regulators have chosen to incorporate the approaches from other jurisdictions in their

regulations. For example, many jurisdictions already refer to the U.S. Environmental Protection Agency's instrument detection standard — EPA Method 21. Further detail on these technologies can be found in *Chapter 8: Inventories* and *Chapter 9: Monitoring*.

Frequency of inspections. The frequency of inspections (annual, quarterly, etc.) influences the emission reduction potential of an LDAR program. More frequent surveys lead to faster detection and repair of leaks but at an added cost. At some point, additional surveys can reach a point of diminishing returns. One source of guidance on survey frequency and measurements is MiQ, which provides a methane emissions certification standard.[46]

Repair requirements. LDAR regulations can require companies to repair any leaks detected during the periodic surveys. The regulation can require a specific timeline for these repairs, such as 30 days. A longer period may be needed for complex repairs. A shorter repair deadline ensures leaks are repaired more quickly but can have operational implications for facilities. Some regulations state that if a repair can be made without shutting down the facility, repairs are required in a short time frame, such as 30 days, but allow a longer time frame for repairs that necessitate a full shutdown.

Reporting, certification, and auditing. LDAR regulations can require companies to keep records of their leak detection surveys, detected leaks, and repair actions. These can be done through specified templates or an online reporting tool. These reports may include:

- ➔ Date of the survey.
- ➔ Type of detection instrument.
- ➔ Details on the source surveyed (location, type of facility).
- ➔ Information on any leaks detected (type of component, type of service, etc.).
- ➔ Action taken on repairs, including dates.

➔ The outcome of repairs, including follow-up surveys.

Some regulations require that LDAR reports be certified or audited by a third party. This practice can aid the regulator in ensuring that reports are complete and accurate, with additional administrative burdens on operators.

Example: Canada's Federal LDAR Requirement

In 2018, the Canadian federal government established a national LDAR requirement that has many of the features mentioned above.[47]

Scope of inspected facilities. Canada's regulation only applies to large facilities, generally covering all upstream oil and gas facilities, including well pads and compressor stations, that produce or handle more than 60,000 m3 of natural gas annually.[48] Section 28(1) of the regulation also explicitly excludes certain pieces of equipment from the LDAR requirement:

Section 28 (1) Sections 29 to 36 do not apply in respect of:

➔ *(a) an equipment component used on a wellhead at a site at which there is no other wellhead or equipment except for gathering pipelines or a meter connected to the wellhead;*

➔ *(b) a pair of isolation valves on a transmission pipeline if no other equipment is located on the segment of the pipeline that may be isolated by closing the valves; and*

➔ *(c) an equipment component used at an upstream oil and gas facility whose inspection would pose a serious risk to human health or safety.*

By specifying the exempted facilities, equipment, or circumstances, Canada's regulations focus the inspections on the

sources of leaks that are most important to achieve meaningful reductions. For example, because leaks often occur from components or equipment at a facility, wellhead-only sites with few components and no other equipment (e.g., storage tanks, compressors, etc.) are exempted because of a lower probability of leaks. Similarly, isolation valves on transmission pipelines are exempted in (b) because the emission potential from these components at these facilities is low. The third exemption at (c) covers any instance where the inspection could pose a risk to human health or safety, providing less clarity on where it would apply. Exemptions can reduce burdens on operators but may miss emissions from significant methane emitters and increase burdens on the regulator to address exemption requests.

Detection technology and detection threshold. Canada requires instrument-based inspections. It specifies two instruments that are eligible for use: (1) portable monitoring instruments that meet certain operational and calibration specifications and (2) OGI instruments capable of meeting specific detection requirements. Section 30(2) provides that a portable monitoring instrument must comply with EPA's Method 21 in its specification, application, and calibration. For OGI cameras, the regulation sets a concentration threshold of "at most 500 ppm [by volume] and at a flow rate of at least 60 [grams/hour] leaking from an orifice that is 0.635 centimeters in diameter." It also includes requirements regarding the viewing distance.[49]

Requiring the use of these instruments can entail training and equipment costs but can detect leaks that AVO methods would miss. By referencing existing specifications from another regulator, the Canadian rule avoids the need to develop a detailed technical standard while ensuring consistency for those operators that must comply with the same specifications in their jurisdictions.

The Canadian regulation allows operators to establish an alternative LDAR program so long as it "results in at most the same quantity of those fugitive emissions as would result from"

an LDAR program in line with the regulation.[50] The regulation also provides that an alternative program must have the following elements:

(a) the inspection for leaks;

(b) the operation, maintenance, and calibration of leak detection instruments, if applicable; and

(c) the repair of leaks detected.[51]

This flexibility allows an operator to use an instrument not directly listed under the regulations or to inspect with different frequencies. Using an alternative program places the burden on the operator to demonstrate program effectiveness with supporting documents that must be submitted to the regulator.

Frequency of inspections. Canada's regulation specifies the timeframe for initial and subsequent inspections:

30(3) The period for inspections is as follows:

(a) for the first inspection, on or before the later of May 1, 2020, and the day that occurs 60 days after the day on which production at the facility first began; and

(b) for subsequent inspections, at least three times per year and at least 60 days after a previous inspection.

For example, a new facility would be required to perform an LDAR inspection within 60 days after the first day of production and then at least three times per year at each facility with at least 60 days between inspections. This frequency allows operators to determine the best inspection schedule across multiple facilities within the limits of the regulation.

Repair requirements. Canada's regulation requires that detected leaks be repaired. The deadline for repair varies depending on the ease of making the repair. Where a repair can be made while the component operates, the operator must make the repair within 30 days:

32 (1) A leak from an equipment component that is detected, whether as a result of an inspection or otherwise, must be repaired.

(a) if the repair can be carried out while the equipment component is operating, within 30 days after the day on which it was detected.

However, if a repair would require a shutdown, the repair can be carried out during the next planned shutdown:

32(1) (continued)

(b) in any other case, within the period before the end of the next planned shutdown unless that period is extended under section 33.

The regulation further specifies that the deadline for making the next planned shutdown is based on the relative size of the leak compared to the emissions that would be emitted in the process of repairing:

(2) The next planned shutdown must be scheduled not later than the date on which the estimated volume of hydrocarbon gas, expressed in standard m3, that, beginning from the day on which the leak is detected, would if no repairs are made be emitted from the leaking equipment component in question and from all other equipment components that are also leaking as of that day is equal to the volume of hydrocarbon gas, expressed in standard m3, that would be emitted due to purging of hydrocarbon gas from equipment components to repair.

In other words, because shutting down and repairing components may require venting the gas inside the component, the repair must be scheduled before the cumulative emissions from the leak exceed the anticipated emissions the shutdown would cause.[52] This approach allows flexibility for companies to schedule the repair while providing limits to ensure that the leak does not continue indefinitely.

Reporting, certification, and auditing. The Canadian regulation requires operators to create and keep records and supporting documents, including:

- Each calibration of inspection instruments.
- Date of inspections.
- The type and location of the equipment with GPS coordinates.
- The type of instrument used.
- In the case of OGI, images were recorded with embedded indications of data and time.
- Leaks that were detected and documentation of steps taken to repair leaks.[53]

Canada requires that these records must be created within 30 days following when the information becomes available and that those records be kept for five years.[54] The regulation requires that they be submitted within 60 days upon request.[55] This approach reduces the ongoing administrative burden on the regulator from receiving and reviewing reports while providing a mechanism for government officials to obtain information for review as needed. Failure to comply with this regulation's reporting or other provisions can subject an operator to monetary penalties.

For more on compliance mechanisms, see *Chapter 10: Ensuring Compliance*.

6. Flaring and Venting

Key Takeaways

- Addressing the flaring and venting of natural gas is one of the primary ways regulators can abate methane emissions from the oil and gas sector.
- Technologies to reduce or eliminate routine flaring and venting are well-known and, with appropriate infrastructure, can be deployed.
- A number of countries have adopted regulations to reduce flaring and venting. These flaring and venting regulations generally include several key features, which this chapter discusses in more detail.
- Colombia and Kazakhstan have recently enacted new regulations to reduce flaring and venting. This section looks at the texts of their regulations as a source of insight into how other regulators can craft their flaring and venting regulations.

Flaring is controlled natural gas burning for operational, safety, or economic reasons. **Venting** is the intentional release of natural gas into the atmosphere. From a greenhouse gas emission perspective, flaring is better than venting because it combusts methane into carbon dioxide rather than directly releasing methane gas — which has a higher global warming potential — into the atmosphere.

This chapter focuses on instances where natural gas is flared or intentionally vented for operational, safety, or economic reasons. Note that venting from the regular operation of equipment or maintenance or other processes is covered in the equipment standards section of *Chapter 7: Equipment and Process Standards*.

Flaring and venting are a waste of energy resources and are sources of greenhouse gas emissions in the oil and gas sector. They contribute to local air pollution levels as well. Flared gas releases CO_2, black carbon (soot), and a certain amount of uncombusted methane. Even the best-performing flares do not achieve 100 percent destruction efficiency (some assumptions

are as high as 98 percent; the IEA estimates that the typical destruction efficiency is 92 percent), and many achieve significantly lower efficiencies.

Features of Flaring and Venting Regulations

Flaring and venting restrictions are relatively common. Recently, some jurisdictions have taken steps to expand or enhance laws aimed at reducing flaring and venting, including Colombia, Nigeria, and Kazakhstan. Others have adopted regulations to largely prohibit routine flaring, including the Netherlands, Norway, and the U.S. State of New Mexico.

There are tried-and-tested regulatory options for regulators to reduce or prevent routine flaring or venting, particularly for associated gas from oil production. These include:

When a permit is required. Some jurisdictions require that operators obtain a permit or authorization for flaring. If an unplanned event occurs, the regulation may require operators to submit a report after the fact. A permit requirement provides an opportunity for a jurisdiction to collect information on the flaring and venting taking place, which could help it understand overall emissions levels. The costs of complying with flaring limits can be considered in the permit approval process.

Exceptions to bans on flaring and venting. Flaring is often allowed for safety purposes or to protect human health. Some countries allow exceptions to flaring bans where flaring would be economically unjustified, cost-prohibitive, or where the cost of utilizing the gas is greater than the value received. Some jurisdictions have stipulated that a lack of available pipeline infrastructure does not justify flaring. When deciding which exceptions to allow, governments may weigh the costs to the

industry against reducing emissions and avoiding the waste of natural gas. The impact on oil revenues may also be a consideration.

Reduction of flaring over time. The World Bank Global Gas Flaring Reduction Partnership (GGFR)[56] secures global commitments from governments and companies to end routine gas flaring. Some countries and companies have signed on to the Zero Routine Flaring by 2030 initiative.[57] Some countries have included this target or an earlier target date, such as 2025, in their regulations.

Flare efficiency. Not all natural gas that is flared will be fully combusted. Some flares may not function properly and operate less efficiently than industry standards.[58] Some flare flames (also called pilot flames or pilot lights) may be extinguished, leading to the venting of methane. Improving flare efficiency is an important technology development and emission reduction research area.[59]

Some countries have regulations that set design standards or operating envelopes for flare equipment to ensure minimum destruction efficiency levels for flares.[60]

Royalties, penalties, and other economic incentives. Flaring and venting regulations can include a prescriptive element, such as a ban or permit requirement, and an economic element, such as a royalty charge. Flaring is comparatively easy to measure and meter (*see Chapter 9: Monitoring*), so economic incentives are more viable for flaring than for fugitive emissions (or venting). A flaring royalty or tax can provide a monetary incentive for companies to reduce their flaring. These charges can be imposed on all flared volumes or volumes above a threshold. The impact of these measures can be affected by the royalty rate, infrastructure, gas prices, and demand.

Measurement and reporting. Many governments require operators to report volumes of gas flared or vented. In some cases, direct measurement of flared volumes is required, while in

other cases, the amounts are estimated using gas-to-oil-ratio and oil production volumes.

Incentives to increase gas utilization. Some countries have developed incentives to help create a domestic market or other potential use opportunities for gas that would otherwise be flared. Some countries require operators to develop gas utilization plans and offer direct investments in infrastructure for gas utilization or other incentives to encourage gas utilization. A recent project in Angola redirects gas that would have been flared to LNG exports.[61]

Example: Flaring and Venting Restrictions in Colombia

Colombia has significantly reduced flaring through regulations and the efforts of its NOC, Ecopetrol. Between 2012 and 2022, Colombia reduced its absolute flare gas volumes by 75 percent, while production decreased by about 20 percent. Over this same period, flaring intensity (cubic meters of gas flared per barrel of oil produced) decreased by about 65 percent, making Colombia one of the top performers for flaring reduction worldwide, along with Norway, Canada, and Brazil.

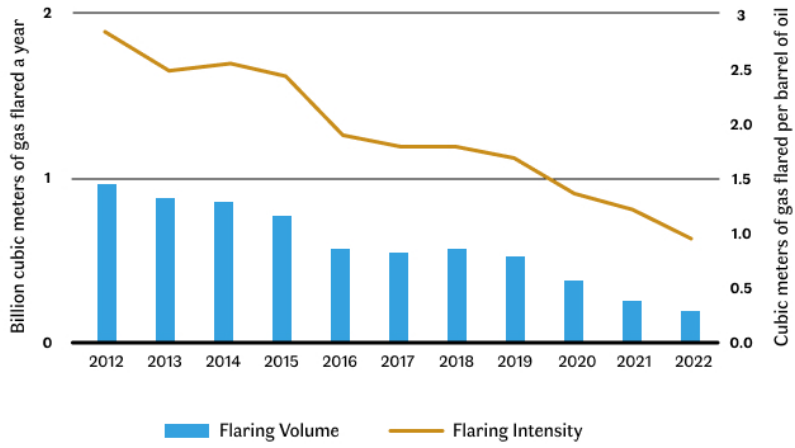


Figure 6.1: Flaring volumes and intensity in Colombia, 2012-2022.[62]

Colombia's associated natural gas regulations include:

- Enforcement of flaring and venting measures by the regulators, the National Hydrocarbons Agency (ANH), and the Ministry of Mines and Energy (MME).
- Financial payments by operators to the government on flaring and venting.
- The encouragement of a competitive domestic gas market through open and non-discriminatory access to gas infrastructure.

Colombia's landmark Resolution 40066, adopted in 2022, provides:

- Venting is banned in both exploration and production, with exceptions during an emergency or for maintenance.
- All flaring requires prior regulator authorization, which must be included in an annual permit.

- ➔ In general, flaring is not allowed, with limited exceptions, including for safety reasons, planned maintenance, and economic non-viability.
- ➔ Flaring due to unplanned events must be estimated in advance based on the previous year and is subject to a phase-out over five years.
- ➔ Operators must pay royalties on flared, vented, or otherwise wasted gas unless authorized by a permit.[63]

Resolution 40066 addresses the key features of venting and flaring regulations:

When a permit is required. Resolution 40066 prohibits the intentional venting of associated gas and requires collection for use or routing to a flare where technical or economic conditions prevent use. This provision includes limited exceptions without prior authorization. The operator is required to inform the regulator within 24 hours of the emissions event.

Resolution 40066 prohibits operators from flaring natural gas without a flaring authorization and permit issued by ANH. An annual permit is required.

To obtain the annual flaring permit, operators must submit a request at least 30 days before starting operations or the expiration of the current permit, with information on the expected flaring levels for each of these reasons, a justification, and supporting information. To flare gas because it is not economically viable, the operator must demonstrate that the associated gas cannot be commercialized.

Article 18 sets out what the operator must submit to obtain an annual permit:

[Excerpt from Article 18:]

1. *Cause and justification for the natural gas flaring.*

2. *Maximum volume of natural gas to be flared determined in accordance with Article 17 of this resolution.*
3. *Estimated volume of gas to be flared for safety reasons, supported by calculations or values established by the supplier.*
4. *Estimated volume of economically unfeasible natural gas supported by its respective technical-economic study.*
5. *Estimated volume of planned events gas supported under a maintenance plan.*
6. *In the case of presenting gas volume from unplanned events, they must be duly justified with the delivery of an operational optimization plan.*
7. *Estimated volume of gas from intentional venting collected for flaring supported by the respective calculations.*
8. *Alternatives and supports to carry out gas utilization, when applicable.*[64]

In addition, a special case flaring permit is required for events not included in the annual permit and resulting from gas management or causes not attributable to operational practices. If a permit is not submitted, the operator must provide notification within 24 hours. ANH must decide on each permit request within 30 days of receipt. ANH may also request additional information to evaluate the permit request within 7 days of receipt.

Exceptions to a ban on flaring and venting. Resolution 40066 (Article 34) provides three exceptions to the ban on venting.

1. Venting may occur in an emergency, and ANH must be informed within 24 hours of the end of the emergency.
2. Venting may occur in connection with a facility's preventive maintenance program, and ANH must be notified within 24 hours.

3. When the volume of gas is less than that needed to keep a flare pilot light burning.

Flaring authorizations can be granted in the following circumstances:

- ➔ Safety reasons.
- ➔ Routine flaring is subject to limits found in the regulation (e.g., pilots).
- ➔ Where capture is not economically viable (with a demonstration of justification).
- ➔ Flaring related to planned maintenance events.
- ➔ Gas collected that would have otherwise been intentionally vented.
- ➔ Unplanned events that are duly justified.

Operators must submit supporting documentation to justify flaring. The Resolution provides that a flaring authorization will be granted whenever gas is being collected that otherwise would have been vented. This eliminates the incentive to vent gas rather than seek a flaring permit.

Reduction of flaring over time. Resolution 40066 includes a calculation for the maximum volume of gas that may be flared, which is essentially the sum of estimates for authorized flaring under each of the exceptions listed above. The maximum allowable amount due to unplanned events, however, must decrease by 20 percent each year over five years, until it reaches zero in year five. This phase-out only applies to that specific category of flaring (unplanned events) and does not apply to situations where capture is not economically viable or to the limited instances where routine flaring is allowed.

Flare efficiency. Resolution 40066 (Article 22) requires operators to verify annually that each flare has been inspected and operates within acceptable ranges. The operator can do the

verification itself, provided they have the necessary equipment and technical capabilities. Also, monitoring equipment must be installed to ensure the flare is functioning properly:

[Excerpt from Article 22:]

For this, the best available technology will be used to monitor the flame, such as an infrared camera to determine the generation of smoke from the burning of liquid hydrocarbons or emission measurement drones to check the status of the ignition system of pilots or similar equipment. [65]

If issues or problems are found, the operator must (1) make repairs as soon as possible, in no case exceeding 6 months, and (2) report the condition to the regulator.

Royalties, penalties, and other economic incentives. Resolution 40066 and its predecessors established two financial incentives for operators to incentivize them to not flare more than allowed under their permit:

- **Royalties**. Article 18 states that royalties will be due on any flaring exceeding the volume allowed in the flaring permit. Thus, whatever amount they report beyond the permit will be automatically subject to royalty payments.
- **Administrative penalty.** Under Resolution 40066 and the 1953 Petroleum Code, the penalty for violations (flaring more than allowed under the permit) will be $5,000.

Measurement and reporting. Resolution 40066 requires measurement and monthly reporting of flared volumes and provides a reporting format:

Article 24. Measurement and Reporting of the Volumes of Natural Gas Flaring. All volumes of natural gas flaring must *be measured and reported by the Operator on a monthly basis to the [ANH] through the attached [Reporting Form] or the one that acts as such.* [66]

Resolution 40066 also requires that intentionally vented gas be reported to the authorities, together with a justification. It does not, however, require measurement. Instead, it specifies that volumes must be quantified and reported following production reporting templates and procedures.

Example: Associated Gas Utilization in Kazakhstan

Kazakhstan is an example of how a country can reduce flaring by encouraging the use of associated gas. Flaring in Kazakhstan has dropped significantly over the last decade, as is illustrated below:

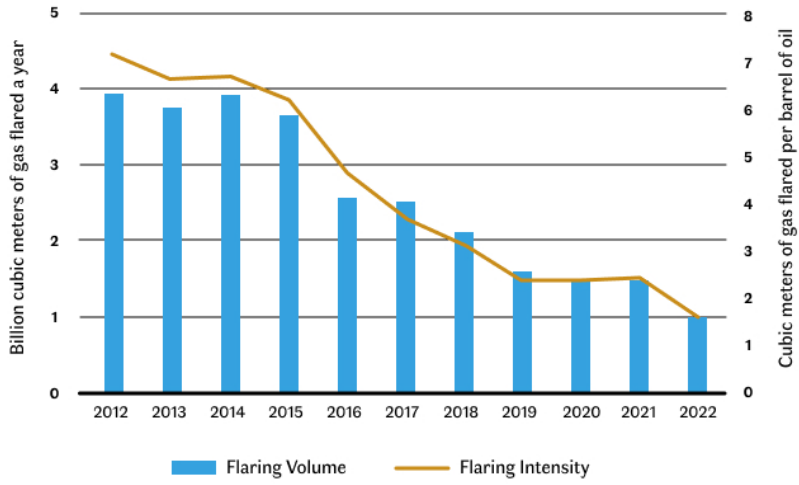


Figure 6.2: Flaring volumes and intensity in Kazakhstan, 2012-2022.[67]

Incentives to increase gas utilization. Like many countries, Kazakhstan has banned flaring and venting, subject to certain exceptions, including to protect human health and safety.[68] In parallel, Kazakhstan has encouraged oil producers to utilize or market associated gas.

In Kazakhstan, petroleum resources — including associated gas — are the property of the State.[69] The State's ownership provides a strong incentive for the government to ensure the resource is put to productive use and not wasted.

Kazakhstan's Petroleum Law requires operators to develop a plan to utilize associated gas before receiving permission to construct any new oilfield projects. The regulator must approve these plans before the project obtains a permit, and must be updated every three years. The operator must also submit an annual report on the implementation of the gas utilization plan.[70]

The Kazakhstan law provides four options for using associated gas:

1. Gas may be flared if it qualifies for one of the exceptions (e.g., emergency flaring to protect human health and safety, flaring during testing, etc.).
2. Gas may be used for the operator's immediate purposes, such as burning for onsite power.
3. Gas may be sold to another user for processing and marketing.
4. If raw gas processing is uneconomic, gas may be reinjected into an underground reservoir for storage or to maintain reservoir pressure.[71]

The operator must submit a capture and utilization plan (that does not include routine venting and flaring) for a new project to be approved. The law empowers the regulator to work with existing facility operators to establish progressive targets for capture and utilization based on economic feasibility.

The utilization requirement may help create a domestic market for associated gas and incentives for the installation of necessary infrastructure. Because companies are required to actively seek out utilization opportunities, this creates a business opportunity for companies that may be able to use that gas productively.

Kazakhstan started with the advantage of existing gas infrastructure — including midstream pipelines, city distribution, and export pipelines — and an existing consumer and industrial base of customers. Oil producers could thus ship gas through existing transmission infrastructure to domestic and export markets. Other features of the regulatory regime, including flaring restrictions in the Environmental Code, encourage gas utilization. Kazakhstan also imposes monetary penalties for breaches of permitting requirements. Kazakhstan's focus on ensuring associated gas can reach consumer markets, along with these regulatory restrictions, has significantly reduced flaring.

Useful Resources on Flaring and Venting

World Bank 2022: Comparative Review of Global Flaring and Venting Regulations, *https://flaringventingregulations.worldbank.org/summary-report*

Methane Guiding Principles 2019, Reducing Methane Emissions: Best Practice Guide — Flaring, *https://methaneguidingprinciples.org/resources-and-guides/best-practice-guides/flaring*

Global Gas Flaring Reduction Partnership, Oil and Gas Climate Initiative, Methane Guiding Principles, and Methane Flaring Toolkit, *https://flaringmethanetoolkit.com*

7. Equipment and Process Standards

Key Takeaways

- Methane can be emitted from equipment used in the oil and gas sector as a result of the design of that equipment or by the operating standards for that equipment. Accordingly, requiring operators to adopt equipment and process standards is an important regulatory tool for methane abatement.
- Equipment and process regulations may require companies to replace higher-emitting equipment with lower-emitting alternatives or adopt specific procedures that avoid or limit methane emissions.
- There are many examples of equipment and process standard regulations in the oil and gas sector. These regulations apply to well completions and pneumatic devices, including valve controllers and pumps, compressors, storage tanks, glycol dehydrators, and liquids unloading.
- The November 2022 regulation in Nigeria shows how a country is using equipment and operating standards as part of its methane reduction plan.

Equipment standards are the design requirements for specific types of equipment in the oil and gas sector. Process standards, including standard operating procedures, are requirements for operating those pieces of that equipment or conducting specific activities. Methane may be released from equipment due to its design and during regular operation. For example, when an operator needs to conduct maintenance on equipment like an oil and gas separator, the standard operating procedure may be to vent the pressurized gas inside so that workers can safely carry out that maintenance. Venting emits methane.

The methane emissions from equipment and processes can be significant. Therefore, many governments have adopted regulations requiring equipment to be upgraded to newer versions with fewer or no methane emissions. Many governments have also adopted regulations requiring changes in procedural steps that can potentially reduce emissions compared to prior operating procedures.

Better equipment and process standards can help reduce methane emissions even without robust, measured data from

individual emissions sources. That said, a good inventory of sources — even one based on standard emissions factors — can help regulators understand what regulations will have the most impact and the potential costs to the industry for implementing the standards.

What a Typical Equipment or Process Regulation Looks Like

The specific elements of an **equipment-related emissions** standard depend on the emissions source targeted. These can require companies to replace a device known to emit methane with an upgraded version that emits less or not at all or require companies to install new equipment that recovers emissions.

For **process-related emissions**, prescriptive standards can specify changes to procedures that can potentially reduce emissions compared to standard operating procedures.

Targeted equipment/process. Determining what equipment to focus on with the regulation is the most important question when designing equipment standards. The specific control requirements can differ depending on the prevalent technology in the jurisdiction and the available technical abatement options.

Regulations can target:

- Pneumatic devices, including valve controllers and pumps. Some parts of the world may refer to this as instrument gas use.
- Compressors.
- Storage tanks.
- Glycol dehydrators.
- Liquids unloading.
- Well completions.

Regulators may consider the volumes of emissions from different sources and the feasibility and costs associated with abatement options. Each of these considerations could be influenced by regional or local factors, such as topography or climate. Often regulators looking to craft or update equipment and process standards regulations can learn more about the local nature of these sources from stakeholders.

Some equipment regulations require zero-bleed pneumatic controllers, which mandates using either electricity (from the grid or solar panels) or instrument air instead of natural gas. This specificity can provide clarity and predictable reductions but may not incentivize the use of technologies that may emerge later to reduce emissions to an equivalent degree at a similar or lower cost.

Other regulations use **performance-based equipment standards**. Instead of requiring a specific device, a regulation can list the required level of performance — for example, a pneumatic controller that emits less than 0.17 standard cubic meters per hour. This approach allows the company to choose any technology that meets the performance targets, sometimes with cost savings.

Coverage of sources. As discussed earlier, methane abatement potential and cost curves can be important considerations in regulatory design. Regulations may distinguish between large and small sources or provide other distinctions related to the cost or feasibility of compliance. A phased implementation period can provide existing facilities time to adjust to standards immediately applicable to new sources. In some regulations, existing sources can petition for an exemption or extension of the deadline based on technical issues or cost.

Monitoring. Another key consideration is determining the emissions reductions achieved by a requirement. Some regulations rely solely on manufacturer specifications — if the product is designed to emit less than the limit in the regulation,

then the requirement is met. In other cases, the regulation requires periodic testing of the equipment. Routine testing provides greater certainty regarding emissions with higher implementation costs for the industry.

Reporting, certification, and auditing. Reporting requirements are important for tracking compliance and can also themselves help improve compliance by assuring that companies know how they are performing. Reporting is also the foundation of transparency to create public accountability, itself a key driver for better performance. In some cases, regulations require companies to maintain records for a specified period, and the regulator can obtain those records upon request. Requirements to electronically submit some of the most essential records can also be valuable, so companies know that government has ready access to those records.

Some regulations require third-party certification via an audit. Third-party certification increases confidence that a company is complying without requiring a large government assurance apparatus, albeit with additional cost for the regulated industry. Third party certification programs are most effective when the third parties are completely independent of the entities being audited; random assignment of auditors is a proven effective approach for more accurate verification.

Example: Equipment Standard Regulations in Nigeria

Nigeria adopted a regulation in 2022 that established specific standards for several classes of equipment used in upstream oil and gas operations, including pneumatic controllers, pneumatic pumps, centrifugal compressor seals, reciprocating compressors, glycol dehydrators, and liquid storage tank.[72] Nigeria's regulation

is a good example of using equipment standards to abate methane. This section discusses some of these new equipment standards in detail:

Liquid Storage Tanks

Section 3.4.6 of Nigeria's regulation sets standards for liquid storage tanks.

Alternative equipment/process. Nigeria's regulation requires operators to implement a vapor recovery system or a combustion device (flare) for tanks that meet a certain size threshold:

1. Control requirements

i. For all fixed roof storage tanks with the potential to emit more than 2 tons per year of volatile organic compounds due to flash gas, working losses, and breathing losses, operators shall route emissions, including all emissions of flash gas and emissions due to working losses and breathing losses, either to a vapor recovery system or, in some cases, to a combustion device.[73]

Operators can select either (1) a vapor recovery system or (2) a combustion device. Including two alternatives for compliance gives companies the flexibility to choose the most appropriate solution for a specific circumstance.

In addition, operators must evaluate their pollution control systems and certify that the system is large enough to capture emissions associated with several different tank processes.

iv. Require operators of controlled tanks to evaluate their systems for controlling tank emissions and certify that each system, as designed, is large enough to capture all potential emissions (flash gas, working losses, and breathing losses) from the tank.[74]

Separately, the regulation includes operational practices associated with hatches and other access points used for inspection or level gauging purposes:

iii. Prohibit venting of hydrocarbon emissions from hatches and other access points on tanks during normal operation.

a. Hatch may be opened for measurement purposes, but the hatch shall be closed immediately after the sample is taken.

b. Alternatively, the operator may use an auto-gauging system or spigot to sample hydrocarbons in the tank without opening the hatch.[75]

Operators may comply with this regulation by installing auto-gauging systems or spigots to take tank samples but are not required to install them. If these options are not installed, the

operator must close tank hatches after a sample is taken as soon as possible. This option gives the operator significant flexibility because the equipment upgrade is not mandatory.

Coverage of sources. The Nigerian regulation applies to all fixed roof tanks with the potential to emit more than two tons per year of VOCs, regardless of the age of the tanks. However, there is a phased implementation schedule requiring controls to be implemented sooner on larger tanks:

Implemented using the following phase in a schedule (except for case noted in section 3.4.6, 1(ii)).

a. Tanks with VOC >12 tpy controlled within one year of implementation of present guidelines.

b. Tanks with VOC 6-12 tpy controlled within two years of implementation of the present guidelines.

c. Tanks with VOC 2-6 tpy controlled within three years of implementation of the present guidelines.[76]

Separately, the regulation allows operators to seek an exemption if using air pollution control equipment would be "technically infeasible without supplemental fuel":

ii. Owners or operators of storage tanks for which the use of air pollution control equipment would be technically infeasible

without supplemental fuel may apply to the NUPRC for an exemption from the control requirements of Section 3.4.6, 1(i). Such request shall include documentation demonstrating the infeasibility of the air pollution control equipment. The applicability of this exemption does not relieve owners or operators of compliance with the storage tank monitoring requirements.[77]

This exemption is intended for the situation where the regulation would be unduly burdensome for companies due to the need to transport supplemental fuel to operate pollution control equipment. A company must specifically request an exemption and submit supporting documentation. Section 2.iii provides that operators must conduct annual tests on exempted tanks to evaluate whether the exemption remains warranted (see below).

Monitoring. Nigeria's regulation includes a specific monitoring requirement for tank control devices. This requirement requires that the storage tank and associated vapor recovery systems be included in activities like audio, visual, and olfactory (AVO) surveys and in instrumented LDAR programs:

2. Monitoring

i. Require at least quarterly visual and AVO inspections of the floating roof and fixed roof storage tanks with emissions of more than 2 tpy and control devices to ensure emissions are being routed to control units and flares are operating as designed.

ii. Monitor storage vessels, access points, vapor recovery systems, and combustors as part of instrumented LDAR.

iii. All tanks (with emission >2tpy) that do not employ a vapor recovery system shall conduct annual flash analysis testing for these tanks to estimate annual methane emissions from the tanks and evaluate whether the exemption in Section 3.4.6, 1(ii) remains warranted.[78]

Reporting, certification, and auditing. The liquid storage tank regulation requires the operator to submit an annual report

demonstrating compliance. However, the record-keeping requirements are relatively limited by comparison, with only records required for quarterly visual and AVO inspections.

Pneumatic Controllers

Section 3.4.1 of Nigeria's regulation requires replacing high-bleed devices with low-bleed or zero-bleed devices, retrofitting high-bleed devices, and improving maintenance practices. These steps can reduce emissions and, in some circumstances, can have short payback periods.

The regulation prohibits operators from using a natural-gas-driven pneumatic controller that vents gas directly to the atmosphere for many facilities:

i. The following requirement applies to all compressor stations and processing plants. In addition, it applies to well production facilities with access to grid-electricity operators and all new well production facilities constructed after the effective date of this rule:

Operator shall not use natural gas-driven pneumatic controllers, and they shall instead retrofit facilities with zero-bleed controllers, including controllers powered by electricity or instrument air or emissions shall be routed to a vapor recovery system that captures the emissions. If it is not feasible to capture the emissions, operators may use a flare.[79]

While Nigeria's regulation requires zero-bleed controllers, it notes that emissions could be routed to a vapor recovery system or, as a last resort, flared. This allows natural gas-driven controllers to continue to be used in some cases but would require that the natural gas is ultimately captured or controlled.

Coverage of sources. Nigeria's regulation applies to all compressor stations and processing plants. It only applies to new construction and those with existing grid electricity access for

well production facilities. For existing well production facilities without grid access, the regulation provides a 5-year phase-in period:

ii. The following applies to well production facilities that do not have access to grid-electricity operators:

5-year phase-in period:

a. Within one year of implementation of the present guidelines, an operator shall ensure that 25 percent of these pneumatic controllers are zero-bleed controllers (as defined in the previous section), and the remainder are low bleed (i.e., emit less than 0.17 standard cubic meters per hour of natural gas).

b. Within two years of implementation of present guidelines, the operator shall ensure that 65 percent of these pneumatic controllers are zero-bleed controllers (as defined in the previous section), and the remainder are low bleed (i.e., emit less than 0.17 standard cubic meters per hour of natural gas).

c. Within three years of implementation of present guidelines, the operator shall ensure that 75 percent of these pneumatic controllers are zero-bleed controllers (as defined in the previous section), and the remainder are low bleed (i.e., emit less than 0.17 standard cubic meters per hour of natural gas).

d. Within four years of implementation of present guidelines, the operator shall ensure that 85 percent of these pneumatic controllers are zero-bleed controllers (as defined in the previous section), and the remainder are low bleed (i.e., emit less than 0.17 standard cubic meters per hour of natural gas).

e. Within five years of implementation of the present guidelines, the operator shall ensure that all pneumatic controllers are zero-bleed controllers (as defined in the previous section).[80]

The requirement to use zero-bleed devices increases quickly from 25 percent to 65 percent in just two years and then approaches 100 percent over the next three years. As a backstop, emissions

from pneumatic controllers that are not replaced with zero-bleed devices are limited to less than 0.17 standard cubic meters per hour. This provision operates as a **performance standard** as it does not require a specific type or model of controller and leaves it up to the operator to select any controller that meets the performance standard.

Monitoring. Nigeria's regulation for pneumatic controllers requires an annual test and regular inspections:

2. Monitoring

i. As long as an operator has gas-driven pneumatic controllers on site, they shall be tested annually using a direct measurement method (high volume sampling, bagging, calibrated flow measuring instrument), and the operator shall repair any device with a measured emissions flow rate greater than 0.17 standard cubic meters per hour within 14 days from the date of leak detection.

ii. Any gas-driven intermittent controllers venting to the atmosphere shall be monitored with instruments during any inspection conducted pursuant to the requirements of Section 3.2 to ensure that no emissions occur between actuations. If emissions occur between actuations, the controller shall be fixed or replaced within 30 days.[81]

For low-bleed devices, Nigeria's regulation requires an annual test using direct measurement to determine if the flow exceeds the threshold. It further requires the operator to make prompt repairs if an issue is detected.

Reporting, certification, and auditing. The regulation requires each operator to keep records of the bleed rate or pneumatic controller type for at least five years and to submit an annual report every year demonstrating compliance. This allows the Nigerian authorities to track operator compliance by reviewing the annual reports.

8. Inventories

Key Takeaways

- Emission inventories are essential for understanding the relative magnitude of different emission sources.
- The development of emission inventories is typically distinct from activities that monitor emissions, although recently, there have been efforts towards bringing these two types of data closer together.
- Initial inventories might be compiled using emission factor-based calculations (multiplying activities by emission factors) without actual emissions measurements. This step can be most appropriate for a regulator first building a methane emissions inventory.
- There is an ambition to move towards measurement-informed methane inventories, which can include additional monitoring information from sources like satellites and aircraft to improve estimates of methane emissions.
- Many free resources are available to assist countries in developing their inventories and the associated monitoring, reporting, and verification programs.

Governments develop national-level greenhouse gas (GHG) emission inventories to track and report GHG emissions, including methane, as part of the U.N. Framework Convention on Climate Change (UNFCCC) process. The UNFCCC reporting guidelines require use of the methodological guidance from the Intergovernmental Panel on Climate Change. Methane emissions from the oil and gas sector are generally based on emission factors. The Intergovernmental Panel on Climate Change (IPCC) describes tiers of reporting practices. The IPCC tiered methodological hierarchy includes simpler estimation methods based on production or throughput applied to regional or global emission rates per unit of production or throughput (Tier 1) to higher tiered methodologies that use country specific information, including use of country or facility-specific data or models (Tier 2 or 3). For some countries, moving to the higher tiers will require gathering additional data to develop more refined emission estimates. This additional data will include

information that will also be useful to identify emission reduction opportunities and can help to track the emission reductions from completed projects. Finally, the inclusion of robust estimates for this sector in national greenhouse gas inventories will help countries include the reductions of methane from policies as counting towards meeting their nationally determined contributions under the Paris Agreement.

Emission Inventories vs. Monitoring

Historically, sectors with dispersed emissions, including agriculture, waste management, and oil and gas, have developed emissions inventories using activity data and standard emission factors. Emission factors estimate the average emissions for an activity or equipment (i.e., kilograms of methane per hour per pneumatic device) and have generally been developed from academic studies or field measurement campaigns.

Recently, scientific studies from top-down estimation methods, like using measurements from aircraft, have calculated higher emissions levels than estimates from emissions factors. Detection of emissions from super-emitters — lower probability but high emission magnitude events — may account for some of the difference.

Technologies to monitor methane emissions from oil and gas operations are increasingly utilized, often as part of LDAR programs. These technologies are typically non-quantitative — determining whether there was a leak without measuring the emissions volume. While technology evolves, most emission inventory development activities remain distinct from monitoring activities. Increasingly, the trend is to align monitoring observations and emission inventory development activities. To improve utility of monitored data from top-down studies, and their use for identifying improvement areas in

emission inventories, it is important to engage early on to ensure design and scope of work align, and to ensure comparative analysis where applicable.

Data Needed for Emission Inventories

Much of the information needed to develop emission inventories requires key data inputs from operators. National inventories compile expected operator-reported or asset-level emissions, sometimes augmented with estimates or measurements. For example, the U.S. Greenhouse Gas Reporting Program generally has a reporting threshold of 25,000 tonnes of CO_2 equivalent emissions per year. The Inventory of U.S. Greenhouse Gas Emissions and Sinks uses a number of data sources to quantify national emissions and sinks, including information reported to the GHGRP, research studies, and national statistics.

Inventories are often compiled from estimates generated by combining emission factors with activity data. Emission factors estimate the average emissions for an activity or equipment (i.e., kilograms of methane per hour per pneumatic device) based on studies or field measurement campaigns. Activity data can include equipment counts (i.e., the number of pneumatic devices) or tracking of ancillary data like fuel use. Emission factor-based approaches are intended to cover average emissions over a wide range of assets, and thus, they may not precisely correspond to the emissions of any one site. In some cases, engineering estimates for specific sources may augment emission factor-based estimates.

One criticism of methane inventories that rely only on emission factors is that they can miss information on super-emitters,

whether arising from normal process and operation conditions (like maintenance or unloading) or unplanned events (like pipeline ruptures, equipment failures).

Today governments and operators looking to improve methane emissions information seek to move from simple factors (i.e., based on production or throughput) to source-specific emission factors and towards measurement-informed reporting that utilizes additional information sources such as continuous emission monitoring or periodic aerial or satellite surveys.

Inventory of Plugged and Abandoned Wells

IPCC inventory best practices include country-level estimates for existing unused wells, typically based on emission factors. Unused wells can emit significant volumes of methane and other substances.[82] Emissions can be estimated using emissions factors and counts of plugged and unplugged wells. When properly plugged, these wells account for a small fraction of emissions compared to emission sources from active operations.

Orphaned wells are unplugged wells that have no responsible owner on file. The financial burden to plug these wells is left to governments and the public. To prevent wells from being orphaned, operators can be required to provide upfront financial assurance in the form of a bond sufficient to cover the closure cost of a well. Also helpful to prevent orphaned wells is to have robust asset transfer applications to track ownership and responsibility. Another policy option is to fund agencies to plug, cap, and reclaim land associated with orphaned wells as part of a methane reduction strategy.[83]

Design Considerations for Developing Reporting Programs and Emissions Inventories

A well-designed facility- or operator-level reporting program can serve as a key input to the development of national-level emission inventories and to mitigation analyses.

Scope of reporting. A key decision point is what GHG emissions to include in a facility- or operator-level reporting programs, and thus in emissions inventories. While the sources of carbon dioxide and methane emissions will differ, it is useful to include both in an oil and gas reporting program.

A second key decision is applying the same reporting requirement to all operators. Some governments have excluded smaller operators due to the cost of collecting and reporting the necessary data. However, even though operators are small, this does not mean that their emissions are proportionately smaller than large operators, particularly as small operators may have less funding for mitigation actions.

The requirement to use specific methodologies. When developing a reporting program for the first time, a key decision point is whether all reporters should be required to utilize the same methodology for each identified source. Standardization would allow for more direct comparison between different operators in a country. It would provide methodological clarity for reporting, but when there are competing standards, it can also impose additional costs, particularly on international operators.

Transparency of inventory data. While country-level GHG emission data is typically made public as part of UNFCCC

reporting processes, not all countries publicly release data for individual companies or assets. This information can be valuable for benchmarking emissions sources and performance between operators, and many stakeholders have called for broad public availability of this information. The United States, for example, makes most facility-level data publicly available.[84] Another example is the North Sea Transition Authority (NSTA) in the United Kingdom, which has developed an emissions monitoring report and dashboard publicly available on its website.[85] While it provides GHG emissions trends and benchmarking for national production, it only provides partially disaggregated data based on type and infrastructure age groupings, not by individual operator.

Inclusion of additional data. In some circumstances, collecting additional data and information facility- or operator-level reporting programs may be useful for benchmarking performance across operators and understanding opportunities for further methane reduction. For example, well counts, production or throughput data, and information on the type of asset may be useful for understanding the relative performance of different assets and why emissions may be larger or smaller for some operators.

Third-party verification of data. Some jurisdictions require third-party service providers to verify reported emission information. Sometimes, the regulator provides training or certification for the verifier and mandates their training or qualification requirements. Third-party verification can increase the costs of developing the GHG inventory, particularly in locations where trained individuals are not already present, and can necessitate additional time in emission reporting cycles.

Third-party certification should not be confused with third-party development of emission inventories, such as initial inventory development by consultants. Certain policy options, such as carbon markets or offset programs, require third-party data verification.

Factors contributing to uncertainty. Inventory quality, emissions factors, and technology all contribute to uncertainty. For jurisdictions where methane reporting is mature, there is an expectation that methods and technologies will continue to evolve as new information emerges.

Resources Available to Support Inventory Development

Many governments and NGOs offer resources or services to establish methane emission inventories to support governmental methane emission reduction programs, including:

Climate and Clean Air Coalition (CCAC)	→ CCAC advises governments directly in developing methane inventories and Methane Action Plans.[86] The CCAC "stands ready to meet one-on-one with countries to discuss priorities and needs and help develop the most efficient methane mitigation strategies."
U.N. Framework Convention on Climate Change (UNFCCC)	→ Reporting guidelines for countries in compiling and submitting their national GHG information, including analysis on key sectors. → Fugitive emissions in the UNFCCC context include flaring, venting, and fugitive emissions, as described in this handbook.
Intergovernmental Panel on Climate Change (IPCC)	→ Methodological framework and guidance for estimating national GHG emissions. → Under Volume 2 on Energy, the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse GHG Inventories includes a chapter on estimating fugitive emissions across a variety of sectors, including oil and gas systems.

Clean Air Task Force (CATF)	➔ The Country Methane Abatement Tool[87] can help countries identify methane reduction opportunities using different levels of available information, ranging from generic opportunities that typically exist to more detailed recommendations when more specific information is available.
U.S. Environmental Protection Agency (EPA)	➔ The U.S. Greenhouse Gas Reporting Program (GHGRP)[88] has regulatorily-defined methodologies and publicly available reporting forms[89] for calculating methane and carbon dioxide for oil and gas facilities. ➔ This includes custom methodologies and calculation approaches for onshore, offshore, midstream, and downstream sources within the value chain. ➔ The U.S. EPA has made periodic updates to the methodology for this sector. This could be a benefit for some countries in keeping up with the latest emission factors and methods or a challenge if countries tie their regulations to an evolving methodology over which they do not have control.
Oil Climate Index plus Gas (Rocky Mountain Institute)	➔ Model developed by leading experts at the Rocky Mountain Institute, this tool "reveals the size, scope, and nature of the methane problem by quantifying and comparing greenhouse gas emissions from over two-thirds of the world's oil and gas supplies."
Oil and Gas Methane Partnership 2.0 (OGMP 2.0)[90]	➔ Offers source-specific emission estimation approaches that cover emission factors (defined as Level 3 under the program), more detailed engineering calculations or source-specific measurements (Level 4 under the program), and reconciliation with field-derived information (Level 5 under the program). ➔ The program is housed under the UNEP and includes a review of submitted data by UNEP contractors for companies signed up under the program. ➔ Positive elements of this program include global participation, standardization, and learning from others regarding improved reporting.

Oil and Gas Methane Partnership 2.0 (OGMP 2.0)[91]	➔ From a country perspective, reliance on the full OGMP 2.0 process may have downsides regarding the amount of data ultimately available to regulators (currently, only company-level global total information is released and asset-level data is considered proprietary) and the timeliness of data provision, which is expected to be at least nine months after data provision. ➔ OGMP 2.0 plans to make periodic updates to the methodology for this sector. This could be a benefit for some countries in keeping up with the latest emission factors and methods or a challenge if countries tie their regulations to an evolving methodology over which they do not have control. ➔ For NOCs and multinational companies, using OGMP 2.0 could present either efficiency opportunities for those already reporting under the program or compliance challenges for operators that have yet to sign up.
Carbon Limits	➔ An online tool and data storage system known as MIST[92] provides step-by-step instructions for developing methane emission inventories with different levels of available information. ➔ Currently, the tool is built for 28 methane sources in the upstream portion of the oil and gas industry based on philanthropic funding sources and industry financial support through the Oil and Gas Climate Initiative (OGCI) and the Methane Guiding Principles (MGP). ➔ The tool is currently free for operators to develop their emission inventories and may be a good starting point for countries that do not have current emission inventory tools. ➔ As with any non-commercial software tool, there may be disadvantages concerning a lack of long-term control over the system of record for GHG information and the long-term funding model for the product and services.

American Petroleum Institute (API)	→ Compendium of GHG Emission Methodologies from the Oil and Gas Industry[93] that includes potential sources and available estimation methodologies. → Can supplement other methodologies, particularly for unique emission sources that are not well-characterized in other programs.
MiQ	→ Provides an independent framework for assessing methane emissions from the production of natural gas, for certification. → Is a source of technical standards for each segment of the natural gas supply chain.

Technologies for Monitoring

The evolution of monitoring technology to detect and measure methane emissions will be discussed extensively in *Chapter 9: Monitoring*. Over time, this technology evolution may allow for additional options for regulatory agencies to track and verify methane emissions from the oil and gas industry and provide information to operators to support more significant emission reductions.

The costs and benefits of the options outlined in *Figure 8.1* will vary. Low-cost interventions like the use of publicly-available satellite data could form the baseline of such a program in the near term. Additional options sometimes require government resource expenditures to contract with third-party technology providers for aerial or mobile monitoring services or to install fixed monitoring networks near significant facilities. Approaches are not mutually exclusive, and a satellite-based program could add additional elements such as aerial, mobile, or continuous monitoring as such a program matures.

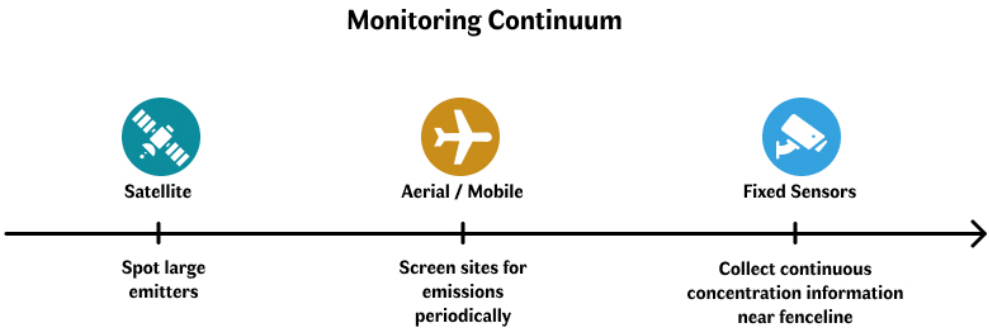


Figure 8.1. Remote methane monitoring tools.

9. Monitoring

Key Takeaways

- ➔ Many monitoring technologies are available on the market today, and new ones are currently under development. However, these technologies all have different limitations and optimal use cases.
- ➔ Most leak detection and repair regulations today use a prescriptive approach based on instrument monitoring technologies.
- ➔ Regulations today can include requirements that improve data and reporting, which can lay the groundwork for the future.
- ➔ Governments can take advantage of different resources from international organizations and non-governmental organizations to improve monitoring — including one-time aerial surveys and satellite monitoring.

Available Monitoring Technologies

Monitoring programs provide insights into where and why emissions may occur and how to avoid or prevent emissions. There are a large number of technologies for operators on the market today, and new ones are being commercialized and under development. The most mature monitoring technologies involve source-level detection by instruments, while new and emerging technologies allow for aerial sensing and continuous monitoring. The most effective monitoring programs incorporate multiple technologies to improve leak detection and source attribution.

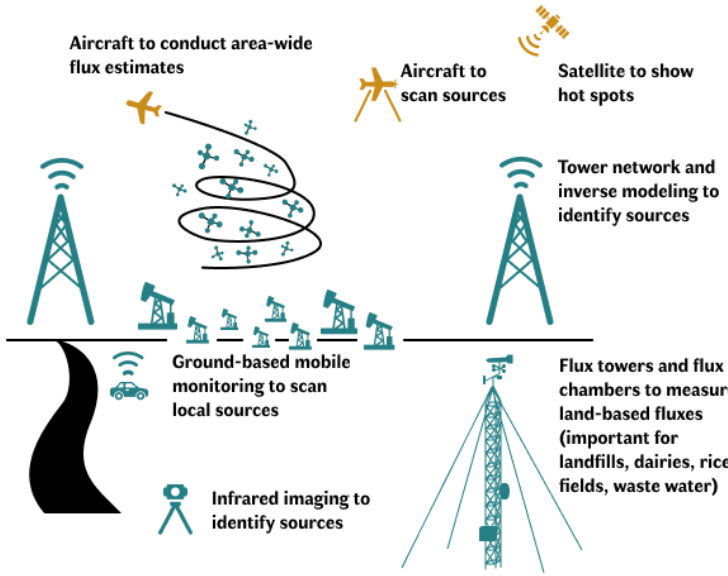


Figure 9.1: Tiered methane observation system concept.[94]

Most common detection instruments. Traditional leak detection and repair programs in the oil and gas sector are typically based on optical gas imaging (OGI) or the use of EPA Method 21 sniffer surveys. OGI involves a trained operator with an infrared camera observing potential leak points, such as valves or flanges within a facility, to determine if a leak is present. EPA Method 21 sniffer survey involves an operator taking detection readings at each potential leak interface. A reading above a specified threshold, such as 500 ppm, would indicate a leak. Both OGI and Method 21 are labor-intensive and require specialized training to deploy.

Emerging and advanced technologies. Recent developments have expanded the types of technologies that are available for detection and measuring methane emissions. These advanced

technologies include (1) sensors that screen a number of sites for methane emissions that may be mounted on satellites, planes, drones, or vehicles and (2) sensors that are permanently installed at a single site to provide more near-continuous monitoring of methane concentration. There are benefits and trade-offs to each type of approach. Some methods will require follow-up activities by an operator to identify the cause of a methane detection and prescribe steps for repair.

Continuous process monitoring and digitization. Although still in its early stages, combining continuous monitoring sensors with digitizing the operator's process control systems shows great promise for future reductions. Combining these data can link real-time methane data with information on process activities and help identify emissions events associated with process failures or maintenance issues.[95]

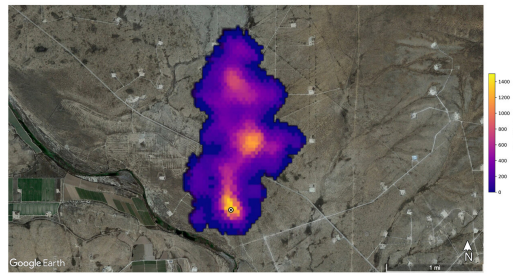
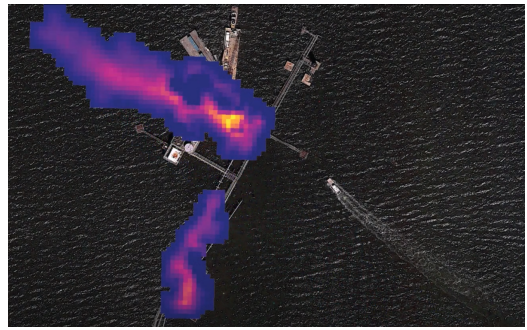
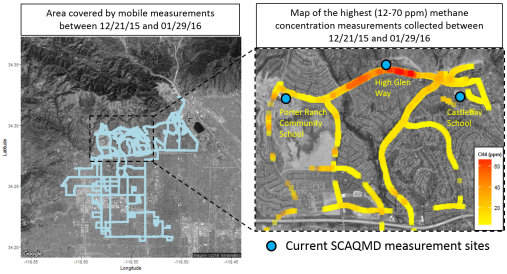
Tiered approaches. Combining different types of monitoring technologies — including regular instrument surveys, aerial and satellite surveys, and continuous monitoring — can greatly enhance the ability of operators to detect, mitigate, and prevent emissions. Different technologies are best at detecting various types of emissions. Thus, a tiered monitoring system leverages the complementary capabilities of different methods and avoids some of the individual limitations of each technology.

Case Study: Scaled Emission Monitoring via Aircraft

In some countries, the oil and gas industry has a large number of facilities and is spread out geographically. Aircraft-based methane screening can screen areas on the scale of hundreds or thousands of sites per day and is being increasingly adopted by operators. There are performance differences between different technologies, with methane detection limits ranging from 3-50 kg/hr and geolocation precision ranging from the equipment level to the site level for detected emissions. Aircraft-based technologies can enable relatively rapid identification of key emission sources across broad geographic areas. However, there are tradeoffs among providers between the number of sites covered and detection levels.

Vendors may need a number of anchor clients to justify the costs of a monitoring campaign and permission from relevant aviation authorities to permit flights in new regions. On the ground, operators often need to be prepared to follow up on detection emissions with a confirmation solution like OGI or other types of operational information to understand the detected sources and available mitigation options.

Table 9.1: Sample detections from different monitoring technologies.

	Episodic Monitoring
Satellite	 Source: NASA/JPL-CalTech
Aerial	 Source: Carbon Mapper
Mobile	 Source: South Coast Air Quality Management District, State of California[96]

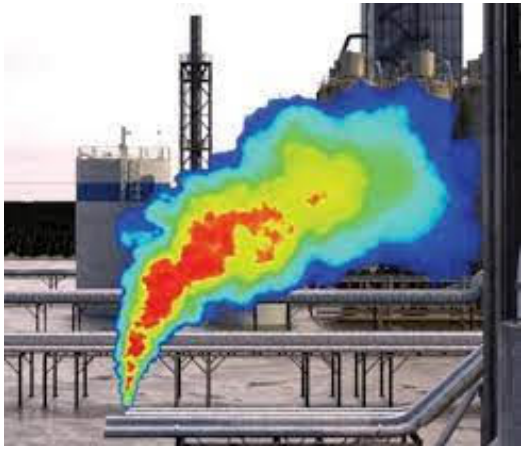
Episodic Monitoring

Handheld camera

Source: U.S. EPA[97]

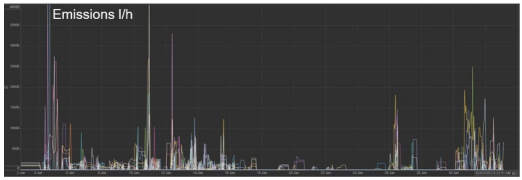
Continuous Monitoring

Fixed camera



Source: Honeywell

Fixed sensors



Source: Honeywell[98]

Need for Monitoring to Support Regulatory Frameworks

As discussed in more detail in *Chapter 5: Leak Detection and Repair*, most current regulations for LDAR programs have adopted a prescriptive approach that requires monitoring by instruments, but they do not generally require active measurement. For example, LDAR requires detection technologies like OGI cameras or EPA Method 21. Still, it does not generally require technology that can quantify the size of detected leaks.

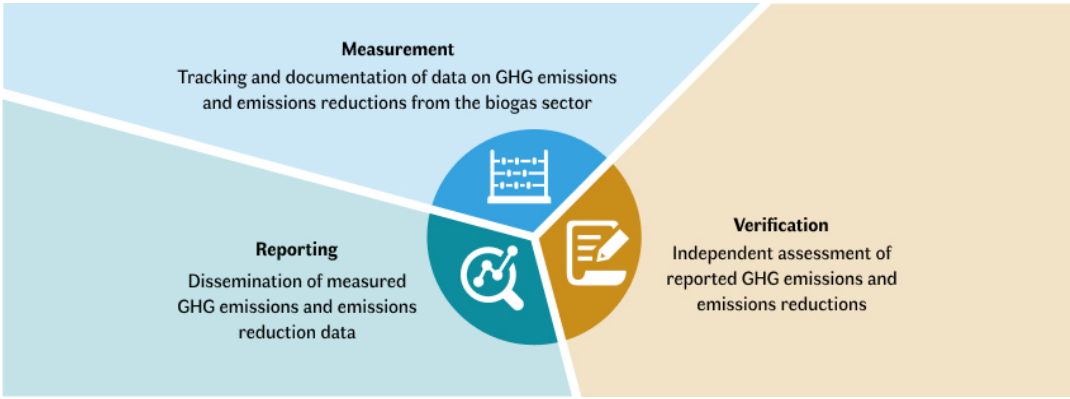
Performance and economic-based regulations typically require a robust measurement and reporting regime based on active monitoring and measurement. Although economic measures are common in the environmental field in general, only a few cover methane. The U.S. Inflation Reduction Act[99] of 2022 establishes a methane waste emissions charge on methane emissions that exceed an emissions intensity threshold for certain segments of the oil and gas sector. There are also limited examples of the incorporation of methane into GHG pricing schemes. Norway applied a tax on CO_2 and methane emissions[100] to offshore oil and gas emissions. Methane reduction projects are also eligible for carbon credits in some circumstances, including in the California cap and trade system and some projects certified under the Kyoto Protocol Clean Development Mechanism (CDM).

Some economic or performance provisions are based on proxy measures assumed to correlate with emissions. Massachusetts issued a regulation to reduce methane emissions from gas distribution lines via performance requirements for each company, with emissions estimated according to emissions factors for different pipe materials specified in the law.[101]

As technologies are improving rapidly, regulators should consider whether regulatory measures today include requirements that will enhance data and reporting, which can lay the groundwork for more efficient economic or performance-based regulations.[102]

Considerations for Monitoring, Reporting, and Verification Protocols

Monitoring, Reporting, and Verification are often lumped together as "MRV" but each has its own meaning. Monitoring is the creation of data through the measurement of emissions. Reporting is the dissemination of that data. Verification is the independent assessment of that emissions data. The Global Methane Initiative has an excellent summary of MRV (which they refer to as Measurement, Reporting, and Verification), including the following visual:[103]



Cost profiles. Technologies that provide periodic screening for emissions tend to have different cost profiles. OGI and drone

surveys often have both a capital and operational cost component that operators must pay. At the same time, aircraft and commercial satellite options typically operate on a per-site service fee basis, with all costs incorporated into the service fee. Technologies that can be permanently mounted but provide near-continuous monitoring (e.g., cameras) may require a company's upfront capital investment.

Effectiveness. The frequency of inspections (annual, quarterly, etc.) influences the emission reduction potential of an LDAR program. In addition, LDAR surveys are primarily helpful in detecting emissions that are associated with faulty or malfunctioning equipment. Even frequent leak detection surveys may not capture releases related to process-related failures. Although the technologies are not as widely deployed, continuous monitoring may be more effective at detecting these types of emissions events.

Regulatory barriers. Some countries have banned the private use of drones and non-government use of satellite imagery or established no-fly zones around crucial infrastructure. These laws may prevent certain technologies from being used to detect methane emissions, limiting the number of detection options available to operators and discouraging the deployment of new technologies.

Training requirements. Certain monitoring technologies require specialized training and experience to operate. Studies have shown that experience is critical for a technician's ability to detect leaks when carrying out an LDAR campaign.[104]

Surveyor independence. Some LDAR programs allow the operator to decide between in-house staff or a survey contractor. Some stakeholders believe that surveyors independent of the operator will have more incentive to find and document leaks than someone in-house who is aware of the costs for repair.

Available Support for Governments

Many organizations are available to support governments in detecting and estimating emissions levels using various technology options.

The CCAC Methane Science Program can provide one-time studies of oil and gas regions using aircraft surveys coordinated by the Environmental Defense Fund. This program typically provides a snapshot of total emission rates within a region of interest over a few days. Still, it may not provide the information needed to understand why emissions differ from expectations.

The United Nations Environment Program (UNEP) uses the Methane Alert and Response System (MARS) program to collate large methane detections from existing public satellites that can detect very large super-emitters. Current satellite technology can cover flat, mid-latitude onshore regions[105] better than offshore assets or those in equatorial or polar regions.

Upcoming philanthropy-funded satellite missions led by the Environmental Defense Fund (MethaneSAT) and Carbon Mapper could increase the number of open-source satellites monitoring for methane emissions from key regions (increasing the observation frequency) and improve spatial granularity, detection limits, and the ability to monitor offshore assets. Data from these satellites will be publicly posted to internet portals for use by different stakeholders.

Case Study: Methane Alert and Response System (MARS)

The UNEP's International Methane Emissions Observatory (IMEO) launched the Methane Alert and Response System (MARS), the first global system providing actionable and transparent data on methane emissions from satellites in near-real time. MARS is designed to accelerate methane emissions reductions (including in support of the Global Methane Pledge) by detecting large sources of anthropogenic methane emissions using satellite data, notifying the relevant stakeholders, assessing and mitigating individual emissions events, and tracking events, including public data sharing.

MARS harnesses state-of-the-art satellite data to quickly identify major emissions events, notify and engage countries and operators, support mitigation, and track progress through time. While the full operational model is still under development, at the time of writing this book, the initial phase of MARS will focus on detecting and attributing specific emissions events in the energy sector and then work to identify and notify the relevant stakeholders among government contacts and companies that have joined the IMEO's Oil and Gas Methane Partnership 2.0 (OGMP 2.0). Countries may appoint a point of contact to receive notification from UNEP that includes relevant information to enable mitigation and are requested to share any information about actions taken. Once fully operational, UNEP intends to make data and analysis of specific detections through MARS and government and operator response publicly available between 45- and 75-days post-detection. The ultimate impact of the MARS program may hinge on available financing for sustained satellite observations and delivery of actionable information to guide super-emitter notification, assessment, and mitigation.

Useful Resources

The International Methane Emissions Observatory

https://www.unep.org/explore-topics/energy/what-we-do/methane/imeo-action

This U.N.program "catalyzes the collection, reconciliation, and integration of empirically based near real-time methane emissions data to provide unprecedented climate transparency and the information required for reducing this powerful greenhouse gas."

Carbon Mapper

https://carbonmapper.org/

Carbon Mapper is a nonprofit initiative, partnered with California and NASA's Jet Propulsion Laboratory, that works to "offer a rapid methane leak detection service to facility operators and regulators" through remote sensing technology. They aim to launch two satellites in 2023 to provide widespread access to this data.

MethaneSAT

https://www.methanesat.org/

This Environmental Defense Fund initiative plans to launch a satellite in early 2024. They promise to identify large methane plumes "virtually anywhere on Earth," noting that "cutting methane emissions from oil and gas is the single fastest, most impactful thing we can do to slow the rate of warming today."

Climate Trace

https://climatetrace.org/

This partnership provides freely available, open data on known and estimated emissions, including methane. It gives jurisdictions an immediate but general sense of their methane emissions profile.

NASA EMIT

https://earth.jpl.nasa.gov/emit/data/data-portal/Greenhouse-Gases/

Using an instrument affixed to the International Space Station, NASA maps significant methane plumes with limited global coverage. This tool may identify some plumes in a jurisdiction but is not exhaustive or frequently updated.

TROPOMI

http://www.tropomi.eu/data-products/methane

TROPOMI is an instrument aboard the Copernicus Sentinel-5 Precursor satellite, commissioned by the European Space Agency, that provides methane data.

Satellite Point Source Emissions Completeness Tool (SPECT) (Rocky Mountain Institute)

https://rmi.org/clean-energy-101-methane-detecting-satellites/

The SPECT tool is designed to help users compare satellites for completeness concerning "identifying and tracking super-emitters of methane."

Global Methane Initiative 2023: Oil and Gas Sector Resources. *https://www.globalmethane.org/oil-gas/index.aspx*

Many emerging technologies offer different types of emission detection. Several resources, including GTI Energy,[106] collaboration by members of IPIECA, OGCI, and IOGP,[107] and company-specific experience (such as that of Chevron)[108] provide information on the types of technologies available and their trade-offs.

10. Ensuring Compliance

Key Takeaways

- Regulatory compliance systems for methane abatement requirements can include penalties and rewards.
- Regulatory compliance systems can also include the types of monitoring, reporting, and public accountability structures to make operators' performance more self-implementing, so regulators do not have to rely only on enforcement.
- In designing a regulatory compliance program, therefore, regulators can draw on many options.
- Enforcement actions foster compliance and a level playing field by providing a credible threat of enforcement for violations; transparency programs built on required monitoring and reporting serve a similar function.

The traditional approaches for regulatory compliance can include penalties as deterrence against violations and incentives to reward those who abide by regulatory requirements. This stick-and-carrot approach is one that regulators can use in designing and implementing compliance programs.

The effectiveness of both penalties and incentives is closely tied to the strength of the enforcement regime underlying the regulations. Where enforcement is consistent and predictable, operators will tend to take actions that maintain compliance and avoid those that trigger violations. It can also be the case that the number of potential sources of methane will vastly outnumber the available enforcement resources, so effective methane reduction programs should not rely on enforcement alone. Regulators can incentivize operators to reduce emissions through rules that require monitoring, electronic reporting, use of third party monitoring capability to identify large emissions events, public accountability, use of automation where possible and no fault equipment.

Figure 10.1: Icons representing methane abatement compliance activities.

Communicating Expectations

A critical aspect of an effective compliance regime is the clarity and breadth of the outreach by the regulator to regulated actors in the market.

For clarity, regulators may adopt a multi-tiered approach where detailed requirements are set out in regulation, operational direction on implementing the regulation is shared via guidance, and further explanation is shared through media, training, and peer learning.

The breadth of the regulators' outreach campaign should seek to reach not only primary actors in the oil and gas sector, such as field and facility operators but also other critical actors, such as sub-contractors, monitoring services, auditing/accounting firms, etc. By seeking a broad understanding of regulatory requirements across the industry, together with rules that

force bad performers to face public scrutiny and accountability, the regulator can establish a self-reinforcing culture of compliance where actors encourage each other to act appropriately.

Verifying Compliance

Detection of violations is a critical component of effective compliance assurance systems. In addition to enforcement, regulations can establish self-regulation criteria for companies. A methane abatement regulation may also include a process for public participation. However, there are options in determining the roles of whether the national government, a regional/local government, or a sub-contracted private entity is conducting the oversight. Clear authority for such activities can create greater certainty and reduce litigation risk.

Incentivizing Self-Regulation

Although it may seem counterintuitive, experience in many markets worldwide has shown that companies may respond positively to incentives that encourage them to voluntarily acknowledge their mistakes. For example, regulators can commit to penalizing violations identified, promptly reported, and expeditiously corrected by companies less harshly than unreported violations.[109] Operators with a good compliance record may be granted favorable tax treatment, carbon credits, or price enhancements. In addition to shifting some oversight costs to companies, these strategies encourage operators to act quickly to limit the impact of violations rather than wait for regulatory intervention.

Compliance and Monitoring Strategies

There are many monitoring approaches for methane regulations. An effective program can utilize all of them.

Self monitoring. Requiring companies to monitor their own emissions achieves two things at the same time: companies know what their emissions are (a first step to fixing them), and they know that the government (and also the public) knows about the emissions too.

Inspection should be understood as government action to verify compliance. The regulation may establish inspection requirements, such as checking certification records, taking samples, and engaging with company personnel, to determine compliance. Because the number of sources is normally vastly more than government can inspect, inspections should be focused on sources that data targeting suggests are the worst offenders.

Third party emissions monitoring. There are many companies today capable of monitoring methane emissions from satellites and aerial overflights and bringing needed attention to the largest emissions events. Governments can tap that expertise by bringing that third party data into government programs. If third parties identify the large emissions events, and government requires companies to take action to remedy them, outside capability can be joined with government authority to reduce large emissions.

Third-Party Audits (different from third party emissions monitoring discussed above) employ independent organizations or specialists to assess the accuracy of information supplied by the oil and gas operators to the regulator. This type of support may be advantageous when a national regulator has not established its own audit capacity. However, it still requires that the regulator manage the certification and ensure the independence of those third-party auditors. For example, third-party auditors should be assessed for any conflicts of interest and have the necessary competence to conduct environmental compliance audits. One proven option for increasing the independence, and thus accuracy, of third party audits is to

assign auditors randomly from an approved pool. Importantly, the compliance determination lies with the regulator and third-party audits should be carefully reviewed with an opportunity for input from operators. Argentina and Mexico both require that third-party auditors verify company reports.[110]

Fence-line Surveys allow remote inspection in conditions where on-site inspection is challenging. Ground-based or aerial measurement instruments can screen sites for potential methane emissions. Third parties can conduct remote sensing for identification of large emissions events as well. The results of such surveys may indicate a need to follow up with the operator or on-site inspection.

Electronic reporting measurement and other compliance reports can dramatically improve the efficiency of compliance efforts, and allow for much greater transparency, a key compliance-driving strategy. Digital tools can lower the burden of compliance paperwork, especially for large operations that generate voluminous data. Incorporating automation and artificial intelligence reduces errors in reporting and accelerates the identification of opportunities to improve compliance and, potentially, violations.

Governments have many options for the wide variety of regulatory strategies to drive compliance.

Inspection should be understood as government action to verify compliance. The regulation may establish inspection requirements, such as checking certification records, taking samples, and engaging with company personnel to determine compliance.

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Digitization of measurement and reporting mechanisms can improve the efficiency of compliance efforts. Digital tools can lower the burden of compliance paperwork, especially for large operations that generate voluminous data. Incorporating automation and artificial intelligence reduces errors in reporting and accelerates the identification of opportunities to improve compliance and, potentially, violations.

Governments have many options for both the 'carrots' and the 'sticks': the incentives and the penalties. These options build on one another like a pyramid, as illustrated below.

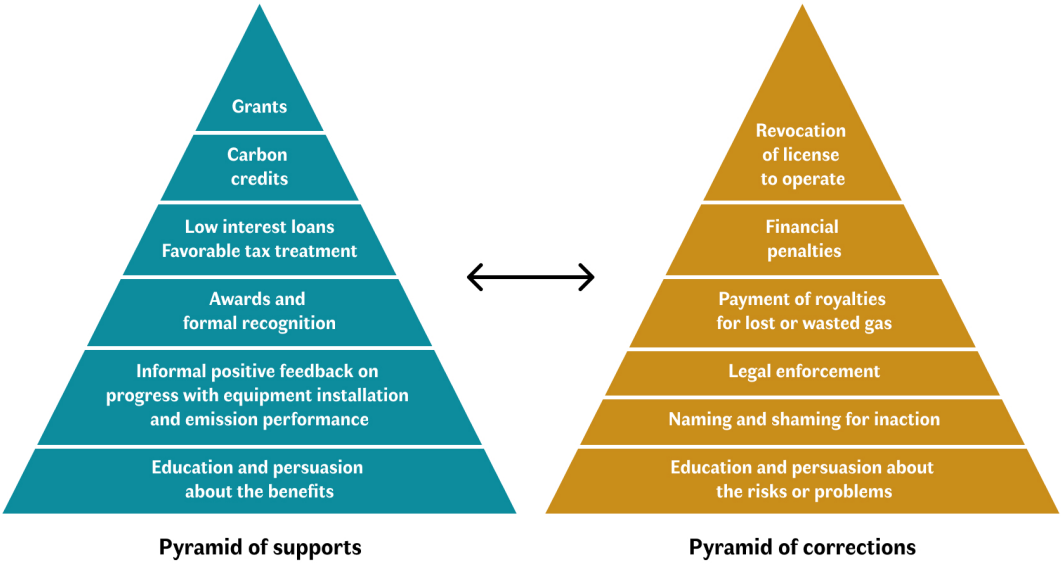

Figure 10.2: Pyramid of supports and pyramid of corrections

To promote efficiency and to keep up with the increasing pace of technological change, regulators of different jurisdictions can adopt an **equivalency assessment approach**.[111] This approach allows a regulator to understand and approve an operator's proposed alternative to a regulation's required methane mitigation equipment and/or practices (for example, with regard to LDAR) without sacrificing the environmental benefit.

Enforcement

Enforcement actions foster compliance and a level playing field by providing a credible threat of appropriate actions for violations. The government agency responsible for enforcing

methane abatement regulations needs clear legal authority to enhance the credibility of its enforcement efforts. This includes the authority for inspections and enforcement, with the power to impose an escalating range of appropriate actions to incentivize compliance.

Warning letters can inform a company of the violations found and list specific steps to come into compliance. Warning letters allow the regulator to engage with the company to correct violations and come into compliance in a cooperative manner. Formal enforcement action may be limited to situations where a warning letter does not lead to compliance.

At the outset of a formal enforcement action, it is vital to assess the dimension of the violation based on many factors, including:

- ➔ The actual or potential harm.
- ➔ The extent of deviation from the requirements.
- ➔ The violator's compliance history.
- ➔ Whether the violation was self-disclosed or discovered on inspection.

These factors may also influence the magnitude of the civil penalty. Determining an appropriate penalty may also be influenced by the overarching goal of ensuring that violators do not financially benefit from non-compliance. A key opportunity for driving better performance through enforcement is in requiring that companies found to have committed violations come into compliance, but also requiring them to reduce their emissions in the future, i.e., make the environment whole in addition to paying a penalty that recoups all of the money they saved by violating and is sufficient to deter future violations.

Good regulatory design should include a mechanism by which an operator can appeal or challenge enforcement actions, including corrective actions and penalties. Financial constraints are not a valid reason for failure to comply; if a company determines that a

facility cannot afford to operate in compliance, it can avoid future penalties by choosing to shut down that facility. However, in some jurisdictions, a penalty may be reduced when official company financial records document the company's inability to pay. Alternatively, a company may be allowed to submit payments in installments over a specified time when it can prove paying the penalty will prevent it from paying ordinary and necessary business expenses.

Inspection Plan

The following section outlines some key questions that a regulator can use to develop its inspection plan to ensure compliance with the methane abatement regulations.

Because inspection resources will always be limited, it is important to prioritize for inspection the most serious emissions violations, repeat violators, and companies with a history of large emission events.

Developing an Inspection Plan

Objectives

- What is the purpose of the inspection?
- What is to be accomplished?

Tasks

- What information will be reviewed (e.g., permits, licenses, regulations, previous inspection reports, and information on compliance history)?
- What coordination with detection personnel, other environmental programs, lawyers, or government agencies is required?

Procedures

- Which specific facility processes will be inspected?
- Have inspectors established a right of entry to the facility?
- Will the inspection require special procedures?
- Has a quality assurance/quality control plan been developed and implemented?
- What equipment will be required?
- What are the responsibilities of each member of the team?

Resources

- What personnel will be required?
- Has a safety plan been developed and implemented?

Schedule

- What will be the time requirements for an order of inspection activities?
- What will the priorities be? What must be done and what is optional to complete?

Useful Resources on Ensuring Compliance

International Network for Environmental Compliance and Enforcement (INECE): Principles of Effective Environmental Enforcement. *https://inece.org/*

United States Environmental Protection Agency (EPA): Enforcement Response Policy and EPA Audit Policy. *https://www.epa.gov/enforcement/enforcement-policy-guidance-publications*

United States Environmental Protection Agency 2022: Next Generation Compliance. *https://www.epa.gov/compliance/next-generation-compliance*

11. Financing for Methane Abatement

Key Takeaways

- Methane solutions have one of the highest emission reduction benefits per dollar of capital invested but are underfunded globally.
- Sufficient finance flows towards methane abatement in the oil and gas sector are needed to help reduce emissions.
- Realization of the methane opportunity requires investment in technical solutions and enabling activities. Ineffective financing of soft costs to governments could be a significant bottleneck to deploying technical solutions.
- Financing sources include Development Finance Institutions (DFIs), climate-specific funding mechanisms, and Green Bond Issuers.
- The Global Methane Pledge may contribute to the integration of methane abatement into the climate finance architecture.
- Methane emissions are a form of waste, but absent a GHG price, not all sources are cost-effective for companies to fix or prevent.
- Some companies might only voluntarily utilize previously wasted methane that provides the most attractive investment opportunity. In many countries, governments will need regulation to drive methane reduction action.

Seizing the opportunity to abate methane from the oil and gas sector will require significant investment. While 39 percent of methane emissions come from the energy sector, only 0.8 percent of the methane abatement finance was directed to the energy sector. Addressing this financing gap will require contributions from the private sector, national governments, multilateral institutions, and climate finance funds. This chapter discusses these funding sources, their approaches to financing methane abatement, and case studies illustrating practical examples of how financing can accelerate abatement efforts.

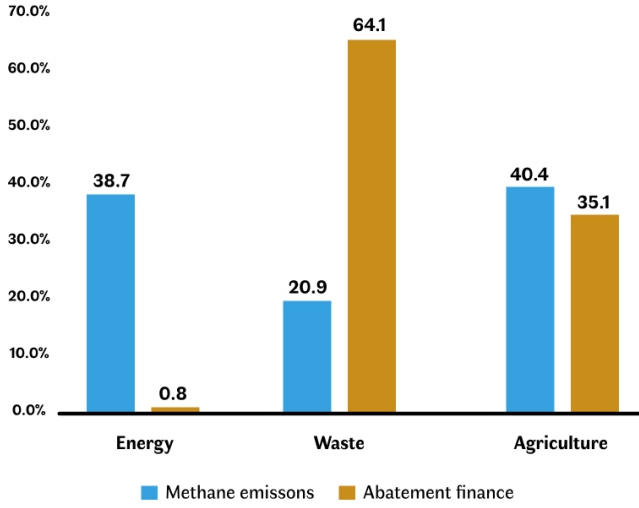

Figure 11.1: Distribution of abatement finance and distribution of methane emission across sectors by percentage.[112, 113]

The Financing Gap

Methane abatement measures are underfunded.[114] Based on the Global Methane Pledge, methane accounts for 17 percent of global GHG emissions from human activity. However, methane has received less than 2 percent of total climate finance flows (~ USD 11 billion in 2019/2020). More than USD 100 billion is needed annually — at least a ten-fold increase from current levels.[115] The fossil fuel sector, which has the highest potential for methane mitigation by 2030, has received the least methane abatement finance.

According to one estimate from the IEA, around $100 billion in total investment is needed by 2030 to achieve a reduction of

about 75 percent in the energy sector.[116] Considering the benefits of methane abatement delivery in the oil and gas sector, this financing gap is a critical challenge.

What Needs Financing?

Curbing methane emissions requires investment in infrastructure and the enabling environment for that infrastructure — the policies, laws, regulations, and contracts, including incentives and penalties structures, to reduce methane emissions.

Infrastructure. Methane abatement measures encompass existing sources and potential new emissions sources. While it is logical to target large point sources urgently, financing is also needed to avoid sources of *new* emissions. Financing methane abatement infrastructure could therefore include interventions that:

- ➔ Avoid or prevent methane emissions from occurring, for example, designing to new standards.
- ➔ Make use of methane: Projects that capture this gas then use or reinject it.
- ➔ Abate or reduce current emissions levels.

Enabling environment. Financing methane abatement includes technical assistance to build capacity. For example, developing domestic gas markets requires significant technical assistance and can contribute to methane abatement in oil projects.

Financing Sources

Financing for methane abatement solutions in the oil and gas sector could be done on a sector-specific basis or as part of national climate change financing. Some key sources for funding methane abatement solutions include the following:

Development Finance Institutions (DFIs). DFIs are development-focused and most active in markets with limited access to private finance or for projects lacking a firm commercial basis. DFIs can lower pricing, provide long-term loans, add transparency, and offer coverage for investors in high-risk places. They are also often willing to take technical risks on emerging technologies if it aligns with their policy objectives, such as mitigating climate change. They aim to support government objectives and provide funding to projects that fall within their prescribed mandates. DFIs usually have comprehensive environmental and social conditions for their support.

Dedicated climate funds. Several DFIs administer climate funds to promote the rapid deployment of low-carbon technologies, focusing on renewable energy. These include the Green Climate Fund, the Global Environment Facility, the Global Methane Hub, and the Climate Investment Funds (the Clean Technology Fund and the Strategic Climate Fund). The primary advantage of these funds is the ability to lend at below-market rates (concessional financing). This lending improves a methane investment's capital structure by reducing the financing cost. These funds also have significant amounts of lending capacity. For example, the Global Methane Hub is a philanthropic organization that provides direct funding for methane abatement projects and has raised over $340 million.

Export Credit Agencies (ECAs). A country's government establishes an ECA to promote exporting its goods and services. ECAs may be able to support transactions for methane abatement solutions, software, and technology where those transactions involve imports from the ECA's market. ECAs cover a transaction through insurance or by means of a direct guarantee of payment, providing commercial and political risk coverage. Where ECAs are involved, exporters will likely offer more competitive business terms. In addition, ECAs can provide appropriate cover when commercial lenders are more reluctant to assume political risks.

Oil and gas companies. These companies can be incentivized to finance abatement measures when the value of the abatement, in terms of additional captured methane or the avoidance of regulatory penalties, is greater than the costs. Several international oil companies have dedicated portions of their capital budgets to projects that will reduce their operational GHG emissions, including methane emissions. These programs are structured such that these abatement projects compete for capital against other internal GHG reduction opportunities but not other uses of capital, such as drilling a well. As the oil and gas industry is diverse, this may not be an option for every company, geography, or methane abatement opportunity.

National Oil Companies. In countries where NOCs are active participants in the oil and gas sector (as operators or joint venture partners), they may be a source of funding for methane abatement projects. NOCs can support abatement projects both as an investor, by redirecting a share of their retained profits, or as a lender, by redirecting funds that would otherwise flow to the national treasury. Even where NOCs do not have the revenue necessary to support methane abatement, governments may still elect to use a NOC as the focal point for public financial support, either through direct allocations from a central budget or through re-lending where the government is borrowing and passing the funds on to the utility.

Commercial banks and private equity funds. Lenders such as commercial banks and private equity funds will evaluate the commercial viability of methane abatement investment opportunities as they would any other investment. These lenders may not consider the value of climate-related benefits as a DFI would. However, many lenders do have internal ESG goals, including methane abatement. Additionally, if methane abatement benefits can be monetized (i.e., carbon credits, tax rebates, etc.), these financial incentives will be factored into the lender's evaluation of project economics.

Government funding. Some governments have successfully raised infrastructure bonds, including green bonds for climate change mitigation projects. However, most public funds continue to flow to agricultural sector methane abatement programs. Some governments have established mechanisms to fund specific methane projects, such as Canada's Orphan Well Program CAD $1.7 billion to help clean up orphaned and abandoned oil and gas wells in Alberta, Saskatchewan, and British Columbia.[117] In many developing countries, this option may not be available, considering a government's other fiscal spending commitments, high debt levels, and other development priorities.

Table 11.1: Climate finance mechanisms and specific financial institutions

Development Finance Institutions (DFIs)	
Multilateral DFIs	World Bank, Asian Development Bank, European Bank for Reconstruction and Development, International Finance Corporation
Bilateral DFIs	CDC Group (United Kingdom), Swedfund (Sweden), International Development Finance Corporation (United States)
National DFIs	China Development Bank, KfW Banking Group (Germany), Export-Import Bank of India
Subnational DFIs	Buenos Aires Guarantee Fund, Lower Austria Guarantees and Investments, Rio de Janeiro Development Agency
Climate-specific Funding Mechanisms	
Dedicated Multilateral Climate Funds (UNFCCC)	UNFCCC's Adaptation Fund, the Green Climate Fund, Least-Developed Countries Fund and Global Environmental Facility (GEF)
Non-UNFCCC Climate Funds	UNDP Low Emission Capacity Building Programme, UNEP Enlighten Energy Efficiency Initiative
National Climate Funds (NCFs)	Indonesia Climate Change Trust Fund, UK International Climate Fund, Bangladesh Climate Change Trust Fund, and the German IKI Initiative
Philanthropy	Rockefeller Foundation, Bloomberg Philanthropies, Energy Foundation, Ford Foundation, Global Methane Hub

Green Bond Issuers	
Development Banks	European Bank for Reconstruction and Development, World Bank, African Development Bank, European Investment Bank
Asset-based security issuers	Fannie Mae, Credit Agricole CIB, Toyota
Financial corporate issuers	BNP Paribas, Bank of America, Bank of China, Morgan Stanley
Government-backed entities	Japan Railway Construction, Transport and Technology Agency, Indian Renewable Energy Development Agency
Sovereign issuers	The Republic of Fiji, Federal Government of Nigeria
Nonfinancial corporate issuers	Canadian Solar, Tesla Energy, Beijing Enterprises Water Group
Local governments	Tokyo Metropolitan Government (Japan), City of Gothenburg (Sweden), New York MTA (USA), State of Connecticut (USA)

Trends in Financing

There are currently several trends in the global financial markets which could either close or widen the financing gap for methane abatement. Financing for methane abatement projects in the oil and gas industry could increase if the benefits of those projects were more prominent. However, there are challenges to investments in methane reduction in the oil and gas sector, given energy transition and climate change objectives.

Role of philanthropy. With growing awareness of the methane opportunity to contribute towards environmental, economic, energy, and employment goals, philanthropy could play a more significant role. The Global Methane Pledge and its associated financing initiatives may catalyze others to enhance the methane share of climate finance.

Blended finance. Private funding of methane abatement activity/projects is 40 percent larger than public funding, starkly contrasting other climate change interventions where public financing plays a significant role. A mixture of public, private, and philanthropic funding will likely emerge.

Cooperation. Networks of city governments are leveraging economies of scale to undertake pro-climate activities, such as collective procurement of technologies in the U.S. and Nigeria. This leveraging could be extended to methane abatement solutions (e.g., regional solutions for utilizing associated gas for power generation and energy access).

ESG Requirements. Environmental, Social, and Governance-based investing has driven governments, DFIs, commercial banks, and other private firms away from the oil and gas sector investment. ESG guidelines are also being developed to improve company reporting of how their activities impact the climate. For example, the Task Force on Climate-Related Financial Disclosures (2015) and the Climate Disclosure Standards Board (2007) are joint efforts among private actors, central banks, financial stability boards, and national regulators to develop consistent ESG and climate standards for reporting by companies.

Increased Scrutiny in Financing

Showing that oil and gas sector methane abatement will meet climate and ESG objectives could unlock funds.

Limits on International Lending to Carbon-intensive Projects

On August 16, 2021, the U.S. Department of the Treasury issued a policy guidance memo titled Fossil Fuel Energy Guidance for Multilateral Development Banks (MDBs).[118] The primary focus of this policy was to announce the U.S. Government's opposition to "international financing of carbon-intensive fossil fuel-based energy," specifically that it would use its role as a board member on multiple MDBs to vote against such projects. The Treasury memo is the latest in a growing number of statements by major donors opposing the use of development finance to support fossil-fuel projects. For example, the policy states unequivocally that the U.S. will oppose "upstream natural gas projects." It allows limited support for "midstream and downstream natural gas projects" in IDA-eligible countries so long as it includes "greenhouse gas reduction strategies." Critically, the new policy does provide an exception for the funding of methane abatement projects, but with important caveats (emphasis in original):

> "*Open to support for Carbon Capture, Use and Storage (CCUS) and methane abatement projects*. We are open to supporting CCUS and methane abatement solutions as standalone investments for existing fossil fuel projects assuming they do not expand the capacity of the existing project or significantly extend its operational life."

The lesson for countries seeking to secure international development finance for oil and gas projects is that they will face increasing scrutiny of their project proposals and feasibility assessments. Countries covering over half of the global gas imports and one–third of global gas exports recently called for minimizing flaring, methane, and CO_2 emissions across the supply chain to the fullest extent practicable at COP27.[119]

Innovative or non-traditional approaches. Sovereign wealth and strategic investment funds with ambitious climate objectives are

potential sources for financing methane abatement projects. For countries facing energy access and security challenges, pursuing

methane projects aligned with national low-carbon development pathways and national development plans delivers on a country's energy access priorities while mitigating methane emissions. Transition bonds and sustainability-linked loans are emerging mechanisms that provide high emitters with flexibility in structuring their financing activities.

Carbon markets. Methane abatement projects could generate revenues through carbon markets if designed and structured well. The current challenge is the limited quantification of the climate-positive impact, which can be translated into tradeable emission permits. It is particularly challenging for fugitive emissions as it is difficult to determine the baseline to quantify the reduction achieved through the actions taken by the sector. As progress is made in estimating and monitoring emissions, this could become a future source of financing for projects.[120]

Making the Economic Case for Methane Abatement

Regulators must mount an economic case within the government or persuade operators that abatement solutions are suitable for short- and long-term investments. While operators have a financial incentive to avoid waste, some solutions are more cost-effective than others. Cost-effectiveness analysis specific to the local operating environment can help develop workable methane abatement regulatory policies. Methane abatement investments such as upstream LDAR and vapor recovery units can yield a positive return depending on the circumstances.

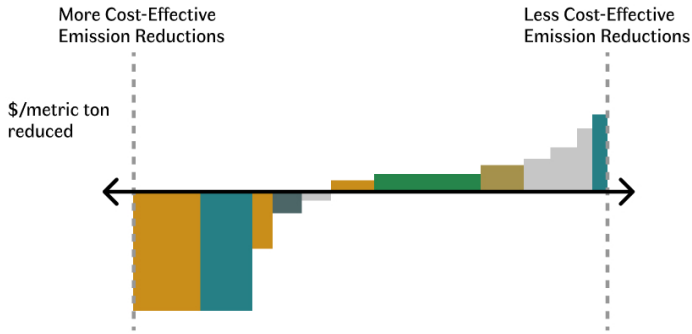

Figure 11.2: Example of a marginal abatement cost curve. Each bar represents a type of emission reduction project, and the colors indicate thematic emission reduction opportunities, like leak detection and repair programs.[121]

Private operators will tend to prefer low-cost or even negative-cost options. Even in those cases, however, an initial investment is usually required, so short payback periods will make investments more attractive relative to other possible assets. In many cases, methane abatement activities can be a commercial opportunity that will pay for the initial investment and maintenance costs and lead to additional income.

Cost-effectiveness of Methane Emission Reductions

Clearly explaining the economic case for methane abatement projects can enhance investor interest. However, how one views the cost-benefit proposition may vary, depending on one's vantage point.

The Company Perspective. Cost-effectiveness for the company means that the value of the additional gas recovered or the fees or enforcement fines avoided by recovering the gas exceeds the incremental capital and operating cost of the abatement project. Measures that meet these criteria might be described as having a positive net present value (NPV), a short payback period, or an internal rate of return (IRR) that meets a company's investment criteria.

The Economy Perspective. This approach considers the net benefits to the national economy. For example, transmission and local distribution companies typically do not own the gas they transport. Regulators usually require them to return the value of loss reduction from methane abatement to their customers. As a result, methane reductions in these industry segments will not have a positive return to the company. That said, the value of reduced losses will accrue to other parts of the economy in the form of lower gas prices and pollution avoidance. Thus, a broader benefit exists even when the entity implementing a reduction cannot directly benefit from reduced losses.

The Regulatory Perspective. This approach considers public health and environmental goals to determine the benefit to society. The cost-effectiveness varies for different pollutants and regulatory programs. In this context, methane reductions may be considered cost-effective due to reduced local pollution and global warming, even if they have a net cost to the company. Regulators may also weigh the additional fiscal revenues from prevented emissions against the investment in detection equipment and staffing.

Monetizing Methane Abatement

The benefits of methane reduction can be both direct, such as the capture of gas that would otherwise be flared/vented, or indirect, such as the issuance of a resellable carbon credit.

Gas Capture

Methane abatement investments that result in the capture of gas can provide significant returns if the captured gas can be redirected to consumers with gas demand. Such investments can offer the company as high returns as other investment opportunities. Instead of flaring, the captured methane can be monetized by:

- ➔ Selling the gas for domestic consumption (cooking, home heating, etc.).
- ➔ Producing Liquified Natural Gas or Liquified Petroleum Gas if the gas is wet.
- ➔ Reinjecting the gas into an oil and gas reservoir for enhanced recovery.
- ➔ Using natural gas for power generation.
- ➔ Supplying feedstock for hydrogen, methanol, and gas-to-liquid industries.

Each option comes with its unique set of challenges. For example, the Nigerian Gas Flare Commercialization Programme had a bidding process (2020-2023) for flaring sites to monetize their associated gas, including the production of petrochemicals and fertilizers.[122] This bidding process was premised on an existing supply chain system (processing facility, transport) that bidders could rely on for moving the natural gas to market. In Colombia, in the Florena Field, investment was made to utilize a high-

pressure reinjection compressor. But only part of the total amount of gas could be reinjected into the reservoir. Therefore the surplus gas was converted into power supplied to the electricity grid.[123]

Carbon Credits

Carbon markets, where GHG savings are translated into actively traded credits, have grown increasingly common in recent years. The implementation and policy implications of carbon markets are a subject worthy of its own handbook and will not be discussed in detail here. Methane reduction is, however, one way to produce credits in a GHG market. The following is an example of how the abatement of fugitive emissions from a gas distribution network translated into credits that supported the project's economics.

Monetizing Methane Abatement Case Study: Methane Emission Reduction Initiatives in Bangladesh

Natural gas is the main source of primary energy in Bangladesh. About 65 percent of commercial energy in Bangladesh is derived from natural gas. About 13 percent of the total natural gas supply is used for residential cooking purposes through a distribution gas pipeline. As the distribution gas network aged, gas distribution companies have identified many leaks. Companies engage third parties to identify and repair methane leaks to improve operational efficiency and safety. Distribution companies do not need to invest when a program is funded under the Clean Development Mechanism (CDM). LDAR activities are one example of a CDM-funded methane project.

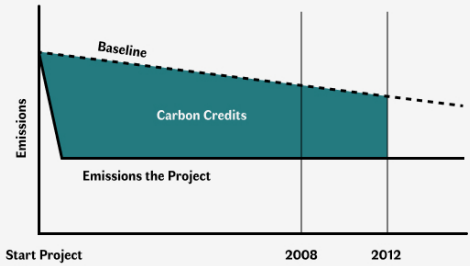

Figure 11.3: Illustration of Carbon Credit Returns Based on Reduced Emissions.[124]

Titas Gas Transmission and Distribution Company Limited (TGTDCL), a supplier of gas in the capital Dhaka and surrounding areas, signed the Certified Emission Reductions Project Investment Agreement with NE Climate A/S (NES) of Denmark in 2012 to reduce methane emission by deploying LDAR. UNFCCC registered the project in 2015. Under this project, about 4.0 million metric tons of CO_2 equivalent methane emission is reduced annually. In addition, TGTDCL is generating revenue by selling CERs.

Considering the initial success of the CDM project, TGTDCL signed another contract with the same company for Verified Emission Reduction (VER) in 2021. The sponsor started LDAR with the new project at Rise/RMS level, seeking to save 10.91 million metric tons of CO_2 equivalent via methane emission reductions.

Paschimanchal Gas Company (PGCL) signed a contract with Eco Gas Asia Limited. As a result, about 0.36 million metric tons of CO_2 equivalent methane emission reductions have been saved each year, and this has started generating revenue as a benefit of the CDM project.

Karnaphully Gas Distribution Company (KGDCL) started a CDM project considering the LDAR strategy. As a result, about 2.64 million metric tons of CO_2 equivalent methane emission reduction reductions have been saved between 2019-2022. In addition, KGDCL started another gas leakage detection system in the gas pipeline using a mobile gas detection system. This gas leakage detection system is replicated in other distribution companies (BGDCL, JGTDSL) under Petrobangla, the government-owned national gas company of Bangladesh.

All these CDM projects contribute to achieving the targets of Bangladesh's NDC for fugitive gas emissions in the energy sector and generate funding for reducing methane emissions.

12. Capacity Building for Action

Key Takeaways

- Methane abatement is a new priority — governments and companies worldwide are taking bold action. Several areas of expertise are important for governments to be able to act effectively to reduce methane.
- In developing a strategy for capacity building, governments can develop new skills progressively over time.
- Depending on existing circumstances and existing capacities, capacity building could be done quickly and with limited financial resources.
- Assistance is available: a number of existing capacity-building initiatives provide tailored expert and peer-to-peer support to national and subnational jurisdictions. Resources are available to support governments and National Oil Companies to act quickly on methane.

Expertise Needed for Methane Management

Core areas of expertise needed across the industry lifecycle include the following:

Policy development. Expertise in evaluating existing environmental, energy, and petroleum policies, skills in drafting, and experience in navigating the political landscape. Clear policy commitments will enhance the chances of obtaining technical assistance.

Regulatory design. Knowledge of the legal, institutional, and policy implications of options. The design of methane abatement regulations will determine if they achieve effectiveness, efficiency, feasibility, accountability, affordability, and safety.

Legal expertise. Knowledge and application of local laws, the legality of specific interventions, and legal drafting are critical for preventing any violation of existing laws that render the new regulation unimplementable.

Technical expertise. The various quantification frameworks and techniques and how these work with advanced technologies and software contribute to understanding how to develop effective regimes for monitoring, reporting, and verification.

Economic expertise. Understanding the macroeconomic trends, financing options, market incentives, and pricing mechanisms of methane abatement in the oil and gas sector. As discussed in this book, one of the most powerful policy and regulatory design tools is the marginal abatement cost curve.[125]

Industry experience. Familiarity with contemporary issues, regulatory successes and failures, operational matters, and implementation feasibility of the industry. Formal feasibility studies coupled with tacit knowledge of a region, sector, technology, and regulation inform the assessment of the risks and benefits of various options.

Expertise in oversight, enforcement, and compliance. Expertise in the review and approval of projects, award of permits, and monitoring, compliance, and enforcement. Engineering, safety, and environmental specialists bring an understanding of the technical aspects required for submissions and operations in order to identify any changes required by the country's methane abatement program.

Intra-governmental coordination and conflict resolution. Coordination across agencies to encourage information exchange, negotiation of differences, convergence of effort, and alignment of regulations. To ensure effectiveness, the coordinator must seek endorsement and legitimacy from the highest leadership levels and be placed at a sufficiently high level of authority to effect changes.

Coordination with subnational jurisdictions supports the delivery of flexible solutions for addressing the local needs of the industry and communities. This is especially true in climate policy, where state and regional governments have shown the will and capacity

to lead, including through jurisdiction-specific goals and regulations. Subnational governments now have the opportunity to take early action on methane, and many have already made commitments[126] to reduce methane emissions from oil and gas. The Subnational Climate Action Leaders Exchange (SCALE)[127] incorporates the Global Methane Pledge which provides capacity-building opportunities through peer learning of cross-sectoral and multi-level coordination and finance mobilization mechanisms.

Developing a Strategy for Capacity Building

Developing economies are often poorly resourced for regulatory design and oversight activities. In creating a capacity-building strategy, national governments should (1) assess their needs, (2) identify resources, and (3) secure funding.

1. Assess Needs

The assessment examines individual and institutional capacities. Individual capacity is the knowledge and skills of personnel managing the methane regulatory framework.

Institutional capacity is a system including procedures for data management, strategy planning, workforce development, resource allocation, and dispute resolution.

The assessment will depend on several features. It will, for example, consider the country's industry-specific development stage: no production, nascent development, consistent supply, peak production, and sunsetting. The assessment will also look at the capacity required based on the understanding of the industry's future outlook: fast boom-bust cycle, price instability, and golden period.

One of the most important aspects of any capacity-building assessment, moreover, will be determining where existing authority and expertise are already located: the country's existing governance arrangement. In some countries, there is one umbrella agency with much of the necessary expertise housed within. Other countries will have expertise distributed across multiple agencies. Finally, some countries have NOCs with a level of independence from the government. NOCs can pose a challenge to coordination and operational efficiency, but they can also be a source of significant strength for fast methane abatement action. Many NOCs have robust individual and institutional capacities in networking, process optimization, and joint decision-making. The illustration below provides a simplified contrast between these three governance arrangements.

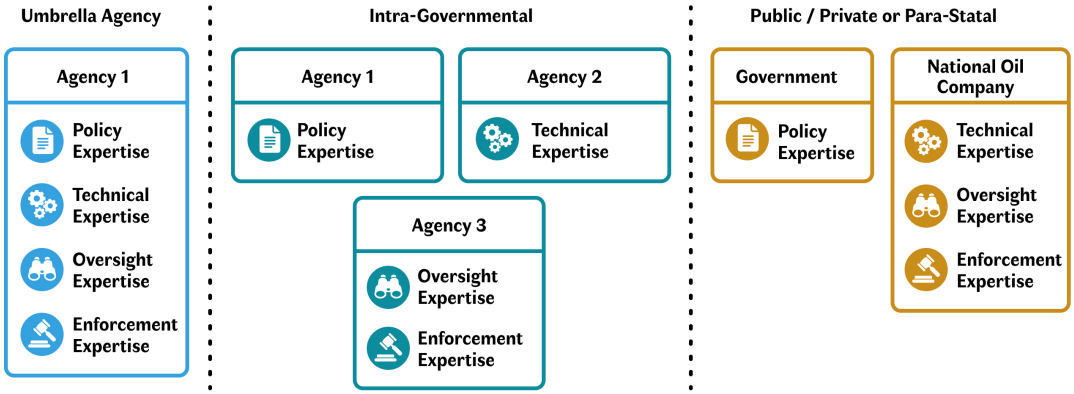

Figure 12.1: Different structures of regulatory systems.

2. Identify Resources and Support

This handbook contains a list of resources that may be a good starting point for capacity building; details are provided in

Chapter 13: Resources for Implementation. The transfer of knowledge and skills can occur through desktop research, in-person or virtual training, on-the-job training, coaching, and mentorship. The following are sources of support:

Research/Analysis/Publications. A wealth of existing written research, publications, and reference documents can provide government officials with a foundation of critical issues associated with methane in the oil and gas sector. The resources can inform strategies, policies, and regulatory regimes. Commercial entities provide some of these resources for a fee, but others are freely accessible. For example, the IEA regularly provides data and analysis on oil and gas methane emissions, abatement potentials, and technologies to support governments in drafting effective methane policies.

International methane initiatives. Through its solution center, the *Climate and Clean Air Coalition (CCAC)* works with participating countries to identify resources to support methane mitigation. The CCAC meets one-on-one with countries to discuss priorities and needs. They also help develop methane mitigation strategies designed to realize the goals of the Global Methane Pledge. The Global Methane Alliance aims to support countries that commit to ambitious methane reduction targets in the oil and gas sector. *World Bank Global Gas Flaring Reduction Partnership (GGFR)* is a multi-donor trust fund composed of governments, oil companies, and multilateral organizations committed to ending routine gas flaring at global oil production sites. The *European Bank for Reconstruction and Development (EBRD)* provides technical assistance and facilitates knowledge transfer on methane emissions measurement, reporting, and reduction and may consider providing finance for methane reduction investment plans. The above are only some examples of international methane-specific initiatives.

Subject matter experts. These experts could be across the public, private sector, or multilateral agencies. Leveraging outside expertise is often vital in developing solutions specific to a

jurisdiction. Experts can often be obtained freely through NGOs, multilateral exchanges, and U.N. programs. In other cases, contractors may be hired to provide advice. Domestic and foreign academic institutions may offer guidance at little or no cost.

Industry-led initiatives. These provide technical assistance and guidance in the industry. For example, the *OGCI Aiming for Zero Methane Emissions Initiative*[128] calls for an all-in approach that treats methane emissions as seriously as the oil and gas industry already treats safety.

Peer-to-peer exchange. Through formal and informal networks, countries can explore shared lessons and challenges with their peers. Meanwhile, countries with extensive regulatory experience and technical expertise can provide relevant advice. Regulators benefit from peers' wisdom in undertaking their methane mitigation initiatives. Please see *New Producers Group* as an example of government-to-government communities of practice.

Development partners. These are international networks designed for knowledge-sharing across borders and resource providers that can help bring governments together to identify effective capacity development strategies and share positive outcomes. Please see the examples below.

The Climate and Clean Air Coalition (CCAC)

The CCAC is a key first-step resource for capacity-building assistance on methane reduction. Through its solution center, CCAC works with interested partners to assist all governments and other actors ready to make solid and ambitious commitments to reduce methane emissions from the oil and gas sector. The CCAC has helped countries to build up the capacity to design and implement policies and regulations for methane abatement:

- **Mexico**. The CCAC provided capacity building to Mexico's ASEA (Agencia de Seguridad, Energía y Ambiente, or Safety, Energy and Environment Agency) for it to implement a bold 2018 regulation to control methane emissions from the oil and gas industry. The CCAC provided training on data management, inspections for LDAR, and third-party verification, among other things. Mexico set a goal of reducing 40-45 percent of methane emissions from the oil and gas sector by 2030.[129]
- **Nigeria**. CCAC assisted Nigeria with its recent policies and regulations on methane abatement, some of which are discussed in this book. By connecting Nigeria on a peer-to-peer basis with policymakers and experts from around the globe, CCAC assisted Nigeria's key oil and gas sector regulators, such as its Upstream Petroleum Regulatory Commission, in the design of provisions on flaring, LDAR, and MRV.[130]

New Producers Group: Government-to-Government Knowledge Network

The New Producers Group (NPG) is an example of a successful 10-year Global South knowledge and experience-sharing network. It brings together more than 30 developing countries that are relative newcomers to the oil and gas sector, such as Guyana, Ghana, Kenya, Mauritania, Mozambique, Senegal, Suriname, Tanzania, Uganda, and Namibia. It was established in 2012 by Chatham House, the Natural Resources Governance Institute, and the Commonwealth Secretariat. It connects over 700 government officials (ministries, regulators, NOCs) with peers, think tanks, industry experts, and energy companies. The NPG aims to support governments in effectively managing petroleum resources, navigating the energy transition, and integrating climate-resilient strategies for sustainable development outcomes. A core aspect of the NPG activity is building the GHG competency of government officials, which has been done through webinars, research, and workshops such as *Aligning Petroleum Sector with National Development, Energy and Climate Goals (2021)* and *Minimising GHG Emissions from the Petroleum Sector (2022).*

3. Secure Funding

Understanding the available financial resources will help frame the opportunity to set and determine where governments can obtain funding. Sources include:

Development partners. While this can be accessed in the short and medium term, reliance on this in the long term should be avoided, and structures should be established to ensure long-term self-funding.

Operators through existing training and development requirements. Regulatory regimes can include a provision, in law or through petroleum agreements, creating a training fund, or contributing to local capacity building. In countries with an active oil and gas sector, the regulator may impose a fee on operators to establish a capacity development fund.

National budget allocations. Governments prioritizing methane abatement will raise finance through taxation and budgetary savings under their climate policy framework.

Climate finance. There could be opportunities for accessing climate finance for mitigation efforts. These opportunities would require developing project proposals that clearly outline the methane emissions to be reduced or avoided.

Climate resilience tax. Such a tax could help fund state-of-the-art capacity building. As methane emission reduction generates revenue, some funds can be allocated to sectoral capacity building.

Research grants. Funding for appropriate technology solution research grants can be allocated to potential researchers, especially at the university level. Governments, in some instances, could act as the grantor, where they are asked to be custodians of funds dedicated to methane capture and abatement — doling out funds to areas likely to have the most significant impact.

Detailed mapping of finance sources can be found in *Chapter 11: Financing for Methane Abatement*.

Case Study in Successful Capacity Building: The Montreal Protocol

The Montreal Protocol has successfully reduced the use of ozone-depleting substances to protect the stratospheric ozone layer. National Ozone Units (NOUs) staffed by National Ozone Officers were set up in developing countries with the authority to manage their national programs to comply with the Montreal Protocol, including agreed phaseout schedules for controlled substances. The establishment of the NOUs illustrates the need for capacity building to effectively implement the Montreal Protocol.

Meanwhile, these NOUs engage with one another in regional networks and capacity-building workshops where they can benefit from additional guidance and expertise. As a result, policymakers in developing countries learned from the experiences of their peers and received access to additional resources. Despite this success, the Protocol has had difficulty carrying out the established regulatory functions due to high staff turnover in countries with smaller NOUs.

Developed countries funded these activities through the Montreal Protocol's Multilateral Fund. Through this model, jurisdictions succeeded in sharply curbing ozone-depleting substances. This model could be replicated to reduce methane emissions.

13. Resources for Implementation

You Are Not Alone

Methane abatement is a challenge, but there are lots of resources to help — and many are free. These range from primers, data portals, and modeling tools to organizations whose mission is to assist governments — often at no cost. The list below is not intended to be exhaustive but reflects a cross-section of available resources.

Tailored Expert Advice

The Climate and Clean Air Coalition

https://www.ccacoalition.org/en/content/methane-technical-assistance

This partnership of governments, intergovernmental organizations, businesses, scientific institutions, and civil society organizations, with a Secretariat hosted by the U.N. Environment Program, provides advice on methane abatement. With a focus on air quality and climate pollutants, CCAC "stands ready to meet one-on-one with countries to discuss priorities and needs and help develop the most efficient methane mitigation strategies." In addition, they provide projections, national planning support, policy guidance, regulatory tools, and more.

The Clean Air Task Force

https://www.catf.us/methane/international-oil-gas/

This NGO helps oil and gas producers and policymakers build robust methane regulations. They have worked with Nigeria, Mexico, Colombia, Ecuador, and others to support methane abatement in the oil and gas sector. They also work to facilitate access to multilateral engagement and funding.

Environmental Defense Fund

https://www.edf.org/issue/methane

This NGO has numerous tools to assist policymakers and regulators with methane reduction. EDF works with a variety of partners and stakeholders, and advises on regulatory options for methane abatement globally.

The Global Methane Initiative

https://www.globalmethane.org/about/index.aspx

Since 2004, this international coalition has advanced "cost-effective, near-term methane abatement" by connecting policymakers with financial institutions and peer governments. GMI provides technical support to deploy methane-to-energy projects around the world that enable partner countries to launch methane recovery and use projects.

The Under2 Coalition

https://www.theclimategroup.org/methane-project

This consortium of subnational governments contains over 160 states and regions taking the lead on climate action. It provides a significant forum for governments to "share effective ways to reduce methane emissions, beginning with a focus on the oil and gas sector."

Financing

The Climate and Clean Air Coalition

https://www.ccacoalition.org/en/content/methane-technical-assistance

This partnership of governments, intergovernmental organizations, businesses, scientific institutions and civil society organizations, with a Secretariat hosted by the U.N. Environment

Program, can direct governments toward financing opportunities. They provide customized expert assistance to help governments achieve their methane goals across sectors.

The Landscape of Methane Abatement Finance (Climate Policy Initiative)

https://www.climatepolicyinitiative.org/publication/the-landscape-of-methane-abatement-finance/

This report focuses on established methane abatement solutions across sectors to "assess global investment in methane abatement activities and create a baseline against which investment needs, and progress can be measured."

The Global Methane Hub

https://globalmethanehub.org/

This philanthropic organization provides direct funding for methane abatement projects. Launched in March 2022, they intend to "support and sustain action from civil society, government, and private industry, including in the more than 100 countries that have signed on to the GMP by meaningfully investing in methane reduction solutions."

Global Methane Initiative Project Network

https://www.globalmethane.org/about/index.aspx

This network "consists of representatives from the industry, the research community, financial institutions, state and local governments, and other expert stakeholders interested in developing and supporting methane abatement, recovery, and use projects in Partner Countries."

World Bank Group Green Bond Program

https://treasury.worldbank.org/en/about/unit/treasury/ibrd/ibrd-green-bonds

This program offers funding for methane abatement from gas flaring, along with agricultural and waste sector projects.

Financing Solutions to Reduce Natural Gas Flaring and Methane Emissions

https://openknowledge.worldbank.org/entities/publication/e7bb2e64-799c-59d7-9f92-4531d541b129

This report provides a framework for policymakers to evaluate the feasibility and financial attractiveness of flaring and methane reduction (FMR) projects, analyzes investment barriers, and identifies vital variables and success factors backed by lessons learned from case studies. Simplified financial modeling templates are suggested to help policymakers to assess FMR options.

Guides

Global Methane Assessment: Summary for Decision Makers (U.N. Climate and Clean Air Coalition)

https://www.ccacoalition.org/en/resources/global-methane-assessment-summary-decision-makers

This resource was drafted by the U.N. Environment Program and the Climate and Clean Air Coalition. It explains the health, economic, and climate imperatives for tackling methane across sectors.

Regulatory Roadmap for Oil and Gas Methane (International Energy Agency)

https://www.iea.org/reports/driving-down-methane-leaks-from-the-oil-and-gas-industry/regulatory-roadmap

The International Energy Agency developed this practical step-by-step guide. Regardless of jurisdiction, it is a resource in developing oil and gas methane policies. The Roadmap guides policymakers through a ten-step process, from understanding the legal and political context to reviewing and updating policies.

Primer on Cutting Methane: The Best Strategy for Slowing Warming in the Decade to 2030 (Institute for Governance and Sustainable Development)

https://www.igsd.org/wp-content/uploads/2022/09/IGSD-Methane-Primer_2022.pdf

As the Institute for Governance and Sustainable Development (IGSD) explains: this Methane Primer "provides the scientific and policy rationale for decision-makers to achieve the 'strong, rapid, and sustained' cuts to methane emissions necessary to slow global warming in the near term and limit the risk of triggering climate, economic, and social tipping points. Topics covered include the science of methane mitigation and why action is urgently needed; current and emerging mitigation opportunities by sector; national, regional, and international efforts that can inform emergency global action on methane; and financing initiatives to secure support for fast methane reduction. The Methane Primer also supports the need for research and development of technologies to remove methane from the atmosphere at scale."

Minimising Greenhouse Gas Emissions in the Petroleum Sector (New Producers Group)

https://www.newproducersgroup.online/minimising-greenhouse-gas-emissions-in-the-petroleum-sector-the-opportunity-for-emerging-producers/

This report focuses on new producers, helping them "design their laws, regulatory systems, monitoring regimes and projects" to lower greenhouse gas emissions.

Guide to Subnational Action on Methane (Under2 Coalition)

https://www.theclimategroup.org/our-work/resources/tackling-methane-guide-subnational-government-action

Developed by a coalition that includes over 160 subnational jurisdictions, this overview is designed to give city, state, and

regional governments a range of resources to address methane across sectors.

Financing Solutions to Reduce Natural Gas Flaring and Methane Emissions (World Bank)

https://www.worldbank.org/en/programs/gasflaringreduction/publication/financing-solutions-to-reduce-natural-gas-flaring-and-methane-emissions

This report "provides a systematic framework to evaluate the feasibility of flare reduction projects at medium-sized flaring sites. The approaches and tools developed will help policymakers and operators analyze investment barriers, identify key variables and success factors, and model financial options for those medium-sized flares that have historically been overlooked."

Global Gas Flaring Reduction Partnership (World Bank)

https://www.worldbank.org/en/programs/gasflaringreduction

This fund develops country-specific flaring programs, shares best practices, and secures global commitments to end routine flaring. Its goal is "ending routine gas flaring at oil production sites worldwide."

Methane Resources (Center for Law, Energy, and the Environment)

http://methaneresources.org

Researchers at University of California, Berkeley School of Law developed this platform as a gathering point for information on methane abatement across sectors. It directs users to a comprehensive suite of resources to help "governments, businesses, NGOs, and others seize a vital climate opportunity by addressing methane emissions."

Tools

Country Methane Abatement Tool (Clean Air Task Force)

https://www.catf.us/comat/

Developed by the Clean Air Task Force, this tool offers an easy-to-use and unique mix of data-gathering, reporting, engagement, and policy design tools that enable users to gain insights, analyze data, build consensus, and develop mitigation plans, recognizing that there is no one-size-fits-all solution to the problem of methane emissions.

Oil Climate Index Plus Gas (Rocky Mountain Institute)

https://rmi.org/oci-update-tackling-methane-in-the-oil-and-gas-sector/

Developed by leading experts at the Rocky Mountain Institute, this tool "reveals the size, scope, and nature of the methane problem by quantifying and comparing greenhouse gas emissions from over two-thirds of the world's oil and gas supplies." It intends to present a life-cycle emissions assessment at the wellhead and during processing, refining, and transportation.

Satellite Point Source Emissions Completeness Tool (Rocky Mountain Institute)

https://rmi.org/clean-energy-101-methane-detecting-satellites/

The SPECT tool is designed to help users compare satellites for completeness in "identifying and tracking super-emitters of methane."

MiQ

https://miq.org/

MiQ is an independent not-for-profit established by RMI and SYSTEMIQ to facilitate a rapid reduction in methane emissions from the oil and gas sector. It is the world's first certification system to grade gas on methane emissions.

The Methane Flaring Toolkit

https://www.worldbank.org/en/programs/gasflaringreduction/publication/methane-flaring-toolkit

Published by the World Bank, this document provides practical advice and information on measurement and monitoring of methane emissions from gas flares in the oil and gas industry.

Reporting Templates and Technical Guidance (Oil and Gas Methane Partnership 2.0)

https://ogmpartnership.com/guidance-documents-and-templates/

These guidance documents and templates simplify the reporting process and explain key oil and gas equipment operations concepts.

The Methane Guiding Principles

https://methaneguidingprinciples.org/

The 24 oil and gas signatories to these principles work toward "action in the industry and governments to reduce methane emissions from the natural gas supply chain." They also "develop and share hands-on interactive tools and guidance to help others learn from their experience and put those lessons into practice."

The Methane Framework Series (Center for Law, Energy, and the Environment)

https://methaneresources.org/

This series provides the policy basis for methane abatement. It prepares governments to realize opportunities for methane action in the oil and gas sector and agriculture, coal, and waste.

Data Sources

The International Methane Emissions Observatory

https://www.unep.org/explore-topics/energy/what-we-do/methane/imeo-action

This U.N. program "catalyzes the collection, reconciliation, and integration of empirically based near real-time methane emissions data, to provide unprecedented climate transparency and the information required for reducing this powerful greenhouse gas."

Carbon Mapper

https://carbonmapper.org/

Carbon Mapper is a nonprofit initiative whose partners include Arizona State University, the University of Arizona, the Rocky Mountain Institute, the State of California, and NASA's Jet Propulsion Laboratory, which works to "offer a rapid methane leak detection service to facility operators and regulators" through remote sensing technology. They aim to launch two satellites in 2023 to provide widespread access to this data.

MethaneSAT

https://www.methanesat.org/

This Environmental Defense Fund initiative plans to launch a satellite in early 2024. They promise to identify large methane plumes "virtually anywhere on Earth," noting that "cutting methane emissions from oil and gas is the single fastest, most impactful thing we can do to slow the rate of warming today."

Climate Trace

https://climatetrace.org/

This partnership provides freely available, open data on known and estimated emissions, including methane. It gives jurisdictions an immediate but general sense of their methane emissions profile.

NASA EMIT

https://earth.jpl.nasa.gov/emit/data/data-portal/Greenhouse-Gases/

NASA maps major methane plumes with limited global coverage using an instrument affixed to the International Space Station. This tool may identify some plumes in a jurisdiction.

TROPOMI

http://www.tropomi.eu/data-products/methane

TROPOMI is an instrument aboard the Copernicus Sentinel-5 Precursor satellite, commissioned by the European Space Agency, that provides methane data.

Annex: About Methane

Methane (CH_4) is a colorless, odorless, flammable greenhouse gas (GHG) that has both natural and anthropogenic sources. The anthropogenic sources include agriculture, oil and gas, coal and waste sectors. In the oil and gas industry, methane is also natural gas — the same natural gas used in power plants, industrial processes, combustion engines, commercial applications, and residential heating and cooking. In addition, methane is a feedstock for various chemical and elemental (hydrogen) resources. As natural gas, methane is the molecule that makes up Compressed Natural Gas (CNG), an alternative fuel for vehicles. And methane makes up Liquefied Natural Gas (LNG), one of the great energy shifts in the last half-century.

Sources of Methane

Around 60 percent of global methane emissions come from human activities (anthropogenic), with the rest coming from natural sources, including wetlands, freshwaters, geologic seepage, wild animals, termites, wildfires, permafrost, and vegetation.[131]

Agriculture

Agriculture is the largest single source of human-caused methane emissions, and reductions of these emissions in the sector present an opportunity to slow the pace of near-term global warming. Agricultural methane is released through the storage of organic energy in low-oxygen conditions. These include rice paddies, the digestive systems of ruminant animals, and, in some countries, manure pools at large cattle operations.

Agricultural methane reduction techniques can control emissions while improving product generation, often boosting the profits of herds and farms.[132] For cattle, methane solutions

include simple dietary improvements, improved breeding practices, methane-fighting feed additives, improved manure storage, and the capture of manure methane. Strategies for rice may consist of different rice cultivars and the water drawdown in paddies.

Energy

The energy sector (oil, gas, coal, and bioenergy) accounts for ~33 percent of anthropogenic methane emissions. This handbook discusses methane emission sources and abatement options for oil and gas sources in detail.[133]

Waste

The waste sector is the third-largest source of anthropogenic methane, accounting for about 20 percent of the total. Waste methane releases result from the decay of organics in oxygen-free conditions, including in landfills, wastewater facilities, septic systems, and latrines. Waste sector methane reduction techniques can control emissions and, in some cases, redirect this energy for productive uses, including products and fuel. According to the Global Methane Assessment, about 60 percent of waste methane solutions have negative or no cost.

Because landfills and wastewater systems tend to be managed at the subnational level, waste sector methane presents an opportunity for cities, municipalities, states, and provinces to lead. While research in this domain is ongoing, many well-established waste methane strategies can be deployed today with significant effect. These include waste prevention and composting programs, landfill covers and gas capture systems, and improved wastewater sanitation systems.

This handbook addresses only methane emissions from the oil and gas sector but could help inform a more extensive strategy focused on multiple methane-emission sources.

Acronyms

AVO	Audio, Visual, and Olfactory
CATF	Clean Air Task Force
CCAC	Climate and Clean Air Coalition
CCUS	Carbon Capture, Use, and Storage
CDM	Clean Development Mechanism
CoMAT	Country Methane Abatement Tool
DFI	Development Finance Institution
EDF	Environmental Defense Fund
EPA	Environmental Protection Agency (U.S.)
ESG	Environmental, Social, and Governance
GGFR	Global Gas Flaring Reduction Partnership
GHG	Greenhouse Gas
GMP	Global Methane Pledge
GWP	Global Warming Potential
IMEO	International Methane Emissions Observatory
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
LDAR	Leak Detection and Repair
LNG	Liquefied Natural Gas
NOC	National Oil Company
MACC	Marginal Abatement Cost Curve
MARS	Methane Alert and Response System
MDB	Multilateral Development Bank
M-RAP	Methane Roadmap Action Program

MRV	Monitoring, Reporting, and Verification
NPV	Net Present Value
OGCI	Oil and Gas Climate Initiative
OGI	Optical Gas Imaging
OGMP	Oil and Gas Methane Partnership
SCALE	Subnational Climate Action Leaders Exchange
TPY	Tons Per Year
VOC	Volatile Organic Compound
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change

Notes

Chapter 1

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8 IEA 2023: Global Methane Tracker 2023, *https://www.iea.org/reports/global-methane-tracker-2023*

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Colophon

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