Driving Down Coal Mine Methane Emissions

A regulatory roadmap and toolkit

International Energy Agency

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Abstract

Tackling methane in the coal sector is a major opportunity for climate action that can also strengthen energy security. Experience shows that there are several steps countries can take today – using existing technologies and tools – that can lead to significant reductions in methane emissions from coal mining. This report highlights the lessons learned in different coal-producing jurisdictions to support the development of smart and effective methane regulation. It then provides detailed guidance on the process of designing, drafting and implementing new regulations. Finally, it discusses the different regulatory approaches currently in use for methane, with the aim of providing a comprehensive toolkit for policy makers.

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Executive Summary

Action to cut methane emissions from coal mines is needed in parallel with measures to reduce coal consumption. Yet global coal demand is set to rise in 2022 amid the upheaval of the energy crisis and this will have implications for meeting current emissions-reduction targets. Under the IEA's Net Zero Emissions by 2050 Scenario, methane emissions from coal operations fall by more than 70% to 2030 while the world's coal supply falls close to 50%. Dedicated abatement measures are therefore essential to driving emissions reductions at the pace and scale needed. Reductions in methane emissions are especially important for coking coal, mainly used in steel making, which often comes from underground mines where large-scale emissions cuts are most feasible. For steam coal, reductions in consumption are likely to be the best way to reduce methane emissions, as it can often be cost-effectively replaced by renewables in the power sector, and it is mostly produced from surface mines, where methane abatement is less feasible. The Global Methane Tracker 2023 provides information on the sources and abatement opportunities for coal mine methane (CMM), such as drainage for power generation or ventilation air methane oxidation.

Policy and regulation are needed to encourage companies to reduce methane emissions from coal mines. Methane emissions cause harm not only to the climate but also to crops, the health of communities, the safety of mining operations and to energy security. Policy makers should not assume that the industry has the right incentives to undertake voluntary action sufficient to address its methane emissions. While the industry may take action on its own, most mitigation opportunities are not cost-effective without pricing externalities. In such cases, policy and regulation can be used to change company incentives. Sound strategies will be needed to overcome the technical, institutional and economic barriers to coal mine methane reduction. This includes promoting best industry practice to monitor and manage emissions, facilitating access to energy markets and establishing the right mix of carrots and sticks to drive CMM mitigation. Voluntary industry initiatives can complement and broaden these policy efforts.

Better and more transparent data is needed but this should not stand in the way of mitigation action. There are large differences between data based on measurement campaigns and scientific studies, and the emissions levels reported by official public bodies, such as to the United Nation's (UN) Framework Convention on Climate Change, that rarely make use of direct measured data. Technical solutions are already available for lowering methane emissions in some contexts, but better and more transparent data are needed to facilitate targeted policy action.

Many countries are already taking action to curtail methane emissions. Following the launch of the Global Methane Pledge, several countries are working on national action plans to reduce methane emissions from human activities. International co-operation – through the Clean Development Mechanism, for example – has already contributed to CMM mitigation. New initiatives, including the Joint Declaration from Energy Importers and Exporters on Reducing Greenhouse Gas Emissions from Fossil Fuels, call on fossil fuel importers to reduce the methane emissions associated with their energy consumption. Some countries have clarified the status of CMM as an alternative resource to facilitate its use as an energy source. Others have introduced feed-in tariffs to encourage CMM utilisation for power generation. Some jurisdictions are also using prescriptive requirements to curtail CMM emissions. These are just a few examples of policy tools that can help address methane emissions.

This Regulatory Roadmap and Toolkit shares experience on CMM regulation. It highlights lessons learned in different jurisdictions to support the development of effective regulations. It provides a comprehensive guide covering both the **process** for establishing new policies and regulations and the potential **content** of policies aimed at CMM. In developing this Roadmap and Toolkit, we identified important insights for policy makers drawn from the experience of coal-producing countries.

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 specific 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. Every regulatory approach has its own advantages and disadvantages that depend on circumstances that vary across jurisdictions, and policy makers should consider how these circumstances play out within the local context. The steps outlined in this report are designed to help regulators understand these circumstances and make decisions as to which regulatory approaches fit their unique situation best.

Regulators should implement policies sooner rather than later. It is easier to incorporate abatement technologies into coal developments if these are considered from the outset. High-concentration sources of methane can be captured if emissions-reduction measures are planned prior to the start of mining operations. Degasification wells and drainage boreholes can capture methane from coal deposits, for example, which reduces the potential for emissions during production. These systems can also be applied to working mines before operations migrate to new areas of coal exploration or after operations have ceased in an area. Abandoned underground coal mines continue to emit methane, especially in the first few years after the end of operations, making this an important window for mitigation action. Coal phase-out policies can incorporate methane abatement to minimise climate impacts, generate energy and jobs.

Introduction

Action is needed on methane

Methane emissions are responsible for around 30% of the current rise in global average temperatures. Rapid and sustained reductions of these emissions represent a significant opportunity to limit the near-term effects of climate change.

Reducing methane has a major and immediate climate benefit because it has a much shorter atmospheric lifetime than carbon dioxide (around 12 years compared with centuries for CO_2), and it absorbs much more energy while it remains in the atmosphere: Over a 20-year period, methane absorbs more than 80 times the energy of a comparable volume of CO_2. Over 100 years, methane's absorption rate drops to about 30 times that of CO_2. Action on methane will be particularly important in the period to 2030 because sharp cuts in methane can deliver a net cooling effect within a relatively short period. This could help to keep the door open to a 1.5°C stabilisation in global average temperatures, while the world simultaneously pursues reductions in CO_2 emissions.

The Global Methane Pledge was launched at COP26 in November 2021 to catalyse action to reduce methane emissions. Led by the United States and the European Union, the Pledge now has 150 country participants who together are responsible for around 50% of global human-caused methane emissions. By joining the Pledge, countries commit to work together to collectively reduce methane emissions by at least 30% below 2020 levels by 2030.

Why focus on coal mine methane?

Coal seams naturally contain methane, referred to as coal mine methane (CMM) when it is associated with coal operations. CMM can be released during or after mining operations in a number of ways, including:

- Seepage from coal seams exposed in surface or open pit mines
- Ventilation and drainage in which methane is extracted from underground coal mines as a safety measure
- Post-mining activities such as processing, storage and transport when methane that is still trapped in the matrix of the coal seeps out
- Abandoned mines, since methane can continue to escape from coal that remains after operations have ended.

Ventilation air methane is the largest source of CMM at underground coal mines, whereas drainage systems are often the main source at surface mines.

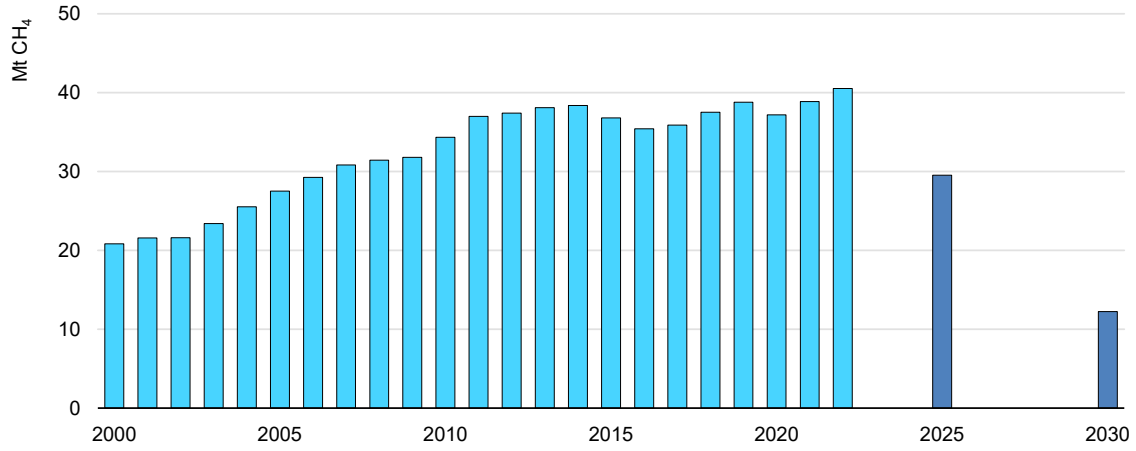
Methane emissions tend to be higher for underground mines than for surface mines, as deeper coal seams tend to contain more methane than shallower seams. Coal type also affects its methane content: lignite tends to have the lowest methane content, followed by steam coal and coking coal. More than 80% of all coal produced today is steam coal, which is mainly used for heat and electricity generation. Nearly 5% is lignite, which is also generally used for power generation. Coking coal makes up around 15% of global production and is mainly used in steelmaking. Steam coal and lignite can be replaced cost effectively by renewables in the power sector, whereas there are fewer readily available alternatives for replacing coking coal in industry.

Coal mine operations released around 40.5 Mt of methane into the atmosphere in 2022, representing more than 10% of total methane emissions from human activities. This is equivalent to around 1.2 Gt CO_2-eq[1], which is equivalent to more than all the energy-related CO_2 emissions from Central and South America. Tackling methane emissions in the coal sector should be an integral part of efforts to reduce global methane emissions alongside action on methane from oil and gas operations, waste and agriculture.

Addressing methane from coal will require a two-pronged strategy: transitioning away from coal use, particularly in the power sector, while simultaneously encouraging mitigation strategies where economically feasible. In the IEA's Net Zero Emissions by 2050 Scenario (NZE), coal-related methane emissions fall by more than 70% from 2022 to 2030. A major driver of this drop is a drastic fall in coal use: demand almost halves from 2022 to 2030.The largest share of the decline in coal mine methane comes from a transformation in the power sector as coal-fired plants are rapidly replaced by renewables in the NZE Scenario. As a result, the supply of steam coal falls by around 50% by 2030. Meanwhile, coking coal supply drops by 25% from 2021 to 2030.

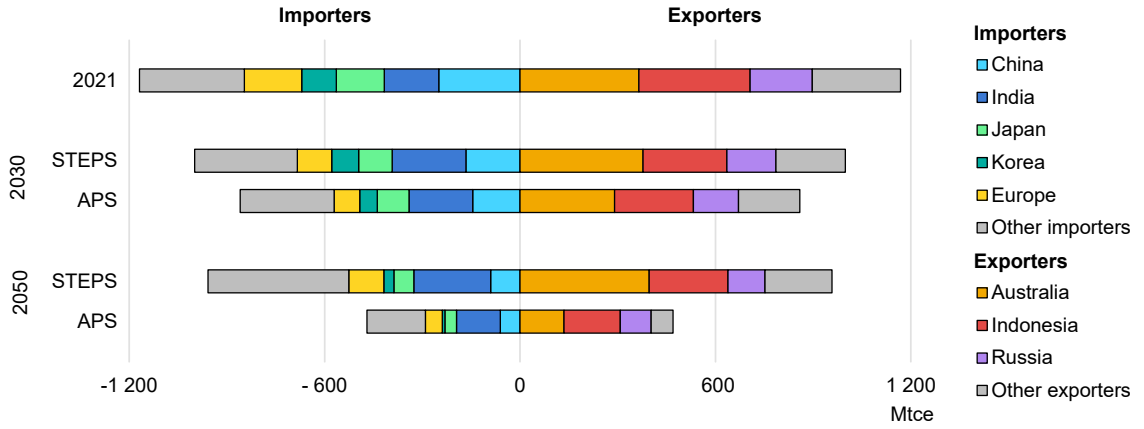
[1] Methane is converted to CO_2-equivalents based on the 100-year global warming potentials reported by the Intergovernmental Panel on Climate Change Sixth Assessment Report.

Figure 1 Coal mine methane emissions in the NZE, 2000-2030



As the energy sector transitions from coal-fired power generation and industries develop viable alternatives to its use, policies have an important role to play in limiting its climate impacts. Countries with a strong reliance on steam coal might need help to transition. International initiatives, such as the Just Energy Transition Partnership launched by Indonesia and a group of leading economies, can support such efforts. Coking coal importers might look to help producer economies to mitigate emissions and reduce the climate impact of their industries.

Figure 2 Top coal importers and exporters by scenario, 2021, 2030 and 2050



Note: Mtce = million tonnes of coal equivalent. STEPS = Stated Policies Scenario. APS = Announced Pledges Scenario.

In parallel with measures to reduce consumption, it will be necessary to invest in abatement technologies at active and abandoned mines. We estimate that it is technically possible to avoid more than half of global methane emissions from coal operations today with existing technologies.

Potential abatement options include capturing methane using degasification wells and drainage boreholes prior to the start of production. For underground mines already in operation, methane is often already pumped out through ventilation systems. This ventilation air methane can be captured and concentrated for use as an energy source, for example to heat mine facilities or for coal drying. CMM abatement technologies have already been implemented at numerous sites, but are still far from being standard industry practice. The Global Methane Tracker 2023 provides country-level information on abatement potentials, mitigation technologies and coal mine methane emissions.

Closed or abandoned coal mines also emit methane, and research has suggested that these could be a major cause of methane emissions, in particular as more mines reach the end of their operational lifetimes. Mine flooding is an effective way to reduce methane emissions from these mines as it stabilises the hydrostatic pressure on the coal seams. In cases where water levels do not recover naturally and flooding is not technically feasible, mines can be sealed and technologies put in place to ensure that emerging gas is captured and used. These measures are not widely deployed at present, and new policies and regulations dealing with emissions from legacy sites are needed to ensure their future deployment and proper mine closure.

The case for methane regulation

The coal industry often regards methane as primarily a safety hazard that can hamper the speed of production. Standard operations dilute methane concentrations to avoid explosion risks by bringing in air to mines and emitting the resulting mix of gas. Reducing methane emissions generally requires investments in additional equipment and maintenance without providing significant revenue or savings – especially in the absence of an effective tax on greenhouse gas (GHG) emissions.

While the fossil fuels industry shares concerns for methane and safety, the coal sector is quite different from the oil and gas sector for several reasons. There are more financial and technical barriers to voluntary methane reduction efforts in the coal industry than in the oil and gas context, where gas leaks are much easier to monetise and the deployment of abatement technologies is often less challenging.

There are, however, instances when CMM can be captured and utilised, thereby generating savings, particularly where both coal mine methane concentrations and energy prices are high. In the absence of a viable recovery project, methane can either be destroyed by thermal oxidation or flared to reduce its climate impact. There are several projects globally that have installed the equipment necessary to do this, but they remain uncommon. Safety concerns and a lack of supporting

regulatory frameworks, including an unclear ownership structure of coal mine methane, are cited as reasons for the lack of progress.

Understanding what prevents companies in different countries and market contexts from undertaking actions is a vital starting point in the design of a regulatory approach to methane abatement. There are three main types of barriers that explain why companies are not taking action to abate methane emissions: technical, institutional and economic.

Technical barriers

Mitigating coal mine methane is often challenging because the methane concentration of emissions can be very low and fluctuate significantly. The lower the concentration of methane, the more technically and economically difficult it is to abate. The same applies to methane emitted during the mining process. For example, air from the ventilation systems of underground mines (called ventilation air methane) often contains less than 1% methane.

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.

In some cases, CMM may be captured and mobilised to provide heat or power to mining operations, or sold to local markets. This requires both the availability of companies capable of delivering methane abatement solutions (e.g., degasification systems) and a way to use captured methane to meet existing energy demand. Many coal mines are in remote locations with rugged terrain, making the installation and operation of some abatement technologies challenging.

Additionally, while there may be a desire to implement best practices on CMM mitigation, companies need to operate and maintain specialised equipment – for which there is often a dearth of service providers, project developers and technical specialists. Further, innovation is necessary to tackle some sources of CMM, such as post-mining emissions, for which abatement pathways are not well understood to date.

Institutional barriers

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. In other words, the personnel in the best position to act – those on the ground – are not necessarily aware of the importance of doing so.

Also, in many cases, pathways or businesses do not exist to bring the gas that is captured to productive use. In these cases, it may be necessary to construct new infrastructure to use captured gas, including new grid connections, gas processing equipment or pipelines.

From a policymaking perspective, policies that enable or incentivise productive use of CMM could be missing. For example, grid access policies may not yet have been developed. An established mechanism for utilisation, which can take time to set up, may not yet exist. Existing pricing mechanisms might also need to be adjusted specifically for CMM, which may include allowing price premiums and mitigation subsidies to encourage CMM utilisation.

In addition, where ownership of CMM is not well defined, the coal company might not be entitled to abate emissions as they do not have the pertaining rights – or they may be unwilling, if the benefits would only accrue to the owner of the gas. Also, state-owned firms may not directly benefit from cost-saving measures because they return earnings to the government treasury and receive pre-determined appropriations to cover operations.

Economic barriers

There are also situations where methane concentrations do not allow for its recovery and utilisation as an energy source. When the amount of drained gas is limited and there are no feasible alternatives to use its energy content, flares can combust methane to reduce its climate impact. For ventilation air methane coming from underground mines, thermal or catalytic oxidation technologies are technically feasible at low methane concentrations and enable the destruction of methane to reduce its climate impact. Policies and regulations are needed to create incentives or to require mine operators to install these types of CMM abatement technologies.

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 toward investments where a higher rate of return is possible.

Additionally, the transition from coal outlined in many countries' climate action plans may affect the cost-effectiveness of capital investments in methane abatement. Capital costs for the deployment of methane abatement equipment and infrastructure are more significant for mines with relatively short remaining operational time. This can lead to a difficulty in securing funding or obtaining financing for abatement technologies in this sector.

What can governments do to drive methane reductions in the coal mining sector?

Governments can address many of these barriers with policy and regulatory tools. Technical barriers can be bridged in a number of ways: through training; measures to support the monitoring, reporting and verification of emissions; support for voluntary reporting standards; and initiatives to encourage knowledge-sharing and best practices. When it comes to institutional challenges, governments can introduce requirements in the planning stages of projects, directly invest in abatement measures or clarify rights concerning CMM. Policies can also price environmental externalities, create financial incentives for onsite use of captured gas (e.g., offer rebates for expenditures in CMM abatement), or remove barriers to investment. There are many different policy approaches, but they all have one thing in common: they change the cost-benefit analysis for companies and drive them to internalise the societal cost of methane pollution.

The aim of regulatory interventions is fourfold: First, they can unlock the abatement measures that are already economically advantageous today, i.e., the methane emissions that can be abated at no net cost. Second, they can facilitate and promote actions that address the range of methane emissions that are technically possible to abate. Third, they can encourage the coal industry to privilege production from mines where emissions are low or abatement is more feasible. Fourth, they should ensure emissions monitoring, reporting and verification. To reach these four objectives, it will not be enough to simply remove the barriers that prevent companies from acting on their own. Broader regulatory efforts will have an important role to play.

Regulations customised to each jurisdiction's specific goals can ensure that companies undertake appropriate abatement actions. There are already a number of examples of different types of policies and regulations around the world that have begun to address aspects of the problem. This Roadmap and Toolkit is based in large part on those examples and is designed to assist policy makers in learning from this existing experience. The Annex to this Roadmap and Toolkit provides a non-comprehensive list of policies and regulations concerning CMM abatement from around the world that we reference throughout this report.

Also, in-depth case studies have led to tailored policy recommendations. For example, the Global Methane Initiative has developed country profiles for most coal producers, assessing their unique CMM abatement challenges and opportunities. A joint study for Kazakhstan recommended including CMM in the feed-in tariff scheme, developing methodologies to count credits for the emissions trading scheme, providing tax benefits for CMM projects, and clarifying CMM ownership and leasing rights. The IEA has previously focused on CMM opportunities in the People's Republic of China (hereafter "China"), where it advocated support for local authorities to implement provincial-level policies, engaging stakeholders for CMM subsidy development and providing incentives for skilled workers to run CMM recovery and utilisation projects in smaller coal mines. A report for the Russian Federation (hereafter "Russia") proposed clarifying ownership and licensing of recovered methane, raising levies on industry for emissions and providing tax credits for CMM recovery and utilisation and participating in international co-operation efforts.

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 coal mine 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 encyclopaedia of the different regulatory tools that are available to them as they craft new policies.

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.

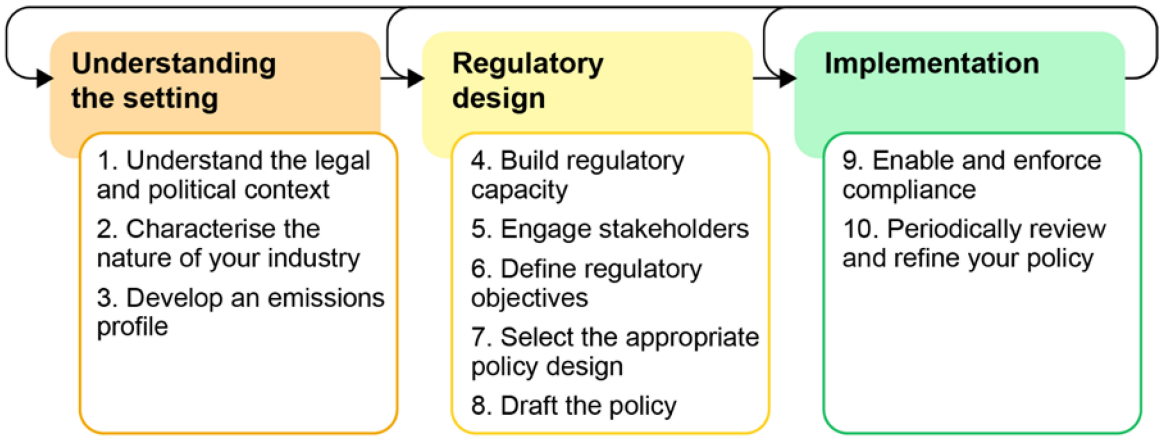
A ten-step roadmap for policy makers

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 3 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 fossil fuel 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 governance arrangements that exist 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

Regulations 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
- information-based requirements.

The table below illustrates each regulatory approach by describing its application to ventilation systems, which are used in underground coal mines to remove methane and other gases and bring in fresh air. Ventilation systems enable safer working conditions within a mine, but they are also the largest source of CMM emissions due to the large quantities of diluted methane they emit into the atmosphere. Abatement technologies for ventilation air methane (VAM) include oxidation or capture and recovery for use.

Table 1 Regulatory approaches applied to VAM

Regulatory approach	Definition	Example
Prescriptive	Prescriptive instruments direct regulated entities to undertake or not to undertake specific actions or procedures.	Underground coal mines are mandated to seal previously mined areas and take them off the ventilation network, decreasing VAM emissions.
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.	An annual methane emissions limit is set for coal mines, which might choose to recover VAM to meet established limits and reduce coal used for heating.
Economic	Economic instruments induce action by applying charges or introducing financial incentives for certain behaviours. This may include taxes, subsidies, or market-based approaches such as tradeable emissions permits or credits.	Operator must pay a pollution tax for emissions. Alternatively, the operator may deduct the costs of deploying abatement technologies from its tax liabilities. Under either scenario, the operator may choose to oxidise VAM 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 ventilation systems. In view of the volume quantified, the operator may choose to reduce emissions associated with VAM.

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. The last section of the Toolkit presents additional resources, including reports, tools and institutions that support coal mine methane mitigation.

Regulatory Roadmap

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 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. The information-gathering phase begins here in 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 considered?

In this step, you will consider how regulating methane emissions from the coal mining 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. During this process, you can consult the Coal Mine Methane Country Profiles developed by the Global Methane Initiative to support CMM reduction opportunities across 37 countries.

Agencies with relevant regulatory authority

What is the jurisdiction and how can that be leveraged to abate methane?

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, safety). Certain types of regulatory authority may be maintained at the federal level or disbursed among state or provincial agencies where coal deposits are concentrated.

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

strategies are available. In Indonesia, for example, the Ministry of Energy and Mineral Resources leveraged its position as a government body to encourage unconventional gas production through a right of first refusal for a mine contractor. It issued a regulation that specifies procedures for unconventional oil and gas working areas (including coal mine methane) which allows the contractor bid first by submitting a work plan and budget for a potential study to be conducted by the Ministry. If the results show that cultivation of the unconventional gas is technically and economically feasible and the contractor does not submit the proposal within six months, a new contractor will be invited to cultivate it.

Natural resource rights

How are ownership rights for coal and CMM distributed?

Generally speaking, regulation of a natural resource – and the pollution that its exploitation may cause – follows ownership of the resource. Historically, gas released during coal mining operations is managed from a safety perspective and disposed of as a waste product. This has precipitated both technology development for methane capture *within* operating coal mines and the development of unconventional natural gas industries – referred to as coal seam gas (CSG) or coalbed methane (CBM) – that extract methane from coal seams *outside* of mining operations.[2] Rights to the exploitation of this associated gas do not necessarily follow the rights to coal exploitation in the same field. In order to facilitate methane abatement and the resource development, the distribution of rights may need to be clarified.

Even if CMM rights are not automatically granted along with coal concessions, jurisdictions may have existing rules in place that give coal mining operators the clearance to perform natural gas operations under specific circumstances. This is the case in Alberta, Canada, where the Alberta Energy Regulator may authorise coal lessees to recover coalbed methane contained within the territory of the coal lease for safety and energy conservation reasons.

In jurisdictions where coal and gas are permitted separately, existing regulations may determine priority and stipulate a co-ordination mechanism for coal mining and gas operations. In Australia, for example, coal permit holders enjoy a “right of way” to extraction, but must offer to supply, on reasonable terms, any incidental coal seam gas to a petroleum permit holder in the overlapping territory. In India, the Hydrocarbon Exploration and Licensing Policy (HELP) replaced a previous

[2] CBM is natural gas, predominantly methane, which is deliberately extracted from unmined underground coal seams that generally are not suitable for normal mining. However, in some countries – most notably in China – CBM can also include CMM emissions that are captured and subsequently marketed.

regime that required a separate licence for each hydrocarbon. HELP allows for a single uniform licence for all forms of hydrocarbons.

Other jurisdictions choose to promote a "pre-drainage" strategy in which methane is extracted prior to coalfield development. For example, the US Bureau of Land Management (BLM) established Conflict Administration Zones in 2003 and 2006 to encourage methane drainage prior to coal extraction in the Wyoming Powder River Basin. BLM offered a 50% royalty reduction rate to oil and gas lessees who agreed to expedite the extraction of CBM in these zones prior to coal mining.

In the absence of an intentional strategy for resource development, existing legal frameworks may inadvertently hinder methane abatement. This was formerly the case in Ukraine, where one of the key barriers to CMM development was a 2012 tax code amendment that introduced excessive fees for mineral use on companies that engaged in unconventional gas production. The rules were clarified in 2017 to exempt CMM from taxation, in line with a law in 2009 that aimed to attract investments for CMM exploration, capture and utilisation.

Similarly, legal clarity regarding the rights to fugitive methane from abandoned coal mines may be needed to facilitate abatement projects. In Australia, for instance, all underground coal, petroleum, and mineral resources belong to the state, including Abandoned Mine Methane (AMM). State governments regulate the permitting processes by which companies may apply to extract and utilise AMM. In Germany, natural gas is federally owned, and licences for coal extraction include a right to explore gas, whereas AMM use follows a procedure similar to an authorisation for gas-fired power plants.

In some countries, resource development is governed at the state or provincial level. Given that coal production is frequently concentrated within certain regions, co-ordination between national and subnational governments regarding resource rights and permitting processes may be needed to facilitate effective CMM and AMM regulation.

Table 2 Ownership of natural resources

Question	Relevance	Examples
Who owns the gas from coal mines and controls exploitation rights for this resource?	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 China, the state owns coal resources and coal mining companies are largely state-controlled. CMM is considered an associated resource in active mining areas where a coal company has obtained a mining licence.

Question	Relevance	Examples
Who owns the gas from coal mines and controls exploitation rights for this resource?	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 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 may determine exploration terms.	In the US, subsoil resources including gas may be privately owned (depending on state law), in which case CMM and AMM projects would have to acquire resource rights from the landowners.

Regulations on air pollution

Who regulates air pollution?

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. The 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 from coal mining. For instance, while federal laws in the United States grant the Bureau of Land Management (a federal agency) primary authority over permits for the exploitation of coal and other resources in federal lands, resource extraction that occurs on private land would be a matter of state contract law. Furthermore, while the US federal government generally has authority over regulating air pollution, this is often a shared responsibility between the states and the federal government. Under the Clean Air Act (CAA), the US Environmental Protection Agency (EPA) has authority to establish new source performance standards for major stationary sources for pollutants such as methane that are not identified as criteria or hazardous pollutants. EPA may then delegate the authority to implement and enforce those performance standards to states, and states are also required to establish and implement standards that apply to existing sources. The EPA has not listed coal mines as a stationary source to be regulated for methane under the CAA, but this does not prevent states from issuing their own standards as the CAA allows states to establish more stringent pollution standards for pollutants not covered by federal regulations.

Table 3 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 Australia, the acquisition of rights to minerals stems from separate legislative frameworks in each state. However, mines are required to report GHG emissions through a national reporting scheme, which includes measurements for VAM from underground coal mines and fugitive emissions from decommissioned underground coal mines.

Worker and safety regulations

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

Safety regulators may regulate methane concentrations and monitoring procedures to minimise explosion risks. One of the motivations for abating coal mine methane is to improve safety of the workers and communities that live around the mine.

Degasification systems are often in place to reduce methane concentrations during mining operations. In the absence of a regulatory incentive or requirement, associated boreholes will often lead to vents where methane is released into the atmosphere. Likewise, ventilation systems will generally release VAM through ventilation shafts into the atmosphere.

Related requirements may mean that useful information for abatement projects is available, such as methane contents of coal seams or the number and position of drainage boreholes. These can inform feasibility studies and reveal which abatement technologies would be most suited to each facility (e.g., power generation for mines with high methane concentration, or flares for sites with lower concentrations).

Table 4 Safety regulations

Question	Relevance	Examples
What other authorities might be implicated in methane abatement?	Enhanced mine safety through different CMM abatement methods is a concern for the labour authority, occupational safety and health bureau or specific mine safety authority.	The United States Mine Safety and Health Administration (MSHA) enforces safety standards of the Federal Mine Safety and Health Act, which requires extra precautions against methane explosions for mines with a methane concentration of 0.25% or more.
What rules or guidelines may be issued to establish a safer environment for mine site workers?	Rules or guidelines might require technologies or measures that affect methane management.	Russia's Mine Safety Regulations establish requirements for mine ventilation and degassing. This includes permissible standards for the content of explosive gases in a mine, coal seams and goaf, above which degassing is mandatory.

Economic incentives

Are there mechanisms to incentivise CMM abatement strategies?

Many countries are involved in national or international efforts to reduce greenhouse gas emissions. The agencies and officials leading these efforts can establish relevant reporting standards or incentives for CMM abatement. They should also be aware of voluntary initiatives that could be affected by new regulations.

Voluntary carbon markets, whereby companies trade carbon credits (verified metric tonnes of greenhouse gases reduced or removed from the atmosphere), may offer an avenue for CMM abatement. For example, Verra, a major voluntary carbon markets standard, has issued a crediting methodology to quantify the emissions reductions generated by capturing and destroying methane from abandoned or decommissioned coal mines. Climate Action Reserve and American Carbon Registry also manage private carbon markets and have developed their own standards and methodologies to verify CMM projects.

Emissions trading schemes (ETS) could also be relevant for CMM projects. In certain cases, CMM reduction projects might be made eligible to be used by regulated companies instead of ETS allowances to comply with their obligations. Existing institutional arrangements can often be adapted to include measures to encourage methane abatement at coal mines, especially for abandoned facilities or mines with low methane emissions where the most feasible abatement technology is flaring or VAM oxidation.

Table 5 Greenhouse gas emissions-reducing mechanisms

Question	Relevance	Examples
Are CMM projects included in GHG pricing schemes?	National or regional GHG pricing schemes may incentivise CMM abatement projects by including CMM credits in domestic carbon markets or taxes as an alternative way for regulated companies to meet their obligations.	Under the New Zealand Emissions Trading Scheme, coal mines that produce more than 2 000 tonnes of coal annually are obligated to surrender emissions credits for coal seam gas emissions or pay a fixed price per unit.
Are there international mechanisms to incentivise CMM abatement?	Carbon credits from CMM abatement (whether flared or collected, and generated in one country and sold to another entity) can be generated and sold under various Voluntary Carbon Markets, the Clean Development Mechanism, and potentially also under Article 6 of the Paris Agreement.	Projects under the Clean Development Mechanism allowed abated CMM to generate carbon credits. An example of this is the CMM and VAM Comprehensive Utilization Project of Taiyuan, Shanxi Province, in China.

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 CMM 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 or remove them for optimal CMM 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 CMM emissions, it is important to think about the tactics it most often employs to achieve its policy goals. If your agency has experience enforcing standards, then it could make sense to proceed with regulation. If your agency works with large players in the coal industry, perhaps through contracts or agreements, then you might begin by adapting contract provisions on a going forward basis, to incentivise or require methane abatement.

The US Coalbed Methane Outreach Program (CMOP) is an example of a government initiative that co-operates with the coal mining industry to help reduce CMM emissions. CMOP organises events and publishes resources to promote profitable recovery, utilisation, and mitigation of CMM. 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? Are there any that indirectly affect methane emissions?

Greenhouse gas emission reduction goals, or monitoring and reporting requirements, may be applied to coal even if they do not call out CMM specifically. For instance, Colombia's Integrated Climate Change Plan for the Mining-Energy sector includes coal in the list of activities for which it establishes fugitive emissions reduction measures. The related mitigation measure focuses on information gathering, to generate a robust baseline for upcoming policy decisions and regulation, to promote the adoption of mitigation actions and assess the uncertainty of abatement potential.

Many jurisdictions have policies in place that influence oil and gas methane emissions that might be extended or serve as inspiration for the coal sector, considering the differences in emissions sources and abatement strategies between the two industries. For instance, Mexico regulates methane emissions from pipelines transporting associated gas from coal mines under the official standard for the transport of natural gas. The provisions of the standard include design, operation, and maintenance requirements along with guidelines for the monitoring and detection of leaks.

Some countries have systems that capture methane produced from landfills, which can be compared to CMM because it is also a diffuse methane source. California has a Landfill Methane Capture Strategy, created as a result of the California Global Warming Solutions Act. The regulation required owners and operators of landfills to install systems to collect and control methane. Local air districts can voluntarily enter into a memorandum of understanding with the California Air Resources Board to cover costs, get support to enforce the regulation and assess fees.

In other cases, existing policies for the coal mining sector may not mention methane explicitly but nonetheless create opportunities for (or obstacles to) its abatement. Regulations designed from a worker safety perspective, for instance, may require degassing by venting without considering mitigating alternatives like flaring or capture and utilisation. Policies indirectly affecting methane emissions can be more difficult to identify, but they are worth the effort. For example, energy regulations may be preventing CMM projects from accessing electricity grids or

nearby gas pipelines. Air pollution policies may also impact methane abatement, such as when emissions standards limit emissions of volatile organic compounds.

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 choose not to alter an existing policy, but take measures 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 end the policy, or change it so as to achieve the original policy goal without creating a disincentive for action on methane.

Step 2: Characterise the nature of your industry

How might the 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: technical, institutional and economic. 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, and help assess where “problem” sources of methane might lie.

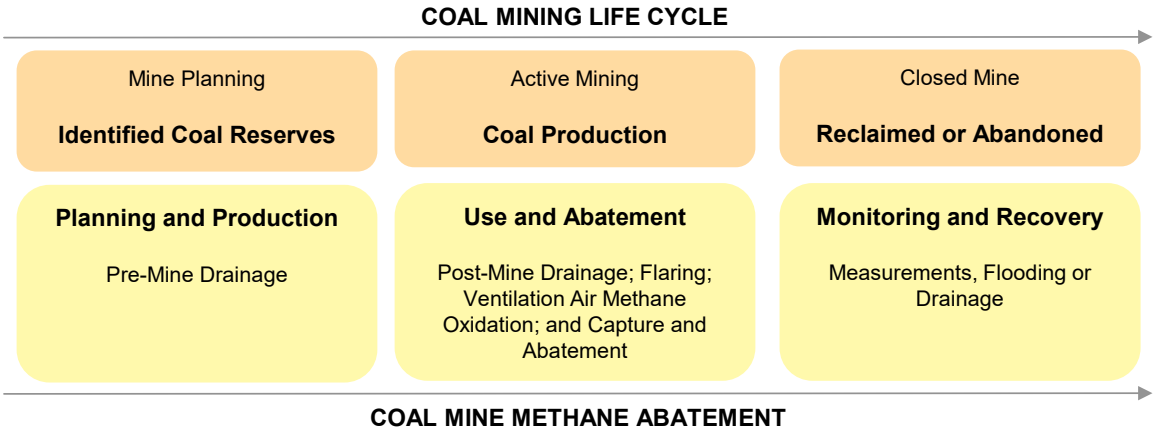
Industry profile

One of the most important aspects of your industry is the makeup of its participants. Key stakeholders in the coal mining industry include: national and local governments giving mining concessions and natural resource rights; mining authorities that regulate the sector; mining operators with mine leases; service companies; end-use consumers that use coal as raw material; and investors. All of these actors have a stake in the progressive regulation of the sector.

The profile of industry participants is particularly important – how old or new are the mines and contracts of the companies involved? If concessions are relatively

new, any loans taken out or investments made still need to be recovered. As such, policies may include economic measures to support the transition to newer abatement technologies. If concessions are old, contract extensions might be linked to abatement requirements.

Figure 4 CMM abatement through the coal mining life cycle



Methane can be released in all stages of the coal mining life cycle; however, there are significant variations in estimated emissions depending on mine type, age, and depth. The IEA's Global Methane Tracker 2023 presents a more detailed discussion on the different sources of methane emissions from coal mines and related abatement measures.

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

If coal production is under the purview of state-owned companies, government agencies may be able to exercise greater influence over methane abatement through direct regulation. This is the case in India, where around 80% of coal is produced by the state-owned mining company Coal India Limited (CIL) under the Ministry of Coal. A CIL subsidiary, CMPDI, has been active in CBM recovery and utilisation since the 1990s, and has thus far been awarded over 30 CBM blocks for commercial development. The company also specialises in generating CBM data in the exploratory phase and has partnered with domestic and international partners on research and development projects for concurrent exploitation of coal and CMM/AMM. As CIL is currently expecting to increase production from deeper – and more gaseous – coal deposits to meet energy independence goals, there is heightened potential for CMM recovery through degasification projects.

Table 6 Industry type (Private vs. State-Owned)

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 China, most developers are state-controlled with the status of an independent legal entity, but CMM projects require permits from the Ministry of Natural Resources and must follow the standards set by the Ministry of Environmental Protection.
	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).	Australia and Indonesia 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 generally subject those firms to sectoral regulation.	Canada has only private firms operating in the coal sector.

In China, the coal industry is dominated by state-owned enterprises, many of which have installed methane abatement technologies. China Shenhua, a subsidiary of China Energy Investment Corporation, has equipped its mines with CMM drainage and utilisation systems, which has reportedly led to a coal gas utilisation rate of 60%. Also, China Coal developed methane extraction technology and applied for two utility model patents for use in its Shaanxi branch.

Are there readily available options for CMM abatement?

Do mining operators in your jurisdiction already have expertise in capturing and utilising or selling methane released during mining activities, or have CBM industries developed apart from the mining industry? CMM abatement prospects depend on the availability and quality of CMM, energy prices, as well as expertise and infrastructure available for methane utilisation. Moreover, it is important to describe the nature of the businesses involved in coal production – companies might not have the structure or expertise needed to develop CMM abatement projects.

For surface mines, methane mitigation options are limited, but pre-mine drainage could be a possibility. For underground mines, ventilation air methane oxidisers might need to be imported, and the best alternative for drained CMM use will depend on the local characteristics, such as availability of suitable gas-fired power engines or purification equipment. Mine operators may partner with specialised

energy technology companies or research centres for technology solutions. For example, the National Science Agency of Australia (CSIRO) has developed a suite of VAM technologies for CMM mitigation.

Table 7 Industry integration

Question	Relevance	Examples
Is there infrastructure that facilitates CMM utilisation?	Local demand may be available for captured gas near coal mines, and when available, CMM can be fed into the natural gas pipelines. Using CMM as a gas resource depends highly on the concentration of methane. With the proper technology, CMM can be processed to achieve the 95% methane concentration necessary for feeding into pipelines.	Although GHG emissions from coal mining activities in the United States are not regulated, recovered CMM is often fed into natural gas pipeline systems. CMM is usually processed to remove the contaminants and upgraded to pipeline quality then fed into the pipeline. The eastern US market is suited to CMM utilisation because pipeline systems are often located close to gassy coal mines.
Are there companies specialised in CMM abatement and project development?	In many jurisdictions, there may already be industry expertise in methane capture and/or utilisation, whether from coal mining or CBM companies or third parties. Assessing what players are already active in CMM mitigation will inform how much time and resources need to be mobilised to meet your policy goals.	Biothermica, a Canadian company, offers various financial schemes for domestic and international coal companies to implement VAM projects using their commercial technologies. The multinational company Dürr has specialised in coal mine VAM abatement solutions since 1994, with projects across four continents.

Lastly, it may be important to check whether gas pipelines in your jurisdiction are open-access pipelines, where producers would be allowed to inject purified CMM into the system. Otherwise, they may sell to natural gas providers. Similarly, you will want to ensure that CMM-to-power projects have access to power grids and customers. In such a case, policies can be developed to manage the difficulties of accepting fluctuating output of CMM from smaller plants, such as allowing price premiums to be passed on to consumers. Under Indiana's Voluntary Clean Energy Portfolio Standard, regulated electric utilities qualify for financial incentives if they meet specific targets for including renewable energy resources (including CMM) in their generation and supply portfolios.

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 mines than regulate existing or closed mines.

What is the state of the coal industry?

If your jurisdiction has a long history of coal development, you may need a regulatory strategy to address methane emissions from abandoned mines. In Pennsylvania, for example, where the coal mining industry has been active for more than two centuries, there are an estimated 5 000 or more abandoned mines scattered across the state. While methane emissions tend to slow down after mine closure, abandoned mines may continue to release methane for decades. Depending on the age of the abandoned mines and on the evolution of the regulatory regime in the intervening years, the current ownership of such sites may be unknown or contentious. An important step toward methane recovery is to establish clear ownership and transfer rights to the resource. In Germany, ownership and transfer procedures for abandoned mines were established in the 1990s, and the country is now home to the most active AMM industry in Europe.

What are your country's plans regarding coal production?

The IEA's Coal in Net Zero Transitions report outlines a path of steep decline in coal use to meet the global 1.5°C target for climate stabilisation. As countries transition away from coal production and toward a carbon neutral economy, it becomes increasingly important to integrate methane abatement strategies into environmental and land reclamation procedures related to mine closure from the outset. Many jurisdictions require integrated environmental assessments for mine closure planning prior to the commencement of mining operations.

Mine closure and subsequent land reclamation projects typically involve multiple government ministries – although some countries have designated special-purpose agencies to streamline the process. For example, the United Kingdom Coal Authority is responsible for overseeing all aspects of post-closure monitoring and maintenance, including managing water pollution, safety concerns, and other environmental and social legacies of mining.

Methane recovery projects from abandoned or closing mines may also offer opportunities for alignment with just transition strategies by minimising safety hazards and prioritising the local employment of former coal miners. The US Methane Emissions Reduction Action Plan outlines the administration's strategy for extended support of the Abandoned Mine Land (AML) grant program, which

supports both land reclamation and local economic development in former mining communities. The USD 11.3 billion of funding allocated by Congress in the 2022 Infrastructure Investment and Jobs Act can help to reduce methane emissions from the currently known unremediated abandoned mine sites throughout the country with a stated focus on employing dislocated workers and encouraging meaningful community engagement.

The World Bank's Managing Coal Mine Closure: Achieving a Just Transition for All finds that strong government commitment, legal and regulatory review, and genuine stakeholder engagement are critical components to improving social and economic outcomes for communities impacted by coal mine closure. POTENTIALS, a research project co-funded by the European Commission, identifies mine gas utilisation among other opportunities to stimulate economic activities and jobs in Coal Regions in Transition that contribute to renewable energy development and the circular economy. Another EU-funded project, MERIDA (Management of Environmental Risk during and after Mine Closure), provides guidance on identifying and mitigating the risks associated with gas emissions from closed and abandoned coal mines. Researchers used geological and mine-specific data at the Anna Mining Complex in Rydultowy, Poland, to conduct a hazard analysis for potential gas outflow to help identify areas exposed to risk of explosions from high concentrations of methane before, during and after mine closure. Among the proposed solutions to this hazard is the implementation of AMM recovery technology.

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 coal mine 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 as 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 for degasification systems.

Estimated level of emissions

Most likely, you will need to develop an initial estimate of your emissions to use as reference point in setting your goals and tracking progress. Given that CMM emissions vary significantly depending on the gassiness of the mine, production rates, coal permeability and other factors – and that data collection and reporting requirements may be scarce relative to other sectors – generating reliable emissions estimates may require additional research and planning. By studying data about methane emissions from different points and activities in the mining life cycle, you can track general trends going forward and adjust your policies accordingly. You can take a phased approach for this, looking to estimate emissions from the most likely large sources first and undertaking additional efforts as more resources become available.

Does your country already have estimates of coal mine sector methane emissions?

As a member of the United Nations Framework Convention on Climate Change (UNFCCC), your country may already compile greenhouse gas inventories: in 2022, 28 Parties to the convention reported methane emissions from coal mining. To support this or other regulatory programmes, your jurisdiction may already have reporting requirements in place, for some or all sources of methane. The United States is an example of a country whose national greenhouse gas inventory includes methane emissions from coal mines. The United States has a Greenhouse Gas Reporting Program to collect detailed emissions data from specific sources of GHG emissions from underground coal mines. This is used to develop the Inventory of US Greenhouse Gas Emissions and Sinks, which estimates total emissions in the country and reviews emissions data since 1990.

Initially, the information available – even under a mandatory reporting regime – may be quite limited. That is to be 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. You may start by using information that coal operators already collect for safety or operational issues, such as methane contents of coal seams, flow of ventilation systems, mine depths or the expected year of mine closure.

Moreover, as satellites begin producing more publicly available data on methane emissions, you may be able to use such data to confirm and reconcile estimates you have developed based on an inventory of emissions factors. A recent article compared national greenhouse gas budgets reported in UNFCCC inventories against atmospheric inversions, providing country-level estimates for the main emitters of methane from fossil fuel operations. See the Monitoring and Reporting section of the Regulatory Toolkit for more information on satellite technologies.

How might you generate in-country emissions estimates?

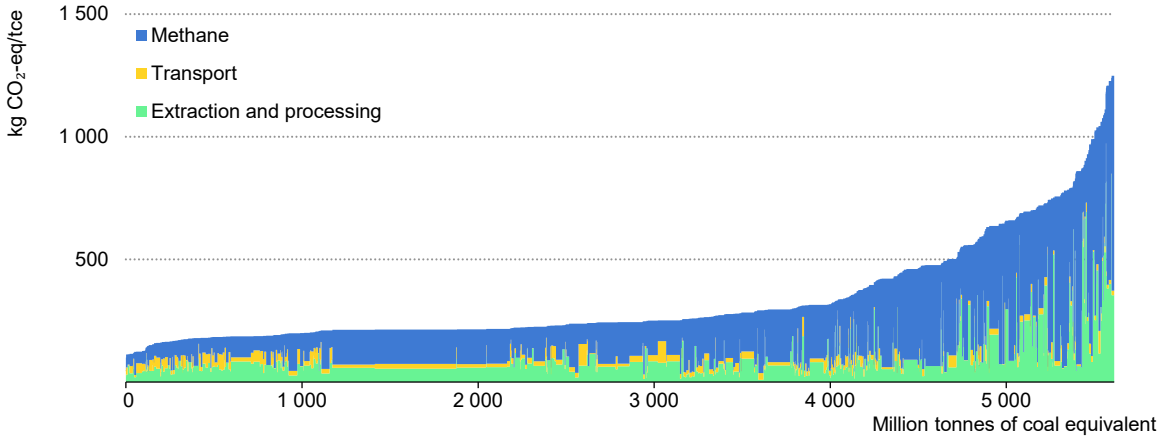
If your country or jurisdiction does not already have a mandatory reporting regime in place, you may be able to collect initial numbers from companies operating in your jurisdiction as part of your national emissions inventory or through a data collection exercise. You might also refer to inventories done by countries with similar industry vintage and structure.

The IEA Methane Tracker Data Explorer offers country-by-country CMM emissions estimates based on the best available data. The estimates in the Tracker are based on mine-specific emissions intensities that consider mine depth, coal type and regulatory oversight. These emissions estimates are a good starting point – but ultimately, the development of accurate emissions estimates based on empirical data should 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 exists, you can look to emissions from similar installations elsewhere to get a sense for this information.

Problem sources

The amount of methane in a given coal seam varies widely based on geological and environmental factors, meaning there is no one-size-fits-all approach to CMM abatement. There is a wide variation in the methane intensity of coal production (the amount of methane emitted by unit of coal produced). The worst-performing coal emits as much as 100 times more methane than the best-performing.

Figure 5 Indirect CO_2 and methane emissions from global coal supply, 2021



IEA. CC BY 4.0.

Notes: tce = tonnes of coal equivalent. Methane is converted to CO_2 equivalents based on the 100-year global warming potentials reported by the Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC, 2021), with one tonne of methane equivalent to 30 tonnes of CO_2.

Often, a few mines will be responsible for an outsized volume of emissions. These sites could also be the least costly to abate due to high methane concentrations and economies of scale – which makes them an interesting target for policy efforts. Implementing abatement technologies at these sites could open the way to spread such practices to other mines, since the industry will be more familiar with them and institutional barriers less prominent.

Coal mine methane emissions vary based on the type of coal produced (steam, coking, lignite), the type of mine (surface, underground, active, abandoned), and other characteristics, including mine depth and age. Deeper coal seams tend to contain more methane than shallower seams, while older seams have higher methane content than younger seams. Underground mines tend to have higher methane emissions than surface mines. Although most methane emissions occur during the active phase of the coal mining life cycle, gas may continue to leak from abandoned mines for decades in the absence of mitigation measures. This may include biogenic methane from old mines.

Vented emissions (i.e., intentional methane emissions) are generally related to drainage or ventilation systems. Methane may be drained from undeveloped coal seams in both surface and underground mines. The output is often gas with high methane concentration, which can be utilised as an energy source (e.g., for power generation). In underground mines, to ensure worker safety and avoid the risk of explosion, mine gas is typically mixed with fresh air and released through ventilation shafts. The output is generally air with low methane concentration, known as ventilation air methane (VAM), which can be oxidised to reduce its climate impact.

Fugitive emissions are unintentional methane emissions that occur at every stage of the mining life cycle. Fugitive emissions from coal mines can arise from mine openings, fractured ground and outcrops or post-mining activities, such as coal crushing, storage or transport. Methane emissions also occur due to incomplete combustion (i.e., methane slips from flares, engines, boilers or oxidation systems).

When a mine is closed, ventilation shafts and other openings are typically filled with gravel or concrete. However, methane may still migrate through unsealed entries or poorly sealed shafts, as well as through cracks and fissures in the overlying strata – leading to emissions for many years. Vents may be installed to control gas migration, but the most effective way to reduce emissions from closed and abandoned mines is to allow natural mine flooding, which stabilises the hydrostatic pressure on the coal seams. Even under the right conditions, however, mines may take several years to flood, in which time significant amounts of gas may escape. Where flooding is intentional, projects should also consider the risk of acid mine drainage, which can contaminate nearby aquifers and subsoil. Also, there are cases where flooding is not feasible due to the prevailing geological or

climatic conditions. To avoid related emissions, mines can be sealed and drainage systems put in place to ensure that emerging gas is captured.

Regulators can facilitate the identification of abandoned mines where degasification systems could offer a solution for AMM abatement. For example, the US EPA developed a (non-comprehensive) map of abandoned coal mines to identify priority candidates for AMM recovery and utilisation using company survey data combined with emissions estimates.

Abatement solutions

The final set of considerations relates 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.

In China, the biggest emitter of coal mine methane, a 2020 notice on environmental impact assessments for coal developments requires improvements in the utilisation rate of coal mine methane. It stipulates the need to use CMM where concentrations are above 8% and encourages its utilisation even when concentrations are below that level. Since the 1990s, China has implemented several large-scale CMM projects for power and heat generation, some of which have received funding under the Clean Development Mechanism of the Kyoto Protocol.

Some technologies relevant to methane abatement do not directly reduce emissions, but are useful for finding and measuring methane releases. Detection and measurement technologies can help to identify unknown sources of CMM or to better understand the magnitude of known sources, which facilitates abatement.

Abatement can also depend on the establishment of monitoring and reporting protocols. Emissions captured through greenhouse gas mitigation projects must be verified and validated to be used in carbon credit schemes. Thus, establishing a clear framework for monitoring, reporting and verification can support voluntary initiatives to abate CMM.

Step 4: Build regulatory capacity

After working through Steps 1, 2 and 3, you should have a good understanding of the local context – including your legal and regulatory environment, the nature of your 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 **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 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 coal mining 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, 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 does not 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 coal 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.

What relevant expertise resides within 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 through targeted hiring, trainings and professional development. For instance, the Global Methane Initiative, the United Nations Economic Commission for Europe (UNECE and US EPA developed free training modules to help stakeholders understand the basics of CMM, principles behind CMM capture, and abandoned mine methane. UNECE and EMBER organise Methane Mondays – a series of online events to discuss coal mine methane related issues. An agency might also supplement its expertise by working with outside experts to understand emissions profiles and 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.

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 monitoring aircraft at its disposal 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 few personnel may run an effective regime by relying on remote sensors, third-party verification, or self-audits with steep penalties for incomplete or erroneous reporting to enhance enforcement efforts.

There is international support available for action on CMM. The Coal Mines Subcommittee of the Global Methane Initiative provides a series of technical resources for the deployment of methane mitigation technologies in the coal sector. The Climate and Clean Air Coalition supports developing countries in efforts to reduce short lived climate pollutants, including methane, and has funding

for the development of related mitigation action plans. The European Bank for Reconstruction and Development has recently collaborated with the government of Kazakhstan to develop a National Methane Emissions Inventory and Reduction Programme that will target emissions across a variety of sources, including coal mining. Collaborating with these entities can help fill some resource gaps needed for the development of policies and regulations on CMM.

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, their workforce, the communities affected by coal 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. Some of the international companies working in your jurisdiction may have made climate commitments, and can provide information about methane emissions and abatement approaches based on operations in other countries. 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. Also, coal users, such as the steel industry, might be able to support CMM reduction projects, both at a domestic and an international level.

Some communities or members of civil society may have been pushing you to act – so be sure that your process engages with them, acknowledges their leadership and solicits their ongoing support. Other stakeholders – often the regulated

community and industrial consumers of coal – 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 to act. For communities that are 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 formally announce plans to regulate, their presence can signal that you view methane abatement as 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 context of methane abatement. 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 makeup 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, others include an industry-wide, sector-specific or 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.

Rather than setting a high-level goal for the whole industry, you may wish to set more granular goals (or sub-goals) for different activities within the industry (e.g., underground vs. surface mines, or for steam vs. coking coal). You may also consider whether to establish separate objectives for emissions from new mines and existing mines, and whether to establish a plan for addressing abandoned mines in your jurisdiction.

Abatement regulations that do not set an explicit volume, percentage or intensity goal (for instance, a rule to ban VAM venting) still implicitly target reduction. Prescriptive regulations might reflect a specific goal: for instance, to use degasification systems to capture all gas with a high methane concentration by a certain date.

You might also have a few regulatory objectives that are not focused on emissions reductions. For example, 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.

As you think about your objectives, you may wish to refer 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 your objectives 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 previous 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.

In designing a policy, it is important to consider potential unintended adverse consequences of the regulation. For example, while an emission standard adopted by China in 2008 was meant to support the flaring or use of CMM by prohibiting the emissions from coal mine drainage systems with a gas concentration above 30%, evidence from site visits and interviews suggested that the standard may have created an incentive for mine operators to dilute CMM to avoid the requirement. This outcome not only undermines the intention of reducing greenhouse gas emissions but also creates an additional worker safety hazard due to the increased risk of explosion from lower-concentration CMM streams.

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 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.

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 have selected.

Once you have 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.

As coal mine methane is a niche field, understanding the environment of expertise and different perspectives surrounding coal mining is important. 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, which can be especially helpful if this issue is underdeveloped in your jurisdiction. For drafting very specific provisions, it can be beneficial to consult multiple experts from different backgrounds. Reviewing the provisions from the lens of different stakeholders during the drafting process helps to ensure regulations are complete and robust.

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. Keep in mind that industrial players may influence work opportunities and opinions on the topic. Thus, it may be useful to create a forum for people to make suggestions anonymously.

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 goes into effect to ensure that companies are ready and able 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 the rules. A policy that takes regulated entities by surprise is less likely to engender compliance. Help companies anticipate regulatory expectations, and provide clear direction so that your policy goals can be achieved. Some of this work may also take place in Step 5, when you elicit feedback from companies: for example, 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. The Australian Government's Clean Energy Regulator, for example, offers webinars that help industry and auditors understand the National Greenhouse and Energy Reporting framework and process. Consider early action credit like California's Air Resources Board did for its Cap-and-Trade Program, so that firms do not hang back and wait to make effective investments for fear it will not 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 and to track overall progress towards the big policy goal. This may include requirements for companies to monitor and report their own emissions, through a combination of direct measurement and estimates based on emissions factors. This may be supplemented by monitoring carried out by third parties (via hand-held sensors, drones, aircraft or satellites) as well as direct inspection by the regulatory agency. This guide provides further information on monitoring, reporting and verification for CMM mitigation.

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. For example, many operators of underground mines have continuous emissions monitoring systems that might be incorporated into reporting requirements.

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. They can also facilitate public disclosure of reported information.

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 is provided in the Regulatory Toolkit.

Enforcement

Depending on your institution's legal authority, you may be empowered to investigate regulated entities and enforce compliance with your methane rules. Enforcement actions may be made based on 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). There can be challenges to this, including the potential need to develop a new market 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 – as well as partnerships with universities, 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 policy or regulation, you should consider 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, it may 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 on data that could justify a policy shift within those bounds identified.

You may also consider building flexibility mechanisms into your regulation to keep it up to date. The technology of methane abatement can move very quickly. 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 multiple 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 8 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 • Record-keeping 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 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

Does your overarching regulatory structure use 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, contracting arrangements or a licensing scheme, typically provide more space for adaptation – but they 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 gas from coal seams 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 the concession of exploratory areas to service procurement, including project appraisal, direct development through national companies or shared production agreements.

For example, concessions could include a criterion rewarding operators that commit to lowering emissions. Alternatively, contracts might specify what measures must be taken to mitigate CMM or establish performance standards regarding emissions. Permits may limit venting or require mine closure plans that include methane abatement measures.

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, exploration 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. Permitting regulations also provide clarity over natural resource ownership that is essential to CMM development. In Ukraine, for example, existing mines are required to obtain a permit for CMM use and mines may sell their CMM rights.

Governments may grant contractual licences to companies to exploit resources through concessions, production sharing contracts, joint ventures, technical service contracts and 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. Authorities may include specific provisions in contracts (e.g., through a model contract) requiring the coal mine licensee to take all necessary steps to safely shut down the mine and comply with the latest international standards for mine closure.

Adding such provisions to the contract provides an additional legal component that requires operators to follow prevailing international legal standards. For example, India's Ministry of Petroleum and Natural Gas formulated a Model Co-development Agreement for simultaneous coal mining and CBM operations in overlapping areas to entitle the coal mine holder to extract CMM. It includes the provisions on resource rights and safety requirements, entitling the licensee to extract CMM and follow relevant mining safety rules and regulat

Generally applicable regulations

The key difference between generally applicable regulations and the case-by-case approach is that the same rules apply to all regulated activities without individualised tailoring. However, standards may still differ based on predetermined categories, such as type of coal or the status of the project, or the kind of technology employed.

Some countries have developed regulations specifically targeted at reducing emissions from coal mines. In China, all underground coal mines must comply with the 2008 Emission Standard of CBM/CMM, which prohibits VAM emissions with more than 30% methane concentration. In other cases, policies may apply more broadly to other sectors and other pollutants besides methane.

Box 2 Methane regulation

Some jurisdictions have established regulations for methane pursuant to general legislation such as a mining law or environmental code. These sometimes establish the means and procedures required for emissions control. Others might have a regulation directly targeted at methane emissions.

The European Council has reached an agreement on a general approach to the Commission's proposal for a regulation on methane emissions reduction in the energy sector. The proposal includes measures for CMM monitoring, reporting and verification as well as measures to mitigate methane emissions in operating underground mines and closed and abandoned underground mines. Under the proposed regulation, mine operators shall perform continuous ventilation air methane emissions measurement and quantification on all exhaust ventilation shafts. They shall also take monthly sample-based measurements. Venting of methane from drainage stations would be prohibited except in the case of an emergency, a malfunction, or where it is unavoidable and strictly necessary for maintenance. In such cases, drainage station operators shall vent only if flaring is not technically feasible or risks endangering safety of operations or personnel.

Furthermore, member states are required to make publicly available an inventory of all closed and abandoned coal mines in their territory or under their jurisdiction – and develop and implement mitigation plans for emissions at such sites. The proposal establishes a permitting procedure for the alternative use of abandoned coal mines, which obligates the permit holder to comply with monitoring, reporting, and mitigation measures to avoid methane emissions.

Even broader still, methane may be covered by 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.

Notably, in some countries broad enabling legislation already exists that may authorise regulations on methane mitigation 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 below.

Table 9 Regulatory approaches drawbacks and benefits

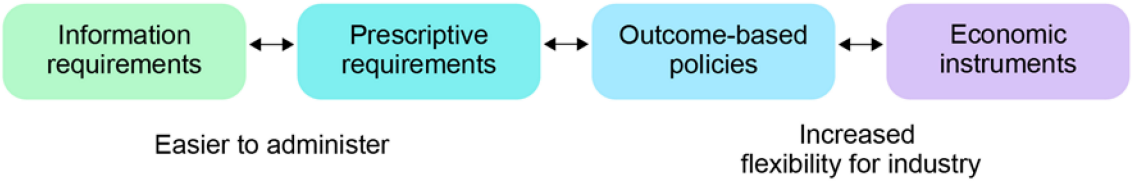
Regulatory approach	Transaction costs	Rigidity	Preconditions	Consider when…	Examples
Prescriptive	**Low** Simple to administer for both regulators and firms	**High** Only prescribed changes will take place	**Moderate** Knowledge of facilities' emissions needed	You have identified key abatement opportunities	Prohibition (EU)
Performance- or outcome-based	**Moderate** Monitoring and follow-up are needed	**Low** Encourages different solutions	**High** Requires data on baseline and overall emissions	You have a reasonable understanding of emissions and monitoring capabilities	Concentration limits (China)
Economic	**High** Requires robust verification systems	**Low** Enables company-specific strategies	**Moderate** Requires knowledge of baseline emissions and related methane contributions	A monitoring system is in place and you want to mobilise different solutions	Offsets (California)
Information-based	**High** Requires data collection, analysis and transmission	**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	Monitor and report (Australia)

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 that are 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 one another. An information-based 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 company compliance or create incentives for the industry to go above and beyond existing requirements. That said, a lack of information or institutional resources need not delay methane regulation: Rather, it may suggest certain policy design options to compensate for – and perhaps overcome – those deficiencies.

Figure 6 The spectrum of regulatory approaches



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.

Some regulations direct companies to follow specific procedures or processes with respect to their operations. Kazakhstan, for instance, prohibits the development of coal fields with an increased level of natural methane content in coal seams unless the necessary measures for advance degassing, ventilation and reservoir degassing programmes have been carried out. There must also be

subsequent utilisation of the resulting methane, which ensures that the gas content in coal seams is reduced to the established standards.

Prescriptive regulations may also direct companies to adopt specific equipment practices or to replace certain high-emitting equipment or components. Finally, prescriptive regulation may also include an outright prohibition on certain activities in the energy sector, such as venting of CMM.

Box 3 Best available technologies requirements

Best available technologies (BAT) typically refer to a benchmark technology or process for reducing emissions that has been determined to be reasonably available. Often linked to what is considered reasonably practicable, BAT evolves according to technological development. It might be a design standard, in which a regulator requires the use of specific equipment, or a performance standard, which requires a certain level of emissions per unit of output. Regulations also mention regular updates to reflect advancing standards and environmental concerns.

Establishing BAT requirements for the coal industry can support methane abatement, utilisation, and monitoring, and spread best industry practices. Russia's Federal Law on Environmental Protection introduces the definition of best available technologies and outlines several provisions to encourage large emitters (Category I) to employ BAT. This includes specific reference documents for mining and enrichment of coal, which outline pertaining methodologies and technologies relevant for environmental protection.

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 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 mine or individual piece of equipment, but they could be applied at wider scale as well. Some jurisdictions have adopted sector-wide or national-level strategic performance targets for methane emissions (or methane intensity). For example, Colombia's Short-Lived Climate Pollutants Strategy identifies several actions in the oil and gas and mining sectors designed to reach the goal of reducing national methane emissions by 170 000 tonnes by 2030. Among the actions proposed in the strategy is the recovery, use, and oxidisation of methane from coal mines.

Box 4 Strategic targets

Strategic targets involve establishing greenhouse gas emissions mitigation goals for specific sectors. These may be made in a methane action plan, national climate change plan, in a country's Nationally Determined Contribution, or announced by a state or provincial agency. Coal-producing countries can benefit from developing specific targets for the mining sector.

Viet Nam established an Action Plan for Methane Emissions Reduction to reduce emissions by at least 30% below 2020 levels by 2030. This plan includes a target for methane emissions from coal mining of two tonnes per year by 2030. To achieve this goal, the government will adopt policies to encourage methane drainage and recovery before and during underground coal mining operations. It will also invest in the installation and operation of automatic monitoring systems to promote energy-saving in coal mines.

Colombia enacted an Integrated Climate Change Plan for the Mining-Energy Sector under the Ministry of Mines and Energy that establishes reduction targets for the energy-mining sector, including coal. The targets are based on estimates made under assumptions defined for different strategic lines and their actions. Specifically, for fugitive emissions (methane and carbon dioxide), the mitigation commitment for the mining sector is 3.2 Mt CO_2-eq by 2030.

Canada, in its 2030 Methane Strategy, acknowledged that coal mining is responsible for 1% of its methane emissions or 29% of other emissions sources. With the 2030 Emissions Reduction Plan reduction target at 40% to 45% below 2005 levels by 2030, it specifies a 0.41 Mt CO_2-eq by 2030 target for other sectors. To reach this target, it aims to phase out unabated coal-fired electricity and ban thermal coal exports by 2030.

These examples illustrate the main advantage of performance standards compared to 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 can reduce their compliance cost, this kind of policy design can encourage technological development while also encouraging cost-effective improvements in emissions.

Performance standards are an especially useful tool if you already have thorough methane estimates or measurement requirements and a developed reporting scheme.

Economic approach

Economic provisions induce action by applying financial penalties or incentives. This may include taxes, subsidies or market-based instruments such as tradeable emission allowances or credits that allow firms to choose between different strategies to address emissions. To date, most economic instruments for CMM abatement operate by promoting desirable behaviour. In this context, regulations would provide the industry with an incentive to capture and/or utilise methane rather than venting it, effectively changing the cost curve of abatement. Such 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.

Incentives can take the form of grants or subsidies for project implementation, feed-in tariffs for electricity produced from CMM projects, or the inclusion of such projects in carbon offset crediting schemes. The German Renewable Energy Sources Act (EEG) provides a guaranteed fixed payback tariff for 20 years through feed-in tariffs or fees paid for electricity produced from previously approved CMM or AMM projects. Since CMM is recognised as a renewable energy source under the EEG as “mine gas,” coal mine operators can sell the carbon credits generated by the project and are exempted from local taxes or royalties on CMM projects.

Box 5 Carbon credits from CMM projects and emission trading schemes

Emission trading schemes (ETS) are market-based instruments developed to incentivise emissions reductions across sectors to meet an overall target. Policymakers can establish limits on greenhouse gas emissions in a given segment of the economy by issuing a “cap” or a limit to the number of emission allowances for each sector. Regulated companies that take measures to reduce their emissions may sell their excess allowances to those that face higher abatement costs. Governments also set benchmarks against which the

performance of regulated companies is evaluated. Some ETS programmes, such as the one in California, allow carbon credits from CMM projects.

The California Air Resource Board manages the California Cap-and-Trade Program, which allows companies to earn carbon offset credits for implementing greenhouse gas reduction measures. It is important, however, that such projects satisfy the requirements of additionality – meaning that the measure would not have been pursued in the absence of a carbon market – before credits can be issued. Under the programme, several different types of CMM projects can issue carbon credits, including:

- installation of a collection system for ventilation air methane in active underground mines
- methane drainage in active underground mines
- methane drainage in active surface mines
- methane recovery at abandoned underground mines.

As the price of the carbon increases, more projects have become cost-effective. Since 2017, 33 flaring projects in active and abandoned mines have been issuing credits, representing emission reductions of more than 2.7 million tonnes CO_2-eq as of August 2022.

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

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 basic 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 (GHGRP) requires all facilities that emit at least 25 000 tonnes CO_2-eq 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. Approximately 8 000 facilities are required to report their emissions, and the reported data are made available to the public annually. In the underground coal mines sector, facility owners and operators that emit at least

36.5 million actual cubic feet of methane annually are required to report total annual methane released from ventilation and degasification systems. In 2021, 60 facilities came under this requirement.

Box 6 Reporting requirements

Many countries establish a reporting scheme for greenhouse gases across all sectors. This helps jurisdictions understand their climate impact and develop mitigation goals. Usually, nationwide data is categorised per sector, so goals can be set by sector.

Currently at final draft stage, the **Metcoal Methane Partnership** outlines a performance and reporting framework for the metallurgical coal industry. Established under a memorandum of understanding between member companies and the United Nations Environment Programme, it includes standards and performance frameworks for industry reporting and commitments on methane emissions consistent with the Paris Agreement.

Several jurisdictions have already established reporting schemes that can also serve as a reference. Australia's National Greenhouse and Energy Reporting (NGER) scheme is a national framework for reporting and disseminating company information about greenhouse gas emissions, which requires companies to report CMM emissions. Information collected through this scheme is fed into a public database to increase transparency.

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 act. Also, regulators can opt to publish information on emissions to inform interested stakeholders, such as investors or civil society, of the performance of industry actors. For example, the Australian Clean Regulator publishes annual data highlights of energy and emissions data reported through the national reporting scheme. Under the safeguard mechanism, detailed reports are published for individual facilities that annually emit more than 100 kt CO_2-eq of Scope 1 emissions.

Many jurisdictions require developers to undergo an environmental impact assessment (EIA). 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. EIAs on coal mine projects can be an opportunity to identify significant environmental impacts of a project in addition to methane emissions and enable the introduction of effective reduction measures. Australia's Department of Climate Change, Energy, the Environment and Water issued national guidelines to assist impact assessment of coal seam

gas and large coal mining developments on water resources. In South Africa, the Department of Environmental Affairs requires that coal mining operations that emit over 0.1 Mt CO_2-eq of certain greenhouse gases, including methane, submit pollution prevention plan for approval.

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 do not require direct action in this direction, especially in settings where it may not be feasible to market captured methane.

Ultimately, making information more accessible and transparent is a worthwhile undertaking. This may be particularly useful when you need additional information about your industry 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.

Essential elements

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

Based on 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. In addition, clarification around resource rights to methane emitted from active and abandoned coal mines is necessary to lay the foundation for the beneficial use of the gas. 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 to be successful.

Finally, with the speed that technology is moving, your policy may be out of date before it is 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 and reporting

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 (e.g., repairs in abatement systems), 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 mines, the amount of coal produced) and either general or specific emission factors (e.g., IPCC standard emission factors or facility-level estimates) to calculate overall emission rates. Top-down quantification features direct measurement, normally by ground, 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. Monitoring systems often combine bottom-up and top-down approaches for optimal results, and consider a range of information sources to improve accuracy (e.g., coal gas composition, since monitoring devices may be affected by the presence of other gases than methane).

Monitoring policies can require measurement of methane concentrations coming out of ventilation systems and associated volumes at underground mines. For surface mines, assessments can be based on spectrometer sensors and quantification equipment or consider the methane content measured in coal seams. Larger installations and post-mining operations can be monitored periodically by devices set up on vehicles or aerial surveillance, through optical imaging or other techniques. This can also be done continuously at facility level using monitoring towers and cameras.

Box 7 Remote sensing

Satellite technology has the potential to support better emissions data and enable targeted abatement action. Existing satellites and processing technologies can already detect and quantify large leaks over a wide geographic area. Technology is moving rapidly in this field, facilitating the use of remote sensing technologies, with ever-lower sensitivity thresholds and cost.

The United Nations Environment Programme's International Methane Emissions Observatory aims to advance the understanding of methane emissions and supports measurement efforts. It has recently launched the Methane Alert and Response System (MARS) to help stakeholders identify large point sources of methane. MARS will engage directly in notifying relevant stakeholders and

providing assistance with assessing mitigation options. This will be based on data from a range of satellites, including Sentinel-5P, part of the European Space Agency Copernicus programme. Sentinel-5P carries the Tropospheric Monitoring Instrument (TROPOMI), which measures methane concentration across areas of 5 km by 7.5 km and scans the entire globe every four days, on average.

Other initiatives are also working on tracking methane emissions from space: Kayrros is helping to estimate methane emissions on coal-producing regions like the Appalachian basin in the United States; GHGSat made around 1 500 emission detections from coal mines in 2022, with several mines showing emissions on multiple days. Furthermore, the list of satellite sensors is expanding. A new satellite supported by Germany, Environmental Mapping and Analysis Program (EnMAP), started operations in November 2022. Separately, the US Environmental Defense Fund is planning to launch MethaneSat in 2023, with enough detail to identify the location of leaks to within 400 metres of the source and detect differences in concentrations of methane as low as two parts per billion. Carbon Mapper is working to expand satellite capability to monitor areas with anthropogenic sources of methane emissions.

Nonetheless, satellites still have some shortfalls, including coverage issues (e.g., it is difficult to detect emissions in mountainous, cloudy or ice-covered regions) and accuracy limitations. Also, the process of using changes in the atmospheric concentration of methane to estimate emissions from a particular source can rely on a large level of auxiliary data and be subject to a high degree of uncertainty. Thus, fixed-winged aircraft, drones and other measurement technologies should be used in combination for optimal monitoring results.

Record-keeping 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.

Record-keeping 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.

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 record-keeping 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 shafts) and the state of facilities, as well as a summary of significant occurrences (e.g., accidents or shut-downs). 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.

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., a ban on venting drained CMM), it may be easier to determine compliance than if the requirements relate to overall emissions.

Box 8 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 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.

Qualified independent third-party companies or organisations add a degree of transparency to CMM projects. Verification is specifically integral to reporting requirements under emissions trading schemes. California, for example, requires verification by an independent third-party before a project can sell offsets under their cap-and-trade programme. The EU proposal on regulating energy sector methane emissions mentions accredited verifiers to assess the conformity of emissions reports and review data sources, methodologies, and quality control systems. Australia requires third-party auditing for carbon credit units and has listed audit requirements and standards for its Emissions Reduction Fund.

Regulations may also empower the regulator to carry out inspections where regulators can enter a company's site and inspect activities or infrastructure. 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 to impose 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.

Policy co-ordination

Coal companies are typically subject to multiple regulations and must consider different concerns, including connections to the pipeline or grid, 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.

Box 9 Voluntary carbon markets and international carbon markets

Carbon market mechanisms allow companies to trade carbon credits (verified metric tonnes of CO_2 reduced or removed from the atmosphere), providing economic efficiency and flexibility as to where and when greenhouse gas emissions are reduced or removed, thereby in theory reducing the costs of mitigating climate change. They can help countries and corporates achieve their net zero emissions targets at a lower cost. Such markets also provide an extra revenue stream to de-risk the operations of clean energy investments. Specific methodologies are used to issue carbon credits, and these are claimed by the purchasing companies (or non-party stakeholders) to meet their emissions reduction target.

Under the Clean Development Mechanism (CDM) established by the Kyoto Protocol, CMM destruction and utilisation projects may be eligible for carbon offset credits under established methodologies to calculate the amount of reductions. As of 2022, more than 100 projects applied under CDM methodology for credits linked to abatement of methane from coal mines, of which 23 were validated. For example, the project Coal Mine Methane Utilisation and Destruction Programme in DPR Korea issued more than 137 $ktCO_2$-eq of carbon credits.

Article 6 of the Paris Agreement provides the opportunity for countries to voluntarily co-operate through the transfer of International Transfer Mitigation Outcomes (ITMOs) to meet and go beyond their nationally determined contributions (NDCs). ITMOs can be traded bilaterally or multilaterally among parties to the Paris Agreement. The implementation guidelines to operationalise Article 6 are still being developed, although some pilot projects are already coming online. As of January 2023, there are no known projects focusing on CMM destruction and utilisation, but some projects that were validated under CDM may also be eligible to participate under Article 6.

VCMs are private standards whereby non-governmental entities can register projects to issue carbon credits. While the role of these markets will remain complementary to other policies in driving global decarbonisation, voluntary markets are growing fast following corporate and national net zero announcements since 2019. Private standard-setting bodies register individual projects and jurisdictional programmes, and manage programmes through which offsets can be traded. They create standards for and certify climate projects through a set of methodologies that reflect best practices, market conditions, and technical developments within a sector. Two examples of these bodies are: the Gold Standard, which manages the Gold Standard Impact Registry; and Verra, which manages the Verified Carbon Standard Program.

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 – that offer benefits to companies looking to take action on methane. Meanwhile, regulations may also include charges and fees, such as a methane emissions tax. 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.

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, market and energy regulations can help create necessary infrastructure or institutional arrangements for gas utilisation, such as grid connections or injection to natural gas pipelines (see Step 2).

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 high methane concentrations are encountered or when they become aware of critical equipment maintenance schedules.

Furthermore, **nonregulatory actions** can support methane abatement. Governments may facilitate the uptake of abatement measures and technologies through direct funding for mitigation or investment in research and innovation programmes for technology development. The US Department of Energy is currently funding three projects focused on developing technologies to reduce methane emissions in coal mine shafts through the Reducing Emissions of Methane Every Day of the Year (REMEDY) programme. The Australian province of New South Wales administers funding for projects that encourage greater investment in and uptake of VAM abatement technologies through the Coal Innovation NSW Fund. If your jurisdiction has access to or supervision over funding that is meant to support the coal sector, this could also be leveraged to facilitate the uptake of methane mitigation measures.

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

As countries transition to clean energy systems, 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 10 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 a stakeholder request.

In Australia, independent goal review for climate policy is legislated at both the federal and state level. At the federal level, the National Greenhouse and Energy Reporting scheme is updated annually by the Department of Climate Change, Energy, the Environment and Water and undergoes review by the Climate Change Authority every 5 years. The Australian National Audit Office periodically reviews the teams responsible for the legislation; and the methodology and emissions factors used are subject to regular review by the UNFCCC Secretariat.

At the regional level, one example is the state of Victoria's Climate Change Act, which outlines long-term emissions reduction target for this province, setting a net zero greenhouse gas emissions target for 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.

Built-in **flexibility mechanisms** allow regulations to incorporate new technologies, provided 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.

Additional resources

The IEA Methane Tracker provides emissions profiles and information about abatement options and related policy efforts. Its 2023 update also includes marginal abatement cost curves for coal mine methane. Meanwhile, The IEA Policies Database highlights regulations and policies by topic (e.g., methane abatement), sector (e.g., coal and lignite mining) and policy type (e.g., finance and taxation).

The Global Energy Monitor has released a Global Coal Mine Tracker, which provides a worldwide dataset of coal mines and proposed projects with asset-level details on ownership structure, development stage, coal type, production, workforce size, reserves, methane emissions, geolocation, and other categories.

The Global Methane Initiative periodically updates Coal Mine Methane Country profiles that characterise the coal and coal mine methane industries of 37 countries. The GMI Coal Subcommittee hosts a variety of events, trainings, and resources and relating to coal mine methane abatement. They have compiled an International Coal Mine Methane Projects Database featuring more than 200 CMM recovery and utilisation projects in various stages of development around the world.

The International Methane Emissions Observatory, part of the United Nations Environmental Program, was launched to catalyse methane reductions by making available open, accurate, and actionable data on methane emission sources including coal mine methane. Using science studies, it is developing a policy-relevant global public dataset of empirically verified methane emission data to support actions to reduce methane emissions.

The United Nations Economic Commission for Europe (UNECE) Group of Experts on Coal Mine Methane and Just Transition has created best practice guides for methane recovery and utilisation in active and abandoned mines. It also published the Best Practice Guidance for Effective Management of Coal Mine Methane at National Level, which has a useful glossary of terms used in this area as well as further references on CMM management. Together with EMBER, the group also hosts periodic Methane Mondays workshops to facilitate discussion on CMM issues among interested stakeholders.

Operating under the UNECE, the International Centres of Excellence on CMM are self-supporting, not-for-profit businesses that support capacity-building activities in UN Member States through Memoranda of Understanding. Centres have been

established in Poland and China to co-operate with other actors for research activities, and analyse legislation on CMM for improvement, among others.

The US Environmental Protection Agency has developed several in-depth resources through the Coalbed Methane Outreach Program. This includes: the Conducting Pre-Feasibility Studies for Coal Mine Methane Projects Training and other training modules; mitigation resources such as the web-based CMM Cash Flow Model that helps coal mine operators to evaluate the financial viability of CMM abatement measures; information on abatement technologies and related experiences, for example, on VAM utilisation technologies; as well as case studies on several countries that have successfully developed an enabling regulatory environment for abandoned mine methane recovery and utilization.

The Clean Air Task Force supports governments working on methane reductions and has published on the barriers and opportunities for CMM mitigation.

The Australian Government Clean Energy Regulator manages an information hub with resources that provide stakeholders with an understanding of the different facets of carbon abatement. The page includes links to other pages such as auditing information, carbon markets, the carbon pricing mechanism, case studies, among others. Its website also includes Calculators to help reporters assess emissions against reporting thresholds, revised each reporting cycle.

Abbreviations and acronyms

AMM	abandoned mine methane
BAT	best available technologies
CAA	Clean Air Act
CBM	coal bed methane
CMM	coal mine methane
CSG	coal seam gas
CO_2-eq	carbon dioxide equivalent
ETS	emissions trading scheme
EPA	Environmental Protection Agency
EU	European Union
GHG	greenhouse gases
Gt	gigatonne (1 tonne x 109)
kt	kilotonnes (1 tonne x 10^3)
Mt	million tonnes (1 tonne x 10^6)
NZE	Net Zero Emissions by 2050 Scenario
VAM	ventilation air methane
UNFCCC	United Nations Framework Convention on Climate Change

Annex: Policies related to CMM

Country	Policy	Level	Policy Type
Australia	National Greenhouse and Energy Reporting Regulations 2008	National	Information
Australia	Emissions Reduction Fund	National	Economic
Australia	(Queensland) Mineral and Energy Resources (Common Provisions) Act 2014	State	Prescriptive; Resource rights
Australia	(NSW) Coal Innovation Fund	State	Economic
Australia	National Greenhouse and Energy Reporting (Measurement) Determination 2008	National	Information
Australia	(Victoria) Climate Change Act 2017	State	Information
Australia	(Queensland) Coal Mining Safety and Health Regulation 2017	State	Performance-based
Australia	(New South Wales) Work Health and Safety (Mines and Petroleum Sites) Regulation 2022	State	Performance-based
Canada	(Alberta) Mines and Minerals Act	State	Prescriptive; Resource rights
Canada	Faster and Further: Canada's methane strategy	National	Information; Prescriptive
China	Emission standard of coalbed methane/coal mine gas (trial)	National	Prescriptive
China	National Methane Action Plan	National	Prescriptive; Information
China	Opinions of the State Council on resolving overcapacity in the coal industry and realizing development out of difficulties	National	Prescriptive; Economic; Resource rights
China	Law on Air Pollution Prevention and Control	National	Prescriptive

Country	Policy	Level	Policy Type
Colombia	Resolution 40350 – 2021: Integrated climate change plan for the mining and energy sector	National	Performance -based, Information
Colombia	Short-Lived Climate Pollutants Strategy	National	Performance-based
Egypt	Prime Minister Decree No. 964 of 2015, Amendment of executive regulation of Law 4/1994	National	Prescriptive, Information
European Union	Proposal for an EU regulation on methane emissions reduction in the energy sector	Regional	Information; Prescriptive
Germany	Renewables Energy Act	National	Economic
Germany	Federal Mining Act (as amended by 2017)	National	Prescriptive; Resource rights
India	Hydrocarbon Exploration Licensing Policy (HELP)	National	Prescriptive; Resource rights
India	Policy for early monetisation of coal bed methane gas marketing and pricing freedom for CBM gas	National	Economic
Indonesia	Permen ESDM 35/2021, Procedure for determination and bid of oil and gas working areas	National	Prescriptive
Kazakhstan	National Methane Emissions Inventory and Reduction Programme	National	Information; International co-operation
Kazakhstan	Code “On subsoil and subsoil use” No. 125-VI (as amended)	National	Performance-based

Country	Policy	Level	Policy Type
Mexico	Official Mexican Standard NOM-007-ASEA-2016, Transport of natural gas, methane, and gas associated with coal by pipeline	National	Prescriptive
Multiple	Joint Declaration from Energy Importers and Exporters on Reducing Greenhouse Gas Emissions from Fossil Fuels	International	Prescriptive; International co-operation
New Zealand	Emissions Trading Scheme	National	Economic
Russian Federation	Decree on approval of the list of areas of application of the best available technologies	National	Prescriptive
Russian Federation	Federal law on state regulation in the field of mining and use of coal, on the features of social protection of employees of coal industry organizations	National	Prescriptive
Russian Federation	Chapter 26 of Russian tax code on the extraction of commercial minerals	National	Economic
South Africa	Declaration of greenhouse gases as priority pollutants	National	Information
Ukraine	Regulation on approval of safety rules in coal mines	National	Prescriptive
Ukraine	Law on gas (methane) from coal deposits	National	Economic; Prescriptive; Resource rights
Ukraine	State Commission of Ukraine on Mineral Reserves Instruction N 523	National	Prescriptive
United States	California Air Resources Board Offset Program for Mine Methane Capture (MMC) Projects	State	Economic
United States	Coalbed Methane Outreach Program	National	Information; International co-operation
United States	Safety standards for methane in metal and nonmetal mines	National	Prescriptive
United States	Inventory of US greenhouse gas emissions and sinks: 1990-2020	National	Information

Country	Policy	Level	Policy Type
United States	Greenhouse Gas Reporting Program (GHGRP)	National	Information
United States	Bureau of Land Management Instruction Memorandum No. 2003-253	Regional	Prescriptive; Resource rights; Economic
United States	Methane Emissions Reduction Action Plan	National	Economic
United States	Indiana Voluntary Clean Energy Portfolio Standard Program	State	Economic
United States	Advanced Research Projects Agency Energy (ARPA-E) "Reducing Emissions of Methane Every Day of the Year" (REMEDY) program	National	Economic
United States	California Air Resources Board Cap and Trade Regulation	State	Economic; Information
Viet Nam	Viet Nam Action Plan for Methane Emissions Reduction by 2030	National	Prescriptive; Information

Note: This table reflects entries in the IEA Policies Database linked to the topic **Methane abatement** and to the sector **Coal and lignite mining**. We welcome feedback from jurisdictions regarding any updates to existing policies or on additional policies that are missing from the database.

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