Driving Down Methane Leaks from the Oil and Gas Industry

A regulatory roadmap and toolkit

International Energy Agency

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Abstract

Reducing methane emissions from oil and gas operations is among the most cost-effective and impactful actions that governments can take to achieve global climate goals. There is a major opportunity for countries looking to develop policies and regulations in this area to learn from the experience of jurisdictions that have already adopted methane-specific regulations in order to design frameworks that are adapted and tailored to local circumstances. One of the aims of any new policy effort should be to improve measurement and reporting of emissions data, which can in turn lead to more efficient regulatory interventions. However, the current state of information on emissions should not stand in the way of early action on methane abatement. Experience shows that countries can take an important "first step" today based on existing tools, which may include prescriptive requirements on known "problem sources" combined with monitoring programmes that seek to detect and address the largest emissions sources ("super-emitters"). In terms of process, implementing a new policy or regulation should involve three distinct phases, each covered in detail in this roadmap: understanding the local setting and circumstances, regulatory design and development, and finally, implementation.

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Overview

The case for methane regulation

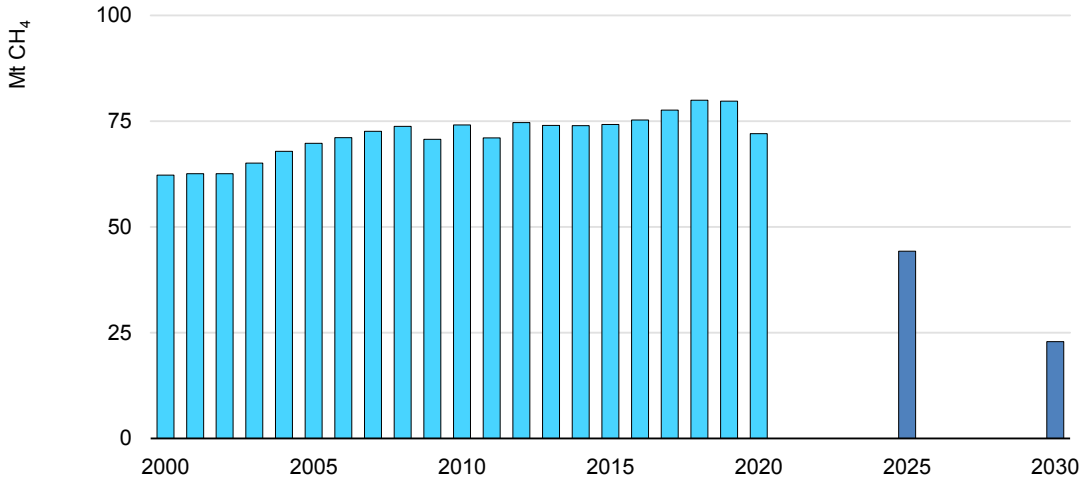
Reducing methane emissions from oil and gas operations is among the most cost-effective and impactful actions that governments can take to achieve global climate goals. What's more, a growing number of jurisdictions recognise that regulatory action plays an important role alongside voluntary industry action.

Action is needed on methane

Methane is a potent greenhouse gas with important implications for climate change. Although methane has a much shorter atmospheric lifetime than carbon dioxide (CO_2) – around 12 years, compared with centuries for CO_2 – it absorbs much more energy while in the atmosphere. Thus, while methane tends to receive less attention than CO_2, reducing energy-sector methane emissions will be critical for avoiding the worst effects of climate change.

The IEA estimates that the oil and gas sector emitted around 70 Mt of methane (approximately 2.1 Gt CO_2-eq) in 2020 – just over 5% of global energy-related greenhouse gas emissions. Early satellite data suggest that the incidence of large-scale leaks fell in 2020, although some of this likely stems from the major drops in production as a result of the Covid-19 pandemic. Under the IEA Sustainable Development Scenario (SDS), emissions from this sector will need to fall to around 20 Mt per year by 2030 – a drop of more than 70% from levels in 2020.

Figure 1 Oil and gas sector methane emissions in the SDS, 2000-2030



This 70% reduction coincides with the amount that would be technically possible to abate, according to the IEA Methane Tracker. In addition, a significant share of these emissions can be abated at no net cost, because the value of the captured methane is sufficient to cover the cost of the abatement measure, i.e. there should already be an economic incentive to avoid the release of this gas to the atmosphere. The precise share of emissions that can be avoided at no net cost will undoubtedly vary from year to year and from region to region, with the prevailing gas price being a key variable. Natural gas prices in 2020 were a lot lower around the world than in previous years, so the share of abatement that pays for itself is lower than in previous years. But it will pick up again as natural gas prices rise.

There are a number of voluntary, industry-led efforts to reduce methane emissions, and a number of individual companies have announced methane reduction targets in the past year. Nevertheless, an immediate and significant change in ambition is needed to achieve the sorts of reductions that would be consistent with international climate objectives. While industry efforts can and should continue, government policy and regulation will be critical to removing or mitigating obstacles that prevent companies from getting started and going further.

Barriers to voluntary action

The IEA's country-specific methane cost curves suggest that a significant number of abatement measures would pay for themselves, provided that the captured gas can be delivered to market and sold at the going market rate. Although this simple cost analysis suggests that companies should be willing to undertake some of these actions voluntarily, this is not necessarily the case in practice. Understanding what prevents companies in different countries and market contexts from undertaking actions that appear to be cost-effective is a vital starting point in the design of a regulatory approach to methane abatement.

There are three main types of barrier that explain why companies are not taking full advantage of these opportunities: information, infrastructure and investment incentives.

Information

There is a significant information gap in many companies about methane, regarding both its environmental impacts and, more specifically, the level and sources of emissions from company operations. There is also a lack of awareness in many cases about the abatement technologies that exist, their costs, and the benefits of capturing and using or selling gas that would otherwise be emitted. Even if senior management is aware of the risk of methane releases, this may not be reflected in the broader company culture and its operating practices so that the personnel on the ground, who are in a position to take action, are not doing so. Often this lack of information is an oversight; however,

existing policies may also create a disincentive to obtaining full knowledge. For instance, in a jurisdiction that charges emitters a fee or tax based on volume of pollution emitted, companies may fear raising their compliance costs if they discover new sources of methane.

Infrastructure

In many cases, captured gas can be easily brought to market. However, in other cases, particularly where gas is co-produced (or "associated") with oil, existing pathways or businesses may not exist to bring the gas to productive use. In these cases, it may be necessary to construct new infrastructure to bring the gas to a consumer, including new compression equipment, gathering pipelines and transmission pipelines, or liquefaction facilities. Methane abatement may falter without policies that require or incentivise productive use of natural gas.

Investment incentives

While context matters for corporate decision-making, all firms have limited capital to deploy. Thus, opportunities to invest in methane reduction must compete with other investment opportunities. Even where abatement is cost-effective, companies may opt to direct capital towards investments where a higher rate of return is possible. Moreover, abatement may seem less cost-effective as long as the environmental costs of pollution are not factored into the investment calculation. In addition, where the owner of the gas is not the owner of transmission infrastructure, there may be an issue of "split incentives," whereby the pipeline company that pays to repair leaks sees the benefits accrue to the owner of the gas, from additional throughput. Finally, state-owned firms may not directly benefit from cost-saving measures because they return earnings to the government treasury, and then receive pre-determined appropriations to cover operations.

What can governments do to drive methane reductions?

Governments can address many of these barriers with policy and regulatory tools. If information poses a barrier, policies could include educational strategies, such as trainings; certificate programmes for workers; measures on monitoring, reporting and verification of emissions; reference to international voluntary corporate reporting standards; or initiatives to encourage knowledge-sharing and best practices. With respect to infrastructure, governments might introduce requirements in the planning stages of projects, directly invest in building new infrastructure or adopt policies that allow spreading of the development costs across multiple firms and end users. Governments may also be able to price environmental externalities or create financial incentives for onsite use of captured gas, expenditures in abatement technologies, or repair transmission equipment to remove barriers to investment.

The aim of these interventions is twofold. First, they can unlock the abatement measures that are already economically advantageous today, i.e. the methane leaks that can, in our view, be abated at no net cost. Second, they can facilitate and encourage actions that address the range of methane emissions that are technically possible to abate, i.e. the 70% reductions that are achieved in the Sustainable Development Scenario by 2030. To reach this level, it will not be enough to simply remove the barriers that prevent companies from acting on their own. Broader regulatory initiatives also have an important role to play. Firms are increasingly recognising this and are expressing interest in "sound methane policies and regulations that incentivise early action, drive performance improvements, facilitate proper enforcement, and support flexibility and innovation."[1]

Regulations calibrated to each jurisdiction's specific goals will be critical to ensuring that companies undertake the appropriate abatement actions alongside voluntary action by companies. There are many types of regulations, but what they all have in common is that they can fundamentally change the cost-benefit analysis for firms and drive them to internalise the societal cost of that pollution.

A Regulatory Roadmap and Toolkit

This report aims to provide a complete "getting started" guide for policy makers looking to develop new regulations to tackle oil and gas methane emissions within their jurisdictions. This guide consists of two companion pieces: a **Regulatory Roadmap** and a **Regulatory Toolkit**.

The Roadmap focuses on the **process** of establishing a new regulation. It details ten key steps in developing a new regulation and provides a step-by-step guide to aid regulators in gathering the information they need to design, draft and implement an effective regulatory scheme.

The Toolkit focuses on the **content** of methane regulations. It characterises the different regulatory approaches that are currently in use for methane, with appropriate links to the IEA Policies Database for specific examples. The aim of the Toolkit is to provide regulators with an encyclopedia of the different regulatory tools that are available to them as they craft new policies.

[1] Principle number 4 from the Methane Guiding Principles, a voluntary initiative that brings together industry and non-industry organisations in support of methane emissions reductions.

How can governments design and implement new regulations?

The IEA has identified ten steps that will assist regulators in selecting a regulatory approach and implementing a set of effective methane policies that match the local situation. Although presented sequentially here, these steps may be carried out in a different order, may take place concurrently, or may even be repeated once new data on emissions or new technologies become available.

A ten-step roadmap for policy makers

Step 1: Understand the legal and political context

Step 2: Characterise the nature of your industry

Step 3: Develop an emissions profile

Step 4: Build regulatory capacity

Step 5: Engage stakeholders

Step 6: Define regulatory objectives

Step 7: Select the appropriate policy design

Step 8: Draft the policy

Step 9: Enable and enforce compliance

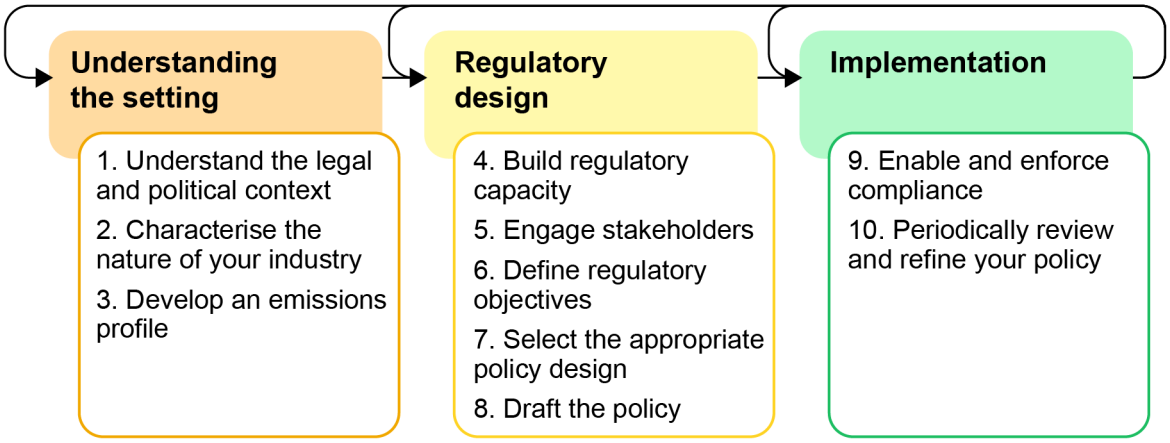
Step 10: Periodically review and refine your policy

Across these steps, the process of implementing a new regulation unfolds in three distinct phases. The first phase takes place before any formal development of a regulatory proposal. It consists of an **information-gathering exercise** designed to equip policy makers with an understanding of how best to match policies and regulations to the institutional circumstances, existing regulatory framework, market context and emissions profile of the jurisdiction. This information-gathering phase corresponds to the first three steps of the Roadmap.

Once policy makers have gathered this information, the next phase involves **designing and developing the regulatory proposal**, taking care to enhance institutional capacity and engage with internal and external stakeholders. This regulatory development phase corresponds to Steps 4 through 8 of the Roadmap. At this stage, regulators should also consider the examples of different regulatory approaches that are collected in the Toolkit.

Even after a regulation is published, a great deal of work remains to ensure that it operates effectively. In the **implementation** phase, policy makers will need to assure compliance with requirements and develop a plan to update the regulation as needed. This corresponds to Steps 9 and 10. Note that although implementation does not begin until a regulation is finalised, policy makers should consider these steps at the drafting stage to build in compliance assurance and adaptive strategies from the start.

Figure 2 Ten steps in implementing new regulations



What policy and regulatory tools are available to regulators?

A growing number of jurisdictions have already recognised that regulatory action plays an important role in driving these actions in the oil and gas industry. Some governments have taken action; others have pledged to follow in the coming years. From our survey of early actions, we have developed a **typology of regulatory approaches** designed to demystify the complex web of regulations that exists in many countries. An introduction to this typology is outlined below, and the Toolkit section of this report provides specific examples for each approach.

Typology of regulatory approaches

The regulatory approaches that have been applied to methane can be categorised into four main types of regulatory approaches:

- prescriptive requirements,
- performance-based or outcome-based requirements,
- economic instruments and
- information-based requirements.

The table below illustrates each regulatory approach by describing its application to the replacement of "high-bleed" pneumatic controllers. These controllers, used for a variety of purposes across the oil and gas value chain, can represent a significant share of the industry's methane releases. For instance, according to the US greenhouse gas emissions inventory, emissions from these pieces of equipment represented about 25% of methane emissions from petroleum and natural gas systems systems in the United States.[2]

Table 1 Regulatory approaches applied to pneumatic controllers

Regulatory approach	Definition	Example
Prescriptive	Prescriptive instruments direct regulated entities to undertake or not to undertake specific actions or procedures.	Operator is directed to replace pneumatic controllers with lower-emitting controllers by a certain date.
Performance- or outcome-based	Performance-based instruments establish a mandatory performance standard for regulated entities but do not dictate how the target must be achieved.	Operator is directed to achieve facility-wide methane reductions from a baseline. The operator then decides to replace the highest-emitting controllers because it is most cost-effective to target these pieces of equipment to meet the overall target.
Economic	Economic instruments induce action by applying penalties or introducing financial incentives for certain behaviours. This may include taxes, subsidies, or market-based approaches such as tradable emissions permits or credits.	Operator must pay a pollution tax for emissions. Alternatively, the operator may deduct the costs of replacing high-emitting equipment from its tax liabilities. Under either scenario, the operator may choose to replace the controller for financial reasons.
Information-based	Information-based instruments 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.	Operator is directed to report emissions of known high-emitting equipment or activities. In view of the volume quantified, the operator may choose to reduce rather than disclose emissions associated with pneumatic controllers.

Most jurisdictions with methane-specific oil and natural gas regulations have relied heavily on **prescriptive requirements** to achieve emissions reductions. This "command and control" approach focuses on directing the installation or replacement of specific pieces of equipment. For example, if a jurisdiction determines that many of its routine emissions come from "high-bleed" pneumatic valve controllers used across the oil and natural gas value chain, a prescriptive rule could direct operators to replace existing

[2] See US Environmental Protection Agency (2020), Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018, table numbers 3-45 and 3-65.

controllers with "low-bleed" or "no-bleed" alternatives, and prohibit installation of high-bleed equipment at new facilities.

By contrast, **performance- or outcome-based requirements** require firms to meet a specific emissions target for a specific piece of equipment or facility, but they do not specify how the firm must meet that target. For example, Mexico's 2018 regulation requires operators of existing facilities to establish and achieve six-year emissions reduction goals for each facility. Operators required to reduce emissions will look for the most cost-effective repairs and replacements across each facility. If some "high-bleed" controllers are contributing heavily to the overall emissions profile of the facility and can easily be replaced, operators will replace these controllers.

Some jurisdictions may opt to use **economic instruments** that deploy penalties or incentives to induce action. The simplest form of economic regulation would be a tax on emissions of methane. For the given example, this would in essence encourage a firm to "replace valve controllers or pay for the methane that they emit." In response, an operator might prefer to replace the higher-emitting controllers rather than pay a methane tax. Norway's carbon tax, which covers methane emissions from offshore oil and gas facilities, represents this approach.

In contrast to policies that assess a penalty of sorts for emitting methane, a government may offer inducements or economic incentives to encourage abatement. An incentive rule might state, "If you replace a valve controller, you can deduct the cost of the replacement from the royalties owed to the state." For example, Nigeria allows companies to deduct capital expenditures on equipment to capture associated gas from its profits, and to deduct royalties assessed on associated gas that is sold and delivered downstream.

One of the biggest hurdles to effective regulation of methane from the energy sector is the extent of uncertainty – about the magnitude of emissions, emissions sources and variability. Given this, a particularly fruitful approach might be **information-based requirements**. A rule might require firms to "tag all high-emitting valve controllers and submit monthly reports on their emissions." For some operators, this may provide new insight into the magnitude of their emissions. Once they learn how much they are emitting, they may take voluntary action. If these emissions reports must be made public, this may also give rise to pressure on operators to reduce emissions from external stakeholders.

Table 2 Methane policies in selected producing countries categorised by regulatory approach

	Prescriptive					Performance-based				Economic			Information-based		
	Permitting require-ments	Leak detection and repair	Restrict-ions on flaring or venting	Technol-ogy standards	Enforce-ment and related provisions	Strategic targets	Facility or company emissions standards	Process or equip-ment standards	Flaring or venting standards	Taxes, fees and charges	Emissions trading and credits	Other financial incentives	Emissions estimates	Measure-ment require-ments	Reporting require-ments
Brazil	●		●	●	●				●	●	●		●		●
Canada	○	●	○	●	○	●	○	●	○		○	●	●	●	●
China (People's Republic of)	●		●	●	●										
Iraq	●				●										
Iran	●														
Mexico	●		●	●	●	●	●	●	●		●		●	●	●
Nigeria	●		●	●	●	●			●	●		●	●	●	●
Norway	●		●		●					●			●	●	●
Russia	●								●	●					
Saudi Arabia	●			●	●										
United Arab Emirates	●				●										
United States	○	●	○	●	●	○	○	●	○	○		○	●		●

Notes: A full circle indicates a policy applied at the national-level. An empty circle indicates a subnational policy (e.g. at state or provincial level in a federal system). Definitions for each type of instrument can be found in Annex A. This table reflects entries in the IEA Policies Database as of 18 January 2020. We welcome feedback from jurisdictions regarding any updates to existing policies or on additional policies that are missing from the database

Many examples of these regulatory approaches are already in place. Table 2 shows a snapshot of the tools currently in use across the 12 top producers of natural gas. This guide relies heavily on these examples, drawn from the IEA Policies Database, in order to point regulators to real-world examples of these existing policy tools and related resources. These examples should be a primary resource for regulators following this guide, providing a source of inspiration and illustrating best practices.

Key insights for policy makers

Policy makers that have already established methane regulations have learned a great deal. This guide seeks to share those best practices and lessons learned in order to maximise the effectiveness of new regulations.

Policy and regulation can help countries meet emissions goals

Policy makers should not assume that the industry has the right incentives to stimulate voluntary action sufficient to address the methane problem. As noted above, a growing number of jurisdictions have recognised the importance of sound policy and regulation alongside voluntary action by industry. Even if industry may take some action on its own, not all of the necessary reductions will be cost-effective on their own, and policy and regulation can work to fundamentally change company incentives in this regard.

There are no one-size-fits-all solutions

A policy and regulatory regime 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. Different regulatory approaches have particular advantages and disadvantages that depend on circumstances that will vary across jurisdictions, and policy makers should take the time up front to understand how these circumstances play out within the local context. The steps outlined in the Roadmap are designed to help regulators understand these circumstances and make decisions on which approaches fit their situation best.

Better information can enable more efficient regulatory requirements

Performance-based requirements and economic instruments can produce more economically efficient outcomes by enabling an operator to identify the most cost-effective abatement options. However, these approaches often require a robust measurement and reporting regime to function properly. For instance, a methane tax

cannot be effectively enforced if no one knows how much methane is being emitted. Developing and implementing a robust measurement and reporting regime may take several years. For jurisdictions in the early stages of regulating methane, prescriptive standards may be the best option until a robust measurement and reporting regime is in place.

However, countries do not need to wait for better data to take action

Fortunately, prescriptive requirements can be effective at reducing emissions in their own right. Moreover, they can serve as a useful first step on the path to more flexible and economically efficient regulations because they are relatively simple to administer and do not require an accurate baseline understanding of the level of emissions or a robust measurement and estimation regime. Therefore, a starting point for jurisdictions regulating methane for the first time might be to combine prescriptive requirements on known "problem" sources with a monitoring programme that detects "super-emitters" using satellite or inspection data and requires companies to address them as they arise. Over time, it may be possible to incorporate aspects of other approaches into a primarily prescriptive regime, such as broad facility or company level targets that complement other requirements.

Critically, this path is well worn. Policy tools adequate to address methane emissions already exist, in one form or another. Regulators following this guide and drawing on the different resources available will be equipped with the information needed to decide among the available approaches, and ultimately, to execute that vision.

How to use this guide

This guide is divided into two main components, the Roadmap and the Toolkit. The Regulatory Roadmap treats in detail each of the ten steps highlighted above and identifies key considerations and decision points for each step. The steps are presented sequentially, but will generally prove to be modular, with feedback loops and iterations between different stages of policy making. Feel free to focus on the steps that you have greatest interest in and skip steps that you have already mastered.

Next, the Regulatory Toolkit presents different elements of policy making to support regulators throughout the policy development and implementation phases. It discusses general regulatory strategies, providing further detail on the four general regulatory approaches described above and illustrating their use through examples of current methane regulations. As with the Roadmap steps, each topic is intended to be modular and stand-alone, and you may wish to refer to aspects of the Toolkit as you walk through the Roadmap steps.

Regulatory Roadmap

The following steps will help you choose a regulatory approach and implement a set of effective methane policies that match your particular situation. Across these steps, the process of implementing a new regulation unfolds in three distinct phases – understanding your setting (Steps 1-3), designing and developing your regulation (Steps 4-8), and implementation (Steps 9-10). If you are new to regulating methane, you might consider starting at Step 1 and working through the list. If your jurisdiction has already done work in this area, you could enter the steps further on, or skip steps based on work you have already done. Although presented sequentially here, these steps may be carried out in a different order, may take place concurrently, or may even be repeated once new data on emissions or new technologies become available. For example, depending on your institution's capabilities, you may carry out step 3, "build regulatory capacity", throughout the process, only at the implementation and enforcement stage, or not at all.

A ten-step roadmap for policy makers

Step 1: Understand the legal and political context

The first phase of the process takes place before any formal development of a regulatory proposal. It consists of an **information-gathering exercise** designed to help you gather information that will inform your selection of a regulatory approach. This includes exploring how your institutional circumstances, existing regulatory framework, market context and current emissions may impact your decision-making. This phase begins here with Step 1 and continues through Step 2, where you will characterise the nature of your local industry, and Step 3, where you will develop a detailed emissions profile.

What characteristics of the institutions in your jurisdiction should be taken into account when crafting a regulatory regime?

In this step, you will consider how regulating methane emissions from the oil and gas sector might fit your political and regulatory context. Understanding where legal authority and political power for action on methane sit can help activate the most promising institutions within your government. Reviewing existing policies can suggest where to amplify methane abatement efforts, or what to change to remove disincentives for action. By considering the following questions, you can identify who should be involved and design policies that fit your agency.

Agencies with relevant regulatory authority

From the outset, it is important to know which institutional actors have regulatory authority. The answer may depend on the ownership of the resource, the location of the resource, and the nature of the regulation (energy, environmental, economic). Many jurisdictions understandably focus on natural resource and environmental authorities, but other types of regulators can be engaged in this important work. Moreover, thinking through the approaches different groupings of regulators can take can help to settle potential jurisdictional disputes between ministries and suggest a more productive partnership going forward.

What is the agency's area of jurisdiction, and how can that be leveraged to abate methane?

Considering how your agency's jurisdiction might be deployed to tackle methane from oil and gas enables you to build on existing authority and think creatively about new applications of your regulatory tools and programmes.

Table 3 Regulatory scope

Question	Relevance	Examples
How can your agency act to reduce methane emissions from oil and gas?	*Agencies with authority over mineral resources* might use rents, royalties or concession payments to discourage waste of the resource.	The National Oil, Natural Gas and Biofuels Agency in Brazil charges royalties for all flared gas; the federal Bureau of Land Management in the United States charges royalties for excessive flaring and waste of natural gas.
	Environmental agencies might use existing air pollution programmes or climate ambitions to tackle methane pollution.	Canada's (Environment and Climate Change Department) methane pollution abatement standards and Mexico's methane regulations support each country's international climate commitments.
	Labour or safety agencies might consider safety practices that also reduce methane venting.	The Department of Treasury and Finance in South Australia and SafeWork in New South Wales have safety standards for gas fitting and coal mining; such standards can promote safety while preventing methane release.
	Economic regulators might consider disallowing "lost gas" costs to be passed on to customers, or creating business opportunities for capturing and marketing associated gas.	Texas and Pennsylvania utility commissioners capped "lost gas" costs to customers at specified percentages of metered throughput. Quebec utility regulators authorised natural gas companies to charge premiums for "responsibly produced" gas (including robust methane abatement programmes). Nigeria's 2017 Natural Gas Policy sought to catalyse a midstream market for natural gas.

A given agency may have jurisdiction over resource development, air quality, worker safety or economic expertise. The policy focus of the particular government body affects what strategies are available.

Actors with jurisdiction over **natural resource extraction** will likely pursue methane abatement strategies from a waste prevention (or product conservation) perspective. For instance, you might focus on the revenue owed to the government for production of the resource, requiring the installation of meters at production facilities and assessing royalties for methane that is vented and flared rather than captured and sent to market. Brazil has imposed this type of regime, as has the United States when

production occurs on public lands.[3] Natural resources or energy agencies may also impose operational requirements like leak detection regimes or routine maintenance and replacement of leaking equipment, again with the primary aim of preventing or reducing waste of a strategic resource.

Environmental actors, by contrast, will focus on methane abatement as an air quality or climate mitigation strategy. In some instances, these agencies may regulate volatile organic compounds and benzene for their contribution to air pollution, and capture methane indirectly through these requirements. The US Environmental Protection Agency first regulated methane emissions from the oil and gas sector in this way, as have several US state environmental agencies, such as Wyoming and Pennsylvania, as well as Alberta, Canada. Rules targeting methane abatement as an air quality strategy may focus on larger sources of volatile organic compounds (including methane) located close to population centres, based on public health concerns. Environmental rules may also target methane as a greenhouse gas, taxing emissions based on a Social Cost of Carbon, or tying requirements to commitments previously made under the Paris Agreement, or to be made in the nationally determined contributions (NDCs) due in November 2020. For instance, national methane rules issued by the Environment and Climate Change Department in Canada and the Safety, Energy and Environmental Agency in Mexico were drafted with international climate goals in mind.

Labour agencies may have jurisdiction over methane-emitting oil and gas activities, where emissions create unsafe work environments. These agencies, for instance the Department of Treasury and Finance in South Australia and SafeWork in New South Wales, might focus on mitigating the threat of fire or explosion from methane leaks. Traditionally, safety agencies might have recommended release of methane gas to the atmosphere, for instance before welding a pipeline or mining coal, or to release vapours from an oil tank to prevent explosion. However, as understanding of the environmental risks posed by methane emissions grows, agencies are realising they can act to keep workers safe while also minimising the release of methane emissions.

[3] See US BLM NTL-4A. The United States strengthened this programme in 2016 with a comprehensive set of rules limiting venting and flaring on public lands, see Waste Prevention, Production Subject to Royalties, and Resource Conservation, 81 Federal Register 83008 (18 November 2016), but reversed itself in 2018, Waste Prevention, Production Subject to Royalties, and Resource Conservation; Rescission or Revision of Certain Requirements, 83 Federal Register 49184 (28 September 2018). On 15 July 2020, a federal court vacated the 2018 rule and directed the BLM to implement the 2016 rule but then delayed both actions for 90 days or until October 13, 2020 (to allow time for continued litigation over the rules). California vs. Bernhardt, Case No. 4:18-cv-5712-YGR (Northern District of California, 15 July 2020). Just days before the California court's order was set to go into effect, a federal court in Wyoming struck down the 2018 rule. Wyoming v. U.S. Department of the Interior, Case No. 2:16-cv-00285-SWS (District of Wyoming, 8 Oct 2020). The pre-2016 rules remain in place, while litigation continues.

Labour agencies may focus on inspections, monitoring, maintenance of equipment, worker training and community education.

Finally, **economic regulators** can create financial incentives for methane abatement. In jurisdictions that approve natural gas rates set by natural gas producers or transporters, rate-making rules can be structured to incentivise the prevention of methane emissions. For instance, by capping the costs of "lost and unaccounted-for gas" that a company can pass on to customers, the US states of Texas and Pennsylvania hope to induce industry to plug pipeline leaks. Or, an economic regulator might take Quebec's example and allow gas distribution companies to charge a premium for gas produced using leading management practices to control methane leakage.[4] Similarly, legislatures may invest in research and development, or award grant funds to innovative abatement practices. The US Department of Energy in the fall of 2020 requested information on new technologies to promote methane abatement. Finally, government actors may have economic development goals to meet, from universal electrification to advanced manufacturing. In these cases, requiring or encouraging oil producers to capture and sell co-produced natural gas could reduce methane emissions while providing fuel for power plants or feedstock for chemical production. Nigeria's 2017 Natural Gas Policy reflects some of these interests.

Who owns the oil and natural gas, and controls exploitation rights for these resources?

Generally speaking, regulation of a natural resource – and the pollution that its exploitation may cause – follows ownership. In countries where the national government owns and manages the mineral estate, including for instance Mexico, Indonesia, Kazakhstan, and Nigeria, the national government also decides who can produce oil or natural gas, and on what terms.

[4] The Canadian Press (2020), "Deal with Alberta gas producer is Quebec utility's first under certification program", Global News, 10 February. Similarly, British Columbia has allowed a premium to be assessed on "renewable" natural gas (biomethane). See British Columbia Utilities Commission, In the Matter of FortisBC Energy Inc. Application for Approval of Biomethane Energy Recovery Charge Rate Methodology, Decision and Order G-133-16.

Table 4 Natural resource rights

Question	Relevance	Examples
Who owns the oil and natural gas, and controls exploitation rights for these resources?	If the *national government owns the resource*, it likely can control activities that produce methane emissions and prevent or discourage venting and waste of the resource.	In Mexico, the nation owns the mineral estate, and a collection of national agencies regulate this sector. Indonesia's laws makes clear that oil and gas are national assets which are controlled by the state; the same document directs the government to establish a national regulatory entity.
	If *subnational governments own the resource*, they will enjoy more authority over exploitation (and methane). However, the national government may still exercise other authorities, e.g. over air pollution.	In Argentina and Canada, subnational governments own the resources located within their borders, and take the lead on regulating exploitation including limits on venting and flaring of methane.
	If *private actors own the resource*, private contracts determine royalty terms, including whether royalties should be paid for vented or wasted gas.	In the United States, many oil and gas deposits are privately owned. There, private leases can but do not have to include terms to prevent or limit methane venting.

In other countries, such as Argentina and Canada, mineral resources may be owned and managed by the subnational governments where they are located. Those subnational governments also hold primary authority over the operation of oil and natural gas facilities, including activities that might cause or inhibit the release of methane to the atmosphere. Where provincial actors are the lead regulators, national agencies are more likely to play educational and supportive roles – in Canada, for instance, the national Natural Resources Ministry directs non-regulatory research and development of non-binding methane abatement equipment and practices, which provinces may adopt in their onshore oil and natural gas standards. The same ministry jointly manages and regulates offshore resources with the Maritime Provinces, underscoring that location of the target resource may shift the locus of regulation. (Meanwhile, as discussed in the next section, Canada's national environment ministry exercises plenary authority to regulate air pollution from oil and gas operations.)

A handful of countries enable private ownership of minerals. For instance, in the United States, the federal government, state and local governments, or private parties may own oil and natural gas resources. The owner of the mineral estate sets the terms for royalty payment, including whether to charge royalties for gas that a

producer leaks, vents or flares. Therefore, if a private entity owns the mineral estate, royalties are negotiated through private contract.

How is associated gas treated and permitted?

Table 5 Associated gas regulation

Question	Relevance	Examples
How is associated gas treated and permitted?	If associated gas has been treated as a *waste product*, the government may need to clarify that it is a resource and enable legal ownership before regulating it.	Nigeria's Petroleum Act makes clear that the national government owns associated gas and may take it without paying royalties. Nigeria used this authority to grant associated gas production rights to companies focused on the recovery and sale of gas.
	If associated gas is *not considered part of an oil or coal concession/leasehold*, agencies can contract with third parties to exploit it.	Kazakhstan requires coal companies to separately acquire the rights to capture and sell associated gas.
	If associated gas *is considered part of the concession or leasehold*, the governing documents can require companies to use the gas on site or to pay royalties on it.	In the United States and Brazil, oil companies must pay royalties on some flared and vented associated gas. (In the United States, this is only for oil and gas owned by the federal government.)

In some jurisdictions, gas that is co-produced (or "associated") with oil or coal is considered a waste product rather than a resource; governments may have to clarify that they own the associated gas and establish a separate permitting regime. For instance, Nigeria's Petroleum Act treats associated gas as separate from a petroleum lease and authorises the government to take that gas "free of cost at the flare or at an agreed cost and without payment of royalty." This enabled the Nigerian Ministry of Petroleum Resources to establish a permitting system to grant associated gas production to someone other than the oil leaseholder. Similarly, Kazakhstan made clear in 2010 that coal mines must reduce associated methane emissions, and authorised the leaseholder to use the methane on site or to separately secure the right to produce the gas for delivery to market. By contrast, in other countries the associated gas is considered part of the leasehold. As a result, the government may not separately lease the associated gas; on the other hand, the oil producer may be liable for royalties on unnecessary flaring and venting.

Who regulates air pollution?

Table 6 Air pollution regulation

Question	Relevance	Examples
Who regulates air pollution?	Sometimes, the governmental agency that regulates exploitation of resources sits at the same level of government as the agency that regulates associated environmental concerns.	In many countries, the national government not only controls these resources but regulates air pollution from these activities. This includes Indonesia, Mexico, Nigeria and Norway.
	One level of government, or a particular agency, may regulate access to and exploitation of resources. A different level of government or agency may regulate environmental aspects of these activities.	In Canada, despite the provinces taking the lead role in permitting the exploitation of oil and natural gas, the national government has a shared authority with the provinces over environmental matters. Therefore, while provinces such as Alberta and British Columbia have established flaring and venting rules in their capacity as resource regulators, Canada has issued methane pollution abatement standards for the whole country, which may be displaced by provincial regulations determined to be "equivalent".

Authority over air pollution may not be the same as for natural resources. Air pollution may be seen as exclusively either a national or local issue, or as a shared responsibility. Environmental authority may also differ depending on the pollutant, and whether methane is defined as a pollutant at all under the law.

These distinctions determine which government body has authority and how it might regulate methane emissions. For instance, while the Canadian constitution grants provinces and territories primary authority over the exploitation of natural gas and other resources, the national government enjoys plenary authority over environmental matters. Therefore, while Canadian provincial energy agencies issue rules for minimising the venting and flaring of methane as operational standards for natural resource exploitation, the national Ministry of the Environment has implemented air pollution rules targeting methane emissions from oil and gas facilities. The provinces then have to implement these directly or through rules that the national Minister of the Environment approves as "equivalent", as set out in the Canadian Environmental Protection Act. Under this authority, Canada has

determined that the methane regimes in Alberta, British Columbia and Saskatchewan[5] are equivalent to the national methane rule.

Do worker or community safety institutions have authorities that might be implicated in methane abatement?

Table 7 Safety regulation

Question	Relevance	Examples
What other authorities might be implicated in methane abatement?	*Worker or community safety authorities* could be engaged in the enterprise of reducing methane venting to the atmosphere. Currently, many safety rules do not prevent methane venting, and could be improved to achieve this goal while maintaining safety.	Mexico's and Nigeria's oil and gas regulators have issued national safety standards for oil and gas activities. In Canada and Australia, subnational agencies take the lead on safety issues. The United States has a federal safety administration that issues rules applicable to different industries, including oil and gas.

Depending on the country, national or subnational authorities may also focus on worker safety. In Mexico, the national agency ASEA issued guidelines in 2016 for the implementation of management systems for industrial and operational security and environmental protection in the hydrocarbons sector. These guidelines included a requirement to conduct risk analyses of operations. Similarly, the Minister of Petroleum Resources in Nigeria has issued safety regulations. Meanwhile, in Canada and Australia, subnational governments have issued work health and safety rules related to methane emissions. In most of these examples (except for Australia), the safety rules were a subset of operational/exploitation rules. In the United States, a stand-alone safety agency in the national Department of Labour, the Occupational Safety and Health Administration, sets safety standards for industries including those along the oil and natural gas value chain.

Are there staging considerations for when your agency should act in relation to other government actors?

Mapping the political landscape beyond your agency can be incredibly useful for determining the right time to act. If leadership in your legislature or the head of state wants to reduce methane emissions, you can seek new authority through statutes or

[5] The equivalency agreement covers Saskatchewan's venting and flaring and measurement directives. The Ministry found that these regulations are equivalent through the end of 2024 but noted that "the Government of Saskatchewan will have to put in place additional regulatory measures in order for a new equivalency agreement to be concluded beyond 2024."

executive decrees for a more optimal approach to methane abatement. If not, you may proceed using the powers that you already have. If national and subnational governments share jurisdiction, it may make sense to let the subnational actors with extensive oil and gas experience act first. The most effective solutions forged on that smaller stage can then be replicated or scaled up to the national level. Where multiple ministries share oversight of oil and natural gas activities – perhaps those regulating energy, environmental, safety and economic issues – they should attempt to co-ordinate to avoid overlap and inconsistency. For instance, it may be useful for agencies that work more closely and co-operatively with industry to jointly identify best practices and begin to work those into contracts and concession agreements, for later adoption by other agencies through regulation.

Pre-existing policies

The next grouping of regulatory characteristics to consider in Step 1 concern existing governmental capacities and policies that might be leveraged to achieve methane abatement. Building a regulatory regime that plays to your institutional strengths will help to ensure success. Meanwhile, once you identify pre-existing authorities that directly target methane or indirectly affect decisions that drive methane emissions, you can step up their use, adapt their application, amend them or remove them for optimal methane outcomes.

What tactics or strategies does your agency typically deploy to achieve its policy missions?

Once you have established that your agency or ministry has the jurisdictional authority to tackle some aspect of oil and gas methane emissions, it is important to think about the tactics it most often employs to achieve its policy goals. If yours is a regulatory agency with experience enforcing standards, then it could make sense to proceed with regulation. If your agency tends to work collaboratively with large players in the oil and natural gas industry, perhaps by facilitating joint ventures and other contracts, then you might begin by adapting contract provisions on a going-forward basis, to incentivise or require methane abatement. If your agency is a research institution, you could partner with universities, industry and international organisations to test new methane abatement equipment or practices. Finally, if your entity is a data collection body, you might be trusted by the industry and by the public to enhance emissions monitoring and estimation. Build on your natural strengths and expertise to promote adequate measurement and reporting.

Do any pre-existing policies explicitly address methane emissions? Beyond this, are there existing policies that indirectly affect methane emissions?

Chances are, whether intentional or not, you will have policies in place that influence methane emissions from oil and gas producers in your jurisdiction. Sometimes, these policies directly apply to methane combustion or release of natural gas to the atmosphere, even if they were not implemented for climate reasons. For instance, Nigeria requires a permit for flaring and enables companies investing in equipment to capture and deliver associated gas to write these off as tax-deductible capital expenses. The Russian Federation (hereafter, "Russia") assesses a fee for flared gas, but allows deduction for investment in associated gas infrastructure. The United States has imposed air quality standards that apply to volatile organic compounds (VOCs) and methane emissions from oil and gas facilities.

In many other instances, pre-existing policies will not mention methane explicitly but nonetheless create opportunities for (or obstacles to) methane abatement. For instance, a country with a carbon tax may take inspiration from Norway and extend that tax to cover methane emissions from the oil and gas sector.

Policies indirectly affecting methane emissions can be more difficult to identify, but they are worth the search. Economic regulations may enable companies to charge customers for lost gas; production tax credits may incentivise a rush to complete wells and move on, perhaps undercutting the motive to perform low-emissions completions; environmental rules may require emissions monitoring that indicates methane leakage; safety regulations may require venting of methane to the atmosphere before conducting repairs or inspections.

Where an existing policy facilitates abatement, you might consider enhancing it – increasing the stringency, the length of time the requirement is in place or the level of subsidy – or ratcheting up enforcement to ensure more consistent compliance. Where an existing policy has the potential to facilitate abatement, you might consider applying it in new ways to realise that potential. Alternatively, you might leave an existing policy as you found it, but then know to avoid undermining it with any new policy.

Likewise, it may make sense to remove existing policies that create the wrong incentive structure. If an existing policy inhibits abatement, you might remove the policy, or change it so as to achieve the original policy goal without creating a disincentive for action on methane. For instance, when economic regulators enable natural gas utilities to pass the costs of "lost and unaccounted-for gas" on to customers, they may disincentivise pipeline maintenance. Some utility commissions

in the United States have recognised this incentive problem and capped the amount of lost and unaccounted-for gas that can be included in customer rates.[6]

Step 2: Characterise the nature of your industry

How might the particular characteristics of the industry in your jurisdiction affect the types of policies you put in place?

In this step, you will continue the exercise of gathering information about your local context, focusing here on the nature of your industry. As you consider the questions outlined in this section, you should keep in mind the three categories of barriers to reducing methane emissions: information, infrastructure and investment incentives. Understanding the nature and shape of your industry will help you to identify where policy intervention can be most effective at addressing these barriers within companies. This may suggest particular regulatory strategies and focal points.

Analysis may also suggest which government bodies and personnel need to be involved in methane abatement policy making (see the last section), and help you predict where your "problem" sources of methane might lie (see the next section).

Industry segments

How much of the value chain is represented in-country?

Table 8 Oil and gas value chain

Question	Relevance	Examples
How much of the oil and natural gas value chain is represented in-country?	Countries that have most or all industry segments represented have more policy levers at their disposal. They can regulate production, transportation and consumption of the commodity in a way that supports methane abatement.	The United States, Canada and Russia have all industry segments represented within their borders, and a robust natural gas market (although access to market issues remain for associated gas across all three jurisdictions).
		In Russia, the industry is entirely regulated by the national government, while in Canada and the United States, different segments are regulated by national or subnational levels of government.

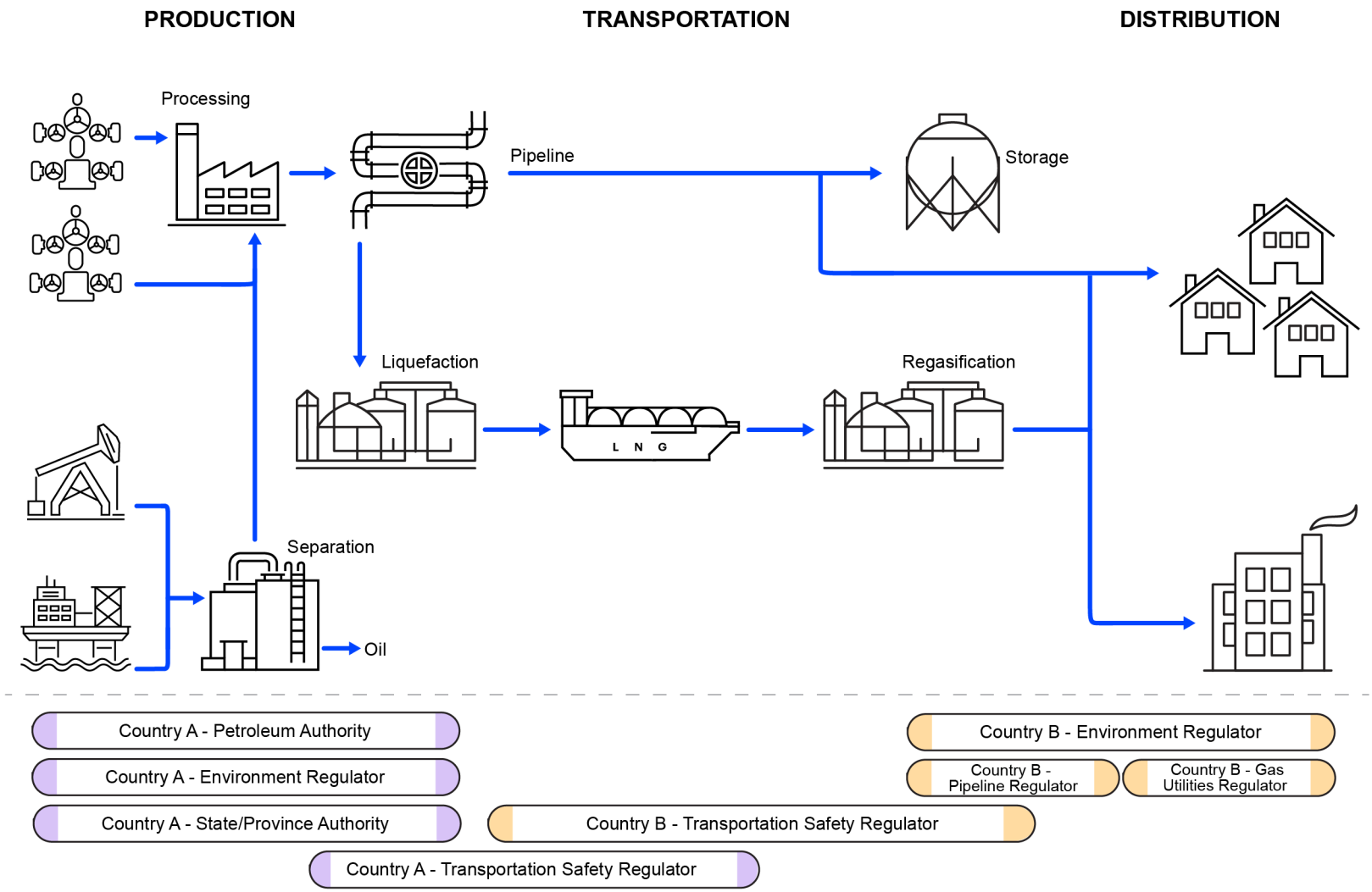
[6] See e.g. Costello, K. (2013), Lost and Unaccounted-for Gas: Practices of State Utility Commissions, National Regulatory Research Institute Report No. 13-06, Table 2.

The natural gas value chain extends from the point of production to the final consumer. Along the way, natural gas is gathered, processed, transported by pipeline (or in its compressed or liquefied form, by truck or ship), stored, distributed and used in industrial, residential, electrical power and transportation applications. When natural gas is used for electricity production, this chain of industry segments is often described as "well to burner tip". Each industry segment has a different set of methane emissions profiles, challenges and abatement opportunities.

Some countries will have all industry segments represented within their borders, such as the United States, Canada, Mexico and Russia. Others will have just a subset, as will be described below. It is important to identify which part of the value chain your country will regulate, to match the right policies to the particular challenges posed by each segment. Generally speaking, countries with all industry segments represented within their borders may have more policy levers at their disposal to target methane leakage and venting across the value chain.

Sometimes, governmental jurisdiction may change by industry segment. In Australia and Colombia, the national pipeline regulator oversees transmission and distribution pipelines, while in the United States, states (such as Texas) separately regulate intrastate distribution gas lines while a federal agency regulates interstate pipelines.

Figure 3 Diagram of natural gas value chain and indicative division of governmental authorities



Are there robust domestic markets for natural gas?

Table 9 Gas markets

Question	Relevance	Examples
Are there robust domestic markets for natural gas?	Countries that do not have domestic markets for natural gas will need to find export markets, to induce development of the infrastructure necessary to bring associated gas to market.	Nigeria and Brazil have worked to develop a midstream natural gas market and drive domestic demand of natural gas, to make use of otherwise vented or reinjected associated natural gas (reinjection being a better outcome than venting, of course).

Many countries or regions that produce natural gas as a co-product of oil or coal production may not have midstream or downstream natural gas industry segments because they lack domestic markets for natural gas. Without adequate pipeline and processing capacity, or end-use demand, these regions and countries may find it difficult to require or incentivise the capture of natural gas at production facilities. For this reason, countries such as Nigeria and Brazil are working to develop a midstream market and to drive domestic demand of natural gas, notably to electrify rural communities and support industrial growth. If your country faces this situation, policy will have to overcome both the infrastructure and investment incentive barriers to methane abatement.

Is your country a natural gas net importer or exporter?

Table 10 International gas trade

Question	Relevance	Examples
Is your country a natural gas net importer or exporter?	*Net importers* of natural gas do not have direct regulatory authority over upstream activities beyond their borders and must leverage their consumer power to induce methane abatement outside of their borders.	Nearly 44% of the world's natural gas imports are delivered to the European Union. Methane abatement policies must be tied to consumption, or seek to apply methane-intensity standards at the point of import.

Question	Relevance	Examples
	Net exporters of natural gas may be driven to reduce methane emissions because of climate policies in the markets where they sell. Alternatively, export countries could be proactive in abating methane leakage, to achieve climate commitments and to distinguish their product in the world market.	Countries that export natural gas to Europe and East Asia are tracking the climate policies of those countries and large industrial consumers in those countries to anticipate the methane abatement that may be demanded or preferred in these markets.

Countries without all industry segments represented have more limited policy targets. For instance, the European Union has very little oil and natural gas production, meaning that a policy that directly regulates upstream methane emissions would have little effect. By contrast, nearly 44% of the world's natural gas imports come to the European Union. Therefore, policies that aim to reduce consumption of natural gas, or to ensure that all gas consumed comply with certain standards, would be a more effective strategy for this jurisdiction. Procurement standards are emerging as a powerful policy tool. Large consumers of natural gas may demand a "low-leakage" supply chain as a basis for eligibility to bid or as a performance condition in a contract. Importing countries may impose similar methane intensity standards at the point of import, though there may be some legal risk. Importantly, you should consult with the trade authorities in your government, and you will need to establish a mechanism to judge the upstream emissions profiles of importers. Such a mechanism does not currently exist anywhere in the world (although the European Commission's Methane Strategy contemplates eventually establishing one). As a first step, it may be more efficient and effective to work with your top importing countries, to seek assurances of their emissions profile or to encourage an effective regulatory regime upon their producing sources. Net exporting countries could anticipate these new rules with domestic methane abatement policies likely to meet importer standards, or gain a competitive edge if their cleaner product is subject to a small carbon border adjustment, or gives the exporter a marketing edge in climate-conscious markets.

Description of industry participants

One of the most important aspects of your industry is the makeup of its participants. A country dominated by one vertically integrated, state-owned enterprise working with a handful of other multinational corporations may call for a different regulatory regime than a segmented and heterogeneous industry landscape. Most notably, where regulatory requirements are implemented through contractual or concession terms, this may be the primary vehicle for imposing methane reduction requirements.

Is the industry vertically integrated or segmented?

Table 11 Industry structure

Question	Relevance	Examples
In the industry in your country vertically integrated or segmented?	Countries with vertically integrated industry may centralise regulation of all methane-emitting activities. Moreover, vertically integrated firms may achieve economies of scale in methane abatement. That said, it may be harder to move a single regulator or industry actor that is resistant to change.	Brazil, Colombia, Argentina, Russia and the United States (offshore) have an industry dominated by vertically integrated firms.
	Countries where the natural gas industry is broken out by segment may have more industry players to regulate, fewer cross-sector strategies to deploy, and more regulatory actors involved. But this context can also create opportunities for experimentation.	The United States (onshore) has a highly segmented, diverse industry.

The last section discussed the parts of the value chain represented in your country. Even where the full value chain is represented domestically, your natural gas industry may be vertically integrated – meaning the same firm controls natural gas across the value chain – or broken out by segment.[7]

Where the same firm controls most or the entire natural gas industry (or those segments existing in a country), it is more likely that regulation will be consolidated at the national level or within a single agency. This can create regulatory efficiencies. Vertical integration also facilitates flexible regulatory strategies such as industry-wide emissions goals, which enable a firm to find the most cost-effective reductions across the value chain. On the other hand, there are drawbacks to a single firm working with a single regulator. If either entity is resistant to change, or if the close working relationship leads to regulatory capture, regulation may be difficult to introduce. In addition, regulation of a few large actors can create transparency concerns. For instance, in jurisdictions with a few large actors, regulators are more able to negotiate specific terms in individual permits. While this enables tailored regulation, these

[7] If both oil and natural gas are produced in your jurisdiction, that may splinter the industry in different ways; for instance, in 1997, Colombia's state-owned, vertically integrated, oil and natural gas company spun off Ecogas to separately own and manage natural gas pipelines with Ley 401 de 1997. Ecogas was sold at auction in 2006 and purchased by the private Grupo Energía Bogotá.

permits are often not disclosed to the public. In Norway and Nigeria, therefore, it can be challenging to determine the stringency of requirements – or the leeway a permit writer has to weaken or waive requirements. Publication of the permits, as is done in Brazil, might be a way to enable better tracking and accountability.

A more segmented industry will by definition involve more industry actors. Regulation of these actors can be more decentralised and more complex. In this context, methane abatement policies are more likely to focus on a single segment and emanate from different agencies. For instance, in the United States, at least four federal agencies – the Department of Transportation, the Federal Energy Regulatory Commission, the Department of the Interior and the Environmental Protection Agency (EPA) – may regulate different upstream and midstream segments. In turn, the EPA issues distinct rules for each industry segment for stationary sources. Additionally, subnational and local governments regulate methane from wells, gathering lines, and distribution pipelines, often through a public safety, economic or consumer lens. (By contrast, offshore of the United States, the federal government owns the resource, is the sole regulator and oversees activities dominated by vertically integrated firms.) While decentralised operations and regulation may be less efficient, it may also allow for more experimentation in different jurisdictions and across companies, and lead to more policy innovation.

A single company or entity may dominate each segment. If so, within that segment, you may have the same close relationship as a regulator would have with a vertically integrated utility across the value chain. For instance, in Russia, different state-owned firms have strong positions in different aspects of production, refining and pipeline transportation of oil and natural gas. At the other end of the spectrum, segments of the US industry, including upstream oil and gas production, are quite competitive and involve many actors of varying sizes and levels of sophistication. This can foster opposition to regulation out of a fear of the excessive burden that might be placed on smaller actors. At the same time, a more opportunistic regulatory approach may work better in this context – the regulator can search for willing partners from among the firms to pilot new abatement technologies, inventory emissions or propose methane reduction standards. This opportunistic context does not require a competitive market such as the one in the United States; even having one or two multinational corporations working with and alongside a national company might spur these firms to take action.

Are the firms involved private or state-owned?

Table 12 Industry type

Question	Relevance	Examples
Are state-owned firms involved along the energy value chain?	Countries with *state-owned companies* may or may not directly regulate those companies. Where they do, attention must be paid to the different motivations of state-owned firms to ensure methane abatement policies will be effective.	In 2014, Mexico created a new regulator to oversee worker safety and environmental protection in the oil and gas sector, for the existing state-owned enterprise and private firms beginning to participate.
	Where *both state-owned companies and private companies* operate in a country, policies may apply differently (and in some cases, the state-owned company may be in the position to regulate the private entity).	Indonesia, Nigeria, Kazakhstan and Colombia allow for joint ventures or concessions for private companies to develop resources with or alongside state-owned firms.
	Countries with *exclusively private companies* operating in this space will subject those firms to regulation.	The United States and Canada have only private firms operating in the oil and gas sector.

The companies operating in your jurisdiction may be privately held or state-owned – often known as national oil companies (NOCs). In many countries where oil or natural gas production is dominated by state-owned enterprises, government agencies do not have legal authority to regulate these activities (although there may be political or budgetary oversight). In a departure from this standard practice, some countries have begun directly regulating NOCs. For instance, Mexico recognised the need to create a separate regulatory authority over Pemex, the state-owned oil company, to tackle methane pollution and other sustainability issues.

Although state-owned enterprises may be more aligned with the public policy goals of your government's leadership, easing implementation, they may also be viewed in the legal structure as co-regulators or as self-regulated entities, which could make it more difficult for government agencies to impose methane standards. Alternatively, they may be legally bound to meet certain performance metrics that do not align with the goal of methane abatement. In these cases, it will be important for government agencies and NOCs to work closely together, and to identify other policies that might interfere with methane reduction activities.

In some countries with state-owned oil and gas enterprises, including Indonesia, Nigeria and Kazakhstan, oil and natural gas production can occur through joint ventures with, or concessions to, private firms. The state-owned enterprise may enter

into contracts with those private firms, as a partner as a stand-in for the regulator (as in pre-2004 contracts in Colombia).[8] Including methane abatement provisions directly in these standard contracts may be an effective way to impose methane limits on those private partners.

If the private companies have operations in other countries, check to see if those other countries have implemented methane abatement policies, or have expressed interest in doing so. A company that has to comply with methane regulations elsewhere may be more willing to work co-operatively with you to forge similar rules in your jurisdiction.

Resource targeted

Oil and natural gas production can both result in methane emissions.[9] Since natural gas is primarily composed of methane, the entire natural gas value chain is a potential source of methane emissions. By contrast, methane is processed out of oil, so methane ceases to be an issue as the product moves through to the midstream market. Therefore, methane abatement policies as applied to oil need to focus only on upstream activities up to and including refining.

Is the natural gas a by-product of oil production?

Methane abatement becomes more challenging when natural gas is not targeted as a resource. If your jurisdiction has a complete natural gas value chain, the requisite infrastructure and consumer demand should be there to incentivise the capture of methane for sale. This makes it more likely that the firms in your jurisdiction are already taking some voluntary measures to reduce methane venting or leakage and are more likely to be productive partners in any future regulatory venture.[10] However, if upstream producers are focused on oil production and lack the gathering infrastructure or markets to deliver natural gas, it becomes more costly and more difficult to make the case for methane capture. Finally, as already mentioned, how your legal system views "associated" gas may have large implications for your abatement policies. If treatment of this gas as a waste incentivises its release to the

[8] In 2003, Colombia restructured EcoPetrol, and created the National Hydrocarbons Agency (Agencia Nacional de Hidrocarburos) to administer production agreements going forward. Prior to this, EcoPetrol administered the agreements as an arm of the Colombian government. It still plays this role on contracts negotiated before 1 January 2004.

[9] Coal production can also result in methane emissions. This is often referred to as coal seam gas or coalbed methane. Although methane emissions from coal production can be significant, this Roadmap and Toolkit does not focus on efforts to reduce these emissions.

[10] Note that this may be a subnational or regional inquiry. For instance, the United States has a complete natural gas value chain, but some oil patches are disconnected from that value chain, creating associated gas issues similar to what a country without a gas market might face.

atmosphere, or makes it unclear who owns the associated gas, changing those policies may be an important threshold step to take to realise your methane emissions reduction goals.

What is the geochemistry of your natural gas?

More detailed inquiries into the type of natural gas that is produced or transported through infrastructure, including its geochemistry, may be useful. For instance, if the natural gas in your jurisdiction is particularly corrosive, a more robust leak detection and repair regime may be necessary. If produced gas is sour (i.e. contains significant amounts of hydrogen sulphide), then detection measures are probably already in place due to safety concerns and you can build onto these requirements.

Where is your natural gas production located?

The location of natural gas infrastructure may also suggest policies of different types and frequencies. Offshore oil and gas production wells generally take more abuse from the elements than onshore wells; valves on pipelines that experience extreme temperatures will be under more stress than pipelines through temperate zones. These remote facilities may be visited less often for inspection; use of remote sensing and continuous emissions monitoring may be more critical in these locations. Offshore facilities may also be far removed from natural gas gathering lines; here, gas reinjection might be encouraged as a climate policy as well as to stimulate offshore oil production. As we learn more about methane emissions profiles of different activities and types of infrastructure, these details may prove to be even more useful in designing relevant emissions standards.

State of energy development

Finally, it helps to understand your industry's stage of energy development. This inquiry will be informative in two respects. First, it may indicate how much institutional expertise you have in your state-owned firms and agencies, which could be tapped for methane abatement efforts. Second, you may use different policies to address new infrastructure than to retrofit or replace existing facilities.

How extensive is your existing infrastructure? How old is it?

Where lower-emitting equipment is readily available (for instance, low-bleed and no-bleed valve controllers), regulators can dictate the use of this equipment for new construction. More challenging, by contrast, is the application of methane abatement standards to existing infrastructure. Payback times for methane abatement investments may extend beyond the remaining useful life of certain equipment.

Retrofitting old equipment may be more difficult – and more expensive – than building a low-emission facility from a greenfield. Mapping existing infrastructure can be a good starting point for emissions inventories, while also suggesting where regulatory efforts should be focused. For instance, your regulatory framework might aim to replace ageing infrastructure over time, and in the meantime, inspect it more frequently for leaks. Some jurisdictions might contemplate phased regulation, applying methane abatement standards to new infrastructure and then setting deadlines further into the future for the replacement of older equipment. Establishing requirements to tag, meter and report emissions of existing infrastructure can also lead companies to voluntarily replace sources that represent a disproportionate share of their overall emissions.

If your jurisdiction has a long history of energy development, you may need a regulatory strategy to address methane emissions from abandoned wells. Pennsylvania, where the first American oil well was drilled in 1859, could have as many as 750 000 "orphan" wells, many of which could be releasing methane. Across the globe there are millions of abandoned wells, a number expected to increase in 2020 due to the Covid-19 pandemic and in the future once the world has passed peak demand.

The US-based Clean Air Task Force has created an online tool to help identify the abatement potential of your existing infrastructure; other resources may be available as well.

What are your country's future resource development plans?

Today, your country may produce natural gas from onshore wells, but it may be eyeing a new offshore oilfield. Your industry may be focused on oil production, while you want to develop a domestic midstream and downstream gas industry to market associated gas. Look beyond today's development and anticipate where the country may be headed when developing methane abatement policies. The IEA Methane Tracker is a good starting point to establish your past, current and future energy development patterns. The IEA publishes reported numbers on energy production and consumption for each country.

As momentum builds for global efforts to reduce emissions, many countries are also looking to scale up the use of low-carbon fuels, including biogases and low-carbon hydrogen. Depending on the production routes involved, these may also involve the risk of methane leaks to the atmosphere. The need for a robust approach to methane abatement can extend throughout energy transitions and beyond.

Step 3: Develop an emissions profile

How much methane is emitted in my jurisdiction and what are the biggest problem sources?

With a good sense of the features of your regulatory and industry structure in hand, you can now characterise your jurisdiction's methane challenge. Understanding the nature and magnitude of your emissions will be critical to designing sound regulations – the inquiry will show where to focus your efforts and where abatement efforts are likely to have the most impact. Newfound awareness about a country's emissions can also be a big kick-start to action, particularly when coupled with the knowledge that the technology already exists to effectively reduce these emissions.

It may be useful to think of this step in terms of establishing a baseline that will serve as a benchmark for your regulation. That information will allow you to gauge progress as your regulation is implemented. This is a useful reference point even if your regulation does not explicitly reference a baseline – for instance, if you are imposing a prescriptive requirement to replace high-emitting valve controllers. However, for many performance-based standards, you will in fact direct companies to reduce total emissions (or the rate of emissions) from a baseline level. Then you might use as your regulatory baseline the most recent year for which you have complete data. You might also select earlier years for at least two reasons. First, companies in your jurisdiction may have undertaken voluntary measures prior to implementation of any regulation. If you implement a policy with a goal of reducing methane emissions by a specified percentage from a baseline year, you can give "credit" to those early-action companies by setting the baseline to a year preceding voluntary action. Second, an earlier baseline year may be warranted if the most recent year was an outlier. For instance, using 2020 might be discouraged, because of the enormous impact that Covid-19 had on energy commodity prices and demand. You might be setting too low a baseline because of these very atypical conditions.

Estimated level of emissions

More likely than not, you will need to develop an initial estimate of your emissions to use a reference point in setting your goal and tracking your progress. Moreover, by studying data about methane emissions from different sources and activities, going forward you can track general trends and adjust your policies accordingly.

Does your country already have estimates of oil and gas sector methane emissions?

As a member of the United Nations Framework Convention on Climate Change (UNFCCC), your country may compile greenhouse gas inventories. To support this or other regulatory programmes, your jurisdiction may already have reporting requirements in place, for some or all sources of methane. Canada and the United States are good examples of countries with national inventories that target methane emissions. Over time both jurisdictions have worked to estimate this pollution at a relatively granular level.

Initially, available information, even under a mandatory reporting regime, may be quite limited; that is expected and can be managed. As you learn more about methane emissions in your jurisdiction, you can amend inventory reporting rules to collect better information – and amend abatement policies to match reality on the ground.

How might you generate in-country emissions estimates?

As long as some of the sources are reporting, you may be able to derive country-specific emissions factors for a set of sources or activities. In addition, guidance created by the Intergovernmental Panel on Climate Change (IPCC), initially released in 2006 and refined in 2019, includes more generic emissions factors that could be applied to your industry. The IPCC's fugitive emissions estimations document is particularly relevant to calculations of a methane baseline for abatement policies.

The IEA Methane Tracker offers country-by-country methane emissions estimates, which may inform your inventory. The tracker estimates methane emissions from the oil and natural gas value chain, using generic emissions factors (often those generated for North America). These are a good starting point; however, development of locally derived emissions factors should ultimately be the goal. In addition, companies in your jurisdiction may already be tracking their methane emissions for corporate governance purposes and might be willing to share what they have learned. If no such information already exists, you can look to emissions from similar installations elsewhere to get a sense for this information. Moreover, as satellites begin producing more publicly available data on methane emissions, you may be able to use those data to confirm and reconcile estimates you have developed based on an inventory of emissions factors.[11] See the **Monitoring** section of the **Toolkit** for more information on this.

[11] For more information, see the IEA case study on Norway's efforts to improve its emissions inventories in the 2020 Methane Tracker.

To use emissions factors effectively, you will need to estimate the number of pieces of a particular type of equipment being used in your jurisdiction, or the number of times an activity (i.e. completing or cleaning out a well) takes place. These "activity factors" are often the most overlooked source of data. Activity factors help you estimate the magnitude of your emissions. They also suggest the policies that might be most successful to address your particular sources of methane by cataloguing the most prevalent activities and types of equipment represented in your industry.

How can you gather information about equipment and components used at a typical site?

If methane pollution is emitted by a relatively small number of somewhat homogenous large sources, run by large companies with adequate technical expertise and resources, you may be able to require more robust remote sensing and emissions tracking. Norway's offshore oil and natural gas industry fits this model and indeed, that country has worked closely with the industry to craft highly granular emissions factors based on emissions monitoring and testing protocols on its offshore platforms. As a result, Norwegian industry has published a number of highly useful emissions guidelines and handbooks.

Short of this, there are other ways to estimate activity information. You can collect initial numbers from companies operating in your jurisdiction as part of your national emissions inventory or through a data collection exercise. You might also refer to inventories done by countries with similar industry vintage and structure.

Sometimes, these data will have been collected by another agency. For instance, a government worker safety programme might track miles of pipeline and number of accidents along those pipelines. While the information was not collected with methane in mind, the miles of pipelines figure could be used to generate emissions estimates for pipelines, while accident data could point to large emissions events and inform root cause analyses to prevent future accidents.

If your country has a long history of energy development, you may want to embark on a survey to estimate the number and location of abandoned facilities that are emitting methane. Your jurisdiction may also have to think of creative ways to finance dismantling or shutting in these facilities, either because the industry is dominated by state-owned enterprises, or because, as in the United States, many of the private entities that operated these abandoned facilities no longer exist.

At this stage, your emissions profile will be incomplete and based on unconfirmed numbers. Over time, it will be important to build better data collection and reporting into your methane abatement regulatory regime. "Bottom up" emissions estimates

that are based on generic emissions factors are useful as a starting point, but better data based on robust measurement – and over time, "top down" aerial surveys and satellites – can lead to more effective regulatory actions and better confidence in the outcome of specific emissions reduction efforts.

As regulators and companies alike become more adept at emissions estimations (and measurement technologies improve), you may find that your initial baseline overestimated some emissions and underestimated others. That is to be expected. You can maintain that initial baseline year but adjust total emissions from that year retroactively, to reflect the latest and best understanding of your emissions profile. You might also consider using error bands and discount factors to account for the uncertainty in the estimates.

In any case, having a sense of the scope and nature of the problem at the outset will help you build the case for action, show progress once your policy is implemented and suggest future adjustments of your policy to improve emissions outcomes. You need not and should not wait for a perfect dataset to act to abate methane.

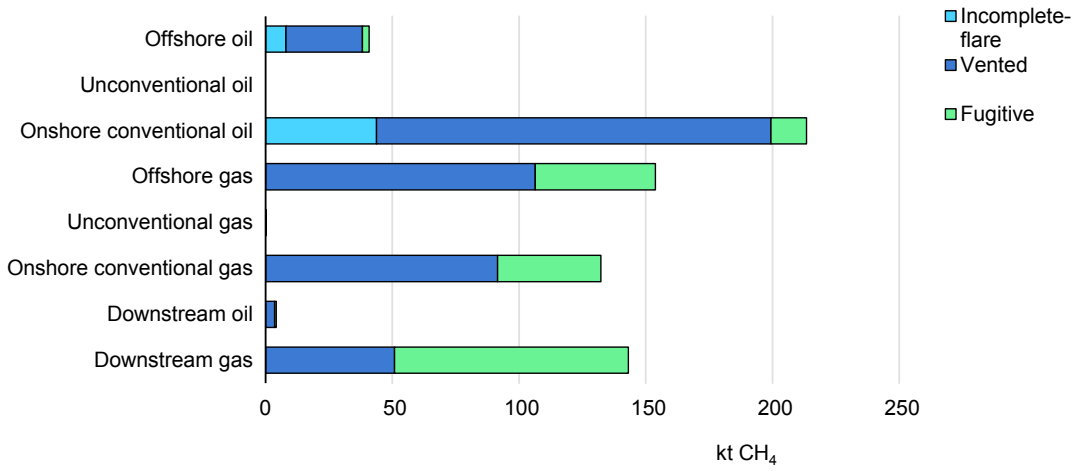
Problem sources and abatement solutions

With the emissions information you now have, and by communicating with companies and regulators in other jurisdictions, you can begin to identify your problem sources.

Do you have a plan for identifying your biggest emission sources, over time?

Once again, the IEA Methane Tracker can be a good starting point for identifying large sources. The country-by-country emissions estimates are broken down by industry segment, component and activity. For instance, in Indonesia, the IEA estimates that most methane emissions come from onshore oil and natural gas facilities. Most methane emissions from onshore oil wells are from venting or incomplete flaring, while fugitives play a larger role in the emissions profile of onshore natural gas wells. Within those facilities, the IEA identifies vapour recovery units on tanks, leak detection regimes and replacement of emitting instruments as big potentially mitigating technologies.

Figure 4 Sources of methane emissions, Indonesia



How will you locate intermittent "super-emitters"?

Knowing the industry segments and type of equipment that dominate your emissions picture is useful, but not the end of the story. A major technical challenge for addressing methane from the oil and gas is the intermittent and variable nature of the emissions. Valves do not fail on a schedule, and when they do, they may deviate widely from an expected emissions rate based on system pressure, climatic variables, contemporaneous failures and other factors. Depending on company work practices, some crews may not complete a well blowdown in one session and instead may leave the well open overnight or until the next shift, producing many times the emissions for the same activity. Different geological formations and even the time of day affects emissions being released from equipment.

As a result, studies have suggested that at any given facility, or across a producing field or region, a small number of sources drive most of the emissions.[12] Much of this research has been done in North America, though early findings in other regions suggest similar patterns. In 2006, the US National Gas Machinery Laboratory found that the top ten leaking components in a facility containing thousands of potentially leaking components contributed 29-87% of overall emissions over time. A 2015 paper reported that in the Barnett shale gas-producing region of Texas, 10% of measured facilities drove 90% of emissions. These data also suggest that across-the-board

[12] Brandt, A.R. et al. (2014), "Methane leaks from North American natural gas systems", Science, Vol. 343, pp. 733-735, https://doi.org/10.1126/science.1247045; US EPA (2014), "Oil and natural gas sector leaks", report for the Oil and Natural Gas Sector Leaks Review Panel, EPA Office of Air Quality Planning and Standards, Research Triangle Park, NC, https://beta.regulations.gov/document/EPA-HQ-OAR-2010-0505-5110; Zimmerle, D.J. et al. (2015), "Methane emissions from the natural gas transmission and storage system in the United States", Environmental Science & Technology, Vol. 49/15, https://doi.org/10.1021/acs.est.5b01669.

command-and-control regulatory requirements may not be the most cost-effective way to address the largest sources.

In addition, "super-emitters" sometimes are the result of highly unpredictable process failures and accidents, from a heavily leaking compressor station in Turkmenistan to a failed natural gas storage well near Los Angeles, California. These events create a great amount of uncertainty in emissions estimates. Fortunately, new developments in satellite data acquisition and processing are increasingly providing ways to identify these type of sources. Companies such as Kayrros and GHGSat offer surveillance services that detect, quantify and can attribute emissions to oil and gas assets based on local information and satellite imagery resolution. Recently the IEA *World Energy Outlook* included global maps of methane hotspots associated with the energy sector, and GHGSat published an interactive global map of methane emissions showing areas with high concentrations of methane in the atmosphere that might be linked to super-emitting sources.

The goal should not be to try to have a perfect emissions set, but to collect enough initial data and then monitor over time sufficiently to characterise and anticipate your problem sources. Sometimes, by reviewing data, you might find surprisingly large sources of emissions – venting a pipeline before making repairs, perhaps, or forgetting to close a hatch on a collection tank – that require a tailored policy. Similarly, if other jurisdictions have reported that a particular activity generates a lot of emissions, but you do not yet have that data, you could design a policy that gives companies an option to measure emissions or control the source. That will give you a better idea of the magnitude of emissions from those sources, while beginning to clean some of them up. California took precisely this approach with liquids unloading. For sources that may become super-emitters based on data patterns, installation of remote sensors may be a good way to locate big emissions as they occur – setting up the ability to address them quickly.

Technological solutions

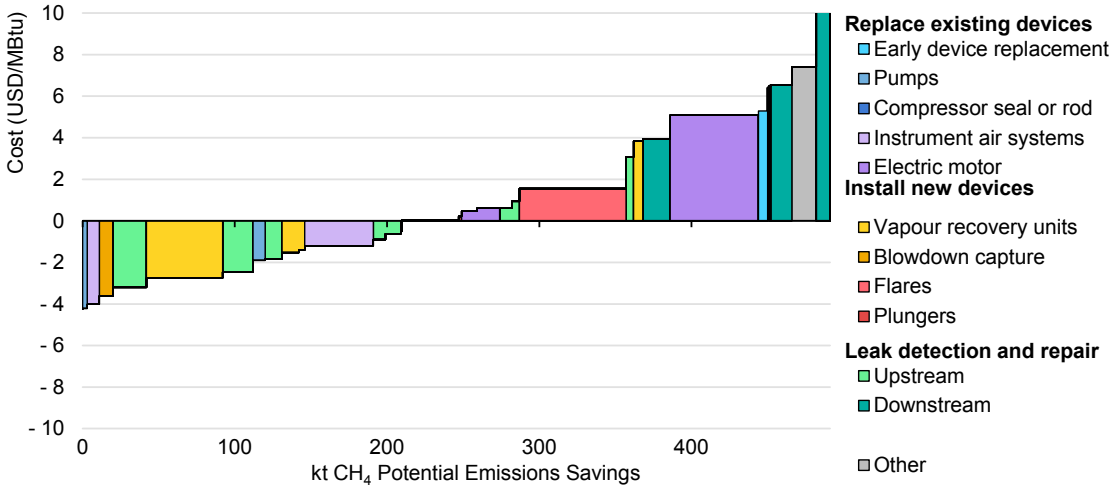
The final set of considerations that provide the basis for policy development relate to the available technologies and abatement strategies that match your regulatory, industry and emissions context. Where successful technologies and strategies have been identified, your policy could require their use or set performance standards that can be met through their adoption. For instance, once companies began implementing "reduced emissions completion" techniques at oil and gas wells in the United States, and established their feasibility and cost-effectiveness, the US Environmental Protection Agency required their use at all new gas wells and new oil wells. Where a technology is not yet available, a government might invest in research and development efforts or lead voluntary abatement programmes with the industry

to find new mitigation strategies. Over time, regulators should monitor developments in abatement technologies to ensure that regulatory requirements do not inadvertently lock in old technologies and prevent uptake of new options.

The IEA Methane Tracker includes a list of existing abatement technologies. These are presented, on a global and country-by-country basis, along a continuum from least to most expensive per million British thermal units of methane avoidance. The chart also demonstrates at what point capturing and selling the natural gas, at current prices, pays for abatement. The Methane Guiding Principles initiative has published best practice guides that provide a summary of current known mitigation options, costs and available technologies covering leak detection, venting, pneumatic devices and other topics. These resources are a good starting point for identifying the most cost-effective interventions that policy might promote.

Some technologies relevant to methane abatement do not directly reduce emissions but help to find (and sometimes, measure) methane releases. Given the intermittent and stochastic nature of methane emissions, detection and measurement technologies are critical to tackling this pollution challenge. In fact, many existing methane abatement policies, including those in Mexico and Canada, include a leak detection and repair (LDAR) regime, directing companies to inspect and repair leaking equipment on regular intervals. In recent years, technological advances have enhanced detection and improved measurement precision and accuracy, while lowering costs. For more information, please refer to the improving methane data section of the IEA Methane Tracker.

Figure 5 Marginal abatement cost curve, Indonesia



Step 4: Build regulatory capacity

After working through Steps 1, 2 and 3, you should have a good understanding of different characteristics of your local context that may inform your regulatory decision-making, including your legal and regulatory context, the nature of your oil and gas industry, and your jurisdiction's emissions profile. With a firm grip on your jurisdiction's setting, you are ready to start the **regulatory development** phase. The steps in this phase—Steps 4 through 8—will walk you through actually **designing and drafting your regulatory proposal**, taking care to enhance your institutional capacity and engage with internal and external stakeholders.

Do you have the institutional resources and expertise you need to design and implement your proposed regulation?

A good way to start is by considering your agency's capacity, and how it might be most effectively deployed in the regulation of methane emissions from the energy sector. Then, depending on the results of your assessment, you will need to develop a plan to increase the institution's capacity. By capacity, we mean the ability of an agency to understand the methane emissions challenge, to write rules to address that challenge, and to implement and enforce those rules. Capacity, then, encompasses four concepts: political support, trust, expertise and resources.

To the extent you identify deficiencies or areas for improvement, this does not mean that you must wait until you obtain new capacity before developing new policy. No regulator has ever acted under optimal conditions. But by understanding your limitations, you can take targeted steps to reinforce and build capacity, while in the meantime designing regulations that take account of your current situation.

Does your agency have the political support to act?

The level of political support your agency possesses will determine the path and prognosis for action. Institutional power may be a result of the legal framework for your government and where your agency sits in the formal structure. Much of it may also be situational – a relatively obscure agency may grow in power if its leadership or priorities are close to those of the government as a whole, while an agency with a lot of legal authority may nonetheless waste time and resources battling with another agency that has overlapping jurisdiction. If you do not have obvious political independence or support, this doesn't mean you cannot act, but circumstances may counsel that you start small, perhaps launching pilot projects or co-operative ventures with energy producers to prove a concept and engender political support for a broader methane abatement programme.

Is your agency trusted by the public or civil society?

Some of your power to act may derive from civil society or the general public. You may also have to earn their trust and convey that you can fairly implement and enforce methane abatement policies. Key stakeholders beyond the regulated community may include members of your own country's civil society, international organisations working with your government, or oil and gas consumers in other corners of the world. You earn the trust and support of these stakeholders when they view your actions as promoting the public interest and achieving real emissions reductions. To build this trust, you may want to consider policies that feature transparency during rule development and throughout the regulatory process, third-party verification of company activities, and citizen suit or petition powers to encourage enforcement. Maryland addressed community concerns in its recent methane rule-making by requiring companies to publicly post the results of their LDAR inspections and notify the public before conducting blowdown events (controlled releases of methane to relieve system pressure or enable maintenance or repairs to take place without fear of explosion).

What relevant expertise resides in your agency?

It is important to inventory an agency's expertise as well. Rules written to play to institutional strengths will be more effective, because staff will be better able to monitor and enforce compliance. Of course, an agency or ministry can always develop a particular expertise if you know that's the regulatory direction you want to head, through targeted hiring, trainings and professional development. For instance, offering certifications in optical gas imaging and other leak detection methods could build confidence and competence on your enforcement or compliance assistance team. In addition, training may be available from professional societies, other companies or external sources. The Society of Petroleum Engineers offers technical workshops, and international organisations and energy companies have joined forces to offer courses as well.[13] An agency might also supplement its expertise by working with outside experts to understand emissions profiles, to write and implement methane abatement policies, forging partnerships with local universities and non-governmental organisations, working with international organisations and institutions, or co-ordinating with sister agencies with complementary skill sets.

[13] For example, under the Methane Guiding Principles Initiative, several oil and gas companies have partnered with civil society organisations to develop a series of Methane Masterclasses aimed at industry executives and mid-level managers that includes material on methane regulation. E.g. Training Session: Methane Emissions in the Gas Sector (26-27 November 2019, Vienna, Austria) (programme sponsored by GIE, Marcogaz, Energy Community, and Methane Guiding Principles).

Even if you may be able to supplement your expertise, your internal capacity and structure remain highly relevant; don't set rules that agency officials won't know how to implement or enforce.

Does your agency have sufficient resources to achieve the mission?

Resources will also have enormous impact on the type and complexity of your methane abatement rules. Resources may mean budget, number of enforcement personnel, access to sufficient basic information technology resources, or specialised methane detection technologies.

A lack of resources will not prevent you from acting, but it will suggest less resource-intensive approaches. An agency with tablets for each inspector may build a very different reporting regime than an agency without a modern computer system or consistent internet access. One regime is not necessarily better than another; problems arise from designing reporting or enforcement regimes without a realistic assessment of an agency's resources. For instance, a small agency with very few personnel may run an effective regime by choosing to rely on remote sensors, third-party testing companies, or self-audits with steep penalties for incomplete or erroneous reporting to enhance enforcement efforts. For example, some countries, including Argentina and Mexico, have built third-party verifiers into their oil and gas regulations, to build confidence in company data without having to rely on government inspectors.

Step 5: Engage stakeholders

Before you take any formal action to regulate methane emissions, you should conduct outreach to the companies that will be subject to the regulation, the communities affected by oil and gas development, other regulators within your government, and other segments of civil society. Outreach at this exploratory stage need not be comprehensive, but it should be strategic. Are there allies to shore up for the road ahead? Are there sceptics whose concerns can be mitigated by sharing data or promising an open process? Are there domestic and international partners whose expertise and information can help you set aggressive but achievable policy goals? Are there interest groups who deserve a heads-up on your plan to regulate? Can you avoid bureaucratic turf battles later by co-operating with other agencies today?

Engaging the firms active in your jurisdiction will be critical. You may be required or directed by political leadership to discuss your plans with a state-owned firm before proceeding. But as noted throughout this paper, some of the international companies

working in your jurisdiction may have made commitments to methane abatement, and can provide information about methane emissions and abatement approaches based on operations in other countries and participation in international methane abatement alliances. Speaking to them and soliciting this information before any policy announcement can help to make your initial pledges appear more feasible and informed. Moreover, by sharing your intention with them before going public, you create an opportunity for firms to ask questions, seek assurances and become more positive about the endeavour by the time you go to press. Providing information to the public about these outreach efforts and soliciting input from other stakeholders, meanwhile, will build trust in the outcome.

Other industry players may also be good targets for outreach. Contractors who conduct many of the activities relevant to methane abatement, technology providers, third-party auditors, insurance firms and financial backers may also have important insights that could help you design a more effective policy.

Some communities or members of civil society may have been pushing you to act; ensure that your process engages with them, acknowledges their leadership and solicits their ongoing support. Other stakeholders – often the regulated community and industrial consumers of oil and gas – will have questions about the impact of policies on the cost of energy; to the extent you are able, you should try to commit to an open process with a transparent assessment of the policy's costs and benefits.

In the early stages of your policy making, you are more likely to employ discreet methods of reaching out to stakeholders on an individual or small group basis. In some cases, you can pair these quiet meetings with a more public gathering. For instance, you might meet with leaders of a community to discuss your intention to act, and then agree to hold a town hall to listen to community concerns without publicly committing at that event to take action. For communities not well versed on the climate and safety risks posed by nearby methane releases or the steps you envision taking to mitigate those risks, an outreach strategy might include an educational component as well. In addition, you might seek out strategic opportunities for your agency or ministry staff to speak about methane abatement at conferences that key stakeholders might attend; even if staff do not formerly announce plans to regulate, their presence can signal that you find methane abatement an important issue.

You may also want to look further down the road, to predict and nurture the types of stakeholder engagement you will need for your policy-making process. In some jurisdictions, regulators may establish advisory boards that are consulted at particular points. In the United States, "negotiated rule-making" or "reg-neg" (for "regulatory negotiation") has emerged as an administrative law trend that might also

be applicable in the methane abatement context. Where a rule-making will affect only a few regulated entities, an agency may create a committee that fairly represents the different interests at stake and "negotiate" policy language with that committee through a collaborative process. In a less formal variation on the reg-neg approach, some regulators in the United States will conduct an informal information-gathering exercise or direct a diverse group of stakeholders to negotiate a policy solution before the regulators formally take up the issue. The regulators are not necessarily bound by that informal process, but they know the solution reflects consensus.

Stakeholder engagement will take valuable time and resources but these early interactions can help you anticipate opposition, tailor policies and save time later in the process.

Step 6: Define regulatory objectives

Now you can begin to design your regulation. Before you begin drafting, you will need to establish a set of regulatory objectives that you would like to achieve. In essence, this involves answering the question, "What problem are we trying to solve?" From this, you can map backwards to identify the preconditions that are necessary to solve this problem. As you do this, the information you have gathered in the previous steps will help you set objectives tailored to the specific source make-up and emissions of your industry.

There are many different forms a policy goal can take. Some methane abatement policies are based on an economy-wide methane reduction goal, as in California. Others include an industry-wide or sector-specific[14] goal. Mexico's regulation, meanwhile, requires the setting of facility-specific reduction goals.

Goals may be expressed in tonnes of methane reduced, a percentage reduction below historic emissions or a declining ratio of methane emissions over volume of production. The Global Methane Alliance (established by the UN Environment Programme and the Climate & Clean Air Coalition) has called on countries to set targets of at least 45% reduction from 2005 levels by 2025, and 60-75% by 2030. Targets may also be set in terms of the average "methane intensity" of natural gas, such as that announced by companies in the Oil and Gas Climate Initiative to reduce their methane intensity to "near zero" – defined as between 0.25% and 0.2% – by 2025.

[14] Colorado created a process for establishing a methane goal just for the transmission and storage segments of the oil and natural gas value chain.

Rather than setting a high-level goal for the whole industry, you may wish to set more granular goals (or sub-goals) for different segments of the industry – e.g. upstream versus downstream, onshore versus offshore, conventional versus non-conventional. You may also consider whether to establish separate objectives for emissions from new facilities than for emissions from existing facilities and whether to establish a plan for addressing abandoned wells in your jurisdiction.

Abatement regulations that do not set an explicit volume, percentage or intensity goal (for instance, a rule to replace leaking valves across a system) still implicitly have reduction as a goal even if it is not a specific quantity or rate of emissions. Prescriptive regulations in particular might reflect a bottom-up engineering goal; for instance, to eliminate all high-emitting pneumatic devices from existing oil and gas infrastructure by a date certain. LDAR requirements reflect a desire to identify and address new sources of emissions as they arise.

You might also have a few regulatory objectives that are not focused on emissions reductions. For instance, when designing a greenhouse gas inventory requirement, you might set a goal of having a certain percentage of companies complying with the law within one year. As another example, for a new environmental assessment requirement, you might set a goal of ensuring that all projects approved in the next six months include a specific estimate of the project's impact on methane emissions. Still another policy objective might be to stimulate the development of an auditing industry, or a midstream gas sector that can purchase associated gas. Some of these objectives might work in concert; for instance, following development of a midstream gas sector, you might set out to eliminate flaring and venting of associated gas.

As you think about your objectives, you may wish to refer back to some of the stakeholder conversations you had in the previous step. Communities, companies and civil society will ask why you are acting and what you want to accomplish. They will want to know if the objectives you are setting are achievable with current technology. And they will wonder what this means for them in terms of compliance costs, environmental and safety co-benefits, jobs, and the price of energy.

Step 7: Select the appropriate policy design

In this step, you will bring together the information you gathered in the early steps of this Roadmap and decide which regulatory approaches will be most appropriate to help you meet the regulatory objectives identified in Step 6. As you undertake this exercise, we suggest that you refer to the companion Regulatory Toolkit, which provides in-depth information about the regulatory approaches that have been used around the world. Through the Toolkit, we have sought to reference the most

common approaches; it is then up to you to select from among those options the ones that are most appropriate for your context. The Regulatory Toolkit also includes sections on essential elements that are common to most regulatory regimes, for instance reporting and information requirements, as well as monitoring and verification schemes.

There is no right answer to policy design. What is most important is that you select approaches that work with, not against, your policy context. The inquiry is not always straightforward and requires asking a series of questions. For instance, a carbon tax that addresses methane might seem to be the most efficient and flexible of approaches, but your agency may lack the authority to impose a tax over companies in your jurisdiction or the ability to track emissions to assure compliance.

In the remainder of this section, we offer a set of examples to illustrate policy design and how your system`s characteristics might influence methane regulations. Where pertinent we provide links to the relevant sections of the Regulatory Toolkit and examples from the IEA Policies Database.

Example A: Achieving methane intensity reduction alongside natural gas development

Suppose you are the national environmental regulator, with leadership backing your efforts to achieve Paris Agreement climate commitments. Your country has a mature natural gas industry but is about to embark on a rapid expansion of natural gas development. As a result, you have identified the policy goal of reducing the methane intensity of oil and natural gas produced in your jurisdiction; that is, you want your regulatory target to require companies to reduce the leaked or vented methane associated with each unit of production. This will allow you to set an ambitious target while enabling the development of new production capacity.

To achieve this goal, you will need a fairly rigorous understanding of your baseline "leak rate". Then you will need to set a feasible reduction target and determine how prescriptive or flexible your standard will be. For purposes of illustration, you have determined that your agency has:

- Authority to generally regulate methane (however, the energy agency or ministry regulates venting and flaring volumes through permits).
- Institutional strengths of regulation, enforcement and data collection.
- Limited methane expertise over oil and gas activities, and limited resources.
- Authority over air pollution related to the multinational oil and gas companies in your country, and more limited authority over the state-owned enterprise.

You have domestic demand for gas but you are also a large exporter; new development is intended to supply that export market. Despite ambitious methane pledges at the top levels of the multinational oil companies operating in your country, employees on the ground seem to have little understanding of the methane issue or what to do about it. Profit incentives are also misaligned with the goal of methane reduction.

Given this combination of factors, you might select certain design elements for your methane regulation. Writing an enforceable rule plays to your strengths of regulation and enforcement. However, co-operation with the energy ministry could enhance the effectiveness of your regulation. The ministry's venting and flaring permits will help you establish the industry's baseline leak rate and identify feasible intensity reduction targets. Their authority over the state-owned enterprise further requires their support of your rule. Their broader network with industry actors could facilitate training and other ways of improving company understanding of the methane issue. And their authority over oil and gas exploration means that they could offer deductions from rents or royalties owed for investments in methane abatement infrastructure, reinforcing your rule and aligning profit and abatement incentives. If you do not have a good working relationship with the energy agency or ministry, a head of state or government might consider launching an inter-agency working group or a monthly briefing by the heads of both ministries. You might also request energy ministry personnel to be seconded in your agency while you write your rule.

Meanwhile, if your country is about to embark on new natural gas development, your rule could partially achieve its methane intensity reduction goal by requiring low-emitting and non-emitting infrastructure to be installed at any new facility. It may be less expensive to install lower-emitting equipment in the first place. Even where it is not, a new facility can amortise the investment over more years, making it more cost-effective. Therefore, while your rule will also have to target existing infrastructure, it should not ignore future installations.

Given that you have domestic demand for gas, and have domestic and export infrastructure to move the product, your target may be more stringent because of the reasonable expectation that operators can sell all the recovered gas. Moreover, if your natural gas is being exported to serve markets that have set or are considering methane performance standards for imported gas, a tougher standard could advantage your producers for those markets. To build importer confidence in your reported reductions, a robust monitoring and verification programme will be critical.

As for the methane intensity standard itself, you could set prescriptive standards for each piece of equipment or activity, on the understanding that if an operator complies, in aggregate these actions will achieve the overall targeted reductions. In

this "command and control" approach, the operator will be responsible for installing this particular piece of equipment or conducting that maintenance activity in exactly the required way, but will not be held liable for meeting an overall reduction target. (Under the approach, the regulator has in essence assumed the burden of achieving the intensity target.) By contrast, you could set or – as in the case of Mexico – direct each company to set an overall intensity reduction target, and then allow them to take whatever steps are necessary to achieve that target.

A "command and control" approach makes sense if you understand the potential for reductions from particular interventions – the application of reduced emissions completions to complete a new well, or the installation of ambient air controllers and pumps instead of natural gas-driven components – because then you can be fairly confident that the required actions will collectively achieve the goal. There is ample literature establishing, for instance, expected reductions from the use of zero-bleed valves instead of high-bleed valves (including from EPA and Carbon Limits). It is often easier to enforce discrete actions than an emissions target, leading regulators, particularly when they are under-resourced, to lean more heavily on prescriptive standards. (You could also reframe your policy goals in terms of these prescriptive targets, for instance as a plan to phase out all high-bleed valves from your industry in five years.)

As your agency develops a better sense of the baseline leak rate and total emissions profile, it could supplement prescriptive requirements with facility- or industry-wide intensity standards that enable companies to decide what additional actions to take to meet the target. By writing information-based regulations requiring detailed reporting of company actions, you might identify discrete actions that should become required across all facilities. You could also learn from the emissions monitoring technologies and approaches that the companies use to confirm their reductions – this type of monitoring is what enabled Norway to develop country-specific emissions factors. That said, given the uncertainties of methane monitoring, additional safeguards might need to be employed to ensure compliance. Third-party auditors might be one approach; down the line, satellites may be able to confirm or question emissions reported by large facilities.

Example B: Achieving methane intensity reduction in existing facilities

Now suppose all of the above characteristics are present, except you do not have significant new development on the horizon. Here, your rule will focus more exclusively on existing production facilities. You might work with the energy agency or ministry to employ a more aggressive version of the incentive-based system mentioned in Example A, whereby investments in methane abatement strategies may

be deducted from rents or royalties. Alternatively, if the energy regulator is not co-operating, or if the country is too reliant on the royalties to offer large deductions, the environmental regulator might design an offsets strategy, requiring a company that builds new production capacity to "net out" the new emissions with reductions in emissions at existing facilities. Those approaches can work alongside a prescriptive regulation or a more flexible performance-based standard. All else being equal, a flexible standard may make more sense with existing infrastructure, to reduce cost and enable workarounds where retrofits are not feasible; however, the risk remains that without a robust understanding of baseline emissions, knowledge of actual reductions remains elusive.

Example C: Mobilising gas utilisation

Now suppose your jurisdiction has largely targeted oil production, producing only associated gas. Under this scenario, you may not have sufficient domestic natural gas demand to incentivise the capture of gas for resale. This issue may be more pronounced where there is no natural gas infrastructure to gather, process and transport the commodity to other markets. Here, your regulation might generate some onsite demand by requiring diesel power to be replaced by natural gas. You might then require reinjection of associated gas that cannot be used. However, for greater uptake of the associated gas, you may need to partner with your jurisdiction's energy and economic regulators to devise a strategy for creating a midstream market and downstream demand, so that associated gas becomes a marketable product and not just something to remove from the value stream. Nigeria and Brazil have worked to tackle these issues and have identified possible solutions.

Example D: Tackling methane emissions through information provision

Now suppose that in your development of a baseline leak rate, you realise you have extremely limited information about the emissions associated with wellhead maintenance activities. You might design information-based regulations that support your emissions abatement goals while also creating a record for improving your inventory. California has instituted this type of policy for liquids unloading. Companies in that jurisdiction have the option of capturing all gas that would be vented during unloading from the wellhead, or metering the gas as it escapes and reporting the magnitude of these emissions. Similarly, Canada's methane rules require certain emitting requirements to be phased out; in the meantime, operators must tag, measure and report emissions. This provides important emissions data to the regulators – and might induce early action by firms.

These examples are far from comprehensive, offering just a sample of ideas for the type of work you can do at this critical stage to design your abatement policies. If your agency is a subnational agency, you will need to understand your powers relative to the national government. If your oil and gas facilities are offshore, or in the Arctic, you may need to adjust your rule to account for these environments (for instance, Canada requires LDAR inspections only three times a year, because the winter is not conducive to personnel visits to many facilities). If your industry is segmented, different government bodies may have jurisdiction at different points of the value chain.

Step 8: Draft the policy

Whether you are drafting an amendment to an existing policy or an entirely new one, it is finally time to write a policy that will meet your context, achieve your objectives and fill in the details around the regulatory approaches that you've selected.

Once you've selected your policy approach, seek out examples that already exist of similar models – either from other jurisdictions or similar local laws applied to different contexts. As noted, the Toolkit includes references to examples for many of the different regulatory approaches, together with appropriate links to further information in the IEA Policies Database. You may also wish to work with officials from other jurisdictions or agencies to understand what has worked well for them and what can be improved. Although it will be a rare case that you can simply copy and paste the text from another context, this should help you ensure your policy covers the basics.

If you have relevant expertise within your agency, take advantage of that experience. If not, you may consider hiring consultants or requesting assistance from non-governmental or international organisations.

Your drafting may be guided by the legal procedures of your jurisdiction, if they establish a formal process and general timeline for proposing, vetting or negotiating, and finalising policies. If those procedures do not require feedback from companies and stakeholders, seek this out on an informal basis to the extent you are able, to improve your policies.

Step 9: Enable and enforce compliance

Having a clear picture of the regulatory objectives and how it will operate, it is time to enter the last phase of this Roadmap, how to address **implementation**. Although this and Step 10 are primarily focused on the measures needed after a policy is finalised, it is important to consider these questions while you are designing your

policy as some of your choices may impact your ability to ensure compliance. Further, you can do a lot before your regulation becomes effective to ensure that companies are prepared and ready to comply on time. For more information about the approaches described in this step, see the **essential elements** section of the Regulatory Toolkit.

Enable compliance

Alongside the rule-making process, begin compliance assistance outreach while finalising rule-setting. A policy that takes regulated entities by surprise is less likely to engender compliance. Help companies anticipate regulatory expectations, to help them succeed so that your policy goal might be achieved. Some of this work may also take place in Step 5, when you elicit feedback from companies – you might learn that a particular intervention is not possible for certain facilities, or that a better technology is now available.

Conduct training to generate expertise in the agency and in the industry. Consider early action credit so that firms don't hang back and wait to make effective investments for fear it won't count towards compliance. Identify compliance incentives, including government recognition of early compliance or even super-compliance (actions taken by a firm that exceed legal requirements).

Ensure monitoring, reporting and verification on a periodic basis

Your policy should include metrics that can be used to determine whether individual firms are in compliance, as well as track progress towards the big policy goal. This may include requirements for companies to monitor their own emissions, through a combination of direct measurement and estimates based on emissions factors. This may be supplemented by measurement carried out by third parties via drones, airplanes or satellites, and direct inspection by the regulatory agency.

Typically, methane regulations also include requirements for companies to maintain records and reports on their measurement campaigns and estimates. These schemes may already exist within your government as part of your jurisdiction's UNFCCC national inventory programme, but you may wish to revisit these requirements to ensure they will adequately support your methane regulations.

If you impose reporting requirements on firms, you will need to ensure that you have a system and process to handle and receive this information, particularly if you anticipate receiving a large volume of data. You should consider in advance if there are steps you can take to enhance the usability of this data. This may necessitate setting clear standards for the content and format of data that must be submitted.

You may also need to establish an electronic platform for companies to submit their data. An advantage of these systems is that they can be designed to automatically flag submitted information that signals a violation of regulatory standards, an error or a pattern of failures that could be used to prioritise equipment inspection and replacement.

Finally, once you have collected this information, you will need a mechanism to verify its accuracy. This may include direct verification through inspections or third-party measurement. Or you may ask companies to certify their compliance with regulations and submit independent audits of their submissions. More detail on how to implement effective monitoring, reporting and verification protocols are provided in Regulatory Toolkit.

Enforcement

Depending on your institution's legal authorities, you may have authority to investigate regulated entities and enforce compliance with your methane rules. Enforcement actions may be made on the basis of reported and submitted information, or through regulatory inspections or third-party complaints. It will be important to think through ahead of time what tools you will have to police and investigate potential cases of non-compliance as this may affect your regulatory design choices.

In some cases, agencies issuing regulations have limited direct authority to enforce their own regulations, particularly against state-owned firms. In this case, you may need to co-ordinate with partner agencies to ensure that they have the information they need to develop an effective enforcement regime or to otherwise induce compliance.

You may also be able to build in reliance on third parties to gather more accurate information or publicise non-compliance (which might in turn might make it easier to enforce). For instance, Argentina and Mexico require third-party auditors to inspect company reports and verify compliance. There can be challenges to this, including the potential need for a new market to develop for these services and the assurance that such auditors are truly independent of the companies, but done well, this approach can enhance the capacity of the regulator. Public reporting of information, including publication on a website, can inform investors, insurers and civil society and create new accountability structures for companies, furthering incentives to comply. Finally, employing aerial surveillance, including public satellite data as they become more available and more useful, partnerships with universities, other research institutes, and international organisations can enhance national inventories, detect non-compliance, and build enforcement capacity.

Step 10: Periodically review and refine your policy

Before finalising your regulation, you should also begin to think about what would be necessary to update and change it in the future. Changes may be necessary to refine your regulations to take account of lessons learned, to update requirements to stay abreast of technological developments or to increase the level of ambition of your objectives. Recognising that these changes may be unpredictable, there are measures you can take in advance to smooth this process in the future.

You may want to write into your policy an express plan for periodic review. Review may be tied to predefined timelines, be performed on an ongoing basis at administrative level or result from stakeholder request. However you organise it, including a clear process in your policy will signal to regulated entities that you intend to revisit and refine the policy, and help you justify agency resources down the line to meet this milestone.

Programme evaluation marks another good time to convene regulators, companies, researchers and international organisations. Outside experts and stakeholders might help you design an evaluation programme. Alternatively, representatives of these groups might serve on a regulatory review advisory board, reviewing records and interviewing key players in your policy world to provide you with a fresh take on how your programme is performing.

You may also want to enable the concept of "adaptive regulation" in your rule. For instance, the regulation could explain that regulators might make small changes in the future, perhaps within a predetermined range, without having to undergo a formal amendment process. A regulatory review might then focus, at least in part, on data that could justify a policy shift within those bounds identified at the outset.

You may also consider building flexibility mechanisms into your regulation in order to keep it up to date. The technology of methane abatement can move very quickly. In order to ensure that new developments can be utilised, you may consider including a flexibility mechanism that allows companies to apply to have new technologies recognised as accepted compliance methods. In adopting such a mechanism, you should take care to ensure that the process for availing it is not so onerous that no one will be willing to use it.

Regulatory Toolkit

By making your way through the Roadmap, you have conducted a landscape review of your regulatory setting and context (Steps 1-3). You have also assessed your regulatory capacity and stakeholder engagement and developed a plan for outreach (Steps 4-5). You should have also established a baseline and set appropriate goals and objective for your regulation (Step 6). In brief, you are ready to **set a strategy**, work on **policy design** and **implement** your regulation. Your outlined strategy will likely include a number of elements and include several governmental bodies. This Toolkit presents the different mechanisms that are already in use in various jurisdictions along with information about how you can use them.

Table 13 Outline of regulatory toolkit

Topic	Subtopic	Key questions
Regulatory structure	• Case-by-case • General application	What is the overarching structure of your regulatory regime?
Regulatory approach	• Prescriptive • Performance or outcome-based • Economic • Information-based	What types of tools are best suited for each strategy and setting?
Regulatory elements	• Monitoring • Recordkeeping and reporting • Verification and enforcement • Policy co-ordination • Adaptive regulation	What are the key aspects of successful regulatory regimes for methane?

We start by considering the different **regulatory structures** that will aid you in selecting an appropriate policy design (Step 7). We proceed to further explore the four main **approaches to methane regulation**, describing their typical requirements, benefits and drawbacks. For each approach, we present concrete examples from our **Policies Database** that will provide models for you as you draft your policy (Step 8). Finally, this Toolkit discusses **essential elements** of regulation. This includes mechanisms for enabling compliance and enforcement (Step 9) through the use of monitoring, reporting and verification provisions, approaches to co-ordinating

complementary policies, and strategies to ensure your policy can be adapted through periodic review and refinement (Step 10).

Regulatory structure

What is the overarching regulatory structure: a case-by-case approach or generally applicable requirements?

Governments usually either apply requirements on a case-by-case basis through individualised permits or contractual provisions, or establish broad, generally applicable standards. These two options can also be used in combination, providing different degrees of regulatory discretion and flexibility.

Case-by-case requirements, whether they are applied through permits, bidding rounds, contracting arrangements or a licensing scheme, typically provide more space for adaptation – but individually tailored provisions may require additional resources on the part of the regulator. On the other hand, generally applicable regulations – focused on addressing climate change, air pollution, worker safety or resource efficiency – may be more rigid in application but potentially demand less institutional commitment.

Depending on the regulatory structure of your jurisdiction, you may already have regulations of one or both types. Many countries use a licence or concession process to grant rights to exploit oil and natural gas but at the same time, impose generic regulations to control air pollution. A key starting point may be to determine whether enabling legislation already exists, and in what form. If so, you may be able to incorporate provisions on methane within an existing regime by updating applicable guidelines or norms that orient procedures already in place.

Case-by-case approach

Methane requirements can be introduced within **authorisation or contracting procedures**, from bidding of exploratory areas to service procurement, including project appraisal, direct development through NOCs or shared production agreements.

For example, auctions could include a criterion rewarding bidders that commit to low emission levels. Alternatively, contracts might specify what measures must be taken to avoid leaks or establish performance standards regarding emissions. Permits may limit flaring and venting or require periodic monitoring of abandoned wells to ensure no methane leaks are active.

Box 1 Permits

Permits are a means of granting authorisation for specific operations or procedures that would otherwise be legally prohibited (e.g. pollution permits, drilling permits, flaring permits). Permits also include conditions that limit their validity, which may be temporal, technological or spatial. Non-compliance with permit provisions may result in the suspension or withdrawal of the permit, interrupting or leading to the termination of related undertakings.

Oman requires projects with significant greenhouse gas emissions to apply for and obtain a climate affairs permit, which authorises the emission of greenhouse gases. A permit is required of oil and natural gas developments that emit 2 000 tonnes of CO_2 equivalent per year or more, or that product and consume 30 TJ or more of energy per year. The request for a licence requires an initial approval of the project by the competent authority and an initial report on the expected amount of greenhouse gas emissions. As part of the permitting process, projects are required to monitor and report their greenhouse gas emissions annually; use energy-efficient and low-emission technologies; submit a plan to increase green space; and undertake adaptation measures to protect their business from the impacts of climate change.

Permits can often enable methane reduction through targeted provisions. In Norway, operators must apply for production permits every year, presenting flaring/cold venting volumes among other matters for approval.

Requirements can be introduced in permits or licences that cover a range of ongoing activities. These requirements may be individually developed for each permit, or they may be based on provisions found in overarching codes, model clauses or guidelines, such as Northern Territory of Australia's code for onshore oil activities in its northern region. This regulation applies to all interest holders and requires baseline assessments, routine air monitoring, venting and flaring restrictions, and the need for businesses to present methane reduction plans before the start of production, with reduction targets set "as low as reasonably practicable". Thus, it sets minimum standards that will be assessed for each permit on a case-by-case process, without limiting the ability of the regulatory authority to adjust or tailor these requirements for a specific permit or to establish more stringent measures if deemed necessary.

Certain activities may also be subject to a specific authorisation or consent procedure. Nigeria's standards for the petroleum industry, for example, state that if flaring must occur, operators must secure a waiver and permit for each instance of flaring, and must pay the necessary fines for every standard cubic metre flared, ensure complete combustion and prevent venting.

One key **benefit** of these approaches is that they can be adapted based on the specific circumstances. Requirements are individualised depending on the characteristics of the particular project, and this can provide a more tailored approach that can ensure the most cost-effective measures are applied.

Case-by-case systems offer **multiple avenues** for regulators and companies to address methane emissions. Regulators can establish reduction requirements across the board or introduce them more gradually through pilot projects with interested operators. If an initiative is successful, it can be rolled out to the whole industry.

Box 2 Contracts

Petroleum contracts refers to systems where the government grants contractual licences to companies to exploit oil and gas, including through concessions, production sharing contracts, joint ventures, technical service contracts and unitisation agreements. These instruments typically grant the licensee a right to explore, develop and exploit public resources under certain conditions. These conditions may include restrictions related to methane emissions. Due to the contractual nature of these restrictions, it may be difficult to alter provisions in existing contracts without specific statutory authority to do so.

The United Kingdom has published model clauses that are included in petroleum licences for both onshore and offshore production. These clauses include a requirement that the licensee may not flare or vent gas without obtaining the prior consent of the Oil and Gas Authority. In addition, every petroleum licence includes a provision requiring the licensee to take all practicable steps to prevent the escape or waste of oil or gas from its operations. In previous updates to the United Kingdom's statutory petroleum authorities, the legislature has made changes to model clauses automatically applicable to all existing contracts.

The Oil and Gas Authority has recently published a report on venting and flaring from regulated activities, including a commitment to take a stronger stance on flaring and venting through its consents, field development process and project stewardship activities.

Generally applicable regulations

Methane requirements may also be addressed through generally applicable regulations. The key difference between this and the case-by-case approach is that these requirements apply to **all regulated activities** without individualised tailoring of requirements. However, standards may still differ based on predetermined categories, such as industry segment, age and type of facility, or kind of technology employed.

Some countries have developed regulations **narrowly targeted at reducing oil and gas methane**. Mexico, for example, has developed a regulation for the prevention and comprehensive control of methane emissions from the hydrocarbons sector. Under this regulation, facilities must develop and implement a Program for Prevention and Integrated Control of Methane Emissions. They must identify all sources of methane, calculate an emissions baseline, set an emissions reduction goal and establish an implementation schedule for mitigation measures, demonstrating annual progress towards their goal.

Box 3 Methane Strategy

Regional or national strategies provide roadmaps for curbing overall or sector-wide methane emissions. They are often non-binding and provide information about future regulatory actions to the public.

The EU Methane Strategy sets forth cross-sectoral measures for key emitting sectors (energy, agriculture and waste management). For the energy sector, it points to legislative proposals in 2021 on compulsory measurement, reporting and verification for all energy-related methane emissions, building on the Oil and Gas Methane Partnership methodology. It also cites requirements for LDAR programmes for both the upstream and downstream segments, as well as the goal to eliminate routine venting and flaring. Furthermore, the strategy puts forth international actions, including promoting global co-ordination on methane reduction efforts. Thus, it refers to a methane supply index to empower buyers to make informed choices when purchasing fuels as well as to the establishment of an independent international methane observatory tasked with the detection and monitoring of super-emitters through the use and integration of satellite imagery.

Other examples include Nigeria's National Action Plan to reduce short-lived climate pollutants and Saskatchewan's Methane Action Plan.

In other cases, policies may apply more broadly to other sectors and other pollutants besides methane. For example, methane provisions may be included in **instruments that set policy for the entire oil and gas sector**, either focusing on a specific segment, such as the upstream or downstream industry, or addressing the entire oil and gas value chain. Nigeria's national gas policy encourages the use of flare gas capture technologies, including those related to power generation, prohibiting flaring at greenfield projects and promoting gas utilisation initiatives.

Even broader still, methane may be covered by **broad environmental regulations that apply to many sectors and many air pollutants**. For example, methane may be covered by a directive setting overall greenhouse gas targets. This could include a

set of complementary requirements, such as greenhouse gas reporting, emissions intensity limits and a carbon market, including accredited voluntary methane reductions as a way of generating offsets.

Box 4 Methane regulation

Some jurisdictions have established regulations for methane pursuant to general legislation such as a petroleum law or an environmental code. These often direct the means and procedures required for emissions control.

British Columbia (Canada) has issued regulations for oil and gas methane in its Drilling and Production Regulation. This rule requires operators to check each well for surface casing vents, at key moments in well development and as part of routine maintenance. If vents are discovered, operators must notify the regulator and eliminate the hazard. If gas migration is discovered, the operator must notify the regulator and submit a risk assessment. The regulation also forbids venting unless the gas heating value, volume or flow rate is insufficient to support stable combustion and a series of conditions are met, including the minimisation of the volume vented. It has further restrictions on flaring and requires a fugitive emissions management programme. This, in turn, is the subject of the Fugitive Emissions Management Guideline.

Note that the federal government of Canada has also issued methane regulations. Pursuant to the 2020 equivalency agreement between British Columbia and the federal government, only the subnational regulations apply within the province, though federal requirements still apply to interprovincial pipelines and other federal works.

Notably, in some countries broad enabling legislation already exists that may authorise regulations on methane abatement at different scales. Often environmental laws or energy legislation have provisions on the need to develop economic activities in line with sustainable development, resource efficiency or industry best practice, and these provisions could be further developed through regulations.

Once you have settled on a **general strategy**, additional **tools and elements** can be incorporated to effectuate your regulation and achieve your policy goals. The following sections of this Toolkit describe key regulatory typologies and essential regulatory elements.

Approaches to regulation

What types of tools are best suited for your strategy and setting?

We have outlined four main regulatory approaches in our Typology of regulatory approaches. Here, we explore examples of these different approaches and consider some of the benefits and drawbacks of each approach, as summarised in Table 14.

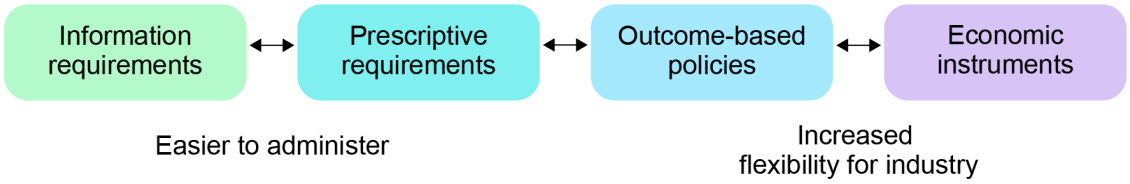
Table 14 Regulatory approaches drawbacks and benefits

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)
Performance- or outcome-based	Moderate Monitoring 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)
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 mobilise different solutions	Royalties (Brazil)
Information-based	High Demands collecting, analysing and transmitting information	Moderate Allows for different 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)
Often different approaches are combined, e.g. Viet Nam 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).					

It bears emphasis that the choice for regulators is to select the right approach for a given regulatory goal and institutional context. Often, a methane regulation is part of a broader effort with multiple policies co-ordinated towards reaching a larger goal. It can also be designed to align with efforts from other jurisdictions, allowing for fair competition among areas that share common markets. Ultimately, an effective policy effort will likely involve the co-operation of different stakeholders and a mix of different regulatory approaches and tools – all working together to tackle methane emissions in a complementary manner.

Thus, different regulatory approaches can build on and complement each other. An information regulation might help to identify key sources that are then tackled by prescriptive or performance-based instruments. Over time, as a regulator improves their understanding of the industry and abatement options, it may be possible to adopt market-based or other economic instruments to facilitate companies' complying and going above and beyond existing regulations. That said, lack of information or institutional resources need not delay methane regulation, but instead may suggest certain policy design options to compensate for – and perhaps overcome – those deficiencies.

Figure 6 Regulatory approaches continuum



This continuum reflects the different considerations at play in selecting regulatory approaches. At one end of the spectrum, your information is limited, so you might want to focus on building information to understand sources and abatement opportunities. Moving a step further, you have identified some clear and worthwhile abatement opportunities, which you can implement in a command-and-control fashion. Once you have established an institutional environment where you have reasonable estimates and are capable of monitoring emissions, you can use economic instruments or outcome-based standards to ensure greater flexibility and enable creative solutions.

Prescriptive approach

Prescriptive requirements (or **command-and-control** requirements) achieve emissions reductions by directing regulated entities to undertake or not to undertake specific actions or procedures. Prescriptive requirements may set procedural, equipment or technological requirements such as the installation or replacement of specific devices.

Box 5 Leak detection and repair

LDAR programmes are designed to locate and repair fugitive leaks. Policies may address the type of equipment used, frequency of inspection, the leak threshold that triggers repair requirements and the length of time allowed to conduct the repairs. The most typical requirement is for quarterly LDAR campaigns, although there are a number of exceptions. These campaigns may be carried out with drones, vehicles or properly equipped personnel.

Alberta (Canada) has different requirements for different types of facilities (e.g. gas plants and compressor stations should conduct surveys three times a year). The regulation defines accepted methods to conduct surveys (e.g. a gas-imaging camera that can detect a stream of pure methane gas emitted at a rate of 1.0 gramme per hour or less operated within 6 metres of the equipment being surveyed), yet also allows for the use of equally capable equipment (subject to demonstration requests). It further provides guidelines for the type of equipment that must be surveyed, personnel training requirements, and reporting and repair directives (e.g. must address detected sources of fugitive emissions within 24 hours of identification if fugitive emissions are the result of a failed pilot or ignitor on a flare stack).

LDAR protocols may be a part of a fugitive emissions management plan. Alberta's manual on How to Develop a Fugitive Emissions Management Program and Queensland's (Australia) code of practice for leak management, detection and reporting for petroleum operating plants provide further detail.

Some regulations direct companies to follow specific procedures or processes with respect to their operations. For example, many jurisdictions have required companies to establish leak detection and repair programmes. As another example, the US EPA's 2012 standards for volatile organic compounds (as amended to September 2020) set procedural requirements for well completions including requirements to route flowback into well completion or storage vessels.

Prescriptive regulations may also direct companies to adopt specific equipment practices or to replace certain high-emitting equipment or components. Maryland's

regulation requires operators to convert continuous-bleed natural gas-powered pneumatic devices to compressed air or electric systems or to install a vapour collection system.

Prescriptive regulation may also include an outright prohibition on certain activities. Many countries prohibit routine flaring and venting. Algeria's hydrocarbon law prohibits flaring and venting absent a compelling safety reason without express permission from the regulator.

Box 6 Best available technologies requirements

Best available technologies typically refers to a benchmark technology or procedure for reducing emissions that has been determined to be reasonably available. This is often linked to what is considered reasonably practicable and evolves according to technological development. Often regulations mention regular updates to reflect advancing standards and environmental concerns.

Colorado (United States) sets standards according to facility type. Thus, installations that store, process or handle oil or natural gas liquids must minimise the leakage of VOCs and hydrocarbons "to the extent reasonably practicable," through vapour recovery systems or flares. The regulation specifies that best available technologies are required at equipment level (e.g. flares must have auto-igniters, and open lines must have caps, plugs or valves that seal except when in use) and what types of devices must be replaced with better alternatives (e.g. operators must replace continuous-bleed pneumatic controllers at upstream sites with low-bleed controllers).

For another example, see California (United States), which requires the implementation of a best practices management plan to limit methane emissions.

A **key advantage** of prescriptive requirements is that they have the potential for a significant impact on overall emissions without the need for an emissions baseline or a continuous monitoring programme. Another advantage of prescriptive standards is that they are **relatively simple to administer** for both the regulator and the firms, as it is clear what must be done to comply and it is relatively easy for regulators to determine if the standard has been met.

However, there are drawbacks to this type of regulation. It **may not be the most cost-effective** approach to reducing emissions because companies may not have an incentive to seek out more efficient strategies that are allowed by the regulation. That said, it may be possible to incorporate mechanisms that provide flexibility for companies to select among several available options to reduce emissions.

In any case, for countries in the early stages of regulating methane, **prescriptive standards may be an important first step**, especially when clear abatement opportunities have been identified. Over time, it may be possible to incorporate performance standards or economic instruments to enable companies to seek cost-effective solutions.

Performance- or outcome-based approach

A **performance- or outcome-based requirement** establishes a mandatory performance standard for regulated entities, but does not dictate how the target must be achieved. Such regulations are most often applied at the level of a facility or individual piece of equipment, but they could be applied at wider scale as well.

Performance-based regulations often set a standard of performance for specific types of equipment. The Colorado (United States) regulation includes examples of equipment-level performance standards. For example, large storage tanks must meet a 95% VOC reduction target, and flares must be designed for 98% efficiency.

At a somewhat wider scale, a regulation could mandate that all firms achieve a specific methane reduction goal. This is the approach that Saskatchewan (Canada) has taken in setting requirements at company level for yearly methane reductions. The regulator sets a methane limit each year for all upstream companies that emit at least 50 000 tonnes of CO_2 equivalent per year. At the same time, businesses must submit and develop a related methane emissions reduction plan.

Although not mandatory, some jurisdictions have also adopted sector-wide or national-level strategic performance targets for methane emissions (or methane intensity). For example, Nigeria has set targets of achieving a 50% reduction in fugitive emissions from production and processing and from transmission and distribution by 2030.

Box 7 Emissions standards

Emissions standards set limits on pollutant emissions from specific sources. They are set in terms of a specific metric related to atmospheric emissions, such as quantity (e.g. volume), characteristics (e.g. temperature) or means (e.g. height of discharge). Although they are set in terms of performance, they can be incorporated within regulatory regimes that are primarily prescriptive in nature.

Canada's federal regulation on the release of methane and certain VOCs places performance standards at facility and equipment level. Conditional requirements apply to covered upstream oil and gas facilities handling significant volumes (at least 60 000 m^3/year of gas). For example, as of 1 January 2023, production facilities must limit annual vented volumes of methane to 15 000 m^3. This requirement does not apply to vented gas from temporary activities, such as emergencies or equipment start-ups, nor to certain processing equipment. Pneumatic devices are also regulated: operators of natural gas-powered pneumatic controllers must ensure that ongoing emissions remain below 0.17 m^3 per hour, and pneumatic pumps are prohibited from emitting methane where the volume of liquid being pumped exceeds 20 litres per day.

These examples illustrate the main **advantage** of performance standards compared with prescriptive standards. Namely, the regulated entity has more leeway to decide on how it will comply with the regulation, which frees the company to seek the most cost-effective solution. Furthermore, because companies that develop cheaper technologies are able to reduce their compliance cost, this kind of policy design can encourage technological development while also encouraging cost-effective improvements in emissions.

On the other hand, these examples also illustrate the key drawbacks of performance standards. In order for this type of regulation to be effective, both the company and regulator must have accurate baseline data and reliable mechanisms to track progress, which may require significant monitoring efforts and/or sophisticated methods for estimating emissions. Considering these requirements, performance standards are an especially useful tool if you already have **thorough methane estimates** or measurement requirements and a developed **reporting scheme**.

Box 8 Methane intensity

The methane intensity concept represents the total methane emissions from oil and gas production as a percentage of the associated volume of gas marketed. It is intended to serve as a performance standard and to allow the comparison of methane emission levels from different actors and segments of the petroleum industry.

Although not a regulatory action, the Oil and Gas Climate Initiative 2025 methane intensity target is an example of how an intensity target functions. The target covers all sources from operated assets within the upstream sector, including fugitives, venting and incomplete combustion. The overall objective is to be consistent with the Paris goals and approach near-zero methane emissions (0.25-0.2%) by 2025. It applies to initiative member companies (BP, Chevron, CNPC, Eni, Equinor, ExxonMobil, Occidental, Petrobras, Repsol, Saudi Aramco, Shell and Total). The initiative outlines a series of methane reduction measures, including a commitment to zero routine flaring by 2030.

Targets such as these could theoretically be incorporated into regulatory or policy requirements. Ten companies suggested as much in their policy recommendations for Europe's Green Deal, proposing a methane intensity-based performance standard to be applied to the upstream segment of the supply chains. The Global Methane Alliance also advocates for methane intensity targets, recommending that countries pursue a 0.2% intensity goal.

Economic approach

Economic provisions induce action by applying financial penalties or incentives. This may include taxes, subsidies or **market-based instruments** such as tradeable emissions permits or credits that allow firms to choose between different strategies to address emissions. In this context, regulations would provide the industry with a choice between reducing emissions and paying for the methane released, effectively changing the cost curve of abatement. In response, an operator might prefer to reduce venting rather than pay a methane tax.

Economic instruments often influence behaviour by making undesirable behaviour more expensive. An emissions tax, such as Norway's carbon tax, described in Box 9, is perhaps the simplest example of such an instrument. Other versions may provide different compliance options, such as Alberta's (Canada) Technology Innovation and Emissions Reduction system, where regulated facilities must undertake one of several options: reduce their emissions, redeem credits from facilities that have exceeded their reduction targets, purchase offsets from non-regulated entities, or pay into a compliance fund.

Box 9 Emissions taxes

In the context of methane, the term carbon tax is generally used to refer to a carbon dioxide equivalent tax. It corresponds to a fee on greenhouse gas emissions coming from an economic sector or entity. It follows the "polluter pays" principle and aims to reduce emissions by making companies and consumers internalise pollution costs. A challenge of this approach is setting an appropriate cost for externalities associated with greenhouse gas emissions.

Norway imposes an emissions tax that is due for the burning of petroleum and the discharge of natural gas from offshore oil production (the tax includes methane and CO_2 emissions resulting from the production or transportation of petroleum). It also sets up systems for the calculation and payment of the tax, including metering and reporting requirements to determine the volume of emissions. The offshore industry is subject to a rate of 500 kroner per tonne (about USD 58).

Some countries already have some form of a carbon tax in place for some sectors, although it may not apply to methane emissions, e.g. Canada for fuel consumption and industrial emissions and South Africa for large emitters.

Economic instruments can also operate by promoting desirable behaviour. Governments may offer economic incentives to nudge a firm to take action. Russia enables offsets of its pollution impact fee when an operator can document that the money was used to invest in the capture and use of associated gas. Similarly, Nigeria allows companies to deduct capital expenditures on gas equipment from profits for taxation means, as well as royalties assessed on gas that is sold and delivered downstream. Canada and the province of Alberta are providing more direct economic incentives through loans and grants to companies for methane abatement projects at existing and orphaned wells.

Economic instruments share some of the benefits and drawbacks of outcome- and performance-based instruments. The primary benefit is that companies are free to seek out the most **cost-effective** method of reducing their emissions, which can encourage innovation. This may further mobilise other stakeholders, including service providers and different segments of the value chain, in the search for all solutions that are cost-effective taking into account the economic incentives.

At the same time, economic instruments generally require a **structured information** base and a robust **monitoring, reporting and verification system**. Robust data are necessary in order to allow regulators and markets to get prices right and follow through with necessary measurements and reporting.

Box 10 Venting and flaring tax

Levying a tax on vented and flared gas is a way to discourage this practice by making companies pay a fee for the amount of gas lost. Flares and vents are used to dispose of unwanted gases during upstream operations, be it for safety or economic reasons. Venting entails intentional release of gases into the atmosphere, while flaring involves burning of natural gas, which normally occurs at incomplete combustion rates, leading to residual methane emissions.

Nigeria has imposed flaring taxes that are differentiated according to the size of facilities (e.g. an operator that produces more than 10 000 barrels of oil per day must pay USD 2 for each 28.317 m^3 of gas flared, while small facilities pay USD 0.50 per 28.317 m^3 of gas flared). Greenfield projects cannot engage in routine flaring or venting at all. Nigeria has also set related recordkeeping and reporting requirements.

Brazil also maintains a fee for flaring by charging royalty payments on methane that is unnecessarily flared or vented. The regulatory agency outlines annual and monthly limits for flaring and losses, linking these to royalty fees. If limits are exceeded due to operational restrictions, operators must reduce the production of oil and natural gas.

Information-based approach

Information-based regulations are designed to improve the state of information about emissions. They aim to bridge information gaps and equip regulators and members of the industry and the public with better information about key problem sources and opportunities. Information provisions may also address other aspects of data compilation and organisation, including public disclosure, and the process for collecting and handling data.

The simplest version of this regulation is a simple reporting requirement whereby regulated entities must quantify, either by measuring or estimating, and report their emissions to the regulator. The US EPA's Greenhouse Gas Reporting Program requires all facilities that emit at least 25 000 tonnes CO_2 equivalent per year to report their emissions. For methane, emissions may be estimated using facility inventories, EPA emissions factors and process information relevant to emissions estimates.

Box 11 Environmental impact assessment

Many jurisdictions require developers to undertake an environmental impact assessment (EIA) linked to project appraisal. EIAs enable the identification of consequences of a proposed action, support decision-making (e.g. granting or refusing a permit) and aid development of environmental management plans.

In Brazil, EIA practice is embedded in the environmental licensing process for oil and gas installations. EIAs also serve as a basis for requirements included in environmental management plans. An informative note summarises common practice, including timetables for the operationalisation of gas treatment and destination systems (e.g. export pipelines); authorisations to start production of wells, often linked to a platform´s efficiency regarding utilisation of produced gas; offsets required from extraordinary volumes of gas flared or vented; and flaring limits. Compensation measures are defined before operation and can take the form of reforestation projects, contributions to climate funds or acquisition and liquidation of carbon credits.

EIAs can be an opportunity to identify significant methane sources and enable the introduction of effective reduction measures. This guide aims to assist practitioners in this process.

In other cases, information provisions may be presented as a compliance means or to facilitate enforcement of other provisions such as taxes and royalties. For example, the United Kingdom requires operators to obtain consent before flaring or venting. Consent is not required for unforeseen events related to worker safety, but the operator must promptly inform the regulator of any such events.

Information provisions may also contribute more directly to emissions reduction. In some cases, companies may not be acting to reduce their methane releases because they are unaware of how much they are emitting. Requiring them to quantify their emissions equips them with better information and may encourage them to take action. Also, regulators can opt to publish information on emissions to inform interested stakeholders, such as investors, of the performance of industry actors. Alberta, for example, publishes an annual statistical report that includes a list of operators ranked by their flaring and venting emissions. Companies that are ranked near the top of this list may receive increased pressure from investors and other stakeholders to reduce their emissions.

One benefit of information-based regulations is that they generally have **low implementation costs**. Thus, they are usually useful throughout regulatory development, providing necessary figures early on, and often constitute a condition

for the implementation of other institutional approaches. On the other hand, such regulations might **have a low impact on emissions** since they don't require direct action in this direction, especially in settings where it might be unfeasible to market captured methane.

Ultimately, making information more accessible is a worthwhile undertaking. This may be particularly useful when you need additional information about your industry in order to develop regulations or as a way to **raise awareness of methane emissions** and linked environmental, safety, energy and economic benefits. Such policies can also play a key supporting role for other regulatory strategies.

Box 12 Information provision

Information disclosure is a form of promoting the management and sharing of data. It may allow individuals to have access to evidence produced in monitoring programmes or require public authorities to disclose environmental data.

Nigeria's regulation on flaring, for example, requires operators to keep a daily log of methane flaring and venting, based on metering, and to submit them monthly. The competent administrative body then compiles an annual report, which includes a ranking of producers by associated gas utilisation. Alberta (Canada), does a similar procedure, publishing a report with a summary of flared and vented volumes for the various oil and gas industry sectors, including a ranking of operators based on gas flared, gas vented, and total oil and gas production.

The United Kingdom's Environmental Information Regulations requires public authorities to disseminate publicly held information and promote data accessibility. It further mandates authorities to make information available upon request wherever possible, citing pertaining exceptions (e.g. for matters of national security or when it would compromise personal data).

Essential elements

What are the key aspects of successful regulatory regimes for methane?

From the IEA's review of existing methane policies, as well as conversations with regulators, industry, advocates and researchers, we have identified a number of essential policy design elements that support methane regulations. These elements should be strongly considered for any methane abatement regime.

Monitoring, reporting and verification are key supporting elements of different regulations. These requirements ensure enforcement is viable by providing necessary information to regulators. They also enable regulators to track progress towards regulatory objectives. Further, all regulatory regimes require some mechanism for enforcement in order to be successful.

Finally, with the speed that technology is moving, your policy may be out of date before it's even published. Therefore, it is important to develop a plan up front for how you will ensure it can be adapted to technological advances, incorporate learning and manage changing objectives.

Monitoring

Monitoring encompasses **systematic observation and review** of selected parameters. The identification and assessment of methane sources, including purposeful venting, unlit flares, releases due to emergency situations, and fugitive emissions all depend on recurrent surveillance efforts.

Monitoring can be deployed to detect or quantify methane releases. Detection is sufficient to verify the need for action (repairs, the closing of a hatch), but quantification is needed for a better understanding of emissions and to establish baselines and related goals (Step 6). Quantification through a bottom-up approach is the more common way to estimate general emissions. It relies on activity data (e.g. the number of facilities, the number of operations, oil and gas production volumes) and either general or specific emission factors (e.g. default values or leak rates for particular equipment types) to calculate overall emission rates. Top-down quantification features direct measurement, normally by airborne or satellite sensors, of atmospheric methane concentrations to infer emission releases. Top-down measurements often do not require support from operators and can be used on a larger scale.

Box 13 Measurement campaigns

Measurement campaigns usually entail mandatory data collection and reporting elements, requiring operators to record, process and submit requested information. They may constitute a necessary step for the elaboration of inventories of potential methane sources or emissions estimates for operating facilities. They often support the definition of specific emission factors linked to other regulatory instruments, such as emission taxes.

The Norwegian industry, for instance, developed a handbook for quantifying direct methane and non-methane VOC emissions, following studies showing inadequacies in its previous system. The document outlines measurement techniques for different types of devices. For example, where facilities have flow meters on vent headers, these measurements can be used as the basis instead of quantifying the individual contributory sources, and provided this yields equally accurate or more accurate data (documentable). If the gas emitted through the vent header contains large volumes of inert gases, their proportion should be measured and deducted.

The industry in Norway also set guidelines for quantifying and reporting of emissions that impose measurement obligations. This article offers a review of methane measuring and screening technologies for the upstream sector.

Thus, regulators should consider outlining minimum monitoring requirements in a manner that is co-ordinated with the overall policy. Periodic monitoring focused on detection, such as LDAR campaigns, may help identify unknown or intermittent fugitive emissions. Measurement campaigns, on the other hand, can support better emission factors and methane inventories. Continuous monitoring may be warranted in particular cases to both ensure better quantification and provide ongoing detection capability for quick action on high-emission events.

At the most basic level, monitoring policies can require assessments by personnel who walk around a facility and look, listen and smell for malfunctions. In a more instrumented approach, personnel may use handheld VOC detectors or infrared sensors (also known as optical gas imaging). Other options include the use of acoustic leak detectors, soap bubble screening, spectrometer sensors, laser leak detectors and quantification equipment such as flow meters or volume samplers. Chapter 2 of this guide gives more information on quantification methodologies and its Annex 2 presents a summary of related mature detection and quantification technologies.

Larger installations and industrial areas can be monitored periodically by devices set up on vehicles or aerial surveillance, through laser radars, optical imaging or other techniques. This can also be done continuously at facility level using monitoring towers and cameras.

Box 14 Satellite detection

Satellite measurements are progressively enabling the identification of large methane sources remotely. In the coming years, satellite systems are expected to provide regular global coverage of methane emissions from oil and gas operations. Orbital data can help locate super-emitters and improve our understanding of methane emission sources.

The satellite Sentinel-5P, part of the European Space Agency Copernicus programme, carries the Tropospheric Monitoring Instrument (TROPOMI), providing readings of methane concentration across areas of 5 km by 7.5 km, covering the entire world on average every four days. These data have been used by Kayrros to monitor methane emissions in the energy sector. GHGSat also used Sentinel-5P data, alongside its own observations, to develop an interactive world map of methane emissions. The list of satellite sensors is expanding, with a new satellite supported by Germany, Environmental Mapping and Analysis Program (EnMAP), due for launch by the end of 2020. Separately, the Environmental Defense Fund is planning to launch MethaneSat in 2022, targeting key regions that account for more than 80% of global oil and gas production, with enough detail to identify the location to within 400 meters of the source and detect differences in concentrations of methane as low as 2 parts per billion. Nonetheless, satellites still have some shortfalls, including coverage issues (e.g. it is difficult to detect emissions in offshore areas) and accuracy limitations.

Technology is moving rapidly in this area, enabling the use of more remote detection technologies, with ever-lower sensitivity thresholds and cost. Thus, fixed-winged aircrafts, drones and satellites might constitute useful tools depending on the extent of area covered and the leak rates targeted. In general, broader coverage also means less sensitivity, so these technologies might be used in conjunction with others for optimal results. For instance, a promising approach to cost-effective LDAR is to integrate high-level screening and close-range detection technologies. In this context, orbital images may help identify accidents and super-emitters, while aerial detection pinpoints facilities that have significant methane contributions and onsite monitoring efforts assist in managing smaller leaks.

Using public **satellite data** may require partnering with specialised companies with processing and decoding capabilities. Monitoring solutions currently available, including TROPOMI, Sentinel-2 and Landsat 8, can provide global coverage and daily measurements. Furthermore, while technological developments are enabling the launch of satellites with increasing resolution (e.g. EnMAP, GHGSat), satellite images need to be supplemented by other detection means because they are impaired by several factors besides high detection thresholds, including cloud coverage, offshore environments and forested areas. The optimal system will combine satellite measurements with bottom-up sources, including ground sensors and activity data. Therefore, adequate means of data structuring and analysis are critical to monitoring methane emissions in a comprehensive manner.

Recordkeeping and reporting

Recordkeeping and reporting requirements go hand in hand with monitoring requirements and ensure that regulators have **access to the information** they need from the industry, both to verify compliance and to support emissions inventories. Typically, regulations specify the definitions and methodology that should be used for submitted information, ensuring comparability among different company reports and data. This may include guidance on how to carry out measurements or specifications regarding the methodology for calculating estimates. In this sense, they can describe what type of emission factors should be used and how these can be established.

The Oil and Gas Methane Partnership is working on a new reporting framework, scheduled to be published by the end of 2020, aiming to provide a gold standard for companies reporting on methane emissions.

Recordkeeping requirements set technical standards for what companies must track and maintain in their own files. These regulations may specify how long records should be kept and under what conditions. They may also set training requirements for workers conducting calculations, and establish a right of inspection for the regulator.

Box 15 Greenhouse gas reporting

Greenhouse gas reporting is a common requirement related to greenhouse gas inventories and climate change provisions. It may be mandatory or voluntary. Regulations may define reporting conditions and scope, defining which sources must be covered, the time frame for data collection and related aspects.

The United States established a Greenhouse Gas Reporting Program, which includes methane and applies to facilities that emit at least 25 000 tonnes of CO_2 equivalent per year (e.g. underground coal mines; onshore and offshore oil and natural gas production facilities; natural gas processing, transmission, storage and distribution facilities). Furthermore, it states that records must be kept for three years, identifies sources of emissions in each industry segment and provides methodologies for calculating emissions. The rule also indicates how to report on activity levels, defines applicable subparts for each source category, and includes provisions to ensure the accuracy of emissions data.

British Columbia (Canada) also requires greenhouse gas reporting and stipulates the format of the reports (e.g. requires a process-flow diagram). For more on this topic, see the UNFCCC reporting guidelines on annual inventories for Annex I parties to the Convention.

Reporting provisions require companies to send information to the regulator and may include guidelines regarding the specific format, collection method and mechanism for submission. Reporting requirements support compliance follow-up and help understand whether progress is being made. They are particularly relevant for the establishment of emission baselines. Baselines elaborated by companies may be subject to administrative approval or peer review. They may be established with the support of direct measurements or entirely through emissions factors and estimates. Related recordkeeping and reporting requirements should consider addressing base years, activity levels and other pertinent settings.

Apart from compliance reporting and emissions estimates, it might be convenient to require reports on activity levels, inventories of relevant equipment (e.g. venting stacks) and state of facilities (e.g. pipeline conditions), as well as a summary of significant occurrences (e.g. major maintenance campaigns, accidents or venting events). This will enable a better understanding of emissions sources and underlying events and can support the identification of critical risks and opportunities to develop new practices or implement complementary safety procedures.

In this context, regulators should aim to strike a **balance** between prompting enough **information** to follow up on aspects linked to methane emissions, and not overwhelming the industry and administrative bodies with **processing and assembling** low-impact data.

Box 16 Reporting on flaring and venting

Reporting requirements can apply particularly to flaring and venting, covering factors such as the amount of gas released or flared, definition of what is considered a routine operation, emissions estimates or gas utilisation indexes (percentage of the gas produced that was used). They can also address the frequency and volume of emissions from operational activities such as facility ramp-up, shutdown or well testing. These reports may be used as a basis for enforcement or for tax/royalty levies.

Nigeria has Guidelines for Flare Gas Measurement, Data Management and Reporting Obligations. They require producers to submit a series of annual and monthly reports related to flaring. Thus, operators must report on the composition of different gas streams, calculate gas-to-oil ratio of associated gas, provide an associated gas utilisation factor (defined as the volume of gas that is not flared or vented), and provide routine and non-routine flaring quantities. The regulation also has provisions on unaccounted-for flared gas.

Algeria's law governing hydrocarbons activities includes a reporting system for greenhouse gas emissions. If flaring occurs without prior authorisation due to safety needs, a report must be sent to the competent agency to regularise the activity within ten days of the completion of the operation.

Verification and enforcement

Enforcement of a policy creates a culture of **compliance**, ensures **effectiveness** and builds **trust** in the methane abatement regime – the trust of the public, of importing countries, of the shareholders of multinational corporations operating in your country, and of climate-focused non-governmental organisations around the world. Enabling compliance starts with clear communication and engaging in outreach. It further builds onto prevention efforts, including inspections that may point key issues to address before sanctions are necessary.

In order to fairly and effectively enforce the policy, you will need the technical ability to detect non-compliance as well as the political will and power to apply penalties and remove privileges (in a number of jurisdictions, repeated non-compliance authorises the regulator to pull or deny future permits). The ability to detect

non-compliance will depend on the nature of the requirements. If they focus on discrete actions (e.g. eliminate routine flaring), it may be easier to determine compliance than if the requirements relate to overall emissions.

Box 17 Third-party verification

Third-party verification is a process where independent organisations or professionals observe and report on the validity of the information provided by oil and gas operators. It may entail examination of records and books, inspection of facilities, interviews, or other verification procedures to ensure that projects are in compliance with established criteria and requirements. The procedure allows the identification of improvement opportunities and the conformance to codes and standards. Related regulations may specify assessment contents, methods and frequency, or necessary qualifications.

Mexico requires companies to contract annually the services of an authorised third party to verify the fulfilment of the related programme. All compliance submissions must then be submitted to the regulator following review by an authorised third party. Ideally, these third-party verifiers will be a multidisciplinary group with experience on emissions reductions, including know-how on the management of such programmes, familiarity with oil and gas projects, and emissions quantification skills.

For another case, see Argentina's National Program for Control of Losses of Air Tanks for Storage of Hydrocarbons and their Derivatives, which requires independent audits of covered facilities.

One approach to verification is to rely on **third-party audits**. This has a main benefit of allowing the agency to rely on external verifiers rather than developing significant in-house audit resources. Third-party verifiers may carry out some of the same activities as government auditors, including external inspections, report reviews or new monitoring measurements. There may be potential challenges if no third-party verification business already exists in your jurisdiction, and it may take some time for these businesses to develop. Furthermore, auditing regimes may prove to be expensive for companies or require guidance from regulators as to what aspects should be covered and how to proceed with their assessments.

Many jurisdictions have imposed specific **notice requirements** directing operators to alert the regulator or nearby communities when high-risk activities will take place. In Maryland, for example, companies must provide public notice prior to blowdown events. Such activities might include completing a well or performing maintenance on a storage tank. The regulator then has the option to come to the site to supervise

the activity, perhaps taking methane measurements while the activity is under way. And in any event, with this information reported events might be correlated with spikes in methane emissions, provided this reporting requirement is coupled with surveillance.

Regulations may also empower the regulator to carry out **inspections** where regulators can enter a company's site and inspect activities or infrastructure. Argentina's regulations, for example, authorise regulators to visit without notice. This can be more difficult for offshore facilities where the regulator will likely have to arrange a flight to the facility from the operator. Instead of onsite inspections, regulators may conduct **fence-line surveys** from outside the facility, with either ground or aerial measurement instruments. Results might trigger a follow-up inspection or discussion with the company.

Finally, regulators need the ability to bring enforcement actions for non-compliance, including authority for **monetary penalties** or other sanctions. In addition to covering instances of failure to meet a standard, these should also be available for failure to accurately report or keep records.

Box 18 Sanctions

Sanctions are penalties or other means of enforcement that ensure conformity to the law. They are often progressive, with larger sanctions for repeated violations depending on the magnitude of the infringement. Sanctions include fees, suspension or revocation of permits or operations, as well as prohibition of entering into new contracts and other forms of punishment.

Gabon outlines different sets of penalties according to particular categories of violation in its sectorial regulations (e.g. for contractors who fail to submit required studies and reports; for non-compliance with requirements on safety, hygiene, health, security and the environment). Thus, any contractor that violates the ban on gas flaring is liable to a penalty of 50 million to 2 500 million Central African CFA francs (XAF) (about USD 90 000 to USD 4.6 million). Contractors who do not duly execute their flaring reduction plan or do not comply with the flaring thresholds are also subject to sanctions. Moreover, failure to follow measurement, recordkeeping and calibration provisions is subject to penalty of XAF 1 billion to XAF 2.5 billion (about USD 1.8 million to USD 4.6 million).

Colombia, in its resolution to maximise recovery and avoid waste of hydrocarbons, also lays out applicable sanctions. Drilling permits can be suspended or revoked for noncompliance and penalties for violations can reach up to USD 5 000.

Policy co-ordination

Oil and gas companies are typically subject to multiple regulations and must take into account different concerns, including environmental requirements, the safety of their operations, economic needs and social imperatives. **Policy alignment** is a key part of **regulatory effectiveness**. It avoids mixed incentives and allows the co-ordination of enforcement and compliance efforts. This can relate to other policy fronts, such as gas pricing, existing subsidies or the contract structure for distribution operations.

You may want to consider how to achieve the **right mix** of **incentives** and **sanctions** to fulfil your regulatory objectives. Policies can incorporate financial incentives, such as loans and grants, in order to offer benefits to companies that want to take action on methane. Meanwhile, regulations may also include charges and fees, such as when unaccounted-for gas is included in the calculation of royalties. Moreover, certification schemes can add to the picture, acting on the information axis and affecting companies' reputation. A mixture of instruments can provide different types of economic motivation to encourage the industry to take action.

Box 19 Loans and grants

Policy makers can use financial incentives, such as funds, loans, subsidies or grants, to support emissions reduction efforts. Loans and grants are a way of ensuring interested companies have capital to invest in methane abatement options.

Alberta (Canada) is working to address the issue of inactive and abandoned oil and gas sites by implementing a new upstream oil and gas liability management system, and by providing a loan for the Orphan Well Association to speed up work on legacy sites. Wells from oil and gas companies that no longer exist often have active methane leaks. This loan will ensure that approximately 1 000 more wells will be properly decommissioned and enable the creation of up to 500 direct and indirect jobs in the oil services sector. The loan will be repaid by the industry through an existing orphan fund levy. This regulator has also recently launched a Site Rehabilitation Program – mainly funded by the federal government's Covid-19 Economic Response Plan – that will provide grants to oilfield service contractors to perform well, pipeline, and oil and gas site reclamation work.

Canada's Federal Government also established a 750 million Canadian dollar (about USD 586 million) Emissions Reduction Fund to address emissions in the oil and gas sector, with a focus on methane reduction.

It is common for **multiple agencies** to have jurisdiction over methane. As noted in Step 2 of the Roadmap, all relevant agencies should co-ordinate to ensure that agencies avoid working at cross-purposes and reinforce each other's regulatory objectives.

Economic and market regulations can also take into account the need to create necessary infrastructure for gas utilisation, particularly where associated gas may not have a path to market. Moreover, planning within the **power sector** can consider future gas developments and how to incorporate gas surpluses. Otherwise, a possibility is to aim for the development of **exporting** facilities, working with other jurisdictions to secure demand from different sectors.

Often existing executive bodies can support enforcement. Your government might have specialists in **geospatial data processing** that could help define the appropriate requirements for satellite monitoring or **metrology** branches that can assist with measurement specifications. Worker **safety and health** inspectors may also be able to communicate to emissions regulators when methane leaks are encountered or when they become aware of critical equipment maintenance schedules.

Box 20 Research and development

Governments often play a large role in funding research and development efforts through the development of strategic plans and direct support for developing new technology and best practices that can support methane abatement.

In 2014, the US Department of Energy's (DOE) Advanced Research Projects Agency – Energy (ARPA-E) launched a round of funding designed to further develop innovative technologies to identify and measure sources of methane emissions from natural gas operations. The DOE ultimately provided USD 30 million to 12 projects, including the development of a field test facility at Colorado State University that provides a testing ground for researchers and companies that are developing innovative methane detection technology.

The DOE has also announced further direct research and development funding in successive rounds (2016, 2019, 2020) to fund projects designed to reduce or mitigate methane emissions from the oil and gas sector.

Natural Resources Canada has also provided funding for methane reduction research and development through its Energy Innovation Program (including ten projects in 2017-18).

Furthermore, **non-regulatory actions** can support methane abatement. Research and development support can encourage development of new abatement technologies, while policies encouraging voluntary action, such as through labelling or certification programmes, can promote industry engagement and further the competitiveness of the industry.

Integrating different policy spheres and regulatory actors provides opportunities to make the **best use** of existing **resources** and enforcement means. Frequently it also provides a clear path for companies to follow and enables them to reduce costs related to compliance.

Adaptive regulation

The oil and gas sector is dynamic and new technologies are always under development. Further, over time, regulatory objectives may change with increasing ambition. Thus, it is important to consider provisions up front to provide opportunities to review the effectiveness of **policies** and provide an avenue to update and incorporate new **learning**. Using an adaptive approach may enhance the effectiveness of policies and reduce the impact of errors, but it does lead to additional costs for data collection and decision analysis, as well as potential policy instability.

An adaptive approach foresees continuous learning, retaining flexibility and dealing with risk. It builds upon the principles of experimentation and dynamic adjustment, resulting from information and knowledge advances, changing system conditions and stressors, as well as the observed effects of past actions. The following items aim at enabling repeated rounds of optimisation and feedback links between policy design and follow-up.

Scheduled, periodic reviews provide an opportunity to review targets, procedures and requirements. If the programme is authorised by the legislature, statutory language could include discretion for adjustments within a certain band or authority to make modest changes without having to seek new statutory authority or undergo another rule-making process.

Box 21 Goal review

Policy and goal review are part of the process of continuous improvement and development of the regulatory system. This can involve assessing established targets, performance standards or the effectiveness of procedural requirements. Review may be tied to predefined timelines, be performed on an ongoing or ad hoc basis, or result from stakeholder request.

Victoria's (Australia) Climate Change Act of 2017 outlines the long-term emissions reduction target for this province, reaching net-zero greenhouse gas emissions by the year 2050. It also refers to interim emissions reduction targets, stating that the premier and the competent minister must determine reduction targets every five years, starting in 2025. It further defines 2005 as the baseline year and requires that goals be set in view of independent expert advice and must consider opportunities across the Victorian economy for reducing greenhouse gas emissions in the most efficient and cost-effective manner.

Brazil also uses review provisions, which are applied by the competent agency for annual operational limits regarding methane losses and flaring.

Built-in **flexibility mechanisms** allow regulations to incorporate new technologies as long as they meet certain performance metrics or present relevant advantages in view of policy goals. Regulations might also allow firms to choose among different compliance paths (e.g. reducing emissions or buying certified offsets), enabling companies to align governance and business strategies.

Provisions regarding **phased requirements** allow regulatory objectives to be ramped up over time while smoothing planning and adaptation for regulated entities. A common approach is to set different compliance deadlines for new facilities and existing ones. Another possibility is to establish incremental standards, with different timelines for installations to adapt to stricter requirements.

Finally, depending on the administrative procedures required in your jurisdiction, you may find that the simplest approach is to make amendments to your regulation. If you can adopt regulations relatively quickly, you may be able to keep abreast of new developments.

Adaptive regulatory provisions are a way to **deal with uncertainties** and improve regulations over time. They may be applied to all regulation types, but depend on functional monitoring and information systems to be effective.

Box 22 Alternative means of compliance

Alternative means of compliance refers to provisions that allow regulated entities to comply with established requirements through technologies or procedures that are not mentioned in the normative framework. Such alternatives can be subject to pre-approval by regulatory bodies or demonstration on a case-by-case basis as a way to ensure their adequacy.

Colorado (United States), in its regulation on the control of emissions from the oil and gas sector, allows for the use of alternative methods and strategies. Sources covered by the regulation can submit for approval alternative emissions control plans or compliance methods that provide control equal to or greater than the emissions control or reduction required by the regulation. Furthermore, test methods or procedures not specifically allowed in the applicable regulation are also subject to approval, and may be utilised if approved through a revision to the State Implementation Plan.

Mexico also allows for alternative methodologies in the measurement or estimation of greenhouse gas emissions, including methane. For more on this topic, see this report from the Environmental Defense Fund on pathways for alternative compliance.

The aforementioned regulation from Alberta has a section enabling innovative and science-based alternatives to fugitive emissions management programmes.

Additional resources

- The IEA Methane Tracker provides emissions profiles and information about abatement options while the Policies Database provides examples of methane regulations and policies.
- United Nations Environment Programme has been actively promoting methane mitigation, organising training opportunities on this topic. It is part of the Climate & Clean Air Coalition (CCAC) Mineral Methane Initiative, which calls on countries, organisations and companies to commit to reducing oil and gas methane by 45% over estimated 2015 levels by 2025 and 60% to 75% by 2030. The CCAC also provides expert assistance at no cost and regularly issues articles on methane action.
- The Global Methane Alliance brings together governments, financing institutions, international organisations such as United Nations Environment Programme, non-governmental organisations and industry to support methane reduction targets from the oil and gas industry. The related Oil and Gas Methane Partnership has issued a series of technical guidance documents on quantification and mitigation options for methane emissions from upstream oil and gas operations.
- The Clean Air Task Force has developed a tool (the Country Methane Abatement Tool [CoMAT]) to help countries estimate how much methane pollution they can reduce from their oil and gas industries as well as a compendium that offers a source-by-source summary of the best regulatory policy in North America.
- The Environmental Defense Fund has developed several in-depth resources on methane, and is expected to launch a satellite (MethaneSAT) in 2021 focused on methane observation.
- The Global Methane Initiative is an international public-private partnership focused on reducing barriers to the recovery and use of methane as a clean energy source. It provides technical support for methane-to-energy projects as well as a number of information resources.
- The Oil and Gas Climate Initiative is a consortium that aims to accelerate the industry response to climate change, including actions to reduce methane emissions.
- The Methane Guiding Principles are a voluntary, international multi-stakeholder partnership between industry and non-industry organisations with a focus on priority areas for action across the natural gas supply chain. Alongside information regarding its five guiding principles, it publishes best practice guides and toolkits.
- The Florence School of Regulation has organised a series of webinars and published policy briefs that discuss methane reduction opportunities.

Annex A: Policy type definitions

The following definitions are used throughout this report when categorising policy types, including the categories referenced in Table 2.[15] These categories correspond to specific tags in the IEA Policies Database.

Category 1: Prescriptive – Regulations that direct regulated entities to undertake or not to undertake specific actions or procedures. This command-and-control approach focuses on setting procedural, equipment or technological requirements such as the installation or replacement of specific devices.

- Permitting requirements– Permits are a means of granting authorisation for specific operations or procedures (e.g. pollution permits, drilling permits). Permits also include conditions that limit their validity, which may be temporal, technological or spatial.
- Leak detection and repair (LDAR) – Requirements to implement fugitive emissions management plans that include the process of locating and repairing fugitive leaks. Policies may address the type of equipment used, frequency of inspection, the leak threshold that triggers repair requirements and the length of time allowed to conduct the repairs.
- Restrictions on flaring or venting – Regulations that limit the amount of flaring or venting allowed or that prescribe the equipment or process for flaring or venting. This includes limitations on total volume, banning of such activities in routine proceedings (allowed only for safety reasons or special conditions), the need to request authorisations beforehand, or specifications of equipment or procedures.
- Technology standards – Requirements that outline the equipment, technology or procedure that must be employed in a regulated activity (e.g. requires the use of no-bleed pneumatic devices; both high- and low-pressure gas-liquid separation stages must be used to minimise vapour released from produced hydrocarbon liquid; vented natural gas from liquids unloading must be collected). This includes best available technology requirements, which refer to a benchmark technology or procedure for reducing emissions that is considered reasonably practicable and evolves according to technological development.
- Enforcement and related provisions – Encompasses enforcement, inspections and auditing requirements. Enforcement provisions authorise enforcement actions, set enforcement policy, specify sanctions or outline procedural requirements. Regulatory inspection provisions authorise officials to conduct onsite verification

[15] Note that the typology below includes additional divisions not included in Table 2

in order to assess compliance and enforce regulations. Auditing provisions establish verification processes whereby officials or third parties observe and report on the validity of the information provided by oil and gas operators.

Category 2: Performance- or outcome-based – Regulations that establish a performance standard for regulated entities, but do not dictate how the target must be achieved. An absolute or relative performance target can be applied at the national level, through economy- or sector-wide targets; at the company level; at the level of each facility; or even to individual types of equipment.

- National or sectoral reduction targets or plans (strategic targets) – These refer to reduction goals, including the definition of baselines, intermediate goals and means of assessing progress, reviewing objectives and achieving established targets. At national level (e.g. net-zero greenhouse gas emissions by 2050) or sectoral level (e.g. 50% methane reductions in the oil and gas industry in 2030 from the 2010 baseline), these generally serve as a strategic instrument and do not impose specific requirements on companies.
- Facility-or company emissions standards – Regulations that limit emissions through a performance metric set at the facility or company-level (e.g. each company must reduce emissions by 20% on a per unit basis). They generally cover different aspects related to atmospheric emissions, such as quantity (e.g. volume) or characteristics (e.g. concentration). This includes company or facility specific limits and associated reduction plans.
- Process or equipment standards – Regulations that limit emissions through a performance metric set at the process- or equipment-level (e.g. glycol dehydration units must control emissions by 95%). They generally cover different aspects related to atmospheric emissions, such as leak rates, discharge characteristics (e.g. temperature) or means (e.g. minimum height of discharge).
- Flaring or venting standards – Regulations that limit the amount of flaring or venting for the purpose of disposal allowed through a performance metric (e.g. minimum gas utilisation rates, admissible volume as a percentage of output) or establish other performance requirements (e.g. flaring must be designed for 98% efficiency). Regulations aimed primarily at fugitive emissions are not included in this category.

Category 3: Economic approach – Regulations that use economic provisions to induce action by applying financial penalties or incentives. This may include taxes, subsidies or market-based instruments, such as tradeable emissions permits or credits, that allow firms to choose among different strategies to address emissions (e.g. directly reduce emissions or pay for offsets), effectively changing the cost curve of abatement.

- Taxes, fees and charges – Taxes, fees or other charges that are levied on emissions, including nationwide carbon taxes applied to methane or royalties and other charges imposed on flared, vented or unaccounted for gas. Taxes, fees and charges may be further divided into two sub-categories:
  - Taxes, fees and charges on gas disposal (flaring or venting) – This refers to taxes, fees and charges that are are levied when operators dispose of excess gas by flaring or venting.
  - Taxes, fees and charges on other emissions – This refers to all other taxes, fees and charges, including those levied on fugitive emissions and methane emitted as a result of operation of equipment or certain processes (e.g. emissions from high- or intermittent-bleed pneumatic devices).
- Emissions trading schemes and certified reduction credits (emissions trading and credits) – Emissions trading schemes typically define an emissions limit and allocate emissions allowances among the regulated community. These allowances can then be traded among companies according to their needs and capabilities. Certified reduction credits allow entities that go beyond established requirements to be accredited as voluntary methane reductions, which may be traded. This item also includes any requirement that allow companies to achieve emissions reduction requirements by buying tradable credits.
- Loans, grants and other financial incentives (other financial incentives) – This includes all types of positive financial incentives that governments pay provide to reduce emissions. This could include direct provision of loans or grants to invest in reduction measures or other incentives such as allowing cost recovery for abatement costs via reductions in royalties, taxes or fees.

Category 4: Information-based approach – Regulations that 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.

- Emissions estimates and quantification (emissions estimates) – Requirements to estimate methane emissions through the use of activity factors and emission factors.
- Measurement requirements – Mandatory data collection for activities, equipment or production flows (e.g. volume of gas flared or vented, fugitive emissions leak rates from compressors), requiring operators to record, process and submit requested information. They support the definition of activity or emission factors that are specific to measured devices, facilities and settings.
- Reporting requirements – Regulated entities must record and report required information. This can include reporting emissions monitoring data, key events (e.g. accidents, flaring), state of facilities or operational data. Regulations can

indicate if information must be disclosed to the public or sent to regulatory authorities.

- Public disclosure – Requirements for regulated entities to share specified information related to methane emissions with the public (e.g. requirements to publish methane emission reports online, to undertake public information campaigns, or to disclose information upon public request). This also includes instruments that require public bodies to make specified information received from regulated entities available to the public.

Abbreviations and acronyms

ARPA-E	Advanced Research Projects Agency – Energy
ASEA	Agencia de Seguridad, Energia y Ambiente (Mexican Agency for Safety, Energy and Environment) (Mexico)
BAT	best available technology
CCAC	Climate & Clean Air Coalition
CO_2	carbon dioxide
CoMAT	Country Methane Abatement Tool
DOE	Department of Energy (United States)
EDF	Environmental Defense Fund
EIA	environmental impact assessment
EPA	Environmental Protection Agency (United States)
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute of the Environment and Renewable Natural Resources)
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LDAR	leak detection and repair
MRV	monitoring, reporting and verification
NDC	nationally determined contribution
NOC	national oil company
OGCI	Oil and Gas Climate Initiative
SDS	Sustainable Development Scenario
TROPOMI	Tropospheric Monitoring Instrument
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	volatile organic compounds

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